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Nicola Bianco · Agostino De Marco ·
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A Decade of Research Activities at the Department of Industrial Engineering (UniNa-DII)

From Five Existing Departments to the Excellence in Research

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In these years, some of us passed away: this volume is just dedicated to all of them. They actively did work for the common goals and certainly are now enjoying and still walking with us.

Preface I

This book has been conceived to celebrate the ten-year anniversary of the *Dipartimento di Ingegneria Industriale* at the *Università degli Studi di Napoli Federico II*.

In 2013, five pre-existing departments merged, and the research findings presented in this book serve as evidence of the successful synergy achieved by combining our skills, expertise, and projects.

The realm of industrial engineering now primarily focuses on devising and evaluating novel solutions that are both environmentally and human-centric, in response to contemporary challenges.

The previous paradigm revolved around "Is it feasible?" whereas the new one is centered on "Is it compatible with the environment and with humanity?".

While there is still much work to be done in pursuit of this objective, the contents of this book bear witness to the fact that the initial steps have been taken in the right direction.

All the researchers, the administrative officers, and the technicians belonging to the department contributed to the content of this book. It essentially boasts over 140 authors and is a collective product of the collaborative journey we have embarked on together.

According to GUSTAV MAHLER, this book reminds us that tradition is not the worship of ashes but the preservation of fire.

Napoli, Italy
October 2023

Nicola Bianco
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A Note by the Delegates to the Research

The changes that have taken place in the last decade (2013–2023) are innumerable and have profoundly marked the Italian university, also under the influence of external events such as those linked to the COVID pandemic. The three fundamental pillars of the Italian university system, teaching, research, and third mission, have been shaken both by the events mentioned and by mechanisms and transformations which are attempting to guide choices that directly impact the future of our country.

The Department of Industrial Engineering, one of the 26 departments of the Università di Napoli Federico II, has played an even more important game over the decade since its birth linked to the merger of the five original departments.

This has led to the adoption of a difficult path, just think about the specific lexicon, the difference among administrations, and the sharing of the laboratories. At the same time, this path immediately proved to be exciting due to the new opportunities that opened. Without a doubt, there have been difficult moments as well as great satisfactions.

Since its creation, the department has placed the issues of energy transition and sustainable development at the center of its development.

Evidently, the advent of the PNRR (*Piano Nazionale di Ripresa e Resilienza*), the success achieved in the 3rd VQR (the periodic procedure for the national evaluation of the quality of the research of the universities and the departments), and, even more importantly, the subsequent inclusion in the 180 departments of excellence of the Italian University has consolidated this modern vision and above all well-oriented toward the future, providing an important driving force for the continuous growth of the department in the three cited fundamental fields. This is within a university that will celebrate its 800th anniversary in 2024 and which has certified its constant overall growth in the aforementioned VQR.

The volume is introduced by a chapter in which the three heads will recount the process that began 10 years ago. The individual research groups will then present the most important developments of their research in the following chapters, highlighting their impact and vision for the future, also emphasizing how much belonging to a department that sees industrial engineering as a main theme has represented a factor of noticeable acceleration.

The main research results will then be presented in the various disciplines that are included in the denomination of industrial engineering, thus ranging from aerospace to naval and terrestrial mobility, to applied mechanics, to thermo-energetics, to the use of advanced technologies and augmented reality, and to the management of complex systems.

The international relevance and multidisciplinary approach of the developed research will be also underlined as well as the guidelines already planned for the next years.

We—who have had the honor and the burden of accompanying the heads in their difficult tasks—consider the drafting of this volume, in extreme synthesis, as the set of three photographs. In the first, the details of who and where we were can be seen; in the second, there is our present with the ongoing projects; the latest is a still-in-development instant picture containing our greatest ambitions.

Napoli, Italy
October 2023

Sergio De Rosa
Michele Grassi

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Historical Background and Evolution in the Decade

Nicola Bianco, Rita M. A. Mastrullo, and Antonio Moccia

Abstract The Department of Industrial Engineering was established on 1 January 2013 in application of Law 240/2010 which has reframed the organization of the Italian university system. This chapter summarizes the efforts and the main achievements of the Department in the research, management of research and technology transfer activities in the decade 2013–2023.

The Department of Industrial Engineering was established on 1 January 2013 in application of Law 240/2010 on the reorganization of the Italian University system. The form of governance envisaged by the law is based on the centrality of the Departments, as bodies which on the one hand interface with the University's Board of Directors and on the other become the driving force behind scientific, teaching and technology transfer activities.

Over the years of application of Law 240/2010 and drafting of the new University Statute, the engineering departments have played an important proactive role, suggesting solutions and best practices for collaboration between different cultural areas, thanks to the extremely positive experience lived within the Faculty of Engineering over many decades. Furthermore, since the engineering Departments are particularly open to the territory, to industries and public bodies, and are part of international research networks, they have also been able to bring valuable experiences in the organizational and management fields. In fact, since 2011, an informal body had been set up, but deeply rooted in the reality of the industrial engineering of the Federico II, made up of the Directors of the old Departments of Energy, Thermo-fluid dynamics and Environmental Conditioning, Aerospace Engineering, Economic-Management

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Engineering, Materials and Production Engineering, Mechanical and Energy Engineering, Naval Engineering, by the Presidents of the Degree and Master's Degree Courses in Aerospace Engineering, Management Engineering, Mechanical Engineering and Naval Engineering and by the Coordinator of the Doctoral School in Industrial Engineering.

To take the opportunity offered by the application of Law 240/2011, the objective of the working group was to define the organizational foundations of a new enlarged structure with relatively much broader organizational autonomy and responsibilities in the sectors in which the university operates. This made it possible to start on January 1, 2013, with a well-sketched idea of the roles and the goals. Naturally, getting out of theory and dealing with the operational organization required commitment and continuous and punctual feedback on the results.

First of all, we worked on the standardization of procedures, starting from the administrative ones but going to those of organization of the teaching activities and of both economic and manpower resources. All this was possible thanks to the commitment of the administrative staff who, despite the limited numbers and experience, were able to adapt their work to new operating conditions, such as the new rules on the University budget, the procedures for the quality of teaching, the reporting of European, national and regional projects, amplified by the dimension of the Department. It should be noted that simply due to the size of the laboratories, the newborn department was the largest among those of engineering and was among the largest in the University by the number of teachers and students.

An analysis of the strengths and weaknesses showed that although teaching had solid historical foundations and provided an excellent service to a vast student audience, namely in terms of occupational effects, it was necessary to increase manpower in weak but important areas, recruiting quality personnel of different seniority and experience. In the didactic field, it should also be noted that the Department of Industrial Engineering was one of the main promoters of the Polytechnic and Basic Sciences School.

In the field of research, by evaluating the recently, at that time, published results of the 2004–2010 Quality Assessment of Research conducted by the Italian National Agency for Evaluation of the University System and of Research, it was clear that, along with areas of excellence, in the mean little attention was paid to the dissemination of results and too much attention had been given to commissioned research and technology transfer, which in any case had allowed the development of laboratories and plants. Corrective actions were taken, based on internal reviews and selection of qualified personnel.

As a matter of fact, the quality of recruitment has always been a goal and a strength of the department, which has always known how to pay attention to a careful staff turnover and to take advantage of both national opportunities and self-financing capacity through research projects to increase its workforce. After 10 years of this new, challenging and surprising common journey, the synergies established have allowed fruitful teaching, research, and social and human activities, inside and outside the ancient walls of our University. We are proud of it.

It has been an amazing journey, sometimes difficult, a road to travel together, and this has been so important as the destination: we apprehended the capability of composing different and plural points of view, and this makes so precious the complexity, our greatest richness that we can offer to students, to the city of Naples, to the south Italian territory and to who feels to be part of the Federico II community.

The road is still long, but the journey has begun, and we look forward, with the confidence of awareness and the robustness of our values.

Antonio Moccia was the first head from 2013 to 2018. Rita M. A. Mastrullo had this role in 2019 and 2020; she terminated when was appointed as vice-Rector. The actual head is Nicola Bianco. He started in 2021 and will finish in 2026.

Naval Architecture and Marine Engineering

Maria Acanfora and Guido Boccadamo

Abstract This chapter summarizes the main research activities and outcomes of the groups engaged in Naval Architecture and Marine Engineering, in the decade 2013–2023. The research topics are typical of the following sectors: "Architettura Navale" and "Costruzioni e Impianti Navali e Marini".

1 Introduction

The ship is an ancient object; the seafaring culture has a millenary tradition. Sea has always been the main way of communication between peoples, goods and a way of exchanging culture above all. The sea is the primary source of food, offers a great potential as renewable energy resources and still more than 80% of goods travel by sea.

The activities of the naval architect and of the marine engineer are focused at the design, construction and operation of ships and offshore structures involved in the activities carried out in the marine environment for the use of natural resources. These complex artefacts require multiple skills in fields such as hydrodynamics, fluid dynamics, theory of structures, fluid machines, automation and automatic controls, as well as expertise in management and economics.

Therefore, the inclusion of Naval Architecture and Marine Engineering (NAME) researchers in a broader context such as the Department of Industrial Engineering appears natural with the vision of the fruitful exchange of skills and results and successful collaborations among researchers from all fields embodied in the new Department. In recent years the growing attention of civil society and consequently of political authorities to environmental issues has led to a close collaboration between NAME researchers and those of the chemical, fluid machine mechanical and

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aerospace areas, related to the energy production from marine renewable sources (offshore wind, production of energy from marine currents and waves, etc.) and to the zero emissions demand in marine transportation (fuel cell, hydrogen propulsion, etc.). Another exquisitely multidisciplinary field is that of autonomous vehicles, where ships cannot be missing, in which cooperation between skills and a transversal approach is crucial.

The skills in the NAME field can be divided, for simplicity of description and for their historical development, into three major cultural areas: Naval Architecture, Naval Construction, and Marine Plants. The topics of interest of Naval Architecture are the conception and design of different ships and marine structures including special, military, submarine, and pleasure units, optimization of the hull form with particular regard to the resistance and the hydrodynamic aspects of the propulsion (unconventional propellers or thrusters), to reduce fuel consumption and emissions, and improve the seaworthiness, i.e., the behaviour of the vessel at sea, manoeuvrability and steering, operational safety and stability against the risk of capsizing or sinking in the event of damage. For these purposes, the numerical and experimental methodologies are developed and used in all phases of design. The topics of interest of Naval Constructions are, in the context of structural aspects, the actions applied to the structures, materials, technological and production processes, the analysis of the static and dynamic structural response, the dimensioning, outfit and fitting. The topics of interest in the Marine Plants area are the propulsion and energy generation plants, the systems for onboard services, the sensors and safety equipment, and the automatic control systems.

In order to increase safety, energy efficiency and comfort and to reduce consumption, and emissions in the atmosphere and in the sea, the life cycle assessment is considered in complete process: design, operation, maintenance, decommissioning. The studies of the sector, addressed with theoretical, numerical and experimental approaches and with deterministic and probabilistic models, are aimed at sustainable mobility and the growth of the sea economy, with recourse to traditional and innovative solutions.

2 Background and Legacy

In the context of the Neapolitan university, the course of Naval Architecture and Marine Engineering is among the oldest, given the consolidated tradition in shipbuilding in the area.

The systematic arrangement of engineering studies dates back to 1808 when Gioacchino Murat established the *"Corpo Reale degli Ingegneri di Ponti e Strade"* (Royal Corps of Bridges and Roads Engineers) with the consequent establishment of the *"Scuola di Applicazione de' Ponti e Strade"* (School of Application of Bridges and Roads, 1811). After several vicissitudes, in 1863 the School passed under the control of the Ministry of Public Education and became the *"Scuola di Applicazione per gli Ingegneri"* (Application School for Engineers). In 1901 a new Industrial

Engineering section was introduced and in 1904 the School of Application was transformed into the Polytechnic School. In 1905, at the Polytechnic School, the naval section was established, with the right to award degrees in *"Ingegneria Navale e Meccanica"* (Naval Architecture and Mechanical Engineering). The Institutes of *"Architettura Navale"* (Naval Architecture) and *"Costruzioni Navali"* (Shipbuilding) are born, to which the Institute of *"Macchine Marine"* (Marine Machinery) was added.

It is necessary to mention the work of Prof. Mario Gleijeses, director of the Institute of *"Architettura Navale"* from 1907 to 1950, and of prof. Leonardo Fea, director of the Institute of *"Costruzioni Navali"* from 1926 to 1954.

The marine section has therefore been characterized since its inception in the university environment by a strong bond with the industrial tradition and, in particular, with mechanics.

In 1925 the Polytechnic School changed its name to become the *"Reale Scuola di Ingegneria di Napoli"* (Royal Engineering School of Naples). In 1935 the Faculty of Engineering was born.

In 1965 the new headquarters of the Faculty of Engineering was inaugurated in *Piazzale Tecchio*. The *Vasca Navale*, (Towing Tank), an important laboratory of marine hydrodynamics, dedicated to the experimentation on ship models, was built within the laboratories of the Faculty. The towing tank is still among the largest in Europe for dimensions in the university area (Fig. 1).

In 1984 the *"Dipartimento di Ingegneria Navale (DIN)"* (Department of Naval Architecture and Marine Engineering) was established, merging the Institutes of *"Architettura Navale"*, *"Costruzioni Navali"* and *"Macchine Marine"*. The professors and researchers of these Institutes become part of this structure.

The DIN promoted and coordinated research activities in the sectors of marine hydrodynamics, naval installations, naval structures, marine technologies and ship safety; contributes to the activities of the Degree Course in Naval Architecture and Marine Engineering and the PhD in Aerospace, Naval and Quality Engineering.

In addition to the hydrodynamics laboratory mentioned above, the Department of Naval Architecture and Marine Engineering has: a plant laboratory capable of carrying out experimental investigations even at sea; a computing center for processing experimental data and developing numerical surveys with modern automatic calculation procedures; a mechanical workshop and foundry, a carpentry shop, an electrical-electronic workshop, a system for surface and underwater photographic and television shooting; a library specializing in naval architecture and marine engineering disciplines.

It was a member of the International Associations: ITTC, International Towing Tank Conference; ISSC, International Ship Structure Conference; SRDC, Stability Research and Development Centre; WEGEMT, West European Graduate Education in Marine Technology (actually CEMT, Confederation European Maritime Technology Societies); IMAM, International Maritime Association of the Mediterranean and since 1980 organizes High Speed Marine Vehicles Conference arrived at 13th edition.

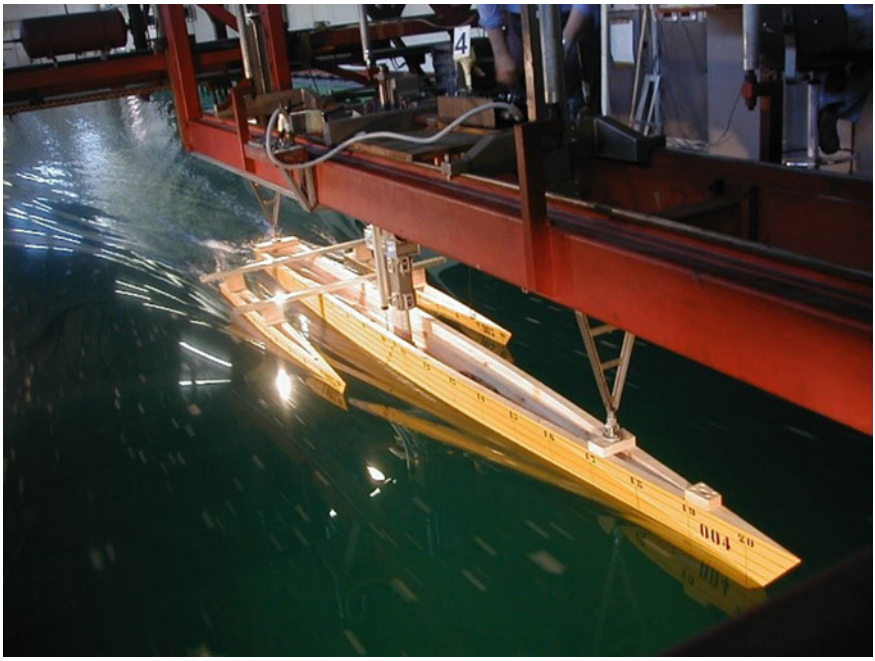

Fig. 1 Example of a multihull

From the point of view of the experimental structures, the marine hydrodynamic laboratory *(Laboratorio Esperienze Idrodinamica Navale LEIN)* was strengthened with the installation, in the years from 2004 to 2006, of a new data acquisition system and of a wavemaker equipment capable of generating waves with high precision.

The Department of Industrial Engineering was born on 1 January 2013 with the confluence of professors and researchers belonging to the dissolved departments.

3 Evolution

In the last ten years, the group of professors and researchers engaged in the fields of Naval Architecture and Marine Engineering has been decisively renewed. Currently, it is made up of 14 members including professors, researchers, and specialized technicians.

Thanks to the possibilities offered by the new departmental structure, there was an enrichment of the research topics with the establishment of profitable synergies with other scientific sectors. For example, the collaborations in the field of self-driving airships, in that of ship propulsion with the use of new energy sources, in the study of methodologies for the use of marine renewable energies.

The development of the topics has been accompanied by the constant adaptation and strengthening of laboratory equipment and with the planning of new structures, like a fuel cells lab.

These activities have also had important repercussions in the educational field: just mention the Erasmus Master Mundus Joint Master Degree Sustainable Ship and Shipping 4.0, delivered together with the University of A Coruna, University of Zagreb and Technical University of Hamburg and coordinated by DII professors; and the recent BIP course Seakeeping and Stabilization of Large Yachts, delivered together with the CMC Marine; the collaborative activity within the Erasmus KA2 ShipMartech project, "Upgrading and Harmonization of Maritime Engineering Master's Level Courses", coordinated by the Technical University Tallinn, Estonia, with the University of Zagreb Faculty of Mechanical Engineering and Naval Architecture and University of Aegeo, on the harmonization of Naval Engineering courses; all initiatives that have projected the teaching of the NAME group into the international field.

Numerous international conferences: STAB, FAST, IMAM, International Hydrodynamic Conference have been hosted and organised. Conference High Speed Marine Vehicles Conference has started in 1991 and since that every three years is organised by the professors of NAME group, under the patronage of the *Università degli Studi di Napoli "Federico II"*, Royal Institution of Naval Architects, UK and *Marina Militare Italiana*.

4 Main Research Programmes

4.1 Hull Performance and Shape Optimization

The relationship between hull shapes and hydrodynamic performances and powering prediction in calm water has been always one of the main research topics in Marine Hydrodynamics group. The group strongly believe in synergy of experimental and numerical approach. The research activities on the hull shape optimization have been focused primarily on two areas: multihulls and monohulls: displacing, planing, and semi-planing [1–3]. The research is conducted experimentally in a towing tank [3–5] and via numerical simulations (by Computational Fluid Dynamics simulations). The behaviour of the vehicles, both in still and rough water, is analysed, [6–10]. Regarding planing and semi-planing vessels, in addition to systematic studies to identify the best hull forms, the effectiveness of conventional and unconventional high lift devices has been investigated. The research on multihulls was focused on catamarans, trimarans, and SWATHs. In particular, the hydrodynamic interferences between the demi-hulls have been systematically analysed, looking into the effects

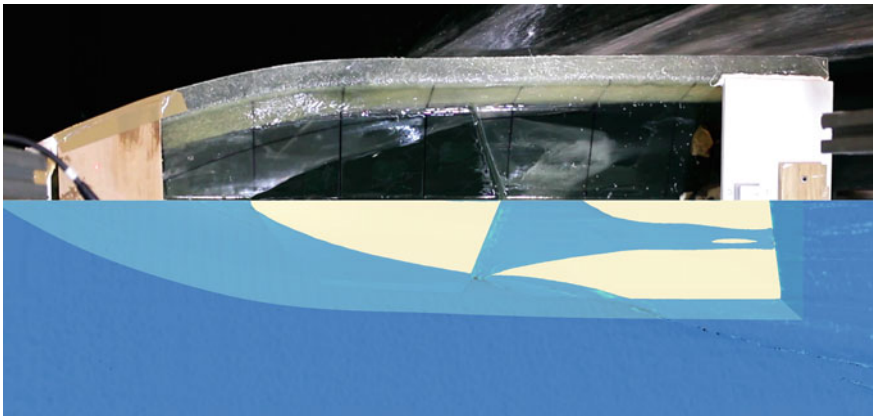

Fig. 2 Wetted surface of a stepped hull: comparison numerical versus experimental [8]

of clearance and stagger variations and asymmetries of both the demi-hulls and the entire catamarans.

On this topic, numerical tools have been largely used to explore the design space with different approaches (e.g., Design of Experiment, Surface responses, etc.) and identify the optimal hull shape (Fig. 2).

4.2 Low Environmental Impact Ships

4.2.1 Integration of Electrical Propulsion Systems Onboard Ships

Electrical propulsion systems are currently used on many types of ships for their advantages in terms of comfort, operational flexibility and controllability. In addition, the hybrid or all electric can achieve also significant reduction in noxious and greenhouse gas emissions.

The integration of storage devices requires the development of energy management procedures that impact the sizing and efficiency of the various components. The challenge is to find the solution to optimal problems subject to different types of constraints.

The theoretical activities are accompanied by an experimental activity in collaboration with the Italian National Research Council, to verify the robustness and the optimality of the control of power flows between sources, batteries, supercapacitors and loads (Fig. 3).

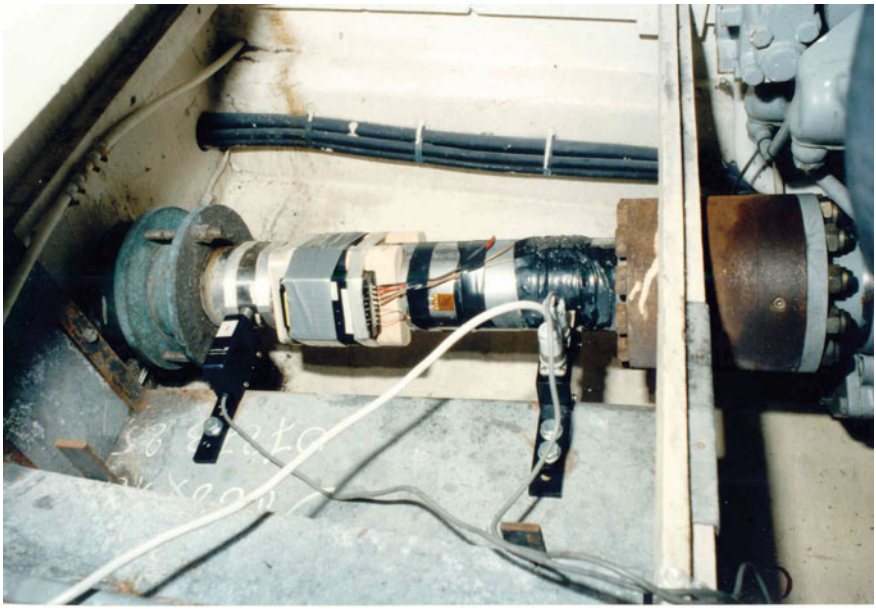

Fig. 3 Measuring the performance of a diesel engine powering a pleasure boat

4.2.2 Emissions from Ships in Port

The problem of emissions from ships in areas close to inhabited zones is one of the most urgent items.

Nowadays, placing ports in crucial positions, especially in large seaside cities, is very attractive for tourism and trade as it is unquestionably suggestive to get off a cruise ship and find yourself right in the center of the city to visit. However, these ships have a great impact on the environment, since, in order to satisfy the hull and hoteling utilities active on board, they must produce very high power with consequent significant exhaust emissions.

This line of research is dedicated to the assessment of emissions from ships (with particular attention to cruise ships) and to the development of devices that would reduce the environmental impact of these emissions on the port environment. It is based on direct measurements of emissions onboard, analysis and post processing of AIS (Automatic Identification System) data, assessment of the emissions using internationally accepted routines of evaluation and reconstruction of the overall quantities of harmful elements emitted in the air [11, 12].

Fig. 4 The instrumentation used for revealing the contents of the air in port (left) and the equipped van with sensors (right)

4.2.3 Overall Impact of the Marine Activity on the Ports of Water Cities

Alongside the study of emissions from ships, another thread of research could be the evaluation of the influence of any source of pollution (including ships, of course) on the quality of the air in port with a particular interest in determining the so-called apportionment, i.e., the exact responsibility of each source of pollution on the healthiness of the air.

This research necessarily involves numerous and accurate measurements in order to have a reasonable knowledge of the contents of harmful elements in the air and their change according to the various phases of the life of the port [13] (Fig. 4).

4.2.4 Transport Phenomena in Ballast Water Management

The systems of ballast water management move very large quantities of water and they are exposed to various kinds of problems. One of these problems consists in the introduction of many elements carried by the flow of the water entering in the double bottoms. Among them, bacteria, living aquatic species, metals, debris and everything that can be gathered from the sea water or produced inside the chests.

In the phase of discharging of the ballast water from the double bottoms, due to the effect of the incrustations formed under the water intake points, debris may be sucked in, end up running along the entire ballast piping and entering in ballast pumps with potential damage to the moving parts of the latter.

For these reasons, the transport phenomena linked to the detachment of debris under the water intake points and their entry into the ballast piping are studied using

a particular system that simulates the real ones installed on board ships to reconstruct with remarkable precision the trajectory of all the particles that detach from the bottom due to the effect of the overlying water flow, to understand the dynamics that move them and to develop systems capable of avoiding the damage potentially caused to pipes, components and pumps [14].

4.2.5 Modeling of Marine Diesel Engines

Another line of research active in our field regards the simulation approach to ship propulsion systems. This line of research involves purely mechanical aspects such as the simulation of marine engines and more generic approaches to innovative on-board power generation systems.

In particular, engine simulation is approached with cutting-edge simulation tools, with commercial software and/or built in the MATLAB/Simulink environment: the former, though requiring greater levels of detail about the individual components and the laws governing heat transfer, losses, turbo group dynamics, and combustion in the cylinders, allow an estimation of atmospheric pollutant emissions. The latter class of models, on the other hand, allows for broad-spectrum results about classic engine performance in slightly less detail [15].

Two-stroke, four-stroke, small, medium and large engines are taken into consideration, working with traditional or alternative fuels; energy recovery, efficiency, dual fuel engines and, in the near future, Fuel Cell, and methanol fueled engines will complete this line of research.

New frontiers in this area are the simulation of engines powered by alternative fuels such as natural gas and methanol, and the use of simulation models to set up an engine digital twin model capable of monitoring and fault diagnostics.

4.3 Sea Keeping and Structural Loads

Seakeeping embodies knowledge of three fields: probabilistic description of environment (wave, wind, current and geographical area) in which ship or offshore structure will operate, deterministic responses of ships in regular waves and seakeeping performance criteria intended as the established limits for the ship's responses [16–18].

First numerical methods, developed in fifties of the 20th century, are based on the linearised physics of the phenomena and improving of mathematical models is very active research area. From nineties, professors and researchers of NAME are working on the improvement of frequency domain codes, development of weakly nonlinear time domain simulations for the displacement ships and fully nonlinear prediction of planing crafts to assess structural loads and motions [19–21].

Since 2006, Marine Hydrodynamic Laboratory has been equipped by wavemaker and researchers enriched their portfolio with the expertise in experimental seakeeping

of planing craft, both in terms of highly nonlinear phenomena for the loads assessment as well as comfort assessment on board of pleasure boats, or working conditions on board [22].

4.4 Ship Propulsion

The topic of ship propulsion investigated at the NAME group of the DII can be divided into conventional and unconventional ship propulsion (Fig. 5).

Regarding conventional ship propulsion, the investigation focused more on the analysis of the interaction between the hull and propeller than the propeller itself.

The interaction between the hull and propeller, as well as the optimization of hull resistance, are the two pillars of optimizing hull performance which has become increasingly important in recent years due to the increased effort to reduce the environmental impact of the maritime transport system. The hull-propeller interaction has been investigated mainly through experimental tests and numerical (Computational Fluid Dynamics) simulations using different propeller models (e.g., Actuator disk, Blade Element Theory or Actual propeller geometry) [23] (Fig. 6).

Regarding the unconventional propulsions, on the other hand, the investigations were more focused on Wind Assisted Ship Propulsion (WASP), specifically on the characterization of the Flettner rotor performances by systematically varying shapes

Fig. 5 1001 Vela Indoor Challenge Trophy 2018

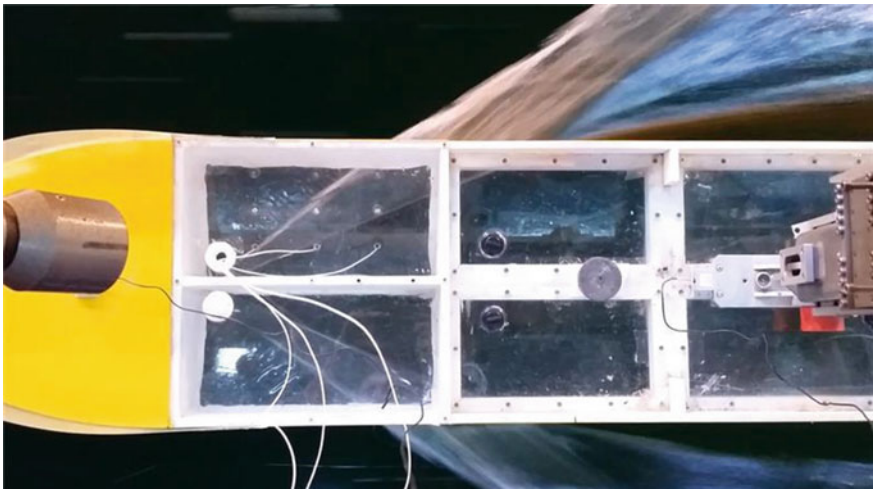

Fig. 6 Measurement of the pressure distribution on the bottom of planing hull

and sizes and the interaction between the Flettner rotor and the whole conventional ship propulsion system [24].

4.5 Ship Stability and Safety

4.5.1 Second Generation Intact Stability Criteria

The stability criteria are the requisites that ships must accomplish to ensure an adequate level of safety against the risk of capsizing, regulated by the International Maritime Organization (IMO), the specialized agency of United Nations with responsibility for the safety and security of shipping and the prevention of marine pollution by ships. The first set of the stability criteria are based on the statistical elaboration of the survived ships and are empirical formulation giving limiting values for the most important parameters which affects ship stability, as proposed in Rahola (1935). After numerous stability failures of intact ships in waves, IMO working group started development of the so called "second generation intact stability criteria" in which the most advanced nonlinear numerical simulations can be used for the direct assessment of the ship dynamics. Phenomena like parametric roll, surf riding, pure loss of stability and excessive acceleration are considered in the probabilistic frame of their occurrence. In this context, the group has given significant contributions, reported in prestigious international journals [25].

4.5.2 Damage Stability and Flooding Analysis

The study of damaged stability is required to ensure the survivability of damaged ships after the accidental flooding of one or more compartments.

The damage stability criteria, as for intact stability, are regulated by the IMO. Currently, two approaches are available at the scope: probabilistic and deterministic damage stability. Probabilistic damage stability is a methodology based on accident statistics on ship-ship collisions and involves some degrees of uncertainty- Deterministic methodology, instead, works on a predefined set of damage scenarios. The research group gave a significant contribution in this context, following also the global research trend on the topic.

Nowadays, time-domain simulations of flooding and motions of damaged ships are more frequently performed to obtain a more realistic overview of the actual survivability in case of a flooding accident. Therefore, the research group currently focuses on the understanding of flooding mechanisms and on the response in terms of ship dynamics by means of experimental tests and numerical simulations [26].

The outcomes of these research activities, together with the participation in a relevant benchmark study on numerical simulation of flooding and motions of a damaged ship, are reported in international journals [27, 28] (Fig. 7).

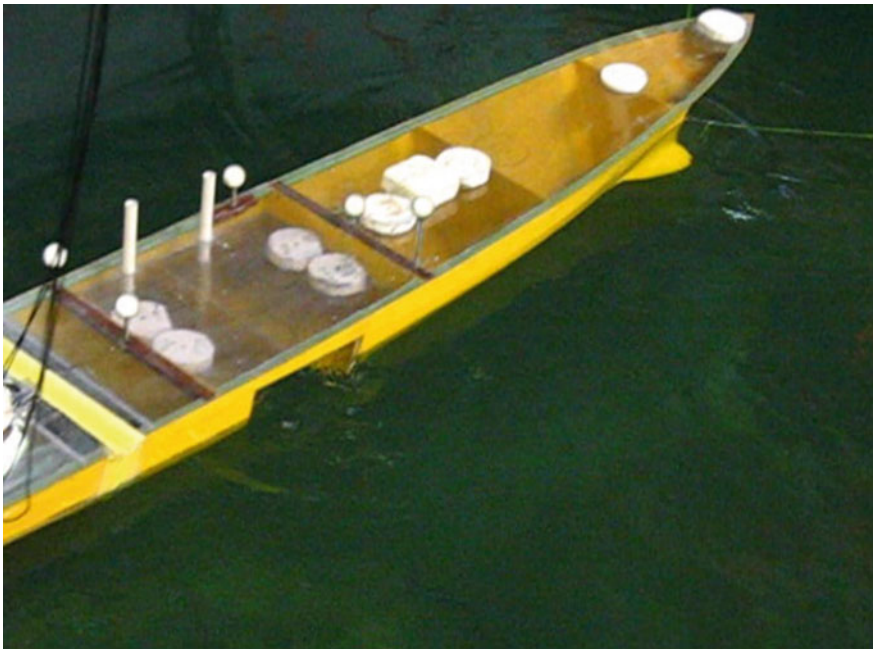

Fig. 7 Experimental study of damaged DTMB 5415 naval vessel

4.6 Ship Structural Analysis—Noise and Vibrations

Shipping has played a central role in transportation and trade with about 90% of internationally traded goods carried by ships. Simultaneously, with the growth in demand for ships and an increase in their complexity, ship structural design and calculation procedures have advanced considerably from prescriptive rules of the classification societies to rational analysis and design methods (Fig. 8).

In this context, the marine engineering section of the Industrial Engineering Department carried out research and studies on the four tasks that identify a rational structural design process:

1. Calculation of environmental loads;
2. Overall and substructure response analysis;
3. Limit state analysis;
4. Formulation of reliability-based structural constrains.

Several methods and tools for the assessment of loads and load effects were developed together with methods for the strength assessment of the hull girder [29]. Moreover, structural reliability, safety and environmental protections were the core topics of several researches [30].

Fig. 8 View of a ship under construction in a dry-dock

4.6.1 Noise from Ships

The NAME group of the Industrial Engineering Department, gave great attention also to the problem of Ship noise and vibrations. These can originate from a variety of sources on board, (including auxiliary engine exhausts, engine room and hold ventilation systems) and have negative impacts in terms of acoustic pollution, in air and in water. A research program was established, aiming at studying the noise levels of the ships and the possible solutions to the problem. A line of research has been treating the noise radiated into the air by ships, especially passenger ships, when engaged in port activities. In particular, the problem was approached from two sides; the first implied experimental measurements on board and in port by using sound level meters and intensimetric sound probes; the second is a simulative approach that, by ray tracing models, takes into account the countless sources of noise on board, the

Fig. 9 Experimental measurements of noise from ships

orography of the area, the buildings present and estimates the transmission of noise in the air that impacts the port city [31] (Fig. 9).

5 Future

Realistically, the marine field will undergo a number of significant changes. There is an urgent need to reduce the environmental impact of the operations of ships in all phases of navigation and, particularly, when the ship is in port. Indeed, since the power released by the engines of large ships is huge, the emissions are correspondingly high. For these reasons, rules and regulations are in progress to reduce the environmental impact of marine engines, above all, during working in ports i.e., close the inhabited zones. Probably, the reduction of emissions from ships will be achieved on various fronts and it will involve different solutions. The use of alternative fuels—such as methanol, liquid methane, LPG, and other fuels—will be further developed together with more radical solutions like the application of fuel cells onboard; this will certainly be achieved but the path towards a truly applicable solution is still long and difficult because the research in this field will have to overcome the problems associated with the production and use of hydrogen on board with all its operational and safety risks.

Autonomous and smart vessels, as in other fields of self-traction vehicles, are under study in order to create ocean-going cargo ships capable of navigating without crew, aiming at generating a significant money saving in the management of the ship and a remarkable improvement in the safety of the navigation. Indeed, the challenge of the researchers in the field is to ensure an adequate level of safety of the autonomous vessel, accounting for the peculiar environment where the ship operates.

The future research topics will also focus on the effects of climate change on the estimation of environmental actions, such as those from wind, waves, and currents, and their consequences on all maritime activities. Changes in ocean wave climate are expected to affect the extreme waves and rogue waves occurrence, demanding an upgrade in the structural design of ships and off-shore structures.

The future research of the professors and researchers of NAME group will further boost the bond of our expertise in experimental and numerical approaches to achieve highly sustainable ships. This synergic approach provides a proper insight on the hydrodynamic phenomena, provides additional information to experimental results not easily measurable and assures validation of CFD simulations. Future research will continue the optimization of the hull forms for zero-emission and energy-saving devices with high fidelity tools through the coupled CFD and FEM methods (e.g., Fluid-Structure Interaction) and the application of mesh-less or mesh-free codes such as Smoothed Particles Hydrodynamics (SPH) and Moving Particle Semi-implicit (MPS) methods. Research on the development of weakly nonlinear simulations in 6 DoF for complex hydrodynamic phenomena for safety and loads assessment will continue within the regulatory framework of Second Generation Intact Stability Criteria and research on the performances of wave energy converters.

The synergic combination of the developed numerical models will allow the simulation of hull-propeller—engine interactions, providing a digital twin of the whole propulsion chain of the ship in different scenarios. The adoption of digital twins, as in other fields, is gathering great attention for future applications aiming at enhancing the safety, efficiency, and sustainability of ship systems.

References

1. Caprio F, Pensa C (2007) Experimental investigation on two displacement catamarans: systematic variation of displacement, clearance and stagger. Trans R Inst Naval Arch Part B Int J Small Craft Technol 149:23–32. https://doi.org/10.3940/rina.ijsct.2007.b1.6707
2. Begovic E, Bertorello C, Bove A, De Luca F (2019) Experimental study on hydrodynamic performance of SWATH vessels in calm water and in head waves. Appl Ocean Res 85:88–106. https://doi.org/10.1016/j.apor.2018.10.012
3. Vitiello L, Mancini S, Bilandi RN, Dashtimanesh A, De Luca F, Nappo V (2022) A comprehensive stepped planing hull systematic series: Part 1 - resistance test. Ocean Eng 266. https://doi.org/10.1016/j.oceaneng.2022.112242
4. Begovic E, Bertorello C, Pennino S (2014) Experimental seakeeping assessment of a warped planing hull model series. Ocean Eng 83:1–15. https://doi.org/10.1016/j.oceaneng.2014.03.012
5. De Luca F, Pensa C (2017) The Naples warped hard chine hulls systematic series. Ocean Eng 139:205–236. https://doi.org/10.1016/j.oceaneng.2017.04.038
6. Begovic E, Bertorello C, Pennino S, Piscopo V, Scamardella A (2016) Statistical analysis of planing hull motions and accelerations in irregular head sea. Ocean Eng 112:253–264. https://doi.org/10.1016/j.oceaneng.2015.12.012
7. De Luca F, Mancini S, Miranda S, Pensa C (2016) An extended verification and validation study of CFD simulations for planing hulls. J Ship Res 60:101–118. https://doi.org/10.5957/JOSR.60.2.160010
8. De Marco A, Mancini S, Miranda S, Scognamiglio R, Vitiello L (2017) Experimental and numerical hydrodynamic analysis of a stepped planing hull. Appl Ocean Res 64:135–154. https://doi.org/10.1016/j.apor.2017.02.004
9. Tavakoli S, Niazmand Bilandi R, Mancini S, De Luca F, Dashtimanesh A (2020) Dynamic of a planing hull in regular waves: comparison of experimental, numerical and mathematical methods. Ocean Eng 217. https://doi.org/10.1016/j.oceaneng.2020.107959
10. De Luca F, Pensa C (2019) The Naples systematic series - second part: irregular waves, seakeeping in head sea. Ocean Eng 194. https://doi.org/10.1016/j.oceaneng.2019.106620
11. Ergin S, Mocerino L, Quaranta F (2023) Possible approaches to the study of the emissions from ships during their operations in ports in sustainable development and innovations in marine technologies. In: Proceedings of the 19th international congress of the international maritime association of the mediterranean, IMAM 2022, pp 371–378. https://doi.org/10.1201/9781003358961-46
12. Toscano D, Murena F, Quaranta F, Mocerino L (2021) Assessment of the impact of ship emissions on air quality based on a complete annual emission inventory using AIS data for the port of Naples. Ocean Eng 232. https://doi.org/10.1016/j.oceaneng.2021.109166
13. Mocerino L, Cascetta F, Cartenì A, Dentice d'Accadia M, Gallo D, Quaranta F (2022) The evaluation of the impact on the quality of the atmosphere of all activities carried out in the ports of Naples and Salerno. Case Studies Chem Environ Eng 6. https://doi.org/10.1016/j.cscee.2022.100263
14. Amoresano A, Iodice P, Langella G, Mocerino L, Quaranta F (2022) Transport analysis of solid sediments in a ballast water flow. J Phys: Conf Ser 2293. https://doi.org/10.1088/1742-6596/2293/1/012003

15. Mocerino L, Soares CG, Rizzuto E, Balsamo F, Quaranta F (2021) Validation of an emission model for a marine diesel engine with data from sea operations. J Marine Sci Appl 20:534–545. https://doi.org/10.1007/s11804-021-00227-w
16. Begovic E, Mortola G, Incecik A, Day A (2013) Experimental assessment of intact and damaged ship motions in head, beam and quartering seas. Ocean Eng 72:209–226. https://doi.org/10.1016/j.oceaneng.2013.06.024
17. Mancini S, Begovic E, Day AH, Incecik A (2018) Verification and validation of numerical modelling of DTMB 5415 roll decay. Ocean Eng 162:209–223. https://doi.org/10.1016/j.oceaneng.2018.05.031
18. Sirigu SA, Bonfanti M, Begovic E, Bertorello C, Dafnakis P, Giorgi G, Bracco G, Mattiazzo G (2020) Experimental investigation of the mooring system of a wave energy converter in operating and extreme wave conditions. J Marine Sci Eng 8. https://doi.org/10.3390/jmse8030180
19. Acanfora M, Rizzuto E (2019) Time domain predictions of inertial loads on a drifting ship in irregular beam waves. Ocean Eng 174:135–147. https://doi.org/10.1016/j.oceaneng.2019.01.051
20. Acanfora M, Balsamo F (2020) The smart detection of ship severe roll motions and decision-making for evasive actions. J Marine Sci Eng 8. https://doi.org/10.3390/JMSE8060415
21. Begovic E, Bertorello C, Bove A, De Rosa S, Fasano E, Franco F, Santoro N (2016) Experimental study of hydrodynamic impact pressures on high speed planing craft. Trans R Inst Naval Arch Part B: Int J Small Craft Technol 158:B15–B25. https://doi.org/10.3940/rina.ijsct.2016.b1.174
22. Acanfora M, Krata P, Montewka J, Kujala P (2018) Towards a method for detecting large roll motions suitable for oceangoing ships. Appl Ocean Res 79:49–61. https://doi.org/10.1016/j.apor.2018.07.005
23. De Luca F, Mancini S, Pensa C, Raiola G (2018) Numerical assessment of self-propulsion factors for a fast displacement hull using different theoretical approaches. Trans R Inst Naval Arch Part B: Int J Small Craft Technol 160:B79–B90. https://doi.org/10.3940/rina.ijsct.2018.b2.214
24. De Marco A, Mancini S, Pensa C, Calise G, De Luca F (2016) Flettner rotor concept for marine applications: a systematic study. Int J Rotat Mach 2016. https://doi.org/10.1155/2016/3458750
25. Begovic E, Bertorello C, Rinauro B, Rosano G (2023) Simplified operational guidance for second generation intact stability criteria. Ocean Eng 270. https://doi.org/10.1016/j.oceaneng.2022.113583
26. Acanfora M, Balsamo F (2021) On the development of fast numerical methods for the estimation of hull girder loads for a flooded ship in waves. Ocean Eng 233. https://doi.org/10.1016/j.oceaneng.2021.109213
27. Acanfora M, De Luca F (2016) An experimental investigation into the influence of the damage openings on ship response. Appl Ocean Res 58:62–70. https://doi.org/10.1016/j.apor.2016.03.003
28. Ruponen P, Valanto P, Acanfora M, Dankowski H, Lee GJ, Mauro F, Murphy A, Rosano G, Veer RV (2022) Results of an international benchmark study on numerical simulation of flooding and motions of a damaged ropax ship. Appl Ocean Res 123. https://doi.org/10.1016/j.apor.2022.103153
29. Acanfora M, Coppola T (2020) Assessment of bending and torsional moments on hull girder due to parametric roll: a case study for a containership. Ships Offshore Struct 15:780–791
30. Campanile A, Piscopo V, Scamardella A (2016) Incidence of residual stresses and steel properties variability on corroded bulk carrier reliability. Ocean Eng 128:58–80. https://doi.org/10.1016/j.oceaneng.2016.10.026
31. Mocerino L, Quaranta F, Viscardi M, Rizzuto E (2021) Airborne noise emissions from marine vessels: an analysis based on measurements in port in developments in maritime technology and engineering. In: Proceedings of the 5th international conference on maritime technology and engineering, MARTECH 2020 1 (2021), pp 349–355. https://doi.org/10.1201/9781003216582-39

Aerospace Engineering

Gennaro Cardone and Francesco Marulo

Abstract This chapter summarizes the research activities and main outcomes of the groups engaged in the fields of Aerospace Engineering, in the decade 2013–2023. The research topics are Aerodynamics, Aerospace Systems, Design of Aircraft and Flight, Fluid-dynamics, Propulsion and Structural Technologies.

1 Introduction

Aerospace is, by its name, a multidisciplinary discipline with main roots in flight mechanics, light structures, systems, fluid dynamics and propulsion. The strong interaction is increasing day by day with electronics and materials engineering, as well as electrical and informatics, and including basic sciences like mathematics, numerical simulation and state-of-the-art testing methods.

The birth and development of the Department of Industrial Engineering has offered a unique opportunity for the Aerospace group to interact and develop mutual interests with Colleagues of such a new big department, but also practicing collaborations with other professors nationwide and strengthening those worldwide. Since the beginning of the development of the Department of Industrial Engineering, Aerospace has played a driving role in both research and education aspects and recently also ramping up the activities of the third mission strengthening the collaborations with local companies and with the international big players of the aerospace field. The new department, innovatively called Industrial Engineering, maintained, as requested, separate degree programs, but received the duty of managing those bachelor's and master's courses, attempting to achieve efficiencies in staffing and class offerings. From the Ph.D. side, the courses were grouped under the umbrella of Ph.D. in Industrial Engineering, but keeping the specialization in Aerospace.

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https://doi.org/10.1007/978-3-031-53397-6_3

Another important legacy inherited by the Aerospace group and appreciated by other colleagues has been, and still is, the international activities which have been spread out through the other disciplines. A well-established Erasmus program, together with more than two decades of participation in the Pegasus network have paved the way to new and accredited participation with a driving role for other international activities. The tradition and the vision developed during the years before the birth of the actual department have been transferred and improved inside the new academic system by offering experiences and taking opportunities and vision from other sectors from the viewpoint of reciprocal interest. Colleagues from the aerospace group have been selected and served for the benefit of the Department of Industrial Engineering at any level of involvement. Academic, staff, and functional, research committees have always benefitted from the voluntary positive participation and collaboration of several colleagues always including persons from the aerospace team.

Initial difficulties in practising in a new environment have been identified and smoothed by the assumption of common interests and the understanding of the possibility of moving a step forward thanks to the harmonized participation of all the departmental components. Managing a big group of academics is never an easy job, which may become extremely complex when interacting with career expectations, at any level, which requires a list of priorities, and identifications of weaknesses and strengths. Optimization of infrastructures, exploring best practices, and improving general efficiency is the main goal, and the most important objectives of the leadership managing such a big academic department. The evolution of such leadership, for which the aerospace group are still playing a strong role, passing through the experience and moving toward the strength of the new generation has resulted in a key point in the success of the department, accredited, at the time of writing these pages, as Department of Excellence.

The principal contribution, of course, to the development of the Department of Industrial Engineering should be attributed to its graduates. They have distinguished themselves in many activities, not only in aerospace but also in academia, government institutions and military organizations. The increased rate of success of the department's graduates is the real figure of a tradition of research and teaching which stresses an appreciation for real applications in an extensive and deep base of fundamentals.

2 Background and Legacy

Aerospace (more properly, Aeronautical) Engineering began at Federico II in 1926, with the establishment of a program in Aircraft Structures by Gen. Prof. Umberto Nobile, appointed Full Professor of that discipline. He was the first Director of the "*Gabinetto di Costruzioni Aeronautiche*", which became, over time based on the activities of two of his most famous students, Prof. Luigi G. Napolitano and

Prof. Luigi Pascale Langer, respectively, the Aerodynamic Institute and the Aircraft Design Institute.

After a period of difficult interactions among the most representative figures of Aerospace Engineering, with further development of the Gasdynamics Institute, those institutions moved toward the birth of two Departments, one more oriented toward the aeronautics and the other with more space attitude. On January 2007 both these Departments finally converge in the Department of Aerospace Engineering (DIAS). The road to reunification has been long and difficult, but in the end, the entire aerospace sector, including some researchers who belonged to other departments, came together in DIAS, to confirm the common identity, the common *aerospace* root that originates from the founder of Neapolitan School of Aeronautical and Space Engineering, Prof. Umberto Nobile.

This long and well-established aerospace tradition in addition to favouring and promoting a strong push towards the creation and consolidation of scientific and didactic relationships with national and international universities, in particular through the European PEGASUS network, has given also a significant contribution to the creation of two new degree programs in Aerospace Engineering for the Universities of Southern Italy.

The Second University of Naples, now *Università degli Studi della Campania Luigi Vanvitelli*, established in 1990, began its activities in the 1991–92 academic year by opening some Degree Courses in Engineering, including that of Aerospace Engineering. A certain number of Professors and Researchers of Federico II moved to this new University and trained in Federico II, enriching the Aerospace Engineering teaching staff of this new University.

In the 2006–07 academic year, the University of Salento in Lecce established the Master's Degree Course in Aerospace Engineering at the Brindisi branch. The Dean of the Faculty of Engineering asked some professors of Federico II and of the SUN to contribute together with other collaborators and researchers to the birth and development of that Degree Course, created with the aim of supporting the development of the Apulian aerospace industry which in those years had strong growth thanks to the Alenia (Grottaglie and Foggia) and AgustaWestland (Brindisi) plants.

Since the birth of the Department of Industrial Engineering, in 2013, the Aerospace section has contributed to its development by sharing interests, perspectives and development paths with colleagues from other groups, seeking synergies both in terms of sharing scientific topics, but also for the multidisciplinary development of the courses, of the laboratory activities and also of the third mission interactions. The requirements created by the new law, especially in organizational and administrative matters, have also permeated at a scientific level without forcing to reject personal attitudes and traditions, but seeking points of contact such as to improve the efficiency of individuals for the benefit of the entire Department. Virtuous examples have been the collaborations of degree courses, and the introduction of new disciplines (Electrical foundations for aeronautics, just to mention one example) which have proved to be important for the achievement of EASA recognition allowing the students to acquire the theoretical part of the aircraft maintenance qualification.

Another very important aspect of academia is managing people's careers. The Aerospace Engineering group has contributed to a balanced growth of the entire Department, locating sectors with development needs and harmonizing them with others historically more consolidated, trying, within the limits of what could be allowed, to drive a shared growth of the entire Department. The transparency of these operations has allowed the acceptance of wise planning of career progression by collaborating to smooth out sharp edges and facilitate interpersonal relationships.

The results of these operations, culminating with the award of the Department of Excellence seal, have been experienced and appreciated day after day, in teaching activities, laboratory experimentation and in nationwide and international opportunities that have engaged the people who work in the department, also from an administrative point of view, as evidenced by the number of research programs, by international doctoral activities, by the opening of new collaborations with Italian and foreign institutions.

3 Congresses

The aerospace group has hosted and chaired several conferences in Napoli:

- PSFVIP 10, 10th Pacific Symposium on Flow Visualization and Image Processing, 15–18 June 2015; https://psfvip10.unina.it.
- FLUCOME 2019, 15th International Conference on Fluid Control, Measurements and Visualization, May 27–30, 2019; https://flucome2019.unina.it.
- MEDYNA, 2020: 3rd Euro-Mediterranean Conference on Structural Dynamics and Vibroacoustics; https://medyna2020.sciencesconf.org.
- ISSM9, 2022: 9th International Symposium on Scale Modeling; https://issm9.sciencesconf.org.
- CLEAN AVIATION International Workshop: "Toward Sustainable Transport Aircraft", 6–7 October 2022.

4 Main Research Groups and Programmes

4.1 Design of Aircraft and Flight Technologies (DAF)

Flight mechanics and flight technologies form a comprehensive field that includes a variety of disciplines, such as aircraft design, stability and control assessment, air vehicle aerodynamics modelling, flight performance prediction, flight dynamics and simulation. The professors and researchers of the flight mechanics field, under the acronym ING-IND/03, bring together the tradition of promoting atmospheric and

transatmospheric flight technologies in line with modern research findings, promoting exchange and integration with the most accredited national and international universities, research centers and companies.

The *Design of Aircraft and Flight Technologies* (DAF) research group is mostly focused on atmospheric flight mechanics and is involved in basic and applied research on the following topics: (i) Aircraft Design and Aircraft MDO, (ii) Digital twin, methods and software for aircraft analysis and design, (iii) Aircraft Aerodynamic Design and Optimization (including propeller design), (iv) Flight Mechanics and Aircraft Performance, (v) Aircraft powertrain optimization and powertrain integration, (vi) Wind Tunnel tests, (vii) Flight Tests, (viii) Flight Simulation.

The DAF research group since 2010 has developed research programmes concerning aircraft design and flight technologies. The research field can be also defined as Flight Physics, which encompasses aircraft aerodynamic design and optimization, flight mechanics and performance, aircraft conceptual and preliminary design, experimental aircraft aerodynamics, flight testing, as well as flight simulation. They are well synchronized and merged bringing the focus on the development of innovative flying vehicles.

The research activities performed by the DAF group in the last 10 years, since the Department foundation, have been focused on the design and development of tools, methods and frameworks for innovative aircraft design and parallel relevant applications on design, optimization and testing (especially aerodynamic testing in the low-speed wind tunnel) of new innovative aircraft configurations. For the last 5–6 years, in particular, the group has been involved in research programmes on hybrid/electric aircraft design, with innovative propulsive powertrain architectures and using fuel cells and Liquid Hydrogen (LH2). The main achievements and the related research topics are summarized in what follows.

The DAF group is very active in applied and financed research projects, especially at the European level and it has a very solid and strict collaboration with many relevant Industries, Universities and Research Centers in Europe, Canada, USA. In the last 10 years, the group has been involved in 2 nationally financed research projects (PON), and in 9 European projects (H2020, Clean Sky, Horizon Europe and Clean Aviation) for a global funding amount of about 5M euro. All research activities are highly applied and in collaboration with industrial partners (Leonardo, Piaggio, Airbus, Tecnam, etc.) for the development of new and innovative products (Fig. 1).

The DAF researchers have been focusing on the design of innovative and green/low-emissions aircraft with new propulsive systems including batteries, fuel cells and Hydrogen [1, 2]. Also for conventional aircraft configuration, the research developed is focused on global aerodynamic optimization, fuel consumption reduction, weight saving, and higher safety [3, 4]. The activities also involve relevant experimental applications, like the wind-tunnel tests (the group is mainly leading the main subsonic wind-tunnel of the Department for aeronautical applications) and flight tests that are developed at full-scale level (flight tests of light and general aviation aircraft, i.e., in collaboration with Tecnam), but recently also at scaled level (scaled flight testing) with small remotely piloted aircraft [5, 6]. The group has been developing in recent years a lot of methods and software for aircraft design. Some

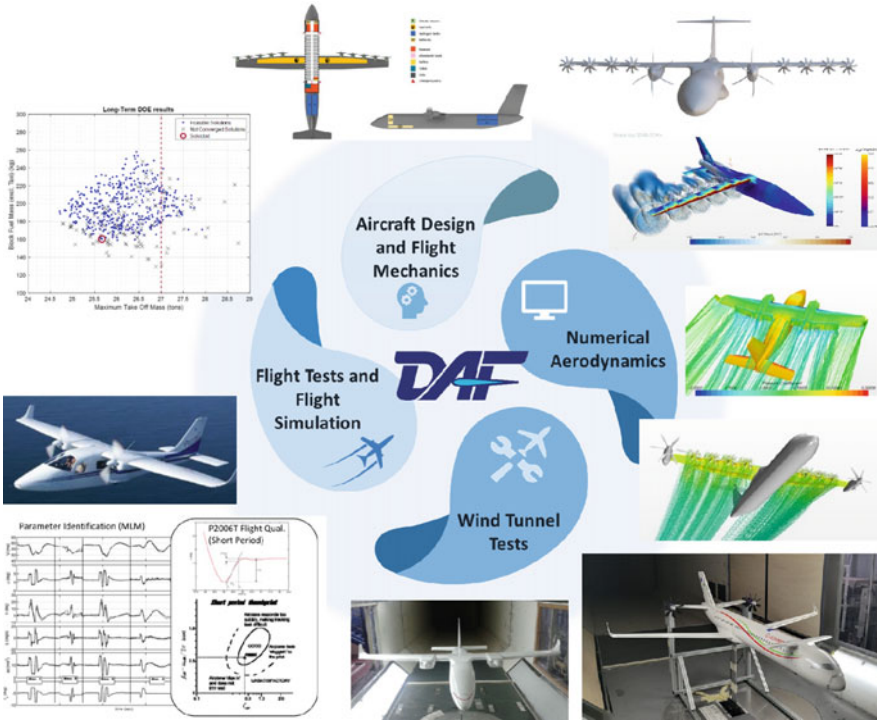


Fig. 1 Research activities within the fields of aircraft design and flight technologies

implemented methodologies (for example, a new method for the prediction of directional stability and control derivatives) have been also derived from wind-tunnel tests or deep CFD campaigns [7, 8].

The first aircraft design software developed in the group was ADAS. Next, the DAF group has been focusing on the development of advanced frameworks and tools for aircraft design. The software JPAD developed in Java language [9] represents a mature framework for aircraft design and became also the main commercial product of the spin-off company SmartUp Engineering (www.smartup-engineering.com) established by the group in 2020. The development of an advanced framework [10] has been also pushed by three H2020 and Horizon Europe European projects: AGILE (2015–2018), AGILE 4.0 (2019–2023) and COLOSSUS (2023–2026). The projects aimed at the development of an efficient and fast collaborative framework for aircraft design with a focus on commonality, production, and supply chain. Many applications with some relevant design cases covering regional turboprop aircraft, unmanned vehicles, and commuter seaplanes have been performed during these projects [11]. In the last years, since 2017, the research group has been focusing on developing tools and frameworks for the design of hybrid/electric aircraft configurations. The software HEAD has been developed and several interesting applications have been

produced during the EU projects IRON, ELICA, and HERA. During the research project ADORNO (in collaboration with MTU) the group has developed advanced methodologies for engine modelling and production of engine performance tables of modern Very-High BPR advanced turbofan engines.

The research group has also developed tools and methods for the aerodynamic analysis of aircraft and aircraft components. The research has been addressing the design of an efficient flap system for the ATR, the design of the Karman for the ATR aircraft, and the design of winglets for light aircraft and regional transport aircraft. The research group has developed a methodology for wing analysis in non-linear conditions to quickly estimate the high-lift characteristics of wings in clean and flapped configurations. Many CFD-dedicated activities are performed for the analysis and optimization of aircraft. Several automatic tools for the generation of geometries and the automatic optimization of aircraft components have been developed. In 2015–2017 the research group has been working on the use of CFD and wind-tunnel tests for the analysis of several different tail and fuselage configurations to build new advanced design methodologies for the design of innovative turboprop aircraft.

During the last 10 years, the DAF group has been extensively operating the main low-speed wind tunnel facility belonging to the Department of Industrial Engineering. Some relevant applications concerning dedicated research contracts or research projects have been performed. In 2013 there was the wind-tunnel test campaign of the Tecnam P2012 Traveler aircraft. Other recent wind-tunnel experimental activities were dealing with the project IRON (wind-tunnel test of the advanced turboprop configuration with 3 lifting surfaces, including some relevant tests concerning indirect propulsive effects on stability and control). In 2020 There were some relevant and interesting tests of a wing model equipped with 4 electric engines to test the effectiveness of a Distributed Propulsive architecture (DEP). In the project PROSIB we covered also wind-tunnel tests of a commuter configuration. Several interesting tests are ongoing (2023) for the project IMPACT (wind tunnel tests of a rear-end and innovative horizontal tailplane).

Flight simulation is an important discipline where DAF researchers have been active for years. A notable contribution to the field is the ongoing support for the development and maintenance of the widely used open-source flight dynamics model library JSBSim (https://github.com/JSBSim-Team/jsbsim). A line of research on AI-based flight control for fixed-wing aircraft and missiles has been pursued in the past few years. Both consolidated and more recent results in artificial intelligence and Deep Reinforcement Learning (DRL) research have been used—also through joint research agreements with CIRA (Italian Center for Aerospace Research) and MBDA—to design AI-based controllers that make high-performance military aircraft or hypersonic vehicles fully autonomous [12].

4.2 Structural Technologies, Methods and Applications

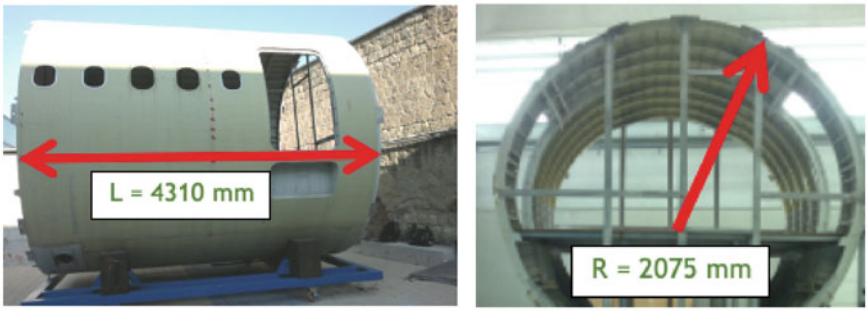
Structural technologies encompass and integrate a broad range of disciplines, from materials development to analysis, design, testing, manufacturing and maintenance of complete aircraft. Materials and structures have traditionally been the key element enabling progress and major performance improvements in many aerospace systems [13]. The development of the computational power of structures, the improvement of the possibilities of experimentation, research in the sector of intelligent structures together with the evolution of advanced composite materials, now a heritage of daily life, have improved structural performance, reduced operational risks and lowered times of development. In addition to enabling technologies for future aeronautical and space systems, materials and structures continue to be key elements in determining the reliability, performance, testability and cost-effectiveness of these systems [14].

The professors and researchers of the Aerospace Structures field, under the acronym ING-IND/04, bring together the tradition of promoting Aerospace Engineering, and developing the methodologies and applications in line with modern technologies, promoting exchange and integration with the most accredited national and international universities, research centers and companies.

Starting from a common base and to keep pace with the high developments of world research, all researchers in the Aerospace Structures field have diversified and specialized their research interests by creating specific laboratories following a historical strong link between research activities, industrial needs of the aerospace sector and the subjects of the teachings offered to students [15].

The backbone of the study of light aerospace structures is represented by the elasticity of its components which makes the difference compared to other structural disciplines. Rotor blades of a helicopter, wings of a sailplane, and thermoelastic and shock-resistant satellites are just simple examples of the complexity of reaching the efficiency of structural solutions [16]. Aircraft safety has been another important topic developed by the structural aerospace group [17–19]. Moreover, in aerospace engineering, the shape is associated with multiple design parameters: aerodynamic efficiency, effectiveness of controls, stability of an aircraft, handling qualities, and so on (Fig. 2).

The structural aerospace topics, inheriting what was already being defined, have been subdivided through mandatory and elective courses and offering all the students the basic principles of the theory of elasticity and methods for solving complex structures while leaving specialized aspects to the elective courses which sometimes are also taken by students of branches different from aerospace. The main idea behind the aerospace structural organization is oriented to transfer approaches that can be used to understand and to analyze the different structural behaviors. The result of such deep knowledge should end up with an efficient structural sizing which enables safety and minimizes the probability of occurrence, during the operational life of any structural element, of any catastrophic event. In a simplified overview, this will be the result of a perfect interaction of theoretical formulations, numerical methodologies



(a) Partial length of a full-scale fuselage.

(b) Vibroacoustic tests of a fuselage bare structure (left), and of the furnished structure (right).

Fig. 2 Testing the acoustic comfort of a medium-range commercial airplane full-scale fuselage

and experimental observations which represent the tools for reaching the best fit for complying with assumed structural requirements [20] (Fig. 3).

The aerospace structural team has traditionally spent great interest and reserved strong sensitivity in experimental and laboratory activities [21, 22]. With the development of experimentation technologies, of structural identification algorithms [23, 24], of increasingly sophisticated sensors, they have moved from the use of strain-gauges, still widely used, to the use of MEMS accelerometers, piezoelectric patches, fibers optics, non-contact laser sensors, together with beamforming and non-destructive ultrasound techniques, [25–27], for monitoring the health of a structure. The topic of structural health monitoring (SHM) has become an important research line with solid international interactions and continuous participation to the most accredited congresses and strong leadership in international research projects [28, 29]. The use of these, and other, measurement technologies has led to the development of specific skills in the field of structural testing, with the creation of research groups interested in each of these technologies and their integration [30]. By virtue of these interests, and the need for suitable laboratory spaces, some of the group's activities have been moved to the new Federico II campus in San Giovanni a Teduccio,

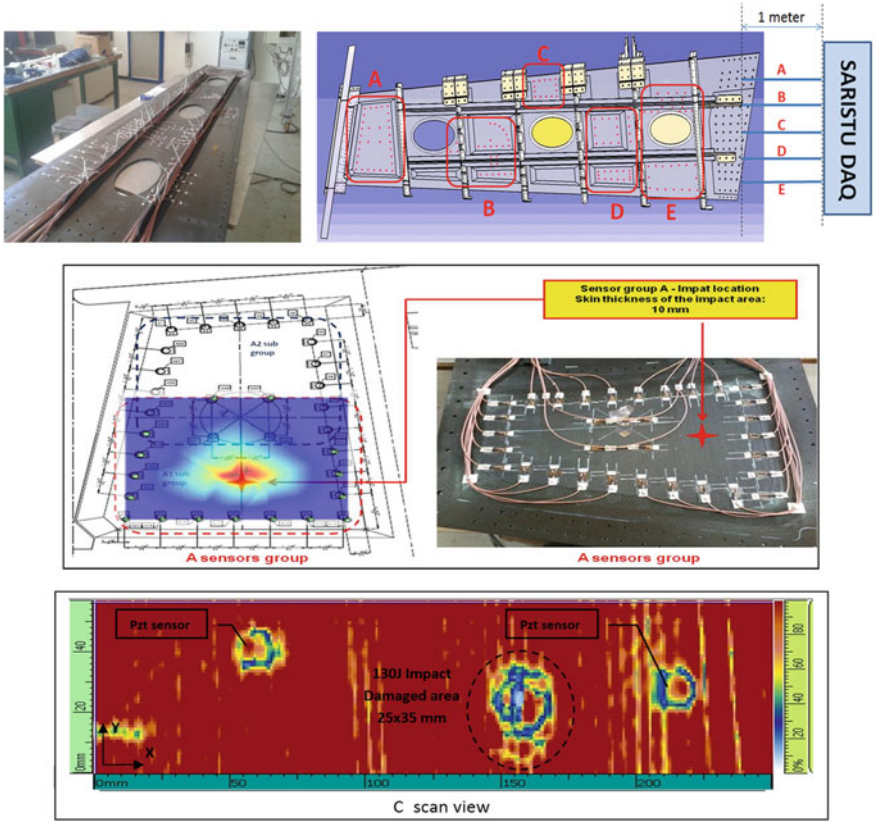


Fig. 3 Application of guided waves based Structural Health Monitoring (SHM) on a full wing composite upper panel (EU funded SARISTU Research Project). Upper row: sensorised wing panel; middle row: SHM implementation on a skin bay; lower row: Impacted location C-Scan

particularly those related to vibroacoustic testing [31, 32] and researches for passenger comfort [33–36]. The constant commitment of the members of the structural aerospace group has driven a significant contribution to the growth and development of the activities headed by the San Giovanni campus, also with the organization of international conferences, student activities and the promotion and assessment of relationships and interactions with national and international interested companies.

The list of international projects including persons in the aerospace structural field would be very long, being them participating to the European Framework programs since 1990. Many other research projects have been developed locally or nationwide with close collaboration with other universities and research centers. Moreover, members of the aerospace structural group have been involved in industrial programs, international bodies for setting up certification guidelines, and scientific committees for editing papers, journals and research projects. Just to name a few of them, European funded research project on a competitive basis are CASTLE

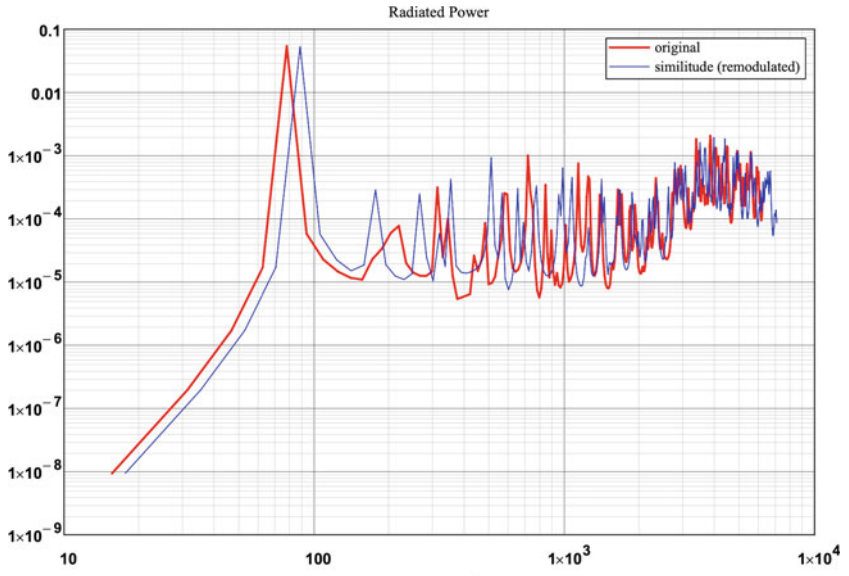


Fig. 4 Acoustic radiated power by two different aluminum plates after having remodulated the response of one over the other: Watt versus Hz

addressing the well-being of the in-flight passenger, T-WING for the design and manufacturing of the wing of the Next Generation Tilt Rotor (NGTR), SOLIFLY for the basic research on structural batteries. A companion example is also represented by a new book on Structural Dynamics [37], which is going to be published in 2024. All this demonstrates continuity in the group's activities as well as their importance and international impact with an open view to the future of aircraft transportation [38].

Some specific topics have been addressed during the last decade. They are related to (i) the scaling laws and similitudes for vibroacoustic systems, [39] (an example is in Fig. 4); (ii) the stochastic response of the elastic structure to the turbulent boundary layer (TBL) excitation [40]; (iii) the application of machine learning to the vibroacoustic problems [41]; (iv) the propagation of the elastic waves in structural components [42] (see Fig. 3); (v) the application of the finite element method (FEM), spectral finite element method (SFEM), the wave and finite element method (WFEM) and the statistical energy analysis (SEA) for the vibroacoustics of complex systems [43] (see Fig. 4); (vi) the analysis and the design of meta-components [44]. (vii) Around these themes a spin-off was also established: https://wavesetconsulting.wordpress.com.

During the years a community (and a series of four symposia) was created around the themes of measurement, modelling, simulation and reproduction of the flow excitation and flow induced structural response (www.flinovia.org, FLow Induced NOise and Vibration Issues and Aspects). These topics are relevant for all the high

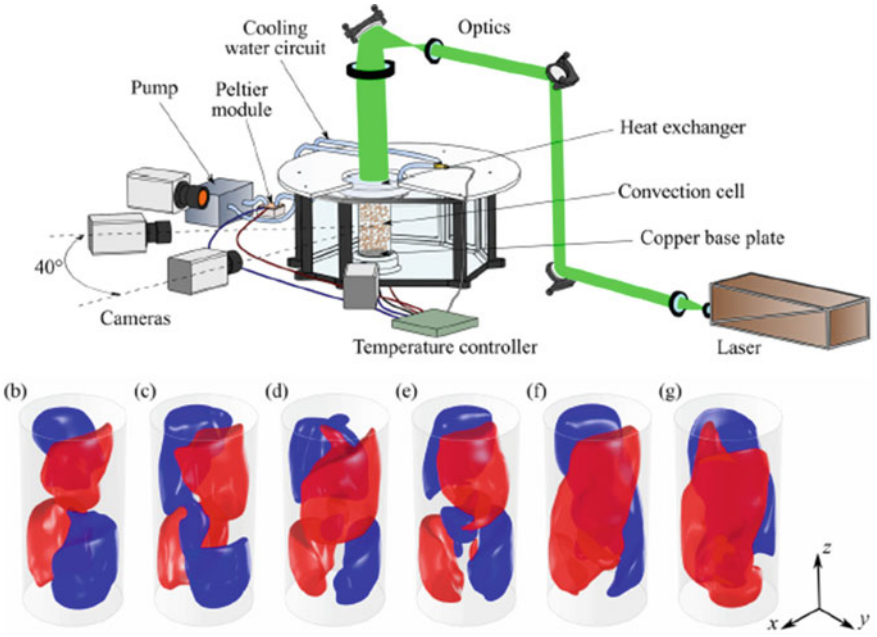


Fig. 5 Rayleigh Benard convection: experimental apparatus and 3D flow field evolution

speed transportation engineering. This community has produced a series of books which represent the evolving state-of-the-art about those topics [45–47].

The fourth volume is to appear during 2024 while the fifth symposium was planned in Napoli during the spring of 2026. The previous editions were held in Rome 2013, Penn State 2017, Lyon 2019 and Sydney 2023.

4.3 Fluid-Dynamics, Aerodynamics and Propulsion

Professors and researchers in the fluid dynamics sector, continuing a long tradition of the University of Naples, have been very active in the last decade in developing methodologies and application in the field of fluid dynamics with particular attention to Aerodynamic (Theoretical and Applied), Aerothermodynamics, Computational Fluid Dynamics, Experimental Thermo-Fluid-Dynamics, Flow control, Fluid dynamic stability, Micro-gravity, Modal analysis and Propulsion. The research activity is organized into five research group.

The *Theoretical and Applied Aerodynamic Research Group* (TAARG) is involved in both Theoretical and Applied Aerodynamics research fields. Aircraft Aerodynamics, Rotary Wing and Wind Turbine Aerodynamics are the macro contents where the group is performing its main research activity. During last decade TAARG cooperated

with many Universities and Research Centers. From the academic side, the cooperation with University of Beijing, San Diego State University and, more recently, Stanford University should be recalled. In addition, TAARG developed joint research programs with CIRA (the Italian Research Center), JAXA (Japan Aerospace Agency) and ONERA (the French Aerospace Labs). It was involved in EU funded Research programs (Clean Sky and Clean Sky 2) and is also active in GARTEUR Projects. During the last ten years visiting researchers coming from China, Japan, France and USA joined the team. Concerning the main scientific activity of the group, it must be cited the fundamental contribution to the development of an Advanced Aerodynamic Force theory which also led to important technology advances in aerodynamic design applications. In particular, the development of a thermodynamic and, more recently, vorticity-based theory [48] allowed for the analysis and decomposition of the Aerodynamic force acting on flying bodies, thus giving the chance of identifying the main physical contributions of the aerodynamic drag (viscous, wave and lift induced), a main concern for the aerodynamic designer. TAARG is world leader in this technology (together with ONERA and Beijing University). The thermodynamic method in particular has been adopted during the design of last generation commercial aircraft. More recently TAARG is dedicating its efforts, together with CIRA, in the still unsolved problem of drag/thrust bookkeeping in steady and unsteady flows. Another important contribution has been given by the understanding of second order effects of riblets. Riblets are streamwise micro-grooves that mimic shark skin and can reduce friction drag in turbulent flows. The models developed by TAARG give now the chance to the scientific community to predict riblet performance on complex aerodynamic surfaces by numerical analyses [49]. The last frontier in which TAARG is now involved is the application of Machine Learning tools in Fluid Dynamics. Together with Stanford University it is focusing on the possibility to adopt Machine Learning in order to finally obtain "exact" virtual aerodynamic, a long time expected results of Computational Fluid Dynamics still far to be reached [50]. Recent activity of the *Computational Fluid Dynamics research group* has been focused on the design and assessment of robust and accurate numerical methods for both compressible and incompressible flows. As regards incompressible flows, has been developed and tested pseudo-symplectic Runge–Kutta time-integration methods for the incompressible Navier–Stokes equations with applications to the numerical simulation of turbulent flows. In contrast to fully energy-conserving, implicit methods, these are explicit schemes of order p that preserve kinetic energy to order q, with $q > p$. Use of explicit methods with improved energy-conservation properties is appealing for convection-dominated problems, especially in case of direct and large-eddy simulation of turbulent flows [51] (Fig. 6).

Other contributions are focused on the development of Fast-Projection methods for the discretization of incompressible Navier–Stokes methods. Fast-projection methods are based on the explicit time integration of the semi-discretized Navier–Stokes equations with a Runge–Kutta (RK) method, in which only one Pressure Poisson Equation is solved at each time step. The methods proposed by the group are based on a class of interpolation formulas for the pseudo-pressure computed inside the stages of the RK procedure to enforce the divergence-free constraint on

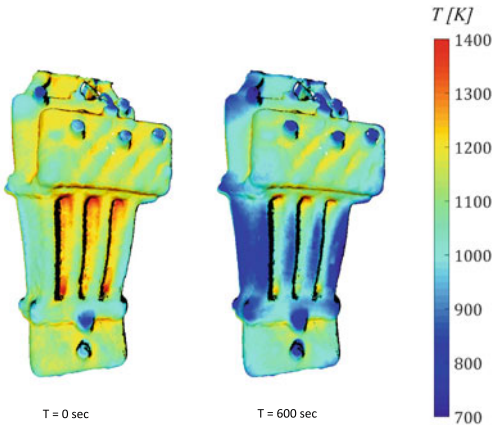


Fig. 6 IR 3D temperature map of turbine blades' ceramic shell mold in industrial environment (METEMI project)

the velocity field. The procedure is independent of the particular multi-stage method and have been applied to some of the most commonly employed RK schemes. As regards compressible flows, the most important contributions [51, 52] have been made in the broad field of structure-preserving numerical methods, with the aim of design robust and accurate methods for turbulent simulations. General conditions for the local and global conservation of primary (mass and momentum) and secondary (kinetic energy) invariants for finite-difference and finite-volume type formulations have been recently derived in a general setting for transport equations relevant to fluid-dynamics problems. This activity completes a systematic analysis of the discrete conservation properties of non-dissipative, central-difference approximations of the convective terms in the compressible flow equations which was previously conducted by the group, and which provides a quite complete characterization of kinetic energy preserving discrete formulations for compressible Euler equations. This analysis has also conducted to novel splittings with exact discrete preservation of kinetic energy. Other recent contributions have been made on the conservation properties of the discretizations of various formulations of the system of compressible Euler equations for shock-free flows, with special focus on the treatment of the energy equation and on the induced discrete equations for other thermodynamic quantities (e.g., entropy) (Fig. 7).

The *Experimental Thermo-Fluid-Dynamics group* (ETFD) undertakes research on a wide variety of fluid flow phenomena, both fundamental and applied, using state-of-the-art experimental methods. The main objectives of fundamental research are the analysis and understanding of the evolution of both transitional and turbulent flows, including boundary layers, jets, swirling flows and natural convection, and hypersonic flows. On the other side, applied research is carried out on the enhancement of the convective heat transfer from different fluidic actuators, such as devices based on synthetic, fractal, swirling and sweeping jets, and flow control of separated flows behind both bluff and aerodynamic geometries. The ETFD group works also in the field of fluid metrology, with focus on the development of Particle Image Velocime-

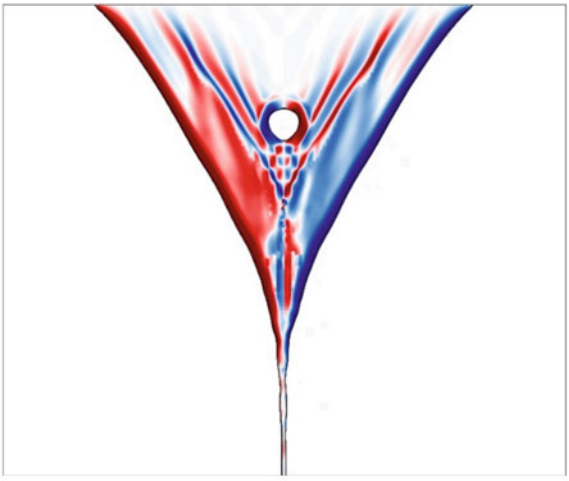


Fig. 7 Numerical simulation of hole-induced dynamics of three-dimensional vertical liquid curtain

try (PIV) and Infrared (IR) thermography methods. Such advanced techniques are applied via state-of-the-art equipment, including both low-speed and high-speed tomographic PIV systems and cutting-edge IR cameras (high-speed MW and LW cameras). More specifically, in the last decade the ETFD research group has given many substantial contributions to the development of: laser diagnostic techniques as PIV, stereoscopic PIV and tomographic PIV. In particular, it has been co-organizer of the 4th International PIV Challenge https://www.pivchallenge.org/pivchallenge4.html [53]. The tomographic PIV has been applied to a large variety of challenging experiments such as: the study of the three-dimensional organization of the flow structure in a non-reactive model aero engine lean burn injection system, Rayleigh–Benard convection in a cylindrical sample and fractal grid turbulence [54–56]; (Fig. 5) Infrared Thermography for 3D surface temperature reconstruction (Fig. 6), heat transfer measurements in fluid flows and transition detection from low-speed to hypersonic flows [57–59]; fundamental understanding of jet flows, such as synthetic, swirling, fractal and chevron jets. In general, the free and impinging flow fields and the wall heat transfer distributions have been investigated [60–63]; technologies for active flow control of wing-tip vortices and bluff bodies wakes [64]. Most of the above scientific research activities are developed within international/national scientific projects: The Advanced Flow Diagnostics for Aeronautical Research (AFDAR); MAteriali e TEcnologie di processo ad alta efficienza per Microfusioni Innovative (MATEMI); Hypersonic Boundary-Layer Transition Prediction, NATO AGARD AVT-RTG; Convective heat Transfer and coherent Structures in Turbulent boundary layers (CONTRAST); High Dynamic Range Measurements in Pipe Flows at High Reynolds Numbers (HIDRA). The ETFD research group has carried out many of its scientific research activities and projects in collaborations with both national and international research institutes, industries and universities, including: Centro Italiano di Ricerche Aerospaziali (IT); Delft University of Technology (The Nether-

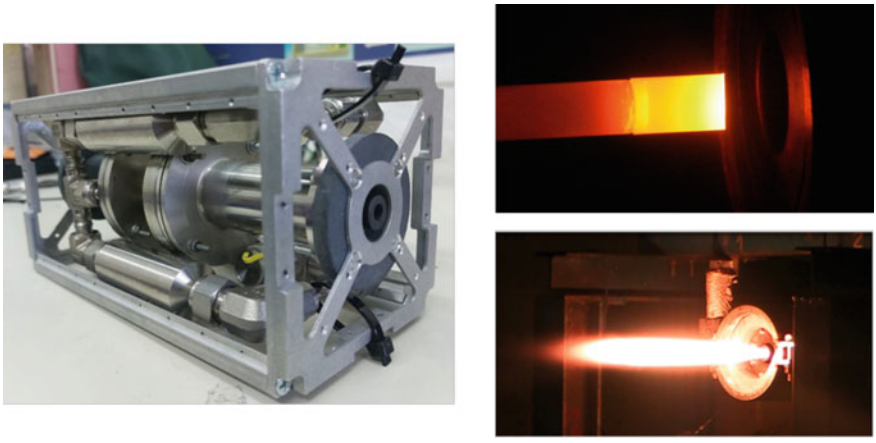


Fig. 8 Left: Technological demonstrator of a nanosatellite propulsion unit. Right: example of tests in arc-jet wind tunnel and rocket propulsion laboratory

lands); DLR (Germany); Europea Microfusioni Aerospaziali (IT); Imperial Collage (UK); KTH Royal Institute of Technology (Sweden); Lavision GMBH (Germany); Monash University (Australia); Politecnico di Torino (IT); Purdue University (USA); Universidad Carlos III de Madrid (Spain); Universität der Bundeswehr München (Germany); University of Lille (France); University of Twente (The Netherlands) (Fig. 8).

The *Modal analysis, Stability and Numerical Simulation for Flow Control group* is currently active in both theoretical and computational research fields of fluid mechanics stability and flow control as well as numerical simulation in thermo-fluid-dynamics. The group has a consolidated background in theory and methods of hydrodynamic stability and in modal decomposition methods of flow fields (Reduced Order Models with POD, SPOD, DMD techniques). The first focus is on linear stability based on the eigenvalues analysis, applied to the study of shear flows [65] and capillary instabilities of two-phase flows, such as the gravitational liquid curtain subjected to surface tension [66], employed in the technology of coating deposition. Recent research has focused on the experimental characterization of air-water mixing layer flow behind a splitter plate, for atomization processes in combustors. Another research regards the design and application of micro-devices for flow control, i.e., piezo-driven [65, 67] and plasma synthetic jet actuators. A lumped-element physical model to predict the frequency response of both kinds of devices has been developed. The model was validated through experimental tests carried out on home-made devices. Applications have been carried out to control the flow over backward facing ramp, morphing flap, and vertical tail of aircraft. The modal decomposition methods have been used to characterize the spatial and temporal properties of flow fields, extracting both spatial structures and dominant frequencies. The flow control devices have been analyzed by direct numerical simulation and data-driven modal

decomposition techniques, with the formulation of Reduced Order Models (ROM) to carry out fast predictions regarding the effectiveness of the control strategies. These techniques have been applied to: two-phase liquid jets; backward facing ramp [67] and curved cylinders [68] piezo-driven and plasma synthetic jets. The numerical simulation work is conducted along three main research directions. The first one is the use of Volume of Fluid (VOF) techniques to complex two-fluid systems. A recent application is the study of 3D vertical liquid jets [69] (Fig. 7). The second topic is relative to the flow through small orifices of particular shaped geometry of thin plates used in the film cooling technology of aeronautic combustors. The third topic regards the simulation of the flow field produced by both piezo-driven and plasma synthetic jet actuators [65], without and with crossflow. Collaborations: University of Princeton, USA; DynFluid Laboratory, Arts et Métiers ParisTech, Paris, France; Harbin Institute of Technology, Shenzhen, China; Rochester Institute of Technology, USA; Delft University of Technology, Delft, The Netherlands; TU Berlin, Germany; University of California San Diego, USA; AVIO AERO GE, Pomigliano; CIRA, Capua; Recent Synergic Research Projects: Distretto Aerospaziale Campano DAC, regional project MISTRAL "Thermal control of a small satellite", WP 1B-ABBB Thermal Analysis Support, 2015–2020; European Project Clean Sky Air Green, JTI-CS2 CPW1-REG-01-02 "Plasma Synthetic Jet Actuators for High Lift Devices", 2015–2022; C.I.R.A. contract SHAFT (Synthetic Jet Actuators for flow control) 2017–2020; AVIO AERO GE, contract "CFD Analysis to estimate the sensitivity of the pressure drop, measured through a shaped hole, by a proper pneumatic gauge, as the geometrical parameters are changed";

The *Aerothermodynamics, Propulson and Microgravity research group* is devoted to the areas that include access to and re-entry from Space (propulsion and aerothermodynamics), as well as the use of space platforms for experimentation in microgravity. Long-term collaborations are established with national research institutions such as CNR, CIRA (Italian Center for Aerospace Research), with numerous Italian universities (La Sapienza University of Rome, Milan Turin and Bari Polytechnics, University of Padua), large and small companies in the aerospace sector (AVIO, Thales Alenia Space Italia, ALI, T4i, Petroceramics). International collaborations include research projects managed by the Italian (ASI), European (ESA) and American (NASA) Space Agencies and the European Community. International research partners include (DLR, ArianeGroup, Airbus, Trinity College Dublin, University of Birmingham, OHB, Université Libre de Bruxelles. In the field of aerothermodynamics, research is currently aimed at the study of innovative re-entry capsules with variable geometry [70] and new-generation hypersonic aircraft. In particular, a program funded by the Italian Ministry of Defense called Hyperion is in progress on this issue, dedicated to the design of an innovative super/hypersonic aircraft. Research is also carried out aimed at the development of thermal protection systems in ultra-refractory ceramic materials for wing leading edges and for aero-propulsive applications [71–74]. In this field, a European Horizon 2020 project (C3HARME) was recently concluded, and an ASI project is now underway with CNR, Milan Polytechnic, CIRA and Petroceramics for the aerothermodynamic characterization of ceramic and composite materials for space applications. Among other things, at

the Aerothermodynamics laboratory, a hypersonic arc-jet wind tunnel is available for investigations on hypersonic flows and new classes of materials for extreme environments (Fig. 8). In the field of Space Propulsion, the research concerns numerical and experimental studies on the internal ballistics of rocket engines powered by hybrid and monopropellants [75]; experimental developments are possible thanks to the unique laboratory available inside the Military Airport F. Baracca, in Grazzanise (CE). Various research programs are currently in progress on the subject, including research and development projects on paraffin-based fuels funded by the Italian Ministry of Research, and a specific project coordinated by ASI with the participation of all the main Italian private and public players involved in hybrid propulsion. Other national projects (FORCE, RODiO) are dedicated to the development of miniaturized propulsion units for Cubesat applications (Fig. 8).

4.4 Aerospace Systems

With more than 30 years track record of funded projects in aerospace systems technology and applications, the professors and researchers of the Aerospace Systems Team, under the acronym ING-IND/05, develop innovative methodologies and applications in line with the most recent developments in the aerospace systems field. Topics can be grouped in four macro areas:

- GNC technologies for formation flying (FF) and Close-Proximity operations
- Remote sensing systems and solutions
- Unmanned Aircraft Systems and Aeronautics
- Space Awareness

In these areas, Team members lead or participate in competitive research projects promoting cooperation with national and international universities, research centers and companies, as CIRA (Italian Center for Aerospace Research), CNIT (National, Inter-University Consortium for Telecommunications), CNR (National Research Council of Italy), the Italian Air Force (Aeronautical and Space Test Division, Air Force Academy), international universities (University of Stanford USA, University of Colorado, Cranfield University UK, Delft University NL, Universitat Politècnica de Catalunya, Technische Universität Braunschweig, University of Pernambuco), large and small companies (Telespazio, AVIO, Leonardo, MBDA, ST Microelectronics, TIM, Thales Alenia Space Italia, Hitachi, Atitech, Autostrade per l'Italia, Ente Autonomo Volturno, Planetek, D-Orbit), and international entities (AIAA, IEEE, DLR, MITRE Corp., NASA, ONERA, Collins Aerospace, NATO Center for Maritime Research and Experimentation). The group is also actively involved in the organization of top-level International Conferences and Forums such as International Astronautical Congress, AIAA Scitech Forum, IEEE Aerospace Conference, IEEE Metroaerospace Conference (Fig. 9).

Concerning GNC technologies for formation flying and Close-Proximity operations, the Team promote the design, development and experimental/numerical vali-

Fig. 9 Aerospace systems team areas of interest

dation of innovative techniques for relative navigation in highly varied mission scenarios, from formation flying to on-orbit servicing (OOS) and active debris removal (ADR). In FF applications, the Team has developed innovative relative positioning techniques based on GNSS data processing, tested with in-flight data, demonstrating real-time centimeter-level relative positioning accuracy. The Team has also developed innovative analytical models for relative motion design, applicable to both FF (e.g., to enable Distributed Synthetic Aperture Radar applications, DSAR) and missions scenarios involving close-proximity operations. Concerning OOS and ADR, which require relative navigation skills with respect to passively cooperative (i.e., equipped with fiducial markers designed to be easily detected and identified within the raw data produced by an electro-optical sensor) and non-cooperative space targets, the Team has developed innovative techniques based on data processing from passive (monocular and stereo cameras) and active (Lidar and Time of Flight cameras) electro-optical (EO) sensors. The above-mentioned techniques have been developed in important projects, as LIDAR-based uncooperative spacecraft relative navigation project (2014–ongoing), funded by Italian Ministry of University and Research (MUR), in which techniques have been tested in cooperation with foreign partners, like Embry Riddle Aeronautical University and Jena Optronik Gmbh; Project GRACC (2020–2022), funded by the European Space Agency (ESA), in which innovative techniques were developed for pose determination and relative state estimation

for a satellited equipped with a robotic arm during the reach and capture phases of passively cooperative and non-cooperative targets; Project FORCE (2020–2022), funded by MUR, where a prototype of a relative positioning module compatible with the installation within 1–2 CubeSat-units has been developed and demonstrated in laboratory environment. Most relevant publications in this domain are [76–81]. In the field of remote sensing, investigated topics include bistatic and distributed SAR relying on FF satellites, algorithms and techniques for marine and maritime SAR applications, Artificial Intelligence (AI) techniques and solutions for image analysis, within important projects as "Distributed Micro-satellite-based SAR performance study" (2017–2018), commissioned by DSO National Labs, Singapore; "Highly Sensitive Radar Change Detection" (2019–2021), funded by the Italian Ministry of Defense, in cooperation with RaSS-CNIT National Laboratory and Israel Aerospace Industries, aimed at DSAR applications in the field of differential Interferometry; RODiO, an innovative mission funded by the Italian Space Agency (ASI) relying on a cluster of 4 passive CubeSats flying in formation with ASI PLATiNO-1 (PLT-1), aimed at demonstrating space-based DSAR with multi-platform image synthesis; IntSen2, (2023–2025), funded by European Commission, aimed at exploiting Imagery Intelligence (IMINT) in Earth Observation, for the defense and security community; Ueikap, (2023–2025), funded by MUR, aimed at accomplishing several tasks, including the development of a sea imaging model to overcome the existing limitation of the discrimination capability between wake and other natural features, the development of wake imaging model and the definition of a novel AI architecture exploiting suitable datasets based on both archived and simulated data; Mercurio, (2023–2026), funded by Italian Ministry of Enterprises and Made in Italy, aimed at monitoring railway infrastructure, exploiting AI and fusion of satellite data, distributed sensors, and aerial inspections. Most relevant publications in this domain are [82–90] .

In the Unmanned Aircraft System (UAS) and Aeronautics domain, numerical and experimental activities are carried out in synergy at the Laboratory for Innovative Flight Technologies (LIFT), located in San Giovanni a Teduccio, and at the Guidance Navigation and Control (GNC) Lab, located in Naples.

With the theoretical and experimental activities carried out at LIFT, the team contributes to CeSMA (the Federico II Center for Advanced Metrological and Technological Services). LIFT is ENAC recognized drone operator with a netted area for safe outdoor operation, at the CeSMA location in San Giovanni a Teduccio, and a reserved volume of Low-Level airspace, under a NOTAM issued by ENAC, at the Pilot Farm of Castel Volturno of the Federico II Department of Agricultural Sciences. The laboratory is a full member of the Association for Scientific Development of Air Traffic Management in Europe ASDA (asda.aero) sponsored by SESAR joint undertaking. The main activities carried out at LIFT concern innovative solutions for Small (100–150 kg MTOW) fixed-wing UAS systems (projects GANNET, for innovative MEMS based inertial navigation avionics, and project DAPHNE, for full-electric hydrogen-fuel-cell on board power generation UAV platform for low-impact environmental monitoring, both funded by the Italian Ministry of Industry and Made in Italy); innovative sensing configurations including Machine-

Learning-based solutions for aerospace; Air-Data-System integrity check; Bio-inspired navigation technique exploiting the skylight polarization; characterization of radar observation of multi-rotor drones for detection and identification, as well as for countermeasures in cooperation with Air Division of Aeronautical and Space Experimentation of Italian Air Force (Project CUTE LAB); payloads and procedures for drones (e.g., projects FOCUS and COVID-19, funded by Regione Campania); development of innovative tools for risk analysis of airport routes in cooperation with Toscana Aeroporti; solutions for exploiting the innovative 5G mobile communication network for application of navigation, surveillance, TLC and TLM, remote piloting, traffic management of drones, in challenging conditions, in cooperation with TIM. Most relevant publications in this domain are [91–96]. Concerning the GNC Lab, UAS-related research involves several interconnected topics, ranging from multi-drone operations and cooperative techniques, to path planning with emphasis on Urban and Advanced Aerial Mobility frameworks, sense and avoid and airspace surveillance, multi-sensor-based navigation and highly autonomous approach and landing. These research paths are followed for civilian and defense applications in collaboration with national and international partners including NASA, ASI, Collins Aerospace, Raytheon, MBDA, Civitanavi Systems, and local SME. Main activities and projects conducted at GNC Lab are: CREATEFORUAS (2019–2023) and 4IPLAY (2023–2025), both funded by MIUR, with a focus on multi-drone cooperation, sense and avoid technologies and swarming techniques for infrastructure inspection; AMPERE (2020–2022), funded by EUSPA within the Horizon 2020 Programme, aimed at dedicated solutions for electrical power network information gathering; SKYNET (2022–2023) and EVOLVE (2021–2024), in collaboration with Collins Aerospace, aimed at low altitude airspace surveillance with ground-based radars and at extending to highly autonomous UAM/AAM frameworks the enhanced sensing technologies and algorithms adopted for low visibility approach and landing; HISENSE (2023–2025), in collaboration with Civitanavi Systems under funding of the Ministry for Economic Development, concerning architectures and algorithms to fuse exteroceptive and inertial sensors information for safety critical applications. Most relevant publications in this domain are [97–99].

In the Space Awareness domain, innovative methods and solutions are developed within a dual use framework, including both Space Traffic Management and Space Situational Awareness for security and defense. Recent developments include ad hoc models for in orbit fragmentation and medium term collision risk assessment, machine learning-based approaches for resident space object characterization, algorithms for light curve inversion and rotational state determination, agile multi-satellite maneuvering logics for responsive Earth observation. The main projects are: INTEGRAL (2021–2024), funded by the European Defense Agency and carried out in cooperation with the most important European SSA industries, under coordination by Leonardo; ISTAR (2023–2026), research project funded by ASI, concerning various machine learning-techniques and integrated approaches with emphasis on fragmentation, space object characterization, space-based SSA, sensor tasking, and cooperative approaches to Space Traffic Management; IHS (2023–2026), funded by

ASI, to realize the Italian civilian infrastructure for SSA/STM, concerning fragmentation and SSA services related to In-Orbit Servicing missions.

5 Future

The aerospace sector's future is brimming with thrilling prospects. These encompass both low-velocity, low-atmosphere flight and high-speed transportation in space, all underpinned by a shared commitment to environmental sustainability and respect for our planet for future generations. Military applications have also received a boost in the research and development from the actual international scenario, but a specific interest is outside the scope of this review.

All the research groups of the aerospace community of the Department of Industrial Engineering are strongly involved in such mid/long-term research and development following a multidisciplinary approach not only among the *classical* aerospace disciplines but including many others and not necessarily from the engineering side, but including biosciences, medicine, agronomy and so on. Specific research lines for the next decade are driven by the decarbonization expected to reach the goal of zero CO_2 by 2050. According to this objective set by the European Commission, the studies of hybrid-electric and full electric airplane will be continued, passing from the use of SAF (Sustainable Aviation Fuel) and hopefully arriving to the hydrogen engine. Meantime the application of the electric propulsion will drive the urban air mobility systems, from small drone to people transportation, which are expected to become normal by the end of this decade. A long list of potential applications is under study in this field. The supersonic and eventually the hypersonic transportation are expected to play an important role, driven by the space transportation activities and by the space tourism activities, which is almost a mature reality.

Space exploration and human settlement on the Moon and on the planet Mars are a challenge which will involve all the scientific community for the next years and, again, the aerospace group of the department has numerous and highly accredited worldwide collaborations.

These activities will also have a direct relationship with the courses offered to the students. The aerospace syllabus has always shown great flexibility, incorporating knowledge from other colleagues, as in the electrical field or for the risk management course, and exporting also courses toward other disciplines. By virtue of this attitude, we can easily forecast an increase of the international contacts with other universities by increasing the students' exchange programs and the number of double degree collaborations. The ability and the recognition of the professors of the aerospace sector in dealing with research institutions and the industrial world will speed-up the third-mission activities, with the support of spin-off companies, student associations and contests.

To be awarded with the seal of Department of Excellence has been an honor, but also a responsibility and the attitude of the aerospace group is to consider the honor for what it has been, and a responsibility for what it will be.

6 Awards

Best Paper by young researcher, 2015 IEEE Metrology for Aerospace—"Large space debris pose acquisition in close-proximity operations" by Opromolla, R. et al.

Yasuki Nakayama Medal, 14th International Conference on Fluid Control, Measurements and Visualization (FLUCOME 2017)—For Keynote speech "Thermo-fluid-dynamic analysis of innovative synthetic jet devices" by Carlo Salvatore Greco, Gerardo Paolillo and Gennaro Cardone. 2017 IOP Conf. Ser.: Mater. Sci. Eng. 249 011001.

ICAS Award for Innovation in Aeronautics, 2018—Awarded to the AGILE Consortium for outstanding and innovative contributions to the development of advanced aeronautical systems. 31st ICAS (International Council of Aeronauticakl Sciences) Congress, September 9–14, 2018, Belo Horizonte, Brazil.

Best Paper Award, 2019 AIDAA XXV International Congress—Awarded by AIDAA (Italian Association of Aeronautics and Astronautics) to the article by Di Martino G. D., Gallo G., Mungiguerra S., Carmicino C., and Savino R., "Modelling of Paraffin-based Fuel Combustion in Hybrid Rockets", AIDAA XXV International Congress of Aeronautics and Astronautics, Rome, Italy, September 2019.

Leonardo da Vinci Award 2019—In 2019 the DII participated to the Leonardo da Vinci announcement, a MAECI-MIUR framework 2017/2020 funded by CRUI and MUR, proposing as unique candidature Giuseppe Petrone, young researcher belonging to Aerospace Structures field (ING-IND/04), for the task 2 "Mobility of young researchers". Dr. Petrone was one of the winners (Proposal ID 158152) and this award gave him the possibility to spend time at Universidad de Chile to conduct some joint research activities.

Measurement Science and Technology's Outstanding Paper Award for 2021 in the field of Fluid mechanics—"On the PIV/PTV uncertainty related to calibration of camera systems with refractive surfaces" by Gerardo Paolillo and Tommaso Astarita, 2021 Meas. Sci. Technol. 32, 094006. DOI 10.1088/1361-6501/abf3fc.

Featured by Physics of Fluids—Article: "Receptivity to forcing disturbances in subcritical liquid sheet flows" by Alessandro Della Pia et al. (2021), Physics of Fluids, 33 (3), art. 032113, DOI: 10.1063/5.0044322.

Featured by Physics of Fluids—Article: "Modal decomposition analysis of unsteady viscous liquid sheet flows" by Antonio Colanera et al. (2021), Physics of Fluids, 33 (9), 092117, DOI: 10.1063/5.0065683.

Best Paper, 2022 AIAA Sensor Systems and Information Fusion—"Using Drone Swarms as Countermeasure of Radar Detection" by Claudia Conte et al., AIAA 2022-0855.

Best Paper, 2023 IEEE Metrology for AeroSpace (MetroAeroSpace)—"Experimental Assessment of a Visual-Laser Relative Navigation Module for CubeSats" by G. Napolano, et al.

Fulbright fellowship—"SPOD and reduced order modeling of separated flows (SPARROW)," carried out at the Princeton University, under the cooperation of professors H. Stone, F. Grasso, and M. Hultmark, from 01/05/2023 to 31/08/2023.

References

1. Marciello V, Di Stasio M, Ruocco M, Trifari V, Nicolosi F, Meindl M, Lemoine B, Caliandro P (2023) Design exploration for sustainable regional hybrid-electric aircraft: a study based on technology forecasts. Aerospace 10. ISSN: 2226-4310. https://doi.org/10.3390/aerospace10020165
2. Marciello V, Orefice F, Nicolosi F, Ciliberti D, Della Vecchia P (2023) Design of hybrid-electric aircraft with fault-tolerance considerations. Chin J Aeronaut 36:160–178. ISSN: 1000-9361. https://doi.org/10.1016/j.cja.2022.05.014
3. Nicolosi F, Della Vecchia P, Corcione S (2015) Design and aerodynamic analysis of a twin-engine commuter aircraft. Aerosp Sci Technol 40:1–16. ISSN: 1270-9638. https://doi.org/10.1016/j.ast.2014.10.008
4. Nicolosi F, Corcione S, Trifari V, De Marco A (2021) Design and optimization of a large turboprop aircraft. Aerospace 8. ISSN: 2226-4310. https://doi.org/10.3390/aerospace8050132
5. Nicolosi F, De Marco A, Sabetta V, Della Vecchia P (2018) Roll performance assessment of a light aircraft: Flight simulations and flight tests. Aerosp Sci Technol 76:471–483. ISSN: 1270-9638. https://doi.org/10.1016/j.ast.2018.01.041
6. Nicolosi F, Ciliberti D, Della Vecchia P, Corcione S (2020) Experimental analysis of aircraft directional control effectiveness. Aerosp Sci Technol 106:106099. ISSN: 1270-9638. https://doi.org/10.1016/j.ast.2020.106099
7. Corcione S, Bonavolont'a G, De Marco A, Nicolosi F (2023) Downwash modelling for three-lifting-surface aircraft configuration design. Chin J Aeronaut 36:161–173. ISSN: 1000-9361. https://doi.org/10.1016/j.cja.2023.03.035
8. Ciliberti D, DellaVecchia P, Nicolosi F, De Marco A (2017) Aircraft directional stability and vertical tail design: a review of semi-empirical methods. Prog Aerosp Sci 95:140–172. ISSN: 0376-0421. https://doi.org/10.1016/j.paerosci.2017.11.001
9. De Marco A, Di Stasio M, Della Vecchia P, Trifari V, Nicolosi F (2020) Automatic modeling of aircraft external geometries for preliminary design workflows. Aerosp Sci Technol 98:105667. ISSN: 1270-9638. https://doi.org/10.1016/j.ast.2019.105667

10. Lefebvre T, Bartoli N, Dubreuil S, Panzeri M, Lombardi R, Della Vecchia P, Stingo L, Nicolosi F, De Marco A, Ciampa P, Anisimov K, Savelyev A, Mirzoyan A, Isyanov A (2020) Enhancing optimization capabilities using the AGILE collaborative MDO framework with application to wing and nacelle design. Prog Aerosp Sci 119:100649. ISSN: 0376-0421. https://doi.org/10.1016/j.paerosci.2020.100649
11. Della Vecchia P, Corcione S, Pecora R, Nicolosi F, Dimino I, Concilio A (2017) Design and integration sensitivity of a morphing trailing edge on a reference airfoil: the effect on high-altitude long-endurance aircraft performance. J Intell Mater Syst Struct 28:2933–2946. https://doi.org/10.1177/1045389X17704521
12. De Marco A, D'Onza P, Manfredi S (2023) A deep reinforcement learning control approach for high-performance aircraft. Nonlinear Dyn 111:17037–17077. ISSN: 1573-269X. https://doi.org/10.1007/s11071-023-08725-y
13. Guida M, Marulo F, Meo M, Grimaldi A, Olivares G (2011) SPH-Lagrangian study of bird impact on leading edge wing. Compos Struct 93:1060–1071. https://doi.org/10.1016/j.compstruct.2010.10.001
14. Arena M, Viscardi M, Barra G, Vertuccio L, Guadagno L (2019) Multifunctional performance of a nano-modified fiber reinforced composite aeronautical panel. Materials 12. ISSN: 1996-1944. https://www.mdpi.com/1996-1944/12/6/869
15. Bernelli-Zazzera F, Martin-Prats MA, Marulo F, Hanus D, Melkert J, Guglieri G, Bauer P, Pantelaki I, Wasser I, Deconinck H, et al (2018) Proposal for a EU quality label for aerospace education. Incas Buletin 10:5–16. https://doi.org/10.13111/2066-8201.2018.10.2.2
16. Lorenzo ED, Petrone G, Manzato S, Peeters B, Desmet W, Marulo F (2016) Damage detection in wind turbine blades by using operational modal analysis. Struct Heal Monit 15:289–301. https://doi.org/10.1177/147592171664274
17. Guida M, Marulo F, Abrate S (2018) Advances in crash dynamics for aircraft safety. Prog Aerosp Sci 98:106–123. https://doi.org/10.1016/j.paerosci.2018.03.008
18. Orlando S, Marulo F, Guida M, Timbrato F (2018) Bird strike assessment for a composite wing flap. Int J Crashworthiness 23:219–235. https://doi.org/10.1080/13588265.2017.1342521
19. Di Mauro G, Gagliardi GM, Guida M, Marulo F (2023) Parachute emergency landing simulation and enhanced composite material characterization for General Aviation aircraft. Proc Inst Mech Eng Part C: J Mech Eng Sci 09544062231181806. https://doi.org/10.1177/09544062231181806
20. Bernelli-Zazzera F, Guglieri G, Marcuccio S, Marulo F, Nardinocchi P, Tortora P (2022) Evolution of (AERO) space engineering studies in Italy in the past 20 years. Trans Aerosp Res 2022:48–58. https://doi.org/10.2478/tar-2022-0023
21. Russo N, Marano AD, Gagliardi GM, Guida M, Polito T, Marulo F (2023) Thrust and noise experimental assessment on counter-rotating coaxial rotors. Aerospace 10:535. https://doi.org/10.3390/aerospace10060535
22. Marano A, Polito T, Guida M, Barbarino M, Belardo M, Perazzolo A, Marulo F (2021) Tiltrotor acoustic data acquisition and analysis: in-flight pressure load evaluation and investigation. Aerotecnica Missili & Spazio 100:111–122. https://doi.org/10.1007/s42496-021-00075-5
23. Boffa ND, Arena M, Monaco E, Viscardi M, Ricci F, Kundu T (2022) About the combination of high and low frequency methods for impact detection on aerospace components. Prog Aerosp Sci 129. https://doi.org/10.1016/j.paerosci.2021.100789
24. Rautela M, Senthilnath J, Monaco E, Gopalakrishnan S (2022) Delamination prediction in composite panels using unsupervised-feature learning methods with wavelet-enhanced guided wave representations. Compos Struct 291. https://doi.org/10.1016/j.compstruct.2022.115579
25. Ricci F, Monaco E, Maio L, Boffa ND, Mal AK (2016) Guided waves in a stiffened composite laminate with a delamination. Struct Heal Monit 15:351–358. https://doi.org/10.1177/1475921716636335
26. Memmolo V, Monaco E, Boffa N, Maio L, Ricci F (2018) Guided wave propagation and scattering for structural health monitoring of stiffened composites. Compos Struct 184:568–580. https://doi.org/10.1016/j.compstruct.2017.09.067

27. Marzani A, Testoni N, De Marchi L, Messina M, Monaco E, Apicella A (2020) An open database for benchmarking guided waves structural health monitoring algorithms on a composite full-scale outer wing demonstrator. Struct Heal Monit 19:1524–1541. https://doi.org/10.1177/1475921719889029
28. Ricci F, Monaco E, Boffa N, Maio L, Memmolo V (2022) Guided waves for structural health monitoring in composites: a review and implementation strategies. Prog Aerosp Sci 129. https://doi.org/10.1016/j.paerosci.2021.100790
29. Banerjee S, Ricci F, Monaco E, Mal A (2009) A wave propagation and vibration-based approach for damage identification in structural components. J Sound Vib 322:167–183. https://doi.org/10.1016/j.jsv.2008.11.010
30. Viscardi M, Arena M, Cerreta P, Iaccarino P, Imparato SI (2019) Manufacturing and validation of a novel composite component for aircraft main landing gear bay. J Mater Eng Perform 28:3292–3300
31. Guadagno L, Raimondo M, Vertuccio L, Barra G, Arena M, Viscardi M (2023) Vibro-acoustic characteristics of multifunctional carbon fiber reinforced panel. Def Technol 24:129–139. ISSN: 2214-9147. https://doi.org/10.1016/j.dt.2022.09.009
32. Viscardi M, Arena M (2019) Sound proofing and thermal properties of an innovative viscoelastic treatment for the turboprop aircraft fuselage. CEAS Aeronaut J 10:443–452
33. Ciaburro G, Iannace G, Passaro J, Bifulco A, Marano AD, Guida M, Marulo F, Branda F (2020) Artificial neural network-based models for predicting the sound absorption coefficient of electrospun poly (vinyl pyrrolidone)/silica composite. Appl Acoust 169:107472. https://doi.org/10.1016/j.apacoust.2020.107472
34. Viscardi M (2022) The challenge of natural fibres for the thermal and acoustic insulation of aircraft. In: 22nd SGEM international multidisciplinary scientific GeoConference proceedings 2022, Nano, Bio. Green and space & technologies for a sustainable future, vol 22, Issue 6.2 (STEF92 Technology, Vienna, Austria)
35. Del Sorbo GR, Truda G, Bifulco A, Passaro J, Petrone G, Vitolo B, Ausanio G, Vergara A, Marulo F, Branda F (2018) Non monotonous effects of noncovalently functionalized graphene addition on the structure and sound absorption properties of polyvinylpyrrolidone (1300 kDa) electrospun mats. Materials 12:108. https://doi.org/10.3390/ma12010108
36. Marulo F, Polito T (2017) Probabilistic analysis and experimental results of sound transmission loss of composite panels. Polym Eng & Sci 57:722–730. https://doi.org/10.1002/pen.24619
37. Maia N, Marulo F, Cooper J, Worden KCM, Di Maio D, Carrella A (2023) Structural dynamics in engineering design. Wiley
38. Ficca A, Marulo F, Sollo A (2022) An open thinking for a vision on sustainable green aviation in international symposium on dynamic response and failure of composite materials, pp 391–400. https://doi.org/10.1007/978-3-031-28547-9_46
39. De Rosa S, Franco F, Petrone G, Casaburo A, Marulo F (2021) A versatile offset operator for the discrete observation of objects. J Sound Vib 500:116019. ISSN: 0022-460X. https://doi.org/10.1016/j.jsv.2021.116019
40. Franco F, Robin O, Ciappi E, De Rosa S, Berry A, Petrone G (2019) Similitude laws for the structural response of flat plates under a turbulent boundary layer excitation. Mech Syst Signal Process 129:590–613. ISSN: 0888-3270. https://doi.org/10.1016/j.ymssp.2019.04.045
41. Casaburo A, Magliacano D, Petrone G, Franco F, De Rosa S (2022) Gaussianbased machine learning algorithm for the design and characterization of a porous meta-material for acoustic applications. Appl Sci 12:333. ISSN: 20763417. https://doi.org/10.3390/app12010333
42. Errico F, Franco F, DeRosa S, Petrone G, Ichchou M (2020) Aeroelastic effects onwave propagation and sound transmission of plates and shells. AIAA J 58:2269–2275. ISSN: 00011452. https://doi.org/10.2514/1.J058722
43. Petrone G, Melillo G, Laudiero A, De Rosa S (2019) A Statistical Energy Analysis (SEA) model of a fuselage section for the prediction of the internal Sound Pressure Level (SPL) at cruise flight conditions. Aerosp Sci Technol 88:340–349 (2019). ISSN: 12709638. https://doi.org/10.1016/j.ast.2019.03.032

44. Catapane G, Petrone G, Robin O, Verdiere K (2023) Coiled quarter wavelength resonators for low-frequency sound absorption under plane wave and diffuse acoustic field excitations. Appl Acoust 209:109402. ISSN: 0003682X. https://doi.org/10.1016/j.apacoust.2023.109402
45. Ciappi E, De Rosa S, Franco F, Guyader J-L, Hambric SA (2015) Flinovia—flow induced noise and vibration issues and aspect. Springers
46. Ciappi E, De Rosa S, Franco F, Guyader J-L, Hambric SA, Leung RCK, Hanford AD (2018) Flinovia–flow induced noise and vibration issues and Aspects-II. Springer
47. Ciappi E, De Rosa S, Franco F, Hambric SA, Leung RCK, Clair V, Maxit L, Totaro N (2021) Flinovia–flow induced noise and vibration issues and aspects-III. Springer. https://doi.org/10.1007/978-3-030-64807-7
48. Mele B, Tognaccini R (2014) Aerodynamic force by Lamb vector integrals in compressible flow. Phys Fluids 26. https://doi.org/10.1063/1.4875015
49. Mele B, Tognaccini R, Catalano P, de Rosa D (2020) Effect of body shape on riblets performance. Phys Rev Fluids 5. https://doi.org/10.1103/physrevfluids.5.124609
50. Saetta E, Tognaccini R, Iaccarino G (2022) Machine learning to predict aerodynamic stall. Int J Comput Fluid Dyn 36:641–654. https://doi.org/10.1080/10618562.2023.2171021
51. Capuano F, Coppola G, Rández L, de Luca L (2017) Explicit Runge-Kutta schemes for incompressible flow with improved energy-conservation properties. J Comput Phys 328:86–94. https://doi.org/10.1016/j.jcp.2016.10.040
52. Coppola G, Veldman AE (2023) Global and local conservation of mass, momentum and kinetic energy in the simulation of compressible flow. J Comput Phys 475:111879. https://doi.org/10.1016/j.jcp.2022.111879
53. Kähler CJ, Astarita T, Vlachos PP, Sakakibara J, Hain R, Discetti S, Foy RL, Cierpka C (2016) Main results of the 4th international PIV challenge. Exp Fluids 57. https://doi.org/10.1007/s00348-016-2173-1
54. Ceglia G, Discetti S, Ianiro A, Michaelis D, Astarita T, Cardone G (2014) Three-dimensional organization of the flow structure in a non-reactive model aero engine lean burn injection system. Exp Thermal Fluid Sci 52:164–173. https://doi.org/10.1016/j.expthermflusci.2013.09.007
55. Cafiero G, Discetti S, Astarita T (2015) Flow field topology of submerged jets with fractal generated turbulence. Phys Fluids 27. https://doi.org/10.1063/1.4935185
56. Paolillo G, Greco CS, Astarita T, Cardone G (2021) Experimental determination of the 3-D characteristic modes of turbulent Rayleigh-Bénard convection in a cylinder. J Fluid Mech 922. https://doi.org/10.1017/jfm.2021.554
57. Imbriale M, Ianiro A, Meola C, Cardone G (2014) Convective heat transfer by a row of jets impinging on a concave surface. Int J Therm Sci 75:153–163. https://doi.org/10.1016/j.ijthermalsci.2013.07.017
58. Avallone F, Schrijer FFJ, Cardone G (2016) Infrared thermography of transition due to isolated roughness elements in hypersonic flows. Phys Fluids 28. https://doi.org/10.1063/1.4941527
59. Zaccara M, Edelman JB, Cardone G (2020) A general procedure for infrared thermography heat transfer measurements in hypersonic wind tunnels. Int J Heat Mass Transf 163:120419. https://doi.org/10.1016/j.ijheatmasstransfer.2020.120419
60. Cafiero G, Discetti S, Astarita T (2014) Heat transfer enhancement of impinging jets with fractal-generated turbulence. Int J Heat Mass Transf 75:173–183. https://doi.org/10.1016/j.ijheatmasstransfer.2014.03.049
61. Greco CS, Cardone G, Soria J (2016) On the behaviour of impinging zero-netmass- flux jets. J Fluid Mech 810:25–59. https://doi.org/10.1017/jfm.2016.703
62. Greco CS, Paolillo G, Ianiro A, Cardone G, de Luca L (2018) Effects of the stroke length and nozzle-to-plate distance on synthetic jet impingement heat transfer. Int J Heat Mass Transf 117:1019–1031. https://doi.org/10.1016/j.ijheatmasstransfer.2017.09.118
63. Ianiro A, Lynch KP, Violato D, Cardone G, Scarano F (2018) Threedimensional organization and dynamics of vortices in multichannel swirling jets. J Fluid Mech 843:180–210. https://doi.org/10.1017/jfm.2018.140
64. Greco CS, Paolillo G, Astarita T, Cardone G (2020) The von Kármán street behind a circular cylinder: flow control through synthetic jet placed at the rear stagnation point. J Fluid Mech 901. https://doi.org/10.1017/jfm.2020.427

65. Palumbo A, Semeraro O, Robinet J-C, de Luca L (2022) Boundary layer transition induced by low-speed synthetic jets. Phys Fluids 34. https://doi.org/10.1063/5.0128798
66. Chiatto M, Pia AD (2022) Natural frequency discontinuity of vertical liquid sheet flows at transcritical threshold. J Fluid Mech 945. https://doi.org/10.1017/jfm.2022.578
67. Chiatto M, Palumbo A, de Luca L (2019) Design approach to predict synthetic jet formation and resonance amplifications. Exp Thermal Fluid Sci 107:79–87. https://doi.org/10.1016/j.expthermflusci.2019.05.013
68. Chiatto M, Cardinale C, Shang JK, Grasso F (2023) Analysis of the wake flow behind concave curved cylinders with velocity measurements by particle image velocimetry and modal decomposition. Phys Fluids 35. https://doi.org/10.1063/5.0158000
69. Acquaviva MR, Pia AD, Chiatto M, de Luca L (2023) Hole-driven dynamics of a three-dimensional gravitational liquid curtain. J Fluid Mech 968. https://doi.org/10.1017/jfm.2023.543
70. Fedele A, Carannante S, Grassi M, Savino R (2021) Aerodynamic control system for a deployable re-entry capsule. Acta Astronaut 181:707–716. https://doi.org/10.1016/j.actaastro.2020.05.049
71. Cecere A, Savino R, Allouis C, Monteverde F (2015) Heat transfer in ultrahigh temperature advanced ceramics under high enthalpy arc-jet conditions. Int J Heat Mass Transf 91:747–755. https://doi.org/10.1016/j.ijheatmasstransfer.2015.08.029
72. Monteverde F, Cecere A, Savino R (2017) Thermo-chemical surface instabilities of SiC-ZrB 2 ceramics in high enthalpy dissociated supersonic airflows. J Eur Ceram Soc 37:2325–2341. https://doi.org/10.1016/j.jeurceramsoc.2017.01.018
73. Mungiguerra S, Martino GD, Cecere A, Savino R, Silvestroni L, Vinci A, Zoli L, Sciti D (2019) Arc-jet wind tunnel characterization of ultra-hightemperature ceramic matrix composites. Corros Sci 149:18–28. https://doi.org/10.1016/j.corsci.2018.12.039
74. Mungiguerra S, Di Martino GD, Cecere A, Savino R, Zoli L, Silvestroni L, Sciti D (2020) Ultra-high-temperature testing of sintered ZrB2-based ceramic composites in atmospheric re-entry environment. Int J Heat Mass Transf 156
75. Martino GDD, Mungiguerra S, Carmicino C, Savino R, Cardillo D, Battista F, Invigorito M, Elia G (2019) Two-hundred-Newton laboratory-scale hybridRocket testing for paraffin fuel-performance characterization. J Propuls Power 35:224–235. https://doi.org/10.2514/1.b37017
76. Nocerino A, Opromolla R, Fasano G, Grassi M (2021) LIDAR-based multistep approach for relative state and inertia parameters determination of an uncooperative target. Acta Astronaut 181:662–678. https://doi.org/10.1016/j.actaastro.2021.02.019
77. Nocerino A, Opromolla R, Fasano G, Grassi M, Balaguer PF, John S, Cho H, Bevilacqua R (2023) Experimental validation of inertia parameters and attitude estimation of uncooperative space targets using solid state LIDAR. Acta Astronaut 210:428–436. https://doi.org/10.1016/j.actaastro.2023.02.010
78. Renga A, Causa F, Tancredi U, Grassi M (2018) Accurate ionospheric delay model for real-time GPS-based positioning of LEO satellites using horizontal VTEC gradient estimation. GPS Solut 22. https://doi.org/10.1007/s10291-018-0710-5
79. Napolano G, Vela C, Nocerino A, Opromolla R, Grassi M (2023) A multisensor optical relative navigation system for small satellite servicing. Acta Astronaut 207:167–192. https://doi.org/10.1016/j.actaastro.2023.03.008
80. Opromolla R, Fasano G, Rufino G, Grassi M (2015) Uncooperative pose estimation with a LIDAR-based system. Acta Astronaut 110:287–297. https://doi.org/10.1016/j.actaastro.2014.11.003
81. Opromolla R, Fasano G, Rufino G, Grassi M (2017) Pose estimation for spacecraft relative navigation using model-based algorithms. IEEE Trans Aerosp Electron Syst 53:431–447. https://doi.org/10.1109/taes.2017.2650785
82. Prete RD, Graziano MD, Renga A (2021) First results on wake detection in SAR images by deep learning. Remote Sens 13:4573. https://doi.org/10.3390/rs13224573
83. Prete RD, Graziano MD, Renga A (2023) Unified framework for ship detection in multi-frequency SAR images: a demonstration with COSMOSkyMed, sentinel-1, and SAOCOM data. Remote Sens 15:1582. https://doi.org/10.3390/rs15061582

84. Graziano MD, Renga A, Moccia A (2019) Integration of Automatic Identification System (AIS) data and single-channel Synthetic Aperture Radar (SAR) images by SAR-based ship velocity estimation for maritime situational awareness. Remote Sens 11:2196. https://doi.org/10.3390/rs11192196
85. Renga A, Moccia A (2016) Use of doppler parameters for ship velocity computation in SAR images. IEEE Trans Geosci Remote Sens 54:3995–4011. https://doi.org/10.1109/tgrs.2016.2533023
86. Renga A, Graziano MD, Moccia A (2019) Segmentation of marine SAR images by sublook analysis and application to sea traffic monitoring. IEEE Trans Geosci Remote Sens 57:1463–1477. https://doi.org/10.1109/tgrs.2018.2866934
87. Renga A, Graziano MD, Moccia A (2021) Formation flying SAR: analysis of imaging performance by array theory. IEEE Trans Aerosp Electron Syst 57:1480–1497. https://doi.org/10.1109/taes.2020.3043526
88. Renga A, Gigantino A, Graziano MD, Moccia A, Fedele A, Natalucci S (2023) Design considerations and performance analysis for RODiO distributed SAR mission. Acta Astronaut 210:474–482. https://doi.org/10.1016/j.actaastro.2023.04.001
89. Graziano MD, Renga A, Grasso M, Moccia A (2022) Error sources and sensitivity analysis in formation flying synthetic aperture radar. Acta Astronaut 192:97–112. https://doi.org/10.1016/j.actaastro.2021.10.047
90. Grasso M, Renga A, Fasano G, Graziano M, Grassi M, Moccia A (2021) Design of an end-to-end demonstration mission of a Formation-Flying Synthetic Aperture Radar (FF-SAR) based on microsatellites. Adv Space Res 67:3909–3923. https://doi.org/10.1016/j.asr.2020.05.051
91. De Alteriis G, Accardo D, Conte C, Moriello RSL (2021) Performance enhancement of consumer-grade MEMS sensors through geometrical redundancy. Sensors 21:4851. https://doi.org/10.3390/s21144851
92. Iervolino I, Accardo D, Tirri AE, Pio G, Salzano E (2019) Quantitative risk analysis for the Amerigo Vespucci (Florence, Italy) airport including domino effects. Safety Sci 113:472–489. https://doi.org/10.1016/j.ssci.2018.12.019
93. Fontanella R, Accardo D, Moriello RSL, Angrisani L, Simone DD (2018) MEMS gyros temperature calibration through artificial neural networks. Sens Actuators A: Phys 279:553–565. https://doi.org/10.1016/j.sna.2018.04.008
94. Conte C, de Alteriis G, Moriello RSL, Accardo D, Rufino G (2021) Drone trajectory segmentation for real-time and adaptive time-of-flight prediction. Drones 5:62. https://doi.org/10.3390/drones5030062
95. Conte C, Rufino G, de Alteriis G, Bottino V, Accardo D (2022) A data-driven learning method for online prediction of drone battery discharge. Aerosp Sci Technol 130:107921. https://doi.org/10.1016/j.ast.2022.107921
96. Conte C, Supplizi SV, de Alteriis G, Mele A, Rufino G, Accardo D (2022) Using drone swarms as countermeasure of radar detection in AIAA SCITECH 2022 forum. American Institute of Aeronautics and Astronautics. https://doi.org/10.2514/6.2022-0855
97. Causa F, Fasano G (2021) Improving navigation in GNSS-challenging environments: multi-UAS cooperation and generalized dilution of precision. IEEE Trans Aerosp Electron Syst 57:1462–1479. https://doi.org/10.1109/taes.2020.3043543
98. Causa F, Fasano G (2021) Multiple UAVs trajectory generation and waypoint assignment in urban environment based on DOP maps. Aerosp Sci Technol 110:106507. https://doi.org/10.1016/j.ast.2021.1065
99. Fasano G, Accardo D, Tirri AE, Moccia A, Lellis ED (2015) Radar/electrooptical data fusion for non-cooperative UAS sense and avoid. Aerosp Sci Technol 46:436–450. https://doi.org/10.1016/j.ast.2015.08.010

Fluid Machinery, Energy Systems and Power Generation

Marcello Manna and Adolfo Senatore

Abstract The chapter summarizes the research activities and main outcomes of the fluid machinery, energy systems and power generation groups, occurred during the 2013–2023 decade. The focus is on the theoretical, experimental, and numerical analysis of power generation systems either from hydrocarbons or from renewables, and more in general, on fluid machinery devices and components.

The research activities of the group cover a wide spectrum of topics belonging to the energy conversion family based on fluid flows. Main emphasis is on power generation systems either from hydrocarbons or from renewables, as well as on fluid machinery in general. Heat pumps and refrigerators are also of interest. Cutting edge technologies at plant or component level are typically faced with a thermo-fluid-dynamic approach of various complexity and fidelity, both from a design and analysis perspective. Operational and performance aspects of steam, gas turbine, combined cycle, piston engine power plants and fluid power systems are fully within the research scope of the group. Likewise, design and analysis issues of power and CHP systems, accounting for efficiency, pollutant emission, size and cost constraints are also covered in detail. Finally, pumps, compressors, turbines specific features, performance assessment, as well as all key aspects related to the design and part load functioning remain within the scope of the group.

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1 Internal Combustion Engines

1.1 Introduction

The research groups operating in the energy and mechanical fields of Industrial Engineering Department (University of Naples Federico II) have undertaken a series of funded research projects [1–4] in collaboration with several Universities, Research centers and Industrial partners. In this framework, the activities mainly focused on the analyses of innovative powertrain technologies and alternative fuels to improve the efficiency and noxious emissions of internal combustion engines (ICEs). The primary objective of research studies is to contribute to the progression of environmentally friendly and highly efficient powertrain systems, thus driving the transition towards a sustainable mobility in the transport sector.

1.2 Research Areas

Research collaborations have been conducted through the development of both experimental and numerical methodologies. The experimental analyses mainly concern the effects of alternative fuels on the performance and emissions of ICEs, while the numerical methodologies are oriented to the simulation of flows in the intake/exhaust pipes and of the in-cylinder processes. A particular emphasis has been devoted to the simulation of combustion process in ICEs, employing both zero-dimensional (0D), one-dimensional (1D) and three-dimensional (3D) computational fluid dynamics (CFD) approaches.

1.3 Results and Discussion

The main findings of research efforts are detailed by the published papers [5–14], listed in the reference section. In the following, some valuable outcomes of both experimental and numerical activities will be briefly discussed. The experimental analyses on ICEs have been carried out with the main purpose to decrease the exhaust emissions while reducing the dependency on fossil fuels. In this regard, ethanol is considered a clean and renewable alternative fuel for Spark Ignition (SI) engines when used in blends with gasoline. Researchers performed experimental studies to investigate the effect of bioethanol-gasoline blends on the exhaust emissions of Euro 3 large-size four-stroke motorcycles, operated on the chassis dynamometer for emission measurements [5]. Experiments were realized without change the engine design, under the original fuel injection system and employing bioethanol/gasoline blends (range of bioethanol 5% vol. to 30% vol.). Regulated and unregulated emissions and fuel consumption were quantified over the execution of chassis-dynamometer tests.

The combustion analysis, realized by acquiring the pressure cycle inside the cylinder, highlighted the auto adjustment of the engine control unit and guaranteed use within the same parameters of several tested fuels, with the except of fuel injection time, which increases with increasing ethanol percentage. A significant reduction in carbon monoxide CO and particle number (PN) was associated with well-defined percentages of ethanol content in gasoline fuel blends. Volatile organic compounds, mainly alkanes and aromatics, were not substantially influenced by the bioethanol content of the fuel, while the contribution of carcinogenic benzene ranged between 2 and 5%. Additional measurements were performed to investigate the effect of ethanol/gasoline blends on both fuel consumption and CO and HC emissions during the cold start transient [7]. Results of the experimental tests and the application of a new calculation procedure, which is designed and optimized to model the cold transient behavior of SI engines using different ethanol-gasoline blends, indicated that CO and hydrocarbons (HC) cold start emissions decrease compared to commercial gasoline, with the 20% v/v ethanol blend achieving the highest emission reduction. More in detail, the reduction of CO and HC cold emission factors is associated to the high oxygen content in the ethanol molecule, and the high volatility of gasoline-20% ethonol (E20) fuel which enhances fuel evaporation during cold operating conditions. Furthermore, the addition of ethanol in gasoline fuel blends (20 and 30% v/v ethanol content) produced lower flame temperature which led to lower exhaust temperature, thereby producing a lower amount of nitrogen oxides NO_x emission. Referring to numerical studies, 0D/1D modelling has been adopted to simulate the turbulent combustion in SI engines, by developing a phenomenological combustion model, based on fractal schematization of flame front. A 0D turbulence sub-model has been also developed and coupled to the combustion one to consider the turbulence-induced enhancement of burn rate. The reliability of combustion and turbulence models can be appreciated in Fig. 1, which reports some results related to the activities realized for National Operative Programs (PON) with Stellantis (ex Fiat Chrysler Automobiles) [1, 2] on a downsized turbocharged Variable Valve Actuation (VVA) SI engine [8]. Figure 1a shows that turbulence model is capable to reproduce the 3D-derived evolution of in-cylinder turbulence intensity at varying the engine speed for the early intake valve closure (EIVC) strategy. A proper description of spark event and characteristic combustion angles has been achieved for different operating points (Fig. 1b). Combustion model accurately reproduces the increase of burn duration at very low loads (Fig. 1b), and it also shows a good prediction of the in-cylinder pressure trace and burn rate at full load (Fig. 1c).

The cycle-to-cycle variation (CCV) phenomenon has been modelled basing on the measurements derived from the collaboration with Lamborghini Auto, considering a high-performance twelve-valve (V12) naturally-aspirated SI engine [9]. To this aim, the burn fraction of average cycle, predicted by fractal combustion model, has been stretched to reproduce the measured pressure peak variability, deriving the "faster-than-average" and "lower-than-average" pressure cycles. The consistency of CCV modelling is demonstrated in Fig. 2a, where the 1D computed high and low cycles well agree with extreme faster and slower measured cycles, respectively. Additionally, knock in SI engines has been modelled using a numerical procedure

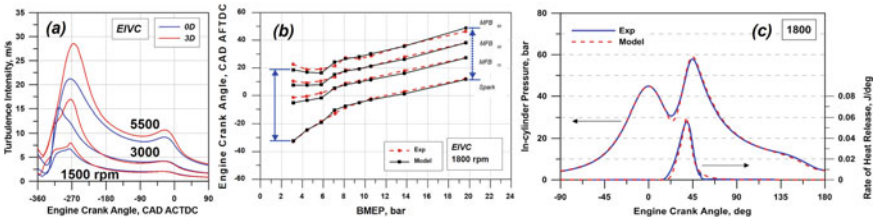

Fig. 1 0D/3D comparison of turbulence intensity for EIVC and different speeds (**a**); numerical/experimental comparison of combustion angles in a load sweep at 1800 rpm and EIVC (**b**); numerical/experimental comparison of in-cylinder pressure cycle and burn rate at full load and 1800 rpm (**c**)

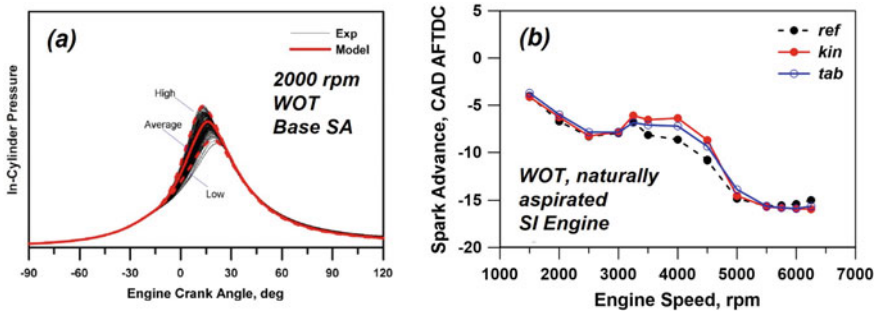

Fig. 2 Numerical/experimental comparison of in-cylinder pressure traces at 2000 rpm, WOT and reference spark advance (SA) (**a**); numerical/experimental comparison of spark advance at WOT of a naturally aspirated SI engine (**b**)

based on a tabulated kinetics of ignition (TKI), describing the fuel auto-ignition in the unburned zone through a progress variable. TKI approach has been verified in comparison to the on-line chemistry method and then adopted to calculate the knock-limited Spark advance (KLSA) referring to a naturally-aspirated SI engine at wide open throttle (WOT), as reported in Fig. 2b.

Recently, advanced combustion modes have been studied, including Turbulent Jet Ignition (TJI), Homogeneous Charge Compression Ignition (HCCI), Reactivity Controlled Compression Ignition (RCCI) and dual fuel. In the European project entitled Efficient Additivated Gasoline Lean Engine (EAGLE) [4], the fractal combustion model has been rearranged to describe the combustion process occurring in a pre-chamber Spark Ignition (PCSI) engine [10]. Pre-chamber combustion model demonstrated to reproduce with good accuracy the in-cylinder pressure trace and burn rate (Fig. 3a) and the combustion evolutions in main and pre-chambers (Fig. 3b) for a reference speed/load point (3000 rpm and 13 bar of Indicated Mean Effective Pressure (IMEP)), also at varying the mixture leaning. Referring to the 0D modelling of HCCI combustion, a multi-zone schematization of combustion chamber has been adopted, where the single zone is treated as a chemical homogeneous reactor and the evolution of auto-ignition chemistry is solved with TKI approach [11]. As an

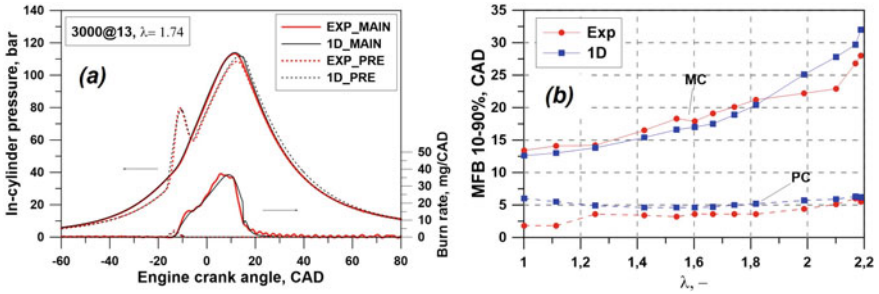

Fig. 3 Numerical/experimental assessment of pressure cycle and burn rate at relative air/fuel ratio $\lambda = 1.74$ for the operating point 3000 rpm and 13 bar (**a**); numerical/experimental comparison of combustion durations for main-chamber (MC) and pre-chamber (PC) at increasing the mixture leaning (**b**)

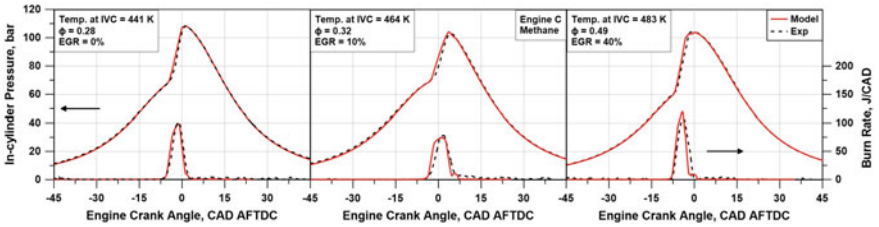

Fig. 4 Numerical/experimental comparison of in-cylinder pressure cycle and burn rate for methane HCCI engine at varying temperature at inlet valve closure (IVC), equivalence ratio, Φ, and Exhaust Gas Recirculation (EGR)

example, Fig. 4 reports the outcomes of a methane HCCI engine, showing good numerical/experimental agreements of in-cylinder pressure cycles and burn rates for different cases. RCCI/dual fuel modes have been studied by developing a phenomenological 0D combustion model. The combustion model is capable to handle both a combustion mode based on a chemistry progression (RCCI with TKI) or one on a fractal-based flame propagation (dual fuel), locally initiated by auto-ignition of high reactivity fuel [12]. Model capabilities can be appreciated by the results obtained in collaboration with Wartsila (Fig. 5).

Dual fuel technology has been also investigated in compression-ignition engine by employing a 3D CFD approach and analyzing the effects of different parameter settings, such as fuel ratios and injection timing, on the performance and pollutant emissions. To describe the phenomena in a cylinder with the aid of CFD tools, it was necessary to model the fuel injection, combustion in all its phases and formation of pollutants. To these numerical simulations, the experimental data have been useful in identifying the trend of the parameters often necessary for the calibration of models in a generalized form. 3D modeling of the combustion phenomenon was carried out using chemical kinetics reduced and then inserting multiple reaction models with approaches such as Finite Rate-Eddy Dissipation, Flamelet Generated Manifold,

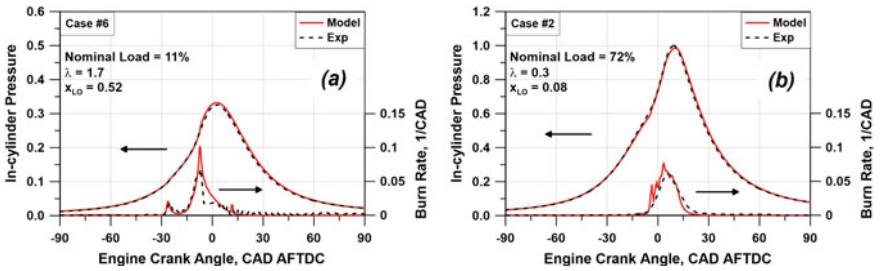

Fig. 5 Numerical/experimental comparison of the in-cylinder pressure cycle and burn rate typical of RCCI mode (**a**) and of the dual fuel mode (**b**) for a large bore research engine

Eddy-dissipation Concept. Simulations of the turbocharged direct injection diesel engine in dual-fuel mode (diesel/methane-hydrogen blends) are described in several papers [6, 13, 14], while some results are reported in Fig. 6.

2 Turbomachinery

The Turbomachinery and Propulsion Group has been rather active both in the numerical and experimental fields, essentially within applied research items. Basic studies carried out with high fidelity simulation tools have also been completed and will be summarized at the end of the section.

2.1 Turbochargers

Advanced experimental campaigns have dealt with high performance turbochargers typically employed in downsized ICE for automotive applications. Data have been collected in a highly flexible modern turbocharger test bench with advanced aerothermal measuring capabilities and automated data processing features. A detailed heat transfer analysis has brought forward new interesting experimental evidence. Combining the power conservation principle as applied to the compressor, the turbine, the bearing housing and to the overall turbocharger, it has been shown that the thermal power transferred to the lubricating oil, as well as to the environment, has a relevant, far more relevant than expected, impact on the performance of the test article. Specifically, it has been found that, at nominal operating conditions, the algebraic sum of the afore-mentioned two thermal powers is roughly speaking 20–30% of the compressor total enthalpy change per unit of time. This also means that the evaluation of both work transfer and efficiency under the assumption of adiabatic flow is largely affected by errors. As a matter of fact, it has been shown that a 5–10% relative error can easily be made when evaluating the compressor efficiency through classical

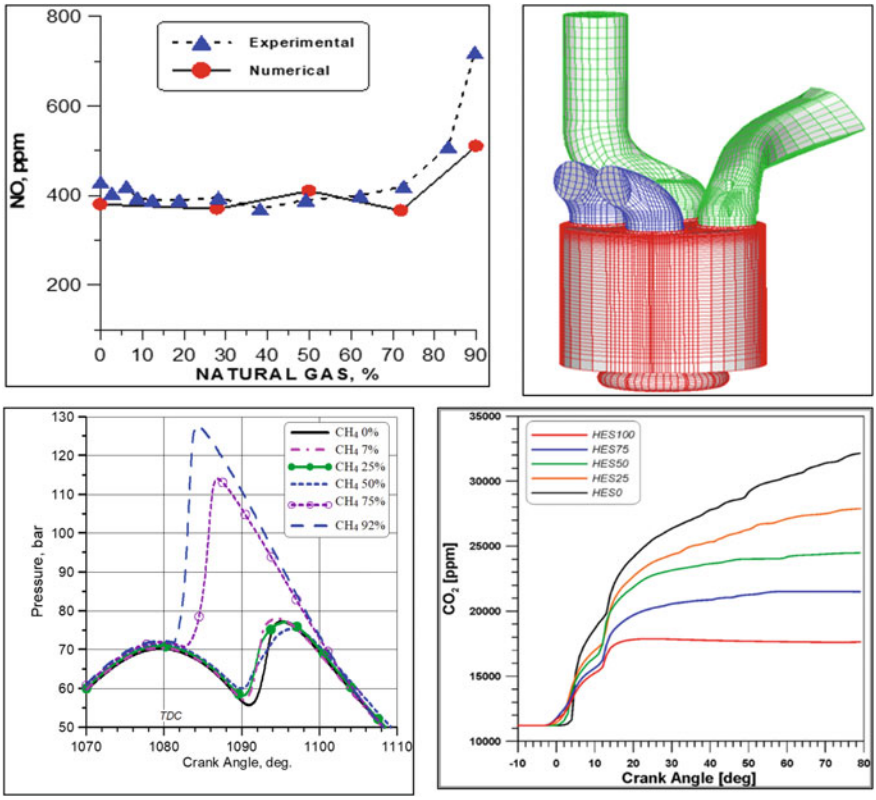

Fig. 6 Experimental and numerical NO_x in dual-fuel engine [14] (**a**); Computational domain and mesh [14] (**b**); in-cylinder pressure cycle in full diesel and dual fuel modes at different methane (CH_4) contents [6] (**c**); carbon dioxide (CO_2) emissions for dual fuel mode by varying hydrogen (H_2) amount [13] (**d**)

expression based on the adiabatic assumption. Those errors may have a major impact on the compressor selection adequacy both for industrial and automotive applications [15]. The unsteady measuring capabilities of the rig have been exploited to investigate in close details basic unexplored features of the surge phenomenon, occurring in a free spool low specific speed centrifugal compressor [16]. The analysis, based on a set of experimental data acquired with high frequency response transducers, has been carried out on the previously mentioned turbocharger test bench. Once a large set of stable operating points were determined, two unstable regimes were investigated at two rotational speeds, with the help of standard statistical tools. Specifically, pressure ratio and mass flow rate unsteady signals were processed as to determine the dominant oscillating frequency to be used to phase average the surge data. The associated spectral analysis of the signals also allowed to ascertain the effects of the rotational speed on the fundamental frequency shift. The unstable states were characterized

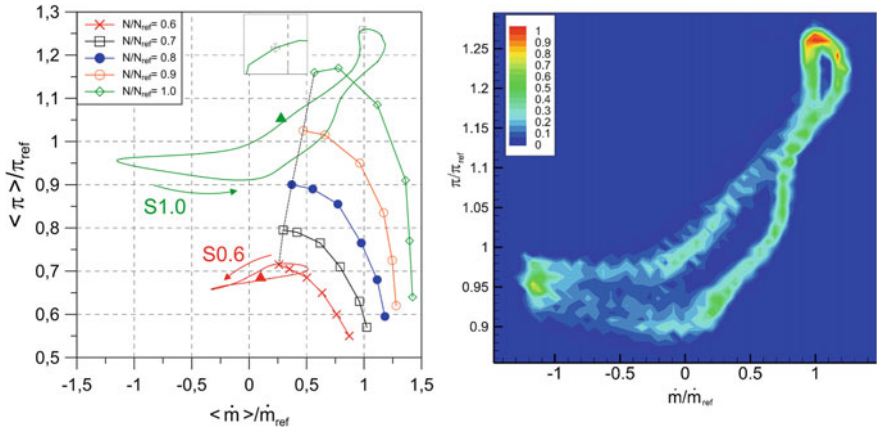

Fig. 7 Mild and deep surge cycles: phase averaged (left) and probability density function (right)

in terms of the modulations, that is, the deviation of the phase-locked averaged-quantities from the long time average of the pressure ratio and mass flow rates in phase space. All analyzed cases exhibited huge mass flow rates variations with moderate pressure ratio changes. Moreover, the effect of the compressor rotational speed has been documented to be impressive. In fact, the overall variation of the phase-averaged mass flow rate increased by a factor three, increasing the compressor rpm from 66 to 100% of the reference velocity. Furthermore, the in-cycle variation occurring under surge regimes have been quantified with the help of a probabilistic approach in the mass flow rate vs pressure ratio operating plane (see Fig. 7). The analysis has allowed the very first identification of the most likely to occur instantaneous states in the unstable envelope. The two deep surge regimes were documented to be characterized by longer time of residences in different quadrants of the characteristic plane, a fact that has a major impact on the shape of the anomalous aerodynamic load applied to the rotor.

On the numerical side several studies concerning the use of axial flow turbines for automotive turbocharging and comparison with typical radial flow turbines have been carried out. Achievements in terms of solutions yielding reduction of the response delay of the turbocharged engines and selection of the optimal solution for the stationary components have been demonstrated.

2.2 Wind Turbines and Propellers

The Turbomachinery and Propulsion Group is also active in the analysis and design of open and ducted rotors, e.g., wind and marine turbines, aeronautical and marine propellers. In the last decade, the group has developed several innovative analysis tools tailored for this kind of devices, such as the semi-analytical (SA), the free-wake

ring-vortex (FWRV) and the CFD actuator disk (AD) models. Moreover, blade-resolved analysis [17] have also been carried out. The nonlinear and semi-analytical actuator disk model [18] relies on the exact solution for incompressible, axisymmetric and inviscid flows. The velocities and the Stokes stream function results from the superposition of ring vortices properly arranged along the duct and hub surfaces and the wake region. Using a general analytical procedure, the flow fields are given as a combination of one-dimensional integrals of expressions involving complete as well as incomplete elliptic integrals. In comparison with similar and previously developed models, the method can deal with ducts of general shape, wake rotation and rotors characterized by radially varying load distributions. Moreover, the nonlinear mutual interaction between the duct and the turbine, and the divergence of the slipstream, which is particularly relevant for heavily loaded rotors, are naturally accounted for. The same original features are also shared by the FWRV [19] which, unlike the semi-analytical model, has been specifically developed to handle radially uniform load distributions. The flows induced by the disk, the duct and the hub are modelled by ring sheet-vortices which are discretized through a classical panel method. An iterative solution procedure is developed to evaluate the density strength distribution of the sheets and the wake shape. To this aim, the homogeneous Dirichlet boundary condition is used for the velocity just beneath the hub sheet, while the free force condition is imposed all along the wake boundary. The latter is also required to be aligned with the overall flow field. These methods have been extensively applied to the analysis of open and ducted rotors. For example, in the open configuration, they have been used to evaluate, for both propellers and turbines [20], the errors arising in the Blade/Element-Momentum Theories, when the wake divergence is neglected, and the swirl terms are linearized. In the ducted configuration, the conditions that must occur for the duct thrust to play a relevant role in the enhancement of the performance have been detailed [21]; likewise, it has been demonstrated that an ideal ducted wind turbine can exceed the Betz limit even if the power coefficient is referred to the frontal area of the device [19]. Moreover, the maximum-power-coefficient/tip-speed-ratio characteristic curve for a diffuser augmented wind turbine has been derived for the first time. Finally, taking into full account the mutual influence of the disk and duct, a new rotor design strategy, capable to evaluate the optimum distribution of the chord and pitch-angle along the blade span, has also been proposed [22].

2.3 Fundamental Study on Wall Turbulence

Fluid mechanics research on basic flow phenomena [23–25] is also worth to be mentioned. The research group has developed a set of very accurate viscous flow solvers with exponential rate of the error decay, which are routinely employed to investigate wall turbulence features. Attention is focused on the mechanisms associated with the turbulence regeneration cycle occurring in wall bounded flows over annular conduits and pipes, both in steady and unsteady regimes of pulsating nature (see Fig. 8).

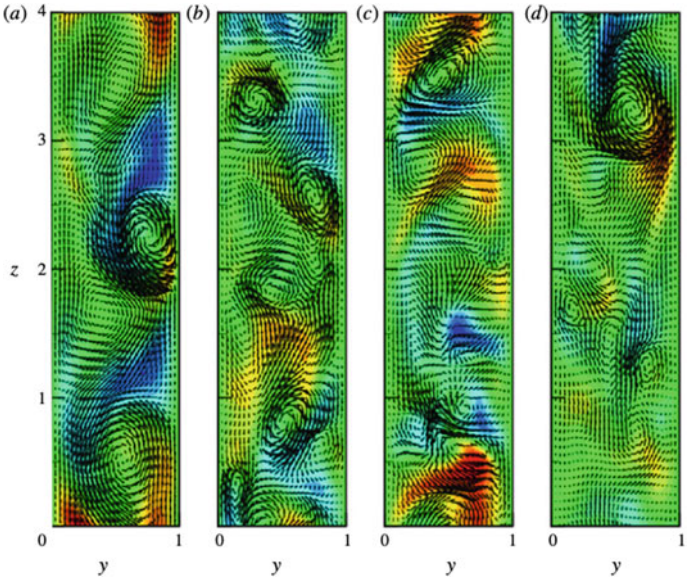

Fig. 8 Instantaneous snapshots in a meridional plane of the azimuthal velocity component with the velocity vectors overlaid. **a** Taylor-Couette Flow (TCF); **b** Spiral TCF (STCF); Pulsating STCF: **c** small amplitude; **d** large amplitude

2.4 Turbomachines for Real Gas Applications

Radial inflow turbines for ORC applications operated with different organic fluids have also been investigated. Attention was focused on the optimal geometrical configuration of the nozzle [26, 27] (see Fig. 9).

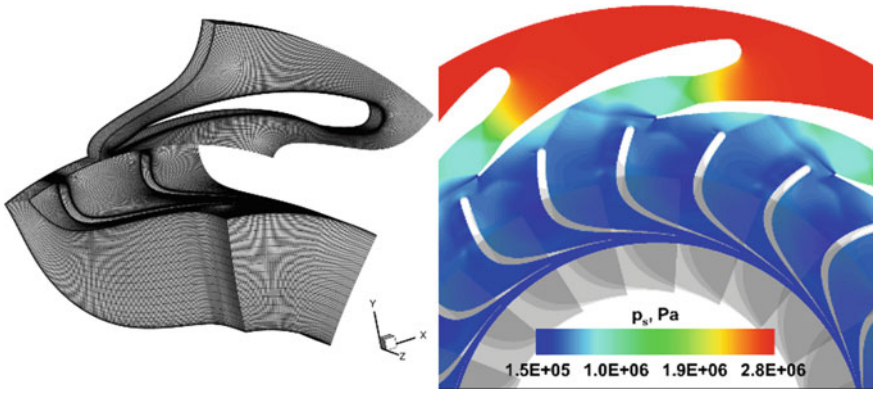

Fig. 9 Stator-Rotor mesh (left) and static pressure contours (right)

The adoption of a 30 kW class micro gas turbine as a range-extender system for electrically driven vehicles has also been proposed [28].

3 Energy Conversion Systems

3.1 Introduction

Energy conversion systems have always been a driving topic in research. This topic governs both directly and indirectly the current directions of modern research and development and is also used as a measure of economic level and environmental safety and defines policy and social relations in society. The Department of Industrial Engineering has developed and continues to develop extensive research activities. Over the past decade, a research group has studied innovative microgeneration plants based on micro gas turbines (MGTs), integrated with a solar array and/or an ORC (Organic Rankine Cycle) system as a bottoming plant to produce additional electricity [29]. Thus, MGTs represent an efficient and widely used solution for both smart-generation and decentralized power generation with low environmental impact The department has also invested resources on the issue of energy transition by studying polygeneration and Multi Energy Systems (MES) and developing research on their management [30]. Scientific production and achievements in solar and energy efficiency have enabled DII to be part of the working group of the EERA (European Energy Research Alliance) and be a leader in the joint programs Energy Efficiency in Industrial Processes and Concentrated Solar Power. DII, in the area of research of solar source energy conversion systems was a partner in the European project INSHIP (Integrating National Research Agendas on Solar Heat for Industrial Processes) under the European Horizon 2020 program. The research activity on this topic has led to the production of various works including the one reported with reference number [31].

3.2 Research Areas

The research topics are developed by using modeling, numerical and experimental approach. The research on the Micro-Gas-Turbine/Organic-Rankine-Cycle systems has been developed simulating the MGT by an advanced CFD that makes use of extended kinetic mechanisms coupled with turbulence-chemical interaction models [32] able to evaluate the combustion process and pollutant emissions formation of different types of fuel including those deriving from renewable sources (Fig. 10).

The “APPlied Energy Research Team (APPER) Group” [33] treated Multi Energy Systems (MES) concerning different types of plants such as DSG (Direct Steam Generator) systems, cogeneration systems with ICE (Internal Combustion Engine),

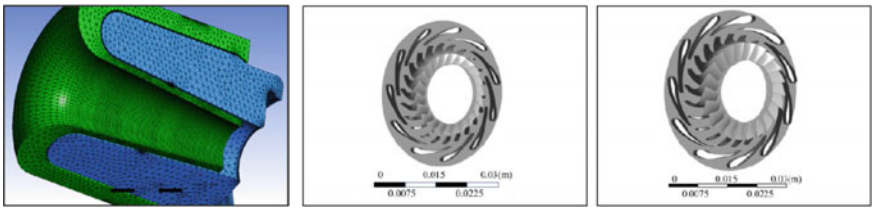

Fig. 10 Mesh of a sector of MGT Combustor and Turbine configuration for R1234ze and R245fa organic fluid

MES systems with electric storage. The optimized management of the different sources was the objective of the research. The optimization was based on the criteria of the multi-objective functions [34] capable of maximizing the variables considered from time by time.

3.3 Results

Since its inception, the Department of Industrial Engineering has understood the strategic importance of energy conversion systems with respect to the environment. The previously analysed research developments highlight the possibility of integrating and recovering energy from conventional energy systems which are however re-proposed with the use of green fuels reducing the pollutants production (Fig. 11 left) and optimized through energy harvesting plants such as Organic-Rankine-Cycle (ORC) systems.

The use of MOGA-type optimization systems has made it possible to optimize energy production plants powered by various sources, from fossil to solar, from photovoltaics to integration into the electricity grid (Fig. 11 right). The study led to energy management methods such as the access of different sources. Participation in

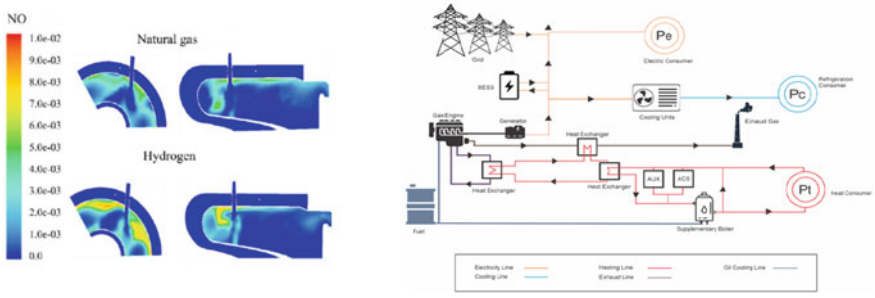

Fig. 11 NO in MGT two fuels combustor (left). Scheme of the Multi Energy System (right)

scientific projects on European tenders has increased the knowledge of the department and its international vocation.

4 Fluid Power Systems

Research and teaching activities in the Fluid Power sector have been available at the Department for more than twenty years. Regarding the research activities in the last 10 years, studies have been focused on the optimization of components, in particular volumetric pumps and valves. Excellent results have been achieved on studying, optimization, and prototyping of new Gerotor, vane, piston, and external gear pumps and valves as well. Through the years numerical models of these components have been developed using both lumped parameters and 3D CFD approaches, using open source and commercial tools. For instance, [35] a 0D-1D model has been presented, that has been built up to simulate the lubrication circuit of an internal combustion engine, which also goes in depth in the modeling of a Gerotor pump and of all the components included in the circuit. Transient simulations have been run in several working conditions. The experience with these types of modeling allowed a very careful evaluation of the influence of the geometry of the pump on the pressure ripples.

Therefore, the scientific production of the sector in the context of Fluid Power has mainly moved, in recent years, in the field of modeling these pumps, as shown in [36–41].

The most important result is the development of a tool that has attracted considerable interest from both academia and companies. The tool, called EgeMATor MP+ (External Gear Machine Multi Tool Simulator for Multiple Gears' Profiles), has been developed by the Fluid Power Research Group at the University of Naples Federico II. It is capable of fully studying and optimizing external gear machines, and allows to simulate pumps with both traditional spur gears and helical gears profiles. The tool is comprised of different subroutines developed in various environments, interconnected to each other, as shown by its workflow presented in Fig. 12, to study the EGMs in depth.

Following the flow chart in Fig. 12, the tool starts receiving an Excel file as input, which contains all the geometrical properties of the pump analyzed. This file also contains the links to the DXF files (Drawing Exchange Format) of tooth profiles and relief groove geometries. This data is acquired by the first developed subroutine, called Surface Tool, which is the core of EgeMATor MP+. This subroutine, written in MATLAB® (MathWorks Inc., Natick, MA, USA), initially verifies the correctness of the gear engagement with the chosen inputs, finding the relative rotation angle to obtain teeth contact with zero gaps and checking the presence of interference in the meshing zone. Then the surface tool generates the required data and files, thus giving the start to the following hydraulic simulation; a model is developed in the Simcenter Amesim® environment (Siemens AG, Munich, Germany). Hydraulic outputs enter in a subroutine written in MATLAB® which resolves the pressure film around the

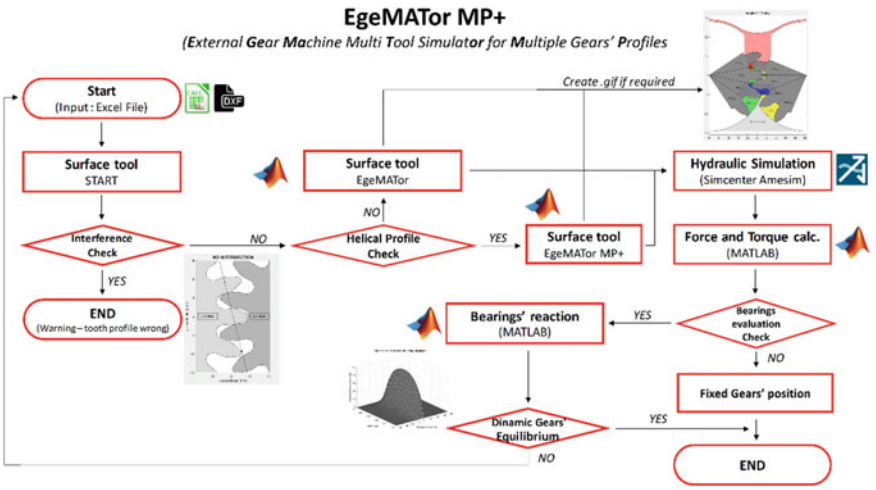

Fig. 12 EgeMATor MP+, workflow

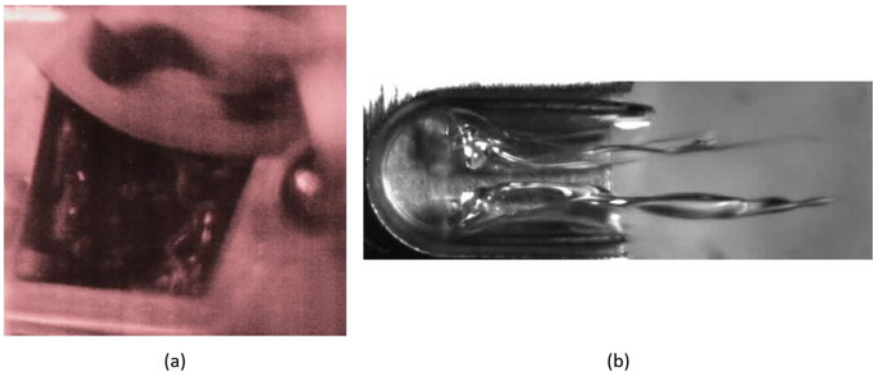

Fig. 13 **a** Cavitation at the suction side of a Gerotor pump; **b** Cavitation in the U-notch of a proportional spool valve

bearing that develops a reaction to counterbalance the load through a finite difference method. The eccentricity and the angle of minimum film thickness values are found through an iterative inverse procedure.

Research activities have been carried on also in the field of axial piston pumps [42] and spool valves [43], in particular with the aim of predicting cavitation phenomena (Fig. 13).

In October 2022, the Fluid Power Research Group organized at the Federico II Conference Center the International Conference "IEEE Global Fluid Power Society Ph.D. Symposium". This conference was attended by all the leading researchers and professors from all over the world, in the field of fluid power. Three professors from the most prestigious universities took invited lectures, in particular Prof. Kim Stelson

Fig. 14 Global Fluid Power Symposium, at the Federico II Conference center

(University of Minnesota), Prof. Katharina Schmitz (Aachen University) and Rudolf Scheidl (Johannes Kepler University Linz). All the most important companies in the Fluid Power fields were present (e.g., Rexroth, Marzocchi, Duplomatic, Parker etc.). More than 60 scientific papers were presented, selected among more than a hundred papers after a severe revision process (Fig. 14).

References

1. MULTIAIR EVOLUTION – Next Generation Ultra low CO2 Spark Ignition Powertrain (PON01-02211). January 2011–January 2015. Funded by MIUR. Total cost of the project: 21.65 MEur. Project Leader, Fiat Powertrain. Principal investigator UNINA: prof. Gimelli A.; UNINA Total cost: 1.071 MEur. Other UNINA-DII researchers: Bozza F., De Bellis V., Muccillo M., Senatore A
2. IDMAP – Innovative Development Methodologies for Automotive Powertrain (PON01-01517). January 2011–January 2015. Funded by MIUR. Total cost of the project: 9.2 Meuro. Project Leader, Fiat Powertrain. Principal investigator UNINA: prof. Bozza F. Other UNINA-DII researchers: Gimelli A., De Bellis V., Muccillo M., Senatore A
3. GREEN POWERTRAIN – Technical solutions and methodologies for the energy efficiency of vehicle powertrains aimed for sustainable public mobility. (POR FESR 2014-2020 – CUP B63D18000300007). Funded by Campania. Total cost of the project: 8.27 MEur. Project Leader, DATTILO. Principal investigator UNINA: prof. Bozza F. Other UNINA-DII researchers: Gimelli A., Giardiello G., De Bellis V., Muccillo M., Senatore A
4. European Project H2020 EAGLE – Efficient Additivated Gasoline Lean Engine. A 42-month project. Unina Funding 400 kEur. Main Proponent: IFP, France. Partners: FEV GmbH, University of Naples Federico II, Renault SAS, Universitat Polit‘ecnica de Valencia, RWTH Aachen

University, Saint Gobain, Continental Automotive GmbH. The project aims to develop an ultra-lean internal combustion Spark Ignition engine concept
5. Costagliola MA, Prati MV, Florio S, Scorletti P, Terna D, Iodice P, Buono D, Senatore A (2016) Performances and emissions of a 4-stroke motorcycle fuelled with ethanol/gasoline blends. Fuel 183:470–477
6. Abagnale C, Cameretti MC, De Simio L, Gambino M, Iannaccone S, Tuccillo R (2014) Numerical simulation and experimental test of dual fuel operated diesel engines. Appl Therm Eng 65:403–417
7. Iodice P, Senatore A, Langella G, Amoresano A (2016) Effect of ethanol-gasoline blends on CO and HC emissions in last generation SI engines within the cold-start transient: An experimental investigation. Appl Energy 179:182–190
8. Bozza F, De Bellis V, Gimelli A, Muccillo M (2014) Strategies for improving fuel consumption at part-load in a downsized turbocharged SI engine: a comparative study. SAE Int J Eng 7:60–71
9. Bozza F, De Bellis V, Minarelli F, Cacciatore D (2015) Knock and cycle by cycle analysis of a high performance V12 spark ignition engine. Part 2: 1D combustion and knock modeling. SAE Int J Eng 8:2002–2011
10. Bozza F, De Bellis V, Tufano D, Malfi E, Müller C, Habermann K (2019) A quasi-dimensional model of pre-chamber spark-ignition engines technical report (SAE Technical Paper)
11. De Bellis V, Malfi E, Lanotte A, De Felice M, Teodosio L, Bozza F (2022) A tabulated chemistry multi-zone combustion model of HCCI engines supplied with pure fuel and fuel blends. Energies 16:265
12. De Bellis V, Malfi E, Lanotte A, Fasulo G, Bozza F, Cafari A, Caputo G, Hyvönen J (2022) Development of a phenomenological model for the description of RCCI combustion in a dual-fuel marine internal combustion engine. Appl Energy 325:119919
13. Cameretti MC, De Robbio R, Mancaruso E, Palomba M (2022) CFD study of dual fuel combustion in a research diesel engine fueled by hydrogen. Energies 15:5521
14. Cameretti MC, Tuccillo R, De Simio L, Iannaccone S, Ciaravola U (2016) A numerical and experimental study of dual fuel diesel engine for different injection timings. Appl Therm Eng 101:630–638
15. Bontempo R, Cardone M, Manna M, Vorraro G (2015) Steady and unsteady experimental analysis of a turbocharger for automotive applications. Energy Convers Manag 99:72–80
16. Bontempo R, Cardone M, Manna M, Vorraro G (2017) A statistical approach to the analysis of the surge phenomenon. Energy 124:502–509
17. Bontempo R, Di Marzo E, Manna M (2023) Diffuser augmented wind turbines: a critical analysis of the design practice based on the ducting of an existing open rotor. J Wind Eng Ind Aerodyn 238:105428
18. Bontempo R, Manna M (2013) Solution of the flow over a non-uniform heavily loaded ducted actuator disk. J Fluid Mech 728:163.195. ISSN: 1469-7645
19. Bontempo R, Manna M (2020) On the potential of the ideal diffuser augmented wind turbine: an investigation by means of a momentum theory approach and of a free-wake ring-vortex actuator disk model. Energy Convers Manag 213:112794
20. Bontempo R, Manna M (2017) Highly accurate error estimate of the momentum theory as applied to wind turbines. Wind Energy 20:1405–1419
21. Bontempo R, Manna M (2016) Effects of the duct thrust on the performance of ducted wind turbines. Energy 99:274–287. ISSN: 0360-5442
22. Bontempo R, Manna M (2022) The Joukowsky rotor for diffuser augmented wind turbines: design and analysis. Energy Convers Manag 252:114952
23. Manna M, Vacca A, Verzicco R (2015) Pulsating pipe flow with large-amplitude oscillations in the very high frequency regime. Part 2. Phase-averaged analysis. J Fluid Mech 766:272–296
24. Manna M, Vacca A, Verzicco R (2020) Pulsating Spiral Poiseuille flow. J Fluid Mech 890:1–25
25. Manna M, Vacca A, Verzicco R (2022) Reverse transition of a turbulent Spiral Poiseuille flow at $T_a = 1500$. J Fluid Mech 941:A6
26. Cappiello A, Tuccillo R (2022) Influence of supersonic nozzle design parameters on the unsteady Stator-Rotor interaction in radial-inflow turbines for organic rankine cycles. J Turbomach 144. ISSN: 0889-504X

27. Cappiello A, Tuccillo R (2021) Design parameter influence on losses and downstream flow field uniformity in supersonic ORC radial-inflow turbine stators. Int J Turbomach Propuls Power 6. ISSN: 2504-186X
28. Karvountzis-Kontakiotis A, Andwari AM, Pesyridis A, Russo S, Tuccillo R, Esfahanian V (2018) Application of micro gas turbine in range-extended electric vehicles. Energy 147:351–361
29. Cameretti MC, Cappiello A, De Robbio R, Tuccillo R (2023) Solar-assisted micro gas turbine with humid air or steam-injected option. Energy 270:126783
30. Gimelli A, Mottola F, Muccillo M, Proto D, Amoresano A, Andreotti A, Langella G (2019) Optimal configuration of modular cogeneration plants integrated by a battery energy storage system providing peak shaving service. Appl Energy 242:974–993
31. Iodice P, Langella G, Amoresano A (2019) Modeling and energetic-exergetic evaluation of a novel screw expander-based direct steam generation solar system. Appl Therm Eng 155:82–95
32. Cameretti MC, Tuccillo R, Piazzesi R (2013) Study of an exhaust gas recirculation equipped micro gas turbine supplied with bio-fuels. Appl Therm Eng 59:162–173
33. Gimelli A. Web page of the APPER group. http://www.dii.unina.it/page.php?id_livello=183&tabella=livello2&livello1=100&livello2=0&livello3=0&flag=pagina
34. Gimelli A, Muccillo M (2013) Optimization criteria for cogeneration systems: multi-objective approach and application in an hospital facility. Appl Energy 104:910–923
35. Frosina E, Senatore A, Buono D, Santato L (2015) Analysis and simulation of an oil lubrication pump for internal combustion engines. J Fluids Eng Trans ASME 137. ISSN: 1528901X
36. Pellegri M, Vacca A, Frosina E, Buono D, Senatore A (2016) Numerical analysis and experimental validation of Gerotor pumps: a comparison between a lumped parameter and a computational fluid dynamics-based approach in 231. SAGE PublicationsSage UK: London, England, pp 4413–4430
37. Buono D, Siano D, Frosina E, Senatore A (2017) Gerotor pump cavitation monitoring and fault diagnosis using vibration analysis through the employment of auto-regressive-moving-average technique. Simul Modell Pract Theory 71:61–82. ISSN: 1569-190X
38. Shah YG, Vacca A, Dabiri S, Frosina E (2018) A fast lumped parameter approach for the prediction of both aeration and cavitation in Gerotor pumps. Meccanica 53:175–191. ISSN: 15729648
39. Frosina E, Senatore A, Rigosi M (2017) Study of a high-pressure external gear pump with a computational fluid dynamic modeling approach. Energies 2017 10:1113. ISSN: 1996-1073
40. Marinaro G, Frosina E, Senatore A (2021) A numerical analysis of an innovative flow ripple reduction method for external gear pumps. Energies 14:471. ISSN: 1996-1073
41. Mazzei P, Frosina E, Senatore A (2023) Helical gear pump: a comparison between a lumped parameter and a computational fluid dynamics-based approaches. Fluids 8:193. ISSN: 2311-5521
42. Marinaro G, Frosina E, Senatore A, Stelson KA (2021) A fast and effective method for the optimization of the valve plate of swashplate axial piston pumps. J Fluids Eng Trans ASME 143. ISSN: 1528901X
43. Romagnuolo L, Frosina E, Amoresano A, Quaremba G, Spirto M, Senatore A (2023) Instability measurement of cavitation conditions in a spool valve through the definition of a cavitation instability index. Flow Meas Instrum 91:102366. ISSN: 0955-5986

Thermal Engineering and Building Energy Systems

Francesco Minichiello and Vincenzo Naso

Abstract This chapter summarizes the research activities and main outcomes of the groups engaged in Thermal Engineering and Building Energy Systems, in the decade 2013–2023. The research topics are typical of the sectors called "Fisica tecnica industriale" and "Fisica tecnica ambientale".

1 Introduction

Research activities in the field of Thermal Engineering and Building Energy Systems have been carried out at the Università degli Studi di Napoli Federico II throughout the last decades. They concerned all the topics pertaining to Fisica tecnica industriale (FTI) ed Fisica tecnica ambientale (FTA) mentioned in the October 4, 2000, Italian Ministerial Decree, which are resumed as follows.

FTI investigates fundaments and industrial engineering applications of thermodynamics, heat transfer and applied energy, thermodynamics of energy processes and their impact on the environment, conversion and use of renewable and non-renewable energy, energy management, thermo-economy, combined heat transfer mechanisms, refrigeration, thermal plants, thermo-physical properties of materials, thermofluid-dynamics measurements and regulation.

FTA investigates fundaments and building applications of thermodynamics, heat transfer and applied energy, lighting and applied acoustics in industrial and civil buildings as well as in territorial planning and architecture, physics of indoor environment, conditioning plants aimed at comfort and air quality, measurement and processing of ambient data, active and passive conditioning systems, energy and environmental planning, management of energy systems.

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In the last decade researches have been focused on the topics described in the following sections: Applied acoustics, Energy efficiency and renewable energy, Heat transfer in civil, industrial and biological systems, Heating, ventilation, air conditioning and energy efficiency of the building-plant system, Indoor environmental quality, Lighting, Experiments and modelling of innovative systems for refrigeration, Refrigeration and heat transfer on systems alternative to vapor compression, Sustainable energy systems.

The above reported topics are also addressed in undergraduated, graduated and Ph.D. courses in Engineering and Architecture at the Università degli Studi di Napoli Federico II; students also attend Ph.D. courses and seminars in other universities in Italy and abroad.

2 Background and Legacy

The research and teaching activities were carried out at the Istituto di Fisica tecnica until the end of the seventies of the last century, then at the Dipartimento di Ingegneria meccanica per l'energetica during the eighties, and at the Dipartimento di Energetica, termofluidodinamica applicata e condizionamenti ambientali up to October 31, 2012, when the Dipartimento di Ingegneria industriale was activated.

Many researchers educated under the Fisica tecnica in the Università Federico II have been serving as professors in several Italian Universities, some of them holding important academic positions.

In the last decades Professors Cesarano, Fucci, Ianniello, Mazzei, Naso, Reale, Vanoli, Vigo retired; Professors Alfano, Berardi, Betta, Cannaviello passed.

3 Main Research Programs

3.1 Applied Acoustics

The research activity of the team is focused on several issues of environmental, industrial and architectural acoustics. It is aimed at the analysis of the interaction between sound waves and porous materials for civil and industrial applications [1–3] as well as for the improvement of acoustic insulation and acoustic comfort in rooms [4, 5]. The research team has also developed models, procedures and measurement equipment for the characterization of porous materials to be used in the development of thermo-acoustic devices [6–9] and for the assessment of the acoustic behaviour of innovative materials, such as metamaterials [10] (Fig. 1).

Experiments are carried out in the acoustics laboratory of the department, equipped with a small semi-anechoic chamber and devices for the determination of the main properties affecting the acoustic behaviour of porous materials and

Fig. 1 Measurement set-up to assess the complex Young's modulus of porous materials

metamaterials as well as for the assessment of the room acoustic quality. Recently, the laboratory has been equipped with two measurement prototypes: one aimed at assessing, at low frequency, the thermal and viscous dissipative effects in porous materials and the other for testing the performance of non-conventional porous materials used in thermo-acoustic devices.

The research team collaborates with several foreign universities, such as the University of Tallinn, the University of Salford, the University of Achen, the Gustave Eiffel University.

The research programmes funded by public institutions have been:

- PRIN 2017: "Thermoacoustic technology for solar and waste heat powered energy conversion systems" in collaboration with University of Naples Parthenope, University of Messina, University of Cagliari and National Research Council.
- Research Agreement DII-CeRICT scrl: "Vibro-acoustic analysis for quality control" in collaboration with P&P Product and Process Development srl.
- Research Agreement DII-MedITech Competence Center: "Measurement of the mechanical characteristics of polyurethane foams and numerical-experimental assessment of the radiation efficiency of EPDM plates combined with polyurethane foams" in collaboration with Adler EVO srl.

3.2 *Energy Efficiency and Renewable Energy (EERE)*

Research activities are carried out on the development and application of advanced models for the dynamic simulation and optimization of systems. The main SW tools used are TRNSYS, Energy Plus, MATLAB, SIMULINK, EES, Fortran, Aspen plus, ENERGY PLAN, Labview. Researches are focused on the thermodynamic and thermo-economic simulation, analysis and optimisation of systems and technologies for energy saving and renewable energy in buildings, industrial applications and transports. Recently, key enabling technologies for the energy transition, such as thermal and electric energy storage systems and hydrogen-based applications, have been emphasised.

The main research topics are:

- solar energy, including Concentrated Solar Power (CSP), hybrid Photovoltaic-Thermal systems (PVT), Building-Integrated PV (BIPV) and combined PV/Wind systems [11–13] (Fig. 2);
- geothermal energy [14];
- renewable district heating and cooling, Combined Heat and Power (CHP), poly-generation and multi-energy systems [13, 15].

In the last decade, the team has reinforced its international cooperations, which now include Virginia Tech (USA); Colorado School of Mines (USA); A. Alto University (Finland); University of Cyprus; University of Zagreb (Croatia); University of

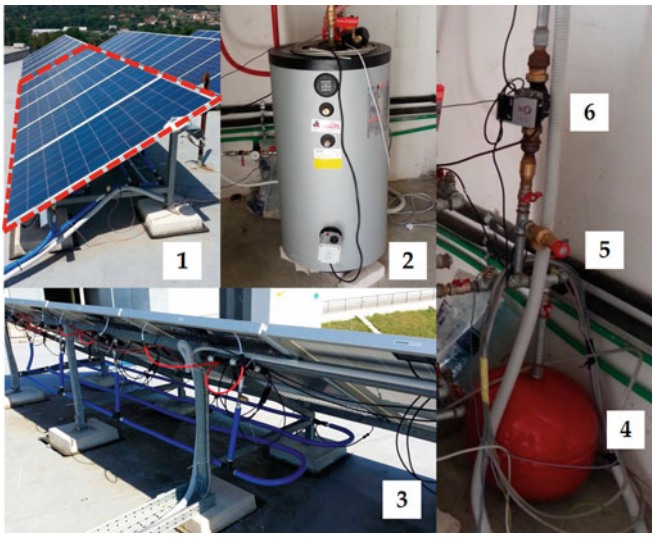

Fig. 2 Experimental set-up for hybrid photovoltaic-thermal collectors: (1) PVT collectors; (2) BSV ELBI storage tank; (3) connection pipes; (4) expansion vessel; (5) safety valve; (6) circulation pump

Zaragoza (Spain); Concordia University (Canada); Universidad Carlos III de Madrid (Spain); University of Krakow (Poland).

Research programmes have been funded by public institutions:

- 2010–2013: SAHARA (Solar-Assisted Heating and Refrigeration Appliances), financed by the Italian Ministry of Environment;
- 2012–2015: "RISE—Research and Innovation in the Energy Field"—Work Package: Solar Energy, financed by Regione Campania, PON 2007–2013;
- 2018–2021: "Biofeedstock—Development of Integrated Technological Platforms for the Valorisation of Residual Biomass", Work Package: biogas and biomethane from organic waste, financed by Italian Ministry of University and Research (MUR), PON R&I 2014–2020 e FSC programmes;
- 2020–2022: "Optimal refurbishment design and management of small energy micro-grids", funded by the Italian MUR, PRIN 2020.

3.3 Heat Transfer in Civil, Industrial and Biological Systems

The research team, by means of experimental, numerical, and analytical approaches, investigates heat transfer phenomena in several applications of life and science. The activities are described in the following.

Energy efficiency in buildings. The research concerns the environmental impact of the use of energy, from the single material to the whole building, both in the operating phase and the lifecycle. Two main areas and challenges for future years are considered: a sustainable retrofitting of existing buildings and a new paradigm of the energy performance of the new architecture, to match the mandatory sustainability requirements for a low-carbon future.

Heat transfer in buildings and in industries is investigated at different deepening levels, depending on the needs of each program. Heat transfer in industrial applications is investigated from micro- to macro- scale, with both theoretical predictive models and engineering devices. Renewable thermal energy conversion in industrial processes, measurement methods and materials suitable for providing renewable heat most efficiently as well as bioheat transfer for various potential clinical applications are studied.

The research team collaborates with the Universities of Seville, Minho, Split, Athens, Thessaloniki, BBSR in Germany, UPV in Valencia, INSA in Lyon, New South Wales (UNSW) in Australia, Connecticut (UConn) in USA, Purdue University in West Lafayette USA, University of California in USA. Experimental studies at a real-scale, living labs and test rooms—performed with numerical calculation labs, workstations, remote controls, IoT, are carried out in partnership with the Università del Molise and the Università del Sannio. Research activities are also carried out with Italian ENEA, CNR and I.S.A.S.I-CNR.

As far as energy efficiency in the civil sector is concerned, within national and international collaborations, methods and technologies to improve the energy

efficiency of the massive and inefficient built environment (buildings with cultural value, health facilities included) are investigated. The research involves primary issues of energy efficiency in the building sector, like materials and technologies of the building envelope, active energy systems for microclimatic control, environmental comfort, and energy supply from renewable energy sources. The main research fields of the research team are:

- EVALUATION METHODS. Methodologies for calculating the energy performance indexes, with reference to both the building envelope and active energy systems, according to the EU EPBD targets and the EPBD cost-optimality. Multi-objective optimization of building energy performances, taking into account investments, indoor comfort, operational energy demands. Model predictive control (a day-ahead planning horizon), to reduce the operating cost of space conditioning and thermal comfort. Research of simplified methodologies for evaluating the energy performance of new and existing buildings, in order to transfer data into Geographic Information Systems (GISs) and develop Urban Energy Maps.
- ENVELOPE TECHNOLOGIES AND ENERGY SYSTEMS. Building components and responsive technologies to mitigate the heat gains and cooling loads (dynamic insulation; airflow in vented walls and double skin facades; cool materials and selective coatings; phase change materials [16]; evapotranspiration in green-based building components). HVAC systems to reduce the operating costs of high-care facilities, cultural heritage, and educational buildings, with reference to both systems for air conditioning and air diffusion equipment. Renewable-based building components and systems, passive and active solar technologies for buildings, and exploitation of the ground source.
- WHOLE BUILDING ENERGY ANALYSES. Evaluation of buildings energy performances through hourly energy simulations, to propose tailored refurbishments. Development and validation of numerical methods, aimed at the integration into hourly energy simulation codes, for the solution of two-and three-dimensional thermal bridges. Integrated optimizations of building energy retrofits, with reference to both energy performances and structural safety, in order to improve the building behaviour by considering the cost-optimality in seismic areas.
- DISTRICTS AND URBAN SCALE. Large-scale energy optimization of the energy retrofit of entire building stocks, by means of either uncertainty and sensitivity analyses or the development of surrogate models, like artificial neural networks [17]. Proposal and testing of mitigation strategies at both building and district scales to improve living conditions in suburbs and massive house for low-income people, paying attention to both energy performance and comfort. Development and Optimization of Smart and Renewable Energy Communities. Digitalization and Artificial intelligence in building energy efficiency, energy sharing, and sustainable management.

Heat transfer in industries. Heat transfer plays a primary role in several sectors, such as electronics, renewables, manufacturing new materials, like metal foams and phase change materials. Heat removal from electronic systems, renewable energy conversion, as well as novel thermal energy storage systems are investigated.

With reference to industrial applications, nowadays new solutions based on innovative materials are required in applications where heat transfer plays a primary role, such as thermal management for heat removing from electronic components or renewable energies requiring more efficient systems. The investigated fields are:

- Metal foams pore-scale analysis, to investigate typical heat transfer parameters, such as effective thermal conductivity, permeability, radiation extinction coefficient, and convection heat transfer coefficient, by using different techniques to generate the metal foam structure [18].
- Macro-scale analysis, using volume-averaged approach, to simulate and optimize engineering devices, like metal foam-based heat sinks and similarly ceramic foam-based volumetric air solar receivers.
- Numerical heat transfer studies on phase change materials, to predict the melting evolution and to improve it by means of metal foams.
- Engineering applications of phase change materials, either to store energy or to be included within heat sinks for electronics, also with metal foams.

Heat transfer in solar-thermal and hybrid collectors. In the context of the global drive towards clean, cost-effective, and sustainable alternatives, solar-based power plants are main actors in renewable thermal energy conversion. This plays a key role in many applications, ranging from the agri-food sector to petrochemical industries. All major components—from collectors to piping—are subjected to heat transfer principles and optimization criteria. Advanced absorbent surfaces and high vacuum insulation are studied, measuring and enhancing the thermal efficiency of high-vacuum solar collectors and power plants.

Several industrial processes, like boiling, steaming, pasteurising, require thermal energy at operating temperatures below 150 °C. At these temperatures, thermal demand can be satisfied by adopting renewable solutions like solar-thermal and hybrid photovoltaic-thermal flat plate collectors. Methods and materials suitable for providing renewable heat efficiently are studied, focusing on high vacuum insulation technology and deposition and characterization of selective solar absorbers. The following fields are investigated:

- Control, measurement, and simulation of radiative and optical characteristics of materials, lowering the emittance of selective solar absorbers to reduce the radiative losses of the collector; development of low emissive materials mounted on the absorber surface; design and development of new selective solar absorber coatings with optimized optical characteristics attaining higher operating temperatures than commercial absorbers (up to 200 °C) [19].
- Building up a Mini Test Box with an experimental set up for the measurement of the emittance and the absorptance of selective solar absorbers. Measurements are made with the calorimetric approach, which allows the sample characterization in a wide range of temperatures; building up an under vacuum oven and designing a procedure for aging tests of new absorber samples; defining a new Performance Criterion based on absorber efficiency and forecasting the service lifetime; setting up a new procedure to reconstruct the specific temperature frequency function of

absorbers, which accounts for the high thermal efficiency and stagnation temperature and predicts the aging of absorbers employed in mid-temperature applications; deriving new efficiency correlations, for both Non-Evacuated and High-Vacuum Flat Plate collectors (different kind of solar absorbers).

- Modeling through Matlab of Novel Hybrid Flat Plane Photovoltaic-Thermal collectors insulated in high vacuum (HV PV-T), optimized for thermal production. The model is based on the Spectral Splitting concept, the thermal coupling of a high-band gap PV cell and a Solar absorber, the adoption of low emissive transparent conductive oxides, and high vacuum insulation.
- Modelling, testing and optimization of several auxiliary technologies for solar thermal power plants; CFD simulation of Sensible Stratified Thermal Energy Storages (SSTES), with the generation and validation of data-based models; experimental and numerical optimization of control logics and functional parameters; data-driven model predictive control applied to thermal energy storage systems and solar thermal power plants; design and thermal test of high-vacuum insulator for heat delivery pipes as well as proposal of a novel high vacuum-based solution; optimization of indirect and direct solar-generated low and middle pressure steam production systems.

Heat transfer in biomedics. Understanding the mechanisms ruling biological processes within the human body is an old-fashioned problem, crucial to propose new potential clinical solutions. Heat transfer—especially when it is relevant in clinical applications—plays a significant role in treating cancer, cardiovascular diseases, and so on. Research is carried out in order to optimize existing medical treatments and to find new ones.

The biomedical industry includes high temperature applications, where heat transfer is of primary importance. They include tumors ablation via radiofrequencies or microwaves, hyperthermia to treat heart arrhythmias, as well as hyperthermia that might affect low-density lipoproteins deposition. The heat transfer team is carrying out the following research activities in the bio heat transfer sector, employing both numerical and analytical approaches:

- Cancer treatment via radiofrequencies or microwave ablation, in order to improve existing predictive models and therapies [20].
- Arrhythmia treatments, like atrial fibrillation, via radiofrequency-induced cardiac ablation, with the aim of improving existing predictive models.
- Low-density lipoprotein deposition in arterial walls, to mark temperature effects on molecules transport and atherosclerotic plaque growth.

3.4 Heating, Ventilation and Air Conditioning (HVAC) and Energy Efficiency of the Building-Plant System

The research team investigates the optimization of the building-plant system, mainly with reference to Heating, Ventilation and Air Conditioning (HVAC) systems.

The main research topics are innovative HVAC systems; energy efficiency of the building-plant system, like Net Zero Energy Buildings (NZEBs); hygrothermal characteristics of the building envelope.

The Earth-to-Air Heat Exchanger and its applications in civil buildings were analysed in [21, 22] by coupling it with an air handling unit, to obtain high energy saving and reduction in CO_2 emissions for the HVAC system. The efficiency of this innovative system has been proven for several worldwide climatic conditions.

A simulation research activity refers to NZEBs, particularly to the integration of a geothermal heat pump and its energy comparison with that of an air-to-water heat pump. The research activity was based on a simulative approach; a multi-objective optimization was also employed [23].

An experimental research activity on the desiccant wheel [24] was performed with the Università del Sannio. This innovative typology of air dehumidification was compared to the traditional mechanical dehumidification, and significant energy saving has been obtained.

The energy performance of a historic building (Palaeontology Museum of the Università degli Studi di Napoli Federico II) was analysed by dynamic energy simulation [25].

Research was carried out on building envelopes, by predicting how a high insulation thickness could increase energy consumption in summer [26], and by evaluating, through experimental laboratory tests, the thermal decay of external thermal insulation of a NZEB [27].

The research team collaborates with the Università di Salerno, Università del Sannio, University of Zagreb (Croatia), Pennsylvania State University (USA), as well as with other departments of the Università Federico II. The researchers in the team have been Guest editors of special issues for the international journal “Energies”.

3.5 Indoor Environmental Quality

Since its birth the research team has dealt with the indoor built environment, occupational hygiene and historical building preservation issues.

Research programs cover three main areas: Indoor environmental quality (IEQ) and indoor built environment, historical buildings, occupational health issues. They were financed mainly by national (PON, PRIN, PNRR) and local (FRA, FARB) programs.

The criticalities in the subjective and objective assessment of thermal comfort conditions [28], consistently with energy-saving requirements, were investigated

[29]. The studies also dealt with the synergies among the four components of the IEQ [30] and the measurement of physical quantities [31–33] (ISO 7726). More recent studies focused on the role of ventilation in public transport environments to predict contagion [34].

Special protocols for the control of microclimatic conditions in historical buildings [35] and the diagnosis of moisture in buildings affected by rising damp [36] were developed. Further studies also dealt with energy issues.

The criticalities of the metrics for the evaluation of heat and cold stress conditions at workplaces were investigated [37]. Results have been included in the revisions of ISO Standards 7243, 7730, 7933 and 11079.

Collaborations were established with the Università degli Studi di Cassino e del Lazio Meridionale, Università degli Studi di Salerno, Technical University of Denmark, Université Catholique de Louvain, Standardization bodies (UNI, CEN,'ISO), technical associations in the field of air conditioning (AiCARR) and scientific societies (AISI).

The team members are leading or joining important research institutions, technical committees and editorial boards of journals.

3.6 Lighting

The research team started research in lighting focusing on the evaluation of indoor daylight availability, the characterization of sky models, and the measurement of indoor and outdoor luminance distribution. A small laboratory was set up, where some main photometric characteristics were measured.

Almost coinciding with the transition to the DII, the world of lighting was revolutionized thanks to various technological and scientific developments: the spread of LEDs, the progress on automatic controls, the discovery of light effects on circadian rhythms. Therefore, the research perspectives expanded as the research activities of the team too. The laboratory was upgraded with several new instruments for spectral measurements, crucial for the evaluation of non-visual effects of light. A test-room was equipped with a false ceiling in which different LED sources are installed. The sources are managed by a controller, setting different scenarios. Moreover, two twin test-rooms have been set up equipped with different LED sources. Both the test-room and the twin rooms are used for the experimental studies evaluating visual and non-visual effects of light on people.

The team carries out numerical and experimental research activities on daylight and its impact on people's well-being and on the reduction in electricity consumption [38, 39], the integration between daylight and electric lighting through automatic controls [40], the "non-visual" effects of light, such as the impact of lighting on performance, mood, attention, and circadian rhythms [41]. The characterization of the quality of the luminous environments and the lighting applied to cultural heritage [42, 43] are also investigated.

The research team collaborates with national and international partners. Moreover, it actively participates in the associations promoting lighting culture both in Italy and around the word. A member of the team is President of the Associazione Italiana di Illuminazione (AIDI) in the period 2023–2025 and Governing Board Member of the Commission Internationale de l'Eclairage (CIE) in the period 2023–2027, another member is vice-coordinator of the CIE National Committee—Division 3: Interior Environment and Lighting Design.

Research activity was mainly funded within the PON SMART CASE 2013–2016, PRIN 2015, PNRR PE PE5 CHANGES PE00000020 and FRA 2020 Linea B programs.

3.7 *Experiments and Modelling of Innovative Systems for Refrigeration*

The research topics of the team are related to experimental activities, modelling and simulation of refrigeration systems and their devices, with a special focus on advanced two-phase heat transfer systems.

The performance of heat pumps and refrigerating plants, using new refrigerants able to reduce their contribution to global warming, has been investigated. As a part of a six-year project funded by the Italian Ministero dello sviluppo economico through ENEA, an experimental and parametric analysis was carried-out on carbon dioxide heat pumps with multi-ejectors expansion devices (Fig. 3). New applications of heat pumps working with natural fluids, within an FP7 European project, their potential use and risks were investigated [44]. Within the SMART-CASE project, the optimal design of heat pumps for residential use, employing several refrigerants with a multi-objective approach including total costs of ownership and environmental impact during life cycle, was investigated [45]. Recently, the integration of heat pumps with energy storage systems and air, sun, ground as heat sources, has been studied in projects with companies and in cooperation with the University of Huelva (ES) [46]. Also, as a part of a project financed by the Italian Ministero dello sviluppo economico

Fig. 3 Prototype of a multi-ejector carbon dioxide heat pump tested in cooperation with ENEA

through ENEA, the effects of multiple faults on the performance degradation of heat pumps have been assessed and the possibility to find such faults based on direct and cheap measurements has been demonstrated [47]. A national project on this topic is also funded by MUR in the frame of PRIN2022 and is coordinated by the group. Several studies related to special applications for the commercial and transport refrigeration have been performed, also with funding from private companies. A special attention is paid to the study of two-phase heat transfer and pressure drop in flow boiling of new refrigerants and spray systems. The main objective is to provide experimental data for the design of innovative heat exchangers and heat sinks to the industry. The research team, one of the leading worldwide concerned on this topic, produced with continuity a large database of accurate experiments for the academy and the industry, also in cooperation with other labs, like LTCM at EPFL(CH) [48, 49].

The research team runs the Refrigeration laboratory at the Università degli Studi Federico II in Napoli and has established several and durable research cooperations with national and international Universities, research centres and private companies, such as CEMAFROID (FR), CNR (IT), ENEA (IT), EPFL (CH), INSA Lyon (FR), University of Byalistok (PL), Università del Molise (IT), Università di Padova (IT), Università del Sannio (IT), Università di Salerno (IT), University of Huelva (ES), University Pol. of Valencia (ES). Also, the group is affiliated and contributes to scientific and technical activities of relevant associations for the sector (like IIR, IEA and AICARR), covering several representative roles in working groups, scientific and technical committes and boards.

3.8 Refrigeration and Heat Transfer on Systems Alternative to Vapor Compression

The research activities are mainly focused on finding new viable alternative systems to vapor compression in refrigeration, air conditioning and heat pumps systems. Vapor compression refrigerants are mostly synthetic (CFC, HCHC, HFC, HFO) or natural (CO_2, NH_3, hydrocarbons). In the past, synthetic refrigerants have been responsible of the ozone layer thinning and have been replaced on the basis of regulations by non-zero Ozone Depletion Potential (ODP). Substitute fluids HydroFluoroCarbons (HFCs), however, are characterized by a significant direct contribution to global warming since they have high Global Warming Potential (GWP). The need, therefore, arises to develop further alternative refrigeration techniques. Among these, there are those based on solid-state refrigerants which aren't harmful to the environment (zero ODP and GWP) and are based on the caloric effect proper of solid materials through a temperature change because of an adiabatic variation of an external field.

Technologies based on the caloric effects are a feature topic. Magnetocaloric was the first caloric effect investigated by the team. The research concerned the realiza-

tion of 8Mag, the first experimental prototype of an Italian rotating magnetocaloric refrigeration, and test campaigns on it as well as the modelling of magnetocaloric devices for numerical investigation [50, 51]. Electrocaloric, elastocaloric, barocaloric were also investigated numerically in order to identify the most promising caloric refrigerants [52, 53]. Elastocaloric technology based on elastocaloric effect, which is a physical phenomenon where a Shape Memory alloy forced through a mechanical stress varies its reticular structure and, consequently, its temperature. Thanks to the project SUSTAINABLE the first Italian heat pump based on solid-state refrigerants showing an elastocaloric effect is being built at the DII Heat Transfer Lab [54]. Within the CHECK TEMPERATURE project, the first elastocaloric device in the world for electronic circuits cooling was designed [55]. Studies on vapor compression about substitutive refrigerants due to high GWP, e.g., the replacement of HFC134a with HFOs, continued [56]. The heat transfer and energy performance of renewable energy source systems, such as Earth-to-Air Heat Exchanger, were evaluated numerically [22].

3.9 Sustainable Energy Systems (SES)

The research team is involved in studies on various cutting edge energy systems. Skill and expertise are modelling, simulation and optimization of systems, especially coupled to renewable energy-based technologies. Energy, economic and environmental performances of systems are assessed through a dynamic analysis by developing in-house simulation models. Renewable energy sources, new energy saving plants and innovative HVAC systems for civil and industrial applications are studied for achieving energy efficiency/flexibility and sustainability in the next generation of buildings, communities, transportation systems (ships, trains, e-cars, etc.) and related infrastructures (ports, stations, etc.) towards the zero-energy goal. Innovative energy saving technologies and materials for systems envelopes are also analysed. Experimental analyses are also employed [57–63].

Scientific activities are carried out in collaboration with international partners through suitable academic Memorandum of Understanding (MoUs): Cyprus University of Technology; Ulster University, UK; Universitat de Lleida, Spain; Concordia University, Canada; University of Colorado Boulder, USA; Imperial College London, UK; Rovira i Virgili Universitat de Tarrragona, Spain; University of Patras, Greece. Joint collaborations are/were also conducted with: Ben Gurion University of the Negev, Israel; Lawrence Berkeley National Laboratory, USA; Fraunhofer Institute for Solar Energy (ISE), Germany; Dublin Institute of Technology, Ireland; University of Cyprus; Eurac (European Academy), Italy; ENEA, Italy.

Research has been also funded by many projects, awarded by members of the team, that received several M€ in grants and public/private funding. The research team is promoter or responsible of the research projects HEMOS—Ship Heat Energy Management System by the Aid of Dynamic Optimization Algorithms, funded by HORIZON Europe; LOVE 4 PIPENET, funded by Italian Territorial Cohesion Agency;

Energy sustainability, air quality and indoor comfort in modern ships for the development of architectures and technologies that enable significant optimization of energy consumption in the naval field, funded by Fincantieri; SuShi—Sustainable Ships, funded by Fincantieri; Strengthening and critical analysis of the Regione Campania School Building Registry (energy aspects), funded by Regione Campania; Comparison of new calculation methodologies with those provided by current regulations, funded by MISE; Smart and sustainable industry, energy and environment: technologies for renewable sources based on innovative solar thermal collectors, funded by the Italian Ministero per l'Istruzione, l'università e la ricerca (MIUR); FC SMART GEN—Fuel Cells and Hybrid Polygeneration Platforms from fossil and renewable sources, PON01 02864 funded by MIUR; NEXT.COM—Towards the NEXT generation of multiphysics and multidomain environmental COMfort models: theory elaboration and validation experiment, PRIN 2017 funded by the Italian Ministero per l'Università e la ricerca (MUR); GREENROAD—GRowing Energy Efficiency through National ROundtables Addresses, funded by Horizon 2020; HERA—Holistic Energy Recovery Agent tool for sustainable urban clusters, PRIN 2022 funded by MUR; DiAGreen—Digital twin of Agricultural Greenhouses: a multi-domain tool for energy efficiency, decarbonization, enhanced production and cost reduction of intensive greenhouse cropping; Nest—Network 4 Energy Sustainable Transition, Spoke 6 (thermal storage) funded by MUR. Adolfo Palombo is national scientific responsible of the project PRIN 2022 funded by the Ministero per l'Università e la ricerca (MUR), ATOL—Advanced Thermal energy storages On Large ships.

Research activities are also carried out either with or funded by industrial companies (CETENA SpA, Fincantieri SpA, Hitachi Rail STS SpA, GESAC SpA, Carrier) and important national research institutions (ENEA, EURAC and the Azienda Universitaria Ospedaliera (AOU) Federico II).

A patent was released by European Patent Office/Register in 2022 (n. 4046834A1) "Electric or hybrid traction vehicle equipped with an air conditioning system, with heat recovery from cooling of electrical and/or electronic components".

In collaboration and co-ownership with Hitachi Rail STS SpA, researchers of the team are members of the International Scientific Committee of the International Center for Sustainable Development of Energy, Water and Environment Systems (SDEWES). They are also permanent members of the editorial board of several Q1 Journals (Elsevier's Renewable energy, Energy conversion and management, and others), also serving as associate and senior editors for the Elsevier Journal Energy reports. Researchers of the team were members of the Management Committee of the Action TU1205 Building Integration of Solar Thermal Systems, BISTS of the European COST (Cooperation in Science and Technology), Transport and Urban Development (TUD) funded by Horizon 2020. Additional present and past memberships: member of the Management Committee of the Blue Italian Growth National Technology Cluster (BIG); member of the Board of Expert of Italian Energy and Environmental Services (IEES); member of the Management Committee of IBPSA-Italy; member of the Board of Experts at the Permanent Observatory on Energy, Water

and District Heating Regulation of ARERA; member of the Board of Verification Activities of Italian Energy Services Manager (GSE).

4 Future

The future research activities of the *Applied Acoustic* team will be focused on the use of auralization techniques to be applied in the insulation of both airborne and structure-born sound, in the construction of binaural room impulse responses and in the assessment of the industrial products sound quality, especially in the automotive field. The use of ultrasound techniques to detect failures in concentrating solar power plants will also be investigated.

In the next future, the *Energy Efficiency and Renewable Energy (EERE)* team will be involved in two major experimental research programs, in the framework of the National Plan for Recovery and Resilience—Next Generation EU program:

- 2021–2024: NEST—Network 4 Energy Sustainable Transition, Spoke 7 (Smart sector integration) and 8 (Final use optimization, sustainability & resilience in energy supply chain), funded by the Italian Ministero dell'università e della ricerca (MUR).
- 2022–2024: GRETHA—a novel GReen Energy Technology based on fuel cells, hydrogen and renewables, funded by the Italian Ministero della Transizione Ecologica.

In the *Heat transfer in civil, industrial and biological systems* field, a strong strengthening of the national and international collaborations to share methods, approaches, and results is expected in the next years. Besides key concepts of nearly, net and zero-energy buildings, the target of the research team is a wider horizon, that looks at the whole community. "Living spaces" should be transformed into "liveable spaces" to contrast the energy poverty and to guarantee the human, universal, and European rights of the well-being and pleasant life, compatible with the right and responsible use of energy, emissions, and environmental impacts. Within the industrial applications, new techniques to improve the capability of managing heat at higher power densities will be proposed and optimized, to be sure that the electronics industry will be able to design better performing devices. On the renewable energy conversion, high vacuum flat plate collectors, equipped with the projected optimized absorbers, will first be designed numerically and then prototypes will be tested by means of real scale experiments. A novel measurement chain will be developed to evaluate the effective thermal energy exploitable with high-vacuum hybrid collectors. Moreover, new thermal energy storage devices will be proposed to improve the overall efficiency of renewable energy-based systems. Finally, new techniques for cancer treatment and other similar diseases will be investigated.

Future research in *Heating, Ventilation and Air Conditioning (HVAC) and energy efficiency of the building-plant system* will concern high-efficiency air conditioning

systems and their influence on Zero Carbon Buildings, through simulation, experiments and multicriteria optimization approaches.

The research on *Indoor environmental quality* will enlarge its horizon consistently with the challenge imposed by the energy transition, climatic change, and cultural heritage preservation. Advanced thermal comfort models, such as adaptive and thermo-physiological for possible applications in naturally ventilated buildings, vehicles, workplaces and not uniform environments (e.g., industrial sites) will be investigated. To balance IEQ levels and energy consumption, specific studies on the mutual interaction among the four facets of the IEQ are in the program. A significant part of the activity will include new integrated monitoring strategies for IEQ parameters, aiming at designing and optimizing the sensors for assessing and controlling indoor environmental conditions, even in historical buildings, where fruition should be compliant with preservation.

Future research in *Lighting* will aim at deepening the non-visual effects of light and the potentiality offered by dynamic lighting control systems. They will be carried out within the scopes of the Subtask B of the IEA Task 70—Low Carbon, High Comfort Integrated Lighting. The activity concerning the effects of light on cultural heritage will continue, also funded by the PNRR.

The research team on *Experiments and modelling of innovative systems for refrigeration* will investigate new high temperature heat pumps for heating and industrial processes and the related technological challenges will be investigated experimentally and numerically. Also, the assessment of the potential advantages for the control, the energy performance improvement and the fault detection entailed by the use of artificial intelligence in the refrigeration sector will be investigated.

In the field of *Refrigeration and heat transfer on systems alternative to vapor compression* numerical and experimental studies will be carried out on the development of new devices based on solid-state cooling. Specifically, a new prototype based on the elastocaloric effect close to commercialization will be designed and constructed. Further investigations will be focused on multicaloric effects, i.e., the simultaneous combination of two caloric effects.

Future research in the *Sustainable Energy Systems (SES)* field will concern energy efficiency and environmental sustainability of innovative systems, including storage systems and renewable-based devices, to be implemented, along with novel energy management strategies, in buildings, communities, transportation systems, and associated infrastructures for flexibility and energy savings aims.

5 Awards

Many awards have been gained in relevant international conferences as well as many papers were rewarded as highly cited paper in Web of Knowledge database.

Fabrizio Ascione, Nicola Bianco, Annamaria Buonomano, Francesco Calise and Massimo Dentice D'Accadia are in the list of the top researchers of Università degli

studi Federico II, ranked into the best scientists according to the standardized citation metrics of University of Stanford.

Fabrizio Ascione was awarded as author of the best paper published in (Solar Energy—Elsevier, 2017).

Diana D'Agostino won a national research award sponsored by the Associazione Nazionale Poliuretano Espanso rigido (ANPE).

Annamaria Buonomano has been an Affiliate Professor at the Department of Building, Civil and Environmental Engineering, Concordia University (Montreal, Canada), since 2017. With this university, several cotutelle Ph.D. programs were also activated.

Best Paper Awards

Best Paper Awards received by researchers of the Sustainable Energy Systems (SES) team at International Conferences are:

- Modelling the thermal response of the human body for thermal comfort assessment in indoor spaces: an experimental validation at METROLIVE 2022.
- Air-based photovoltaic thermal collectors: theoretical and experimental analysis of a novel low-cost prototype at SDEWES 2018.
- Solar Heating and Cooling Systems for Residential Applications: a Comparison among Different System Layouts and Technologies at SDEWES 2016.
- Comparison of the Electrical and Thermal Performance of Double Skin Facade and Insulating Glazing Unit integrating Semi–Transparent Photovoltaics at EU PVSEC 2018.
- Analysis of residential hybrid ventilation performance in U.S. climates at AIVC 2009.

Best Poster Awards

- Buonomano et al., "Solar Heating and Cooling Systems for Residential Applications: a Comparison among Different System Layouts and Technologies", SDEWES 2016.
- Calise et al., "Dynamic Numerical Model for a Geothermal Well", SMARTGREENS 2023.

References

1. Dragonetti R, Romano RA (2015) Considerations on the sound absorption of non locally reacting porous layers. Appl Acoust 87:46–56. ISSN: 0003-682X. https://doi.org/10.1016/j.apacoust.2014.06.011
2. Dragonetti R, Opdam R, Napolitano M, Romano R, Vorländer M (2016) Effects of the wave front on the acoustic reflection coefficient. Acta Acustica U Acustica 102:675–687. https://doi.org/10.3813/AAA.918984
3. Dragonetti R, Napolitano M, Romano RA (2019) A study on the energy and the reflection angle of the sound reflected by a porous material. J Acoust Soc Amer 145:489–500. ISSN: 0001-4966. https://doi.org/10.1121/1.5087565

4. Dragonetti R, Napolitano M, Boccarusso L, Durante M (2020) A study on the sound transmission loss of a new lightweight hemp/bio-epoxy sandwich structure. Appl Acoust 167:107379. ISSN: 0003-682X. https://doi.org/10.1016/j.apacoust.2020.107379
5. Capasso I, Pappalardo L, Romano RA, Iucolano F (2021) Foamed gypsum for multipurpose applications in building. Constr Build Mater 307:124948. ISSN: 0950-0618. https://doi.org/10.1016/j.conbuildmat.2021.124948
6. Dragonetti R., Napolitano M, Di Filippo S, Romano R (2016) Modeling energy conversion in a tortuous stack for thermoacostic applications. Appl Therm Eng 103:233–242. ISSN: 1359-4311. https://doi.org/10.1016/j.applthermaleng.2016.04.076
7. Napolitano M, Romano R, Dragonetti R (2017) Open-cell foams for thermoacoustic applications. Energy 138:147–156. ISSN: 0360-5442. https://doi.org/10.1016/j.energy.2017.07.042
8. Napolitano M, Di Giulio E, Auriemma F, Romano RA, Dragonetti R (2022) Low frequency acoustic method to measure the complex bulk modulus of porous materials. J Acoust Soc Amer 151:1545–1556. ISSN: 0001-4966. https://doi.org/10.1121/10.0009767
9. Di Giulio E, Napolitano M, Di Meglio A, Romano RA, Dragonetti R (2022) Low frequency acoustic method to measure the complex density of porous materials. J Acoust Soc Amer 152:2220–2226. ISSN: 0001-4966. https://doi.org/10.1121/10.0014762
10. Di Giulio E, Auriemma F, Napolitano M, Dragonetti R (2021) Acoustic and thermoacoustic properties of an additive manufactured lattice structurea). J Acoust Soc Amer 149:3878–3888. https://doi.org/10.1121/10.0005085
11. Calise F, Cappiello FL, Dentice d'Accadia M, Vicidomini M (2020) Dynamic simulation, energy and economic comparison between BIPV and BIPVT collectors coupled with micro-wind turbines. Energy 191:116439. ISSN: 0360- 5442. https://doi.org/10.1016/j.energy.2019.116439
12. Calise F, Dentice d'Accadia M, Vicidomini M, Scarpellino M (2015) Design and simulation of a prototype of a small-scale solar CHP system based on evacuated flat-plate solar collectors and Organic Rankine Cycle. Energy Convers Manag 90:347–363. ISSN: 0196-8904. https://doi.org/10.1016/j.enconman.2014.11.014
13. Calise F, Cappiello FL, Cartenì A, Dentice d'Accadia M, Vicidomini M (2019) A novel paradigm for a sustainable mobility based on electric vehicles, photovoltaic panels and electric energy storage systems: case studies for Naples and Salerno (Italy). Renew Sustain Energy Rev 111:97–114. ISSN: 1364-0321. https://doi.org/10.1016/j.rser.2019.05.022
14. Calise F, Cappiello FL, Dentice d'Accadia M, Vicidomini M (2020) Energy and economic analysis of a small hybrid solar-geothermal trigeneration system: a dynamic approach. Energy 208:118295. ISSN: 0360-5442. https://doi.org/10.1016/j.energy.2020.118295
15. Calise F, Cappiello FL, Cimmino L, Dentice d'Accadia M, Vicidomini M (2022) Optimal design of a 5th generation district heating and cooling network based on seawater heat pumps. Energy Convers Manag 267:115912. ISSN: 0196-8904. https://doi.org/10.1016/j.enconman.2022.115912
16. Ascione F, Bianco N, De Masi RF, de' Rossi F, Vanoli GP (2014) Energy refurbishment of existing buildings through the use of phase change materials: energy savings and indoor comfort in the cooling season. Appl Energy 113:990–1007. ISSN: 0306-2619. https://doi.org/10.1016/j.apenergy.2013.08.045
17. Ascione F, Bianco N, De Stasio C, Mauro GM, Vanoli GP (2017) Artificial neural networks to predict energy performance and retrofit scenarios for any member of a building category: a novel approach. Energy 118:999–1017. ISSN: 0360-5442. https://doi.org/10.1016/j.energy.2016.10.126
18. Cunsolo S, Oliviero M, Harris WM, Andreozzi A, Bianco N, Chiu WK, Naso V (2015) Monte Carlo determination of radiative properties of metal foams: comparison between idealized and real cell structures. Int J Therm Sci 87:94–102. ISSN: 1290-0729. https://doi.org/10.1016/j.ijthermalsci.2014.08.006
19. De Maio D, D'Alessandro C, Caldarelli A, Musto M, Russo R (2022) Solar selective coatings for evacuated flat plate collectors: optimisation and efficiency robustness analysis. Solar Energy Mat Solar Cells 242:111749. ISSN: 0927-0248. https://doi.org/10.1016/j.solmat.2022.111749

20. Andreozzi A, Iasiello M, Netti PA (2019) A thermoporoelastic model for fluid transport in tumour tissues. J R Soc Inter 16:20190030. https://doi.org/10.1098/rsif.2019.0030
21. Ascione F, D'Agostino D, Marino C, Minichiello F (2016) Earth-to-air heat exchanger for NZEB in Mediterranean climate. Renew Energy 99:553–563. ISSN: 09601481. https://doi.org/10.1016/j.renene.2016.07.025
22. D'Agostino D, Greco A, Masselli C, Minichiello F (2020) The employment of an earth-to-air heat exchanger as pre-treating unit of an air conditioning system for energy saving: a comparison among different worldwide climatic zones. Energy Build 229. ISSN: 03787788. https://doi.org/10.1016/j.enbuild.2020.110517
23. D'Agostino D, Mele L, Minichiello F, Renno C (2020) The use of ground source heat pump to achieve a net zero energy building. Energies 13. ISSN: 19961073. https://doi.org/10.3390/en13133450
24. Angrisani G, Minichiello F, Sasso M (2016) Improvements of an unconventional desiccant air conditioning system based on experimental investigations. Energy Convers Manag 112:423–434. ISSN: 01968904. https://doi.org/10.1016/j.enconman.2016.01.013
25. D'Agostino D, de'Rossi F, Marino C, Minichiello F, Russo F (2021) Double plus-zero energy historic building and improvement of hygrothermal conditions for the Palaeontology Museum of Naples. J Build Phys 45:148–179. ISSN: 17442591. https://doi.org/10.1177/1744259120923016
26. D'Agostino D, de'Rossi F, Marigliano M, Marino C, Minichiello F (2019) Evaluation of the optimal thermal insulation thickness for an office building in different climates by means of the basic and modified "cost-optimal" methodology. J Build Eng 24. ISSN: 23527102. https://doi.org/10.1016/j.jobe.2019.100743
27. D'Agostino D, Landolfi R, Nicolella M, Minichiello F (2022) Experimental study on the performance Decay of thermal insulation and related influence on heating energy consumption in buildings. Sustainability (Switzerland) 14. ISSN: 20711050. https://doi.org/10.3390/su14052947
28. d'Ambrosio Alfano FR, Ianniello E, Palella BI (2013) PMV–PPD and acceptability in naturally ventilated schools. Build Environ 67:129–137. ISSN: 0360-1323. https://doi.org/10.1016/j.buildenv.2013.05.013
29. d'Ambrosio Alfano FR, Olesen BW, Palella BI, Riccio G (2014) Thermal comfort: design and assessment for energy saving. Energy Build 81:326–336. ISSN: 0378-7788. https://doi.org/10.1016/j.enbuild.2014.06.033
30. Bellia L, d'Ambrosio Alfano FR, Fragliasso F, Palella BI, Riccio G (2021) On the interaction between lighting and thermal comfort: an integrated approach to IEQ. Energy Build 231:110570. ISSN: 0378-7788. https://doi.org/10.1016/j.enbuild.2020.110570
31. d'Ambrosio Alfano FR, Dell'Isola M, Palella BI, Riccio G, Russi A (2013) On the measurement of the mean radiant temperature and its influence on the indoor thermal environment assessment. Build Environ 63:79–88. ISSN: 0360-1323. https://doi.org/10.1016/j.buildenv.2013.01.026
32. d'Ambrosio Alfano FR, Dell'Isola M, Ficco G, Palella BI, Riccio G (2021) On the measurement of the mean radiant temperature by means of globes: an experimental investigation under black enclosure conditions. Build Environ 193:107655. ISSN: 0360-1323. https://doi.org/10.1016/j.buildenv.2021.107655
33. d'Ambrosio Alfano FR, Pepe D, Riccio G, Vio M, Palella BI (2023) On the effects of the mean radiant temperature evaluation in the assessment of thermal comfort by dynamic energy simulation tools. Build Environ 236:110254. ISSN: 0360-1323. https://doi.org/10.1016/j.buildenv.2023.110254
34. Bertone M, Mikszewski A, Stabile L, Riccio G, Cortellessa G, d'Ambrosio F, Papa V, Morawska L, Buonanno G (2022) Assessment of SARS-CoV-2 airborne infection transmission risk in public buses. Geosci Front 13:101398. ISSN: 1674-9871. https://doi.org/10.1016/j.gsf.2022.101398
35. D'agostino V, d'Ambrosio Alfano FR, Palella BI, Riccio G (2015) The museum environment: a protocol for evaluation of microclimatic conditions. Energy Build 95(Special Issue: Historic, historical and existing buildings: designing the retrofit. An overview from energy performances

to indoor air quality):124–129. ISSN: 0378-7788. https://doi.org/10.1016/j.enbuild.2014.11.009
36. d'Ambrosio Alfano FR, Palella BI, Riccio G (2023) Moisture in historical buildings from causes to the application of specific diagnostic methodologies. J Cult Herit 61:150–159. ISSN: 1296-2074. https://doi.org/10.1016/j.culher.2023.04.001
37. D'Ambrosio Alfano FR, Malchaire J, Palella BI, Riccio G (2014) WBGT index revisited after 60 years of use. Ann Occup Hyg 58:955–970. ISSN: 0003-4878. https://doi.org/10.1093/annhyg/meu050
38. Bellia L, Acosta I, Campano MÁ, Fragliasso F (2020) Impact of daylight saving time on lighting energy consumption and on the biological clock for occupants in office buildings. Solar Energy 211:1347–1364. ISSN: 0038092X. https://doi.org/10.1016/j.solener.2020.10.072
39. Bellia L, Blaszczak U, Fragliasso F, Gryko L (2020) Matching CIE illuminants to measured spectral power distributions: a method to evaluate non-visual potential of daylight in two European cities. Solar Energy 208:830–858. ISSN: 0038092X. https://doi.org/10.1016/j.solener.2020.08.021
40. Bellia L, Fragliasso F (2017) New parameters to evaluate the capability of a daylight-linked control system in complementing daylight. Build Environ 123:223–242. ISSN: 0360-1323. https://doi.org/10.1016/j.buildenv.2017.07.001
41. Bellia L, Blaszczak U, Diglio F, Fragliasso F (2023) Assessment of melanopsinbased quantities: comparison of selected design tools and validation against on-field measurements. Build Environ 232:110037. ISSN: 0360-1323. https://doi.org/10.1016/j.buildenv.2023.110037
42. Monteoliva JM, Bellia L, Fragliasso F, Pattini A (2020) Ancient Romans and daylighting: the case of Villa of the mysteries in Pompeii. J Cult Herit 43:204–218. ISSN: 1296-2074. https://doi.org/10.1016/j.culher.2019.12.008
43. Bellia L, Fragliasso F, Stefanizzi E (2020) Effects of light source spectrum and background colour on the perception of paintings. Lighting Res & Technol 52:36–63. ISSN: 1477-1535. https://doi.org/10.1177/1477153519847254
44. Tammaro M, Montagud C, Corberán J, Mauro WA, Mastrullo R (2017) Seasonal performance assessment of sanitary hot water production systems using propane and CO2 heat pumps. Int J Refrig 74:224–239. ISSN: 0140-7007. https://doi.org/10.1016/j.ijrefrig.2016.09.026
45. Botticella F, de Rossi F, Mauro WA, Vanoli G, Viscito L (2018) Multi-criteria (thermodynamic, economic and environmental) analysis of possible design options for residential heating split systems working with low GWP refrigerants. Int J Refrig 87:131–153. ISSN: 0140-7007. https://doi.org/10.1016/j.ijrefrig.2017.10.030
46. Pelella F, Zsembinski G, Viscito L, Mauro WA, Cabeza LF (2023) Thermo-economic optimization of a multi-source (air/sun/ground) residential heat pump with a water/PCM thermal storage. Appl Energy 331:120398. ISSN: 0306-2619. https://doi.org/10.1016/j.apenergy.2022.120398
47. Pelella F, Viscito L, Mauro WA (2022) Soft faults in residential heat pumps: possibility of evaluation via on-field measurements and related degradation of performance. Energy Convers Manag 260:115646. ISSN: 0196- 8904. https://doi.org/10.1016/j.enconman.2022.115646
48. Grauso S, Mastrullo R, Mauro WA, Thome J, Vanoli G (2013) Flowpattern map, heat transfer and pressure drops during evaporation of R-1234ze(E) and R134a in a horizontal, circular smooth tube: experiments and assessment of predictive methods. Int J Refrig 36:478–491(SI: New Developments in Boiling and Condensation). ISSN: 0140-7007. https://doi.org/10.1016/j.ijrefrig.2012.07.016
49. Mastrullo R, Mauro WA, Thome J, Vanoli G, Viscito L (2016) Critical heat flux: performance of R1234yf, R1234ze and R134a in an aluminum multiminichannel heat sink at high saturation temperatures. Int J Therm Sci 106:1–17 . ISSN: 1290-0729. https://doi.org/10.1016/j.ijthermalsci.2016.03.011
50. Aprea C, Cardillo G, Greco A, Maiorino A, Masselli C (2015) A comparison between experimental and 2D numerical results of a packed-bed active magnetic regenerator. Appl Therm Eng 90:376–383. ISSN: 1359- 4311. https://doi.org/10.1016/j.applthermaleng.2015.07.020

51. Aprea C, Greco A, Maiorino A, Masselli C (2016) The energy performances of a rotary permanent magnet magnetic refrigerator. Int J Refrig 61:1–11. ISSN: 0140-7007. https://doi.org/10.1016/j.ijrefrig.2015.09.005
52. Aprea C, Greco A, Maiorino A, Masselli C (2018) Solid-state refrigeration: a comparison of the energy performances of caloric materials operating in an active caloric regenerator. Energy 165:439–455. ISSN: 0360-5442. https://doi.org/10.1016/j.energy.2018.09.114
53. Aprea C, Greco A, Maiorino A, Masselli C (2020) The use of barocaloric effect for energy saving in a domestic refrigerator with ethylene-glycol based nanofluids: a numerical analysis and a comparison with a vapor compression cooler. Energy 190:116404. ISSN: 0360-5442. https://doi.org/10.1016/j.energy.2019.116404
54. Cirillo L, Greco A, Masselli C (2023) A numerical comparison among different solutions for the design of a rotary elastocaloric prototype. Appl Therm Eng 228:120487. ISSN: 1359-4311. https://doi.org/10.1016/j.applthermaleng.2023.120487
55. Cirillo L, Greco A, Masselli C (2023) Development of an electronic circuit cooling system using elastocaloric effect: a FEM comparison among different configurations. Appl Therm Eng 219:119463. ISSN: 1359-4311. https://www.sciencedirect.com/science/article/pii/S135943112201393X
56. Aprea C, Greco A, Maiorino A, Masselli C (2018) The drop-in of HFC134a with HFO1234ze in a household refrigerator. Int J Therm Sci 127:117–125. ISSN: 1290-0729. https://www.sciencedirect.com/science/article/pii/S1290072917302260
57. Buonomano A, Forzano C, Palombo A, Russo G (2023) Solar-assisted district heating networks: development and experimental validation of a novel simulation tool for the energy optimization. Energy Convers Manag 288:117133. ISSN: 0196-8904. https://doi.org/10.1016/j.enconman.2023.117133
58. Barone G, Buonomano A, Del Papa G, Maka R, Palombo A (2023) How to achieve energy efficiency and sustainability of large ships: a new tool to optimize the operation of on-board diesel generators. Energy 128288. ISSN: 0360-5442. https://doi.org/10.1016/j.energy.2023.128288
59. Barone G, Buonomano A, Forzano C, Giuzio GF, Palombo A, Russo G (2022) Energy virtual networks based on electric vehicles for sustainable buildings: system modelling for comparative energy and economic analyses. Energy 242:122931. ISSN: 0360-5442. https://doi.org/10.1016/j.energy.2021.122931
60. Maturo A, Petrucci A, Forzano C, Giuzio GF, Buonomano A, Athienitis A (2021) Design and environmental sustainability assessment of energyindependent communities: the case study of a livestock farm in the North of Italy. Energy Rep 7:8091–8107. ISSN: 2352-4847. https://www.sciencedirect.com/science/article/pii/S2352484721003723
61. Barone G, Buonomano A, Forzano C, Palombo A (2020) Enhancing trains envelope – heating, ventilation, and air conditioning systems: a new dynamic simulation approach for energy, economic, environmental impact and thermal comfort analyses. Energy 204:117833. ISSN: 0360-5442. https://www.sciencedirect.com/science/article/pii/S0360544220309403
62. Agathokleous R, Barone G, Buonomano A, Forzano C, Kalogirou S, Palombo A (2019) Building façade integrated solar thermal collectors for air heating: experimentation, modelling and applications. Appl Energy 239:658–679. ISSN: 0306-2619. https://www.sciencedirect.com/science/article/pii/S0306261919300200
63. Buonomano A, De Luca G, Montanaro U, Palombo A (2016) Innovative technologies for NZEBs: an energy and economic analysis tool and a case study of a non-residential building for the Mediterranean climate. Energy Build 121:318–343. ISSN: 0378-7788. https://doi.org/10.1016/j.enbuild.2015.08.037

From Mechanical to Complex System Modeling and Design

Massimo Martorelli

Abstract This chapter summarizes the main research activities and outcomes of the groups engaged in Mechanical Engineering, in the decade 2013–2023. The research topics are typical of the sectors Mechanical and Thermal Measurements, Applied Mechanics, Mechanical Design and Machine construction, Design Methods for Industrial Engineering.

1 Introduction

Mechanical engineering combines creativity, knowledge and simulation tools to improve the health of the society transforming an idea into reality. This transformation happens from simple products useful for everyday life till to complex systems. Mechanical engineers may design a component, a machine, a system, or an innovative mechanical assembly. This ranges from the macro to the micro, from the largest systems like nuclear fusion reactor, autonomous cars and mechanism as robots to the smallest smart components as wearable sensors. To this end, at DII, competences on applied mechanics, design methods, machine construction and measurement are available.

The applied mechanics for machines sector encompasses the cultural, scientific and professional aspects related to the study of mechanical systems, machines and their components, and structures. The study is developed through a unifying systems-based approach, utilizing methodologies from theoretical, applied, and experimental mechanics, leading to technological and industrial applications with a focus on environmental and energy sustainability. Strong interconnections are established with design methodologies and algorithms developed in the field, as well as industrial engineering methods, dimensional design and machine construction, fluid dynamics, bioengineering, motor sciences, orthopaedic and prosthetic surgery, rehabili-

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tation and assistance methodologies, and finally, the interpretation and analysis of historically significant machines.

The design methods, mechanical design and machine construction sector deals with scientific and educational activities in the fields of concept design, engineering design, representation and modeling, and innovative methods for industrial engineering. The researchers are involved in the design and construction of machines, structures in automotive, aeronautical, railway and naval fields and mechatronic systems. They study the methods and tools for the conception and development of sustainable products, taking care of the entire life cycle. What characterizes these sectors is the interest in process, product, and method innovation, as well as the attention to the related development trends. The methodologies involve the use of advanced theoretical, numerical, and experimental engineering tools, as well as the application of techniques and methods for reducing development times. The relevant industrial sectors include mechanical engineering and transportation systems, biomedical, and energy. The design methods team (IDEAS) is internationally recognized in design and development of products, covering the topics of conceptual and engineering design, modeling and simulation, computer graphics, virtual and augmented reality, design for additive manufacturing and reverse engineering. The research activities are conducted in the following areas: industry 4.0 green technologies, collaborative robotics, bioinspired and soft robotics, exoskeletons, sustainable production processes, assistive devices for disabled people, tools for the safety of workers, human factors and ergonomics methodology, design of systems and robotic solutions for nuclear fusion reactors, naval, automotive, railway and aeronautical industries, healthcare (medical devices for rehabilitation and inclusion, dentistry), design of sports equipments and wearable technology.

The studies in mechanical and thermal measurements field aim to develop research and expertise in the methods of analysis, design, and testing of systems for measuring mechanical and thermal quantities, both for scientific purposes and industrial applications, including those related to human well-being. In general, these studies address issues concerning the integrated design of tools for monitoring, diagnostics, and control of any system affected by mechanical and thermal quantities.

2 Background and Legacy

2.1 Mechanics Applied to Machines

The study and teaching of Mechanics Applied to Machines in Naples has a history of about 200 years. Among the numerous figures who gave prestige and development to the discipline, Prof. Pericle Ferretti (1888–1960), who organized and directed the Institute of Mechanics Applied to Machines, had particular prominence. In 1925 he got the professorship in Mechanics Applied to Machines at the Royal School of Engineering in Naples. The school was aggregated only later, in 1935, to the

Royal University of Naples. Prof. Ferretti himself promoted the birth, in 1940, of the "Istituto Nazionale dei Motori" of the CNR, immediately assuming its direction, which he maintained until 1960, the year of his death.

After 1960, the directions of the Institute of Mechanics Applied to Machines and of the Istituto Nazionale dei Motori were committed to Prof. Mario Taddei (1920–1981). When the Faculty of Engineering was moved to the new headquarters at Piazzale Tecchio in Fuorigrotta, both Institutes, leaving the historic headquarters in Via Mezzocannone, became in practice contiguous, both physically and scientifically. In those years, many theoretical and experimental contributions to the research development of Mechanics Applied to Machines were provided by researchers and professors who often worked in both Institutes. In this period some other disciplines arose in the same scientific ambit, giving birth to new teachings, among which we can mention those of: Theory and Technique of Vibrations, Servomechanisms and Automation, Measurements and Testing Standards. Meanwhile, the teaching of Mechanics Applied to Machines had been held by Prof. Taddei. Subsequently, the teaching was entrusted to Prof. Angelo Raffaele Guido, former full professor of Theory and Technique of Vibrations at the same Institute.

In the following years the "Federico II" University faced a reorganization, regarding the research activity, through a departmental structure model, and the Institute of Mechanics Applied to Machines then merged into the nascent Department of Mechanical Engineering for Energetics (DIME). The growing training needs of that period favoured the development of new research areas, such as: Vehicle Dynamics, Contact Mechanics, Tribology and Lubrication with reference to Hydrodynamic Bearings, Rotor Dynamics, Robot Mechanics. These research activities had natural repercussions in the field of teaching with the establishment of specific university courses. In recent years, the new university reorganization of "Federico II" has led to the establishment of larger departments. Therefore, in 2013 from the unification of smaller departmental structures, all operating in the industry sector including DIME, the Department of Industrial Engineering (DII) arose which today includes all the teachers and researchers in the sector of Applied Mechanics to the Machines.

The current frontiers of the research in industrial field have led to broadening the horizons of Mechanics Applied to Machines, traditionally consolidated in the Neapolitan school, towards topics of strong impact and interesting prospects. New themes of research are therefore being developed within the DII, among which the Dynamics and Control of Mechanical Systems with particular reference to autonomous vehicles; the Industrial Diagnostics of Mechanical Systems; Energy Recovery from Vibration Sources; Insulation systems based on innovative materials (Smart Materials).

The research results obtained in the Mechanics Applied to Machines of the DII have achieved numerous national and international awards. The university training and the students' proficiency in the various disciplines of Mechanics Applied to Machines are the result of a passionate teaching activity which, even following radical changes in university regulations, has been able to keep its mission intact over the years.

2.2 *Mechanical Design, Machine Construction and Design Methods for Industrial Engineering*

At the end of the 18th century, Admiral Acton became the first representative of the Neapolitan Military School to publish a work on the representation and design of cannons using descriptive geometry. In 1811, Murat established the Polytechnic School in Naples based on the model of the French École Polytechnique, as proposed by Gaspard Monge, a scientist of the French Revolution and author of the first scientific book on descriptive geometry. After World War II, when the Faculty of Engineering of the University of Naples was in Mezzocannone Street, the Institute of Machine Construction was directed and reorganized by prof. Raffaele Tarantini, who died prematurely before the Faculty of Engineering moved to its new location in Piazzale Tecchio (starting from 60's). Since its foundation, experimental facilities for mechanical characterization of components in automotive and railway fields have been developed and applied in cooperation with big industries as FIAT - Elasis and Ansaldo, Firema and RFI.

Since the 1980s, the study of computer graphics, CAD and FEM began to develop in various application domains (especially automotive and aeronautics) and with different purposes (CAD-CAM integration, geometric modelling of sculptured shapes, industrial automation, structural analysis). In the 1980s, there were participations in the Finalized Mechanical Technologies Project with Olivetti OCN (Marcianise, CE) on 3D CAD modeling of complex shapes, particularly levers and bicycle gear changers for Campagnolo SpA, and their production using 5-axis CNC machines (milling) based on the geometric model (first CAD-CNC connection with automatic generation of tool path for 5-axis milling). Subsequently, with the two Finalized Robotics projects, the research moved towards the design and development of Flexible Manufacturing Systems (FMS) with Jobs in Piacenza and the National Research Council (CNR). Furthermore, in the 1980s, the first research activities on the characterization of materials for biomedical use were initiated in collaboration with Professor Nicolais's materials research group.

In 1990, with the university reform, the disciplinary scientific sector of the *Design Methods for Industrial Engineering* scientific-disciplinary grouping was established within the Industrial sector. The first full professor and founder of the research group was Professor Francesco Caputo, who initiated research in the indicated areas and organized the ADM conferences in Sorrento (1984) and in the Royal Palace of Caserta (1996).

Over time, research activities have seen the expansion of areas of interest and the potential applications for the concurrent development and dissemination of computer systems for graphic representation and other technologies based on the use of three-dimensional modeling, such as *Computer-Aided Tolerancing* (CAT), *Computer-Aided Engineering* (CAE), *Computer-Aided Manufacturing* (CAM), *Reverse Engineering* (RE), and *Rapid Prototyping* (RP), later known as *Additive Manufacturing* (AM).

Significant contributions to research have been made possible thanks to the laboratories that have been established. Through the PON DIGIPAT project with Elasis (Fiat Research Center in the Mezzogiorno, now Stellantis) and Ansaldo (Naples, now Hitachi Rail) on digital modeling of complex systems (cars and trains), research laboratories on geometric modeling (COGITO) and AM were created. Through the PRIN projects, *ideainVR* and the Reverse Engineering laboratory (CREAMI) were founded. In 2005, the largest Virtual Reality laboratory in Italy VRTest was established thanks to the Center of Excellence of the Campania Region. In 2012, the Fraunhofer Joint Lab IDEAS was founded through an agreement between Fraunhofer IWU (Chemnitz-Dresden) and DII - Federico II. The laboratories collaborate on main research programmes on model based systems engineering (MBSE), digital twin of complex systems, Virtual Prototyping, digital geometrical modelling and simulation, generative design for additive manufacturing and reverse engineering, conceptual design and RFLP modelling of nuclear fusion systems, extended reality for industrial engineering, human centered design of sports equipments, safety tools and rehabilitation devices for inclusion and soft robots.

3 Main Research Programmes

3.1 Integrated Navigation Solutions Based on Cost-Effective Inertial Measurement Units

Research activities for integrated navigation solutions based on cost-effective inertial measurement units are mainly carried out by he group of Mechanical and Thermal Measurements. Aim of the research is the design, implementation and testing of integrated navigation system involving cost-effective inertial sensors by means of a suitable redundant hardware architecture complemented with a proper digital signal processing algorithms for data fusion and enhancement [1]. It has been so possible of overcoming known limitations, thus making low-end MEMS inertial sensors eligible for the implementation of tactical-grade navigation systems for unmanned vehicles both aerial and terrestrial (Fig. 1).

In particular, consumer-grade MEMS sensors have been arranged according to a cubic configuration in order to reduce typical bias errors affecting their outputs. A loosely-coupled integrated navigation has been then exploited to finally improve the estimates of position, velocity and attitude of vehicles, that were very close to those granted by a high-end MEMS inertial sensor, whose costs are about two orders of magnitude greater. Stemming from that experience, research activities have been conducted in cooperation with STMicroelectronics S.p.A. (further improvements obtained by means of the introduction of deep learning algorithms [2]) and Hitachi S.p.A. (implementation and characterization of tightly-coupled integrated navigation systems for pose estimation of trains).

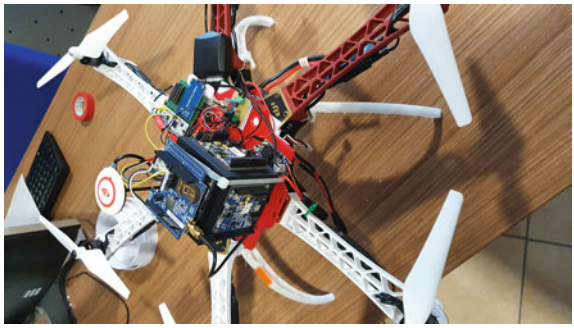

Fig. 1 Low-cost inertial measurement unit for unmanned aerial vehicles

3.2 AR-Based Applications for Remote Control of Measurement Instrumentation for Didactical Applications

Research activities for the implementation of a remote laboratory that can be accessed by means of augmented reality (AR) applications have been carried out by the group of Mechanical and Thermal Measurements in cooperation with researchers of the Department of Electrical Engineering and Information Technologies of the University of Naples Federico II. The availability of laboratory access has become a relevant issue due to recent increment of the number of students attending measurements classes as well as due to restrictions that the country underwent during the recent COVID-19 pandemics (Fig. 2).

While the theory lessons could be continued through remote teaching with few limitations, the laboratory activities (based on students' interaction with the measurement instruments) required devising a solution that would allow them to relive the laboratory experience as if they were right in front of the instruments. This way, an innovative solution, involving a proper hardware device for connecting the instruments to the Internet of Things environment along with a suitable AR app running on students' mobile phones, has been designed and implemented [3, 4]. The reliability

Fig. 2 Example of AR app for oscilloscope remote control

of the provided solution has successively suggested its commercialization through a university spinoff, ARCADIA S.r.l., as well as the initiation of cooperative activities with the company Leonardo S.p.A. in the field of virtual and augmented reality training, which is still active today.

3.3 Control, Health Monitoring and Predictive Diagnostics of Mechanical Systems

The research activities related to control, health monitoring and predictive diagnostics of mechanical systems are developed at the Laboratory of Diagnostics of mechanical systems (DiaMeSys). The aim is to study and develop innovative techniques for the diagnostics, the damage detection and the health monitoring of mechanical systems. The investigation procedures are based on advanced analysis techniques such as Wavelet Transform, Chaos Theory and Discriminant Analysis. The development of the investigation procedures involved experimental tests on existing applications and the build of suitable test benches. The main topics addressed, in the last ten years of research, have been: study and identification of different tribological regimes in a gear pair through signal and image processing techniques; vibrational analysis of a turbine powered by green fuels [5]; determination of the tensional state of metal specimens by means of infrared thermography and Wavelet transform on images; vibrational analysis to detect cavitation phenomena in a directional spool valve (Fig. 3); damage detection in a gear box trough vibrational analysis.

Most of these research topics have also been the subject of thesis projects for the master's degree in mechanical engineering and they have been reported as case study examples during the courses of Tribology and Diagnostics of Mechanical Systems and Applied Mechanics Complements. The research activities have been conducted in collaboration with the companies: M3S spa, Augusta due srl, Advanced Management Solutions Sarl (AMS), Ai4ethic srl, Leonardo, Ducati and FCA. Coupled with the development of diagnostic strategies based on the previously mentioned techniques, the control of mechanical and mechatronics systems, such as electrohydraulic actuators and road vehicles, is made with particular attention to the modelling

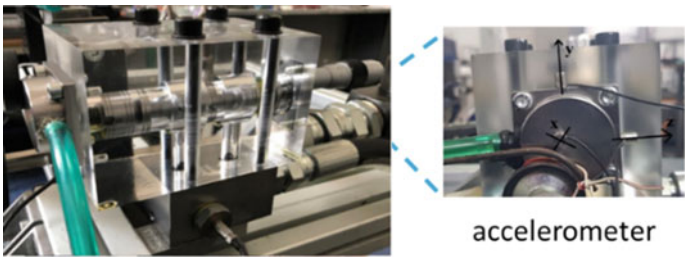

Fig. 3 Experimental test rig to detect cavitation phenomena in a directional spool valve

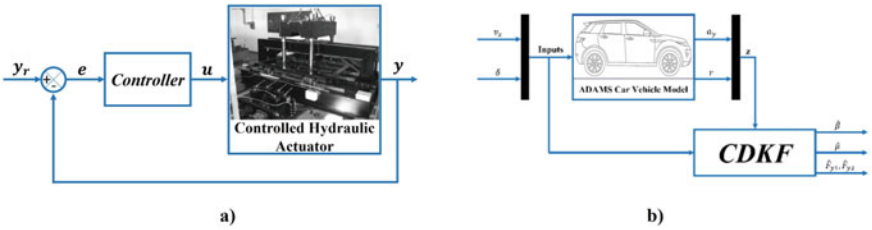

Fig. 4 **a** Controlled hydraulic actuator moving a shake-table; **b** Estimation flow for vehicle and tire-road monitoring through a nonlinear Kalman Filter

approaches adopted to design linear and nonlinear controllers (Fig. 4). Furthermore, another topic is the model-based monitoring of mechanical systems, such as sliding isolators and road vehicles [6], through stochastic state observers such as Kalman Filters, functional to implement predictive maintenance strategies. The basic instruments for approaching the previously mentioned topics related to the control and the model-based monitoring of mechanical systems are provided in the courses Control of mechanical systems and Control-oriented Models for vehicle dynamics, disbursed for the master's degrees in mechanical engineering for Design and Manufacturing and Autonomous Vehicle Engineering.

3.4 Dynamic Behaviour of Rotors and Lubricated Pairs

This topic has been investigated since the last '70s by several researchers of the Mechanics of Machines and Tribology groups, active in the past academic Federico II Univ. organizations operating before the present DII. A significant part of this research work, carried out both theoretically and with recourse to laboratory rig, started in the '90s and was addressed to the nonlinear behaviour of rotors, the operation with journal bearings and squeeze film dampers and the characteristics of the pressure distribution within the squeeze film (Fig. 5a). The effect of the bearing shape on the bifurcating behaviour of the rotor dynamics represents a main topic dealt with in the more recent papers (Fig. 5b) [7, 8].

3.5 Dynamics of Railway Vehicles

The research activity related to railway vehicle dynamics focuses on the model-based monitoring of railway vehicles aiming to improve the reliability and safety of these latter, focusing on the possibility of employing condition-based maintenance instead of the typical predictive or calendarized ones. Monitoring systems, based on model-based stochastic state observers such as Kalman Filters, are developed to

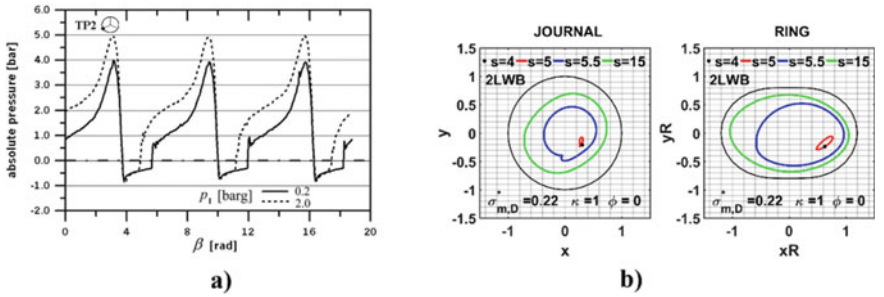

Fig. 5 **a** Characteristics of the pressure distribution within the squeeze film; **b** The effect of the bearing shape on the bifurcating behaviour of the rotor dynamics

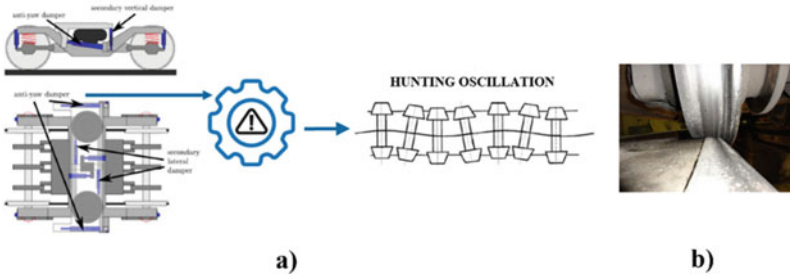

Fig. 6 **a** Model-based monitoring of railway anti-yaw dampers; **b** Model-based monitoring of the wear status related to wheelsets

detect, at each time instant, anomalies in components of railway vehicles for condition-based maintenance purposes, taking into account the sources of uncertainties related to modelling approaches and noises produced by sensors. Estimator design models, based on the railway vehicle dynamics, are implemented in nonlinear forms of Kalman Filters for monitoring purposes of components related to the railway secondary suspension system, such as anti-yaw dampers [9] fundamental for reducing instability phenomena induced by the hunting motion (Fig. 6a) and of the wheelsets by estimating a crucial parameter, called equivalent conicity [10], which increases with the degradation of wheels profiles causing safety issues in the vehicle running due to the generation of high forces at the wheel-rail contact interface (Fig. 6b).

As a part of the research activities related to the Department of Industrial Engineering, some contents, such as the development of state observers oriented to real-time applications for monitoring purposes of railway vehicles, are treated in the Smart Systems Laboratory for introducing the presented topic to students, expanding their knowledge on smart systems applicable onboard railway vehicles. Furthermore, concepts on the estimation of vital parameters related to railway vehicles coupled with their dynamical behaviour functional to develop estimator design models are introduced in courses of Master's degree in Mechanical Engineering for Design and

Manufacturing as Railway Vehicle Dynamics and Control of Mechanical Systems. Established collaborations are underway regarding innovations in rail transport with companies such as Hitachi Rail, RFI, Italcertifer, Blue Engineering, Contact, IVM, EAV, ANM.

3.6 The "Gear Rattle" in Automotive Transmissions

As regards the topic of transmission gears for motor vehicles, a tribo-dynamic model has been developed and perfected which considers the effect of oil on lightly loaded or unloaded gears. The model made it possible to investigate the influence of the oil lubricant in the attenuation of the tooth impacts responsible for a vibro-acoustic phenomenon, typical of the automotive manual gearboxes, known as "gear rattle" [11]. The problem is caused by the torque fluctuations in the internal combustion reciprocating engine which cause repeated impacts in all the gears of the gearbox which mesh without transmitting power [12]. The research activity was started as part of a collaboration with the Elasis research center of Fiat automobiles. Some non-linear models have been developed, both for a single gear pair and for the entire drive-line of the vehicle. The study of the vibro-acoustic phenomenon has been extended also in automated transmission systems equipped with dual clutches (Dual Clutch Transmissions).

To validate the theoretical models, a prototype test rig was designed and built at the D.I.I. Mechanics Laboratory (Fig. 7), through which, using original measurement methodologies, many experimental investigations about the lubrication conditions were conducted, documented by high-impact scientific publications. Some sophisticated techniques moreover have been employed for the analysis and recognition of anomalies during the functioning of unloaded gears, suitable to identify qualitative indices for comparative analysis with respect to the Gear Rattle phenomenon.

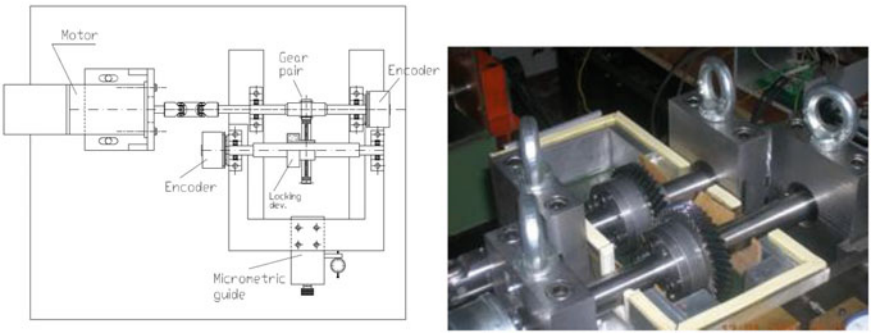

Fig. 7 The experimental test rig for gear rattle investigation

The findings of this research on teaching activity can be found in the Mechanics of Vibrations of Mechanical Systems and in the Mechanical of Transmissions which are addressed in all the Courses of the Mechanics Applied to Machines.

3.7 Robotics

The research activities related to Robotics are developed at the Laboratory of Mechanics of Automated Systems (MecASys). The aim is to address issues concerning the research and development in the field of automation of mechanical systems. The activities range from the design of components and actuation systems, till to control strategies and sensor integration. The study also includes an in-depth modelling of kinematics and dynamics of these systems.

The integration of robotic components with vision systems, such as RGB-depth cameras, is one of the main topics developed in the last years. To this hand, suitable test benches have been built to carry out experimental activities in this field, alongside the development of proper algorithms to handle with vision systems data. As an example, Fig. 1.8 reports a protype developed at the MecASys of a vision guided robotic system for flexible gluing process in the footwear industry. The main topics addressed, in the last ten years of research, have been: development of a mechanical hand with opposable thumb for prosthetic applications: design, modelling, prototyping, sensor integration, control strategies and experimental characterization; integration of vision systems for industrial automation in textile and footwear industry (Fig. 8a) [13]; vision systems to measure and control mechanical systems [14]; rovers for field operations for agricultural and environmental purposes: multibody model, kinematics modelling, navigation, control strategies, sensor integration and prototyping (Fig. 8b).

Most of these research topics have also been the subject of thesis projects for the master's degree in Mechanical Engineering, Biomedical Engineering and Automa-

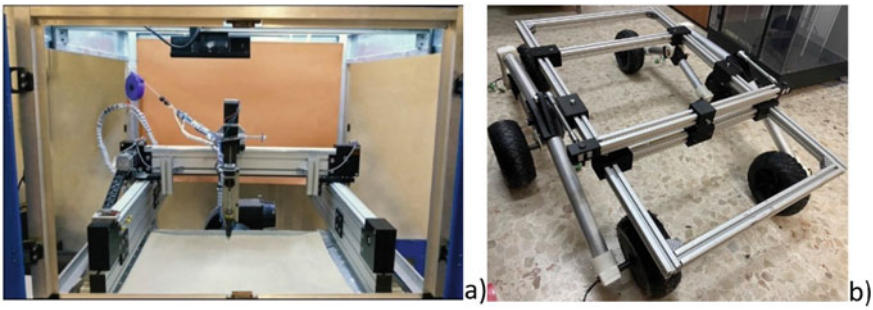

Fig. 8 Vision guided robotic system for flexible gluing in the footwear industry (**a**); prototype of a rover for field operations (**b**)

tion Engineering. The case studies have been also presented during the courses of Robotics Mechanics. The research activities are conducted in cooperation with several companies in the surrounding area, including Battista Accessori srl, Greentech Solution srl and SbS Group.

3.8 Use of Magnetorheological Elastomers as SMART Material in Insulators and Energy Harvesting

Magneto-rheological elastomers (MRE) are composite materials with magnetically polarized particles dispersed in an elastomer matrix. These materials belong to the smart material family because they can change a phisical property in controllable way. Such materials can be exploited in two distinct modalities: MRE direct effect and MRE inverse effect.

The MRE direct effect consists in varying the stiffness as function of the magnetic field in which they are immersed. Specifically, the shear modulus G is the variable more influenced by the magnetic field. The MRE direct effect is defined as the ratio between the modulus increase and initial storage modulus G. This value measures the effectiveness of MRE. The MREs characteristics make such materials suitable for the development of controllable devices for various application including adaptive tuned vibration absorbers and suspensions and semi-active system. With reference to the direct effect, investigations were first carried out in the laboratories of the department to characterize these materials and then hybrid seismic isolators were designed and built. The validation of the models and the evaluation of the effectiveness of the different vibration control algorithms implemented were carried out by means of some specially made test rig. Indeed, we have equipped ourselves with the necessary tools for the construction of magnetorheological rubber specimens with different characteristics and a test bench has been created to carry out tests on varying the magnetic circuit, the type of forcing motion, the configuration of the insulation system (Fig. 9) [15].

The MRE inverse effect consists of converting mechanical energy into electrical one by means of the magneto-mechanical coupling (Villari effect). Since last year an experimental study on this subject has been started. The main results have been published in [16]. The findings of this research on teaching activity can be found in the Mechanics of Vibrations of Mechanical Systems and in the course of Applied Mechanics for Energy Efficiency.

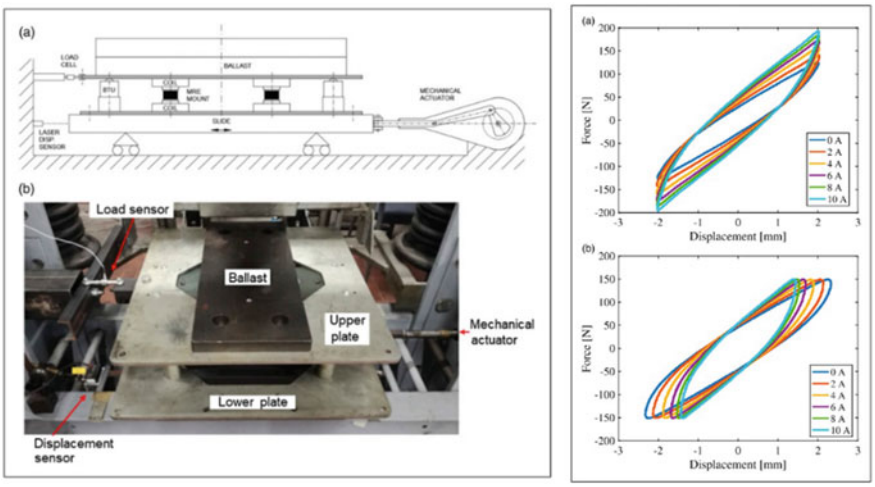

Fig. 9 MRE smart isolator test rig and force-displacement diagrams

3.9 Vehicle Dynamics and Tyre Behaviour

Within the realm of road vehicles, both cars and motorcycles, the study of vehicle dynamics plays a crucial role in enhancing performance, safety, and efficiency. The activities of the Vehicle Dynamics research group, within the Applied Mechanics one, focus on testing, analyzing and modelling the interaction of road vehicles with the external environment, working with a particular emphasis on motorsport vehicles and tire/road interaction. Moreover, their dedication to advancing multiphysical models [17] and tread viscoelasticity testing and evaluation has led to groundbreaking research and two successful spin-off companies, originating from their tech transfer projects.

The research group places tire/road interaction at the core of their activities. By conducting extensive testing and analysis, they seek to unravel the complexities and nuances of this critical dynamic. Utilizing state-of-the-art equipment and cutting-edge methodologies, they evaluate tire performance under various conditions and explore the influence of different road surfaces, temperatures, and speeds. These comprehensive tests generate valuable data that form the foundation for their subsequent analysis and modeling efforts.

One of the distinguishing features of the research group is their commitment to developing advanced multiphysical models. By incorporating principles from various scientific disciplines, such as physics, materials science, and computer modeling, they construct comprehensive frameworks that capture the intricate interplay between different factors affecting tire/road interaction in vehicle dynamics. These models aid in predicting and optimizing vehicle behavior, leading to advancements in performance, handling, and safety.

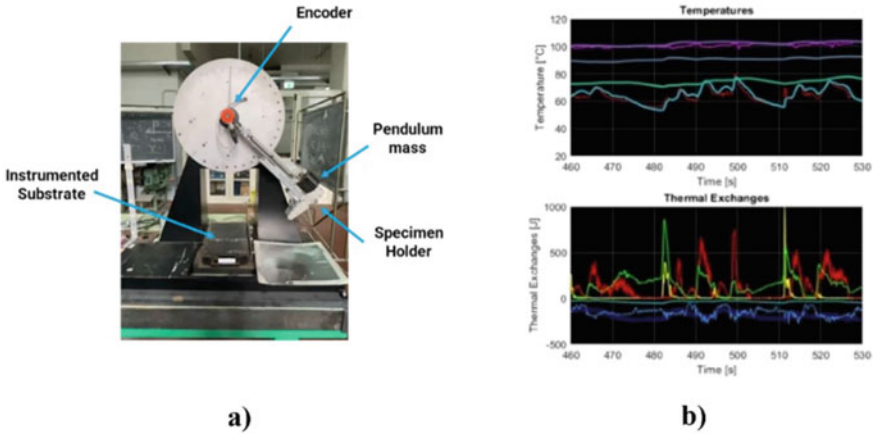

Fig. 10 **a** Tire-road friction tester; **b** Real-time model's outputs

Within the tire research domain, the group focuses on tire tread viscoelasticity testing and evaluation [18]. They explore the viscoelastic properties of tire treads, which are crucial for understanding their deformation characteristics and response to different road conditions. By employing innovative specialized equipment and testing protocols, the research group advances the understanding of tread viscoelasticity, enabling tire manufacturers and vehicle designers to enhance tire performance and tailor it to specific applications.

The research group actively engages in technology transfer projects, leveraging their expertise and discoveries to foster innovation in the industry. Their groundbreaking research and practical insights have paved the way for the establishment of two successful spin-off companies, MegaRide, mainly focused on real-time tire models, and VESevo, patenting and developing an innovative device for viscoelastic materials characterization. These startups, born out of the research group's collaborations with the automotive market, are at the forefront of translating cutting-edge research into practical applications. By bridging the gap between academia and industry, these spin-offs contribute to the growth of the automotive sector and reinforce the research group's impact on real-world challenges (Fig. 10).

3.10 Railways Thermal Buckling Assessment

From the advent of high-speed (HS) trains, continuous welded rail (CWR) tracks have become a necessary requirement to ensure vehicle dynamic stability. At the same time, however, thermal track buckling has become the major problem for infrastructure managers. In fact, when the rails temperature increases over a critical value, the track can buckle, suddenly or progressively, in the lateral plane. The lateral resistance of the sleeper-ballast system is one of the most important factors affecting

this mechanism. For this reason a research activity on the current experimental techniques, as well as on the analytical and numerical thermal track buckling models, has been conducted at first for RFI (the Italian infrastructure Manager) and, recently, for the world reference body on the railway field, the UIC (International Union of Railways).

In this framework, some advanced procedure for tests planning and raw-data analysis aimed at evaluating the effects of track geometric parameters on its total strength were defined [19]. Further, a series of lateral resistance tests on real tracks were conducted in field conditions, with the aim of: - predicting the lateral resistance curve for arbitrary ballast shoulder width, ballast thickness, subgrade composition, sleeper types, ballast compaction degree.

Also, analytical studies for developing models for designing the continuous welded rail against the thermal buckling, post-buckling and sensitivity analysis were carried out by the fem method to identify the mechanical and geometric track parameters more critic for the buckling failure were conducted. These inquires, of which some are still ongoing, motivated the interest toward the methods for analysing the elastic properties of the periodic beam-like structures and their buckling failures. The prediction of the critical temperatures for different values of the track radius, lateral misalignment amplitude, ballast compaction degree, sleepers, and ballast bed geometry are actually adopted by RFI for the management of the risk associated with the thermal track buckling phenomenon in the Italian railway. Both the performances of the numerical model and the findings obtained experimentally have been appreciated by the StableTrack group of UIC, which included the results in the worldwide adopted guideline (IRS 70720) on the risk associated with thermal buckling.

3.11 Railways Fatigue and Fracture Assessment

In railway superstructure, cracks due to fatigue at rail holes of insulated rail joints (IRJs) are a crucial issue, leading to early rails substitution, speed reductions and serious impacts on inspections and maintenance costs. Consequently, to ensure an economically sustainable increase in the safety, methods capable of extending both the fatigue life and the time between non-destructive inspections of structural components are of great industrial and academic interest. This is a long-term research topic where the Machine Design Research Group (MDRG) and the RFI (the Italian railway infrastructure manager) cooperate, taking advantage of the LMMS (Materials and Structures Mechanics Lab) facilities, and of the numerical and experimental knowledge that MDRG developed over many decades. As examples, the crack propagation phenomenological laws into the rails were identified, and crack growth stochastic models were developed for analysing the components' structural reliability under fatigue damage [20]. Further, extensive experimental-numerical research focused on the application of cold expansion on drilled rails (which induces a residual stress beneficial to the fatigue strength) has been conducted. The main tool for the numerical modelling of the stress field and all the failure scenarios is the Finite Elements

Method, whereas the main experimental tools are: fatigue machines with several load axes, optical and electrical strain sensors, temperature sensors and in-house designed load devices.

3.12 Adhesive Bonding in Structural Junctions

In recent years, adhesive bonding as joining technique has become frequent for structural purposes in many engineering fields, also as a consequence of the increasing use of composite materials. In mechanical engineering applications, bonded composites are typically used for the realization of industrial, automotive, naval and aerospace high-tech structural elements. In the last decade MDRG has been involved in many research activities on the identification and modelling of strength characteristics of the adhesive joints. This topic involves theoretical modelling, numerical calculations, experimental testing and the application of several international standards. The more fruitful framework has been recognized being the cohesive zone model and the fracture mechanics. Among several results, the one synthetized into the graphical abstract (Fig. 11) is, in our opinion, worth noticed. It represents a in-house designed device and experimental methodology for applying a pure tearing fracture mode on a bonded joint. In principle, it allows identifying a perfectly detailed cohesive law.

3.13 Model Based Systems Engineering (MBSE)—Digital Twin of Complex Systems

During the last decade, the Laboratory of Interactive Design and Simulation (IDEAS) researchers have deepened the development of complex systems and related digital twins by using and providing methods based on MBSE approach. In particular, the Computer Geometric Modelling and Simulation (COGITO) Laboratory researchers

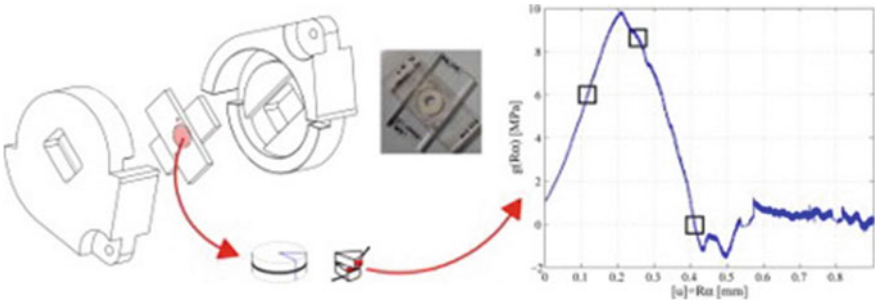

Fig. 11 New mode III debonding device

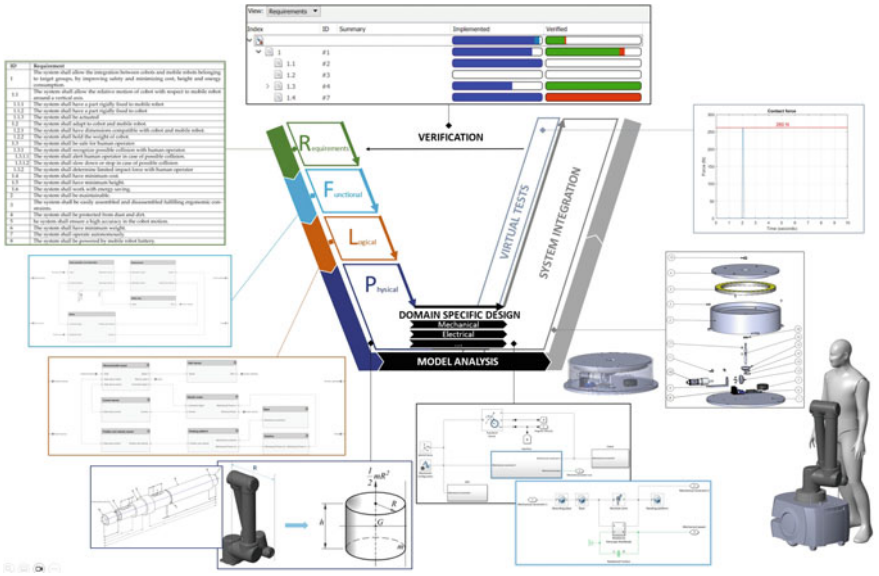

Fig. 12 Visual summary of MBSE approach to the designing of AMR-COBOT interfaces

faced developing complex systems within the manufacturing and electric vehicles fields. By using V-model and RFLP method, the researchers investigated: the designing of collaborative workplace for aircraft assembly; the integration of autonomous mobile robots (AMR) and cobots [21] (Fig. 12); the designing of propulsion and power-train systems. The researchers obtained results on: (i) the structured Natural Language for writing well-formed functional requirements; (ii) the development of functional and logical architectures; (iii) the development of behavioural models for system verification and validation; (iv) the development of digital twin and its integration with system models.

The research activities have been performed in the framework of national and international projects and co-operations, as: 2018–22 PON project ICOSAF—Integrated Collaborative Systems for Smart Factory; SUNISWELL cooperation among ISAE-SUPMECA—Institut Supérieur de Mécanique de Paris, COGITO-IDEAS—DII—University of Naples Federico II, University of Applied Sciences Upper Austria—Campus Wels; cooperation between COGITO-IDEAS—DII—University of Naples Federico II and National Research Council of Italy—Institute of Sciences and Technologies for Sustainable Energy and Mobility.

The accomplished results have progressively fed the course of Modelling and Simulation of Mechatronic Systems and Concept Design of New Vehicles belonging to master's degree programmes managed by DII.

3.14 Virtual Prototyping—Computer Geometric Modelling and Simulation

Both the research topics of Virtual Prototyping and Computer Geometric Modelling and Simulation have been deeply investigated during the last decade at the DII. In particular, advances on Virtual Prototyping Methodologies were provided for the variational analysis of both rigid and deformable mechanical assemblies, in cooperation with the University of Molise. Variational parameters, a constraint solver, and a software tool to quickly analyse variabilities in flexible assemblies in different design scenarios were progressively provided.

Virtual Prototyping and Computer Geometric Modelling were also investigated by addressing digital patterns for product development. In particular, an intensive knowledge-based approach for the designing of mechanical and mechatronic systems was provided. The approach adopts Graph Theory to address and represent the designer knowledge and highlights common Key Characteristics to develop smart virtual prototypes of gearboxes and power window systems with different architectures. The research was developed in the framework of the 2011–14 PON project DIGIPAT—Digital Pattern Product Development in collaboration with FGA Group, ANSALDO Group and SMEs in Italy [22].

Finally, Virtual Prototyping was deepened for the workplace designing, by promoting human–robot collaboration and multi-objective layout optimization. The research goal was achieved in the framework of the 2018–22 PON project ICOSAF—Integrated Collaborative Systems for Smart Factory [23]. Virtual Prototyping and Computer Geometric Modelling were deepened within the research activities of the in-progress H2020 ENERMAN Project—Energy-Efficient Manufacturing System Management, focusing the adoption of AR-VR techniques for sustainability awareness and life-long learning of manufacturing line operators.

The methodological results of the above-mentioned researches have been progressively included in the courses of Geometrical Modelling and Virtual Prototyping, belonging to master's degree programmes managed by DII (Fig. 13).

3.15 Design for Additive Manufacturing and Reverse Engineering

Over the last decade, at DII the attention has also been widely focused on research topics such as *Design for Additive Manufacturing* (DfAM) and *Reverse Engineering*. Specifically, many efforts have been put on the development of customised devices with tailored morphological/architectural features, mechanical and functional properties for industrial (e.g., automotive, aerospace, naval) and biomedical (e.g., prostheses, dental materials and implants, scaffolds for tissue engineering, regenerative medicine) applications. The research led to the design of advanced, lightweight and multifunctional devices, in the form of 3D solid, cellular, lattice, functionally-graded

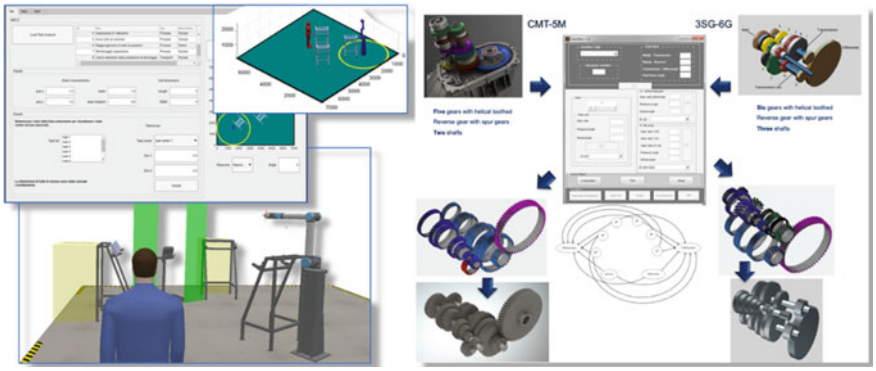

Fig. 13 Left: Virtual prototyping of a collaborative workplace for welding point inspection. Right: KBE-approach to the geometric modelling of automotive gearboxes

or solid-lattice hybrid structures, with a special focus on the improvement of the quality and the environmental impact together with time and cost reduction, enhancing the product development efficiency. The activities were performed with the aim to expand far beyond the state-of-the-art and to develop novel approaches towards the design and manufacturing for next generation components of devices, also considering the search for more sustainable, reprocessable and recyclable polymers and composite materials, as well as the reuse of metal powders. The development of high-performance devices benefited from topology and/or topography optimization as well as from generative design, with a special emphasis on features at the macro- and micro-scale. The activities were related the exploration of design criteria and methodologies in the optimization of additive manufactured devices, as well as to the definition of the relationship among the process parameters, structures and mechanical/functional features [24]. The biomimetic/bioinspired and generative design for AM allowed the extraction of novel wisdoms from biological prototypes and their integration into several technological domains with the aim to create innovative products in the industrial field. The DII unit generated multiple design alternatives based on bioinspired generative design. The obtained methodological results consisted of several design solutions satisfying the input data and design objectives in different ways, contemplating many combinations of materials and structures.

The methodological approaches developed over the last decade were employed in the frame of industrial projects as 2019–2022 PON project ISAF—Integrated Smart Assembly Factory with Leonardo S.p.A. [25]; 2014–2016 PON STEP FAR—Development of eco-compatible materials and technologies of drilling and trimming processes and of robotized assembly with Leonardo S.p.A and scientific collaborations, e.g. with Stellantis Research Center, where members of the DII unit played key roles leading to novel devices, innovative/integrated technological solutions, which were also covered by an international patent [26] (Fig. 14). In addition, two members of the DII unit working in the field were nominated among the World's Top 2% Scientists in 2022.

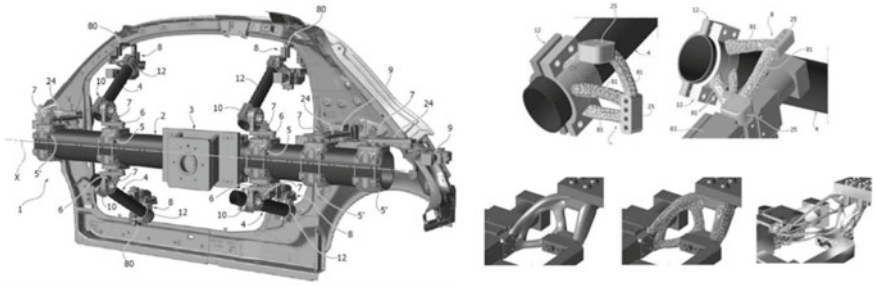

Fig. 14 Innovative gripping tool made in AM using lattice structures, topological optimization and generative design algorithms

3.16 Nuclear Fusion

Nuclear fusion is the energy source that powers our Sun and stars. Should we succeed in replicating this reaction on Earth, we would get a virtually unlimited and "clean" energy source. The most advanced nations in the world are working together to face physics and engineering challenges of future fusion reactors. In this context, the research group at DII is playing a significant role. Indeed, under the coordination of ENEA and CREATE (www.create.unina.it) and with the support of EUROfusion [euro-fusion.org] and F4E [www.fusionforenergy.europa.eu], DII is engaged in several projects, namely ITER, DEMO, IFMIF and DTT. The International Tokamak Experimental Reactor (ITER) [www.iter.org] is the most advanced plasma science and energy project in the world today. DII researchers worked at the piping design and the CAD integration of European test blanket modules at ITER site, which is under construction in southern France. The DEMOnstration power plant, DEMO, will be ITER's successor. Differently from ITER, the main goal of DEMO is the production of electricity from nuclear fusion reaction. Laying the foundation for DEMO is the objective of the EUROfusion Fusion Technology Programme in Horizon 2020 and Horizon Europe. DII is involved in several EUROfusion work-packages about DEMO project (Fig. 15).

The main contributions were related to the conceptual design of the Vacuum Vessel, the Breeding Blanket, the divertor system, the whole balance of plant and the remote maintenance system. Lastly, DII researchers leaded the mechanical design and remote handling system of the Italian Divertor Tokamak Test Facility, DTT, [www.dtt-project.it] which will be one of the most important experimental machines on the Roadmap to the Realisation of Fusion Energy [27, 28]. Furthermore, in the framework of Italian PNRR Research Infrastructure named DTT-Upgrade, DII is developing, with ENEA, the greatest Remote Handling Facility in Europe for tokamak machines.

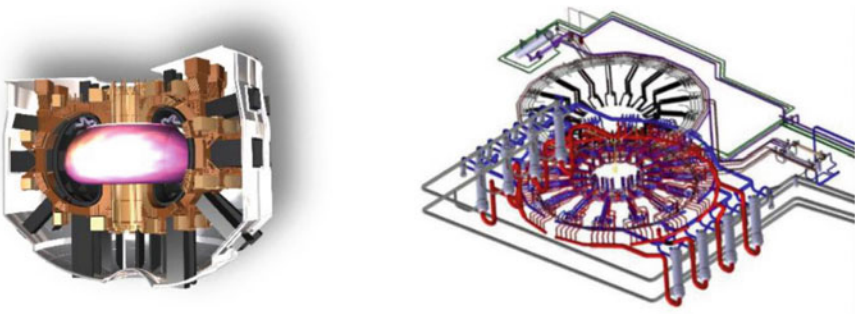

Fig. 15 Left: Virtual prototyping of DTT fusion reactor. Right: Tokamak cooling system for DEMO fusion reactor

3.17 Extended Reality for Industrial Engineering

Since 1999 researchers of IDEAS lab are developing Extended Reality (XR) methods and technologies in the field of interactive design and manufacturing, ergonomics [29], maintenance, human-robot interaction, product and process' digital twin [30], remote control of robotic machines, virtual training. They developed a framework for conducting collaborative Design Review sessions of complex products and systems based on both full "immersive" Virtual Reality (VR) and Mixed Reality (MR) techniques. MARTE lab, realized by DII researchers in 2005 and continuously updated, is equipped with the most advanced technologies that allow interdisciplinary product development teams to interact with the virtual product prototypes long before the realization of their physical counterparts. MARTE lab gives the opportunity to follow the whole product development cycle, from the first conceptual models to the detailed design phase, passing by the testing and the validation of the user experience. It is proved that the so-called virtual product development prevents design errors, increases product quality, and reduces time and costs. The research activities have been conducted in the framework of national and international projects, such as: PON 2020–2023 BRILLO "Bartending Robot for Interactive Long Lasting Operations"; EU Project H2020 REFILLS "Robotics Enabling Fully-Integrated Logistics Lines for Supermarkets"; PON 2018–2022 ICOSAF "Integrated collaborative systems for smart factory"; PON 2014–2016 CERVIA "Advanced and innovative methods for verification and certification in aeronautic design"; POR Campania FSE 2007–2013 CAMPUS VERO: "Virtual Engineering for Railway and automotive"; PRIN 2006 PUODARSI: "Product User-Oriented Development based on Augmented Reality and interactive Simulation".

3.18 *Human Centered Design of Sports Equipment and Safety Tools*

Sports Engineering is a highly interdisciplinary field that connects mechanical engineering to sport science, information technology, human factors and medicine. Focus is given on design of sports equipment for elite and amatorial athletes, to monitor and enhance their performances and reduce the risk of injury. Using a user centered approach, ErgoS-IDEAS Lab has developed products to monitor sport performance and/or infringements in several sports as race walking [31], rowing and cycling [20]. Further, IDEAS has developed the concept design of playground equipment to increase the engagement in sports and motor activity for young and disabled people.

In safety engineering, IDEAS lab, in cooperation with INAIL D.R. Campania, as developed serious games with haptic interfaces to improve the learning process, providing more flexibility, and engaging workers with an intelligent learning experience. These simulation tools can be useful to evaluate functional abilities for healthy workers or residual ones in case of workers with disabilities (Return to Work project). Finally, a safety tool based on Augmented Reality to help the workers to learn about safety procedures and the use of protective devices, when and where they need on the workplace (https://www.dvrplus.it/), has been developed for IoS and Android mobile devices (Fig. 16).

Fig. 16 Sports equipment and safety tools developed at IDEAS lab

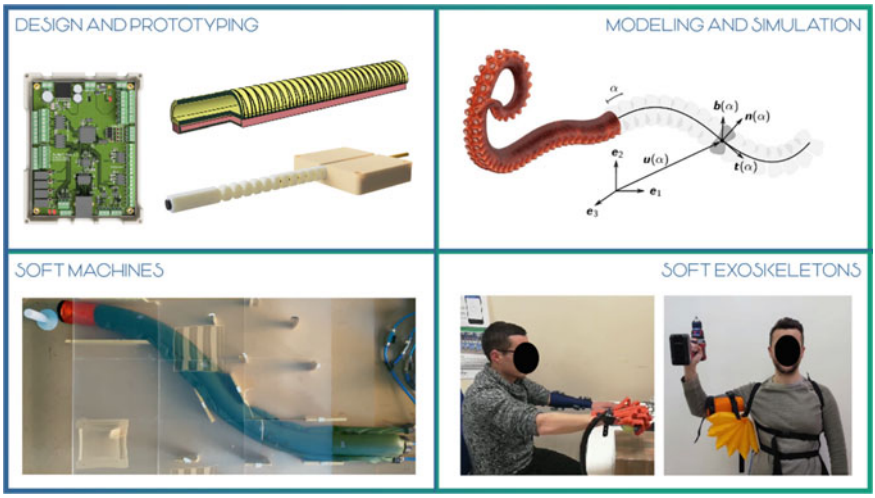

Fig. 17 Research activities carried out in the IDEAS lab about soft robotics

3.19 Soft Robotics

Soft robotics recently emerged as a new robotics discipline where in the mechanical behaviour of the robot body plays a crucial role in enabling applications which are difficult to be conducted using traditional robotics. While soft robots are relatively fast to be fabricated, they are very difficult to be modelled, as their robot body undergone finite (and therefore large) deformations when subject to internal actuation loads and/or external forces. The research group at IDEAS Lab has developed a new approach for accurate, yet computationally efficient modelling and simulation of soft robots [21]. By leveraging on the intrinsic safety in the interaction with the external world, soft robots can be used for the manipulation of delicate objects [32], for the inspection in constrained environments, for maintenance in difficult-to-reach sites, for human-robot collaboration and also for wearable robots. The research results of the group in soft robotics are part of the BIOIC project https://www.bioic.unina.it/ between University of Naples Federico II and Fraunhofer IWU (Fig. 17).

4 Future

Starting from the experience gained in these years, the research activity is moving from low TRL to higher ones to increase the impact on the society. To this end, the commitment of the new generation of researchers is stronger than in the past. The Mechanical Engineering group of researchers have founded seven spin off: Proetico, MegaRide, BeyondShape, ETA Bioengineering, Herobots, Robosan,

VESevo, Sharps, Arcadia. The first two are now autonomous start up independent by the University. These spin off were awarded at national and international level: MegaRide was winner of the StartCup 2016 startup competition and of the Barsanti and Matteucci Award 2022 edition. VESevo was winner of the Automotive Testing Technology International 2021 Award in the "Hardware Innovation of the year" section. BeyondShape was winner of the StartCup 2019 startup competition and of the Myllennium Award 2020. Robosan was Winner of the StartCup 2021 startup competition and of the 2023 edition of Unicredit Start Lab for South of Italy.

The research topics are now founded by many international and national projects, the most important ones are in the framework of NEXT Gen EU program, PNRR fund, in Smart and Sustainable Mobility (CN-MOST) and Circular and Sustainable Made in Italy (PE-MICS).

The classical Mechanical Engineering is evolved also at the Master level, having contributed to start an international course in Autonomous Vehicle Engineering (MOVE) with the challenge to design and management of vehicles for surface, air and marine transport by including functionalities for greater autonomy. These functionalities range from simple forms of enhanced control of a single vehicle to the complete execution of a mission, eventually in coordination with others, without any intervention by human pilot. To this end a strong integration between sensors, information technologies, robotics, vehicle design and modeling is also needed. The main research programmes show how the mechanical engineering is moving towards these new challenges and the background to educate new generations of modern mechanical engineers ready for the Italy of the future. Our Dept, in the South of Italy, has to assure even more a strong contribution to the industrial transition in order to maintain the leading position of Italy in world manufacturing.

References

1. De Alteriis G, Accardo D, Conte C, Lo Moriello R (2021) Performance enhancement of consumer-grade mems sensors through geometrical redundancy. Sensors 21. https://www.scopus.com/inward/record.uri?eid=2-s2.0-85110230561&doi=10.3390d88946b569ffec5a479198bb5e3058
2. De Alteriis G, Ruggiero D, Del Prete F, Conte C, Caputo E, Bottino V, Carone Fabiani F, Accardo D, Schiano Lo Moriello R (2023) The use of artificial intelligence approaches for performance improvement of low-cost integrated navigation systems. Sensors 23. ISSN: 1424-8220. https://www.mdpi.com/1424-8220/23/13/6127
3. Liccardo A, Arpaia P, Bonavolonta F, Caputo E, De Pandi F, Gallicchio V, Gloria A, Moriello R (2021) An augmented reality approach to remote controlling measurement instruments for educational purposes during pandemic restrictions. IEEE Trans Instrum Meas 70. https://www.scopus.com/inward/record.uri?eid=2-s2.0-85112629677&doi=10.11096173a6fa546cc8e2cf9d44e12688e
4. Schiano Lo Moriello R, Liccardo A, Bonavolonta F, Caputo E, Gloria A, De Alteriis G (2022) On the suitability ofaugmentedreality for safe experiments on radioactive materials in physics educational applications. IEEE Access 10:54185–54196. https://www.scopus.com/inward/record.uri?eid=2-s2.0-85130503805&doi=10.1109nerID=40&md5=3ea44a2aa25b4bd8e6ff8af3c8c9ed66

5. Niola V, Savino S, Quaremba G, Cosenza C, Nicolella A, Spirto M (2022) Discriminant analysis of the vibrational behavior of a gas micro-turbine as a function of fuel. Machines 10. ISSN: 2075-1702. https://www.mdpi.com/2075-1702/10/10/925
6. Strano S, Terzo M, Tordela C (2022) A nonlinear estimation approach for vehicle and tire-road monitoring with no interaction modelling in advances in italian mechanism science. In: Niola V, Gasparetto A, Quaglia G, Carbone G (eds) Springer International Publishing, Cham, pp. 389–396. ISBN: 978-3-031-10776-4
7. Adiletta G (2017) An insight into the dynamics of a rigid rotor on two-lobe wave squeeze film damper. Tribol Int 116:69–83. ISSN: 0301-679X. https://doi.org/10.1016/j.triboint.2017.06.029
8. Adiletta G (2020) Stability effects of non-circular geometry in floating ring bearings. Lubricants 8. ISSN: 2075-4442. https://www.mdpi.com/2075-4442/8/11/99
9. Kaiser I, Strano S, Terzo M, Tordela C (2021) Anti-yaw damping monitoring of railway secondary suspension through a nonlinear constrained approach integrated with a randomly variable wheel-rail interaction. Mech Syst Signal Process 146:107040. ISSN: 0888-3270. https://www.sciencedirect.com/science/article/pii/S088832702030426X
10. Kaiser I, Strano S, Terzo M, Tordela C (2023) Estimation of the railway equivalent conicity under different contact adhesion levels and with no wheelset sensorization. Veh Syst Dyn 61:19–37. https://doi.org/10.1080/00423114.2022.2038383
11. Brancati R, Rocca E, Savino S (2015) A gear rattle metric based on the wavelet multi-resolution analysis: experimental investigation. Mech Syst Signal Process 50–51:161–173. ISSN: 0888-3270. https://www.sciencedirect.com/science/article/pii/S0888327014001836
12. Brancati R, Pagano S, Rocca E (2023) Dynamic behaviour of an automotive dual clutch transmission during gear shift maneuvers. Appl Sci 13. ISSN: 2076-3417. https://www.mdpi.com/2076-3417/13/8/4828
13. Cosenza C, Nicolella A, Esposito D, Niola V, Savino S (2021) Mechanical system control by RGB-D device. Machines 9. ISSN: 2075-1702. https://www.mdpi.com/2075-1702/9/1/3
14. Cosenza C, Niola V, Pagano S, Savino S (2023) Theoretical study on a modified rocker-bogie suspension for robotic rovers. Robotica 1–26
15. Brancati R, Massa GD, Pagano S, Petrillo A, Santini S (2020) A combined neural network and model predictive control approach for ball transfer unit–magnetorheological elastomer–based vibration isolation of lightweight structures. J Vib Control 26:1668–1682. https://doi.org/10.1177/1077546320902316
16. Brancati R, Di Massa G, Genovese A (2021) Electromagnetic-mechanical coupling in the magneto-rheological elastomerselastomers: an experimental overview. Int J Mech Control 22. Cited by: 1:27–33. https://www.scopus.com/inward/record.uri?eid=2-s2.0-85121707194&partnerID=40&md5=2e94ac09b1698e9933366bcd4896ae56
17. Farroni F, Russo M, Sakhnevych A, Timpone F (2019) TRT EVO: advances in real-time thermodynamic tire modeling for vehicle dynamics simulations. Proc Inst Mech Eng, Part D: J Automob Eng 233:121–135. https://doi.org/10.1177/0954407018808992
18. Genovese A, Carputo F, Maiorano A, Timpone F, Farroni F, Sakhnevych A (2020) Study on the generalized formulations with the aim to reproduce the viscoelastic dynamic behavior of polymers. Appl Sci 10. ISSN: 2076-3417. https://www.mdpi.com/2076-3417/10/7/2321
19. Caporaso T, Grazioso S, Di Gironimo G, Lanzotti A (2020) Biomechanical indices represented on radar chart for assessment of performance and infringements in elite race-walkers. Sport Eng 23:1–8
20. Caporaso T, Bellitti P, Grazioso S, Serpelloni M, Sardini E, Lanzotti A (2022) Concept generation and preliminary prototyping of a tailored smart glove with capacitive pressure sensors for force grip analysis in cycling. Comput-Aided Des Appl 20:87–98
21. Vitolo F, Rega A, Di Marino C, Pasquariello A, Zanella A, Patalano S (2022) Mobile Robots and cobots integration: a preliminary design of a mechatronic interface by using MBSE approach. Appl Sci 12. ISSN: 2076-3417. https://www.mdpi.com/2076-3417/12/1/419
22. Patalano S, Lanzotti A, Giudice D, Vitolo F, Gerbino S (2015) On the usability assessment of the graphical user interface related to a digital pattern software tool. Int J Interact Des Manuf (IJIDeM) 11:1–13

23. Rega A, Di Marino C, Pasquariello A, Vitolo F, Patalano S, Zanella A, Lanzotti A (2021) Collaborative Workplace design: a knowledge-based Ap proach to promote human–robot collaboration and multi-objective layout optimization. Appl Sci 11. ISSN: 2076-3417. https://www.mdpi.com/2076-3417/11/24/12147
24. Lanzotti A, Grasso M, Staiano G, Martorelli M (2015) The impact of process parameters on mechanical properties of parts fabricated in PLA with an opensource 3-D printer. Rapid Prototyp J 21:604–617
25. Esposito C, Cosenza C, Gerbino S, Martorelli M, Franciosa P (2022) Virtual shimming simulation for smart assembly of aircraft skin panels based on a physics-driven digital twin. Int J Interact Des Manuf (IJIDeM) 16:1–11
26. Gripping Tool. (2022). International patent: EP4015163A1, US2022193923A1
27. Di Gironimo G, Marzullo D, Mozzillo R, Tarallo A, Villone F (2017) The DTT device: first wall, vessel and cryostat structures. Fusion Eng Des 122:333–340. ISSN: 0920-3796. https://www.sciencedirect.com/science/article/pii/S0920379617305355
28. Gironimo GD, Grazioso S (2021) The DTT device: Preliminary remote maintenance strategy. Fusion Eng Des 172:112762. ISSN: 0920-3796. https://www.sciencedirect.com/science/article/pii/S092037962100538X
29. Lanzotti A, Vanacore A, Tarallo A, Nathan-Roberts D, Coccorese D, Minopoli V, Carbone F, d'Angelo R, Grasso C, Gironimo GD, Papa S (2020) Interactive tools for safety 4.0: virtual ergonomics and serious games in real working contexts. Ergonomics 63. PMID: 31648616:324–333. https://doi.org/10.1080/00140139.2019.1683603
30. Tarallo A, Mozzillo R, Di Gironimo G, Amicis R (2018) A cyber-physical system for production monitoring of manual manufacturing processes. Int J Interact Des Manuf (IJIDeM) 12. https://doi.org/10.1007/s12008-018-0493-5
31. Caporaso T, Grazioso S, Di Gironimo G, Lanzotti A (2020) Biomechanical indices represented on radar chart for assessment of performance and infringements in elite race-walkers. Sport Eng 23:1–8
32. Capasso C, Hammadi M, Patalano S, Renaud R, Veneri O (2017) A multidomain modelling and verification procedure within MBSE approach to design propulsion systems for road electric vehicles. Mech Ind 18. https://hal.science/hal-01589898

Business and Management Engineering

Emilio Esposito

Abstract This chapter summarizes the research activities and main results of the management engineering group in the decade 2013–2023. It is herein highlighted that management engineering is not management applied to Engineering, but rather the application of engineering theories, methods, and tools to management.

1 Introduction

Starting from the first half of the last century, the need for economic-managerial training of engineers has been addressed along two lines of development. The first one, according to a widespread approach variously adopted in the American and European contexts, was based on the 'addition' of economic-managerial training to engineering, with study courses aimed at graduates in engineering, often (and preferably) after a period of work experience, as in the case of Masters in Business Administration or Executive Masters in Business Administration. The second line was oriented to the "specialization", i.e., the creation of new degrees or curricula in the field of engineering with the objective of training new professional figures with more or less in-depth skills in technology and business management. In line with this approach, a first example, also in terms of time, has been that of Industrial Engineering, whose first course of study, at the bachelor level, was established in 1909 at the Pennsylvania State University. After the Second World War, the new specialization in Engineering Management, also called Engineering and Technology Management, was introduced in some American engineering schools but also in Europe ed some countries of other continents (Japan, Australia).

Within the variegated path of contamination of the engineering and managerial disciplines, a different perspective has emerged over time, which has led to the birth and diffusion of new programs, different from those of Engineering Management, labeled as Management Engineering. The question was not purely formal as the

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expression Engineering Management has a different meaning from Management Engineering. Hence, Management Engineering can be defined as the engineering of management systems, with the application of engineering theories, methods, and tools to the area of management. In other words, Management Engineering is not management applied to engineering, but rather engineering applied to management.

Among the possible factors that fostered the evolution above described, in the broader framework of the economic-managerial training of engineers, two characterizing elements have to highlight. The first one is the contamination between cultural and scientific areas of different origins but interested in the issues of business management and technology (e.g., system science, operational research, plant engineering). The second element is the setting-up over time of a substantial nucleus of researchers dedicated to the disciplines characterizing the management area; starting from the first groups formed in the sixties and seventies, thanks also to the launch of the "research doctorate" and the opening of new research streams. The establishment of a strong nucleus of reference, capable of transferring the updated results of its research into the training activity, in a framework of growing collaboration with other disciplinary fields, contributed to defining the identity and effectiveness of the teaching activity, appropriate to the educational objectives. In this framework, management engineering courses must be updated, not only with respect to the evolution of the various disciplines, but also with respect to the need to train professionals who are even more aware of the role played in society as bearers of a systemic approach to innovation.

To sum up, Management Engineering deals with developing and transferring the knowledge necessary to design and manage complex organizational systems within the framework of the articulated relationships between technology, economics, and management. Management Engineering brings together the skills related to the integration of engineering culture with the economy and management of companies, organizations, and public and private institutions. These objectives are achieved through the fruitful interaction between teaching, research, and the valorisation of knowledge.

Management Engineering focuses on the processes of transformation, change and innovation, i.e. the complex interactions between technological and social variables, with the aim of understanding their economic implications, the impacts on organizations, territories and society and, consequently, the most appropriate strategic, managerial and policy choices. From this point of view, the issues of economics and management of technology, entrepreneurship, internationalization, digitization, ecological transition, and social innovation are central. In particular the discipline deals with the design and management of complex organizational systems such as global networks, supply chains, innovation ecosystems, cross-sector collaborations, studying their dynamics, managerial processes and choices aimed at generating value.

2 Background and Legacy

Management Engineering born on the base of a solid and sturdy Italian academic tradition. As early as the 1930s, many engineering faculties/schools included an economics course in the student's curriculum. The aim was to combine the technical aspects with the economic feasibility. In this way engineering students received an initial cultural stimulus towards a professional activity that took into account both technical and economic issues. In this framework, attention to economic and organizational issues also has a long tradition at the Faculty of Engineering of the University of Naples Federico II. Already in the 60s it was founded and operated, under the presidency of the late prof. Luigi Tocchetti, the C.S.E.I. (Centre for economics applied to engineering). The C.S.E.I. was always attentive to the problems which, in those times, also emerged in other countries, both in the European and American continents, as well as in the countries of the Far East. The C.S.E.I. became a forge of young researchers who then held important positions in several universities, industries, and important public and private institutions. In the following years, under the guidance of various Deans and Department Directors, the Faculty/School of Engineering of the University of Naples Federico II increasingly strengthened its propensity towards economic and organizational issues. Propensity that led towards the mid-seventies to establish a teaching of economics and business organization, first entrusted to prof. Alfredo Del Monte and subsequently to prof. Mario Raffa. This first teaching represented the cultural nucleus of what would become management engineering in the Faculty of Engineering of the University of Naples Federico II. It was a single teaching offered as part of the training courses of the various traditional degree courses in engineering (aerospace, mechanical, electronics, chemistry, computer science, electrical, naval, etc.). This teaching introduced the engineering student to the topics of microeconomics, macroeconomics as well as to the study of industrial sectors and their significant managerial aspects (economics of small and medium-sized enterprises of the software industry, supply chain management of the aerospace and automotive industry, economics and management of the high-tech industry, product life cycle of different industries, innovation management, and project management, etc.). in the following years, according to the international trend, Naples also followed two parallel paths, that of more or less in-depth economic-managerial training, which is added to the basic training of engineers and that of specialization, with the creation of an ad hoc degree course in the field of engineering: It was the birth, thirty-two years ago of the management engineering degree course. The entry into the labor market of the management engineers of the University of Naples Federico II was rapid and with extremely flattering results judged satisfactory by the companies and by the various institutions in which, the graduates found employment. Currently, there are over a thousand graduates in Management Engineering. To these must be added the conferral (in October 1987) of the "Honorary degree" to prof. Franco Modigliani, former Nobel Prize winner for economics. Management Engineering graduates find ample employment opportunities both in manufacturing companies and in services, as well as in public administration. Currently about 5–7% work in

small and medium-sized enterprises. Large companies (Italian and foreign) as well as multinational companies employ about 40–42% of graduates. 21–23% of management engineers carry out activities in the training sector, research, and public administration (schools, universities, research centers, local public bodies), while 30–32% carry out consultancy activities (both small and medium-sized enterprises and large companies and multinationals). This vast range of opportunities derives from the fact that management engineering is conceived with intersectoral characteristics and is therefore placed outside the logic of traditional specializations while aiming at the training of engineers culturally equipped to enter fields in which the technical variable and interact with economic, institutional, social and environmental ones. In this context, the management engineer does not lose his sincere identity as a technician oriented towards tackling problems concretely. In the confirmation of this pragmatic nature, his specific potentials are consolidated, always well distinct from those resulting from other areas of university studies.

On the base of these essential observations, the research activity in the sector of management engineering at the Department of Industrial Engineering of the University of Naples Federico II is strongly attentive to technology, since the latter has a significant influence on the change of production, economic and organizational processes. The research activity is characterized by a quantitative approach, without neglecting the qualitative variables which often assume crucial importance. Furthermore, it pays significant attention to the issue of complexity that increasingly characterizes companies, business systems, local systems, attention to sustainability (combined in terms of environmental, social, economic sustainability, etc.). The attention to the management aspects of complexity is the result of an activity aimed at developing a systemic culture inherited from the cultural areas that have contributed to the birth, growth, and development of management engineering.

3 Congresses

In relation with the various research streams, many national and international meetings and conferences has been sponsored and organized. Among these the most relevant are:

- 21st annual IPSERA conference, Purchasing & Supply Management in a Changing World, Congress Centre, University of Naples, Federico II, April 1–4, 2012.
- EWGLA and ISOLDE, XXI Meeting of European Working Group on Locational Analysis (EWGLA) and XIII Edition of the International Symposium on Locational Decision (ISOLDE), Naples and Capri, June 16–20, 2014.
- XX SIGEF Congress, Harnessing Complexity through Fuzzy Logic, University of Naples Federico II. July 4–5, 2019.
- XXXII AiIG Scientific Meeting, Rethinking Sustainability and Resilience after the Covid-19 pandemic. Developing research and education in Management Engineering, Naples, October 21–22, 2021.

- 23rd ECKM Conference, European Conference on Knowledge Management (ECKM), Naples, September 1–2, 2022.
- RENT XXXIV, Research in Entrepreneurship and Small Business Conference, Re-thinking entrepreneurship after the crisis, Congress Centre, University of Naples Federico II, November 17–18, 2022.

4 Main Research Programmes

The research activity of Management Engineering is organized into seven main research areas.

4.1 Complexity in Organizational and Innovation Management Studies

This research line has been devoted to building up a computational agent-based laboratory, named CLOD (Computational Laboratory for Organizational Design), to explore the advantages that agent-based approaches could offer to scholars and practitioners in organizational research, particularly in organizational design. The laboratory's conceptual architecture is based on March's organizational learning model, appropriately reframed in the light of Complex Adaptive Systems. It has a modular structure and has been used to perform generative experiments to explore, for example, the eventual benefits in terms of organizational performances obtained through informal coordination mechanisms based on natural language [1].

The Complexity theoretical and methodological perspectives have been also used outside the boundaries of individual firms, by studying organizational and innovation management issues in entrepreneurial networks [2], small firms' clusters, and regional and national innovation systems. In most cases reported above, the research activity has been performed through agent-based platforms developed by the research group and made freely available in an open science perspective. A socio-computational approach is adopted to model business transactions and supply chain formation in Marshallian industrial districts. An agent-based model is presented and used as a virtual lab to test hypotheses concerning firms' behavior in entrepreneurial clusters and the emergence of collaborative networks and specific structural properties at the system level. An agent-based modeling was also developed to support self-sustaining regional innovation systems (RISs). The model is the base of a computational laboratory, CARIS (Complex Adaptive Regional Innovation System), which aims at evaluating the self-sustainability of RISs and at investigating what are the resources, competencies, and mechanisms able to trigger powerful innovation and economic growth processes. Such a topic is particularly interesting for the so-called

"lagging regions", which, notwithstanding noticeable policy interventions, have been unable to significantly improve their innovation performances.

4.2 Empowering Academic Entrepreneurship in the Digital Age: Insights, Innovations, and Future Directions

One of the keyways universities can contribute to advance regional development and economic growth, is by nurturing entrepreneurial awareness among their students and fostering academic entrepreneurship (AE). By leveraging innovative educational models and digital tools, universities can empower students and academicians with entrepreneurial mindsets, ultimately driving economic growth and regional development. Within this context, the literature identifies four major research streams: Digital Technologies for Entrepreneurship Education, the 'maker space movement' for Academic Entrepreneurship, digital technologies for discovering entrepreneurial opportunities, and creating entrepreneurial competences in digital 'university-based' entrepreneurial ecosystems. Also, it reveals the need for further research and a more holistic understanding of the role of digital technologies in shaping entrepreneurial initiatives within academia [3].

Moreover, the role of digital technologies in entrepreneurship education centers is explored in a study analyzing Italian Contamination Labs (CLabs). The analysis reveals a limited adoption of digital technologies within CLabs, primarily utilized for promotional and communication purposes. In response to the challenges posed by the COVID-19 pandemic, researchers investigate the potential of digital technologies in promoting entrepreneurial self-efficacy and intention among engineering students. In [4], the authors reveal that an online-designed entrepreneurial course, leveraging digital technologies such as MOOCs and gamification, positively impacts students' self-efficacy and intention to pursue entrepreneurial endeavors. The synthesis of these studies highlights the transformative potential of digital technologies in fostering student entrepreneurship and academic entrepreneurship. Building upon the research on AE, [5] focuses on exploring the factors that drive university engineering students to become entrepreneurs. Utilizing a configuration approach, this research investigates the entrepreneurial intentions and propensities of engineering students from various European countries. The findings reveal that entrepreneurial intention and propensity are influenced by a combination of factors rather than a single driver. Notably, the intensity of entrepreneurship education emerges as a crucial factor in shaping students' entrepreneurial intentions. This innovative model aims to trigger transdisciplinary abilities in doctoral students, making them better prepared for entrepreneurial ventures. The study demonstrates that the T-shaped doctoral program positively influences students' vertical skills and horizontal capabilities, enhancing their entrepreneurial readiness.

In [6] a comprehensive analysis of the current literature is performed to define the state of student entrepreneurship (SE) and identify potential research directions.

The study involves an extensive review of 288 published articles from International Entrepreneurship and Management Journals, as well as journals in Education and Management Business Accounting subject areas. The results, structured into two macro sections, delve into corpus overview and bibliometrics, analyzing the evolution of SE-related articles over time, authorship trends, citation analysis, and the prominent journals in the field. This analysis highlights the growing significance of SE and the diverse approaches taken by researchers in exploring this area. A content analysis approach is performed to uncover the major themes and issues that emerge from the literature. An investigation of the most common theories used in SE research, the methodologies employed to gather data, and the mechanisms adopted by universities to promote and support SE among students provides valuable insights for researchers interested in exploring the different sub-fields within SE. This work not only contributes to the academic community but also offers valuable suggestions for management educators, business school administrators, and institutional leaders. By enhancing entrepreneurial activities and initiatives, universities can better support student entrepreneurs. Additionally, policymakers can rethink and redesign policies that encourage and foster entrepreneurship among students.

4.3 Links Between Open Innovation Strategies, Sustainability and Digitization of Companies

Adequate management of intellectual property (IP) is critical to sustaining competitive advantage and managing outbound OI, which describes the inside-out flows of knowledge and technology. In [7], it is presented an IP strategic framework comprising the following strategies: a ‘defensive’ strategy, aimed at avoiding knowledge spillovers and building barriers to competition; a ‘collaborative’ strategy, aimed at collaborating with other organizations and entering new markets; and an ‘impromptu’ strategy, which describes firms protecting their IP without a clear purpose. The authors investigate the relationships of such IP strategies with outbound OI and innovation performance in 158 Italian firms. The results show that not having any IP protection strategy can be a barrier to outbound OI and that firms with a defensive IP strategy embraced outbound OI more than those declaring a collaborative IP strategy. Finally, firms with collaborative IP strategies outperformed those with defensive strategies.

In [8], an exploratory analysis of 73 Italian manufacturing firms allowed identifying five intellectual property strategies: defensive, purposely defensive, collaborative, developing impromptu and impromptu. The article describes their differences in intellectual property protection mechanisms and outbound open innovation. Furthermore, a fuzzy-set qualitative comparative analysis identifies the optimal combination of formal, semiformal and informal intellectual property protection mechanisms to nurture outbound open innovation.

The challenges and complexities entailed by the OI should not be underestimated. Through a systematic bibliometric review of the literature on the causes of failure of OI, performed in order to analyze its evolution and to provide a framework to help managers understand and prevent OI failures, ten categories of causes of OI failure to be included in a seven-components framework have been identified. The latter adopts the perspective of the firm and investigates both internal and external causes of failure. In [9], the authors show that firms collaborating with a wider network of external partners to conduct their innovation activities are less likely to abandon them. The article also analyses how different categories of partners are associated with the risk of innovation abandonment. Finally, the results show that international collaborations are more likely associated with innovation abandonment than domestic ones. In [10], the motivations underlying COVID-related innovations, the role of inter-organizational collaboration, and their relationship with innovation novelty are explored. 18 Italian COVID-19-related innovations developed during the initial pandemic phase are studied, considering two industrial motivations based on the exploration-exploitation dichotomy and two institutional motivations (corporate social responsibility and marketing). Using the crisp set Qualitative Comparative Analysis, the authors found that institutional motivations have driven most radical and incremental innovation projects.

More recent literature suggests that OI can help companies also improve their Corporate Social Responsibility (CSR) performance. To this end, a theoretical framework to explain how companies can simultaneously improve OI and CSR through the management of relationships with stakeholders has been developed. Results show that the stakeholders' theory can be used to explain the connection between OI and CSR performance and that companies can collaborate with different stakeholders' categories to achieve a variety of CSR goals. The companies adopt a long-term perspective and explicitly include sustainability objectives in their open innovation strategy to enhance their position as reliable partners and elicit favorable responses from the environment. In [11], the authors suggests that the businesses' collaborative relationships with external consultants or organizations can increase their competitive advantage, as external stakeholders could assist them in the development of sustainable innovations, diversification into different markets, and in the generation of new revenue streams. At the same time, they can support them in addressing numerous deficits in society. On the other hand, an organizational culture that promotes open innovation approaches could expose practitioners to risks and uncertainties, like revealing sensitive information to outsiders, among others.

4.4 Decision Support Systems for Supply Chain and Logistics Design and Management

Within the broad context of process innovation and optimization, a significant research field concerns the design and management of supply chains and logistic

systems. In the following, the performed research activities and those still in progress are illustrated considering three main areas.

The first research area concerns *Supply Chain (SC) design*. SC consists in the definition and the organization of the different actors involved in the production, distribution and consumption of a given good or service (suppliers, producers, logistic providers, final customers). In this area, a fundamental problem is represented by the optimal location of the facilities along the entire chain (suppliers, production plants, distribution centres, warehouses). In this general framework, different real cases of location problems have been investigated, both in the private and the public sector, and general optimization models and methods have been developed, inspired by the so-called locational analysis methodologies. A specific stream is focused on the design of public service networks and, specifically, on the development of approaches able to produce long-term scenarios combining efficiency goals with the need to ensure adequate and equitable levels of user accessibility. The proposed models have been successfully used to solve various real problems in the different fields, e.g., healthcare [12] and reverse logistics [13]. The models have been generally solved by managing huge amounts of data, through the integration of optimization methods, Geographical Information Systems (GIS) and simulation tools. Another research stream concern the theoretical investigation of the location problems and, specifically, the definition of innovative models capable of taking into account the actual complexity of the systems; i.e., the presence of multiple facilities providing various type of services, the possibility of different interaction mechanisms among facilities (cooperative vs competitive), the stochastic nature of different elements of the problems, the adoption of multiple and conflicting performance indicators [14].

The second research area focuses on *Last-mile logistic network organization*. In general, last-mile concerns the delivery of parcels from the logistic distribution centres until the endpoints at which customers want the parcel to be delivered. In recent years, the striking diffusion of B2C and C2C e-commerce, also accelerated by the COVID-19 pandemic, is pushing logistic providers to reorganize their supply chains to reduce costs by satisfying increasing consumer requirements. As such, great emphasis is given to the optimization of this logistics' phase. In this field, the main research activities concern the development of models and methods to support the optimal reorganization of urban infrastructure for last-mile logistics and the definition of novel delivery strategies [15]. Such activities have been carrying out within the framework of a research project funded by the National Italian National Resilience and Recovery Plan (NRRP), devoted to sustainable mobility ("Centro Nazionale per la Mobilità Sostenibile", MUR CN00000023). In particular, two main classes of strategies have been exploring: (i) optimizing home delivery by leveraging novel technologies and shipping methods (electric vehicles, drones, crowd shipping) or by adopting novel logistic solutions; (ii) (partially) replacing home delivery by resorting to the so-called self-collection, which requires customers to autonomously go and collect parcels from manned or unmanned facilities (pick-up points and parcel lockers). To this end, we developed different models to support the location of pick-up points, aiming to maximize customers' willingness to use self-collection and minimize logistic costs. Such models have been applied using real data to support

the major Italian postal provider (Poste Italiane S.p.A) in the decision-making process concerning its self-collection network design.

Finally, the third research area is devoted to *Re-engineering for Sustainable Processes and Supply Chains*. It focuses on the re-design of inbound operations in order to combine productive efficiency with the reduction of environmental impacts. Activities have been stimulated by the participation to European and national projects: TrainERGY—Training for Energy Efficient Operations, 2015-1-PL01-KA203-016919, http://www.trainergy-project.eu/; PrESS—Promoting Environmentally Sustainable SMEs—-538851-LLP-1-2013-1-UK-ERASMUS-EQR, http://www.pressproject.eu/it/; METROPOLIS—METodologie RObuste per l'efficientamento dei Processi e l'Ottimizzazione Logistica nell'Industria Siderurgico-navale, funded by MISE—Ministero per lo Sviluppo Economico; 3A-ITALY, funded in the context of the National Recovery and Resilience Plan NRRP, MUR: PE00000004. In particular, more recently, we have been performing a complex industrial project in partnership with a medium enterprise of the shipbuilding sector, in which we are implementing an holistic approach for the optimization of production processes and their integration with inbound and outbound logistic operations [16]. The projects also aims at defining an appropriate set of KPIs, tailored on the specific production context, to describe the different dimensions of the production environment, and at re-engineering the critical processes to reduce the CO_2-eq output.

4.5 Managing Digital and Sustainable Innovation in Individual Firms and Supply Chains

In the dynamic landscape of business, companies are actively embracing digital transformation to enhance and optimize their processes, including knowledge management (KM) processes. Consequently, knowledge management systems (KMSs) are becoming integral components of business operations. Successful KM requires a synergistic alignment between tools and practices to unlock the full potential of an organization's assets. Efficiency and effectiveness in the adoption of KMSs for small and medium enterprises (SMEs) emerge as significant concerns [17]. We proposed a novel 3D-fuzzy logic methodology to examine the adoption of KMSs in supply firms related to the nature of knowledge and the KMSs used. The adoption of a decision support system assessing the alignment between tools and practices and suggesting strategies for KMSs adoption to improve KM alignment, the efficiency and the effectiveness performance of KMSs, resulted to be particularly valuable in bridging digital tools with managerial strategies.

While operational performance has long been a primary focus, incorporating sustainability performance metrics it has become mandatory. Global awareness prompts a thorough supply chain (SC) re-evaluation. In this context, logistics service providers (LSPs) play a vital role within SCs. The freight industry, including LSPs, is a major

contributor to greenhouse gas and CO2 emissions. The growing influence of green practices and enabling technologies presents opportunities for emissions reduction and climate action. Our research effort has been focused on assessing and improving sustainable performance within the LSPs sector [18]. We proposed a taxonomy of green initiatives guiding LSPs in pursuing environmental sustainability performance. The taxonomy categorizes aims, practices, and technological tools, revealing discrepancies in the prioritization of certain sustainability aspects over others. The prevalence of technology adoption over green practices highlights the need to bridge gaps in technology, culture, and management to achieve comprehensive environmental sustainability.

The growing interest in sustainability objectives has driven our research to provide a comprehensive examination of established sustainability research streams within the SC. Considering the incredibly high number of papers in the literature on this topic, we adopted a novel tertiary-systematic review methodology to identify the most promising future research avenues to be further investigated [19]. Evaluating how reverse logistics and closed-loop SCs can be used to implement sustainable green SC practices and circular economy (CE) strategies, emerged as one of the most interesting future research directions to be further investigated. Consequently, a recent research trajectory has emerged, homing on CE, where emphasis is placed on technological and managerial aspects aimed at optimizing resource usage, minimizing waste, and increasing the value of products beyond their initial use. Central to this pursuit is a meticulous examination of the entire value chain, unlocking the potential to extend product lifecycles and elevate ecological consciousness. This pursuit encompasses a range of strategies, from waste reduction and recycling to other strategies. In this context, we started a multifaceted research stream that encompasses several pivotal dimensions. One of the most critical issues investigated in the current literature relates to the factors affecting the adoption of CE strategies. We investigated relationships between factors such as social pressure, environmental commitment, green incentives, supply chain management, and CE capabilities. The findings highlight the positive impact of commitment and incentives on supply chain management and sustainable design. This research underscores the need for strategic planning to facilitate CE transitions and integrate sustainability into supply chain management practices.

According to the current rules about commitment towards sustainability, businesses are poised to play a pivotal role in demonstrating their commitment towards sustainability through comprehensive accountability measures. Future forces companies to embrace holistic sustainable behaviours by analysing their lifecycle, in line with ISO standards, and leveraging technology. Our preliminary field analysis has been conducted in the agri-food industry, one of the most polluting industries due to the environmental impact of their operations [20]. Given the considerable resource consumption, waste generation, and emissions associated, companies in this industry are increasingly committed to integrate sustainable practices into their core operations, aligning with global efforts to address climate change and foster CE. To address these challenges, it is necessary to start with the assessments of the entire lifecycle of a product, from raw material extraction to disposal. Quantify

its environmental impact through Life Cycle Assessment (LCA) according to ISO standards is imperative. Following the assessment phase, the improvement phase is performed. In this crucial stage, the focus shifts towards integrating CE practices to booster performance. The LCA analysis conducted in a food company uncovered key environmental hotspots within their SC, guiding our efforts towards areas that necessitated immediate attention. Strategies such as efficient packaging and sustainable procurement were strategically introduced, aligning with the company's sustainability objectives and facilitating their transition towards CE.

As far as the knowledge diffusion process between companies is concerned, a hybrid model has been proposed which interprets the knowledge diffusion process within the triadic relationship between customer, first level supplier and second level supplier. The hybrid model is based on two main approaches suggested in the literature to address multi-criteria evaluation problems, the Analytic Hierarchy Process and the fuzzy set theory. The effective usability of the hybrid model is investigated through the sample of 20 supply chains. The hybrid model allowed to identify a taxonomy that highlights the role and the behaviour of first-tier suppliers within the supply chain. Four areas were highlighted: Hub supplier area, Source supplier area, Restrain supplier area, and Sponge supplier area. Taking cue from the proposed taxonomy, it was possible to identify implications for both customers and suppliers, as well as policy makers.

4.6 Organizational and Innovation Management in Healthcare

Health organizations are very fertile ground for management studies. Healthcare services are essential for sustaining and improving human well-being. These services require a strict interconnection among different people (i.e., doctors, nurses, healthcare professionals, managers) across different levels as macro (i.e., healthcare system), meso (i.e., hospital) and micro (i.e., process). Main research activities carried out in this context aimed at: 1) investigating how healthcare organizations transform their processes by introducing digital solutions and technologies, and 2) designing adequate methods to analyze and improve organizational and administrative processes.

Concerning the first line, the research has deepened aspects related to telemedicine, defined as the use of information technology to deliver medical services over distance to propose solutions to accessibility, quality, and costs of medical care. Adopting an explorative approach, we analyzed the implementation of four telemedicine projects located in the Southern Italy, a disadvantaged area in comparison to other Italian and European regions. The goal of this research was to shed light on the characterization of leverages and barriers, as well as the related managerial actions for change implemented in a context whereby the diffusion of telemedicine remains limited [21]. Another research, has investigated the acceptance of telemedicine by people

through the analysis of the innovation journey of a firm, that designed and developed a telemedicine platform, collaborating with different actors – adopters (physicians, nurses, and patients) and health decision-makers. This case study allowed us to put in evidence an interwoven relationship between the Open Innovation approach adopted in the development of the telemedicine platform and the acceptance of the technology itself. Against this backdrop, Open Innovation is not only an enabler supporting knowledge exchanges, but also an enabler of Technology Acceptance [22]. Focusing on the use of digital solutions in healthcare organizations, we have investigated the factors affecting the clinicians' behaviors towards the use of digital decision support systems in therapy appropriateness and deprescribing issue. This research carried out under a strong collaboration with a research group of LIUC University of Castellanza, uses a survey, combining traditional methods (i.e., regression) with Qualitative Comparative Analysis to analyze the results.

Concerning the improvement of organizational processes and studied the Triage, our research focused mainly on Emergency Department (ED). The Triage process regulates access to emergency care through the assignment of a priority level to each patient. An effective Triage process has an impact on ED's quality and efficiency. The Triage code's assignment is an example of a cognitive heuristic, where the decision-making process cannot be simply automatized, since it is affected in a complex manner by Individual, organizational, and contextual factors. In this vein, our research has developed methods and carried out analysis for assessing the impact of individual and organizational factors on individual decisions [23], for providing an analytical learning system to assess the quality of the Triage decision-making process and improve it [24]. Moving from Triage to healthcare processes in general, models based on Activity Based Costing and Social Network Analysis have been designed and experimented with in healthcare units with the aim to improve the processes coherently with a process management approach.

4.7 Project Management in World of Research, Public Administration and Business Start up

The research program is divided into three main areas addressing various perspectives related to project management.

The first area refers to *Project Management in the Management of Research Projects*. As part of this research, two main research projects were carried out.

The first project, carried out in collaboration with the National Research Council (CNR), was aimed at analyzing the diffusion of Project Management skills in a sample of 195 Principal Investigators from the various departments of the Institute. Through a self-assessment questionnaire, the Principal Investigators of the sample assessed their degree of oversight of the following types of skills: Process skills; Personal skills; Technical skills; Contextual and task related skills [25]. The survey results were processed through Partial Least Squares Path Modeling [26]. A model

with theoretical constructs and latent variables is introduced to analyze the causal detection among different types of variables, including the activation of hard and soft PM skills of Principal Investigators.

The second project was carried out in collaboration with Wroclaw University of Science and Technology (Poland) [27]. The study aimed to investigate, in the light of the literature and through a cross-cultural study conducted in Italy and Poland, the relationship between soft skills (empowering leadership style, self-efficacy beliefs, and collective efficacy) of the principal researcher (PR) and the perceived success of research projects and satisfaction with the project, taking into account intercultural differences. A total of 67 PRs of complex projects in public universities (28 in Italy and 39 in Poland) participated in the study, completing a self-report questionnaire. Data were analyzed using descriptive and correlational analyses.

The second main research area focuses on *Uncertainty and Risk in Project Management in Public Administration Organizations*. As part of this research, two main projects were carried out. The first project, carried out in collaboration with the Ministry of Justice, was aimed to investigate whether the adoption of a risk-based approach that allows public managers to take into account the context and external not-controllable factors during goal setting may contribute to overcome unintended managerial side effects of performance management (PM) practices that hamper their success within public organizations. Explorative research was carried out on court officials of Italian public administration [28]. The second project aimed at assessing the uncertainty scope and types present in public projects, with uncertainty defined as a lack of knowledge, and to formulate recommendations for improving the success rate of public projects [29]. Apart from a literature review, a questionnaire was administered among 60 Italian and 40 Polish public-project managers. Questions about the level of knowledge of various project aspects in the project-planning phase were asked. It was found that, in their own opinion, knowledge of essential aspects of public projects in the planning stage was fairly low among public-project managers. On top of that, the results showed in which areas, and in which of the two countries, the uncertainty was mostly present. This type of research has not been identified in the literature. In both countries, an especially high uncertainty level characterized project stakeholders. The survey's conclusions are juxtaposed with results from the literature: the negative influence of lack of knowledge (i.e., uncertainty) on project success, specific features of public projects and public-project managers, and the fact that certain negative phenomena influencing project success are significantly more present in the public than in the private sector. Our results indicate which aspects of public projects in both countries should be subject to deep changes—as far as information collecting and processing, in the project-defining and planning phase, is concerned. All this leads to recommendations of measures to be introduced in the public sector with respect to public-project management, e.g., the establishment of project management offices, project knowledge sharing, project management training—all focused on the identified uncertainty types in public projects, such as management of project stakeholders.

Finally, the last main research area concerns *Project Management and Business Start Up*. Here, a research project was carried out to explore the contribution of

project management (PM) to business startups, presenting a PM-based interpretative framework predicated on the assumption that business startups can be interpreted as entrepreneurial projects [30]. The framework combines the evolutionary path of the business startup life cycle with PM approaches and methodologies to support startuppers in addressing the uncertainty of the entrepreneurial process. Focusing on the business startup project life cycle, the framework examines the critical issues in managing each stage, the most suitable PM approaches, and lastly the tools, techniques, and interpersonal skills that startuppers need to organize their activities. The findings demonstrate that managing flourishing business startup projects can be supported by balancing traditional and agile project management methodologies according to the level of uncertainty and complexity of the different stages of their launch and development. Implications for theory relate to the unconventional connection between the literature on PM and entrepreneurship; implications for practices include the adoption of the proposed framework as a roadmap to support nascent entrepreneurs in managing entrepreneurial projects.

5 Future

As far as *Complexity in organizational and innovation management studies* is concerned, the research will be devoted to designing and implementing an agent-based laboratory to jointly investigate the environmental, social, and economic impact of the introduction of innovative technology for green hydrogen in specific innovation value chains (e.g., high-quality bio-chemicals).

Regarding *Empowering Academic Entrepreneurship in the Digital Age: Insights, Innovations, and Future Directions*, future development of this research stream will investigate how digital technologies affect the university entrepreneurial ecosystem as to provide a comprehensive and up-to-date overview of digital academic entrepreneurship. The study will analyze the new opportunities created by digital technologies within the university entrepreneurial ecosystem, such as incubation and acceleration of new businesses, use of online platforms for communication and commerce, access to new markets and financing tools, and access to new digital knowledge and skills, are analyzed.

Concerning *Links between open innovation strategies, sustainability, and digitization of companies*, in the current landscape of business and innovation, there exists a profound interplay between open innovation strategies, sustainability practices, and the ongoing digitization of companies. This nexus forms the crux of future research, which aims to delve deep into the intricate connections between intellectual capital, the digitization journey, and the overarching domain of corporate sustainability. This exploration is set to unfurl a tapestry of insights, shedding light on the multifaceted relationships and their far-reaching implications. With meticulous attention to detail, our research aims to unravel the precise impacts of cutting-edge Industry 4.0 and the emerging Industry 5.0 technologies on the strategic paradigms adopted by businesses and their ensuing sustainable performance.

Regarding *Decision support systems for supply chain and logistics design and management*, we see various future research directions for each of the outlined areas of interest. For *Supply chain design* and *Last-mile logistic network organization*, we are keen to investigate more comprehensive indicators for accessibility evaluation, coupling geographical and digital dimensions, and novel models and methods for redesigning spatially distributed multi-level services. Finally, as concerns *Re-engineering for sustainable processes and supply chains*, leveraging the ongoing research experiences, our endeavor will be devoted to defining and implementing comprehensive Decision Support Systems involving optimization tools integrated with appropriate KPIs and relevant assessment methodologies for efficient and environmentally effective production planning.

As for *Managing digital and sustainable innovation in individual firms and supply chains*, future research will be devoted in supporting companies to identify inefficiencies and areas for enhancement, leading to more targeted strategies for sustainability improvement. Digital platforms based on blockchain protocols can enable transparency and traceability, fostering responsible sourcing practices and minimizing negative environmental and social impact of company's operations. By unravelling the intricacies of CE strategies and evaluating their real-world impact, we advocate for a paradigm shift towards sustainability. Our research stands in the interplay between technological innovation, strategic management, and corporate social responsibility, towards resilient, sustainable, and responsible business models in the years to come.

Regarding *Organizational and Innovation Management in Healthcare*, future research will address to deepen this topic in a context in which balancing the trade-off among environmental, social, and economic sustainable actions becomes an urgent priority.

Finally, in terms of *Project Management in World of Research, Public Administration and Business Start Up*, a research project aimed at studying the factors that influence the results of the Digital Transformation in the Public Administration is being defined. The research is carried out in collaboration with Association of General Managers of Italian University Administrations (CoDAU) The purpose of the research is twofold: (i) evaluate to what extent the digitization projects influence the perception of student secretarial staff with respect to their work efficiency, relationships with students and colleagues (back office), job satisfaction; (ii) verify which factors influence (positively or negatively) the above perceptions.

References

1. Ponsiglione C, Cannavacciuolo L, Primario S, Quinto I, Zollo G (2021) The ambiguity of natural language as resource for organizational design: a computational analysis. J Bus Res 129:654–665. ISSN: 0148-2963. https://doi.org/10.1016/j.jbusres.2019.11.052
2. Cannavacciuolo L, Iandoli L, Ponsiglione C, Zollo G (2017) Learning by failure vs learning by habits: entrepreneurial learning micro-strategies as determinants of the emergence of co-located entrepreneurial networks. Int J Entrep Behav Res 23:524–546. ISSN: 1355-2554. https://doi.org/10.1108/IJEBR-11-2015-0238

3. Secundo G, Rippa P, Cerchione R (2020) Digital academic entrepreneurship: a structured literature review and avenue for a research agenda. Technol Forecast Soc Chang 157:120118. ISSN: 0040-1625. https://doi.org/10.1016/j.techfore.2020.120118
4. Primario S, Rippa P, Secundo G (2022) Rethinking entrepreneurial education: the role of digital technologies to assess entrepreneurial self-efficacy and intention of STEM students. IEEE Trans Eng Manag ISSN: 0018–9391. https://doi.org/10.1109/TEM.2022.3199709
5. Rippa P, Ferruzzi G, Holienka M, Capaldo G, Coduras A (2023) What drives university engineering students to become entrepreneurs? finding different recipes using a configuration approach. J Small Bus Manag 61:353–383. ISSN: 0047-2778. https://doi.org/10.1080/00472778.2020.1790291
6. Passavanti C, Ponsiglione C, Primario S, Rippa P (2023) The evolution of student entrepreneurship: state of the art and emerging research direction. Int J Manag Educ 21:100820. ISSN: 1472-8117. https://doi.org/10.1016/j.ijme.2023.100820
7. Grimaldi M, Greco M, Cricelli L (2021) A framework of intellectual property protection strategies and open innovation. J Bus Res 123:156–164. ISSN: 0148-2963. https://doi.org/10.1016/j.jbusres.2020.09.043
8. Greco M, Cricelli L, Grimaldi M, Strazzullo S, Ferruzzi G (2022) Unveiling the relationships among intellectual property strategies, protection mechanisms and outbound open innovation. Creat Innov Manag 31:376–389. ISSN: 1467-8691. https://doi.org/10.1111/caim.12498
9. Greco M, Grimaldi M, Cricelli L (2020) Interorganizational collaboration strategies and innovation abandonment: the more the merrier? Ind Mark Manag 90:679–692. ISSN: 0019-8501. https://doi.org/10.1016/j.indmarman.2020.03.029
10. Greco M, Campagna M, Cricelli L, Grimaldi M, Strazzullo S (2022) COVID-19-related innovations: a study on underlying motivations and interorganizational collaboration. Ind Mark Manag 106:58–70. ISSN: 0019-8501. https://doi.org/10.1016/j.indmarman.2022.07.014
11. Camilleri MA, Troise C, Strazzullo S, Bresciani S (2023) Creating shared value through open innovation approaches: opportunities and challenges for corporate sustainability. Bus Strat Environ ISSN: 1099–0836. https://doi.org/10.1002/bse.3377
12. Bruno G, Diglio A, Piccolo C, Cannavacciuolo L (2019) Territorial reorganization of regional blood management systems: evidences from an Italian case study. Omega 89:54–70. ISSN: 0305-0483. https://doi.org/10.1016/j.omega.2018.09.006
13. Bruno G, Diglio A, Passaro R, Piccolo C, Quinto I (2021) Measuring spatial access to the recovery networks for WEEE: an in-depth analysis of the Italian case. Int J Prod Econ 240:108210. ISSN: 0925-5273. https://doi.org/10.1016/j.ijpe.2021.108210
14. Diglio A, Peiró J, Piccolo C, Saldanha-da-Gama F (2023) Approximation schemes for districting problems with probabilistic constraints. Eur J Oper Res 307:233–248. ISSN: 0377-2217. https://doi.org/10.1016/j.ejor.2022.09.005
15. Bruno G, Cavola M, Diglio A, Laporte G, Piccolo C (2021) Reorganizing postal collection operations in urban areas as a result of declining mail volumes–a case study in Bologna. J Oper Res Soc 72:1591–1606. ISSN: 0160-5682. https://doi.org/10.1080/01605682.2020.1736446
16. Bruno G, Cavola M, Diglio A, Piccolo C (2023) A unifying framework and a mathematical model for the slab stack shuffling problem. Int J Ind Eng Comput 14:17–32. ISSN: 1923-2926. https://doi.org/10.5267/j.ijiec.2022.10.005
17. Centobelli P, Cerchione R, Esposito E (2019) Efficiency and effectiveness of knowledge management systems in SMEs. Prod Plan Control 30:779–791. ISSN: 0953-7287. https://doi.org/10.1080/09537287.2019.1582818
18. Centobelli P, Cerchione R, Esposito E (2017) Developing the WH2 framework for environmental sustainability in logistics service providers: a taxonomy of green initiatives. J Clean Prod 165:1063–1077. ISSN: 1879-1786. https://doi.org/10.1016/j.jclepro.2017.07.150
19. Centobelli P, Cerchione R, Cricelli L, Esposito E, Strazzullo S (2022) The future of sustainable supply chains: a novel tertiary-systematic methodology. Supply Chain Manag: Int J 27:762–784. ISSN: 1359-8546. https://doi.org/10.1108/SCM-08-2020-0383
20. Abbate S, Centobelli P, Cerchione R (2023) The digital and sustainable transition of the agri-food sector. Technol Forecast Soc Chang 187:122222. ISSN: 0040-1625. https://doi.org/10.1016/j.techfore.2022.122222

21. Cannavacciuolo L, Capaldo G, Ponsiglione C (2023) Digital innovation and organizational changes in the healthcare sector: multiple case studies of telemedicine project implementation. Technovation 120:102550. ISSN: 0148-2963. https://doi.org/10.1016/j.technovation.2022.102550
22. Aloini D, Pellegrini L, Latronico L, Cannavacciuolo L (2023) Open innovation and technology adoption during emergency: lessons from a case study in telemedicine in time of COVID-19. Technol Anal Strat Manag 1–13. ISSN: 0953-7325. https://doi.org/10.1080/09537325.2023.2196580
23. Barber'a-Mariné MG, Cannavacciuolo L, Ippolito A, Ponsiglione C, Zollo G (2019) The weight of organizational factors on heuristics: evidence from triage decision-making processes. Manag Decis 57:2890–2910. ISSN: 0025-1747. https://doi.org/10.1108/MD-06-2017-0574
24. Pandolfo G, D'Ambrosio A, Cannavacciuolo L, Siciliano R (2020) Fuzzy logic aggregation of crisp data partitions as learning analytics in triage decisions. Expert Syst Appl 158:113512. ISSN: 1873-6793. https://doi.org/10.1016/j.eswa.2020.113512
25. Capaldo G, Orefice CI, Riccardi M, Fusco S (2017) Le Soft Skill per la gestione dei progetti di ricerca 2017/32. FrancoAngeli Editore. https://doi.org/10.3280/PM2017-032008
26. Aria M, Capaldo G, Iorio C, Orefice CI, Riccardi M, Siciliano R (2018) Pls path modeling for causal detection of project management skills: a research field in national research council in Italy. Electron J Appl Stat Anal 11:516–545. ISSN: 2070-5948. https://doi.org/10.1285/i20705948v11n2p516
27. Capaldo G, Costantino N, Pellegrino R, Rippa P (2018) The role of risk in improving goal setting in performance management practices within public sector: an explorative research in courts offices in Italy. Int J Public Adm 41:986–997. ISSN: 0190-0692. https://doi.org/10.1080/01900692.2
28. Kuchta D, Canonico P, Capone V, Capaldo G (2023) Uncertainty in the planning phase of public projects—its scope, consequences, and possible remedies. Adm Sci 13:145. ISSN: 2076-3387. https://doi.org/10.3390/admsci13060145
29. Capaldo G, Capone V, Babiak J, Bajcar B, Kuchta D (2021) Efficacy beliefs, empowering leadership, and project success in public research centers: an Italian–polish study. Int J Environ Res Public Health 18:6763. ISSN: 1661-7827. https://doi.org/10.3390/ijerph18136763
30. Secundo G, Capaldo G (2020) in Innovative entrepreneurship in action: from high-tech to digital entrepreneurship. In: Passiante, G. (ed.), pp. 55–69. Springer International Publishing, Cham. ISBN: 978-3-030-42538-8. https://doi.org/10.1007/978-3-030-42538-8_5

Statistics for Experimental and Technological Research

Massimiliano Giorgio

Abstract This chapter provides a synthetic overview of research activities and main outcomes of members of the scientific-disciplinary sector "SECS-S/02—Statistica per la Ricerca Sperimentale e Tecnologica" at the University of Naples Federico II, in the decade 2013–2023. Research activities of the group focus on modern statistical problems arising in the field of experimental sciences (statistics and probability calculus, design, and analysis of experiments), notably in engineering (reliability, statistical quality control). The main fields of application concern technology, safety, environment, territory, production processes, products, and natural resources.

1 Background and Legacy

The teaching of Statistics in the Faculty of Engineering at University of Naples Federico II was born in the late 1960s from the creative intuition of Prof. Luigi G. Napolitano, at that time Director of the Institute of Aerodynamics. Thanks to this, some years later, a student of Prof. Napolitano, Pasquale Erto, would become the first Full Professor of Statistics in Italy having a degree in Engineering.

In the fall of 1968, Prof. Napolitano proposed to do the MS thesis in Applied Statistics to one of his most devoted students of the Gasdynamics course and to choose a topic in either Reliability or Quality Control. Although understandably surprised by topics so far from those typical of Gasdynamics, the student chose the former on the spur of the moment (figuring that Reliability was, among the two, the topic closest to Mechanical Design, his other passion after Thermodynamics). It was precisely in 1968 that Prof. Napolitano expressed the firm conviction that it was now essential to introduce the teachings of Probability and Statistics in the Faculty of Engineering. Stubbornly he promoted multiple initiatives, even to the point of delivering himself a first course in Statistics, aimed at members of the Faculties

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of Engineering and Economics. Meanwhile, the thesis student in Reliability (future Prof. Pasquale Erto) graduated by discussing the thesis *Statistical Evaluation of the Reliability of Components of Mechanical Systems*. Obviously unable to find a placement in the Institute of Aerodynamics, he migrated to the C.N.R. Engine Institute in 1970. Here, he had the opportunity to cultivate his "unusual" studies, to continue collaborating with Prof. Napolitano as well as to accumulate a significant collection of books and journals.

After having been Professor in Charge of the first course in Italy of *Reliability Theory*, at the University of Calabria in the academic year 1974–1975, in the following academic years 1975–1984 Prof. Erto was in charge of *Reliability and Quality Control* at our Faculty of Engineering where then, in 1985, he assumed the position of Associate Professor of *Reliability Theory* joining to the Institute of Gasdynamics. In 1990, he became a Full Professor of *Statistics* and was enrolled in the Faculty of Sociology of the University of Catania. The following year, on July 23, 1991, Prof. Napolitano died prematurely in Estes Park (Colorado, US) leaving an indelible mark on the scientific education of all his students. In 1993, Prof. Erto was awarded the first position of Full Professor of *Statistics and Calculus of Probability* in the history of our Faculty of Engineering. As a natural and expected decision, he was assigned to the Aerospace field to complete a bumpy road that had begun about twenty years earlier in the visionary mind of the late Prof. Napolitano.

During this long journey, Prof. Erto never ceased to be involved in his activity with other young people who, with undoubted courage and passion, faced academic paths no less bumpy than his. To this cohort belong also some professors who then continued their careers in non-statistical areas of our Department. As the in-homogeneity with the traditional disciplinary fields of Statistics persisted, the young group of Statisticians working in our Faculty of Engineering, promoted and obtained in 1999 the establishment in Italy of the scientific-disciplinary sector SECS-S/02 (formerly S01B) "Statistica per la Ricerca Sperimentale e Tecnologica".

More recently, attracted by the Applied Engineering Statistics activities of this department, the original group of Statisticians has been joined by other very young researchers who have undoubtedly already shown that they know how to employ the cultural heritage, received from those who preceded them, to achieve even more ambitious research and teaching goals.

2 Main Research Programmes

The main research programmes faced by the SECS-S/02 research group at the University of Naples Federico II in the last decade are described below. More details about these research activities as well as other research topics addressed by the Statistics for Engineering Research (SFERe) group are available at www.sfere.unina.it.

2.1 Stochastic Modelling of Degradation Processes and Their Use in Reliability and Maintenance

This research activity focuses on stochastic degradation models and their use in reliability and maintenance. Interest in degradation models in reliability and maintenance is mainly motivated by the fact that many technological units are subjected during their operating life to a gradual degradation process which, in the long run, causes an inevitable situation of failure. These units are typically assumed to fail as soon as their degradation level exceeds an assigned threshold. Consequently, their lifetime can be defined as the first passage time of the degradation process beyond the threshold. Modelling the degradation process of these units can be twofold useful, in fact, it allows estimating their lifetime distribution from degradation data, even in the absence of failures, as well as performing condition-based (i.e., degradation-based) estimates of the remaining useful life, that can be used to plan condition-based maintenance activities. The challenge, in this case, is being able to properly use all the available data and pieces of information and formulate models that have a simple structure (to encourage their use in practical settings) and are statistically tractable (i.e., whose parameters can be easily estimated from data that are usually available in the applications). The main objectives of this research activity are the formulation of (i) new degradation models [1, 2]; (ii) strategies that allow to account for the presence of observable and non-observable forms of heterogeneity (i.e., models with covariates and random effect) [1, 3]; (iii) models and computational strategies that allow the analysis of data affected by measurement errors (e.g., perturbed models, particle filtering) [3, 4]; (iv) classical and Bayesian estimation procedures and related computational techniques (e.g., EM, MCMC algorithm) [3]; (v) prognostic tools (e.g., residual reliability and remaining useful life); (vi) condition-based/predictive/prescriptive/adaptive maintenance strategies [5, 6].

2.2 Software Reliability Growth Modeling

This research path has the ultimate goal of modelling software reliability growth which, in the last decade, has revealed one of the main research topics in statistics, operational research, and computer science. Interest in software reliability growth models (SRGMs) is justified because they can support decision-making in many software development activities to determine when a particular level of reliability is likely to be attained, and to estimate the number of initial or remaining faults in software. The generalized inflection S-shaped software reliability growth model proposed in [7] contributes to advancing the field of software reliability analysis by proposing a powerful and adaptable model that caters to the needs of both practitioners and researchers, by combining the strengths of existing models while introducing the ability to model nonmonotonic failure rate per fault functions.

2.3 Natural Risk Assessment and Mitigation

This research activity aims at developing statistical tools useful for the management and prevention of natural risk. Specific objectives of this research activity are (i) the formulation of statistical tools and techniques for natural (mainly seismic and hydrogeological) hazard assessment [8–10]; (ii) the prediction of damages produced by natural events [11, 12]; (iii) the formulation of early warning/short-term forecasting strategies [10, 12]; (iv) the formulation of decision-making strategies useful for risk mitigation and prevention [10, 12].

Moreover, this research line addresses also the development of unbiased graphical estimators of location-scale distribution parameters, with an application to Pozzuoli's bradyseism earthquake data. The advantage of graphical estimation lies in its ability to facilitate statistical understanding and communication with non-statisticians through visual inspection and model fit evaluation [13].

2.4 Statistical Learning and Monitoring of Complex Data from Industrial Processes

The realm of high-performance computational capabilities of modern Industry 4.0 has made feasible the acquisition of massive and complex amounts of data that are well represented as mathematical *objects* at different levels of complexity, from scalar quantities to vectors, curves, surfaces, and manifolds. These pose new challenges in the development of methods that, to really add value to the industrial practice, must be also *interpretable*, i.e., able to support human decisions based on it in a transparent way. Interpretability [14] is in fact the key issue of the statistical learning and monitoring techniques developed by this group, according to its background and legacy. The main challenges faced through this research line with the higher acknowledged impact on industrial practice are presented in the following.

The first is based on the extension of traditional statistical learning techniques, such as regression and clustering, to data observed in the form of profiles, i.e., functions varying over a continuum. Along this line, novel and more interpretable estimators for functional regression coefficient functions [15, 16] as well for functional cluster analysis are developed [17]. These methods are then applied to map a resistance spot welding (RSW) process in the automotive industry where online sensor data in the form of profiles could be used in place of destructive off-line tests. Moreover, an extended version of regression stacking is developed to address the forecasting of electricity demand at the individual household level for future grid management systems [18].

The second challenge is the development of methods that, to the best possible extent, are insensible to the presence of anomalous observations, which almost always affect the analysis of industrial data and the relative process monitoring, especially in complex and high-dimensional settings. On this path, the well-known analysis

of variance method is extended in a non-parametric framework able to mitigate the influence of outliers, ensuring more accurate and reliable data interpretation in real-world applications such as the additive manufacturing process [19].

The same applies to statistical process monitoring (SPM), which represents the third challenge, where a novel approach, called the robust multivariate functional control chart (RoMFCC), is developed for the multivariate profile monitoring of an RSW process when functional outliers contaminated at least one multivariate functional component. The RSW process was also the motivating case study for the development of efficient monitoring schemes, named adaptive multivariate functional EWMA (AMFEWMA) control chart. Within the SPM challenge and the activities of the industrial engineering department, the SFERe group was called to develop a real-time monitoring procedure for CO_2 emissions in maritime transportation and integrate information, usually available, on mission profile and operating conditions in the form of functional data [20–22]. To improve flexibility, the use of artificial neural networks (NNs) is also explored for the SPM of multiple stream processes (MSPs) through functional and non-functional multivariate data and is applied to signals characterizing systems of railway passenger vehicles. When instead the aim is only the performance comparison of two processes, which often arises in industrial production, a Bayesian control chart is developed for monitoring the ratio of Weibull percentiles [23–25].

The fourth challenge contributes to the application of process capability indices with mathematical criticism and remedies for the right design of lot sample size and critical acceptance value in variable sampling inspection schemes [26, 27].

Based on the aforementioned research lines, we list the main R packages and Python libraries developed by the research group, emphasizing their pivotal role in advancing this field and promoting research reproducibility: [R] `funcharts`; `sasfunclust`; `rofanova`; `slasso`; [Python] `NN4MSP`; `NN4OCMSP`.

2.5 Statistical Methods for the Evaluation of Automotive and Aircraft Seat Comfort

This research aims to develop statistical methods for planning and analyzing experiments in physical or virtual reality to diagnose and improve automotive and aircraft seating comfort. New comfort indexes based on seat interface pressure have been proposed as a good proxy of overall subjective comfort perceptions [28, 29].

2.6 Quality of Subjective Evaluations Expressed as Ratings or Preferences

This research proposes a metrological approach to assess the quality of subjective evaluations. In the absence of a gold standard for defining the reproducibility and the repeatability of subjective judgements, the agreement between ratings [30, 31] and the similarity between preferences are proposed as useful tools for measuring the rater's evaluative performance [32]. Through extensive Monte Carlo simulation studies, the statistical behaviour of the suggested repeatability and reproducibility measures has been investigated under different scenarios in order to provide recommendations for their correct use [33, 34].

2.7 Evaluation of Classifier Predictive Performance

The evaluation of classifier predictive performance is a relevant issue in order to assess the results of the classification process as well as to obtain a datum that must be optimized by tuning classifier parameters. In this research, the behaviour of several measures of classifier predictive performance is investigated under different class imbalance conditions [35]. The effects of class imbalance on the behaviour of the investigated classifier performance measures are assessed by comparing the performance of several machine learning algorithms in real case studies as well as with artificial datasets [36].

2.8 Deep Learning for Smart and Sustainable Agriculture

The research aims to exploit machine learning and deep learning methods to develop tools for accurate yield prediction and plant disease detection. The proposed strategies have shown higher predictive performance with respect to the conventional strategies based on destructive sampling and visual inspections, providing flexible tools that can be deployed as an aid for the sustainable management of farming activities with a positive impact on sustainability in terms of reduction of product waste, costs, labour and time.

References

1. Giorgio M, Guida M, Pulcini G (2015) A new class of Markovian processes for deteriorating units with state dependent increments and covariates. IEEE Trans Reliab 64:562–578
2. Giorgio M, Pulcini G (2019) A new age- and state-dependent degradation process with possibly negative increments. Qual Reliab Eng Int 35:1476–1501
3. Esposito N, Mele A, Castanier B, Giorgio M (2023) A new gamma degradation process with random effect and state-dependent measurement error. Proc Inst Mech Eng, Part O: J Risk Reliab 237:868–885
4. Giorgio M, Postiglione F, Pulcini G (2020) Bayesian estimation and prediction for the transformedWiener degradation process. Appl Stoch Model Bus Ind 36:660–678
5. Giorgio M, Guida M, Pulcini G (2015) A condition-based maintenance policy for deteriorating units: an application to the cylinder liners of marine engine. Appl Stoch Model Bus Ind 31:339–348
6. Esposito N, Mele A, Castanier B, Giorgio M (2023) A hybrid maintenance policy for a deteriorating unit in the presence of three forms of variability. Reliab Eng Syst Saf 237:109320
7. Erto P, Giorgio M, Lepore A (2020) The Generalized inflection S-shaped software reliability growth model. IEEE Trans Reliab 69:228–244
8. Iervolino I, Giorgio M, Polidoro B (2014) Sequence-based probabilistic seismic hazard analysis. Bull Seism Soc Am 104:1006–1012
9. Chioccarelli E, Cito P, Iervolino I, Giorgio M (2019) REASSESS V2. 0: software for single-and multi-site probabilistic seismic hazard analysis. Bull Earthq Eng 17:1769–1793
10. Greco R, Giorgio M, Capparelli G, Versace P (2013) Early warning of rainfallinduced landslides based on empirical mobility function predictor. Eng Geol 153:68–79
11. Iervolino I, Giorgio M, Chioccarelli E (2014) Closed-form aftershock reliability of damage-cumulating elastic-perfectly-plastic systems. Earthq Eng Struct Dyn 43:613–625
12. Iervolino I, Chioccarelli E, Giorgio M, Marzocchi W, Zuccaro G, Dolce M, Manfredi G (2015) Operational (short-term) earthquake loss forecasting in Italy. Bull Seism Soc Am 105:2286–2298
13. Erto P, Lepore A (2016) Best unbiased graphical estimators of location-scale distribution parameters: application to the Pozzuoli's bradyseism earthquake data. Environ Ecol Stat 23:605–621
14. Lepore A, Palumbo B, Poggi J (2022) Interpretability for industry 4.0: statistical and machine learning approaches. Springer International Publishing. ISBN: 9783031124013
15. Centofanti F, Fontana M, Lepore A, Vantini S (2022) Smooth lasso estimator for the function-on-function linear regression model. Comput Stat Data Anal 176:107556
16. Centofanti F, Lepore A, Menafoglio A, Palumbo B, Vantini S (2023) Adaptive smoothing spline estimator for the function-on-function linear regression model. Comput Stat 38:191–216
17. Centofanti F, Lepore A, Palumbo B (2023) Sparse and smooth functional data clustering. Stat Pap 1–31
18. Capezza C, Palumbo B, Goude Y, Wood SN, Fasiolo M (2021) Additive stacking for disaggregate electricity demand forecasting. Ann Appl Stat 15:727–746
19. Centofanti F, Colosimo BM, Grasso ML, Menafoglio A, Palumbo B (2023) Vantini S (2023) Robust functional ANOVA with application to additive manufacturing. Appl Stat, J R Stat Soc Ser C
20. Centofanti F, Lepore A, Menafoglio A, Palumbo B, Vantini S (2021) Functional regression control chart. Technometrics 63:281–294
21. Capezza C, Lepore A, Menafoglio A, Palumbo B, Vantini S (2020) Control charts for monitoring ship operating conditions and CO2 emissions based on scalar-on-function regression. Appl Stoch Model Bus Ind 36:477–500
22. Capezza C, Centofanti F, Lepore A, Menafoglio A, Palumbo B, Vantini S (2023) funcharts: control charts for multivariate functional data in R. J Qual Technol (2023)
23. Erto P, Pallotta G, Palumbo B, Mastrangelo CM (2018) The performance of semi-empirical Bayesian control charts for monitoring Weibull data. Qual Technol Quant Manag 15:69–86

24. Erto P, Lepore A, Palumbo B, Vanacore A (2019) A Bayesian control chart for monitoring the ratio of Weibull percentiles. Qual Reliab Eng Int 35:1460–1475
25. Erto P, Pallotta G, Mastrangelo CM (2015) A semi-empirical bayesian chart to monitor weibull percentiles. Scand J Stat 42:701–712
26. Lepore A, Palumbo B (2015) New insights into the decisional use of process capability indices via hypothesis testing. Qual Reliab Eng Int 31:1725–1741
27. Lepore A, Palumbo B, Castagliola P (2018) A note on decision making method for product acceptance based on process capability indices Cpk and Cpmk. Eur J Oper Res 267:393–398
28. Vanacore A, Lanzotti A, Percuoco C, Capasso A, Vitolo B (2019) Design and analysis of comparative experiments to assess the (dis-)comfort of aircraft seating. Appl Ergon 76:155–163
29. Vanacore A, Lanzotti A, Percuoco C, Capasso A, Vitolo B (2021) A model-based approach for the analysis of aircraft seating comfort. Work 68:S251–S255
30. Vanacore A, Pellegrino MS (2018) RRep: a composite index to assess and test rater precision. Qual Reliab Eng Int 34:1352–1362
31. Vanacore A, Pellegrino MS (2019) Checking quality of sensory data via an agreement-based approach. Qual Quant 53:2545–2556
32. Vanacore A, Pellegrino MS, Marmor YN, Bashkansky E (2019) Analysis of consumer preferences expressed by prioritization chains. Qual Reliab Eng Int 35:1424–1435
33. Vanacore A, Pellegrino MS (2022) Benchmarking procedures for characterizing the extent of rater agreement: a comparative study. Qual Reliab Eng Int 38:1404–1415
34. Vanacore A, Pellegrino MS (2022) Robustness of κ-type coefficients for clinical agreement. Stat Med 41:1986–2004
35. Vanacore A, Pellegrino MS, Ciardiello A (2022) Fair evaluation of classifier predictive performance based on binary confusion matrix. Comput Stat 1–21
36. Vanacore A, Pellegrino MS, Ciardiello A (2023) Evaluating classifier predictive performance in multi-class problems with balanced and imbalanced data sets. Qual Reliab Eng Int 39:651–669

Electrical Power Systems

Davide Lauria and Domenico Villacci

Abstract The chapter describes the characteristics of the research unit of Electrical Energy Systems, affiliated to the DII, which has been progressively consolidated since the end of 2014. Both the research activities in the thematic areas of the disciplinary scientific sector and those integrated with multiple areas of study and research of the DII Department are summarized.

1 Introduction

The research unit of Electrical Energy Systems, affiliated to the DII, has gradually consolidated since the end of 2014 with the affiliation of a full professor to the Department. Starting from 2017, two associate professors joined the unit and finally in October 2021 there was the affiliation of a full professor from another university. The unit carries out research activities in the thematic areas of the disciplinary scientific sector, also trying, however, to carry out research activities integrated with more fields of study and research, which are specific of the DII Department. Only the main topics of research that were addressed in the interest period are reported below.

2 Background and Legacy

The research unit that was progressively established in the Department of Industrial Engineering, before the foundation of the latter, was incardinated in the Department of Electrical Engineering which merged into the Department of Electrical

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Engineering and Information Technology. The research unit of the Gruppo Sistemi Elettrici was headed by Prof. Francesco Gagliardi who was also President of the Gruppo Nazionale Sistemi Elettrici and President of AEIT. The Group carried out intense research activity in the sectors of the production, transmission, distribution and use of electricity. Alongside these traditional sectors of electrical plant engineering, a prestigious school of electrical system reliability established itself, which began with Prof. Gagliardi and Prof. Mongelluzzo, the latter who died prematurely.

3 Evolution

As already highlighted in the introduction, the Group is progressively structured starting from the affiliation of Prof. Lauria to DII who has begun to carry out a collaborative activity with the Course of Studies in Naval Engineering.

In particular, after having held the course of electrical transportation systems (6 CFU) he held the course of Naval Electrical Systems (9 CFU). The Naval Electrical Systems Course was then held by prof. Fantauzzi, who joined the department in 2017. Prof. Fantauzzi interacts with the teachers of the naval area also through the spin-off Dedalo. Also Prof. Chiodo contributed to the Course of Studies in Naval Engineering by teaching for two academic years the course of Probability and Statistics (9 CFU), also attended by students of Civil Engineering, Management Engineering and more Engineering programs. They carried out a didactic activity for the Electrical Engineering, Mechanical Engineering and Electronic Engineering Study Courses.

Since 2021 the group has grown by one unit with the affiliation to the DII of prof. Villacci who is President of the Ensiel Consortium which has, among other purposes, the one of promotion and coordination of studies and researches in the field of Energy, Systems and Electrical Installations, in accordance with national and international research programmes. He has over 25 years of experience in the various sectors of Electrical Energy Systems, with theoretical and experimental studies carried out in collaboration with research groups universities, both national and international, and with important industrial realities, as TERNA; ENEL; EDISON; ATOS-ORIGIN; ANSALDO; RSE; CNR; ENEA, CNR, CEI, Eni Enrico Mattei Foundation (FEEM), European Network Transmission System Operators (ENTSO), Mediterranean Transmission System Operators, Mediterranean Regulators (MEDREG).

4 Main Research Programs

The research group continued to address reliability issues of electrical systems. This is a research topic that has strongly characterized the electrical energy systems sector of the University of Naples in the past. The activities carried out, in continuity with what was carried out in the past, addressed the development of innovative methodologies for the reliable description of electrical components and electrical systems [1–3].

The research unit of the electrical systems group has paid great attention to problems relating to electrical systems characterized by a high rate of technological innovation [4–9]. More specifically, the problems of integrating storage systems and generation systems from renewable sources in electrical distribution and isolated systems were addressed.

The research unit of the electrical systems group has carried out an intense activity on the estimation and control of interconnected electrical systems [10–14]. Particularly relevant results have been achieved in the problem of estimating inertia in the face of the impact of the growing penetration of renewable sources. As many significant results have also been achieved in the estimation of the electro-mechanical oscillations of the interconnected systems. Some activities were carried out in collaboration with Terna, through the formalization of Research Agreements.

5 Awards

- Elio Chiodo was included in the ranking drawn up by the international scientific journal Plos Biology relating to the 2% of world researchers most evaluated on the basis of scientific impact and in it he appears among the Professors of University of Naples Federico II taken into consideration throughout their career.
- Davide Lauria is co-author of the paper: "Experimental evaluation of model-control strategies of sodium-nickel chloride battery plus supercapacitor hybrid storage systems for urban electric vehicles", which received the award 2017 Best ICAE paper (co-authors C. Capasso, O. Veneri).
- Davide Lauria is co-author of the paper: "Three winding transformers for smart power substations", which received the award for the best paper presented at the International Conference on Modern Power Systems (MPS'2019), Cluj-Napoca, Romania, 21st–23rd May 2019, (co-authors G. Celentano, L.P. Di Noia, E. Rizzo).

6 Future

For the future, the research group expects to develop more and more activities fully framed in the research themes of the disciplinary scientific sector, linking them with those of other scientific skills with a view to achieving the general objectives of the energy transition and environmentally sustainable plants. The group will try, as far as is possible, to promote researches that are fully framed with national and international research programs and to encourage collaboration with other universities, research institutions and industrial partners both national and international. The group will also try to promote and encourage educational initiatives aimed at advanced training within Electric Energy Systems, including masters in collaboration with prestigious industrial partners.

References

1. Chiodo E, Lauria D (2015) Some basic properties of the failure rate of redundant reliability systems in industrial electronics applications. IEEE Trans Ind Electron 62:5055–5062. ISSN: 0278-0046. https://ieeexplore.ieee.org/document/7042841
2. Spertino F, Chiodo E, Ciocia A, Malgaroli G, Ratclif A (2021) Maintenance activity, reliability, availability, and related energy losses in ten operating photovoltaic systems up to 1.8 MW. IEEE Trans Ind Appl 57:83–93. ISSN: 0093-9994. https://ieeexplore.ieee.org/document/9226462
3. Chiodo E, De Falco P, Di Noia LP (2022) Probabilistic Modeling of Li-Ion battery remaining useful life. IEEE Trans Ind Appl 58:5214–5226. ISSN: 0093-9994. https://ieeexplore.ieee.org/document/9763429
4. Balsamo F, Capasso C, Lauria D, Veneri O (2020) Optimal design and energy management of hybrid storage systems for marine propulsion applications. Appl Energy 278:115629. ISSN: 0306-2619. https://www.sciencedirect.com/science/article/pii/S0306261920311326
5. Capasso C, Lauria D, Veneri O (2018) Experimental evaluation of model-based control strategies of sodium-nickel chloride battery plus supercapacitor hybrid storage systems for urban electric vehicles. Appl Energy 228:2478–2489. ISSN: 0306-2619. https://www.sciencedirect.com/science/article/pii/S030626191830758X
6. Fantauzzi M, Lauria D, Mottola F, Scalfati A (2017) Sizing energy storage systems in DC networks: a general methodology based upon power losses minimization. Appl Energy 187:862–872. ISSN: 0306-2619. https://www.sciencedirect.com/science/article/pii/S0306261916316282
7. Coppola T, Fantauzzi M, Lauria D, Pisani C, Quaranta F (2016) A sustainable electrical interface to mitigate emissions due to power supply in ports. Renew Sustain Energy Rev 54:816–823. ISSN: 1364-0321. https://www.sciencedirect.com/science/article/pii/S1364032115011867
8. Chiodo E, Lauria D, Mottola F, Pisani C (2016) Lifetime characterization via lognormal distribution of transformers in smart grids: design optimization. Appl Energy 177:127–135. ISSN: 0306-2619. https://www.sciencedirect.com/science/article/pii/S0306261916306171
9. Lauria D, Coppola M (2014) Design and control of an advanced PV inverter. Sol Energy 110:533–542. ISSN: 0038-092X. https://www.sciencedirect.com/science/article/pii/S0038092X14004800
10. Gatta FM, Lauria D, Quaia S, Lauria S (2023) Analytical methods for series compensation of a transmission line. Int J Electr Power Energy Syst 145:108647. ISSN: 0142-0615. https://www.sciencedirect.com/science/article/pii/S0142061522006433
11. Carlini EM, Del Pizzo F, Giannuzzi GM, Lauria D, Mottola F, Pisani C (2021) Online analysis and prediction of the inertia in power systems with renewable power generation based on a minimum variance harmonic finite impulse response filter. Int J Electr Power Energy Syst 131:107042. ISSN: 0142-0615. https://www.sciencedirect.com/science/article/pii/S0142061521002817
12. Allella F, Chiodo E, Giannuzzi G, Lauria D, Mottola F (2020) On-line estimation assessment of power systems inertia with high penetration of renewable generation. IEEE Access 8:62689–62697. ISSN: 2169-3536. https://ieeexplore.ieee.org/document/9049426
13. Bonavolontà F, Di Noia LP, Liccardo A, Tessitore S, Lauria D(2020) A PSO-MMA method for the parameters estimation of interarea oscillations in electrical grids. IEEE Trans Instrum Meas 69:8853–8865. ISSN: 0018-9456. https://ieeexplore.ieee.org/abstract/document/9107075
14. Giannuzzi G, Lauria D, Pisani C, Villacci D (2015) Real-time tracking of electromechanical oscillations in ENTSO-e continental European synchronous area. Int J Electr Power Energy Syst 64:1147–1158. ISSN: 0142-0615. https://www.sciencedirect.com/science/article/pii/S0142061514005675

Real Estate Appraisal

Vincenzo Del Giudice

Abstract This chapter summarizes the research activities and main outcomes of the unit engaged in the fields of Real Estate Appraisal, in the decade 2013–2023, concerning the development of methodologies for the evaluation of programs/plans/projects, as well as the assessment of economic value of assets and rights, or the rates of return in public and private decision-making processes.

1 Introduction

The contents of the scientific-disciplinary sector (S.S.D.) of Real Estate Appraisal concern the development of methodologies for the evaluation of programmes/plans/projects, as well as the assessment of economic value of assets and rights, or the rates of return in public and private decision-making processes. The discipline includes both economic and financial analysis techniques (ACR and ACB) for the assessment of private and social convenience of investments in the construction, civil, industrial, environmental and energy fields throughout the entire useful life cycle of the assets, and approaches integrated and systemic (ACB and AMC), also supported by spatial analysis techniques, for environmental and economic-social assessments of programmes/plans/projects on natural and territorial resources, historical-architectural and landscape assets, in a logic of sustainable development. Main topics covered by this S.S.D. include Civil and Industrial Appraisals, Economic Evaluation of Investments, Sustainability Evaluation of Plans/Programmes/Projects.

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2 Background and Legacy

The research unit that was progressively established in the Department of Industrial Engineering, which absorbed the existing Department of Economic and Management Engineering, is headed by Prof. Vincenzo Del Giudice who is the national Decan in the Real Estate Appraisal sector and was also co-founder of Italian Society of Real Estate Appraisal and Economic Evaluation of Projects. The research Group is currently completed only by Prof. Pierfrancesco De Paola, and carried out intense research activity in the fields of real estate appraisals and evaluations, financial and economic analyzes of projects, estimates of real rights and damages to real estate and environmental resources.

3 Evolution

The research unit develop teacher activities in the Course of Studies of Management Engineering, Building Engineering, Building Engineering-Architecture, Digital Technologies for Construction. Initially, Prof. Vincenzo Del Giudice has coordinated over time the several course of the scientific-disciplinary sector, supported by Prof. Giovanni D'Alfonso and Prof. Francesca Torrieri for the courses in Real Estate Appraisal and Law, Economy and Real Estate Appraisal, Urban Economy and Real Estate Appraisal, Principles of Economy and Environmental Appraisal. After retirement of Prof. Giovanni D'Alfonso, and until 2023, Prof. Del Giudice, Torrieri and De Paola (the latter, structured since 2019 in the Department) were holders of courses, each to the extent of its competence, of Real Estate Appraisal and Professional Exercise, Economy and Real Estate Appraisal, Real Estate Appraisal, Corporate and Industrial Appraisal. At the date of publication of this volume, the research unit is reduced to just Prof. Del Giudice and De Paola. The members of the unit have always worked in synergy with each other. The current unit's members are the reference in the field of Real Estate Appraisal for many public and private institutions of primary importance, both at regional and national level, with the purpose of formulating advice and technical-appraisal assessments.

4 Main Research Programmes

The research unit mainly addressed the implementation of mass-appraisal type statistical-estimative models, which can also be used for the purposes of urban land registers, and also with regard to possible uses in problems of enhancement and redevelopment of territorial areas on an urban scale. This having regard to the different requirements for the use of valuation techniques found in the most recent international experiences and with reference to the issues of interest for real estate markets,

verifying in particular the applicability of the models implemented starting from small real estate samples. The research unit has paid great attention to the following specific topics: the analysis of the real estate market through the construction of estimate models [1–10]; the evaluation of investments with particular attention to the double perspective of public and private evaluation [11]; the relationship between evaluation and project/plan [12].

5 Awards

Pierfrancesco De Paola is co-author of the paper: "Rethinking design and urban planning for the cities of the future", which received the award in 2019 for the 2017 Best Paper by Buildings international journal (co-author: Thomas L. Saaty) [12].

6 Future

In recent years, problems concerning real estate sector have grown very quickly. Therefore, in-depth knowledge of this sector is highly relevant for real estate predictions, investments, and taxation issues. Increasingly important is an expansion of theoretical and empirical research on real estate sector using the paradigms and methodologies of finance and economics. The real estate sector requests accurate tools and approaches useful for stakeholders that pursue several objectives such as keeping real estate values under control or updating their profitability returns. For these reasons, the interpretation of real estate phenomena is a critical issue together with its evolution and dynamism, and at the same time appropriate techniques are required to be able to analyze adequately the characteristics of the real estate sector. Under this last profile, Prof. Del Giudice and De Paola represent the current excellence in the national research landscape. Valuable examples of these new tools and approaches are provided by the selected papers, the main aim of which was to investigate and expand the frontiers of knowledge that cover all areas of real estate economics, management and investments.

References

1. Del Giudice V, De Paola P, Forte F (2016) The appraisal of office towers in bilateral monopoly's market: evidence from application of Newton's physical laws to the directional centre of Naples. Int J Appl Eng Res 11:9455–9459. ISSN: 0973-4562
2. Morano P, Tajani F, Del Giudice V, De Paola P, Di Liddo F (2022) An evaluation method for searching the functional relationships between property prices and influencing factors in the detected data. Int J Bus Data Min 21:23–47. ISSN: 1743-8195

3. Del Giudice V, De Paola P, Manganelli B, Forte F (2017) The monetary evaluation of environmental externalities through the analysis of real estate prices. Sustainability 9. ISSN: 2071-1050
4. Del Giudice V, De Paola P, Forte F (2017) Using genetic algorithms for real estate appraisal. Buildings 7. ISSN: 2075–5309
5. Del Giudice V, De Paola P, Forte F, Manganelli B (2017) Real estate appraisals with Bayesian approach and Markov chain hybrid Monte Carlo method: an application to a central urban area of Naples. Sustainability 9. ISSN: 2071–1050
6. Del Giudice V, Manganelli B, De Paola P (2017) Hedonic analysis of housing sales prices with semiparametric methods. Int J Agric Environ Inf Syst 8:65–77. ISSN: 1947-3192
7. Del Giudice V, De Paola P, Cantisani G (2017) Rough set theory for real estate appraisal: an application to directional district of Naples. Buildings 7. ISSN: 2075-5309
8. Manganelli B, De Paola P, Del Giudice V (2018) A multi-objective analysis model in mass real estate appraisal. Int J Bus Data Min 13:441–455. ISSN: 1743-8195
9. Del Giudice V, Salvo F, De Paola P (2018) Resampling techniques for real estate appraisals: testing the Bootstrap approach. Sustainability 10:3085. ISSN: 2071-1050
10. Del Giudice V, De Paola P, Bevilacqua P, Pino A, Del Giudice F (2020) Abandoned industrial areas with critical environmental pollution: evaluation model and stigma effect. Sustainability 12:5267. ISSN: 2071-1050
11. Del Giudice V, De Paola P, Cantisani G (2017) Valuation of real estate investments through Fuzzy Logic. Buildings 7. ISSN: 2075-5309
12. Saaty T, De Paola P (2017) Rethinking design and urban planning for the cities of the future. Buildings 7. ISSN: 2075-5309

The Project for the Excellence: A Guide for the Next Decade

Nicola Bianco

Abstract This chapter presents the main lines of the project submitted during the procedure for getting the excellence seal for the year 2023–2027. It is centered around the energy transition, sustainable mobility and the analysis of the new industrial systems more compliant with the environmental challenges.

The Italian National Agency for the Evaluation of the University System and Research (ANVUR) evaluated DII research products over the period 2015–2019, ranking it among the top 350 departments nationwide. These departments had the chance to apply for getting the seal of Excellence, which would have seen the top 180 departments as winners. DII then applied for Department of Excellence by submitting a project that was ranked sixth in the CUN 09 area (excluding phase 1 projects) with a score of 97/100 and getting funding for an amount of about 11 million euros over the period 2023–2027.

1 Before the Project for the Excellence

1.1 Some Numbers

DII has a strongly multidisciplinary composition, gathering contributions from faculty members belonging to numerous Scientific Disciplinary Sectors, mainly located in area 09, Industrial and ICT (Information and Communication Technologies) engineering.

The amplitude of DII expertise is evidenced by the high number of research groups (28), and by a large scientific production, which in the last 3 years has resulted in about 1300 papers, of which about 60% are in international journals belonging to

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the first Scopus quartile. In VQR 2015–2019, the evaluation of DII in area 09 was overall in line with the national average (98%), with above-average peaks in some sub-areas (09/B, 09/C and 09/E).

In the decade, the activity of the professors and researchers has resulted in more than 100 research projects with a total economic value of more than 25 million euro, including:

⋆ 24 H2020 projects (about 9 MEur),
⋆ 22 MIUR PON projects (about 8 MEur),
⋆ 11 PRIN projects (more than 1 MEur),
⋆ more than 5 MEur from regional calls.

To date, 39 projects are active, for a total amount of more than 11 MEur.

More than half of the obtained funding comes from projects related to energy transition and sustainable mobility, as well as the dissemination of green and digital skills: only in the last three years, 14 projects have been launched under

- ESF (European Social Fund),
- FISR (Fondo Integrativo Speciale per la Ricerca),
- H2020,
- MISE (Ministero dello Sviluppo Economico),
- MITE (Ministero della Transizione Ecologica),
- PON (Programma Operativo Nazionale),
- PRIN (Progetti di Rilevante Interesse Nazionale),
- PNRR (Piano Nazionale di Ripresa e Resilienza).

1.1.1 Laboratories

The previously cited activities are characterized by a marked experimental approach: both light and heavy laboratories are a great asset for DII.

Nevertheless, they are not always adequately equipped for a large-scale and synergistic experimentation of new technologies in the already mentioned sectors, and they are lacking from the point of view of integrating digital technologies, which, on the other hand, represent an opportunity to expand simulation and experimentation capabilities through the implementation of hybrid, hardware-in-the-loop type systems.

1.1.2 Educational Offerings

DII has a very wide and varied educational offering, with

– 6 bachelor's degree courses and
– 7 master's degree courses,
– with a total of about 7000 enrolled students.

The educational offerings include two Ph.D. programs and an Erasmus Mundus Joint master's degree on Sustainable Ship and Shipping (https://www.master-seas40.unina.it/about-seas-4-0/).

1.1.3 Internationalization

The internationalization became one of the cornerstones of the development plan, by increasing the number of international agreements (34), the Erasmus agreements (73) and activating a master's degree completely in English on the topic of Autonomous Vehicles (Autonomous Vehicle Engineering); this represents a unique case on the national territory and with few equals even at an international level.

However, internationalization is still a weakness point for the department educational offerings. This critical issue is also confirmed in the Ph.D. courses incardinated in DII, where the percentage of doctoral students with degrees obtained abroad is only 6%.

It has to be highlighted that the DII is now a member of the T.I.M.E. Association (*Top International Managers in Engineering*): this will open to great opportunities for the exchanges of students, academic staff and officers as well as the design of joint academic initiatives https://timeassociation.org.

1.1.4 Public Administration

DII has a consolidated experience in relationships with companies and the Public Administration.

To date, DII has carried out more than 400 third-party services, almost 40% of which in the last three years, for a total amount of more than 12 million euro.

1.1.5 Spin-Offs and Patents

DII faculty members have been the promoters of 16 spin-offs, having as their object the design and implementation of high-tech hardware and software solutions for monitoring, diagnostics, and improvement of industrial processes in the naval, mechanical, aerospace and robotic sectors. It has to remarked also that some of the spin-offs are focused on themes of energy transition and sustainable mobility.

Finally, a total of 19 patents have been published and filed with at least one DII author from 2013 to date, including 7 in the last three years.

1.2 Points of Strength and Weakness

The starting point was to highlight the points of strength and weakness with a deep degree of self-evaluation.

Based on the scenario outlined, This lead to the following points of strength:

- Strong multidisciplinary vocation and breadth, and contiguity of expertise on the topics of energy transition and sustainable mobility.
- Solid links with the national and international industrial net.
- Participation in numerous national and international competitive project calls.
- Amplitude and completeness of the educational offerings

These are points of weakness:

- Few broad interdisciplinary projects that promote collaborations between SSDs.
- Weak international attractiveness of the educational offerings.
- Lack of instrumental equipment that promotes synergies between different research groups and directs a more "digital" approach to experimentation.

DII has grown significantly from the point of view of research quality, but there was the need to introduce interdisciplinary initiatives, which, driven by the scientific excellence of the Department, ensure its overall development well centered on challenges of interdisciplinary interest with highest possible economic and social impacts.

Thus, it is natural to consider the topics of energy transition and sustainable mobility as strategic areas for the development of DII, in which it can benefit from a broad and well-established theoretical, numerical, and experimental skills base. As proof of this, it can be considered the consistent participation of DII research groups in projects funded on these topics under the PNRR, as well as its high ability to attract funding through competitive research projects.

These elements are defined in the three-years Development Plan 2021–2023, "Youth for a Future DII Excellence",[1] in which DII has identified development opportunities in the themes of energy transition and sustainable mobility, with the aim of achieving excellence by focusing on young students, researchers, and professors to improve the quality of teaching, research, and third mission.

The Departments of Excellence program therefore represents a valuable opportunity for DII to strongly relaunch itself toward these challenges as summarized in the next section.

[1] http://www.dii.unina.it/source/piano-di-sviluppo-dii-2021-2023-definitivo.pdf, in Italian.

2 The Project for the Excellence

2.1 Main Points

DII intends to consolidate the following aspects of the Next Generation EU project: *energy transition and sustainable mobility*.

The development program aims at strengthening the excellence of DII, enhancing its multidisciplinary vocation in several areas:

- *increase qualitatively and quantitatively the scientific production*;
- *increase the knowledge on strategically relevant research topics*;
- *rank itself in the research laboratories network, in an equal position with other laboratories recognized as internationally excellent*;
- *improve the internationalization of highly qualified teaching*.

To reach the cited objectives, the following actions are scheduled:

A1 Creation of a *department task force* that will see the involvement of professors and researchers already active at DII, supplemented by specially recruited personnel, with the aim of introducing specific skills complementary to the existing ones.

A2 Realization of a new dedicated laboratory that would give a considerable support to increase the excellence level of the research activities, facilitating the participation in competitive calls and increasing the possible activities of technology know-how transmission and collaboration with companies.

A3 Introduction of incentives for the involved staff, which will be recognized according to criteria shared with the department, rewarding their contribution to the improvement of DII performance.

A4 Strengthening of learning activities of the Ph.D. program, by establishing an International Doctoral School, stimulating with incentives the participation of students from other national and abroad universities, encouraging the participation of highly qualified professors, foreign and/or from the corporate world, and financing the international mobility of doctoral students, incoming and outgoing.

A5 Implementation of a recruitment plan aimed at integrating the numerous and qualified skills already available with others that are complementary and strategic in order to achieve the scientific goals of the development plan.

2.2 Future Research Infrastructures

Some new infrastructures will improve the execution of research activities with the aim to increase knowledge, promote products and innovative solutions in the following fields:

R1 propulsion systems with low environmental impact in the automotive, aeronautical, naval, railway sectors, powered by hydrogen, bio-fuel and electricity.
R2 the integration of the aforementioned propulsion systems into their relative users;
R3 energy efficiency and the use of renewable sources, hydrogen and bio-fuels in the industry, the tertiary and the residential sectors.

The laboratory will thus enable the development and validation of new technologies for reducing fuel consumption and pollutant emissions, to support the energy transition and the sustainable mobility, through:

L1 a test bench, which will enable the use of different types of green fuels and energy vectors (e.g., hydrogen, methanol, ammonia, NG) to power Fuel Cells (FC) and/or alternative engines (H2-MACI) equipped with electrical and thermal energy storage systems (for co-generation purposes);
L2 a platform for virtual prototyping of complex models, interconnected to the previous one, capable not only to develop the corresponding "digital twin" of the system, but to control it interacting with the hardware.

2.3 Future Teaching Activities

The project includes the improvement of tertiary education to enhance the young talents emerging from these educational paths.

In detail, it is intended to achieve the goal of improving the attractiveness and internationalization of the Ph.D. program through specific actions, which concern both the training and mobility of students:

TA1 Funding of an Intensive International Ph.D. School and teaching initiatives to be permanently included in the educational offer of doctoral programs incardinated therein.
TA2 Funding of international mobility of doctoral students, incoming and outgoing, through co-tutoring agreements with foreign universities.

In line with the development program, teaching initiatives will focus on the topics of the energy transition and the sustainable mobility and their impacts on the society, with an inclusive and participatory approach.

Courses will be taught by DII professors and international experts, in business and academic fields, invited as Visiting, for periods consistent with the scheduled initiatives.

3 A Final Word

This concluding chapter has provided a brief overview of the project funded for the years 2023–2027. However, it is not just a plan for the immediate future; it lays the

groundwork for the coming decade and represents a milestone for our community's advancement on a global scale.

In wrapping up this book, it's essential to consider the individuals involved. The achievements of the Dipartimento di Ingegneria Industriale can be gauged through internationally recognized benchmarks and the number of projects secured. Nevertheless, these metrics only tell part of our story. Equally important are intangible factors like the enthusiasm of our young researchers, the experience of our senior professors, and the steadfast commitment of an expanding group of contributors. While these qualities cannot be easily quantified, they resonate in our day-to-day interactions.

One of the most profound lessons learned over the past decade is the realization that our most valuable assets are the people themselves. This truth transcends roles and ages.

Central to our success is the recognition and celebration of each individual's unique qualities, as well as the encouragement of open exchange of ideas and knowledge among all members of our community.