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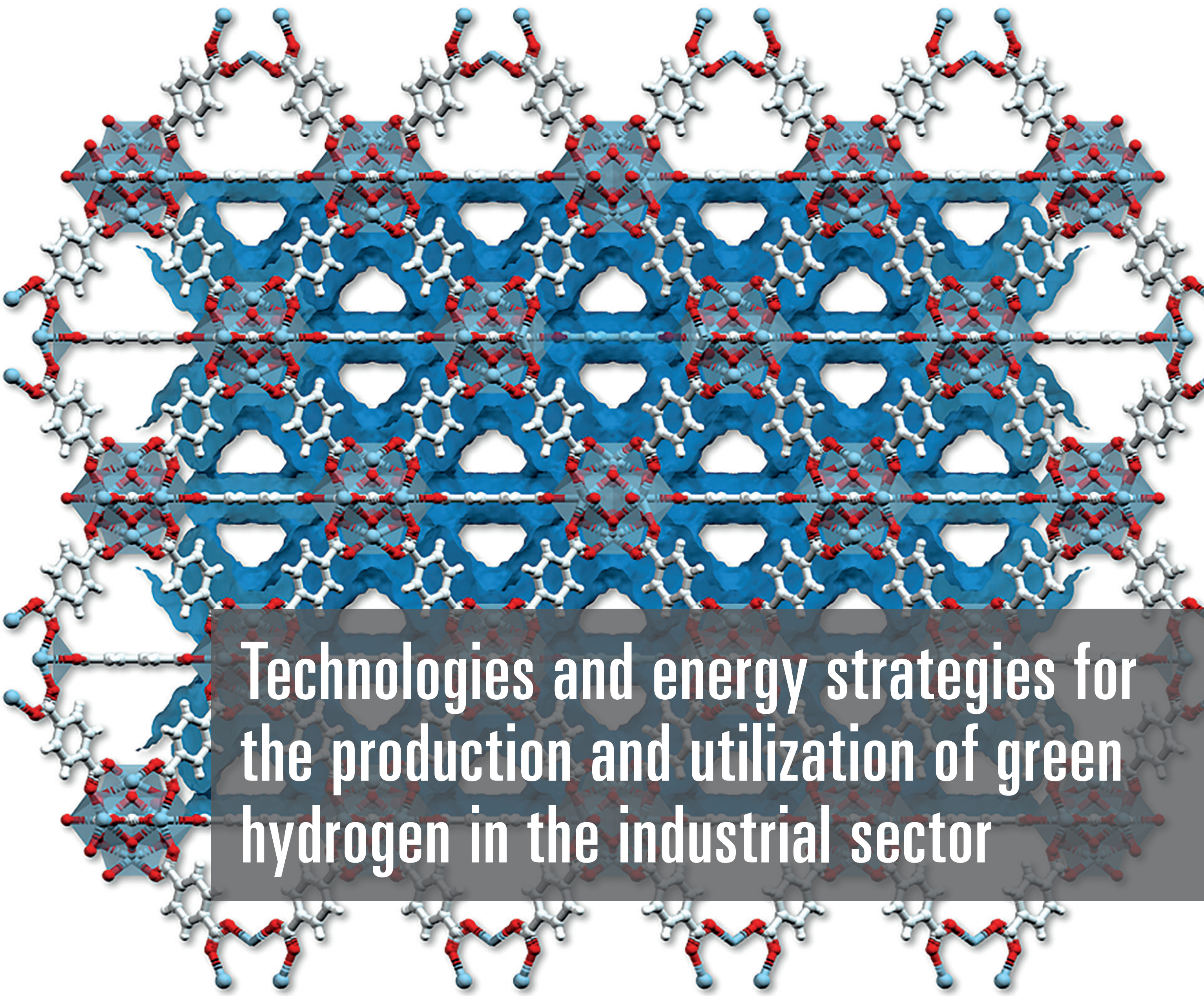
NEWSLETTER DEL DIPARTIMENTO DI INGEGNERIA INDUSTRIALE DELL'UNIVERSITÀ DEGLI STUDI DI PADOVA



Technologies and energy strategies for the production and utilization of green hydrogen in the industrial sector

DIPARTIMENTO DI INGEGNERIA INDUSTRIALE

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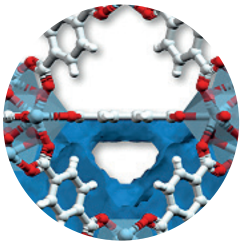
UNIVERSITÀ DEGLI STUDI DI PADOVA



COPERTINA

Tecnologie e strategie energetiche per la produzione e l'utilizzo di idrogeno verde nel settore industriale

Technologies and energy strategies for the production and utilization of green hydrogen in the industrial sector

PAGINA

DIPARTIMENTO
DI INGEGNERIA
INDUSTRIALE

Modeling transport and evaporation of droplets dispersed in turbulent flows

Sistemi aerospaziali

Aerospace systems

DII research group
FLUids: Modelling and Simulation (FLUMS)

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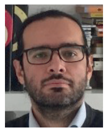

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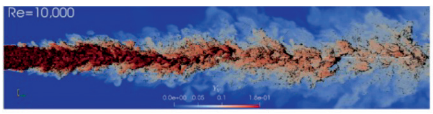
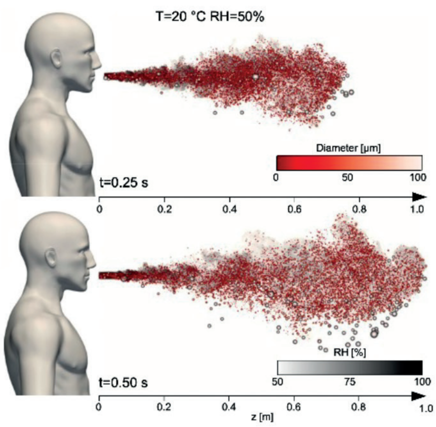
In the aerospace field, turbulent sprays of fuel droplets are always at the basis of liquid-fuel-based internal combustion engines. Sprays composed of millions of fuel droplets are injected into combustion chambers where vaporization and oxidation take place. In these applications, a better control of the involved phenomena, such as evaporation, pyrolysis and pollutant formation, would be critical to develop low-emission and green engines for planes, as well as for liquid rocket engines. The major difficulties of predicting the behaviour of such flows rely on the multiscale nature of turbulence, with vortical structures ranging from the problem macroscopic scale (meters) down to the dissipative length scale (microns), coupled with the presence of multiple interacting phases. In this context, the development of accurate models for the transport and vaporization of dispersed phases in turbulent flows is of crucial relevance for more efficient and greener processes. In addition to aerospace applications, such models can be useful in several different fields. An example relies on the transport of particulate pollutants within urban centres (e.g., PM10). In this case, the pollutants, consisting of a mixture of liquid and solid particulate of different sizes, are carried by the turbulent wind through the complex geometries defined by buildings and may deposit on walls or remain suspended in the air. Another relevant example is the transport of respiratory droplets in closed environments which controls the propagation of respiratory diseases such as Covid-19. In these contexts, our research group is working on the development of original models for accurate simulations of the transport of liquid droplets and solid particles operated by turbulent flows. We have proposed a novel methodology for the evaluation of the evaporation of liquid droplets that has been used to estimate the typical spray vaporization length and also to propose revised guidelines for social distancing during the Covid-19 pandemic. Transport and evaporation models have been also exploited to assess the role of the swirling rate for spray injection in aerospace applications identifying the optimal parameter controlling the process.

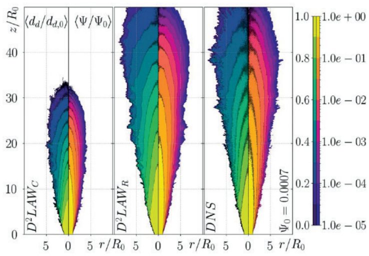
We believe that the new models developed will help not only the aerospace sector towards greener and more efficient engines but will have an impact also in the environmental and safety fields.



[1] Accurate simulation of an evaporating spray.



[2] Simulation of a sneeze of saliva droplets.



[3] Mean liquid mass fraction (right-half) and mean droplet diameter (left-half) for a dilute spray: left d2-law, middle proposed model, right reference data (DNS9.

[1]Wang, J., Dalla Barba, F., & Picano, F. (2021). Direct numerical simulation of an evaporating turbulent diluted jet-spray at moderate Reynolds number. Int. Journal of Multiphase Flow, 137, 103567

[2] Wang, J., Dalla Barba, F., Roccon, A., Sardina, G., Soldati, A., & Picano, F. (2022). Modelling the direct virus exposure risk associated with respiratory events. J ournal of the Royal Society Interface, 19(186), 20210819

[3] Dalla Barba, F., Wang, J., & Picano, F. (2021). Revisiting D2-law for the evaporation of dilute droplets. Physics of Fluids, 33(5), 051701.

Main research topics:

- Turbulent flows
- Multiphase flows
- Fluid-structure interaction
- Environmental flows
- Supersonic flows

Sistemi aerospaziali

Aerospace systems

DII research group

Flight dynamics and space systems - FLIGHTDS

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CISAS Center for Studies and Activities for Space Giuseppe Colombo

Main research topics:

- Flight Mechanics
- Aerospace flight dynamics
- Balloon and Drones Flights
- Space Systems
- Space Environment
- In orbit servicing
- Planetary Exploration

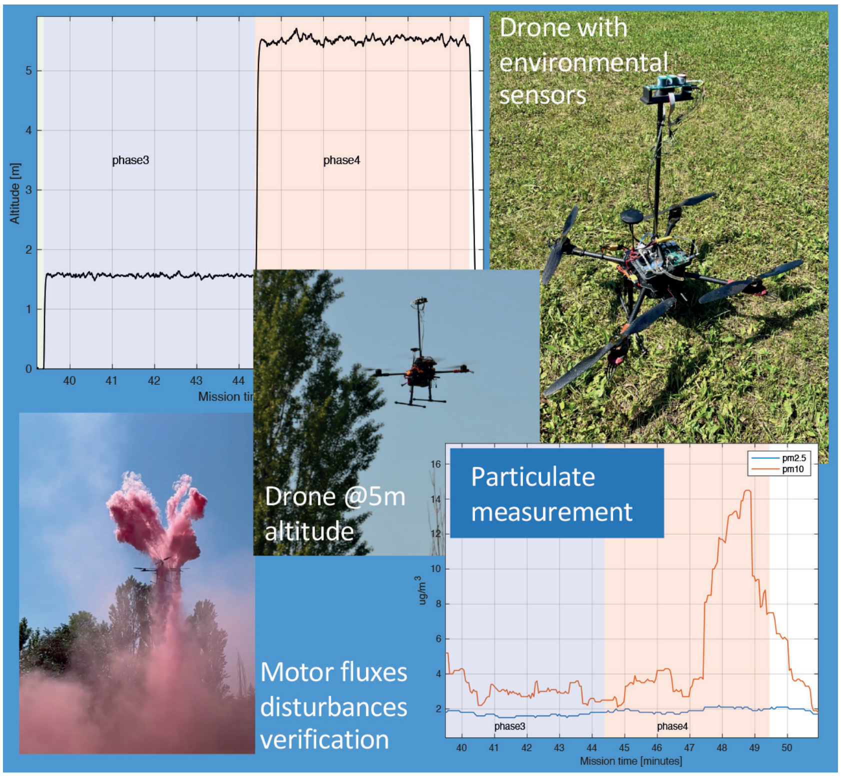
Drones for environment pollution control

Air pollution is caused by different typologies of gas pollutants that are present in the first meters (< 150m) of the atmosphere and cause damages to humans and environment. As air pollution is becoming the largest environmental health risk, the monitoring of air quality has drawn much attention in both laboratory studies and specific field tests and data collection campaigns.

The Flight Dynamics Research Group of our Department (in collaboration with other Centers and Departments of the University) is involved in the area of UAVs (Unmanned Air Vehicles) and balloons for air and atmosphere monitoring. Several UAVs and small balloons are used for research and remote sensing ranging from heavy duty octocopters to small quadcopters to sounding balloons. The available facilities (3D printers and easy to assemble drones) allow a rapid prototyping approach for the study and analysis of environments and terrains difficult to reach.

The ARIA project is a research activity started as a Student Project and now carried on by the Flight Dynamics Group in the framework of pollution studies (air and light pollution mainly). In particular, the ARIA project research is aiming to develop a monitoring system that allows for multiple contemporary measurements of areas and buildings at different heights with improved convenience and flexibility. The ARIA project solution is a low-cost monitoring system based on COTS sensors and on multiple cheap drone platforms. The system is equipped with PM2.5 and PM10 sensors for monitoring the particulate concentration at different altitude and trace the diffusion of air pollutants; several other gas sensors (such as NO, NO_2, CO, etc.) are present on a vertical stub of the UAV platform in order to sense unperturbed air.

For the flight presented here, data have been collected at 3 different heights (0m, 1.5m, 5.5m) in an open field near a high traffic area and at 1 km distance from the city airport.



Novel solutions for tracked crane electrification

Ingegneria dei Sistemi Elettrici

Electrical Systems

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Electric Drives Laboratory

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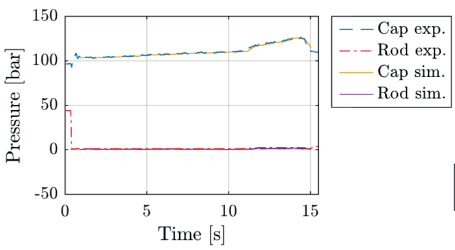
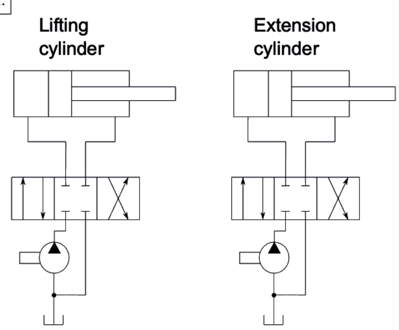
In recent years the industry is increasingly focusing on electrification of vehicles and machinery to reduce energy consumption and emissions. Energy savings are of paramount importance for battery-powered machinery, thus novel electrification solutions are being evaluated.

Among machinery, self-propelled cranes have not received adequate attention. Traditionally these machines rely on a hydraulic system, and the easiest way to electrify them is to use an electric motor to drive the hydraulic pump. This approach is not optimal as it does not fully exploit the potential of electric drives. Decentralization of the system, i.e. splitting the hydraulic system in multiple sections, each driven by a dedicated pump, is a promising solution, as it allows to reduce the losses in the hydraulic system itself. A simulation model for the estimation of the energy savings of a decentralized system was built and validated through experimental tests. The latter showed that a good modeling of the system is possible purely relying on datasheets of commercial components, without the need for time-consuming model calibration tests. A decentralized system exhibited approximately 10 to 30% energy in simulations of cycles coherent with real-world operation.

Another proposal that is currently being evaluated is the so-called electronic load sensing. Hydraulic pump flow rate and pressure can be controlled by controlling the electric motor that drives the pump, implementing strategies otherwise not possible with traditional hydromechanical control systems and simplifying the overall architecture. Energy consumption, system cost, and reliability can potentially be improved.



Comparison of simulated and experimental data



Decentralized hydraulic system

This research is developed in cooperation with Jekko cranes

Main research topics:

- Control of electric drives
- Control of grid connected converters
- Design of electric machines
- Vehicle and machinery electrification

Ingegneria dei Sistemi Elettrici

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https://github.com/DLR-VSDC/IEEE-MVC-2023

Main research topics:

- Control of electric drives
- Control of grid connected converters
- Design of electric machines
- Vehicle and machinery electrification

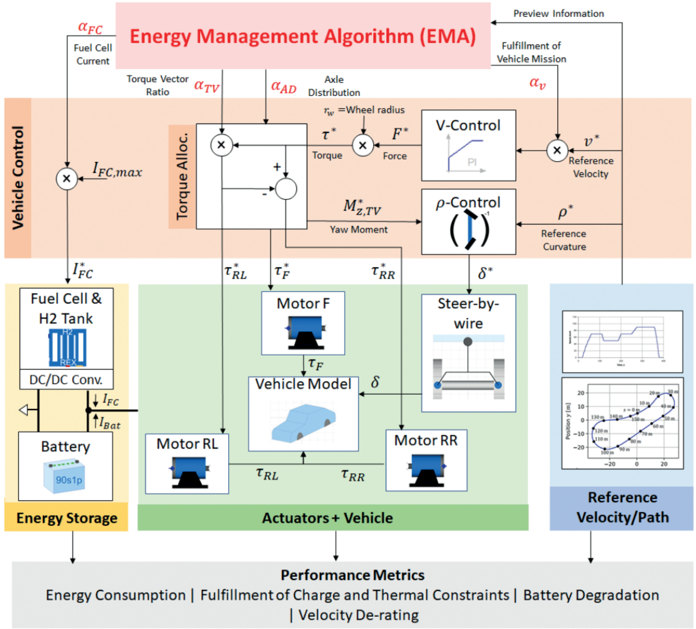
VTS Motor Vehicle Challenge 2023: The Winning Multi-physical Energy Management Algorithm

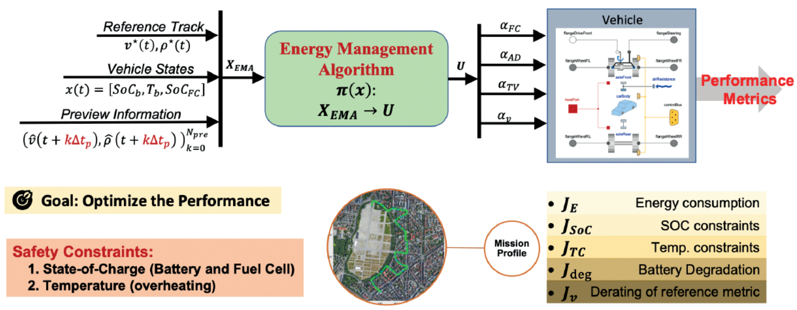
The IEEE Vehicular Technology Society (VTS) Challenge is an annual competition that aims to promote innovation in the field of vehicular technology since 2016. In recent years, the competition has grown, proposing increasingly challenging problems based on the design and optimization of an energy management system of a hybrid vehicle.

The topic of this year's edition was the optimization of a set of parameters which control the energy management system of a vehicle with multiple energy sources and electric motors. The vehicle was characterized by two in-wheel electric motors installed in the rear axle and one central front motor and was powered by a hybrid energy storage system with a fuel cell and battery.

Energy consumption, battery degradation, safety constraints and derating of the vehicle performance are the main metrics of the given cost function to be minimized. The developed algorithm aims at increasing vehicle range and enhancing performance. Torque vectoring control was also exploited.

The algorithm was validated with an extensive simulation stage. Different driving cycles which contain typical operating conditions for the vehicle were used. The effectiveness of the proposed approach is further corroborated by winning the IEEE VTS Motor Vehicle Challenge 2023.





Dual-source solar-assisted heat pump with CO_2 as refrigerant

The performance of conventional air source heat pumps is heavily dependent on operating conditions, particularly on the air temperature. On the coldest days, the energy demand increases while performance decreases due to low air temperature and defrosting cycles that are typically required. One possible alternative to conventional air-source heat pump systems can be solar-assisted heat pumps, which use solar radiation as the thermal energy source at the evaporator. Furthermore, to reduce greenhouse gas emissions, heat pumps should use refrigerants with a low environmental impact.

In this scenario, our research focuses on a novel dual-source CO_2 heat pump (Figure 1) that can operate using two different thermal sources: solar radiation and air. The schematic of the present prototype heat pump for water heating is reported in Figure 2. The heat pump system includes a compressor, a gas-cooler, an internal brazed plate heat exchanger, a low-pressure receiver and various manual valves to change between the operative modes. After the expansion device, in the solar mode, CO_2 is evaporated using photovoltaic-thermal (PV-T) collectors, while in the air mode, a conventional finned coil is used. The specifically designed PV-T evaporators ensure the evaporation of the CO_2 and simultaneously allow to cool the solar cells improving the photovoltaic conversion efficiency. An experimental comparison between the two operative modes has been done in terms of performance coefficient, which can increase up to 30% in the solar-source mode as compared to the air-source mode.

A dynamic numerical model of the system in the Matlab environment has been also developed. The simulation results allowed to develop a switching strategy between the air-source and the solar-source.

Figure 1. Heat pump prototype installed at the Solar Energy Conversion Lab

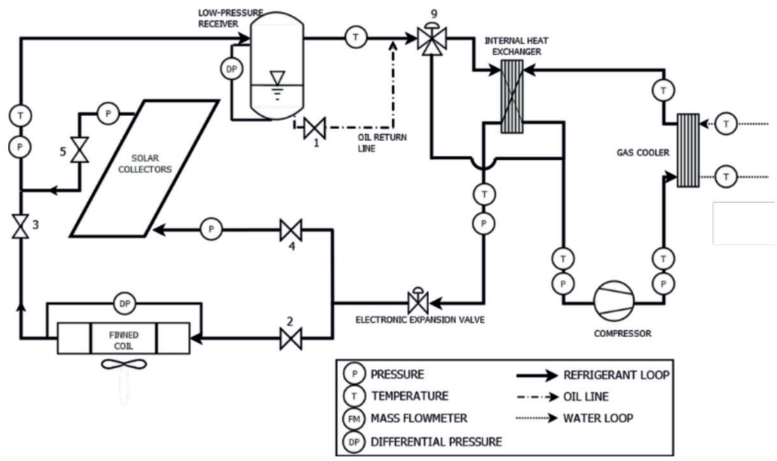


Figure 2. Schematic of the heat pump

Energia

Energy

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(cassa serivizi energetici ed ambientali).
The support of the company
ENEX srl is acknowledged.

Main research topics:

- Heat pumps
- Solar-assisted heat pump
- Low-GWP refrigerants
- Natural refrigerants
- Photovoltaic-thermal solar collectors

Processi e prodotti industriali

Industrial processes and products

DII research group

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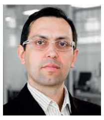

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Dipartimento di Medicina Molecolare dell'Università di Padova

Dipartimento di Ingegneria Meccanica dell'Università di Modena e Reggio Emilia

Main research topics:

- Precision engineering
- Process chain desing
- Injection molding
- Surface functionalization

Design of a process chain for the manufacturing of nano-structured bactericidal plastic parts

Antibacterial surfaces are designed to inhibit the growth and spread of bacteria on their surface. Antibacterial surfaces are becoming increasingly important due to the emergence of antibiotic-resistant bacteria and the need for effective infection control measures. Traditional methods for controlling bacterial growth, such as cleaning and disinfection, are ineffective, especially in high-traffic or difficult-to-reach areas. There are different mechanisms by which antibacterial polymeric surfaces work. Some surfaces work by releasing antimicrobial agents, such as silver or copper ions, that kill bacteria on contact. Other surfaces work by physically disrupting the cell membrane of bacteria, preventing their growth and spread. While the first method has some limitations related to their limited effectiveness in time and the long-term toxicity of metallic nanoparticles and chemical agents on humans, mechanical cues such as surface nanopatterns (NP) have been recognized to offer a significant antibacterial effect without the need for antibiotics. It has been demonstrated that more efficient solutions can be obtained using NP having a nanopillar-like structure. The most significant geometrical characteristics of the nanopillars are their spacing, height, and peak sharpness. This works aim to design and test an innovative process chain for the mass production of polymeric antibacterial surfaces. The processes involved are a particular type of laser-induced periodic surface structuring (LIPSS) to fabricate a ladder-like texture on a mold cavity surface and replicate it by micro-injection molding. Different NP geometries - obtained by varying the most significant geometrical characteristics - have been manufactured and validated. The results show that all the tested NP surfaces have bactericidal effects compared to the flat surface. The direct correlation of the bactericidal performance with the NP surface feature parameters demonstrates that larger, denser, and sharper spikes are more efficient at killing bacteria by perforating their membrane. In conclusion, the proposed process chain can manufacture large-scale, low-cost polymeric NP surfaces with optimized antibacterial properties.

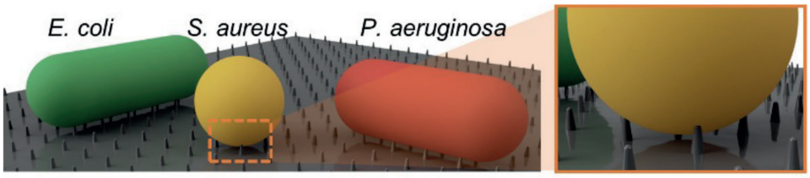

Figure 1. Schematic of the NPs bactericidal mechanism.

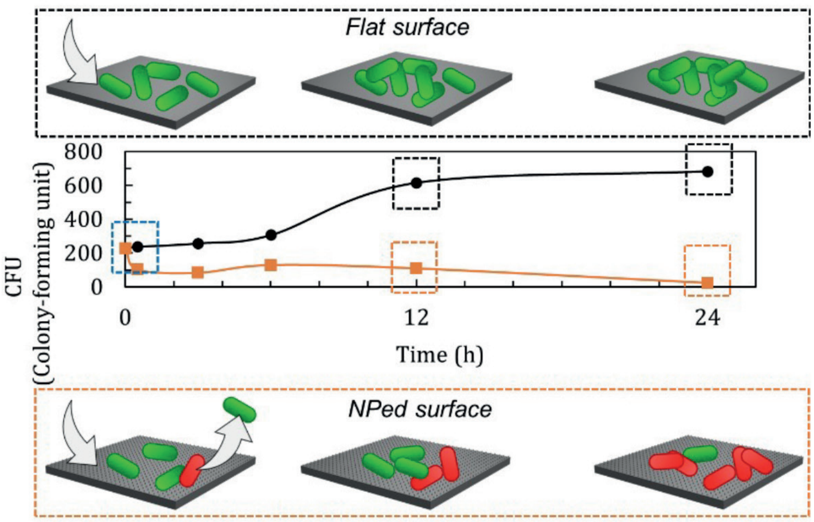

Figure 2. Bactericidal growth curve for NPs surfaces and a flat surface

Protein-rich biomass production exploiting nitrogen-fixing cyanobacteria

Cyanobacteria are emerging as promising high-nutrient food resources, in particular as protein sources. Including environmental benefits coming from photosynthetic CO_2-fixation activity and the possibility to grow on non-arable land, cyanobacteria attractive potential addresses also their ability to synthesize a vast plethora of bioactive compounds. Microalgal biomass stands out for equal or even better nutritional values when compared with vegetal biomass.

However, high production costs still strongly limit large-scale application: one of the most impacting aspects is the upstream cost linked to nutrients supply, especially to nitrogen, which is the second most abundant component in biomass (~8 wt%) and composes approximately 16 wt% of proteins. Since expensive common N-based fertilizers come almost entirely from the energy-intensive and non-environmentally friendly Haber-Bosch process, the ability of some cyanobacteria to naturally fix atmospheric dinitrogen is emerging as a more sustainable alternative.

The aim of this work is to improve protein accumulation in biomass by operating on the cultivation process. The phototrophic cultivation in continuous systems of the nitrogen-fixing species *Nostoc* PCC 7120 is presented to evaluate the effect of two main operating variables: residence time and light intensity. By working in continuous systems, it is possible to achieve high productivity but also to "select" the microorganism physiological state. It was evaluated if the process conditions could have an effect on the amount of proteins that can be produced, as well as on their quality; in particular, whether it is possible to modulate the biomass amino acid profile, linked to its nutritional values, and bioaccessibility.

Processi e prodotti industriali

Industrial processes and products

DII research group

PARLAB - Microalgae

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The research activity has been carried out in collaboration with Prof. Stefano Dall'Acqua (Department of Pharmaceutical and Pharmacological Sciences - Università degli Studi di Padova) and Dr. Fabian Abiusi (Laboratory of Sustainable Food Processing - ETH Zürich, Switzerland).
The 275L photobioreactor was provided by Lgem BV, Netherland.

Main research topics:

- Effect of light and operating variables on continuous cultivation of microalgae in Photobioreactors
- Optimization of sustainable nutrient and CO_2 supply for industrial autotrophic cultivation
- Exploitation of microalgae for Wastewater treatment and CO_2 capture
- Modelling of microalgae growth for process design and optimization
- Optimization of artificial light supply and reactor design
- Process simulation and techno-economic analysis of algal biomass production
- Chemical or biological carbon capture and sequestration/utilization (CCUS)
- Production of hydrogen and carbon-neutral fuels
- Biofuels and biomass-derived products

Management e Imprenditorialità

Management and Entrepreneurship

DII research group

SCENT: School of Entrepreneurship

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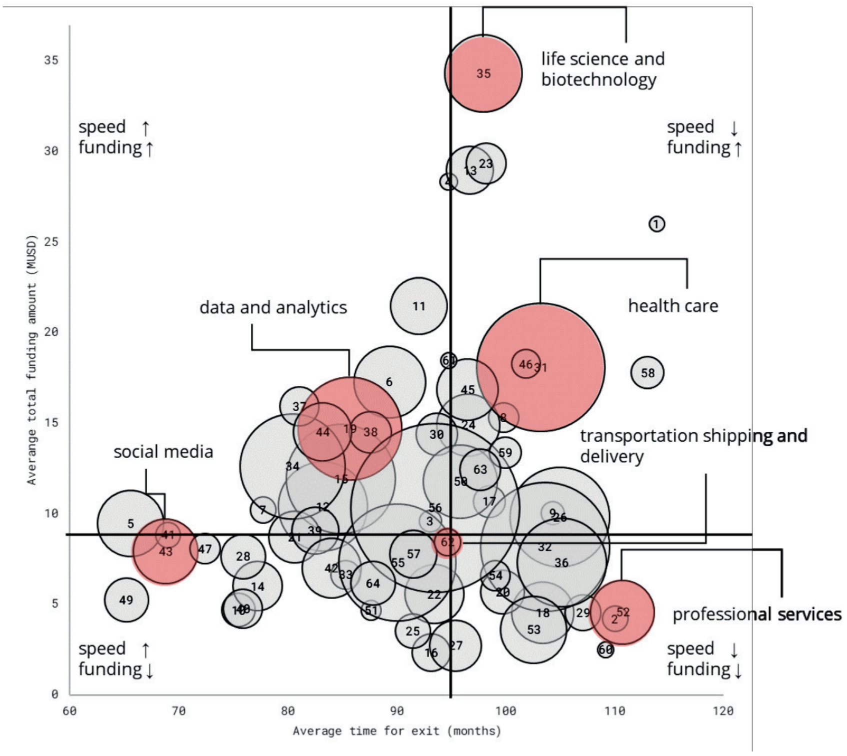
SCENT's research activity is focused on the topics of entrepreneurship and innovation, with the main emphasis on technology startup themes.
From the methodological point of view, strongly quantitative techniques are used, based on the analysis of large volumes of data and the development of machine learning and deep learning models.

Developing machine learning models to get insights into tech-driven ventures.

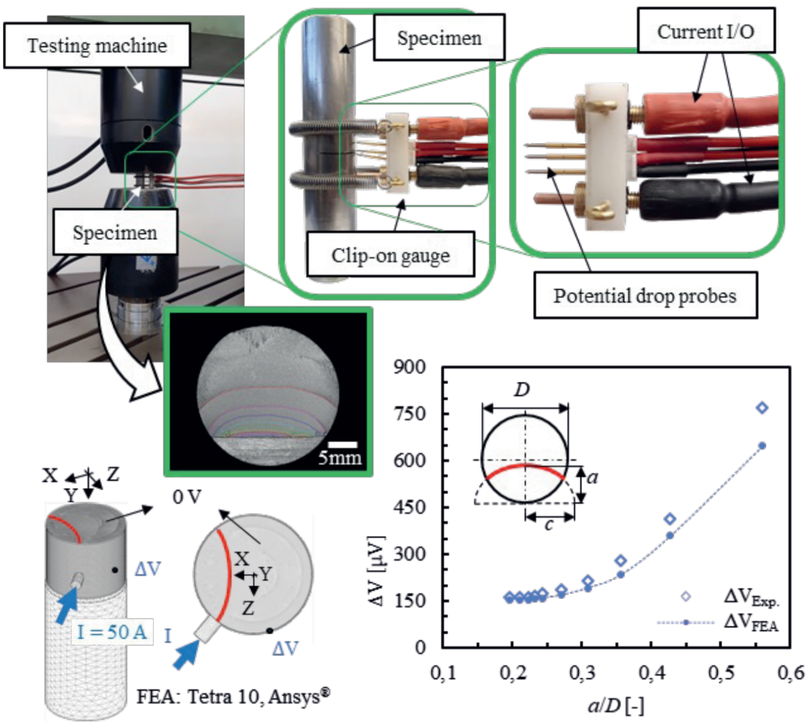
Can Artificial Intelligence (AI) provide new insights to better identify the key elements of successful startup companies? Leveraging the new opportunities offered by online business-related data sources and the ever-growing performance of machine learning models, we apply a data mining perspective to early-stage startups evaluation. Specifically, in this project we focus on the equity investors decision-making process (i.e., business angels and venture capitalists) to explore how our innovative AI-driven tools can improve the funding deal flow. In fact, despite the rigorous evaluation criteria applied by expert VCs throughout the selection funnel, the overall return on investment is often based on a small number of deals (particularly successful ones) capable of covering the losses generated by other companies in the portfolio. In a context where investors' personal experience and their so called "gut feel" do in fact have a significant impact on the final decision, machine learning models could ultimately lead to an improvement in the entire process. For example, algorithms can rapidly analyze large amounts of data and effectively identify specific patterns that are challenging for experts to discern. By analyzing the algorithms' outcome, it is then possible to identify any recurrent biases within the current process, making them evident and opening the way for further analysis of them in inferential terms. So far, we have developed several data mining models to investigate the relevance of multiple key elements in innovative entrepreneurial projects. Outcomes can offer new insights to researchers in entrepreneurship and also several stakeholders in the entrepreneurial ecosystem (e.g., founders, investors, public organizations) aiming at improving their decision-making process in different phases of an entrepreneurial project.



Calibration of the direct current potential drop (DCPD) method for in-situ fatigue crack growth monitoring of single-edge crack in round bars

In recent years, there has been a growing interest from the industry in developing methods for the damage-tolerant design of mechanical structures. As a result, the improvement of measurement techniques for crack propagation has become a significant area of interest in the field of mechanical engineering. Different experimental techniques are available to estimate the size of a propagating crack, one of which is the direct current potential drop (DCPD) method, where the electrical resistance of the tested specimen increases due to crack propagation and the resulting electric potential change is used to calculate the crack length by using proper calibration curves.

This study investigated the application of the DCPD method to a single-edge-crack round bar subjected to axial fatigue. Firstly, 3D electrical FE analyses have been performed to investigate the effect of the current and the potential probe position on the performances of the DCPD method in terms of measurability, sensitivity and reproducibility. The increased sensitivity but decreased reproducibility obtained by injecting the current and by measuring the potential drop as close to the superficial crack tip as possible have been evaluated quantitatively. Thereafter, the accuracy of the numerical analyses has been checked against experimental results obtained by fatigue testing round bar specimens with a straight-fronted crack starter notch. The propagating fatigue crack has been monitored with the DCPD technique with the local configuration of the current and potential probes, which were located at the superficial crack tip. To do so, a dedicated clip-on gauge device housing both current and potential probes has been designed and realized. Experimental crack fronts have been beach-marked, digitally acquired, and modelled in the FE environment to run electric numerical analyses. Interestingly, a quite good agreement has been obtained between FE predictions and measured values.



Vecchiato L, Campagnolo A, Meneghetti G. *Numerical calibration and experimental validation of the direct current potential drop (DCPD) method for fracture mechanics fatigue testing of single-edge-crack round bars*. Int J Fatigue (2021)

Sistemi meccanici

Mechanical systems

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This research activity has been carried out in collaboration with:

Dr. Matteo Cova (SACMI S.C.)

Main research topics:

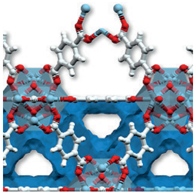
- Fatigue design of mechanical components and structures
- Fatigue design of welded structures
- Materials characterization for structural integrity
- Development of energy-based methods for fatigue l ifetime estimation of mechanical components
- On-road loads acquisition and bench testing of vehicles
- Structural integrity of additively manufactured metals and polymers
- Study and development of bio-mechanical structures for Sports and Rehabilitation
- Development of methods for the static and fatigue strength assessment of polymer components

UNIVERSITÀ DEGLI STUDI DI PADOVA

800 ANNI 1222·2022

DIPARTIMENTO DI INGEGNERIA INDUSTRIALE

Cover story

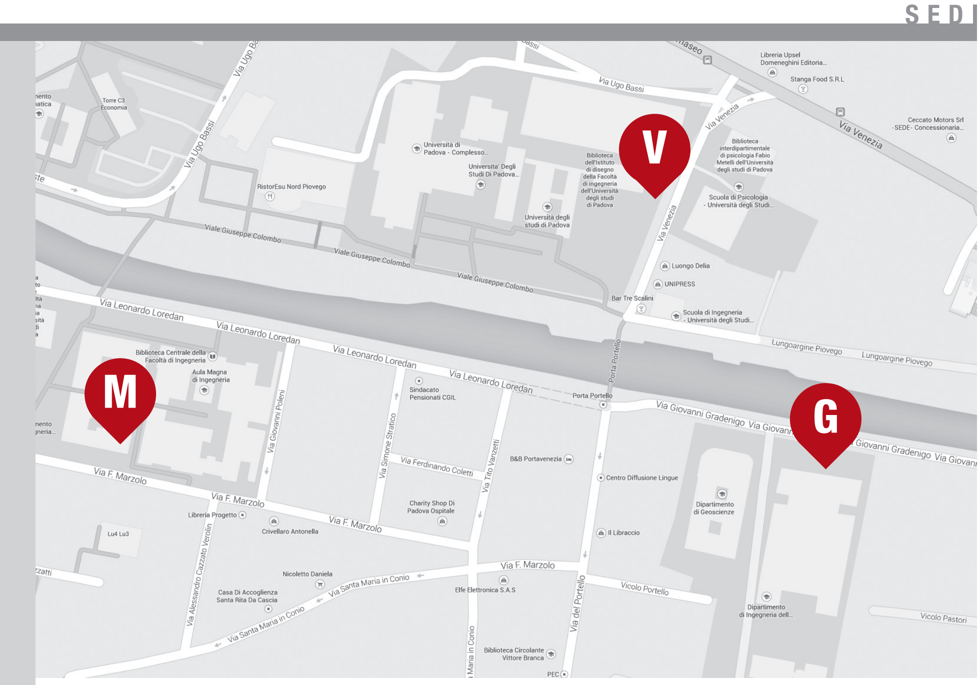


Modello 3D della struttura di un Metal Organic Framework (MOF), chiamato UiO-66 caratterizzato da centri metallici a base di Zirconio connessi tra loro da un linker organico. Tale materiale ealtri analoghi sono stati efficacemente sintetizzati da noi presso il DTU Offshore (Kongens Lyngby,Danimarca). A seguito di mirate modifiche alla loro struttura molecolare, questi materiali si prestano ad essere studiati come alternativa per lo stoccaggio di idrogeno a basse pressioni, infatti, la loro straordinaria area superficiale, che può raggiungere valori dell'ordine di migliaia di metri quadrati per grammo di materiale, insieme ad una porosità variabile, offre l'opportunità di intrappolare le molecole di idrogeno all'interno delle loro maglie strutturali.

Ludovico Linzi

Ludovico Linzi si è laureato in Scienza dei Materiali presso l'Università degli Studi di Padova e attualmente sta svolgendo il dottorato presso la scuola di dottorato in Ingegneria Industriale presso l'Università degli Studi di Padova (curriculum: Energy Engineering, ciclo XXXVII). Il suo progetto di dottorato riguarda lo sviluppo e lo studio di tecnologie e strategie energetiche per la produzione e l'utilizzo di idrogeno verde nel settore industriale. Ha recentemente svolto un periodo di sei mesi in Danimarca, presso il DTU Offshore, lavorando sulla fabbricazione di Metal Organic Framework per lo stoccaggio di idrogeno a basse pressioni.

SEDI



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