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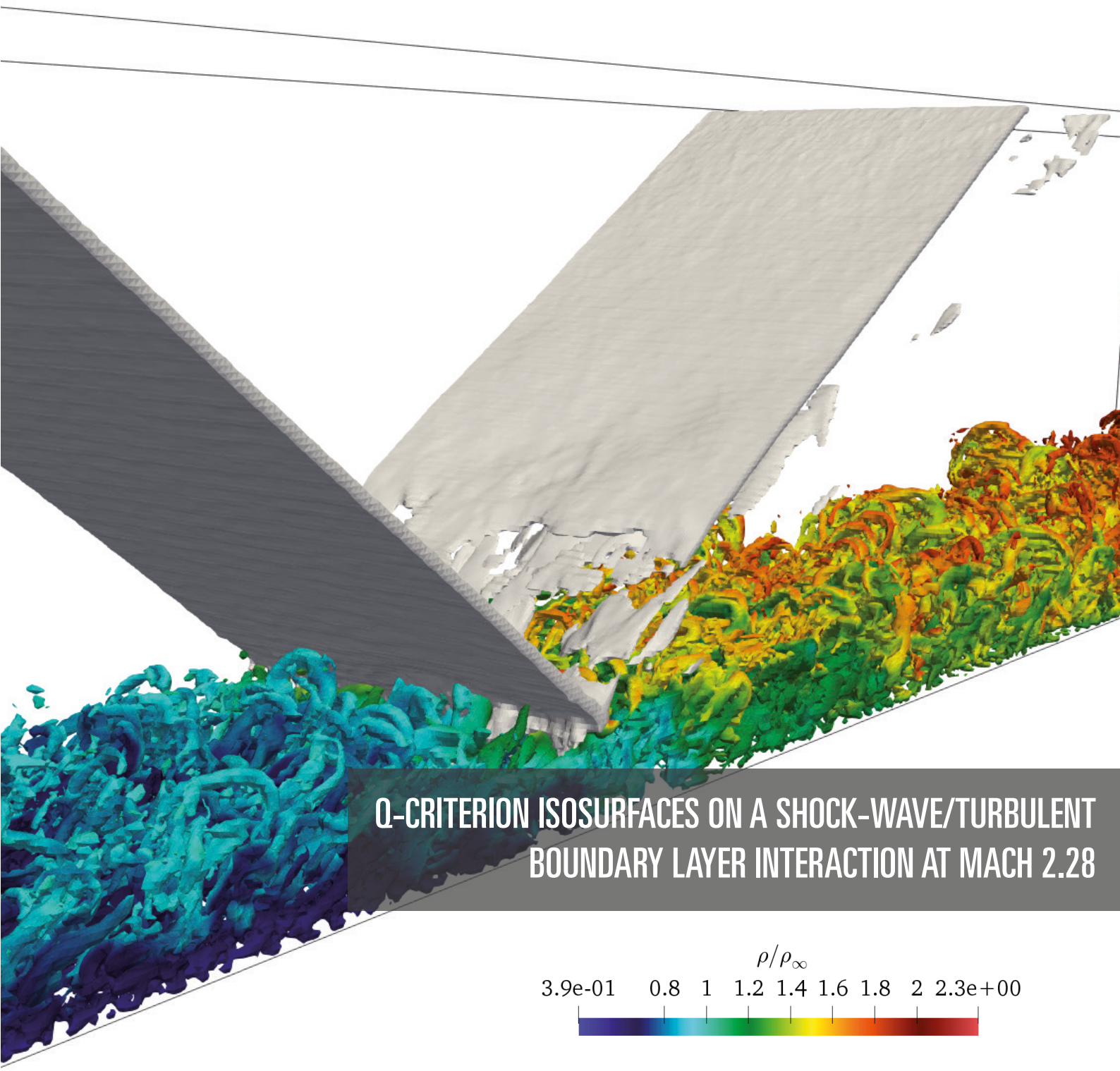
NEWSLETTER DEL DIPARTIMENTO DI INGEGNERIA INDUSTRIALE DELL'UNIVERSITÀ DEGLI STUDI DI PADOVA



Q-CRITERION ISOSURFACES ON A SHOCK-WAVE/TURBULENT BOUNDARY LAYER INTERACTION AT MACH 2.28

DIPARTIMENTO DI INGEGNERIA INDUSTRIALE

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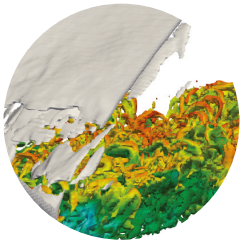

COPERTINA

Isosuperfici Q applicate alla dinamica di uno strato limite turbolento su lastra piana investito da un'onda d'urto a Mach 2.28
Q-criterion isosurfaces on a shock-wave/turbulent boundary layer interaction at Mach 2.28

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DIPARTIMENTO DI INGEGNERIA INDUSTRIALE

Supercritical carbon dioxide as a new and accessible method for food pasteurization

Three professors of the Department of Industrial Engineering of the University of Padova, prof. Sara Spilimbergo, prof. Anna Mazzi and prof. Pierantonio Facco, are involved in the project "Innovative high-pressure process to increase the preservation of ready-to-eat Organic food" or HO-FOOD[1], within the Joint Call ERA-NET SUSFOOD2 and CORE Organic.

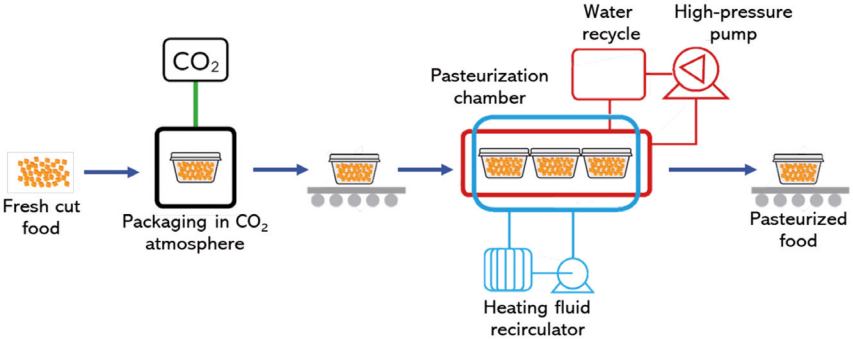
Thanks to the collaboration of 5 international research groups from Italy, Poland, Algeria and Turkey, the project will strongly contribute to addressing the gap of the existing technologies and supporting the local fresh food supply chain by developing a new mild, minimal, and low-cost pasteurization technology for fresh/raw fruits and vegetables as Ready-To-Eat (RTE). The technology is based on the method patented[2] by professor Sara Spilimbergo, schematised in the figure, which has the potential of changing the food chain setup.

The new process consists in pressurizing the product inserted in Modified Atmosphere Packaging enriched with CO_2 until reaching supercritical conditions to inactivate microorganisms and enzymes present on the surface and responsible for food spoilage. The process will be efficient against foodborne and well as pathogenic microorganisms and will increase food safety. By using low temperature, sensorial and chemical properties will be preserved, resulting in healthy and palatable food while preserving the phytochemical components of organic foods.

The implementation of HO-FOOD requires expertise from different scientific fields, such as food science, microbiology, chemical engineering, food engineering and economics. The goals of the project will be indeed addressed by fully studying all aspects of the process regarding not only the microbial safety, the quality and bio-accessibility of the selected products, but also by assessing the economic sustainability and environmental impact of the process and by developing apparatuses for its application.

1) *The project has received funding from European Union's Horizon 2020 grant agreement No. 727473 and No. 727495*

2) *Spilimbergo, S., Zambon, A., Michelino, F., & Polato, S. (2017). Method for food pasteurization. Italian patent n. IT201700098045A1*



Bioingegneria, biotecnologie e tecnologie per la salute
Bioengineering, biotechnology and health technologies

DII research group

superunit CO2 INNOVATION LAB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SUSFOOD2

CORE organic

HO-FOOD is in collaboration with Institute of Agricultural and Food Biotechnology (Poland), Council for Agricultural Research and Economics (Italy), University Ahmed Benbella Oran 1 (Algeria) and Ataturk Central Horticultural Research Institute (Turkey.

Main research topics:

- Use of supercritical fluids for the pasteurization of liquid and solid food products
- Use of supercritical carbon dioxide for food drying
- Pasteurization plant design and construction

Energia

Energy

STET
Sustainable technologies for heating and refrigeration

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PhD students involved:
- Marco Tancon
- Matteo Mirafiori

The research activity is carried out in collaboration with:
Prof. Alessandro Martucci
Dr. Elena Colusso

Main research topics:

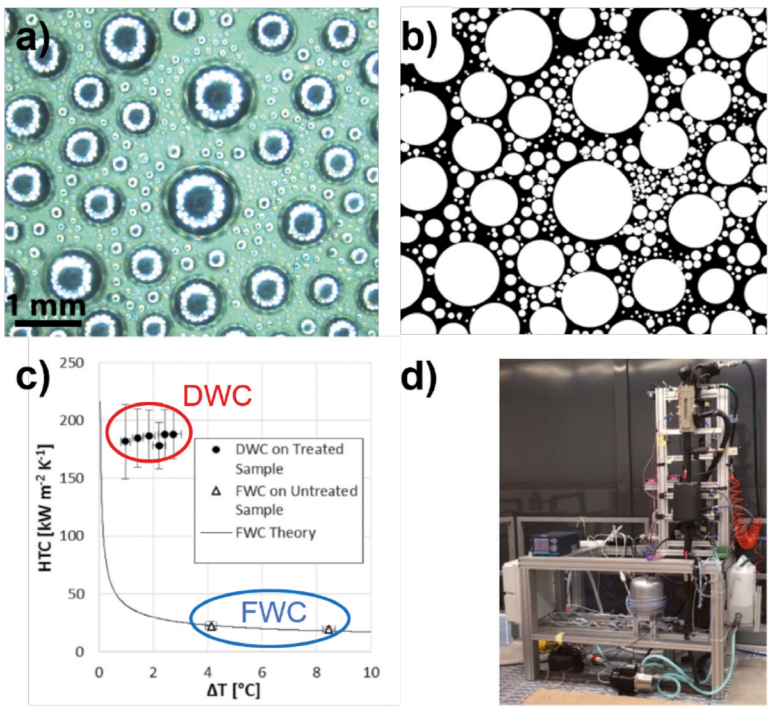
- Refrigeration and heat pumps
- Flow boiling and condensation
- Study of condensation in microgravity conditions
- Computational thermo-fluid dynamics of two-phase flow
- Solar energy conversion and thermal energy storage

Heat transfer enhancement during dropwise condensation over wettability-controlled surfaces

Condensation is a phase change process encountered in many applications as thermal power plants, desalination of sea water, air conditioning systems, water harvesting. The modified wettability can determine a different behavior in the interaction between the liquid and solid phases. Vapor can condense on a surface in two modes: filmwise condensation (FWC) mode and dropwise condensation (DWC) mode (Figure a). Our research is focused on the promotion of DWC over metallic surfaces. The thermal performance of different samples was measured in a thermosyphon loop (Figure d) with pure steam as working fluid at 100 °C saturation temperature. Considering a sol-gel coated aluminum surface, we found an augmentation up to 8 times of the DWC heat transfer coefficient (HTC) compared to the standard FWC mode (Figure c).

Starting from the nanoscale up to the macroscale, DWC involves millions of droplets per square meter. DWC is a cyclic process: condensation begins at molecular scale with drops nucleation. Growing by direct condensation at first and later by coalescence, drops reach the critical size at which external forces (e. g. gravity) overcome adhesion forces and they start to move, sweeping the surface and making new nucleation sites available. The modeling of DWC is thus very complex and the experimental investigation of the droplet population is fundamental. We developed an optical system to detect droplets growth during DWC down to 15 µm radius. Video analyses were carried out looking at droplet departing radius, droplets population and surface time renewal using a home-made software to detect the dimensions of the droplets (Figure b).

Aspects that need to be addressed in the future concern the development of more robust coatings and the understanding of the heat transfer mechanisms in particular at the earliest stages of droplets growth.



a) Image of the DWC process taken by the high-speed camera (https://doi.org/10.1016/j.2020.115718).

b) Black and white image of the observed droplet population after processing.

c) Heat transfer coefficient (HTC) increase measured during DWC over a sol-gel coated aluminum sample.

d) Experimental test rig.

Plasma electrolytic oxidation (PEO) coatings containig particles

Plasma electrolytic oxidation (PEO), also called 'Microarc Oxidation (MAO) is relatively novel surface modification technique that is attracting ever-increasing interest in fabricating oxide ceramic coatings on light alloys such as Al, Ti and Mg. PEO treatment can enhance their corrosion- and wear-resistance properties, or confer various other functional properties including anti-friction, thermal protection, optical and dielectric, as well as a pre-treatment to provide load support for top layers. PEO is derived from conventional anodizing. One of the main properties of PEO layers is the possibility to be composed not only by the oxide of the substrate, but also from compounds coming from the electrolyte, thanks to the spark phenomena that trap compounds into the pores and the local high temperatures produced by plasma. Recent developments in this area are focused on the addition of particles into the electrolyte, aiming at in- situ incorporation or sealing of the porous PEO coatings, and also endowing the coatings with new functionalities. The presence of silver and copper particles incorporated in the PEO coating can be observed in Fig.1A. The average COF data (Fig.1B) show that the addition of graphite nanoparticles in the coating produces a reduction in the coefficient of friction. Considering the results regarding the bactericidal effect (Fig.1C) it can be observed that the presence of silver particles, produce the death of almost all the bacteria present. Considering the antifouling activity (Fig.1D) the presence of copper particles greatly reduces the extent of colonization, demonstrating that Cu is effective as an antifouling agent .

It was proved that it is possible, by simple addition inside the electrolyte, to incorporate metallic and non-metallic particles into PEO coatings. In particular: a) the addition of graphite nanoparticles allows to improve corrosion and wear resistance; b) the addition of silver particles allows to confer bactericidal properties to the coatings; c) the addition of copper particles allows to confer antifouling properties to the coatings.

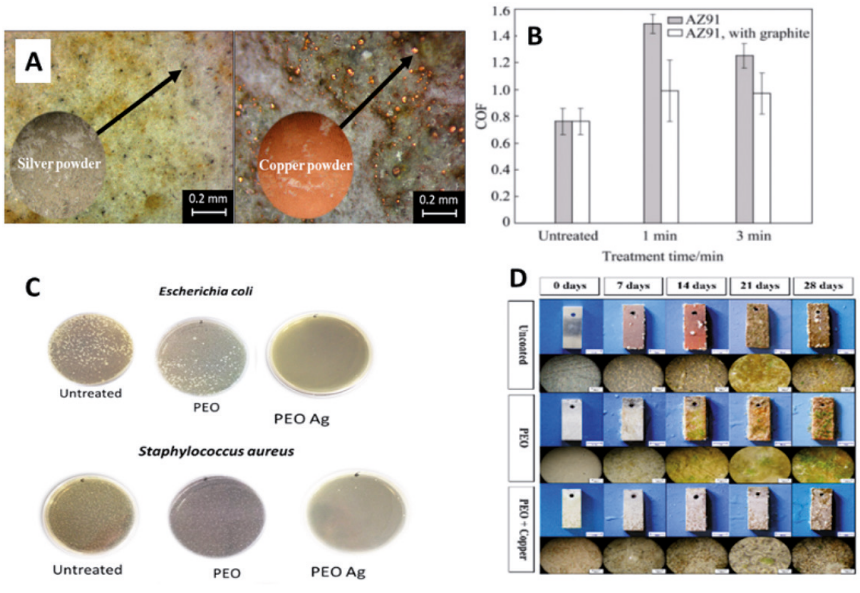


Fig.1 (A) Stereo microscope image of PEO coatings containing silver or copper; (B) COF evolution in dry sliding tests on PEO coatings containing graphite nanoparticles; (C) Antibacterial effect of PEO coatings containing silver; (D) Antifouling effect of PEO coatings containing copper.

Materiali

Materials

DII research group

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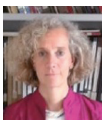
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Part of the project was perfomed in collaboration with:

-Department of Industrial Engineering, Alma Mater Studiorum University of Bologna (prof. Carla Martini)

-Department of Materials Science, University of Mons, Belgium (Prof. Marie-Georges Olivier)

-Department of Biology, University of Padova (Prof. Isabella Moro)

Main research topics:

- Plasma Electrolytic Oxidation
- Innovative coatings to improve corrosion and wear resistance of steels and light alloys
- Advanced High Strengt Steels (TRIP steels)
- Microstructural evolution and corrosion properties of stainlees steels
- Recovery of strategic and precious metals from wastes
- Study of the electroplastic effect on different metals

Sicurezza ambientale e Industriale

Environmental and Industrial Safety

DII research group

Safety Group

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The research activity is carried out in collaboration with the Technische Universität München (TUM) - CRC

Main research topics:

- Risk analysis and process safety
- Decentralized infrastructures for Green Transition
- Design of inherent safer systems
- Modeling of accidental scenarios
- Fire safety engineering

Toward an inherently safer decentralized generation of green H_2

Hydrogen is an energy carrier with high potential for green and sustainable applications, as it is carbon-emission free and energy-dense. It can supply many energy sectors and can be produced from renewable sources.
It can be produced in large-scale centralized production plants or via decentralized generation in small-scale distributed production facilities. The H_2 production via methane reforming in centralized plants is currently cheaper than the equivalent production in decentralized installations. However, H_2 delivery infrastructure and storage technical barriers will make H_2 production in decentralized plants more feasible as the demand for H_2 increases and the availability of renewable sources become increasingly decentralized.
Small-scale decentralized H_2 production installations can rely, as an example, on movable containerized solutions. These «plug&play» installations are highly appreciated thanks to their scalability, modularity, and favourable logistics.
However, these systems require the acknowledgements of various hazard & safety concerns, including:

- Inherent hazardous properties of processed substances (H_2, biogas, CO, NH_3).
- Very high flammability and low detectability of H_2 releases.
- Confinement and related ATEX concerns, including high-pressure and high-temperature operations.
- Automatic unmanned production cycles and scalability of modules.
- Deployment on territories with diversified vulnerability and public acceptance.

In this context, a collaboration with TUM aims to develop and demonstrate an intrinsically safer containerized solution for green H_2 production at TRL 6. It is based on a set of innovative, advanced, and unconventional engineered solutions and operating procedures that minimize hazards and risk. This safer design embeds an innovative sensor-alarm network and specific items preventing accidental releases of flammable mixtures and avoiding effective ignition sources. In parallel, traditional risk assessment procedures are revised and adapted to the flexible distributed and modular H_2 production framework. Benchmark safety requirements specifications (SRS) for decentralized H_2 installations are developed also in partnership with testing and certification bodies.

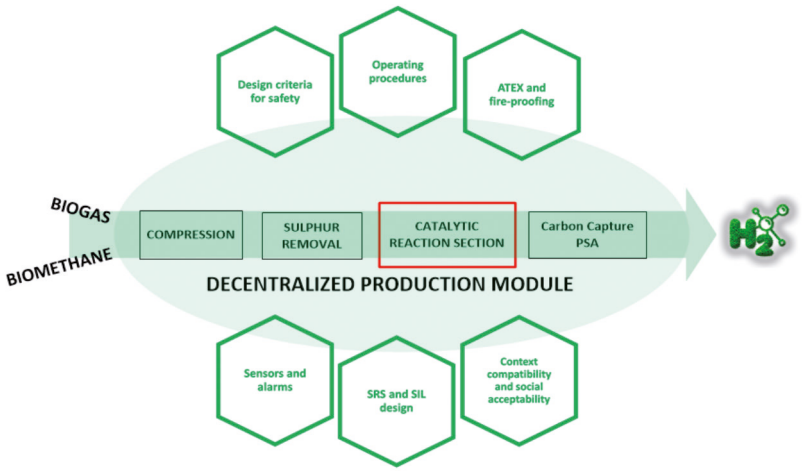

Figure 1. Decentralized modular H_2 production unit in scalable frameworks.

On the short-range transmission of infective droplets for respiratory virus spreading

After the Spanish flu pandemic, it was apparent that airborne transmission was crucial to spread virus contagion. Several fundamental studies like the experiments of Duguid (1946) and the model of Wells (1934) appeared in the successive years. These seminal works have been pillars of past and current guidelines published by health organizations. However, in about one century, understanding of turbulent aerosol transport by jets and plumes has enormously progressed, so we used detailed experiments and accurate computationally intensive numerical simulations of droplet-laden turbulent puffs emitted during sneezes in a wide range of environmental conditions, see fig. 1. Our analysis shows that droplets' lifetime is always about one order of magnitude larger compared to previous predictions, in some cases up to 200 times, see fig. 2a. We have also produced original virus exposure maps, which can be a useful instrument for health scientists and practitioners to calibrate new guidelines to prevent short-range airborne disease transmission. All these results have been published in a recent publication on an prestigious scientific journal[1].

In order to understand and model the longer droplet's lifetime, we have analysed the classical evaporation model used in the Wells theory for infective droplet transmission, i.e. "d-square law". We found a critical assumption behind this model related to the latent evaporation heat, so we proposed its revision [2]. The application of the revised "d-square law" is able to accurately predict the evaporation of infective droplets that is necessary to define proper guidelines to mitigate the contagion risk (blue line in fig 2a).

We are still working on this topic in order to propose a new complete model for the short-range contagion operated by respiratory virus-laden droplets. In fig. 2b we estimate the droplet travelling distance for different respiratory events. The final aim is to quantify the effect on the contagion risk of different safe distances in relation of environmental conditions and the possible use of covering masks.

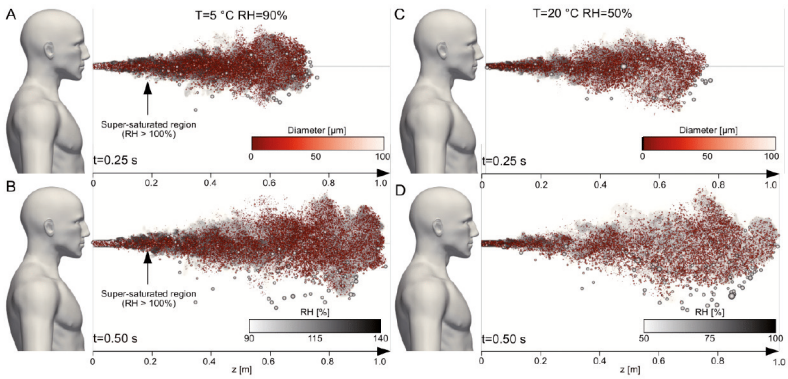

Fig.1: Simulations of droplets emitted in sneezes at different ambient conditions and times.

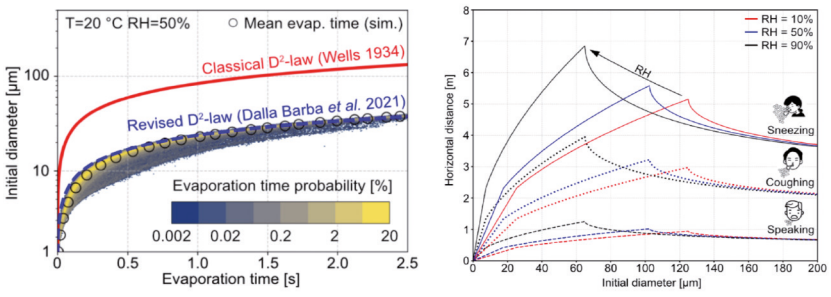

Fig.2:
a) Droplet evaporation time: data, Wells model & proposed model.
b) Estimate of the travelled distance of droplets emitted in different respiratory events and ambient conditions.

Sicurezza ambientale e Industriale

Environmental and Industrial Safety

DII research group

FLUMS


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The project is in collaboration with the group of prof. Alfredo Soldati in TU-Wien and prof. Gaetano Sardina in Chalmers TU.
The project is supported by the Italian national project FISR-COVID «Purity» and the European project PRACE-COVID19 DROPLETS.

Related publications:

[1] "Short-range exposure to airborne virus transmission and current guidelines", Wang et al., Proc. Nat. Ac. Scie. 2021

[2] "Revisiting D2-law for the evaporation of dilute droplets", Dalla Barba et al., Phys. Fluids 2021

Main research topics:

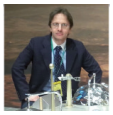
- Computational fluid Mechanics
- Virtual testing
- Environmental quality and safety evaluation
- Aerodynamics
- Fluid Mechanics

Sistemi Aerospaziali

Aerospace Systems

DII research group

Flight dynamics
and space systems



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Project activities are carried out
in collaboration with :

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Mirco Bartolomei
Giacomo Colombatti
Lorenzo Olivieri

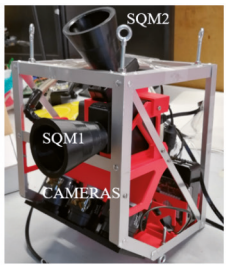
Center of Studies and Activities
for Space “CISAS” G.Colombo

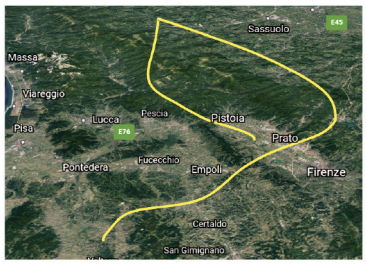
Main research topics:

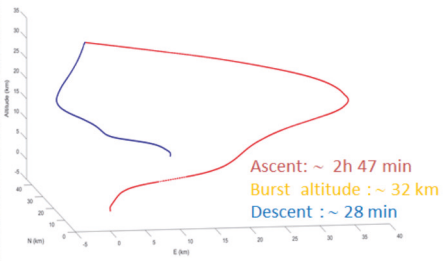
- Dynamics of atmospheric flight and autonomous aircraft
- Dynamic analysis of flight systems

Stratospheric flight of the MINLU payload for monitoring light pollution

The MINLU (“Misurazione dell’ INquinamento LUminoso”) payload was successfully launched on July 7th 2021 with a sounding balloon from Tuscany, achieving the first continuous observation of sky brightness magnitude in Earth atmosphere from ground to stratospheric altitudes up to 32 kilometer.
The operation was the result of a joint effort by the Department of Industrial Engineering (DII) and the Center of Studies and Activities for Space “G. Colombo” of University of Padova which realized the scientific gondola in collaboration with the Space Systems Lab from University of Pisa, that provided its UniPiHAB04 flight platform to carry the system to stratospheric altitude and safely back to ground.
MINLU autonomous payload was designed and tested to provide complete and detailed aerial observations of light pollution sources and sky brightness with the capability to be integrated on stratospheric balloons, tethered balloons or drones. The architecture implemented in the sounding balloon flight included three downward looking cameras with dedicated filters and two commercial Sky Quality Meter (SQM-LE) units, one pointing in horizontal direction and the other monitoring the zenith sky. The whole system was controlled by a commercial Central Data Management Unit (Raspberry PI 3) performing sensor conditioning, data acquisition, compression and storage using custom developed Python software; inertial position and attitude information were measured by an on board Pixhawk Pixcube autopilot system comprising GPS and IMU units and automatically linked to scientific data.







MINLU
Payload and launch trajectory

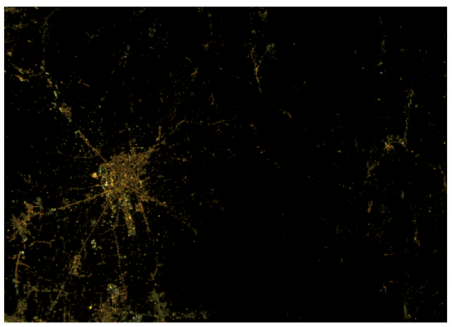


Image of Pistoia area from 32 km altitude from the MINLU color camera

Surface treatment to promote joining of glass fiber reinforced plastic and magnesium alloy via hot metal pressing

Fiber Metal Laminates (FMLs) represent a novel class of advanced engineering materials that find applications in several fields such as aerospace and automotive. This is mainly thanks to the combination of the advantageous properties of their constituent materials, usually Fiber Reinforced Polymers FRPs and light metals, which allow manufacturing components with high strength and stiffness-to-weight ratios. However, FMLs encounter some issues in terms of manufacturing because of the long production times of the conventional methods used to join FRPs and metals. Among the most innovative, fast, and cost-effective bonding techniques, there is the Hot Metal Pressing (HMP) process, specifically developed for thermoplastics. This technique is based on the melting of the polymer that flows creating a bond and later solidifies upon cooling under moderate pressures (Fig. 1). Even if promising, HMP is still at an early stage of exploration, especially in terms of reliability of the joint performances. The joint strength between the metal sheet and the FRPs is affected by the chemical and mechanical properties at the interface. To this end, this study investigated the influence of different induced-surface characteristics of AZ31B magnesium alloy sheets when joint with glass fiber reinforced polyamide 6 (PA6-GFRP). The treatments, carried out to modify the AZ31B surfaces, were annealing (A), sandblasting (SB), and their combination (SB+A). The mechanical and chemical interlocking at the metal-composite interface was assessed in terms of macroscopic and microscopic defects (Fig. 2) as well as lap shear strength (Fig. 3 a). The obtained results indicated that surface modification is crucial to achieve a good bond strength between the AZ31B sheets and the thermoplastic matrix of the PA6-GFRP via HMP. No bonding was obtained when using AZ31B sheets in the as-received conditions. The joint effectiveness was mainly affected by the annealing treatment (Fig. 3 b), which induced both a chemical and morphological modification of the surface (Fig. 4). The formed oxide layer at the interface, combined with surface topography modification, were capable to increase the lap shear strength up to 87% thanks to the simultaneous effect of mechanical interlocking and chemical bonding.

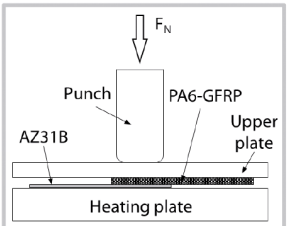


Fig. 1. Experimental setup for the HMP joining.

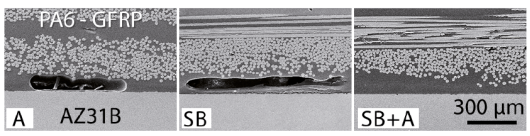


Fig. 2. SEM images of the joint cross-section at different AZ31B surface treatments.

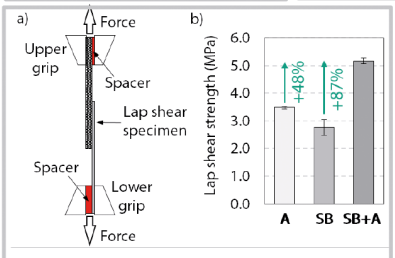


Fig. 3. Experimental setup of the lap shear test of HMPed specimens (a) and lap shear strengths of the HMPed samples (b).

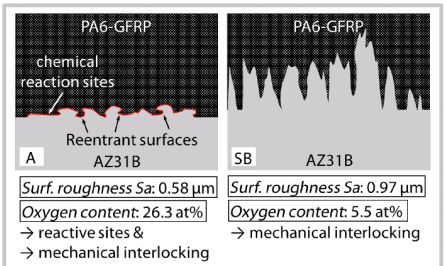


Fig. 4. Adhesive role of the oxide layer at the PA6-GFRP – AZ31B interface.

Ingegneria dei sistemi meccanici

Mechanical systems

DII research group

Precision Manufacturing Engineering

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Main research topics:

- Manufacturing systems and processes
- Micro-technologies and precision technologies
- Shaping of metallic materials
- Processing of polymeric materials
- Geometric metrology

Sistemi meccanici

Mechanical systems

DII research group
MMSA
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Several international collaborations are ongoing. Among the most important projects, it is well worth mentioning the investigation of autonomous drifting cars with Stanford University, USA **(https://dynamicdesignlab.sites.stanford.edu/)** Dr. Lenzo is currently visiting their lab within the prestigious Fulbright program.

Main research topics:

- Industrial and service robotics
- Mechanical drives and control
- Mechanical vibrations
- Mechanisms and automated machines
- Road vehicles
- Robotic systems for human interaction

Enhancing vehicle safety with advanced controls and state estimators, towards electric self-driving cars

With around 1.5 billion vehicles in the world, passenger safety is very important. Yet, despite the current technology level, knowledge of key quantities characterising vehicle motion is still unattainable. This jeopardises progress on vehicle safety systems.

Consider for instance Electronic Stability Control (ESC). It is an active safety system installed (by law) on all modern cars,. ESC helps averting loss of vehicle control in critical driving situations. According to statistics, ESC helps saving thousands of lives each year. While this is great, that is way below the order of magnitude of fatalities, around 1.2 million each year, 90% of which due to human error. Now, if onboard control system knew more about vehicle motion - through so-called «state estimators» - it would be possible to devise control systems that prevent dangerous situations, rather than intervening when such situations occour (as the ESC does). Hence, vehicle safety would greatly benefit.

Dr. Lenzo was awarded the national award «Rita Levi Montalcini» that allowed him to move back to Italy to carry out his research - including experimental validation on full-scale vehicles - on state estimators and advanced vehicle control techniques. For example, such techniques exploit «torque-vectoring», i.e. the possibility of assigning any desired value (within physical limits) of torque to each wheel, thus strongly influencing lateral vehicle dynamics. Electric vehicles are particularly suitable for these applications, as these vehicles normally feature multiple actuators, such as two or four electric motors.

As far as state estimators are concerned, they allow to gather precious information on quantities characterising vehicle motion, without actually measuring them (that is not possible for several reasons), yet making the most of sensors already installed on modern cars. State estimators are also crucial for the development of autonomous driving technology. Despite the importance of an accurate knowledge and understanding of the surrounding environment, a self-driving car needs to know well its own state to make the best possible decisions.

UNICITYLAB: un Laboratorio per la città universitaria di Padova

Che cos'è una Città universitaria? Che relazioni si creano e si alimentano tra università e contesto urbano? Qual è l'impatto economico, ambientale, culturale e sociale della presenza dell'università entro una città? A partire da queste domande nel 2018 è nato il Laboratorio Unicity, un gruppo di ricerca interdisciplinare per la promozione di una co-progettazione locale a supporto dello sviluppo strategico di Padova come città universitaria.
Le ricerche promosse dal Laboratorio Unicity sono fortemente orientate alla terza missione, hanno carattere multidisciplinare e puntano a coinvolgere i diversi attori strategici dello sviluppo urbano. Alle attività di UnicityLab collaborano 20 docenti dell'Università di Padova, afferenti a 7 Dipartimenti, su diversi aspetti della relazione tra università e città: (Fig.1)

- Linea 1 - Housing e servizi universitari
- Linea 2 - Mobilità, trasporti e flussi pendolari
- Linea 3 - Patrimonio culturale e offerta turistica integrata
- Linea 4 - Imprenditorialità
- Linea 5 - Internazionalità
- Linea 6 - Laboratori di co-progettazione della Città universitaria

Nel corso del 2021 la Prof.ssa Anna Mazzi e l'Ing. Elena Battiston (gruppo di ricerca SAM.lab del DII) hanno contribuito alle attività di UnicityLab approfondendo la relazione tra Università e territorio nei progetti di economia circolare. Insieme ad alcuni imprenditori e dirigenti di aziende della provincia di Padova particolarmente attenti alla sostenibilità ambientale, è stato possibile riflettere sul ruolo che ha oggi il nostro Ateneo nel promuovere l'ecoinnovazione a livello locale.
I risultati dell'indagine dimostrano come per le imprese padovane la collaborazione con l'università sia un elemento chiave di competitività, spesso difficile da realizzare, su cui vale la pena investire (Fig.2).
Le attività di ricerca del progetto UnicityLab sono disponibili sul sito: www.unicitylab.eu e saranno pubblicati sulla rivista Regional Studies and Local Development (RSLD). Il 9 dicembre 2021 l'Aula Nievo di Palazzo del Bo ospiterà un evento pubblico di presentazione dei risultati e darà avvio ad altre attività di UnicityLab per le celebrazioni degli 800 anni dell'Ateneo patavino.

Fig.1: Il logo e le linee di ricerca del progetto UnicityLab

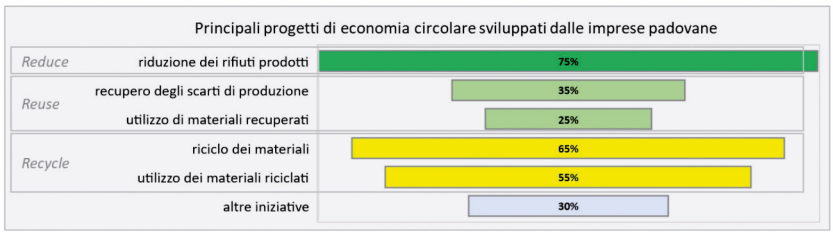

Fig.2: Alcuni risultati dell'indagine condotta da SAM.lab nel 2021

Management
e Imprenditorialità

Speciale

DII research group

SAM.lab


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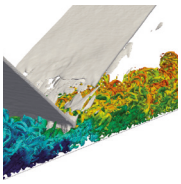
Progetto di Ateneo realizzato in collaborazione con:

- Centro Studi Regionali «Giorgio Lago»
- Dipartimento di Ingegneria Civile Edile e Ambientale (ICEA)
- Dipartimento di Scienze Politiche, Giuridiche e Studi Internazionali (SPIGI)
- Dipartimento di Scienze Storiche, Geografiche e dell'Antichità (DiSSGeA)
- Dipartimento di Sciente Economiche e Aziendali (DSEA)
- Dipartimento di Beni Culturali (DBC)
- Dipartimento di Filosofia, Sociologia, Pedagogia e Psicologia Applicata (FISSPA)

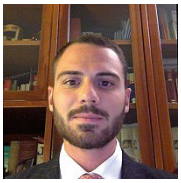
Main research topics:

- Valutazione e gestione della sostenibilità
- Ecoinnovazione ed economia circolare

Cover story



Il criterio Q è una tecnica numerica ampiamente utilizzata in fluidodinamica computazionale. In copertina osserviamo le "iso-superfici Q" applicate alla dinamica di uno strato limite turbolento su lastra piana investito da un'onda d'urto. La colormap si riferisce ai valori locali del campo di densità. Il flusso, caratterizzato da un elevato numero di Mach, presenta porzioni particolarmente caotiche e turbolente nella zona inferiore, ove è prevista la presenza della parete. Si osservano infatti numerose strutture vorticose che creano comportamenti dinamici alquanto peculiari, tra cui la continua oscillazione non-lineare dell'onda d'urto attorno alla sua posizione di equilibrio.



Francesco De Vanna

Francesco De Vanna è assegnista post-doc presso il Dipartimento di Ingegneria Industriale dell'Università di Padova. Dopo la laurea Magistrale Ingegneria Meccanica ha conseguito il Dottorato di Ricerca, sempre presso l'Università di Padova. I suoi temi di ricerca riguardano principalmente la fluidodinamica computazionale con particolare riferimento all'aerodinamica ad alta risoluzione di flussi comprimibili attorno a geometrie complesse. Durante il dottorato, Francesco ha sviluppato URANOS (Unsteady Robust All-around Navier-StOkes Solver), un solutore Navier-Stokes per flussi compressibili che sfrutta la tecnica Large-Eddy Simulations.

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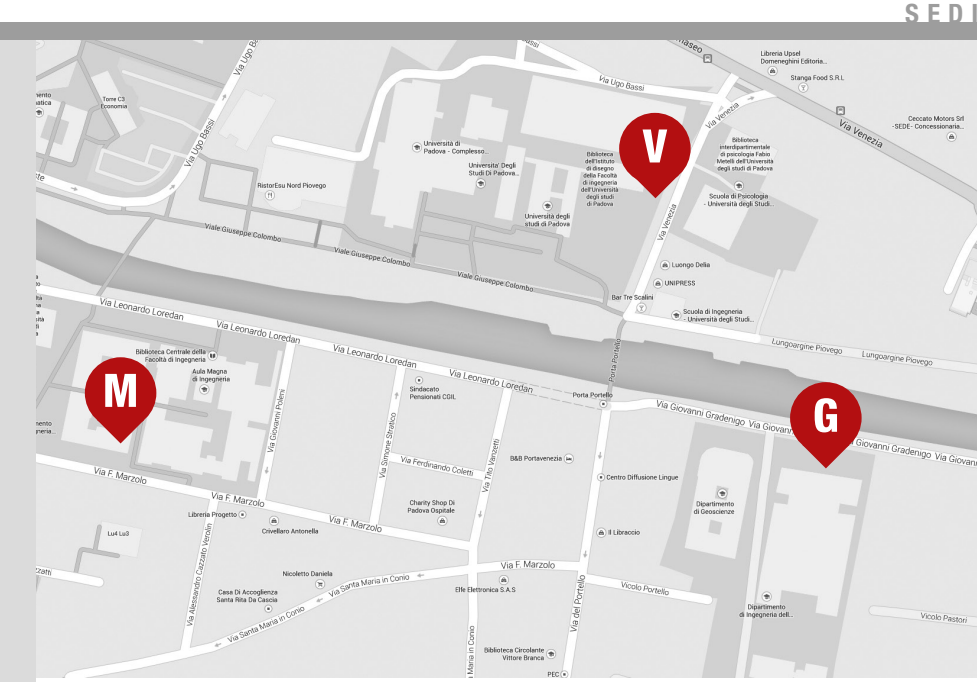

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