DIINFORMA

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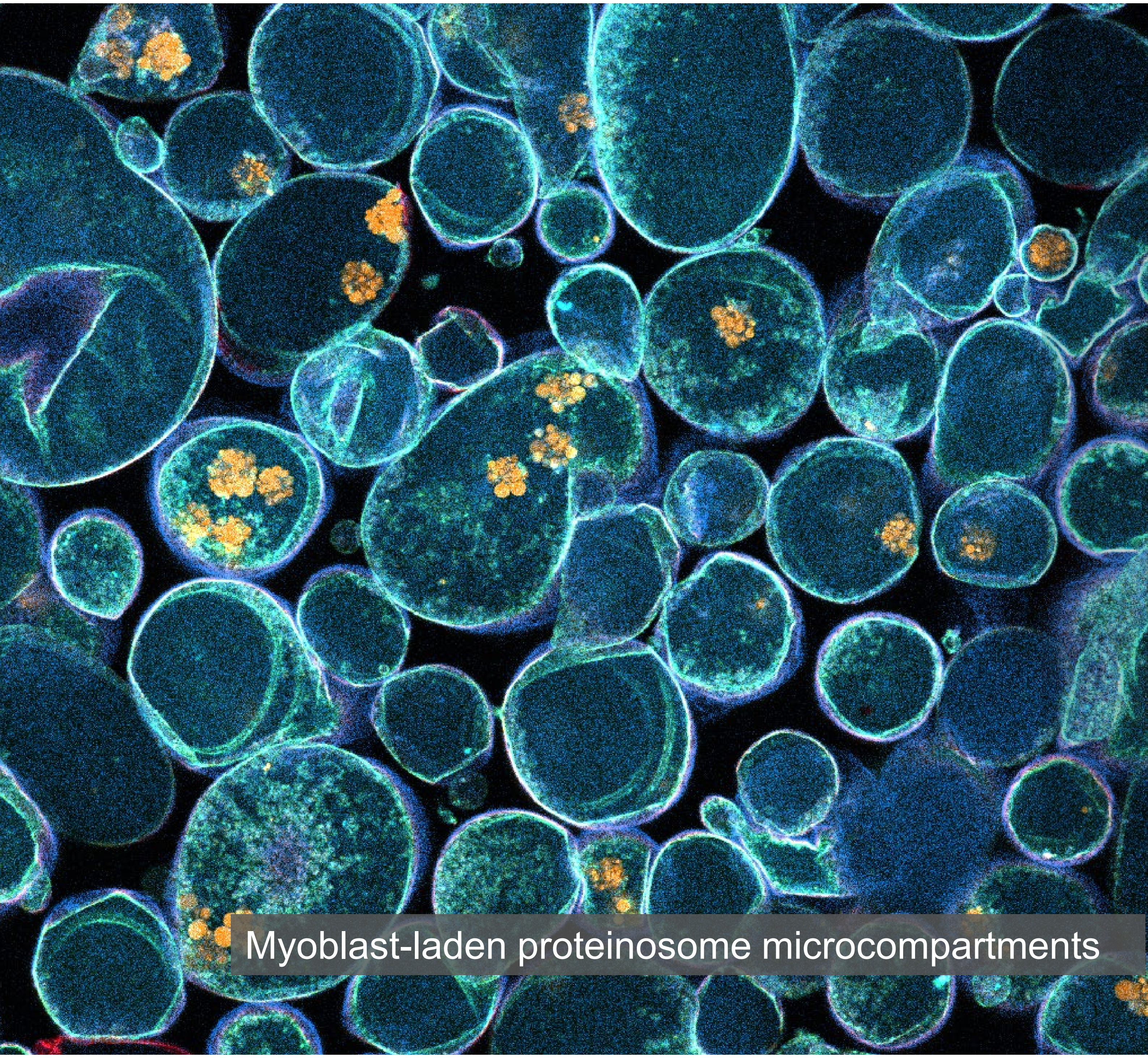
NEWSLETTER DEL DIPARTIMENTO DI INGEGNERIA INDUSTRIALE DELL'UNIVERSITÀ DEGLI STUDI DI PADOVA



Myoblast-laden proteinosome microcompartments

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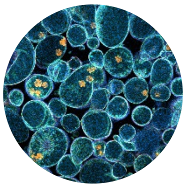

COPERTINA

Myoblast-laden proteinosome microcompartments

PAGINA

DIPARTIMENTO DI INGEGNERIA INDUSTRIALE

THE VISUAL DIIARIES

Il Direttore Prof. Fabrizio Dughiero

Cari colleghi, care colleghe,
studenti, studentesse,
amici e personale tecnico amministrativo
del Dipartimento di Ingegneria Industriale,

con grande soddisfazione il 13 dicembre, nella stupenda cornice della Sala Paladin di Palazzo Moroni, abbiamo inaugurato la mostra «**THE VISUAL DIIARIES**».

La mostra raccoglie una selezione di immagini di copertina pubblicate, nel corso degli anni, su **DII**NFORMA, che proprio quest'anno festeggia il suo primo decennale.

La mostra offre una "testimonianza visiva" originale delle attività di ricerca del Dipartimento attraverso una scelta di contenuti e una forma espositiva che si collocano all'interno di un innovativo approccio divulgativo, già sperimentato dal DII con il cortometraggio "Alla ricerca del futuro".

Il catalogo della mostra permette di associare ad ogni immagine (esposta in formato gigante) la riproduzione di un'opera d'arte o di design, offrendo così al visitatore la possibilità di riconoscere un interessante parallelismo tra contenuti tecnico/scientifici e forme di espressione artistica.

Il progetto espositivo si compone di 15 pannelli e copre un'estensione lineare totale di circa 50 metri. Ogni pannello, corrispondente ad una immagine di copertina del DIINFORMA, viene corredato da un QRcode per gli approfondimenti.

La mostra, collocata presso il Cortile pensile di Palazzo Moroni, è visitabile fino al 12 gennaio 2025.

Un saluto,

Fabrizio Dughiero

Sistemi Meccanici

Mechanical systems

DII research groups

Precision Manufacturing Engineering

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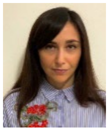

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The research activity was carried out within the following projects:

(i) MICS – Made in Italy – Circular and Sustainable – Extended Partnership and received funded by the European Union Next-Generation EU (PNRR)

(ii) NEMESI – 4D manufacturing based on 3D printing and machining for Nitinol biomedical and sensing applications" funded by the Italian Ministry of University and Research (MUR)

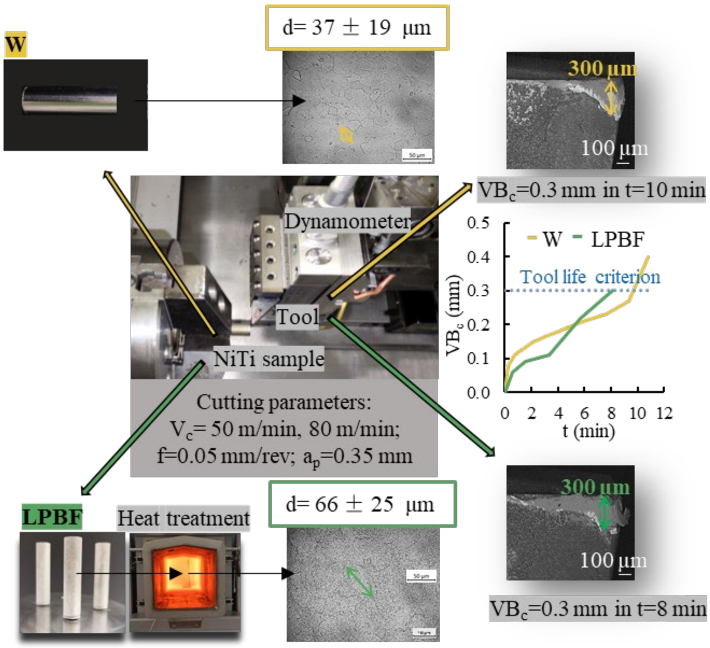
(iii) PROTEO Superelasticity and fatigue life assessment of 3D printed nitinol after machining operations» funded by University of Padova.

Main research topics:

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

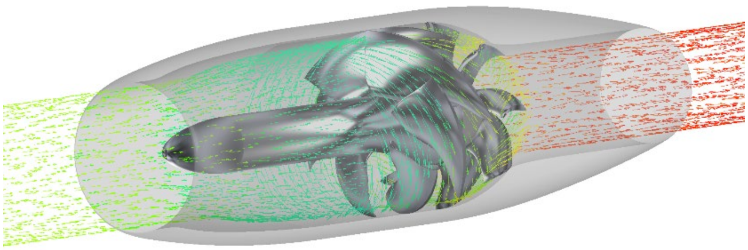
Tool wear and surface integrity analysis when machining wrought and additively manufactured Nitinol

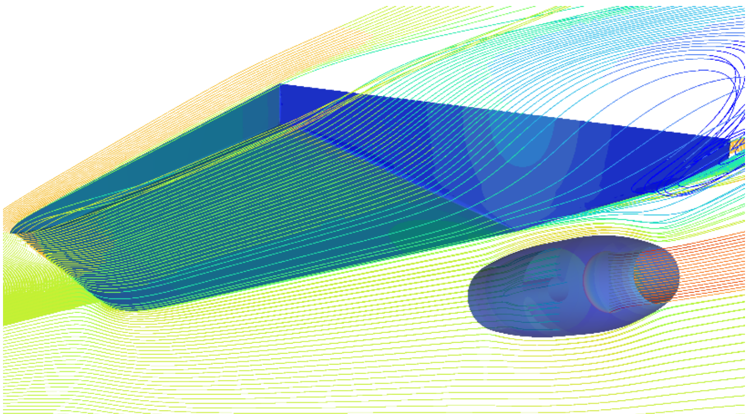
Nitinol (NiTi), with its shape memory and superelasticity (SE), is an attractive material for biomedical, aerospace, and robotic applications due to its ability to regain its original shape and its resistance to high deformation. This study examines the relationship between the microstructure of NiTi alloy and tool wear during machining, taking into account components manufactured using wrought (W) and additive manufacturing (LPBF) processes. The aim is to understand how these microstructural features contribute to the machining as well as the alloy's SE. Machining also suffers from excessive tool wear, which affects the transformation temperatures and the phase of the material in active form mainly impacting SE. The amount of tool wear was assessed using cutting force measurements and SEM imaging, with results indicating that LPBF samples had within them the tendency for faster tool wear particularly at lower speeds owing to both abrasive and adhesive wear mechanisms. High speed cuts reduced adhesive wear due to less time intervals between cutting edges contact with workpiece. Even though the cutting forces were similar, LPBF NiTi exhibited significantly higher wear rates than W NiTi due to inhomogeneous and coarse structure of LPBF. DSC thermal analysis demonstrated that W NiTi has a more stable austenitic phase (lower Af), while LPBF NiTi exhibits greater ductility and bigger grains. SE in W NiTi is largely preserved post-machining, whereas LPBF NiTi shows reduced SE, partially recovered with increased tool wear due to thermal loads. Microstructure investigations show severe plastically deformed (SPD) layers form on both the materials, with thinner layers at higher speeds and thicker SPD in W NiTi as tool wear progresses. Surface roughness increases with tool wear, but LPBF samples maintain smoother surfaces due to lower SE. Fresh tools consistently improve surface roughness in LPBF compared to W NiTi, although higher speeds lead to rougher surfaces at minimal tool wear.



Innovative marine propulsion for sustainable mobility in the Venice lagoon

Water mobility in the Venice lagoon strongly affects the environmental and life quality of one of the most beautiful, iconic, and fragile urban ecosystems in the world. Every day, more than two thousand vessels navigate on the narrow canals and shallow waters, generating noise, waves, and pollutants. The TEMPEST team at the Industrial Engineering Department is working collaboratively with the Venice University of Ca' Foscari in the project IMPRONTA-0 to investigate the impact of novel propulsion concepts on the Venice lagoon with the potential to alleviate the environmental impact of waterborne transport. The outboard dynamic inlet waterjet is an innovative propulsor inspired by aircraft engines that generates the thrust by accelerating a water flow that is first ingested by a submerged inlet and then ejected through a nozzle, after being pressurised by a pump. Differently from screw propellers, the confinement of the pump inside a duct enhances its performance providing high thrust at low speed for excellent manoeuvrability and extended margin to cavitation at high-speed. The outboard installation reduces the retrofitting complexity and makes the system particularly suited for electric power from a totally integrated engine. The research group adopts advanced numerical modelling using multi-phase computational fluid dynamics and state-of-the-art optimization algorithms leveraged by machine learning to derive design rules enhancing the system performance and its interaction with the hull. In the Venice scenario, IMPRONTA-0 studies the adaption of the outboard dynamic inlet waterjet to the specificity of the Venice lagoon, collaborating with local institutions , end-users, and citizens to understand how to optimally configure the system. By removing the annoying noise of thermal engines and being completely submerged, the novel waterjet promises a quiet power with virtually free emissions, contributing to the development of a sustainable mobility in harmony with the city and its inhabitants.





Energia

Energy

DII research group

Turbomachinery and Energy Systems – Propulsion and Power

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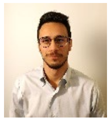

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Il progetto IMPRONTA-0 è finanziato da PR Veneto FSE+ 2021-2027, ed è svolto in collaborazione con l'Università Ca' Foscari di Venezia ed il contributo del Comune di Venezia, Autorità di Sistema Portuale del Mare Adriatico Settentrionale, e gruppo VERITAS S.p.a.

Main research topics:

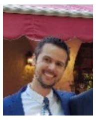
- Design, Modelling, Simulation and Optimization of Turbomachinery for Propulsion and Power
- Advanced numerical modelling and solver development

Sicurezza ambientale e industriale

Environmental and industrial safety

DII research groups

Safety group



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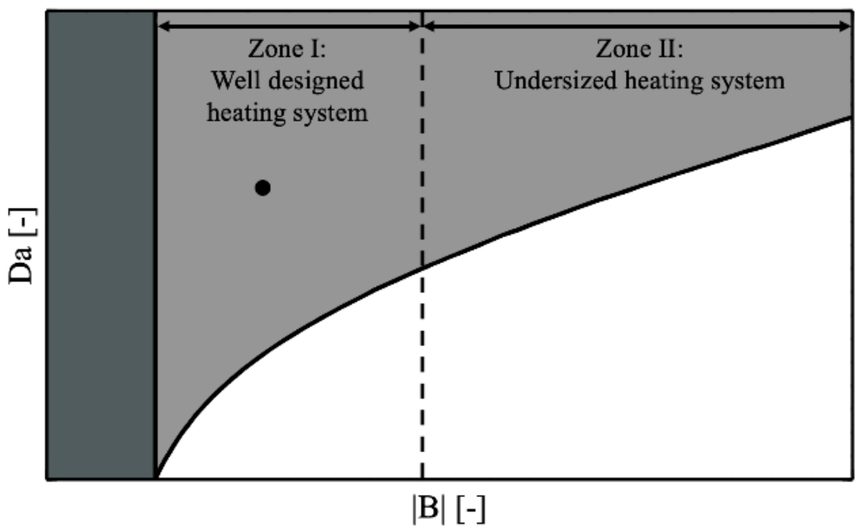
Partners: University of Bologna and industrial companies.
Experiments, modelling activities, and simulations take place in the DII laboratories.

Main research topics:

- Chemical reactors safety
- Equipment design and optimization

Advancing Operational Tools for Inherently Safe Chemical Reactors

Chemical reactors are vital to industrial processes, transforming raw materials into valuable products while influencing product quality and auxiliary equipment performance. The industry's transition toward greener and more sustainable manufacturing practices has driven the development of innovative technologies, such as electrified processes that replace combustion with electrical currents to generate heat, and hydrogen as a cleaner energy carrier to reduce reliance on carbon-based feedstocks. These advancements aim to minimize environmental impacts but bring challenges, including adapting system designs and infrastructure to meet stricter regulatory standards. Significant gaps in technical and legislative guidelines must be addressed promptly to ensure safety and environmental compliance. Current research focuses on creating reliable, versatile protocols to support these technologies. One promising approach is system stability analysis, which generates maps illustrating reactor responses to planned and accidental stimuli. This adaptable method can be applied to any chemical process with a mathematical model, enabling the evaluation of operational performance under normal and unforeseen conditions. Efforts are ongoing to validate this methodology, collect quantitative data, and develop case studies. Future work will integrate these protocols into broader sustainability frameworks, balancing technical, economic, safety, and environmental considerations. The objective is to establish a standardized methodology for consistently calculating metrics, enabling unified, comparable solutions. This research also aims to enhance reactor design, ensuring safer, more efficient, and sustainable operations. Preliminary results from modeling electrified reactors, analyzing industrial accidents, designing pharmaceutical reactors, and studying hazardous substance storage have been promising. These findings provide critical insights into safety, control, and design, addressing challenges often unpredictable qualitatively. Feedback from academia, industry, and inspectors highlights the need for ongoing research to improve these tools.



The dark grey area indicates an oversized heating system, while the white area represents an unproductive regime. The grey area marks the productive regime, with Zone I labelled as the optimal operating window. The black dot shows the reactor's nominal operating point within the optimal window.

A bioprocess engineering approach to boost transformation and selection of fully segregated mutants in cyanobacteria

Cyanobacteria are prokaryotes capable of performing oxygenic photosynthesis and are notable for their potential in biotechnological applications. Due to this industrial relevance, their transformability has been extensively investigated, thus encountering a major challenge: polyploidy. Several species of cyanobacteria possess multiple genome copies, which, while providing evolutionary advantages, complicates mutant generation. For a mutant phenotype to be expressed and maintained stably, mutations must occur across all genome copies.

Among cyanobacteria, the recently isolated *Synechococcus* PCC 11901 appears to be a promising strain for industrial cultivation due to its tolerance to wide ranges of temperature, salinity and light intensities. However ,the effects of growth and nutrient conditions on its polyploidy remain unexplored. In this study, we developed an alternative protocol that combines growth under phosphorus depletion (to favor cells with fewer DNA copies) with transformation in batch mode and selection in a continuous system. The protocol is summarized in Figure 1 and involves the cultivation of *Synechococcus* PCC 11901 in small continuous photobioreactors supplied with a limited phosphorus medium. The culture is then diluted to a desired density and the exogenous DNA with an antibiotic-resistance cassette is added. Transformation occurs overnight in batch mode. After that, an aliquot is plated on petri dishes with antibiotics, which are incubated until colonies appear as a control of occurred transformation. The remaining volume of culture is gradually diluted in P-depleted medium with antibiotics to a final volume that allows continuous growth without washing out. Decreasing residence time and increasing antibiotic concentration are used as selective pressure factors to select the faster-growing and more antibiotic-resistant cells in shorter times when compared to conventional methods. In approximately two weeks, fully segregated mutants were successfully selected, as highlighted by the absence of wild type in Figure 2.

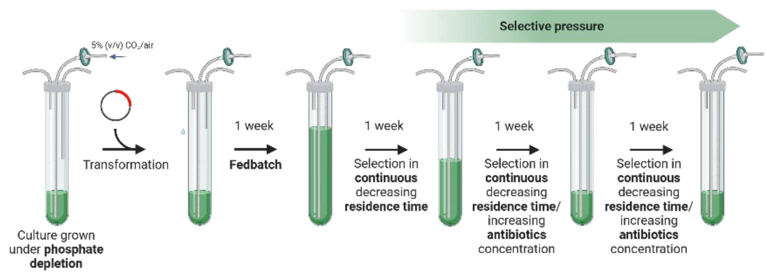


Figure 1: Schematic representation of the transformation and selection process.

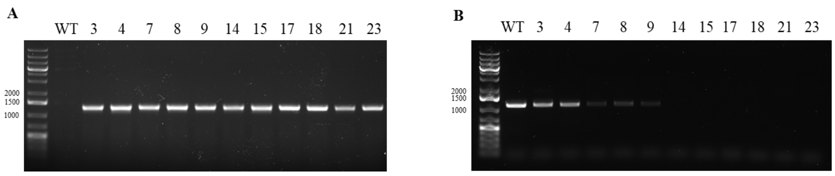


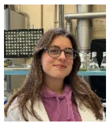
Figure 2: PCR on days 3-23 of selection of Syn11901 mutants. The adopted primers amplify a sequence of A) 1301 bp on the transformant genome; B) 1184 bp on the wild type genome. By day 14, wild type genomes are completely washed out of the reactor.

Bioingegneria, biotecnologia e tecnologie per la salute

Bioengineering, biotechnology and health technologies

DII research group

BiER Lab



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This project received fundings by Next Generation EU - PRIN 2022 PNRR and was conducted in collaboration with Università degli Studi di Verona.

Main research topics:

- Microalgae transformation
- Microalgae cultivation processes
- Bioprocess design and optimization
- Sustainable production

Sistemi Meccanici

Mechanical systems

DII research groups

Machine design

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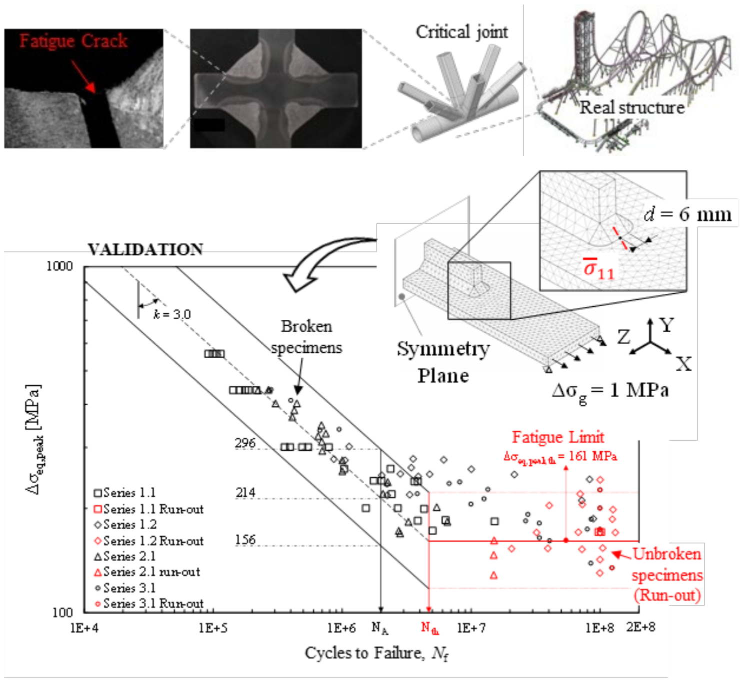
This research activity has been carried out in collaboration with: Dr. Mauro Madia – Bundesanstalt für Materialforschung und -prüfung (BAM), Division 9.4, Berlin (Germany).

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 lifetime 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

An efficient approach to assess the fatigue limit of large welded joints using the Peak Stress method

The structural integrity of large, lightweight welded structures is crucial across industries, where optimizing weight without compromising durability directly affects economic efficiency and safety. Welding, as a primary joining method for metallic materials, plays an important role in achieving these high-performance, lightweight designs. However, the safety and structural durability of metallic structures significantly depend on the strength of their joints, as most in-service failures of metal components occur due to fatigue actions in the joints. To address this challenge, a new approach has been developed that provides a faster and simpler way to estimate the fatigue limit of steel welded joints, which represents the stress level below which a structure can withstand infinite loading cycles without failure. Traditionally, evaluating the fatigue limit of welded structures involves complex analyses and extensive testing, especially for components with sharp notches where cracks are likely to form. The fatigue limit in these cases is linked to the point where a crack stops growing, which depends on the balance between the stress driving the crack propagation and the material's resistance to crack growth. The cyclic R-curve method helps determine this balance, but applying it can be time-consuming and requires significant expertise. The proposed method simplifies this process by using the Peak Stress Method (PSM), an engineering tool which relies on linear elastic finite element analysis to quickly assess fatigue strength of welded joints. By defining a threshold value for the local stress at the weld toe, the new approach effectively estimates when a crack will stop propagating. The combination of PSM and cyclic R-curve analysis makes it possible to estimate the fatigue limit of welded structures without the need for complex crack propagation models, significantly reducing the time and effort required. The method has been validated with experimental data from multiple test series, demonstrating its reliability and potential for industrial applications.



Distributing renewable heat in the Euganean area: from research to a district heating project

The Euganean Thermal Basin is a major touristic destination due to the presence of thermal groundwater, which is extracted at rates of approx. 15 Mm^3/year at temperatures between 65°C and 85°C. According to a Regional Law (P.U.R.T.) dated 1980, the groundwater can only be used for therapeutic purpose. Therefore, it is used by hotels and thermal spas and then released to the environment between 35°C and 50°C. In 2017, the Municipality of Montegrotto Terme financed a research grant to study the possible uses of geothermal energy in their territory, with a focus on the wastewater. In February 2018, we presented to the citizens an overview on all possible uses of the low temperature heat available in the area (Figure 1). We then drafted a pre-feasibility project of a low-temperature district heating network with booster heat pumps supplied by the wastewater of the hotels, that was later presented to a PNRR call in summer 2022.

The project was initially discarded due to budget limits, but in December 2023, it was awarded 4.3 M€ out of 200 M€ available for district heating projects. The initial project was supposed to supply 9 buildings with a low temperature district heating network (45/20°C) and water-to-water heat pumps in the buildings' substations, with an estimated primary energy saving of 102 tep/year. On October 2024, the final design of the DH network has been presented to the citizens in an event patrolled by our Department (see Figure 2). The project includes three central water-water heat pumps (570 kW each) using wastewater as a source, which will be collected through 200 m^3 ponds. A Renewable Energy Community will be established, and PV panels on the roof of the heat supply station will contribute to self-produce part of the electricity needed by the heat pumps. In the meanwhile, the Region has decided to allow the use of groundwater for energy purposes, provided that the well is authorized and connected to an existing monitoring system run by the authority in charge (GU.B.I.O.C.E). The presence of a renewable district heating system will make it possible to decarbonize the Municipality without necessarily retrofitting all the buildings, with economic and environmental benefits for the citizens of the Euganean town.

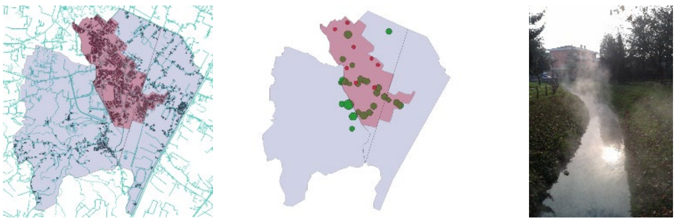


Figure 1: *Spatial distribution of buildings and wells in Montegrotto Terme.*

Figure 2: *Major of Montegrotto Terme (left) during the public presentation of the final district heating project (right).*

Energia

Energy

DII research group

Building Energy & Technology Assessment

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The authors would like to thank the Municipality of Montegrotto Terme and ing. Fausto Ferraresi (STP La Prospettiva) for sharing the details of the final design of the DH system.

Main research topics:

- Energy Efficiency in Buildings
- Urban Energy Systems
- Indoor Environmental Quality
- Applied Acoustics & Sound Quality

Processi e prodotti industriali

Industrial products and processes

DII research groups
PEG

Polymer Engineering Group

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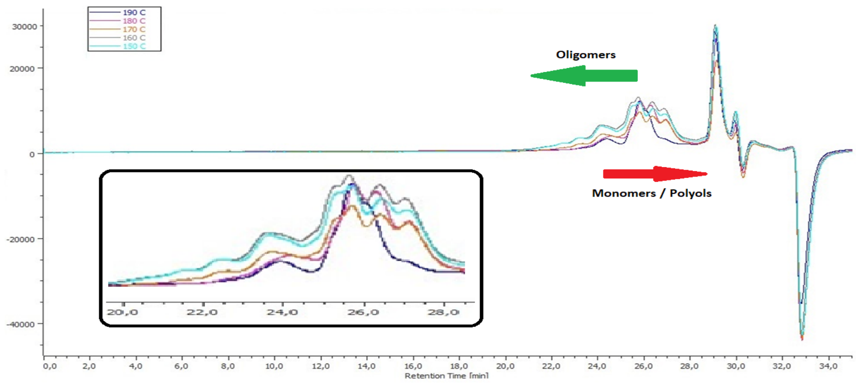
Main research topics:

- Chemical Recycling of Polymers
- Recovery of Polyols form Polyurethane Foam for Circular Economy
- Deamination of Chemically Recycled Products
- Effect of Temperature, Catalyst dose, Glycol compsition, Ratio between Glycol & PUF on Polyurethane Depolymerization
- Effect of these parameters on formation of aromatic amines
- Optimzation of process conditions for minimizing the formation of aromatic amines

Energy-Efficient, Eco-Friendly Chemical Recycling of Polyurethane Foam for Reduced Aromatic Amine Formation

Recycling flexible polyurethane foam (PUF) through complete depolymerization often leads to the formation of toxic aromatic amines and requires high energy inputs. An alternative approach is partial depolymerization to recover oligomers, which can be more sustainable and energy-efficient. In our work, we have depolymerized flexible polyurethane foam in a microwave reactor and through process optimization, we have reduced the formation of aromatic amines from 18000 to 3100 ppm. The milder conditions especially lower temperature i.e. 150 ˚C generate higher %age of oligomers which is also confirmed by GPC analysis , thus reducing energy consumption. Not only that; but the optimal conditions also significantly minimized the release of aromatic amines, which are harmful by-products [HPLC analysis]. The recovered oligomers retain reactive end groups (e.g., hydroxyl or isocyanate) and can be reused in the production of new polyurethane foams, reducing the need for virgin polyols. Recovered oligomers can be directly utilized as raw materials in flexible or rigid foam formulations. By focusing on oligomer recovery rather than complete depolymerization, we can create a more energy-efficient and environmentally friendly recycling process for polyurethane foams. This approach supports circular economy principles by enabling the direct reuse of recovered materials in foam manufacturing.



Stack design and control of Flow Batteries

Energia

Energy

DII research group
EESCoLab

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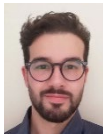

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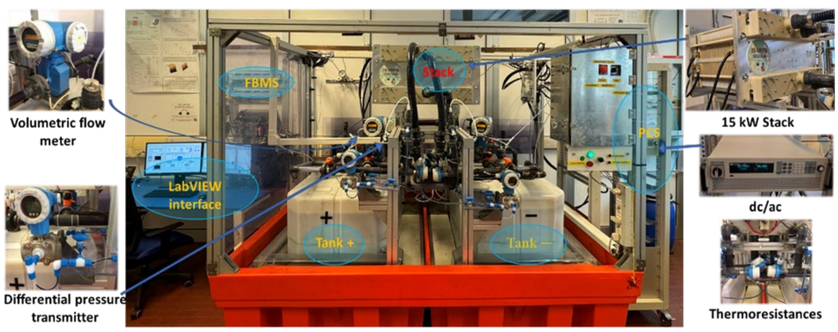
Main research topics:

- Flow Battery Systems
- Fuel Cells – Hydrogen
- Li-ion Systems

The research group is active in modeling, designing, developing, prototyping, and testing electrochemical systems for large-scale electrical energy storage and conversion. The investigated technologies include flow batteries, hydrogen fuel cells and electrolyzers, and lithium batteries. Major attention is devoted to flow batteries, with most activities focused on Vanadium Redox Flow Battery (VRFB), in reason of its several advantages, e.g., long cycle life and reduced environmental impact, thanks to the complete recyclability of vanadium. Research at EESCoLAB is primarily focused on the engineering challenges associated with scaling up these systems to industrial levels, starting from laboratory-developed innovative electroactive materials. These challenges are relevant for flow batteries and represent a largely unexplored research area in academic institutions. As a result, many of the associated challenges remain unresolved or are inadequately addressed, particularly in terms of optimizing the stack (i.e. the electrochemical power converter) architecture and the multi-physical control in operation. Notably, the up-graded test facility dubbed IS-VRFB has been put into service in Spring 2024, that is unique in Italy and among the few in Europe, that includes a stack with a rated power of 15 kW and 1100 liters of electrolytes made of 1.6 M vanadium ions dissolved in 4.5 M sulfuric acid, which are stored in two tanks, with a storage capacity of 27 kWh. Power control and management during charge/discharge cycles are provided by the Power Conditioning System (PCS), which consists of a two-quadrant ac/dc fully controlled static converter rated ±450 A and 0-80 V. The operation of the PCS and electrolyte circulating pumps is controlled by a proprietary Flow Battery Management System (FBMS) based on LabVIEW, designed to perform a wide range of experiments and testing at variable load, state of charge and electrolyte flow rate. A proprietary test system capable of testing single/multiple electrochemical cells in fully controlled condition has also been developed, which include a 20-channel electrochemical impedance spectroscopy (EIS) setup. This system is currently operational at EESCoLAB and is one of the few in Europe capable of conducting multichannel impedance spectroscopy tests on large-scale flow battery systems.



Up-graded Industrial-Scale Vanadium Redox Flow Battery (IS-VRFB), rated at 15 kW/27 kWh, with its main components. Two centrifugal electric pumps controlled by inverters based on PID feedback, circulate the solutions based on the FBMS specifications. The system is equipped with level sensors, differential pressure gauges, flow meters and resistance thermometers. Electrical sensors measure the stack current and all cell voltages, while a wattmeter measures the power supplied to the pump inverters. The HMI interface of the LabVIEW-based Flow Battery Management System (FBMS) and the dc/ac bidirectional inverter are also shown.

Cover story

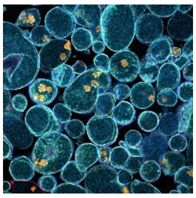


Immagine acquisita tramite microscopio confocale di una popolazione di proteinosomi contenenti cellule muscolari umane: le capsule proteinosomiche sono visibili tramite fluorofori verdi e azzurri mentre le membrane cellulari sono visibili grazie a fluorofori arancioni.

Questa attività di ricerca ha lo scopo di sviluppare, mediante biostampa 3D, un costrutto per il trattamento dell'ernia diaframmatica congenita. Per ridurre le elevate forze di compressione e di taglio che vengono impartite alla componente cellulare durante la biostampa, le cellule sono incapsulate all'interno di microcompartimenti detti proteinosomi, che le proteggano dalle sollecitazioni meccaniche.

I proteinosomi vengono poi introdotti in un hydrogel che agisce da supporto per la biostampa 3D e che, una volta garantito il supporto per la maturazione cellulare, possa essere degradato mediante irraggiamento in luce visibile.

La ricerca è condotta in collaborazione con il laboratorio di Tissue Engineering dell'Istituto di Ricerca Pediatrica Città della Speranza e con il Dipartimento di Scienze Chimiche dell'Università di Trieste.

Sara Manzoli

Laureata in Ingegneria Biomedica nel 2021 e in Bioingegneria nel 2023 presso l'Università degli Studi di Padova. È attualmente Assegnista di Ricerca presso il Dipartimento di Ingegneria Industriale all'interno di un progetto volto a sviluppare un costrutto innovativo per il trattamento dell'ernia diaframmatica congenita tramite l'utilizzo delle tecniche dell'ingegneria tissutale. Lavora sotto la supervisione della Prof.ssa Silvia Todros.

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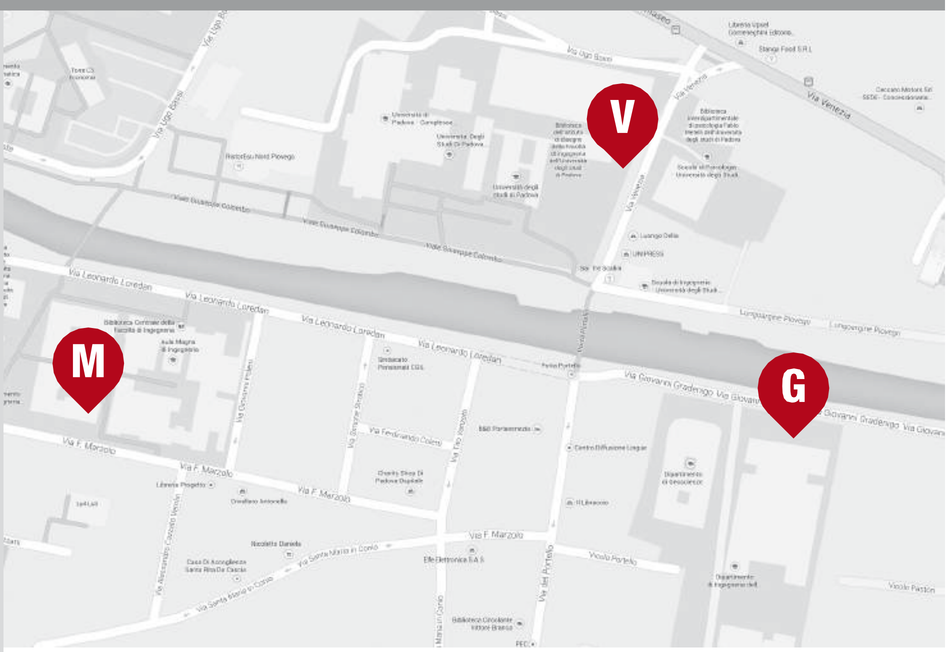

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