AIAS2025 Ph.D. Summer Course

Report of Contributions

Contribution ID: **1** Type: **not specified**

Registration and School Opening

Monday 16 June 2025 14:00 (30 minutes)

L. Vergani, Politecnico di Milano
P. Livieri Università di Ferrara

Contribution ID: **2** Type: **not specified**

The choice of material from an environmental perspective: from the European policies to the Life Cycle Assessment role - Prof. M. Delogu, Università di Firenze

Monday 16 June 2025 14:30 (1h 45m)

The aim of the seminar is to share knowledge on policies, regulations and practices (i.e. methodologies, tools, and standards) functional to the development of sustainable industrial products and technologies with a focus on the importance of material's choice in the circularity perspective. Particularly, special emphasis will be dedicated to the EU regulatory framework conducive to achieving the 17 SDGs of the 2030 SD Agenda and to the main EU flagship initiatives and policies (i.e. the European Green Deal and Circular Economy Action Plan). In this context, the concept of Life Cycle Thinking, and its implementation through methodologies based on the Life Cycle Sustainability Assessment approach, plays a crucial role for evaluating potential environmental benefits of different materials and design solutions that concur to identify the best sustainable trade-off along the whole product life cycle. The importance and the reason for the application of the LCSA approach will be explained and all the steps of the methodology will be described also through the exposition of different case studies

Contribution ID: **3** Type: **not specified**

Sustainable Velomobile Development: A Biomaterial-Based, Holistic Design Approach Across the Product Lifecycle - Prof.a C. Gastaldi, Politecnico di Torino

Monday 16 June 2025 16:45 (1h 45m)

This talk presents a circular design approach to developing a sustainable velomobile, a human-powered vehicle suited for short-distance travel, tourism, and green deliveries. Given the rising demand for alternative mobility solutions, velomobiles offer an efficient and weather-resistant alternative to bicycles. The project integrates Circular Design (CD) and Systems Engineering (SE) to optimize the velomobile's entire lifecycle—from material selection to end-of-life strategies. A key focus is the use of bio-based composites, particularly PLA reinforced with natural fibers, which have been purposely characterized to ensure mechanical performance and environmental sustainability. By integrating life cycle assessments (LCA) with lab testing, this study enables informed material selection that balances durability while minimizing the CO2 footprint. The talk will address the definition of the design requirements, the LCA based characterization of the newly developed materials, and the material selection process.

Contribution ID: **4** Type: **not specified**

Bioinspired Composite Design for Enhanced Mechanics: Part 1 -Dr. Zhao Qin, University of Syracure

Tuesday 17 June 2025 08:45 (1h 45m)

Natural materials exhibit remarkable functions—self-growth, mechanical strength, energy efficiency, environmental friendliness, and tunability—achieved through multiscale structures. Unlocking their gene-structure-function relationships and innovatively applying these materials is essential for transitioning from petroleum-based development to a sustainable, circular future. Through multiscale material modeling and collaborations, we integrate AI-driven modeling, 3D printing with advanced in situ synchrotron-based characterization techniques to study bioinspired composites and optimize their design. For example, we recently examined bamboo epidermis, where the disorder dispersion of silica particles enhances strength by mitigating defects and arresting crack propagation. By combining AI-guided analysis with 3D printing, we revealed how mesoscopic silica distributions significantly improve mechanical strength in fracture. Additionally, we explored mycelium fibers, which grow and bind within porous media such as wood and fibrous networks. Acting as a sacrificial layer, mycelium enhances material toughness and mitigates failure. Through AI-enabled insights and synchrotron-based characterization, we unraveled the mechanisms underpinning these enhancements, paving the way for sustainable applications. Our work spans from molecular modeling to large-scale building and energy applications, offering sustainable, strong, tough, and thermally stable materials for a wide array of challenges.

Contribution ID: **5** Type: **not specified**

Bioinspired Composite Design for Enhanced Mechanics: Part 2 -Dr. Zhao Qin, University of Syracure

Tuesday 17 June 2025 11:00 (1h 45m)

Natural materials exhibit remarkable functions—self-growth, mechanical strength, energy efficiency, environmental friendliness, and tunability—achieved through multiscale structures. Unlocking their gene-structure-function relationships and innovatively applying these materials is essential for transitioning from petroleum-based development to a sustainable, circular future. Through multiscale material modeling and collaborations, we integrate AI-driven modeling, 3D printing with advanced in situ synchrotron-based characterization techniques to study bioinspired composites and optimize their design. For example, we recently examined bamboo epidermis, where the disorder dispersion of silica particles enhances strength by mitigating defects and arresting crack propagation. By combining AI-guided analysis with 3D printing, we revealed how mesoscopic silica distributions significantly improve mechanical strength in fracture. Additionally, we explored mycelium fibers, which grow and bind within porous media such as wood and fibrous networks. Acting as a sacrificial layer, mycelium enhances material toughness and mitigates failure. Through AI-enabled insights and synchrotron-based characterization, we unraveled the mechanisms underpinning these enhancements, paving the way for sustainable applications. Our work spans from molecular modeling to large-scale building and energy applications, offering sustainable, strong, tough, and thermally stable materials for a wide array of challenges.

Contribution ID: **6** Type: **not specified**

To be announced - Prof. Nicola Pugno, Università di Trento

Tuesday 17 June 2025 14:30 (1h 45m)

Contribution ID: **7** Type: **not specified**

A vision towards bioinspired sustainable robotics - Prof. B. Mazzolai, Istituto Italiano di Tecnologia

Tuesday 17 June 2025 16:45 (1h 45m)

Natural organisms are inherently adaptive, continuously learning, and evolving. By studying their life processes and evolutionary strategies, engineers can extract key principles to design functional embodiments and energy-efficient behaviors—essential for artificial machines operating in unstructured and challenging environments. With this vision, our approach draws inspiration from plants and soft-bodied animals to develop robots with high morphological adaptability, distributed sensory systems, and energy-efficient mechanisms. Specifically, in this talk, I will explore how nature provides insights into multifunctional materials for morphological adaptation and computation, mechanisms for movements through growth, strategies for climbing and adhesion, multi-sensory information processing, distributed architectures of functionalities, and novel sustainable energy sources. These bioinspired robots—eco-robots—have potential applications in environmental exploration, monitoring, precision agriculture, and expanding our understanding of natural phenomena.

Contribution ID: **8** Type: **not specified**

A self-healing, adaptive, hierarchical material - Prof. Davide Ruffoni, Universté de Liege

Wednesday 18 June 2025 08:45 (1h 45m)

Damage and failure in ductile metals is characterized by nucleation, growth, and coalescence of voids. The underlying mechanisms and kinetics that control void nucleation and growth have been linked to material microstructure, but the specific controlling mechanisms associated with these processes are not understood or predicted. Hence, it is impossible to quantitatively understand and develop the physics that addresses basic questions like "how do materials fail?"This lack of understanding is in part related to a deficiency in experimental techniques that allow for direct quantitative and statistically relevant observations of void nucleation and early-stage growth. These in-situ observations have long remained a grand experimental challenge, largely due to the extremely fine spatial (nm) and narrow temporal (fs-ns) scales involved during actual loading experiments. In this talk, we will discuss examples where failure in metals is investigated using spall recovery techniques and advanced light sources like the advanced photon source and proton radiography

Contribution ID: **9** Type: **not specified**

Biomimetic tissue interfaces: design, modeling, and applications - Prof. M. Mirzaali, University of Delft

Wednesday 18 June 2025 11:00 (1h 45m)

Natural soft-hard tissue interfaces, such as those found between bone and cartilage or tendon, exhibit remarkable mechanical resilience and functionality. However, replicating these extreme interfaces in engineered systems presents significant challenges, primarily due to stress concentrations that lead to mechanical failure. In this talk, I will explore the fundamental design motifs that enable the durability and adaptability of natural tissue interfaces. I will discuss computational modeling approaches and optimization strategies for designing biomimetic interfaces, as well as fabrication techniques that translate these insights into functional materials. Finally, I will highlight potential applications, including the development of medical devices and in vitro models for guiding cell responses, with the ultimate goal of improving tissue integration and regenerative medicine.

Contribution ID: **10** Type: **not specified**

Bioinspired design: towards multifunctionality - Prof. F. Libonati, Università di Genova

Wednesday 18 June 2025 14:30 (1h 45m)

The high quest for lightweight, strength, and toughness is driving the research toward the design of de novo high-performance materials. Nature is a magnificent example of how–through the design and self-assembly of heterogeneous hierarchical structures–it is possible to amplify the properties of the constituent building blocks of biological materials, optimize such materials for the environment where they live, and adapt them to changing conditions. As evolution continues to drive the adaptive process of making natural materials over time, engineering is now attempting to emulate this extraordinary capability, lately via bioinspired architected materials and additive manufacturing. However, the advance of novel technologies in key areas, such as transportation, biomedicine, building and infrastructures, increasingly requests new high-performance structural materials able to adapt to diverse and changing conditions. Besides key mechanical properties, additional functionalities–characteristic of natural and living tissues–are required, from lightweight to sensing external stimuli, or shape morphing. This talk will review several natural examples of multifunctionality to provide inspiration for the design of novel multifunctional systems: from biological and biomineralized tissues to plants and marine systems.

Contribution ID: **11** Type: **not specified**

Bio-inspired strategies for enhanced tissue engineering - Prof. L. Vergani, Politecnico di Milano

Wednesday 18 June 2025 16:45 (1h 45m)

Contribution ID: **12** Type: **not specified**

Advanced AI Techniques for Material Analysis and Design: Part 1 - Prof. Filippo Berto, Università di Roma La Sapenza

Thursday 19 June 2025 08:45 (1h 45m)

Artificial intelligence (AI) has become a transformative tool in materials science, offering innovative approaches to address challenges in modeling and understanding material behavior. This lesson explores the core mechanic and the application of advanced AI architectures, such as Multi-Layer Perceptrons (MLPs), Convolutional Neural Networks (CNNs), Recurrent Neural Networks (RNNs) and Transformers, in analyzing and predicting the static and dynamic mechanical properties of additively manufactured materials. Key topics include how AI can model material anisotropy, address geometric imperfections, and predict performance under diverse testing conditions.

Contribution ID: **13** Type: **not specified**

Advanced AI Techniques for Material Analysis and Design: Part 2 - Prof. Filippo Berto, Università di Roma La Sapenza

Thursday 19 June 2025 11:00 (1h 45m)

Artificial intelligence (AI) has become a transformative tool in materials science, offering innovative approaches to address challenges in modeling and understanding material behavior. This lesson explores the core mechanic and the application of advanced AI architectures, such as Multi-Layer Perceptrons (MLPs), Convolutional Neural Networks (CNNs), Recurrent Neural Networks (RNNs) and Transformers, in analyzing and predicting the static and dynamic mechanical properties of additively manufactured materials. Key topics include how AI can model material anisotropy, address geometric imperfections, and predict performance under diverse testing conditions.

Contribution ID: **14** Type: **not specified**

Final Test & Discussion - Prof. L. Vergani, Politecnico di Milano and Prof. P. Livieri, Università di Ferrara

Thursday 19 June 2025 14:30 (1h 45m)