POLITECNICO DI MILANO

PhD in INGEGNERIA MECCANICA / MECHANICAL ENGINEERING - 40th cycle

THEMATIC Research Field: DIGITAL BIO-INSPIRED DESIGN AND BIOFABRICATION: SUSTAINABLE STRATEGIES FOR ADAPTIVE BONE REPAIR

Monthly net income of PhDscholarship (max 36 months)
€ 1500.0 In case of a change of the welfare rates during the three-year period, the amount could be modified.

Context of the research activity	
Motivation and objectives of the research in this field	Bones exhibit a remarkable self-healing capability, however large-scale damage beyond a species-dependent critical size necessitates the incorporation of implants to guide the regeneration process. Every year, a few million bone-grafting procedures are performed; despite it being the gold standard for bone substitution, there are multiple challenges associated with the use of autologous bone grafts. These include limited bony stock availability, patient morbidity at the graft harvest site, and elevated major complication rates (8.6 - 17.9%) associated with additional surgeries for bone harvesting. Consequently, the demand for synthetic bone implants is substantial and anticipated to rise with the aging global population. For instance, the projected doubling of patients requiring bone implants due to osteoporotic fractures by 2040 underscores the growing need, fostering a global market for synthetic bone implants with an annual turnover surpassing 90 billion euros. The aim of the research is to design novel tailored sustainable solutions for designing new mini-invasive implants. The adopted multi-disciplinary strategy, combining high-level experimental and numerical approaches, will lead to: 1) the definition of **innovative clinician- and patient-oriented solutions** for **mini-invasively treating bone fragility**; 2) the **digital transition** of design strategies towards the definition of a new bone-inspired personalized scaffold

	concept; 3) a **sustainable perspective** in tacking bone fragility through the adoption of biodegradable solutions.
Methods and techniques that will be developed and used to carry out the research	This research requires a multi-faceted range of methods and techniques to investigate multi-scale damage phenomena and to translate this understanding to the design of novel structures, including: 1. Imaging techniques: micro-computed tomography, synchrotron analyses, scanning electron microscopy are especially useful for identifying microstructural features that may contribute to a material resilience; 2. 3D printing and 3D bio-printing for complex structure design; 3. Multi-scale mechanical testing to study material mechanical properties, including its strength, toughness, and elasticity; 4. Computational modeling, to simulate damage evolution, weakening and toughening phenomena at the multi-scale, including extended finite element (XFEM) strategies to model fracture progression; 5. Image analysis, adopting effective artificial intelligence-based tools for the post-processing of large size datasets, such as high-resolution imaging.
Educational objectives	This cutting-edge research perspective on tailored green solutions for bone repair is a unique opportunity for PhD students to: 1. Elucidate the complexity of the multi-scale structure and characteristics of biological materials, as well as the fundamental principles governing their response to damage towards sustainable engineered solutions; 2. Employ a diverse array of methodologies and approaches, encompassing advanced imaging techniques, mechanical testing, and computational modeling, to investigate and analyze these materials; 3. Cultivate critical thinking and problem-solving abilities while nurturing innovation and creativity by providing guidance to doctoral students in the creation of novel bio-inspired structures that exhibit improved mechanical properties.

	4. Establish interdisciplinary collaboration among students and faculty from various disciplines, including biology, physics, mechanical engineering, and material engineering, to foster cross-pollination of ideas and expertise.
Job opportunities	Employment statistics of PhDs can be found at: https://cm.careerservice.polimi.it/en/employment-statistics/ . Cooperating to this research are: 1. IRCCS Ospedale Galeazzi, for a clinical perspective of the fragility problems; 2. TU Delft, with reference to bio-inspired material design; 3. Elettra synchrotron, for high-resolution real-time imaging of damage.
Composition of the research group	1 Full Professors 0 Associated Professors 1 Assistant Professors 3 PhD Students
Name of the research directors	Prof. Laura Maria Vergani

Contacts
Phone: +39 022399249 *Email:* laura.vergani@polimi.it For questions about scholarship/support, please contact phd-dmec@polimi.it.

Additional support - Financial aid per PhD student per year (gross amount)	
Housing - Foreign Students	--
Housing - Out-of-town residents (more than 80Km out of Milano)	--

Scholarship Increase for a period abroad	
Amount monthly	750.0 €
By number of months	6

Additional information: educational activity, teaching assistantship, computer availability, desk availability, any other information
Financial aid is available for all PhD candidates (purchase of study books and materials, funding

for participation in courses, summer schools, workshops and conferences) for a total amount of euro 6.114,50.

Our candidates are strongly encouraged to spend a research period abroad, joining high-level research groups in the specific PhD research topic, selected in agreement with the Supervisor. An increase in the scholarship will be applied for periods up to 6 months (approx. 750 euro/month- net amount).

Teaching assistantship: availability of funding in recognition of supporting teaching activities by the PhD candidate. There are various forms of financial aid for activities of support to the teaching practice. The PhD student is encouraged to take part in these activities, within the limits allowed by the regulations.