Biomimetic design of implants for for bone tissue engineering

Summary

The PhD position is opened for an Early State Researcher to be involved into the development of bio-mimetic substrates of TPMS architecture composites. Ambitions and expectations of the PhD project are extremely high as the synthetic materials necessitates a precise modulation of composition and structure. Design and simulation of biomimetic load-bearing structures and selection of optimal architectures for the bone-mimicking implant, with cortical and trabecular bone components, to repair bone critical-sized defects is extremely important topic as over the past decades, the use of implants and scaffolds has rapidly grown, driven by an aging population. To meet the demands, new adopted materials should be developed with the shape and size tolerances and compositions modified to fit the nowadays demands. Implants and scaffolds are being developed to support osteogenesis and vascularization and replace damaged tissues in critical- sized bone defects. The triply periodic minimal surface (TPMS) architectures, which can be described as periodic infinite frameworks with a zero mean-curvature at any point along three independent axes, can adequately mimic the interconnected trabecular bone architecture. Tailoring the parameters of the TPMS structures, unit cell shape, and porosity distribution can be controlled to match the mechanical properties of the natural human bone.

Research field:	Production and materials engineering, robotics, transport and logistics
Supervisor:	Prof. Dr. Irina Hussainova
Availability:	This position is available.
Offered by:	School of Engineering Department of Mechanical and Industrial Engineering
Application deadline:	Applications are accepted between October 02, 2023 00:00 and October 23, 2023 23:59 (Europe/Zurich)

Description

The **project aims** at • Design and simulation of biomimetic load-bearing structures and selection of optimal architectures for the bone-mimicking implant, with cortical and trabecular bone components, to repair bone critical-sized defects. The **objective** is development of light-weight highly wear resistant structures successfully working in tribo-conditions exploiting bio-replication of architecture and gradients of bone (energy absorption) and surface texturing of snake (low friction and wear). The **ultimate goal** of the project is twofold: (i) Design, manufacturing and characterization of functionally graded TPMS Ti/ composites, which can further elevates the multifunctionality of the surgical implant regarding biological properties and mechanical compliance; and (ii) Modelling of bio-inspired architectures based on Finite Element Simulations (FES) of the additively manufactured TPMS in different loading scenarios of bending and stretching (compression and tensile regions) and optimization of the geometrical parameters of the constructs to make them both printable and bio-efficient. Simulation of new biomimetic load-bearing implants designed to treat long bone critical-sized defects taking into consideration both cortical and trabecular bonds. To meet the demands, new adopted materials should be developed with the shape and size tolerances and compositions modified to fit the process. TPMS structures with biomimetic architecture should be designed and fabricated by SLM/S technology as the functionally graded TPMS are more conducive to successfully exchange information between the unit cells which can result in the enhanced mechanical properties by minimizing stress-shielding effect. Moreover, the gradient patterns designed in the TPMS surfaces of the composite scaffold can mimic the outer layer of the acetabular rim, which is in conjunction with the femoral head. Henceforth, this biomimicry behaviour of the composite gradient scaffold can be the potential solution to treat osteochondral defects in the articulating cartilage or surface of the acetabulum of the load-bearing implant, which is in vicinity with the lesser trochanter region.

Responsibilities and (foreseen) tasks

- Design/modelling of the bone-mimicking substrate based on triply periodic minimal surfaces (TPMS) strategy.
- Finite element analysis of mechanical properties.
- To collect data and conduct case studies on the selected cases on experimental approaches and institutional innovations
- To characterize the materials (microstructure, composition, mechanical properties)
- To contribute to the organization of research and workshops where project findings are presented

Applicants should fulfil the following requirements:

- a master's degree in Materials Sciences or Materials Engineering (preferably in metals and ceramics; materials chemistry; and powder metallurgy)
- skills and experience in modeling/simulation
- some experience in materials microstructural characterization (optical microscopy, SEM, XRD etc) by use of quantitative methods
- a clear interest in the topic of the position
- excellent command of English
- strong and demonstrable writing and analytical skills
- capacity to work both as an independent researcher and as part of an international team
- capacity and willingness to provide assistance in organizational tasks relevant to the project

The following experience is beneficial:

- Experimental and/or biomechanics
- Experience/knowledge in computational design
- Working knowledge of finite element analysis
- Mechanical testing

We offer:

- 4-year PhD position in one of the largest, most internationalized and only University of Technology in Estonia with a large portfolio of ongoing pan-European and national projects
- The chance to do high-level research in an international team
- Opportunities for conference visits, research stays and networking with globally leading universities and research centers all over the world

About the department

The department of Mechanical and Industrial engineering focuses on the engineering side of self-driving vehicles, developing new coatings and additive manufacturing developments. The curriculums on Bachelor, Masters and Doctor level have hundreds of graduates each year. We also provide engineering services for industry and our partners, starting with modelling and finishing with production optimization.

TalTech houses state-of-the-art powder metallurgy and additive manufacturing laboratories, plus laser, optical, metrology and chemical labs and equipment – the ideal environment for world-class materials development.

Additional information

For further information, please contact Prof Irina Hussainova (Irina.hussainova@taltech.ee) or visit https://taltech.ee/en/department-mechanical-and-industrial-engineering

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