PhD position
X-Ploring Snow: 4D exploration of the ductile-to-brittle transition in snow

Context and work environment

Context: Gaining a better understanding of the mechanical behaviour of snow is crucial for numerous applications, including avalanche forecasting and risk management, modelling the evolution of seasonal snowpack and polar firn, and predicting the loads induced by the snowpack on infrastructure and buildings. Snow is a complex material characterised by a highly porous microstructure and a strong heterogeneity, both of which evolve with external conditions (e.g., temperature, loading). The interplay between microstructure evolution and mechanical response of snow at macro scale remains an active field of research, with specific challenges involved in controlling and testing this material.

The objective of the PhD is to conduct and analyse original mechanical experiments on snow samples coupled to in-situ characterisation of microstructural evolution through X-ray microtomography. A specific focus will be put on the brittle-to-ductile transition, which occurs at a specific strain rate and is associated with discontinuous and localised deformation patterns. Advanced image processing techniques, such as Digital Image and Volume Correlation (DIC/DVC), combined with innovative, AI-assisted approaches will be used to recover the kinematic fields. The methods and results will pave the way for further applications requiring similar spatio-temporal resolutions (e.g. hydro-mechanical coupling in porous media) and involving highly localised mechanisms (e.g. crack propagation in cementitious materials).

Team description: The PhD will take place within two Tec21 labs located on the Grenoble Campus:

- Institute of Geosciences of the Environment (IGE), which conducts research on climate, the pollution of our planet and environmental risks, particularly in regions where societal and environmental issues are most prevalent: the polar regions, the intertropical zone, and mountain regions. IGE is renowned worldwide for its expertise in snow and ice mechanics;
- 3SR Laboratory, which has a strong expertise in the physical and mechanical characterization of porous and multi-phase materials by coupling X-ray tomography, in-situ testing, and 3D kinematic field measurements;

and will benefit from a strong collaboration with the CEN (Center for Snow Study) of the Centre National de Recherche en Météorologie (CNRM), which focuses on snow and mountain meteorology at different scales from the underlying physical processes to climate applications.

The PhD will be supervised by Maurine Montagnat (IGE), expert in ice and snow mechanical behaviour, Emmanuel Roubin (3SR) and Olga Stamati (3SR) experts in modelling of localised mechanisms and X-ray in-situ testing coupled with advanced image processing. The work will be carried out in close collaboration with Guillaume Chambon (IGE) and Pascal Hagenmuller (CEN-CNRM). This team brings together a wide range of expertise in the deformation mechanisms of ice and snow, from mechanical tests and X-ray tomography characterization to numerical modelling and advanced imaging techniques.

This recruitment takes place within the PhD@Tec21 Programme, which is co-funded as part of the Marie Skłodowska-Curie COFUND actions under the grant agreement #101217261. The recruitment process follows a specific selection and evaluation procedure with particular eligibility criteria, all of which are detailed in the applicant guide available on PhD@Tec21 Website.

Mission and main activities

X-ploring Snow: 4D X-ray exploration of the ductile-to-brittle transition in snow
Description of the project: This project aims to decipher the links between the mechanical response, the microstructural evolution, and the deformation fields in snow, so as to provide better insights into the micro-scale mechanisms at play in natural snowpacks. X-ray microtomography will be used to follow the 4D (3D + time) evolution of snow microstructure during compression tests with a high spatio-temporal resolution. Advanced imaging and analysis methods will be developed and applied to track the deformation mechanisms at the grain scale, including the initiation and evolution of localised deformation mechanisms at the ductile-to-brittle transition. **Several research axes will be explored:** 1. **Development of a robust workflow to characterise kinematic fields in snow** over a wide range of strain rates based on Digital Image Correlation (DIC) and Digital Volume Correlation (DVC). In-situ experiments will be conducted using a specific micro-press device and an X-ray tomograph operating in a cold room. At low strain rates, DVC will be applied to reconstructed 3D images to recover the full strain fields. At high strain rates, DIC will be applied to 2D radiographs to track the localised deformation patterns and observe the deformation bands. 2. **Exploration of the ductile-to-brittle transition under various temperature conditions**. The developed workflow will be applied to investigate the mechanisms involved in this transition and the formation of localised compaction bands. Of particular interest is the role played by metamorphism and sintering mechanisms versus mechanically induced microstructure rearrangements. These results will be central in developing a microstructure-inspired constitutive model for snow. 3. **Development of advanced image analysis methods**, such as projection-based DVC (P-DVC) and AI-assisted image reconstruction. These methods have the potential to enable 4D monitoring of fast and localised deformation processes with an unprecedented spatio-temporal resolution. Application to snow remains challenging and will be achieved as part of a collaborative effort covering various applications, in the frame of the development of the open-source SPAM platform. *Depending on the candidates' background and specific interests, the focus of the PhD may be more on one or two of these research axes, although all three are important for the project.*
Supervisors: Maurine Montagnat, Olga Stamati and Emmanuel Roubin
Research fields: Mechanics of materials, material sciences, snow science, advanced imaging techniques
Possible secondments: SLF-WSL Centre for Snow and Avalanche Research, Davos, Switzerland
Doctoral school: I-MEP2: Engineering - Materials, mechanics, environment, energy, processes, production

Desired profile and expected skills

Education, diplomas

The candidate should hold a Master's degree (or equivalent) in Engineering or Applied Sciences with a background in one or more of the following fields:

- Mechanics of materials and physics of deformation.
- Material sciences and engineering

- Applied mathematics or quantitative image analysis

Disciplinary skills, experience

Experience of experimental work and of advanced material characterization method (e.g. X-ray tomography) will be acknowledged. Knowledge of at least one scientific programming language is necessary (Python/Matlab/C++). Fluent English speaking and writing skills are required for oral presentations at conferences and writing articles.

Personal skills

This PhD position requires the ability to work in a research team, which means having autonomy on individual tasks and maintaining interactions for collaborative work. The ability to report authentically on progress and any difficulties encountered, and to contribute to designing adapted solutions is necessary.
The candidate will be required to lead experimental work and data analysis meticulously and diligently. He/She should demonstrate scientific curiosity and perseverance in problem solving.
Strong communication and reporting skills (oral and written) are essential for meeting the expectations of research work.

Employment benefits and conditions

Université Grenoble Alpes (UGA) is offering a 36-month full-time work contract. In line with the European Commission rules for Marie Skłodowska-Curie grant holders, the remuneration will consist of a gross monthly salary of 2,669 EUR. The estimated net salary to be perceived by the PhD fellow will be between 2,050 and 2,152 EUR[1].

Benefits include:

- Access to a high-quality work environment, including a personal computer, scientific equipment and access to library and shared lab facilities
- Full social security benefits and participation to health insurance
- Access to high-level scientific and inter-sectoral training through 120 hours of doctoral courses and workshops
- Opportunity for 2-month secondments at an academic institution or industrial partner during the 2nd year of the PhD
- A vast choice of networking events and activities within the PhD@Tec21 Programme and through the international network of MSCA fellows
- Access to the UGA International Student Office, to assist the PhD fellows in searching for accommodation in Grenoble and support with administrative issues including visas, health, bank accounts, etc.
- Visa fees and registration to the UGA Doctoral School are covered by PhD@Tec21
- Sick leave, parental leave, 45 days of paid holidays

General information

Contact for the questions related to the position:
PhD@Tec21 Management Board: amelie.bataille@univ-grenoble-alpes.fr

[1] As an average over the 3 years, depending on French tax regulations. Fellows might benefit from an additional allowance depending on their family situation (74 EUR monthly net allowance)