IMT Mines Alès
École Mines-Télécom

Open Master thesis position

Supervisor : Sarah Iaquinta – IMT Mines Alès
Other researchers involved : Anne-Sophie Caro, IMT Mines Alès, Baptiste Pierrat, Mines Saint - Etienne
Duration : 6 months, starting in March
Where : IMT Mines Alès / C2MA with trips to Mines Saint-Etienne

Subject : Characterization and modeling of damage in porcine soft tissues under mechanical stress: contribution of phase-field models for the early detection of microstructural damage

Project description :
The objective of this project is to study the damage to porcine soft tissues when subjected to mechanical stress, with a focus on the early detection of damage before it becomes apparent on a macroscopic scale, i.e., before measurable macroscopic stress decreases (Figure 1). This project is a collaboration between two research teams, each contributing their expertise through microstructural modeling using phase-field models (Mines Saint-Étienne) and macroscopic modeling using phenomenological models (IMT Mines Alès).

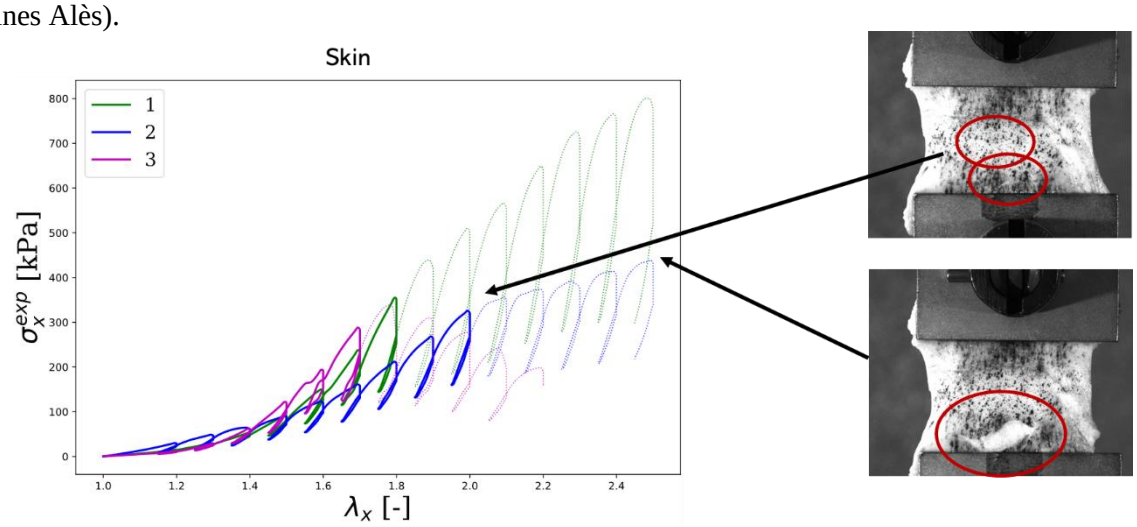

Figure 1: Stress descrease after tearing

Context and challenges:
Damage to biological soft tissues is a complex phenomenon characterized by microstructural alterations affecting the extracellular matrix (e.g., collagen and elastin fibers) before becoming directly observable (e.g., tearing). Early detection of these phenomena is crucial to preventing structural failures, whether in biomedical or industrial contexts. Modeling is a powerful tool for predicting and analyzing these phenomena at a scale not directly observable experimentally. Applications include sports injury studies, rehabilitation, development of medical devices, and reconstructive surgery.

Objectives**:**
This project aims to develop and use numerical models to detect microscopic damage in porcine soft tissues before it becomes macroscopically visible. We will rely on two types of models:

1. **Microscopic phase-field model:** This model aims to account for morphological and structural features observed through histology and to use a finite element mechanical model based on phase-field theory to simulate the initiation and propagation of damage in these structures during macroscopic mechanical stress.
2. **Macroscopic phenomenological model:** Modeling the mechanical properties of soft tissues, integrating damageable viscoelastic behaviors under large deformations.

IMT Mines Alès
École Mines-Télécom

The M2 intern will be responsible for identifying key variables from these models that could be correlated with microstructural evolution observed experimentally (via histology or imaging). The goal is to propose numerical indicators to detect damage before any macroscopic manifestation.

Methodology:

- **Experimental phase:** Perform mechanical tests (tensile tests) on porcine soft tissue samples (e.g., skin). Observe and quantify microstructural evolution using histology and imaging techniques.
- **Numerical modeling:** Use the two models developed by the partners to simulate tissue behavior under stress. Analyze the results to identify variables correlated with damage.
- **Coupling and validation:** Correlate experimental data with model predictions, identifying early indicators of damage.

1. Caro-Bretelle AS, Ienny P, Leger R, Corn S, Bazin I, Bretelle F. Constitutive modeling of stress softening and permanent set in a porcine skin tissue: Impact of the storage preservation. J Biomech. 2016;49(13):2863-2869. doi:10.1016/j.jbiomech.2016.06.026
2. Pillet B, Molnar G, Bel-Brunon A, Pierrat B. Investigating the identifiability of phase-field parameters to model soft tissue rupture. In: Computer Methods in Biomechanics and Biomedical Engineering. ; 2021:S316-S317.

Preferred profile :
3rd-year engineering student or M2 (Master thesis), with an interest in numerical mechanics.

Contact :
Sarah IAQUINTA
IMT Mines Alès, LMGC/DMS
6 Avenue de Clavières
30319 Alès Cedex, France
sarah.iaquinta@mines-ales.fr