Master 2 internship at SAINBIOSE, Mines St Etienne

Design of a Bulge Inflation Experiment to Characterize the Critical Pressure of Aortic Dissection

CONTEXT

This internship is part of the ADRIS (Aortic Dissection Risk from Internal Structure) project, funded by the ANR and starting in 2025.

Aortic dissection is one of the most prevalent catastrophic cardiovascular events. **The ADRIS (Aortic Dissection Risk from Intramural Structure) project aims to predict the risk of type A aortic dissection in patients by analyzing both the intramural structure of the aorta and biomarkers from blood samples**. The project follows a four-step process: characterizing tissue rupture risk through mechanical testing of ex-vivo human tissue, understanding the role of micro-defects in the onset of dissection using synchrotron X-ray tomography, developing a multi-scale biomechanical model of the dissection process, and analyzing biomarkers to correlate with mechanical properties and defect density. This integrated approach will enable probabilistic prediction of dissection based on the structure and composition of the aortic wall.

By combining these experimental and computational findings, ADRIS aims to create a clinical scoring system that can predict aortic dissection using readily available medical data. The project will provide clinicians with a tool to better assess dissection risk, supporting decision-making for patient monitoring and treatment. Additionally, the ADRIS project will enhance the understanding of the biochemical and mechanical processes involved in aortic dissection, with the potential to advance medical imaging techniques and influence future technological developments in cardiovascular healthcare.

POSITION DESCRIPTION

We are seeking a student to initiate this project by **designing the inflation experiment that will characterize aortic tissue up to rupture.** The key challenges of this project (and what makes it exciting!) are:

- In order to reproduce the anisotropy of in-vivo tensions, an appropriate shape should be used for holding the tissue. Finite element simulations will help to address this point.
- The device must accommodate the limited amount of tissue collected during surgery. Additive manufacturing (3D printing) will be used for rapid iteration of designs.
- The tissue will be inflated using a pump capable of applying a physiological pressure profile at approximately one cycle per second. A control loop will be implemented to ensure accurate pressure control.
- The set-up must be compatible with X-ray tomography for in-situ imaging.

You will be co-supervised by Dr. Aline Bel-Brunon (LBMC, Univ. Gustave Eiffel) and Dr. Baptiste Pierrat (SAINBIOSE, Mines St Etienne).

During this project, you will be in interaction with a consortium of researchers in biomechanics, biology, X-ray tomography as well as clinicians (cardiac and vascular surgeons). **A funded PhD position will be available after this internship.**

Figure 1: Bulge inflation test from a previous study showing layer delamination before complete failure.

RESEARCH OBJECTIVES AND METHODOLOGY

1. Finite element simulations of bulge inflation. The objective of these simulations is to determine the optimal elliptic shape for reproducing in-vivo tensions in the aortic arch of a given patient. Multiple simulations will be conducted to explore how the shape of the ring affects tension under pressure.

2. Establish the design requirements. You will collaborate with an engineer to define the experimental setup's requirements and select appropriate technical solutions and components. The setup will then be manufactured and assembled.

3. Performing quasi-static experiments. A preliminary evaluation of the setup will be conducted with quasi-static experiments on porcine aortic samples.

4. Implementing the control loop. You will develop a control loop, such as a PID controller, to replicate physiological pressure profiles.

QUALIFICATIONS

Ongoing Master's or Engineering degree in mechanical engineering, biomedical engineering, or a related field.

A first experience in mechanical testing, and/or design of experimental devices or finite element analysis will be a major plus.

Proficiency in programming (e.g. Python, MATLAB) for data analysis.

Fluent communication in an international background and ability to work in an interdisciplinary team.

POSITION DETAILS

Duration and Location: **6 months** at Mines Saint-Etienne (SAINBIOSE)

Expected start date is **March-April 2025**

APPLICATION PROCEDURE

Candidates are invited to submit the following documents:

- Detailed CV
- Cover letter highlighting relevant experience and motivation for the research project
- A reference letter from an academic or industrial professional (optional but recommended)

Applications should be sent to: Dr. Baptiste Pierrat (baptiste.pierrat@mines-stetienne.fr) and Dr. Aline Bel-Brunon (aline.bel-brunon@univ-eiffel.fr)

Deadline for application: **31 December 2024**

SAINBIOSE

The SAINBIOSE Unit (SAnté Ingénierie BIOlogie Saint-Etienne) combines researchers from Jean Monnet University, Mines St Etienne, the French Blood Establishment, and the Saint-Etienne University Hospital. Its research focuses on osteo-articular biology, soft tissue mechanobiology, and hemostasis-thrombosis. SAINBIOSE includes 48 permanent researchers and 37 technical staff, organized into two teams, and trains 58 PhD students. In the past five years, it has produced 100 publications annually, filed 6 patents, developed 3 software tools, and launched 2 startups. The "Soft Tissue Biomechanics" group, led by Prof. S. Avril, conducts numerical, clinical, and experimental studies on the mechanical behavior of biological tissues and their interaction with medical devices. The lab is equipped with experimental tools such as uni- and bi-axial tensile machines, optical field measurement systems, and microscopy devices. SAINBIOSE collaborates with a strong academic network and partners with companies such as Thuasne, Sigvaris, and Medtronic.

LBMC

The Laboratory of biomechanics and impact mechanics (LBMC, UMR_T9406) is a joint unit between the University Gustave Eiffel and the University Claude Bernard Lyon 1. The LBMC gathers more than 80 members (45 staff members, around 30 PhD students and 10 research assistants and post-docs), in addition 20 trainees are welcomed every year. LBMC members have complementary skills in impact biomechanics, structural mechanics, uncertainties, tissues biomechanics, anatomy and surgery, physical ergonomics, movement analysis, musculo-skeletal biomechanics.

Based on societal challenges, the LBMC leads researches, on two themes:

- Facilitating travel (automated vehicles, autonomous travel)
- Maintaining good health (functional capacities, the repaired body: the implant in its environment).

It has unique experimental platforms :

- For movement analysis (e.g. instrumented treadmill, seat conformer, …),
- For impact characterization (e.g. high-speed loading testing machines, Split Hopkinson bars, …),
- For biological materials characterization (dedicated facilities, robot arm, …).

Among its flagship projects, the LBMC coordinated the european project PIPER(FP7), is abdomen center of expertise for the worldwide project GHBMC since 2008, coordinates the national project ENA (autonomous shuttle). The LBMC is involved in the Virtual Physiological Human Institute (VPH) and the BOHNES network. In 2019, the LBMC founded, with its partners from Canada (Québec), the associated international laboratory EVASYM (anatomo-functional evaluation of the musculoskeletal system).