Experimental characterization of material properties of a bioprosthetic heart valve

General context

In case of severe valvular heart disease (VHD), such as the aortic valve stenosis and regurgitation, it is often recommended to carry out the valve replacement operation[1]. Comparing with rigid mechanical heart valves, deformable bioprosthetic valves generally have better biocompatibility and better hemodynamic performance. Most bioprosthetic valves are made of either bovine pericardium or porcine aortic valves, such as the Sapien 3 of Edwards Lifesciences, etc. The main risk of bioprosthetic valves is the reoperation due to the limited durability[2].

Nowadays, numerical simulation plays an important role in the design and optimization processes for improving the performance and durability of bioprosthetic valves. In order to ensure the reliability of the numerical simulation of blood-valve interaction (Fig. 1), it is crucial to implement a realistic material model for the valve leaflets in the structural modeling such as finite element method (FEM).

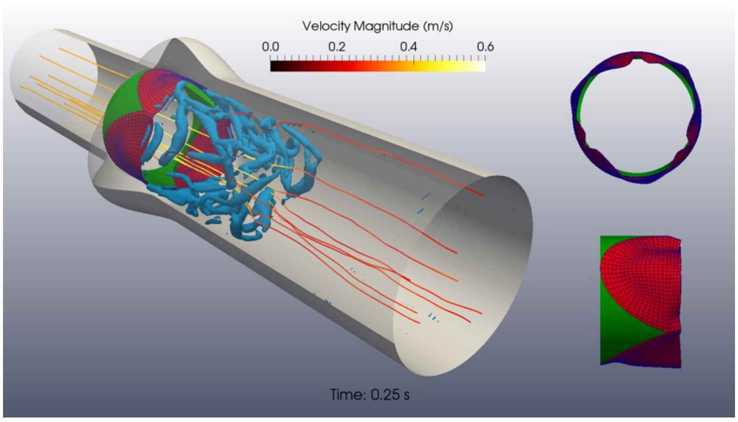

Fig. 1 Numerical simulation of blood flow-heart valve interaction[3]

Scope and objectives

In this internship, the objective is to obtain the material characteristics of a bioprosthetic heart valve by means of a series of experimental measurements, including uniaxial or multiaxial (biaxial) traction mechanical tests, etc[4]. These experimental tests will allow us to obtain the nonlinear relation between the stress and strain of the leaflet material. By adopting the isotropic assumption, we can finally make use of the obtained experimental data to calibrate the Fung-type hyperelastic material model[5], which is widely used for biological soft tissues. The coefficients in the Fung-type model will then be implemented in the existing FEM code for further validation benchmarks.

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Major steps

1) Start with a thorough bibliographic review on the existing experimental studies of biological soft tissues, especially heart valve leaflets;
2) Get familiar with the biaxial mechanical test facility and start to carry out some conventional tests;
3) Development and validation of an adapted mechanical test protocol;
4) Carry out the experimental measurements with the specimen of a bioprosthetic heart valve;
5) Postprocessing of the data and uncertainty analysis;
6) If possible, collaborate with colleagues for implementing the calibrated material model in an FEM code and carry out validation tests.

Expected skills

The internship candidate should have an educational background in mechanics with solid knowledge and competence in experimental studies. Former experience in uniaxial or biaxial traction tests would be a plus. The candidate should be interested in carrying out experimental measurements for calibrating material models and using them in biomechanical applications.

Supervision

Under the collaboration between LHEEA and GeM laboratories of Ecole Centrale de Nantes, this internship will be supervised by the professors and researchers from the two laboratories, including Dr. Annie MORCH (annie.morch@univ-nantes.fr) and Dr. Xiaodong LIU (xiaodong.liu@ec-nantes.fr) from GeM, and Dr. Zhe LI (zhe.li@ec-nantes.fr) from LHEEA.

Period and salary

The duration of the internship is 6 months starting from February or March of 2024 with a salary of about 600 euros per month.

References

[1] A. Vahanian, F. Beyersdorf, F. Praz, et al. 2021 ESC/EACTS Guidelines for the management of valvular heart disease, *Eur. Heart J.* **43** (2021) 561-632.

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[3] Z. Li, G. Oger, D. Le Touzé. A partitioned framework for coupling LBM and FEM through an implicit IBM allowing non-conforming time-steps: Application to fluid-structure interaction in biomechanics, *J. Comput. Phys.* **449** (2022) 110786.

[4] A. Morch., B.Pouseele, G.Doucède, J.-F. Witz, F. Lesaffre, P. Lecomte-Grosbras, M. Brieu, M. Cosson, C. Rubod. Experimental study of the mechanical behavior of an explanted mesh: The influence of healing. *J. Mech. Behav. Biomed. Mater.* **65** (2017) 190-199.

[5] Y.C. Fung, K. Fronek, P. Patitucci. Pseudoelasticity of arteries and the choice of its mathematical expression, *Am. J. Physiol.* **237** (1979) H620-31.