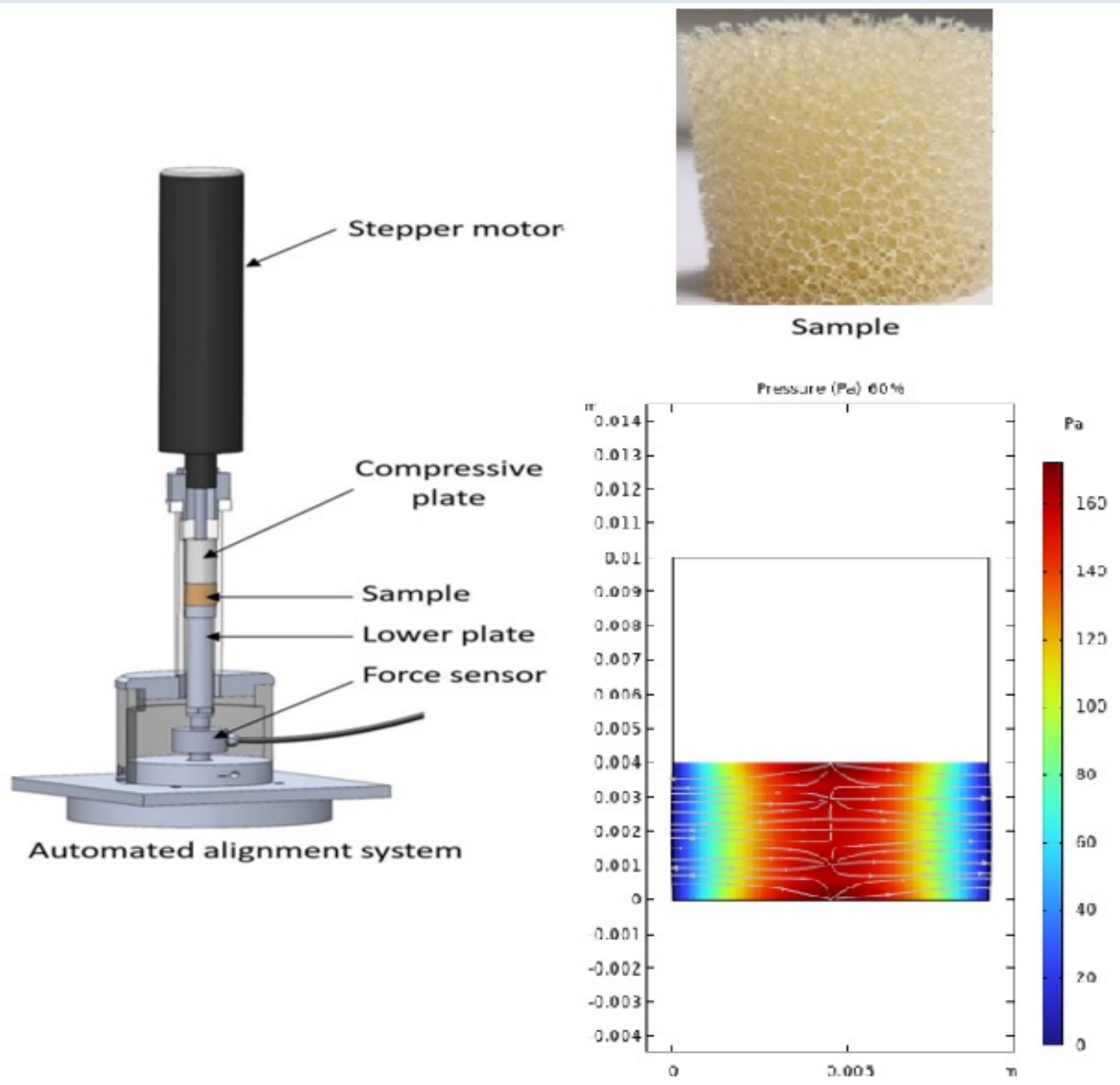

Can Poroelasticity Predict the Response of Fluid Impregnated Foams to Axial Compressions?

New biomimetic lubrication mechanism, the eX-Poro-HydroDynamic (XPHD) lubrication is based on self-sustained fluid film generated within a compressible liquid impregnated porous medium. The mechanical response of this impregnated porous medium to the stress imposed by compression needs to be studied.

A. Beaudoin, D. Sanchez, A.E. Ennazii
Institute P', University of Poitiers, Poitiers, France.

Introduction & Goals

The SOFITT project (Saturated Open-Cell Foams for Innovative Tribology in Turbomachinery), funded by the ANR (French National Research Agency), aims to develop high-performance and environmentally friendly solutions for the guidance and support systems of turbomachinery through the analysis of fluid/structure interaction in porous materials.

The study of this interaction has led to the XPHD lubrication (Lacaj, 2023; Ennazii, 2024). This work presents the development and validation of a numerical model using COMSOL Multiphysics® to simulate the uniaxial compression of dry and oil-impregnated polyurethane foams, as part of the ANR SOFITT project (Sanchez, 2024).

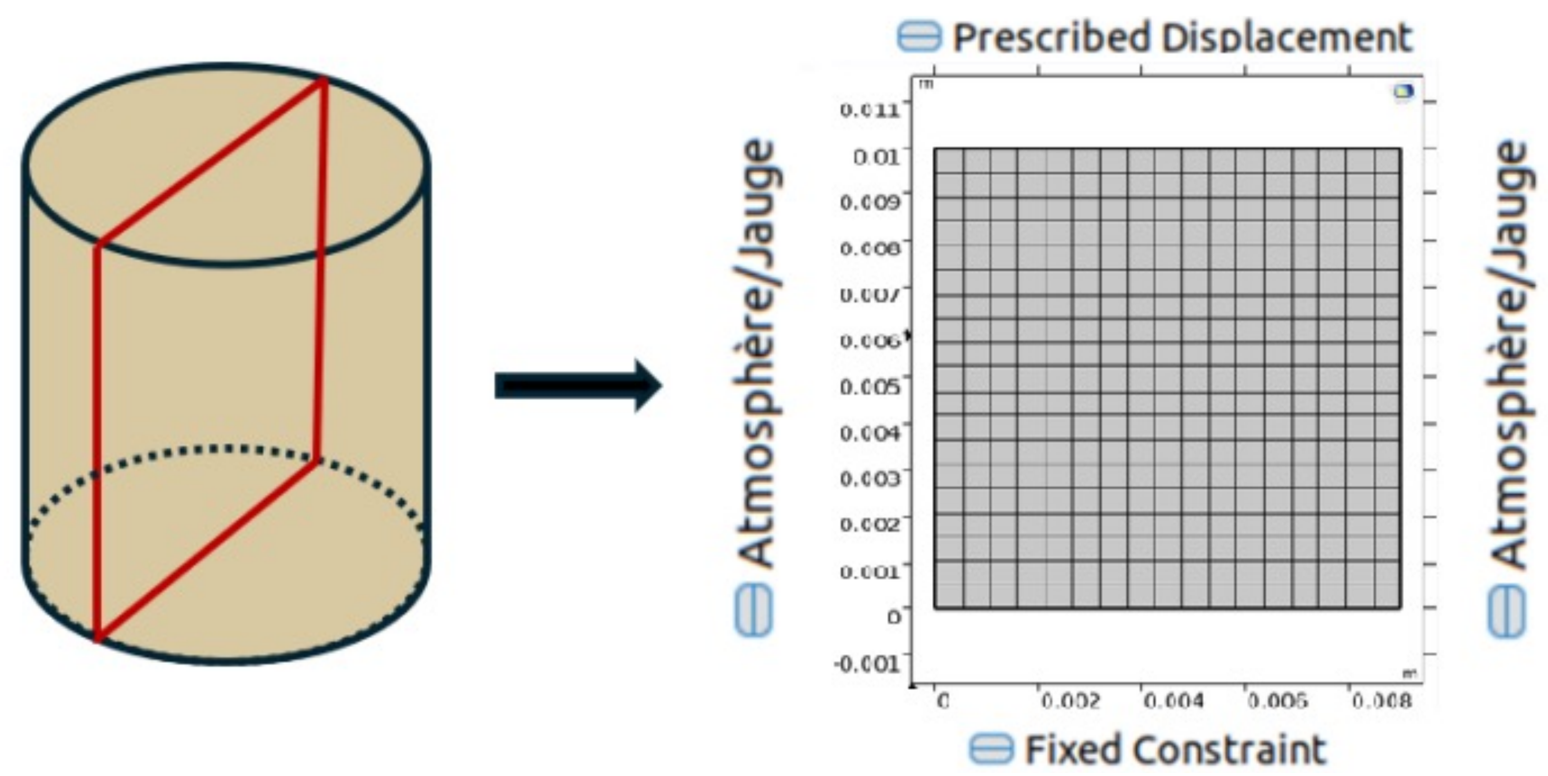

FIGURE 1. Left: 2D representation. Right: computational domain.

Methodology

The compression was conducted on a foam cylinder, 9mm diameter and 10mm height (Lacaj, 2023; Ennazii, 2024). A 2D representation was chosen with a rectangle (see Fig. 1 left). The material is a polyurethane foam 2355 impregnated with ISO-VG-46 oil. The poroelasticity module is obtained by coupling the Solid Mechanics and Darcy's law modules. A non-linear elasticity law was fixed from an experimental stress-strain curve. The permeability was defined using the Kozeny-Carman equation. The Biot-Willis coefficient was defined in the materials tab. A vertical displacement speed 1 $mm.s^{-1}$ was imposed on the upper edge. The lower edge is considered fixed. The two lateral edges are free. The atmospheric pressure was defined at the lateral edges (see Fig. 1 right).

Results

For the dry foam, COMSOL® faithfully reproduces the experimental curve (see Fig. 2 left). The model parameters are adequate to describe the mechanical behavior of the dry foam, thus validating the nonlinear elasticity. For the impregnated foam, there is no significant drop in stress value at the plateau level, contrary to what is observed experimentally (see Fig. 2 left). This absence of a drop is explained by the low pressure generated by the imbibed fluid, which is much lower than the magnitude of the stress. COMSOL closely follows the data from Ennazii's thesis, indicating a good agreement between the results (see Fig. 2 right). The permeability increases with increasing porosity. For a porosity of 0.93, the permeability is approximately 3.5×10^{-10} m². When the porosity reaches 0.96, the permeability increases to about 6×10^{-10} m².

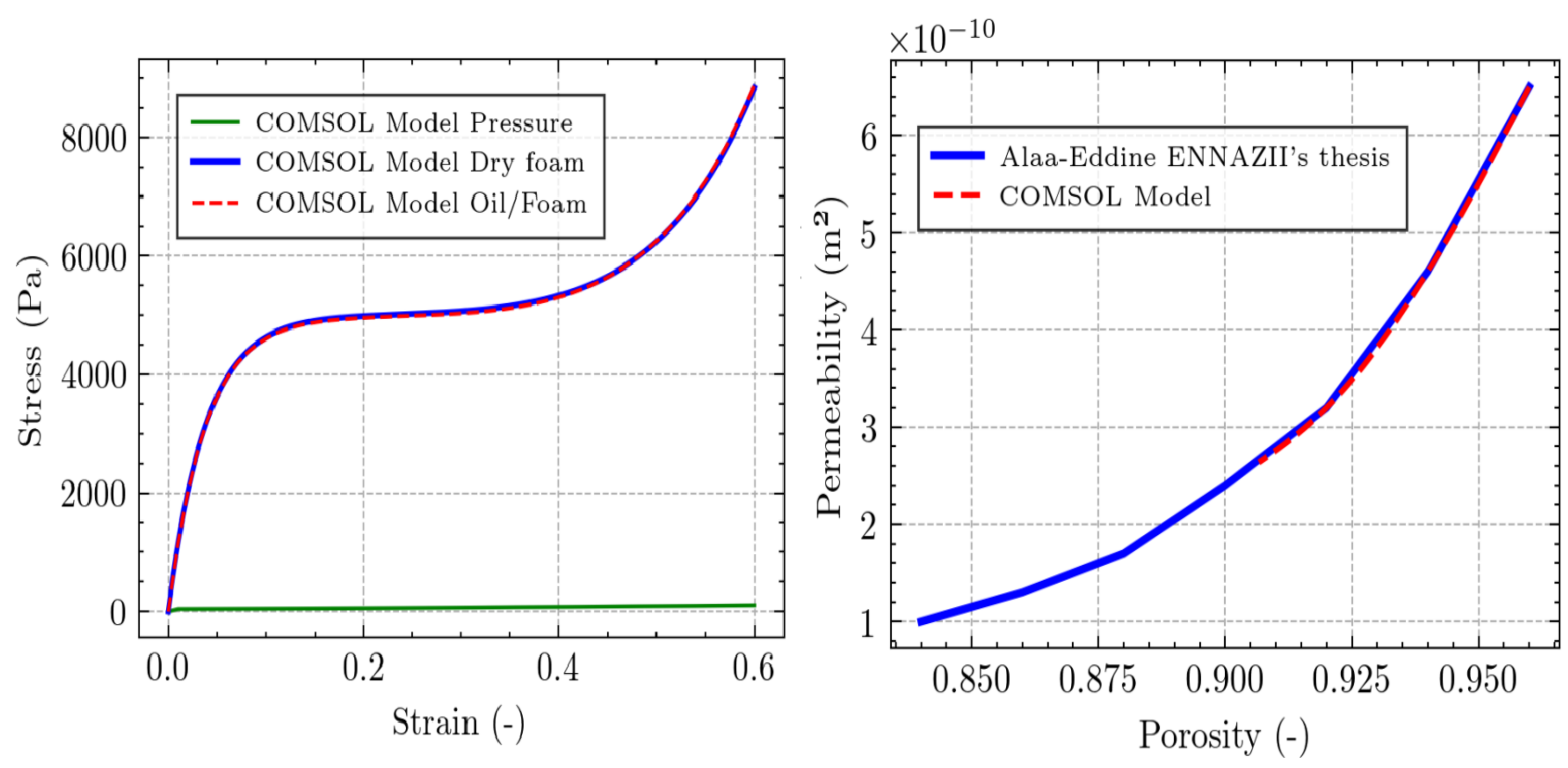

FIGURE 2. Left: stress-strain and pressure curves for dry and oil-impregnated polyurethane foams. Right: permeability-porosity curves.

REFERENCES

1. E. Lacaj, "Étude des propriétés mécaniques des structures complexes poreuses par méthodes de mesure de champ sans contact", PhD thesis, University of Poitiers, 2023.
2. A.E. Ennazii, "Modélisation numérique de l'interaction fluide/structure dans des milieux poreux", PhD thesis, University of Poitiers, 2024.
3. D. Sanchez, "Can poroelasticity predict the response of fluid-impregnated open-cell elastomeric foams to axial compression?", Internship report M1 EUR Material Sciences, University of Poitiers, 2024.

INTREE GRADUATE SCHOOL — INSTITUT P' UPR CNRS 3346 — anr agence nationale de la recherche