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ONERA
THE FRENCH AEROSPACE LAB

PhD PROPOSAL

Turbulence in Porous Media

Reference : **MFE-DMPE-2024-02**
(to recall in all correspondence)

Thesis start date: October 2024 (can be adjusted)	**Application deadline:** if you got this document online, you can still apply

Key words

Turbulence, porous media, triply periodic minimal surface, direct numerical simulation, experiments, laser doppler velocimetry, hot wire anemometry

Ideal Candidate

We seek a highly motivated, innovative, and detail-oriented candidate with a strong background in computational fluid dynamics, strong physical intuition, and who wants to acquire both numerical and experimental knowledge.

Thesis Overview

Turbulence in porous media is a complex and critical phenomenon with implications in various fields, including geophysics, environmental engineering, and aeronautics. Understanding the behavior of turbulence within porous structures is crucial for optimizing fluid transport and dispersion processes, as it features unique characteristics and fundamental challenges. An example of fluid flow in porous media, taken from Ref 1, is given in Figure 1 as illustration.

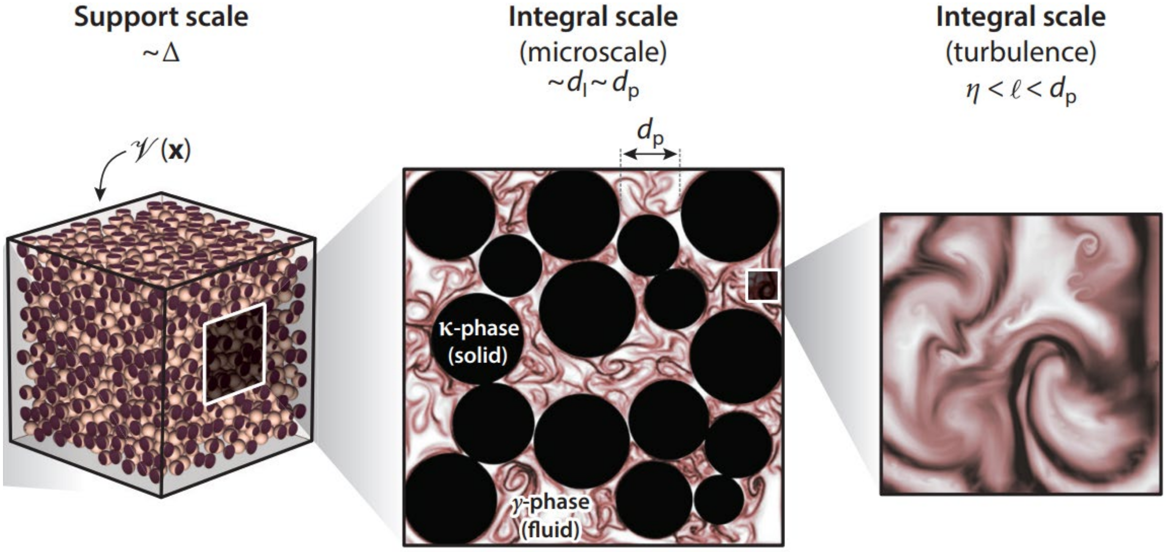

Figure 1 Illustration of the multiple scales of turbulence and porous media flows (from Ref 1)

This research project involves conducting **high-fidelity simulations and experiments** using state-of-the-art numerical and experimental methods to study the turbulence immersed within various porous solids, exploring a broad spectrum of pore topologies and sizes.

You will explore turbulence within porous media represented by **triply periodic minimal surface** (TPMS) matrices, which offer a larger variety of pore topology, when compared with spheres or rods, as currently mainly studied in the literature (see Figure 1). Using Direct Numerical Simulations (DNS), you will investigate some key turbulence properties, such as **turbulent kinetic energy** (TKE) transport, anisotropy distribution, the scales of turbulent motion, and the **energy cascade**.

For selected test cases, you will 3D-print TPMS samples and conduct experimental work, such as Particle Image Velocimetry (PIV) measurements, to compare with the computational findings and help develop advanced measurement techniques: the main challenge is in accessing physical fields within the pores.

Using the obtained numerical and experimental databases, you will then explore how different TPMS structures influence turbulence behavior and acoustic phenomena within porous media. To this end, data analysis tools including sparse regression and Bayesian inference will be used.

This PhD position aims to extend our understanding of turbulence within porous media, particularly with respect to TPMS matrices. The results will have implications for improving our ability to model and predict fluid flow and dispersion in porous structures, with potential applications in aerospace/aeronautics, which are at the core of ONERA research.

The expected outcomes of this PhD will allow us to:

1. Identify mechanisms governing turbulent energy in porous media.
2. Explore the link between pore topology and turbulence characteristics.

Prerequisites

While motivation and autonomy are two key factors for a successful PhD, the following prerequisite are also expected from the candidates:

1. Strong background in fluid mechanics and computational fluid dynamics (CFD).
2. Interest in experimental fluid dynamics and data analysis.
3. Motivation to explore complex and interdisciplinary research questions.

Benefits

The PhD candidate will have the opportunity to work at the forefront of turbulence research, within the scope of the **ERC starting grant POROLEAF**, contributing to the development of clean and efficient energy conversion technologies. This research offers a platform to enhance computational skills and expertise in numerical simulations and modeling, as well as experimental know-how in state-of-the-art equipment and methods. Findings from this study can have profound implications for industries such as power generation, transportation, environmental engineering and aeroacoustics.

Supervising team

The research will **take place at ONERA in Toulouse**, France, and will be supervised by Dr. Chedevergne and Dr. Roncen.

Reference

Ref 1: Wood, Brian D., Xiaoliang He, and Sourabh V. Apte. "Modeling turbulent flows in porous media." Annual Review of Fluid Mechanics 52 (2020): 171-203.

Hosting lab at ONERA	**Thesis director**
Department : Multi-physics department for energy	Name : François Chedevergne
Location: Toulouse	Lab : DMPE/STAT
Contact : Rémi RONCEN	Email : francois.chedevergne@onera.fr
Email : remi.roncen@onera.fr	

Pour plus d'informations : https://www.onera.fr/rejoindre-onera/la-formation-par-la-recherche