PhD offer (F/H)

Title	Influence of air-layer deformation of a superhydrophobic coating on the performances of a turbulent wake: A combined simulation and experimental approach
Contacts	Prof. Nicolas MAZELLIER nicolas.mazellier@univ-orleans.fr Prof. Jean-Christophe ROBINET Jean-christophe.ROBINET@ensam.eu Dr. Pierre-Yves PASSAGGIA pierre-yves.passaggia@univ-orleans.fr
Location	Laboratoire PRISME Université d'Orléans 8 rue Léonard de Vinci 45072 Orléans Cedex 2 http://www.univ-orleans.fr/prisme Laboratoire DYNFLUID Arts et Métiers Sciences and Technologies 151, Bd. de l'Hôpital 75013 PARIS, France https://dynfluid.ensam.eu/accueil-dynfluid-100729.kjsp
Duration	36 months, full time, starting Fall 2023

Topic description

Amongst the large variety of innovating coatings addressing industrial needs, **Super-Hydrophobic Surfaces** (SHS) have received a particular attention for the last twenty years [7,9]. Controlling the physicochemical properties of these bio-inspired surfaces allows for allows for encapsulating a gas layer inside the roughness elements, within the coating. This plastron thereby acts a lubricating layer reducing the contact between the liquid and the solid. This particular characteristic, also called the "Lotus effect", may turn out to be particularly interesting when wetting matters. A growing number amount of studies showed that SHS can allow for reducing friction drag at the laboratory scale within a well-controlled environment. However, **extrapolating these performances towards extreme conditions**, for instance met in strongly turbulent flows, representative of industrial applications (i.e. water-repellent clothing, ships' hull, anti-fogging and anti-icing coatings in the aeronautical industry...), is a key challenge. In particular, recent studies underlined **the importance of plastron deformation at the liquid-gas interface**, which is currently neglected in the design phase of SHS [2,3,5,6].

This PhD thesis aims at **understanding how plastron deformations lead to determinantal aerodynamic effects using a coupled approach between high-fidelity numerical simulations and well-controlled laboratory experiments**. The objective of **this coupled approach is to analyse the hydrodynamic performances of super-hydrophobic coatings over simple bluff bodies**. A particular attention will be dedicated to the analysis of the characteristics of the coating on the hydrodynamic drag, how instabilities are triggered and the dynamics of the plastron. The physical analysis of experimental and numerical databases will allow for proposing new wall models for the design of super-hydrophobic coatings, which can be extrapolated to the industrial scale.

This PhD thesis will hence be undertaken between two complementary laboratories. The **experimental work** will be performed **at PRISME laboratory** at the University of Orleans. The latter will consider the analysis of turbulent bluff-body wakes with custom-made super-hydrophobic surfaces, where roughness elements will be tailored to trigger particular phenomena. Optical methods will then be used to evaluate both the hydrodynamic forces acting on the body and the influence of the coating on the wake. **Numerical simulations** will be performed **with Dynfluid at ENSAM** Paris. This part will focus on analysing the relation between the properties of the roughness elements and how instabilities are triggered in the boundary layer. Experimental data will be used to parameterise numerical simulations and focus on the most relevant cases. These results will be gathered to create wall models where both slip and plastron deformations are present, and where performances will be validated against experimental results.

Work Environnent
The person recruited for this PhD program will become of the Aerodynamics group (ESA) of PRISME laboratory at the University of Orleans. In this group, research activities are carried on the understanding, the physical modelling and control of turbulent wake flows, representative of industrial applications. In particular, this work will build on the knowledge developed within the department for the last ten years on SHS [1,3,5]. First, an experimental rig, already in service, will be adapted to answer to the objectives of this thesis. Then, a parametric experimental campaign will be considered varying the properties of the flow and the roughness elements entrapping the plastron will be explored. Particle-image velocimetry together with Background Oriented Schlieren will be used to characterise the flow and the dynamics of the plastron simultaneously. Visits at Dynfluid laboratory at ENSAM Paris, working for several years on the same topic than the thesis' topic [2,4], will be planned for the duration of the PhD. The aim is to practice, learn, and develop the necessary tools for the prediction of transition in the presence of plastron's deformation at the local scale. In this part, most simulation tools are ready to run.

This thesis fit in a large collaborative project, ANR IDEFHYX (ANR-22-CE51-0021), coordinated by PRISME laboratory and where DYNFLUID is a partner. The person recruited for this project will benefit from a strong and stimulating scientific environment and will be part of a dynamic consortium, recognized for its international expertise on the topic. Interactions and innovating work with the other members of the consortium are also encouraged.

Skills
We are looking for a strongly motivated individual (F/M), with a Master thesis or an engineering degree with strong knowledge in fluid mechanics. The selected candidate will demonstrate a particular interest for experimental research, measurement techniques as well as numerical simulations. A good expertise in MATLAB is also recommended. The selected PhD student will be strongly involved in the diffusion of the results through scientific reports, publications in international journals, and presentations in nationals and international conferences. The candidate will thereby demonstrate a capacity for writing and communicating in both French and English.

Salary
Gross salary: around €24 500/year including basic health insurance.

Starting scheduled October 2023.

Application

Documents to send for the application:

- Curriculum Vitae
- Cover letter
- Grades for the last two years of Master
- Contacts for two scientific advisors

The application is to be sent to Prof. Nicolas Mazellier (nicolas.mazellier@univ-orleans.fr), Pierre-Yves Passaggia (pierre-yves.passaggia@univ-orleans.fr) and Prof. Jean-Christophe Robinet (Jean-christophe.ROBINET@ensam.eu) before **May, 15th, 2023**. Applications with missing documents will not be considered.

References

[10] Bettaieb, N., Castagana, M., Passaggia, P. Y., Kourta, A., & Mazellier, N. (2022). Prediction of resistance induced by surface complexity in lubricating layers: Application to super-hydrophobic surfaces.

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[12] Castagna, M., Mazellier, N. & Kourta, A. (2021) On the onset of instability in the wake of super-hydrophobic spheres, International Journal of Heat and Fluid Flow, 87:108709.

[13] Picella, F., Robinet, J. C., & Cherubini, S. (2019). Laminar–turbulent transition in channel flow with superhydrophobic surfaces modelled as a partial slip wall. Journal of Fluid Mechanics, 881, 462-497.

[14] Castagna, M., Mazellier, N. & Kourta, A. (2018) Wake of super-hydrophobic falling spheres: influence of the air layer deformation, Journal of Fluid Mechanics, 850:646-673.

[15] Seo, J., García-Mayoral, R. & Mani, A. 2015 Pressure fluctuations and interfacial robustness in turbulent flows over superhydrophobic surfaces. J. Fluid Mech. 783, 448–473.

[16] Rothstein, J. P. 2010 Slip on superhydrophobic surfaces. Annu. Rev. Fluid Mech. 42, 89–109.

[17] Legendre, D., Lauga, E. & Magnaudet, J. 2009 Influence of slip on the dynamics of two dimensional wakes. J. Fluid Mech. 633, 437–447.

[18] Min, T. & Kim, J. 2004 Effects of hydrophobic surface on skin-friction drag. Phys. Fluids 16, 55–58.