Proposition of Phd Theisis for CDE 2023

Drag reduction by bubbles injection on a wall of composite material for naval applications

Reducing energy consumption in the naval sector presents a major challenge in energy transition and sustainable development programs. The techniques used in this field are based on the principle of friction reduction by the addition of another fluid. Bubble injection is a very practical and non-polluting method that can be used in the field of wall friction reduction for naval applications (Frigates, anti-mine buildings, submarines, boats, etc.).

The reduction of friction by injecting bubbles into the hulls reduces fuel consumption by up to 15% for medium-sized vessels[1]. Recently, a study[2] showed that friction reduction can reach up to 28% for hulls of 36 meters in length. The addition of bubbles in a turbulent flow near a wall allows to modify the turbulent boundary layer where the viscous resistance decreases, which reduces the friction of the wall with the fluid.

The bubbles can be injected using a pump or created on the wall by the technique of water electrolysis. In this thesis project, two techniques of injection and generation bubbles will be coupled in order to be able to increase the gas fraction to find the optimal conditions for reducing friction on a flowing wall.

The studied wall will be made of composite material ensuring resistant properties. This thesis project aims to study experimentally and numerically the drag reduction close to a wall of

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[1] : I. Kumagai, N. Nakamura, Y. Murai, Y. Tasaka & Y. Takeda, International Conference on Ship Drag Reduction (2010).

[2] : T. Tanaka, Y. Oishi, HJ Park, Y. Tasaka, Y. Murai, C. Kawakita, Frictional drag reduction caused by bubble injection in a turbulent boundary layer beneath a 36-m-long flat-bottom model ship, Ocean Engineering, 252 111225 (2022).

composite material as a function of the size and quantity of bubbles injected and generated by the technique of electrolysis in laminar, instabilities or turbulent flows. This study will aim to propose a composite material wall capable of combining chemical (oxidation resistant), mechanical (resistant to pressure stresses), thermal and energy performance for the ships of the future. This composite material wall must ensure a sufficient quantity of gas to considerably reduce energy consumption.

Near to the wall, the flow of a single liquid can generate vortex structures at the turbulent boundary layer. When the bubbles are injected close to the wall, the vortex structures can capture these bubbles, in this case, the viscous resistance decreases. In this capture regime, the reduction in friction is significant.

The buoyancy of the bubbles modifies considerably the flow regimes close to the wall. For example, in the Taylor-Couette system, the injection of bubbles promotes the creation of "defects-mediated turbulence[3]", which is the coexistence of non-axisymmetric regimes such as the spiral, the wavy toroidal or the wavy spiral. Muraï et al[4]. showed that the friction reduction is maximal in this coexistence regime.

To reduce friction in a real configuration (case of a ship), the presence of bubbles must be independent to the flow regimes (captures of vortex structures). The solution is to obtain the generation of micrometric bubbles permanently by the technique of salt water electrolysis in the absence of the capture regime and vice versa: when the flow regime of the liquid phase is in capture mode, the effective technique is the generation of bubbles by a pump and when the flow regime is dispersive, the technique of electrolysis would be the most suitable. This alternation of bubble generation method would guarantee a great efficiency for the drag reduction as well as the good management of energy in a ship. The aim of the thesis is to study experimentally and numerically the drag reduction close to the wall of a composite material as a function of the size and quantity of bubbles injected and generated by the technique of electrolysis in laminar flows. instabilities or turbulence.

The first step of this thesis will consist the design and the optimization of a composite structure wall allowing the generation of micrometric bubbles:

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[3] : B. van Ruymbeke, N. Latrache, C. Gabillet, C. Colin, Defect-mediated turbulence in bubbly Taylor-Couette flow, Phys. Rev. Fluids 5, 034302 (2020).

[4] : Y. Muraï and H. Oiwa and Y. Takeda, Frictional drag reduction in bubbly Taylor-Couette flow, Phys. Fluids **20** 034101 (2008).

- Test the composite wall under mechanical and thermal stresses.
- Control of the generation of micrometric bubbles on the wall in static salt water.
- Control of the injection of millimetric bubbles near the composite material wall in static salt water.

The second step will be devoted to the study of drag reduction as a function of the flow regimes (laminar, instabilities or turbulent) in the presence of micrometric bubbles and injected bubbles near the wall of composite material. A quantitative study will be devoted to the interaction of millimetric and micrometric bubbles in a uniform (laminar) hydrodynamic field, and in the presence of stationary or unsteady vortices near the wall, this will make it possible to identify an explanation of the drag reduction as a function of the flow regimes, and especially to highlight the role played by the different scales of turbulent in two-phase flow (salt water-bubbles) of different sizes of bubbles.

The third part of this thesis will be devoted to the development of numerical models in fluid-structure interaction capable to reproduce the experimental results.

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