Passive in-plane wall deformations for turbulent drag reduction

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Abstract

In order to tackle the energy crisis and provide sustainable energy for the future generations, humanity needs to place the energy industry on a renewable foundation and aim for more efficient production and usage. Marine energy harvesting has a great potential to help face this challenge. An immersed body in a flowing liquid, such as a marine energy harvesting device, experiences a drag force which negatively affects the device performance. The drag force has two components: the pressure and the friction drag. While shape optimisation is a commonly used method to decrease the pressure drag, there is no well-established way to reduce the friction drag [1]. The long-term goal of our research is to develop a passive coating for tidal turbines that can decrease the friction drag. This will increase the efficiency of the device and decrease the structural load. Since it has been demonstrated that drag reduction cannot be obtained based on wall-normal deformations [2], the present work considers solely in-plane deformations of a coating driven by the friction force. To investigate the complex fluid-structure interaction between the coating and the fully turbulent flow, high-fidelity numerical simulations were carried out. The boundary layer around a small section of the turbine blade was represented by the boundary layer in a canonical channel flow, while the visco-elastic coating was modelled as an array of damped harmonic oscillators. These simulations demonstrated that a well-designed compliant coating can reduce the friction drag. The estimated friction drag reduction potential is at least 4% [3]. However, the material properties need to be optimised to maximise the drag reduction. Since the computationally intensive high-fidelity numerical simulations are not suitable to perform optimisation, a low-order analytical model, inspired by the recent studies of Benschop and Breugem [4], was derived to restrict the parameter space and estimate the optimal material properties. Ongoing work aims to assess the maximum drag reduction that a compliant coating can enable. The authors hope that these results will bring the community closer to the realisation of a fully-functional friction drag reducing passive coating, and the analytical model provide sufficient guidance for the optimisation of the material properties.

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References