Chair: Physics of Fluids group

An experimental study towards flow control by surface modification in turbulent Taylor–Couette flow

Description

Fluid drag is one of the limiting factors in many industrial and biological applications. The topology and chemical properties of the surface contacting the fluid play a mayor role in the friction experienced by the fluid. The effects are significant. For instance, for large (container) vessels it is know that the added roughness from bio-fouling by algae and barnacles on the ship hull has a dramatic effect on fuel efficiency. Compared to a clean hull, the skin-fricion coefficient increases by values up to 100 % as a result of this added roughness. By making smart use of surface properties however, the skin friction drag coefficient can also be reduced, compared to an untreated surface. For instance by using superhydrophobic surfaces, the skin friction drag can significantly decrease. Values of drag reduction up to 50 % by making use of surface modification have been reported.

We study the influence of surface modification using the Taylor–Couette geometry, which is one of the canonical systems to study fluid dynamics. Due to its closed geometry and exactly defined balance between energy input (driving of the flow) and output (viscous energy dissipation), it is very suited to study global parameters such as the influence of surface modifications on fluid drag. Its excellent optical accessibility allows for a range of measurement techniques such as Particle Image Velocimetry (PIV) and Laser Doppler Anometry (LDA) and gives the possibility to create beautiful visualizations of flow phenomena using high-speed imaging.

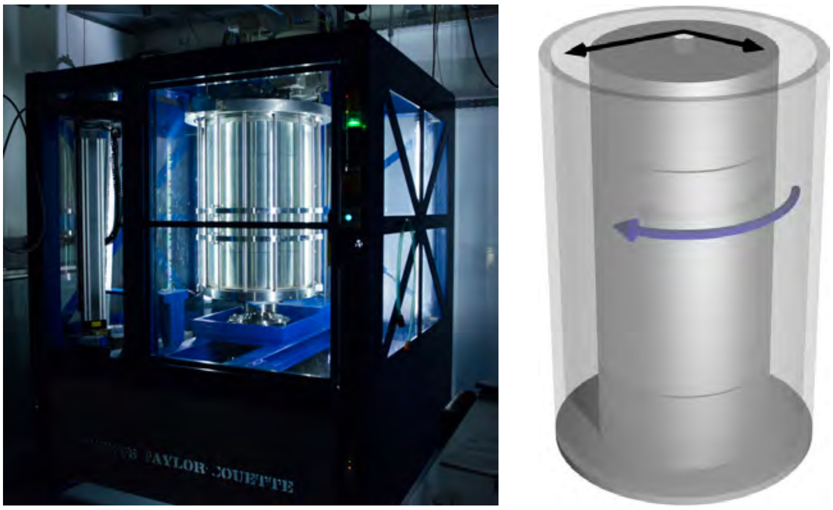

Figure 1: left: Photograph of the Twente Turbulent Taylor–Couette (T^3C) facility. right: Artist's impression of the inner cylinder and transparant outer cylinder

Assignment

We will use the Twente Turbulent Taylor–Couette (T^3C) facility to study the influence of different surfaces on fluid drag in high turbulence flow conditions. This unique facility allows for continues flow measurements at Reynolds numbers up to 2×10^6. It consists of two concentric cylinders, of which the one with smaller radius is placed inside the cylinder with larger radius. The resulting gap is filled with water, and the inner cylinder is rotated to drive the flow. A typical measurement campaign consists of a multitude of torque-measurements, to determine the global drag, combined with PIV and flow visualizations to provide information on local flow properties. Parameters that will be explored are the Reynolds number (based on gap-width and inner cylinder velocity), the surface roughness and chemistry (hydrophobic versus hydrophilic) and the composition of the working liquid (single-phase versus two-phase flow) from the introduction of air bubbles.

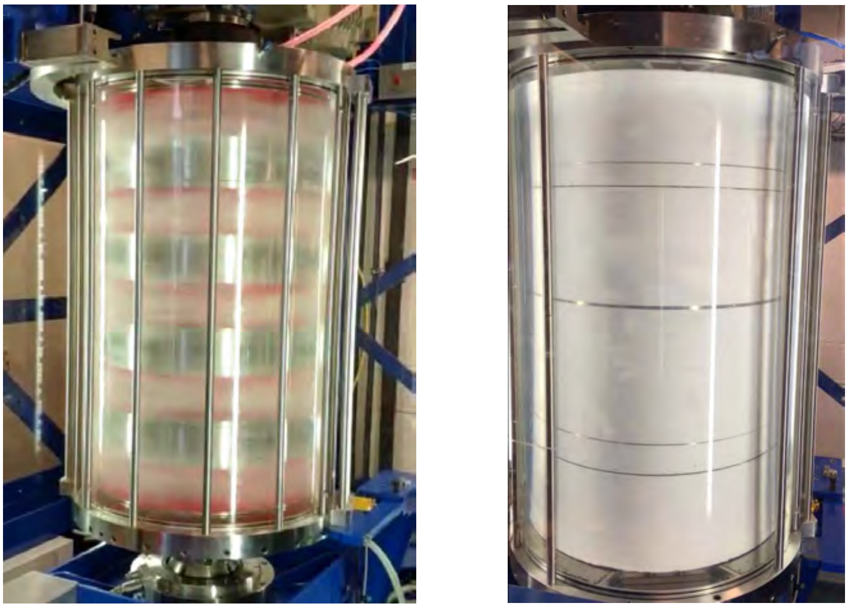

Figure 2: left: Still of a measurement in the Twente Turbulent Taylor–Couette (T^3C) facility, with the inner cylinder covered with roughness patches (red bands). Air bubbles are introduced to the flow that are trapped in the regions of higher intensity turbulence, corresponding to the locations of the roughness patches. right: Photograph of the T^3C where the inner cylinder is covered by a superhydrophobic coating.

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