Investigation of the key parameter defining the flow through a porous hollow cylinder

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The flow around a circular cylinder is well-known and well-documented, and is important in many practical applications[1-2]. Recent research has shown that a porous cylinder surrounding a solid cylinder could have a significant impact on the two-dimensional flow topology[3]. We extend this work by considering the three-dimensional flow and the resulting forces associated with a hollow porous cylinder.

We have investigated the impact of the twine/mesh ratio on the flow through a porous hollow cylinder at Reynolds numbers up to 20 000. For this purpose, 13 circular models, with a surface porosity varying from 0.67 to 0.90, were manufactured. The geometry of our small-scale laboratory is inspired by the structures that are employed in aquaculture net cages[4]. Our results show three different flow regimes that are not simply depending on the porosity factor ε. The same observation is made for load applied by the currents on the structure.

Experimental data acquired using a recirculating flume and Time-Resolved Particle Image Velocimetry (TR-PIV) show the impact of the geometry on the flow dynamics and the formation of vorticity. At a constant porosity, but differing twine/mesh ratio, the flow can significantly vary. Firstly, looking at the time averaged wake, we can observe a difference of wake length, vorticity magnitude and vorticity distribution (Fig. 1). In one case, each twine creates its own wake resulting in a wake pattern similar to the one of an array of tubes (Fig. 1a). In the other case the twine creates only two bulbs of vorticity detectable inside the model and a slow diffused flow in the wake of the cylinder (Fig. 1b). We identify an empirical parameter, α, based on the model geometry that collapses the averaged flow velocity in the wake for models presenting the first or second flow regime. No such collapse could be achieved using ε. Plotting the drag coefficient C_d versus α, collapses our data and displays an asymptotic behaviour, suggesting the existence of an optimized twine/mesh ratio. Finally, the experimental load cell measurements, recording the load acting on the model in the in-line direction, display the same tendency. The porosity factor is not the key parameter as models with equivalent porosity but different geometry are not under the same load. A second empirical parameter, β, can be introduced to predict a load tendency depending of the model geometry.

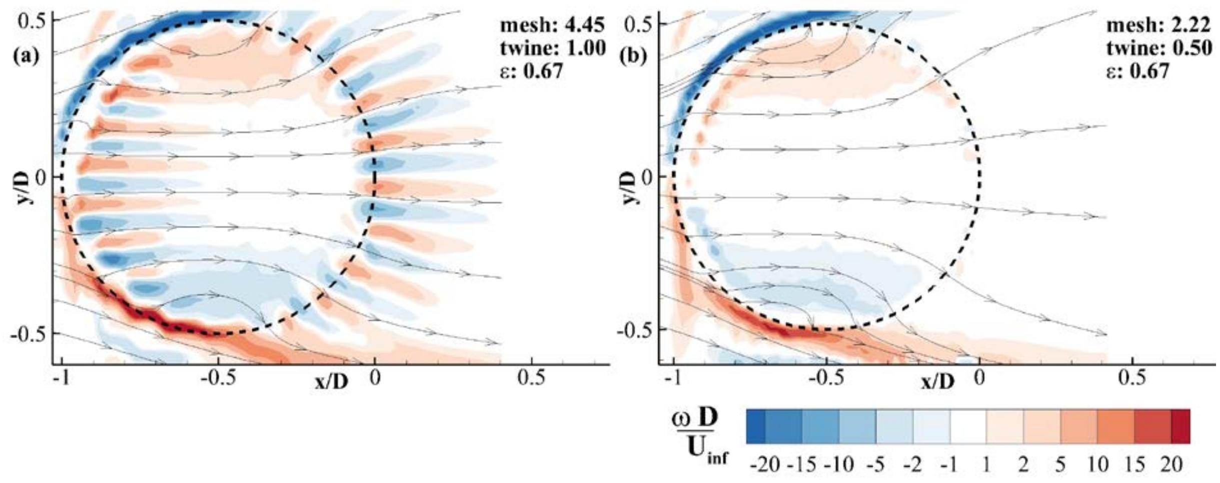

Figure 1: Time averaged vorticity distribution and stream lines around two models of same porosity (ε = 0.67) but varying mesh and twine size (a) mesh = 4.45 mm and twine = 1.00 mm (b) mesh = 2.22 mm and twine = 0.50; Re = 900.

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