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

B. Levy\textsuperscript{a}, H. Friedrich\textsuperscript{b}, J. Cater\textsuperscript{a}, R. Clarke\textsuperscript{a} and J.P. Denier \textsuperscript{a}

The flow around a circular cylinder is well-known and well-documented, and is important in many practical applications\textsuperscript{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\textsuperscript{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\textsuperscript{4}. Our results show three different flow regimes that are not simply depending on the porosity factor $\epsilon$. 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, $\beta$, 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 $\epsilon$. Plotting the drag coefficient $C_D$ versus $\beta$, 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, $\varphi$, 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 ($\epsilon = 0.67$) 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.

\textsuperscript{a} Dept. Engineering Science, The University of Auckland, Auckland, New Zealand
\textsuperscript{b} Dept. Civil and Environmental Engineering, The University of Auckland, Auckland, New Zealand

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