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Flow above the Free End of a Surface-mounted Finite-height Cylinder

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Introduction

The flow around surface-mounted finite-height circular cylinders is more complex than the well-studied case of the two-dimensional or "infinite" circular cylinder (e.g., [1,2]). In many engineering applications, such as high-rise buildings, oil storage tanks, and chimneys, the flow fields of these cylindrical structures are strongly three-dimensional owing to the flow around the free end and the flow at the junction with the ground plane. On the free-end surfaces of these structures, regions of recirculating flow, vortex structures, as well as the flow separating from the leading edge, influence the flow patterns in the near-wake region.

Although the near-wake region of a surface-mounted finite-height circular cylinder has been reasonably well-studied, comparably less attention has been focused on the flow over the freeend and its relationship to the rest of the local flow field(e.g., [3–7]).In the present study, the flow field above the free end of a surface-mounted finite-heightcircular cylinder(Figure 1) was investigated experimentallyusing particle image velocimetry (PIV). Of particular interest was the effect of cylinder aspect ratio (AR = H/D, where H and D are the cylinder's height and diameter, respectively).

Experimental Approach

The experiments were conducted in a low-speed wind tunnel at a Reynolds number of $\mathrm{Re}_D = 4.2\times10^4$. Finite-height circular cylinders withAR = 9, 7, 5, and 3 were mounted normal to a ground plane. The turbulent flat-plate boundary layer on the ground plane had a thickness of $\delta/D = 1.6$ at the location of the cylinders. Velocity measurements were made with a two-component PIV system. Measurements were made in vertical (x-z) and horizontal (x-y) planes at different cross-stream (y/D) and wall-normal (z/D)positions, respectively,in the region above the free end of the cylinders; the measurement planes (fields of view) are shown in Figure 1.Mean velocity fields were obtained fromensembles of 1000image pairs and 528 image pairs in the$x$-z and x-y planes, respectively.

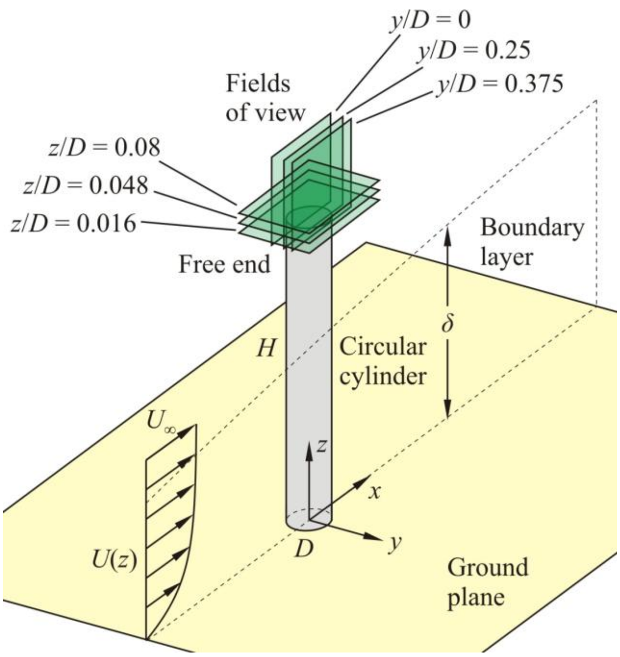

Figure 1: Schematic of the flow around a surface-mounted finite-height circular cylinder partially immersed in a flat-plate boundary layer (velocity profile $U(z)$, freestream velocity U_∞). Shown in the figure are the fields of view for the PIV measurements.

Results and Discussion

Figure 2 shows the mean streamlines in three horizontal (x-y) planes above the free endfor cylinders of AR = 9 and AR = 3.For the cylinder of AR = 9 (upper row), two weak foci are seen near the side edges of the free end. As the wall-normal distance increases (from z/D = 0.016 to z/D = 0.048), the foci move away from the outer edges of the free end towards the centerline of the flow. Farther away from the free end (at z/D = 0.08), there is no evidence of the focal points, while a node is now observed.

For the cylinder of AR = 3 (lower row), a strong pair of wall-normal vortices with opposite directions of rotation isevident very close to the free end surface (at z/D = 0.016). These vortices are centred at (x/D, y/D) = (−0.1, ±0.4). Farther away from the free end (at z/D =

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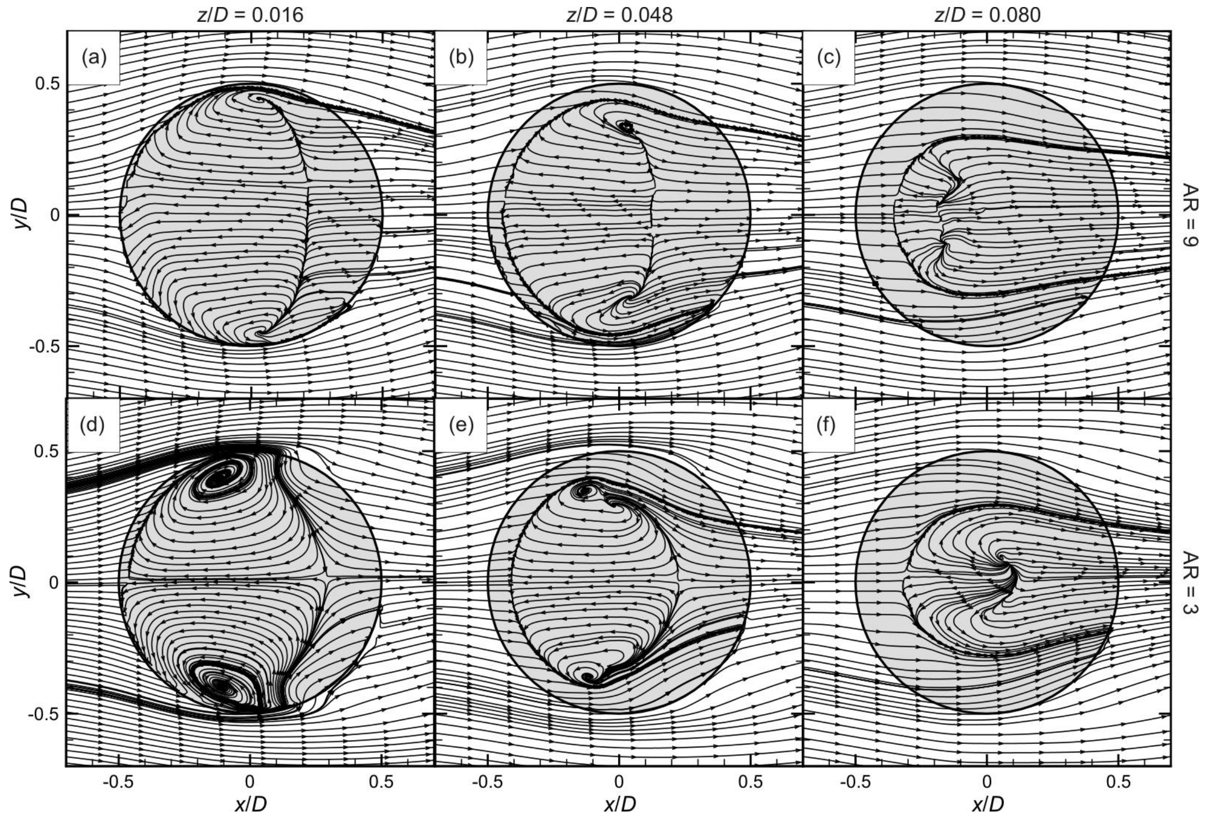

Figure 2: Mean streamlines above the free ends of finite cylinders of AR = 9 (upper row) and AR = 3 (lower row).

0.048), these vortices have moved slightly towards the cylinder centre. At z/D = 0.08, there is no evidence of these wall-normal vortices. At this elevation and about the centre, a node is observed, which may correspond to the centre of a cross-steam vortex.

According to Figure 2, at a given z/D, the size and strength of the wall-normal vortices decrease and their centres move downstreamas AR increases. The difference in flow patterns between the cylinders of AR = 9 (above the critical AR) and AR = 3 (below the critical AR) may be related to the effect of the flat-plate boundary layer on the approach flow separating from the leading edge.

In the full paper, the mean velocity fields, turbulence intensities, and the mean in-plane vorticity fields, in both the vertical (x-z) and horizontal (x-y) planes,will be presented for cylinders of AR = 9, 7, 5, and 3. Details of the mean recirculation zone on the upper surface of the cylinders, flow separation from the leading edge, and reattachment on the free end surface, will be provided.

References

1. Sumner, D., Heseltine, J.L., Dansereau, O.J.P., 2004. Wake structure of a finite circular cylinder of small aspect ratio. Experiments in Fluids 37, 720–730.
2. Rostamy, N., Sumner, D., Bergstrom, D.J., Bugg, J.D., 2012. Local flow field of a surface-mounted finite circular cylinder. Journal of Fluids and Structures 34, 105–122.
3. Kawamura, T., Hiwada, M., Hibino, T., Mabuchi, T., Kumada, M., 1984. Flow around a finitecircular cylinder on a flat plate. Bulletin of the JSME 27, 2142–2150.
4. Park, C.W., Lee,S.J., 2004. Effects of free-end corner shape on flow structure around a finite cylinder. Journal of Fluids and Structures 19, 141–158.
5. Roh, S.C., Park, S.O., 2003. Vortical flow over the free end surface of a finite circular cylinder mounted on a flat plate. Experiments in Fluids 34, 63–67.
6. Pattenden, R.J., Turnock, S.R., Zhang, X., 2005. Measurements of the flow over a low-aspect-ratio cylinder mounted on a ground plane. Experiments in Fluids 39, 10–21.
7. Krajnović, S., 2011. Flow around a tall finite cylinder explored by large eddy simulation. Journal of Fluid Mechanics 676, 294–317.

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