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Large Eddy Simulations of Flow Around Tandem Cylinders Close to a Horizontal Wall

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This study focuses on the numerical simulations of the flow around tandem cylinders placed in the vicinity of a rigid, horizontal plane wall. The cylinders are immersed close to a plane wall in a steady current with a logarithmic boundary layer profile at an intermediate, subcritical Reynolds number (Re = 1.31 × 10^4). The distance between the cylinder centers is $L/D = 2$ and 5, and the gap between the cylinders and the wall is $G/D = 1$. Three-dimensional large eddy simulations (LES) with a Smagorinsky subgrid scale model are performed using the open-source code OpenFOAM. The present results are analyzed through the values of drag and lift coefficients, as well as by the details of the flow fields in the near wake of the cylinders. The results are qualitatively compared to the results of the flow around tandem cylinders for both $L/D = 2$ and 5, as well as to the case of a single cylinder near a plane wall.

INTRODUCTION

Many commonly used engineering structures are shaped as circular cylinders. Subsea pipelines, marine risers, columns of platform legs, and various parts of offshore structures are only some examples in the current- and wave-driven marine environment, while chimneys, power lines, and cables represent some cylindrical structures exposed to the air flow. The key parameter in this type of flow is the Reynolds number, $\mathrm{Re} = U_c D/\upsilon$, where U_c is the free stream velocity, D is the cylinder diameter, and υ is the kinematic viscosity of the fluid. Classification of the flow regimes around a smooth, circular cylinder in steady, uniform flow is presented by Sumer and Fredsøe (2010); it ranges from a laminar flow with two fixed, symmetric vortices to a fully developed vortex street with both a turbulent wake and a turbulent boundary layer.

Due to its widespread engineering applications, the flow around a single circular cylinder immersed in an unlimited fluid is a well-explored fluid flow topic. Detailed experimental results are available from almost a century ago (Thom, 1928) to the modern particle image velocimetry (PIV) measurements of Parnaudeau et al. (2008). Many studies are also published in the field of computational fluid dynamics (CFD) for various Re ranges. Recent large eddy simulation (LES) results are presented by Krajnovic (2011), Lysenko et al. (2012, 2014), and Abrahamsen Prsic et al. (2014). Tremblay et al. (2000) and Wissink and Rodi (2008) published the benchmark case for Re = 3,300–3,900 using direct numerical simulations (DNS), while Dong and Karniadakis (2005) utilized DNS to perform higher Re number simulations for the stationary and oscillating cylinder. Saltara et al. (2011) utilized the detached eddy simulations (DES) to further investigate the oscillating cylinders under the influence of vortex-induced vibrations (VIV). Comprehensive reviews of both the physical phenomenon and the previously published results are given by Zdravkovich (1997) and Sumer and Fredsøe (2010).

In all of the above-mentioned structures, circular cylinders often appear in pairs or bundles. In the simplest case, two cylinders of the same diameter are placed in a tandem formation and exposed to the uniform incoming current in unlimited fluid. The physical behavior of the flow is, however, complex, involving an interaction among the von Kármán vortex streets, the cylinder wakes, and the shear layers. Re is again an important parameter, resulting in turbulent or laminar vortex streets and boundary layers in the wake of the upstream cylinder. The presence of the downstream cylinder has, however, a dramatic influence on the flow behavior around both cylinders. Based on the distance between the centers of the cylinders (L) and Re, Zdravkovich (1985) classified the flow in several regimes. Three main regimes were called the extended body, the reattachment, and the coshedding regime (Zdravkovich, 1987). Although the relatively large distance between the cylinders in the coshedding regime allows vortex shedding from both cylinders, the small pitch ratio (L/D) of the first two regimes suppresses the shedding from the upstream one.

Although less explored than the flow around a single cylinder, the flow around the two-cylinder configurations recently received significant attention. Extensive experimental studies were conducted in attempts to classify the flow types around the tandem cylinders (see, e.g., Zdravkovich and Pridden, 1977; Zdravkovich, 1987, 2009; Lin et al., 2002; Alam et al., 2003; Zhou and Yiu, 2006; Song et al., 2015). A detailed review of the experimental results, including both the classic and various modern measurements, was published by Sumner (2010).

The complexity of the flow implies high demands on the numerical studies of the flow around the tandem cylinders. The

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