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A numerical investigation of the flow over a pair of identical square cylinders in a tandem arrangement

A. Sohankar*,†

Mechanical Engineering Department, Isfahan University of Technology, Isfahan, Iran

SUMMARY

This paper describes a numerical study of the two-dimensional and three-dimensional unsteady flow over two square cylinders arranged in an in-line configuration for Reynolds numbers from 40 to 1000 and a gap spacing of $4D$, where D is the cross-sectional dimension of the cylinders. The effect of the cylinder spacing, in the range $G = 0.3D$ to $12D$, was also studied for selected Reynolds numbers, that is, $Re = 130$, 150 and 500. An incompressible finite volume code with a collocated grid arrangement was employed to carry out the flow simulations. Instantaneous and time-averaged and spanwise-averaged vorticity, pressure, and streamlines are computed and compared for different Reynolds numbers and gap spacings. The time averaged global quantities such as the Strouhal number, the mean and the RMS values of the drag force, the base suction pressure, the lift force and the pressure coefficient are also calculated and compared with the results of a single cylinder. Three major regimes are distinguished according to the normalized gap spacing between cylinders, that is, the single slender-body regime (G <0.5), the reattach regime (G <4) and co-shedding or binary vortex regime ($G \geqslant 4$).

Hysteresis with different vortex patterns is observed in a certain range of the gap spacings and also for the onset of the vortex shedding.

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KEY WORDS: vortex shedding; tandem; square cylinders; hysteresis; numerical study; three-dimensional unsteady simulations

1. INTRODUCTION

The flow resulting from neighbouring structures is a complex problem for wind engineering. This flow is sometime called the *buffeting*, which refers to the unsteady forces that result from the interference of a body situated in the wake of another. Practical applications of the flow past two closely spaced cylinders are found in many cases such as twin chimneys, bundles of electrical transmission lines, groups of free-standing cooling towers, tube bundles in the heat exchangers, tall buildings, high-rise skyscrapers, electronic systems especially in a computer equipment and so on. These bodies can be arranged in tandem, one behind another one in an in-line arrangement, side by side, or in a staggered arrangement relative to the free stream flow.

The behaviour of flow around bluff bodies (e.g. square cylinder) changes as the Reynolds number (*Re*) is increased. At the Reynolds numbers below about unity, the flow around a single cylinder or tandem cylinders is fully attached with no separation [1]. When *Re* increases, the flow separates and a pair of steady symmetric vortices forms behind the body. At higher Reynolds numbers, the formation vortex length of the recirculation region behind the body grows with increasing *Re*. At a critical onset Reynolds number [1, 2], the twin-vortex arrangement becomes unstable, and a time-periodic

*Correspondence to: A. Sohankar, Mechanical Engineering Department, Isfahan University of Technology, Isfahan, Iran.
†E-mail: asohankar@cc.iut.ac.ir