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Gap Effect on Transversal Force Acting on Infinite Array of Cylinders at Low KC and β

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This paper deals with the numerical investigation of an oscillating, 3-dimensional flow over an infinite array of circular cylinders. Two different flow regimes, asymmetric and 3-D, have been investigated. The gap between 2 neighboring cylinders has been changed in a very wide range. A nonmonotonic behavior has been observed in the time evolution of the transversal force and consequently on the root mean square (r.m.s.) variation of this force with the gap. For large to moderate values of the gap, its reduction enhances the 3-D modulation of the transversal force; a further reduction of the gap in the range of small values tends to suppress the axial instability that leads to 3-D motion in the flow field.

INTRODUCTION

The analysis of oscillating flow around a circular cylinder or a group of cylinders is of great importance in offshore engineering, since it is an idealized representation of wave-induced loads over cylindrical structures. As an example of a significant application of this flow, we cite the induced loads over groups of cylindrical riser tubes which transport oil from the seabed to the surface of the offshore platforms. The design of such structures needs a deep understanding of the flow field and an accurate evaluation of the dynamic loads.

Investigations of the experimental as well as numerical literature show that such flow is characterized by vortex shedding, whose pattern can change dramatically depending on the magnitude of 2 nondimensional parameters, namely the Keulegan-Carpenter (1958) number ($KC = U_{\max}T/D$) and the Reynolds number ($Re = U_{\max}D/\nu$), or equivalently the Stokes number ($\beta = Re/KC = D^2/T\nu$), where $U_{\max}$ is the flow's maximum velocity, D is the cylinder diameter, ν is the fluid's kinematic viscosity, and T is the period of the external oscillating flow. Recently, Tatsuno and Bearman (1990) (TB90 hereafter) have identified different regimes that exhibit asymmetric vortex shedding and 3-dimensional flow patterns.

The asymmetry of the vortex pattern gives rise to a net transversal force whose values and main frequency are very sensitive to the flow's structural characteristics.

In spite of its importance in engineering problems, an oscillating flow over a group of cylinders has not been systematically studied. Bushnell (1977) measured the forces acting on cylinders of a square array (3×3) and of a pair, considering different orientations with respect to the direction of the oscillating flow. The gap λ (the distance between the surfaces of 2 adjacent cylinders made nondimensional with the diam) was held equal to 2, and large values of the Keulegan-Carpenter number were considered ($KC > 30$). As regards the case of a cylinder array aligned with the direction of flow, Bushnell (1977) found that the effect of an upstream cylinder on the downstream one during the oscillation consists in the reduction of the in-line force and increase of the transversal force. Similar results were found for both the cases of a pair of cylinders and of the square array of cylinders; Bushnell (1977) then concluded that similar results may also be expected for a long array of cylinders.

Sarpkaya (1980) investigated experimentally an oscillating flow around a pair of cylinders, with different orientations and varying the values of the gap from 0.5 to 1.5, for $10 < KC < 100$. He found similar effects on the in-line force as those observed by Bushnell (1977). For $KC < 40$, a monotonic decrease of the transversal force on the downstream cylinder was observed for decreasing gap values and for small values of the angle of orientation of the array with the direction of flow.

Williamson (1985) (W85 hereafter) studied the oscillating motion around a pair of circular cylinders with different orientations with respect to the direction of flow and for several gap values. This study was carried out by simultaneous flow visualization and force measurements for several values of KC and β, which could be classified as regimes F and G, according to the TB90 map. As for cylinders placed side by side with respect to the flow direction, appreciable flow interference was observed for $\lambda < 4$ only. As for in-line cylinders, consistently with the results of Bushnell (1977) and Sarpkaya (1980), the in-line force on the downstream cylinder was found to decrease, due to a shielding effect when the gap is reduced. As regards the transversal force, W85 could hardly detect any trend with λ, except for very small gap values ($\lambda < 1$).

This paper reports results of a research project aimed at understanding:

- the effect of 3-D modulation of the base 2-D vortex patterns on the forces induced over an isolated cylinder; and,

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