Vortex-Induced Vibration (VIV) On Circular Cylinder With Offset Angle

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ABSTRACT

This paper presents the analysis of vortex-induced forces (VIF) and vibrations (VIV) on undulatory circular cylinder with offset angle. Five geometries with various offset angles (0°, 15.27°, 17.6°, 30° and sinusoidally varying between 15.27° and 17.6°) are simulated with the Immersed Boundary code and Implicit Large Eddy Simulation (ILES) as its subgrid model. The results indicate that offset angles resulted in a slight reduction of VIV as compared to circular cylinder. The largest reduction of VIV is observed for offset angle of 30°. Distortion of the braids, but not the vortex tubes, in the Karman street wake is observed.

KEY WORDS: Undulatory circular cylinder, offset angle, simulations, vortex-induced vibration, 2D freely vibrating.

INTRODUCTION

Many studies have been devoted on flow around circular cylinder. Despite its geometric simplicity, the wakes of a circular cylinder and its corresponding response are found to be nothing less than complex (Williamson, 1996; Williamson and Govardhan, 2004). One of the most challenging conditions in application for the circular cylinder is found at the condition of resonance. It is found that the cylinder vibrates vigorously due to its vortex shedding. This could result in catastrophic failure of the cylindrical structure. As such, numerous efforts have been designated to solve such Vortex-Induced Vibration (VIV) problem. While various shapes have been adopted for VIV reduction, few geometries have succeeded in eliminating VIV at the cost of increasing drag forces(Zdravkovich, 1981). For all the geometries, the amplitude of undulations (w/D, where D is the mean diameter of the undulatory cylinder) is defined to be 0.06. Such studies are performed by constructing a circular cylinder with sinusoidally varying diameter in spanwise direction and offset angle between its leading edge and trailing edge.

METHODOLOGY

Geometries

In order to assess the applicability of the VIV reduction properties of the seal whiskers geometry on circular cylinder, five geometries are constructed. These geometries include a circular cylinder with a sinusoidally varying diameter along its spanwise direction (termed undulatory cylinder), undulatory cylinder with offset angle of 15.27°, 17.6°, 30°, and undulatory cylinder with sinusoidally varying offset angle between 15.27° (node) and 17.6° (saddle). It is important to note that a node is defined as the widest cross sectional area of the cylinder and a saddle is defined as the narrowest cross sectional area of the cylinder. The offset angles of 15.27° and 17.6° are chosen for their direct relevance to the geometry of the whisker. The offset angle of 30° is chosen as to observe the effects of larger offset angle. Referential guidelines for choosing the offset angle of 30° are the studies on VIV properties of circular cylinder with helical strakes. It is found that a minimum helix angle is necessary for VIV reduction to be observed (Zdravkovich, 1981). For all the geometries, the amplitude of undulations (w/D, where D is the mean diameter of the undulatory cylinder) is defined to be 0.06. For all the geometries, the wavelength of the undulations (λ/D) is maintained at 1.82. Fig. 1 illustrates the simulated undulatory cylinder geometries and their corresponding offset angles.

Numerical Method

The studies performed in this paper are based on numerical experiments with the ‘Boundary Data Immersion Method (BDIM)’ simulation code (Weymouth, 2008). The code was developed with immersed boundary method, which allows for motion of the body with respect to the fluid without the need of grid re-meshing. Instead, a meta-equation defining the regions of solid, fluid and transitional region is developed(Weymouth and Yue, 2011). These equations are shown as follows:

\[ M(q_\epsilon) = B(q_\epsilon) + F(q_\epsilon) + S(q_\epsilon) = 0 \]  \[ \text{[1]} \]