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Analysis of flow over a circular cylinder fitted with helical strakes

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Abstract

The effectiveness of the helical strakes in suppressing the vortex-induced vibration (VIV) of a rigid cylinder is investigated by providing a three start helical strakes around a circular cylinder at two Reynolds numbers (100&28000). While the effect of helical strakes on suppression of vortex shedding has been studied extensively, the mechanism of VIV mitigation using helical strakes is much less well documented in the literature. In the present study, a rigid circular cylinder of diameter d=40mm attached with three-strand helical strakes of dimensions of 10d in pitch and 0.15d in height was tested by simulation. To numerically simulate vortex shedding, CFD is used to calculate the unsteady flow that arises from a fluid moving past an obstruction. A computational grid independence study has been done for flow over the circular cylinder and the grid resolution in which there is faster recovery of coefficient of lift is taken for the simulation. The contours of static pressure, velocity magnitude and vorticity magnitude and the hydrodynamic coefficients Cd and CL are obtained. It is found that, as expected, the straked cylinder has a higher drag coefficient in comparison with a smooth bare cylinder. The helical strakes can reduce VIV by about 99%.

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*Keywords:*Helical strakes; Vortex induced vibration (VIV); Hydrodynamic coefficient

1. Introduction

Vortex shedding behind bluff bodies is of concern for many engineering applications. Bluff bodies are structures with shapes that significantly disturb the flow around them, as opposed to flow around a streamlined body. Fluid flow past a circular cylindrical object generates vorticity due to the shear present in the boundary layer. This vorticity in the flow field coalesces into regions of concentrated vorticity known as vortices on either side of the cylinder. When vortices are shed from a bluff body, the latter is subjected to time-dependent drag and lift forces. The lift force oscillates at the vortex shedding frequency while the drag force oscillates at twice the vortex shedding

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frequency. If the cylinder is not rigid enough, these forces may induce vibration of the cylinder. The lift force may induce cross-flow vibrations and the drag force may induce in-line vibrations. This phenomenon is called vortex-induced vibration (VIV). Vortex-induced vibration of bluff structures is one of the key issues in riser and pipe line designs. This is because VIV will increase not only the dynamic load to the structures but will also influence the structural stability. The vibrations may cause structural failure or accelerate the fatigue failure. The above factors may result in an increase in capital investment of the structures and the expenses for maintenance and replacement.

As a result, this subject requires investigation, particularly when the cylinder is fitted with helical fins commonly known as helical strakes, so that a comprehensive understanding about behaviours of the flow for a wide range of conditions can be obtained. Thus the fluid flow around a cylinder, because of complicated phenomena such as vortex shedding and flow separation behind the cylinder, has been studied by many researchers and scientists. They applied some methods and devices to control this flow. Methods are classified in three groups: (1) passive control, (2) active control and (3) compound control. Passive control techniques do not need any external energy. Additional devices in the fluid flow or changing the geometry of the bluff body such as fins, splitter plate and roughness are applied in this method. Active control techniques such as EHD actuators and vibrators need external energy to affect the fluid flow. In compound control method, both active and passive techniques are applied simultaneously.

Inoue et al. [1] constructed a non-uniform mesh but divided the computational domain into three regions, each with a different grid ratio. The smallest cell was located along the edges of the square cylinder with the value of h/D = 0.01. Doolan [2] investigated the grid convergence for three different grid resolutions on DNS around a square cylinder and found that the solution converged when the smallest cell size along the square cylinder edge was h/D = 0.0167. Shuyang Cao et.al.[3] investigated the shear effects on flow around circular and square cylinders. One interesting finding is that the direction of the lift force depends on the body shape, i.e., the lift force acts from high velocity side to low velocity side for the circular cylinder while it is in the opposite direction for the square cylinder. By conducting a numerical investigation Md. MahbubarRahman [4] found that 2-D finite volume method is very much prospective for turbulent flow as well as laminar flow.

T. Zhou et al [5] experimentally investigated the vortex-induced vibration of a cylinder with helical strakes. A rigid circular cylinder attached with three-strand helical strakes of dimensions of 10d in pitch and 0.12d in height was tested in a wind tunnel. It was found that unlike the bare cylinder, which experiences lock-in over the reduced velocity in the range of 5–8.5, the straked cylinder does not show any lock-in region.

Shan Huang [6] , Andy Sworn conducted experiments on two fixed circular cylinders fitted with helical strakes at various staggered and tandem arrangements. It is found that, the straked cylinder has a higher drag coefficient in comparison with its smooth counterpart. It is further found that whilst the strakes reduce the fluctuating forces on the upstream cylinder, the reduction is significantly smaller for the down-stream straked cylinder.

Lee KeeQuen [7] et al. investigated the effectiveness of helical strakes in suppressing VIV of flexible riser. He found that the most effective configuration of strakes in terms of the dynamic responses is p = 10 D and h = 0.15 D model. However, model of p = 10 D and h = 0.10 D performs better in reducing the hydrodynamic forces. The CFD results of two flexible straked risers [8] have also shown that the upstream riser had very little motion than the downstream riser.

Shan Huang [9] found that the helical grooves were effective in suppressing the vortex-induced cross-flow vibration amplitudes with the peak amplitude reduced by 64%. Drag reductions of up to 25% were also achievable in the sub-critical Reynolds number range tested in that study for the fixed cylinders.

Over the last twenty years, a vast amount of studies has been conducted to increase the understanding of different transition processes of the flow past a circular cylinder as well as rectangular cylinders experimentally, numerically and theoretically. By contrast, there are very few similar studies found on flow past circular cylindrical structures provided with helical projecting fins commonly known as helical strakes, at moderate Reynolds numbers.