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Numerical simulation of flow past a rotationally oscillating cylinder

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ABSTRACT

The unsteady flow past a rotationally oscillating circular cylinder is investigated numerically for different values of oscillating amplitude and frequency at a Reynolds number of 200. A random vortex method is developed to simulate the flow past a stationary and rotating cylinder. The approach used to understand the vortex formulation process is to trace the motion of fluid particles. Some basic behaviors of vortex shedding are revealed and the lock-on range for vortex shedding is obtained. The influences of the oscillating amplitude and frequency on the forces acting on the cylinder are determined together with the flow pattern in the wake. For values of oscillating frequency above lock-on frequency, it is found that drag coefficient is below that for the stationary cylinder in a quite wide range of forcing frequency, and the efficacy of drag reduction becomes increasingly remarkable as the amplitude increases. Furthermore, it is observed that vortices shed at forcing frequency from the cylinder interact in the wake and result in a large-scale configuration with a new frequency, which is similar in form to the Karman vortex street downstream of a stationary cylinder. Also the coalescence process behind the cylinder is studied.

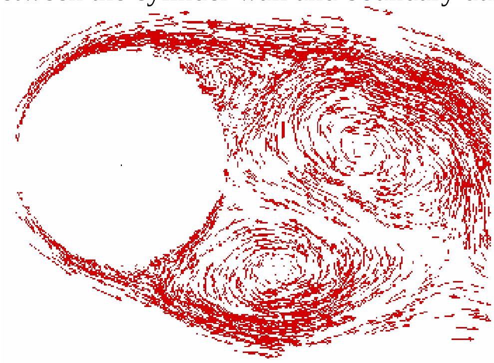
Introduction

The main features of flow past a cylinder are its separation from body surface, vortex shedding and the formation of a large wake. A lot of experiments showed that vortex shedding could be dramatically changed when a cylinder is oscillating in a fluid stream [1]. Several experiments and numerical studies on flow past a rotationally oscillating cylinder have already been conducted. Viscous flow around a rotationally oscillating cylinder was investigated experimentally by Okajim et al. [2] for Reynolds number from 40 to 160 and 3050 to 6100. Their results showed that when the oscillating frequency of the cylinder is at or near the frequency of vortex shedding from a stationary cylinder, the vortex shedding synchronizes with the cylinder motion. In the present work, for a quite wide range of frequency, vortex shedding and development of a wake behind a rotationally oscillating circular cylinder is simulated using numerical flow visualization technique name random vortex method at a lower Reynolds number.

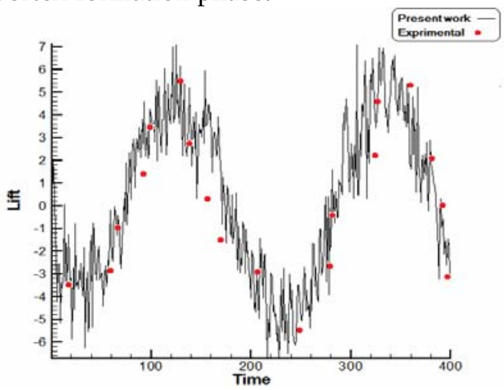
Result and discussion

Rotational oscillation with A_m=0.5

Vortex shedding frequency for various value of forced oscillating frequency is obtained. It is observed that when $f_c / f_0 = 1$, the vortices shed are much stronger as fluid gains additional vorticity from synchronized cylinder oscillation that provides the largest relative velocity between the cylinder wall and boundary during the vortex formation phase.



Fig(2): Patterns of instantaneous streaklines at $f_c / f_0 = 1$



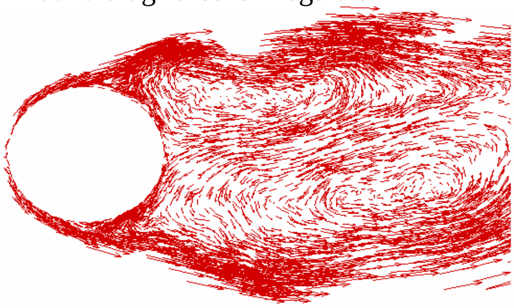
Fig(3): Lift force versus time for $f_c / f_0 = 1$

Also within this lock-on range the fluctuation amplitude of lift force is larger than those outside the lock-on range, and at $f_c / f_0 = 1$, it is the highest in peak amplitude.

As frequency f_c / f_0 further increases, It can be seen that the vortices shed, interact each other in the near-wake. Also the small vortices of opposite sign are generated at frequency f_c from both sides of cylinder; these vortices assemble behind the cylinder and form a large-scale vortex which is then detached from the cylinder. In other words, the vortex does not detach from the cylinder until both its strength and size of vortex have grown to a certain level. In these cases there are two dominant frequencies of the lift spectrum appears and the lift and drag forces become less regular. This indicates that the lock-on no longer exists at these frequencies.

Rotational oscillation with A_m=1.0

In this case as the velocity amplitude A_m of the oscillating cylinder changes, the position, strength and shape of attached vortices from both sides of the cylinder also changes. The larger the amplitude A_m, the more remarkable the behavior of uneven strength and irregular spacing becomes. The amplitude of lift and drag force is irregular.



Fig(4): Patterns of instantaneous streaklines at $f_c / f_0 = 1.5$

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