

The Simulation of Vortex Shedding from an Oscillating Circular Cylinder

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ABSTRACT

The interaction between cylinder oscillation and the shedding of vortices is investigated numerically in this paper. The near wake structure is presented for different values of reduced velocity of a circular cylinder free to oscillate transversely. The method used for the simulation is based on the Vortex-in-Cell formulation incorporating viscous diffusion. The Navier-Stokes equations are solved through the vorticity-velocity formulation, assuming that the flow is two-dimensional. The operator-splitting technique, where convection and diffusion of vorticity are treated separately, is used. The convection part is modelled in a lagrangian way, assuming that the vorticity field is carried on a large number of discrete vortices, while the diffusion part is calculated through the finite-volume method. The calculations are carried out on an unstructured mesh, using the finite-volume technique to solve Poisson's equation for the stream-function and the diffusion equation for the vorticity. Vorticity is created due to the no-slip condition on the cylinder wall, and the mesh is finer close to it in order to have a better description of the boundary-layer. The mesh is also refined behind the cylinder, in order to have a good description of the vortex dynamics in the near-wake region.

KEY WORDS: vortex shedding, flow induced vibration, oscillatory flow.

INTRODUCTION

Many investigations of the effect of transverse oscillations on vortex shedding can be found in the literature. It is observed that sinusoidal transverse oscillations are characterised by the capture of the vortex shedding frequency by the oscillation frequency over a range of cylinder oscillation amplitudes. This phenomenon is called *lock-in*. Meneghini, Saltara and Bearman (1997) investigated square, saw-tooth and parabolic wave forms of cylinder transverse oscillations, and found that only for a parabolic wave did *lock-in* occur in a similar way to that observed with sinusoidal oscillations. Forces on cylinders in oscillatory flow have been extensively investigated by Bearman et. al. (1985), Sarpkaya (1981), among others. In Lin et. al. (1996), a numerical study of oscillatory flow about a circular cylinder is carried out for low values of Beta parameter (relation between Reynolds and Keulegan-Carpenter numbers). Zhang and Dalton(1994) and Yeung and

Vaidhyanathan(1993) investigated in close detail the flow past oscillating circular cylinders.

With a cylinder free to oscillate, the *lock-in* phenomenon is characterised by the capture of the vortex shedding frequency by the natural frequency of the cylinder, over a range of reduced velocities. Excellent reviews about the subject can be found in Sarpkaya (1979) and Bearman (1984). Results by Brika and Laneville (1993), Kalak and Williamson (1996), and Parra (1996) show that in the region of *lock-in* large amplitudes of oscillation are observed for high mass parameter values, i.e. when the density of the fluid is of the same order of magnitude as the cylinder mass. Brika and Laneville showed that two different modes of vortex shedding were observed in their experiments. Albeit their investigation were carried out with a flexible cylinder, similar results were obtained by Kalak and Williamson for a rigid cylinder free to oscillate transversally and with a very low damping parameter. Their experimental results showed the presence of two modes of vortex shedding: one related to a high amplitude of oscillation and designated by Khalak and Williamson as the upper branch, and another mode related to a lower amplitude and referred as the lower branch.

Numerical simulations by Meneghini, et. al (1997) gave amplitude results very similar to those obtained by the simulations of Newman and Karniadakis (1997) using a 3D-spectral element method and where a flexible cable was studied. The range of the lock-in region and the frequency of the induced vibration obtained by Meneghini et. al are similar to the experimental results, but produced smaller amplitudes than the expected values. It seems that only the lower branch of amplitudes is picked up by the numerical simulations. Similar results were obtained by Newman and Karniadakis when the flexible cable was constrained to oscillate only in the transverse direction and there was a finite structural damping.

The reason why only the lower branch is present in the simulations are not yet known and possible ways of inducing the upper branch of amplitudes are under investigation. Newman and Karniadakis results had a high amplitude only when the structural damping parameter was set to zero and the cylinder was free to oscillate in all directions. This is very close to reality for the flexible cylinder case, but for a rigid, two-dimensional and elastically mounted cylinder there will always be at least a small structural damping. In both papers dealing with numerical simulations, they carried out for a Reynolds number equal to 200 and showed only one mode of vortex shedding, and this mode corresponding to the lower amplitude branch in the amplitude versus