LES of the flow around an oscillating cylinder

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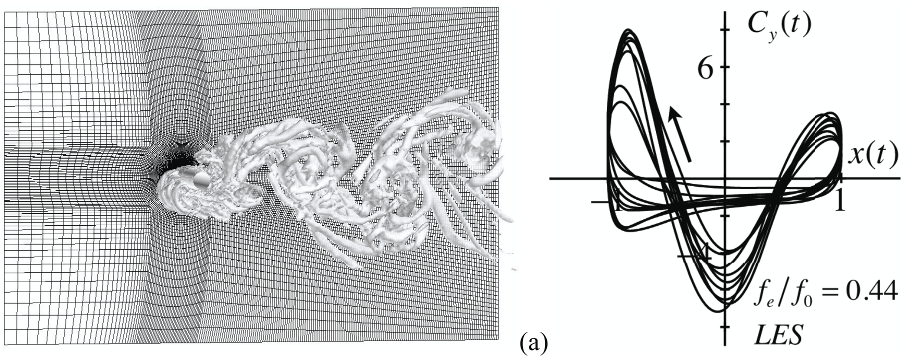
Abstract

In many engineering applications it is vital to understand and somehow predict fluid-structure interactions (FSI). Some of the most apparent cases are noise pollution, fatigue and structural failure caused by flow-induced vibrations. In our field of research, Shipping and Marine Technology, this concerns ships, offshore structures, propellers and mooring cables. The flow around an oscillating cylinder, figure 1a, constitutes a canonical case in these types of flows and has previously been extensively studied experimentally and to a large extent also numerically. Here the experimental study by Cetiner is mathematically modeled and investigated numerically. In both Cetiner's and this study the cylinder, with a fixed diameter D, is forced to oscillate horizontally with fixed frequency, f_e, and amplitude, A. Defining each case is its dimensionless excitation frequency, f_e/f_0. With f_0 being the von-Kármán shedding frequency for a non-oscillating cylinder given by the empirical relationship, St=0.2=f_0D/U$_\infty$, where U$_\infty$ is the, for each specific case, fixed free-stream. Two different dimensionless excitation frequencies are considered, namely f_e/f_0=1.00 and f_e/f_0=0.44. In figure 1a a snapshot of the flow field at f_e/f_0=1.00 is shown. Flow structures can be observed both upstream and downstream of the cylinder, a fascinating feature due to the oscillation. Figure 1b shows the Lissajous curve of the dimensionless lift force versus the displacement of the cylinder during 9 following characteristic oscillations with f_e/f_0=0.44. A strong asymmetry is observed even though the computational setup is completely symmetrical around the horizontal-axis. A more detailed description of the flow physics and the computational setup can be found in Feymark *et al*, [2].

The objective of the study is to provide understanding and give support in the validation of a fluid structure interaction methodology suitable for complex applications. The Computational Fluid Dynamics (CFD) method used is Large Eddy Simulation (LES) in which all the large scales of motions are resolved and only the effect of the small scales is modeled. The computational domain, shaped as a cubiod, is discretized using two grids consisting of 0.6MCells and 1.25MCells. Since the movement of the cylinder changes the position of the boundary of the mesh there is a need for either complete re-meshing or some kind of redistribution of the cells. This has been solved using the cell displacement framework available in OpenFOAM. That is finding the displacement velocity, **w**, in each node by solving, $\nabla\cdot(\gamma\nabla\mathbf{w})=0$, where γ is a diffusion term here defined as the quadratic inverse of the distance to the moving wall. A comparison will be done between implicit and explicit LES, both using a log-law based wall-model. The explicit model used is the One Equation Eddy Viscosity Model (OEEVM). The simulations will be validated against the experimental data of Cetiner in terms of frequency content and Lissajous curves of the lift force.



(a) (b)

Figure 1. In (a) a perspective view of the flow field around an oscillating cylinder with dimensionless excitation frequency f_e/f_0=1.00 in term of iso-surfaces of the second invariant of the velocity gradient. In (b) the Lissajous curve of the lift force coefficient, $C_y(t)$, versus the displacement of the cylinder, $x(t)$, is displayed.

Key words: Oscillating, Cylinder, LES, Unsteady

References

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[2] Feymark, A., Alin, N., Bensow, R., and Fureby, C., "LES of an Oscillating Cylinder in a Steady Flow," 2010 AIAA 2010-560