8th. World Congress on Computational Mechanics (WCCM8)
5th European Congress on Computational Methods in Applied Sciences and Engineering (ECCOMAS 2008)
June 30 –July 5, 2008
Venice, Italy

Vortex shedding in a confined laminar flow past a square cylinder

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Key Words: *Vortex Shedding, Confined Flow, Square Cylinder, Navier-Stokes, Drag Lift coefficient*

ABSTRACT

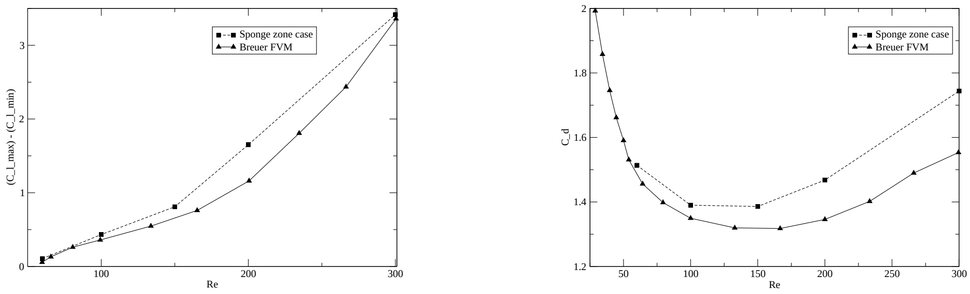
State of the practice of aeroacoustics relies on the use of analogies (decoupling the aerodynamic and acoustic fields), which are based on high quality time resolved aerodynamic solutions in order to accurately estimate the sources of sound [1]. Therefore, to develop a methodology for industrial applications using off-the-shelf commercial software, it is necessary to integrate state-of-the-art simulation of Navier-Stokes laminar and turbulent aerodynamic phenomena. This implies using high-resolution unsteady Navier-Stokes and large eddy simulation (LES) solvers. For this purpose, Fluent commercial CFD package was selected.

The present work focuses on the analysis of the sensibility to the solver settings, namely the outflow boundary conditions within the selected software package. Consider the solution of the unsteady incompressible Navier-Stokes equations in a plane channel inside which a square cross-section cylinder is mounted imposing a blockage ratio of $B = 1/8$. This solution serves to construct the aerodynamic sources of sound used in the Computational Aeroacoustics analogy. Analyzing the general theory of the physics of vortex shedding [2], justification for the chosen approach is derived for the flow regimes of interest. This justification is dependent on the largest Reynolds number considered. The Reynolds number, based on the maximum inlet velocity and the cylinder height, is 300, therefore a 2D laminar approach is deemed sufficient, since no relevant 3D phenomena are present [2,3].

Three different outflow boundary conditions were evaluated to study the limitation of the pressure disturbances due to vortices leaving the outflow boundary. These conditions were: (1) a zero constant pressure variation condition, (2) a zero constant normal velocity gradients condition and (3) a zero constant pressure variation condition together with the introduction of a sponge zone [4]. The sponge zone consists of an additional part of the domain, introducing a gradual stretch of the grid in the outflow direction, in order to dissipate the vortices before they reach the outflow boundary.

The governing equations are discretized in space and time using a finite-volume segregated pressure-based solver with second order schemes on structured grids composed of quadrilateral cells. The calculations were performed on three different grid topologies (skewed, stretched and uniform) with varying cell size and correspondent time-step.

Analysis of the instantaneous velocity profiles as well as the integral results were performed to validate the aerodynamic solution with data available from other published studies [3]. Integral values for the lift and drag are shown in figure 1 and dependency of Strouhal number (based on the frequency of vortex shedding) to the Reynolds number is present in figure 2.



(a) Average lift coefficient amplitude (b) Average drag coefficient

Figure 1: Integral quantities for the case with uniform finest mesh with a sponge zone.

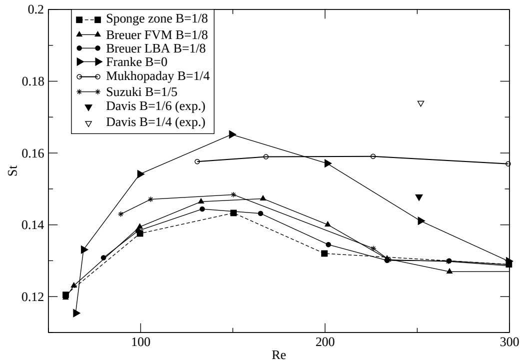


Figure 2: Strouhal number, comparison with the literature

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