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Flow over a bluff body from moderate to high Reynolds numbers using large eddy simulation

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Abstract

Large eddy simulation (LES) is performed to study the uniform approach flow over a square-section cylinder with different Reynolds numbers, ranging from 10^3 to 5×10^6. Two different sub-grid scale models, the Smagorinsky and a dynamic one-equation model, are employed. An incompressible finite-volume code, based on a non-staggered grid arrangement and an implicit fractional step method with second-order accuracy in space and time, is used.

The structure of the flow is studied with the instantaneous and the mean quantities such as pressure, turbulent stresses, turbulent kinetic energy, vorticity, the second invariant of velocity gradient and streamlines. The Strouhal number, the mean and RMS values of the lift and drag are computed for various Reynolds numbers, which show a good agreement with the available experimental results. It is found that the effect of Reynolds number on the global quantities, the mean and the large scale instantaneous flow-structures is not much at the higher Reynolds numbers, i.e. $Re > 2 \times 10^4$. In this range of Reynolds numbers, the small scales of the instantaneous structures are more complex and chaotic as they compare with the larger ones.

1. Introduction

The flow over objects such as high-rise buildings, marine risers, bridges, cooling towers, chimneys and tube banks in heat exchangers are encountered extensively in engineering applications. These objects, which under normal circumstances usually create a massive wake region downstream, are called bluff bodies. Motion of objects such as submarines, ships and cars through fluids are examples of a pivotal role of such bluff objects in industrial applications. Thus, the knowledge of the flow field around these structures is of major importance in a multitude of applications such as civil, wind engineering and technical problems associated with energy conversion and structural design. This type of flow often contains many complex phenomena such as separation, wake flow, vortex shedding, curved free shear layers, dominant large scale structures and high turbulence.

In these bodies, the behaviour of flow changes as the Reynolds number (Re) is increased. At this point, it may be suitable to attend to special type of bluff bodies, circular and square prisms. At the Reynolds numbers below about unity, the flow is fully attached with no separation. When Re increases, the flow separates and a pair of steady symmetric vortices forms behind the body. At higher Reynolds numbers, the formation vortex length of the re-circulation region behind the body grows with increasing Re. At a critical onset Reynolds number [1,2], the twin-vortex arrangement becomes unstable, and a time-periodic oscillation wake and a staggered vortex street form. The separated vortices shed alternately from the upper and the lower side of the body. The periodic phenomenon is referred to as vortex shedding, whereas the anti-symmetric wake flow pattern is referred to as the von Kármán vortex street. This is the first 2D wake transition which is called

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