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NUMERICAL STUDIES ON AERO-ACOUSTIC PHENOMENA ASSOCIATED WITH WALL BOUNDED SHEAR FLOW

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ABSTRACT

Noise is a ubiquitous industrial pollutant whose impact on urban, and increasingly on rural society worldwide is considerable. Noise and vibration are now major factors in determining the marketability and competitiveness of wide range of manufactured products from domestic appliances to aircraft. Controlling noise and vibration effectively at source demands a very good understanding of the cause (flow behaviour and its interaction with the structure) which generates the effect (the noise and vibration). Concern about the effects of noise and vibration on the human environment has lead to the formulation of exposure standards for environmental noise and vibration. Therefore, it is a very important problem worth paying attention.

Over the past decade, the relatively new field of computational aero-acoustics (CAA) has emerged as an attractive and promising technique in furthering the ability to predict and understand flow-generated sound. Although the CAA field has close ties to the field of computational fluid dynamics (CFD), the nature, characteristics, and objectives of aero-acoustic problems are distinctly different from those encountered in aerodynamics. This point can be illustrated by considering sound radiated from a flow at low Mach numbers. At Mach numbers of 10^{-3}, the ratio of the radiated acoustic energy to source energy levels is on the order of 10^{-12}. In addition the length scale associated with the propagating acoustic waves are significantly larger than those governing the near-field flow. These disparate energy levels and length scales require careful numerical treatment to avoid introducing spurious noise sources, excessive dissipation and dispersion of the acoustic quantities, and nonphysical wave reflection from computational boundaries. As such, the technology, e.g., solvers algorithm, and boundary condition types developed for CFD analyses is not always directly applicable to CAA. Recently, Hardin and Pope1 developed an expansion about incompressible flow (EIF) approach for CAA problem. The EIF approach splits the direct simulation approach into an incompressible flow problem and a perturbation problem and does not allow for acoustic back scatter into the flow solution. In the near field, the perturbation quantities are the difference between the compressible and incompressible flow-field variables. The perturbation quantities are equivalent to the acoustic quantities in the far field.

As it is mentioned above, the flow considered here is highly unsteady in nature due to periodic vortex shedding downstream and mutual interaction of two separating shear layers. Correct prediction of turbulence characteristics including transition from laminar to turbulent flow is very much essential. Therefore, in our study emphasis is put to predict the unsteady turbulence characteristics. In this regard a high-order LES turbulent model developed by the author and

tested by carrying out a detail study regarding its performance on various types of turbulent flow problem and DNS data is used. In the present work, in a dynamic eddy viscosity model, a new approach is proposed to transfer information between the sub-grid and large scale eddies by solving an additional transport equation for turbulent kinetic energy in the grid scale level. Here, sub-grid-scale turbulent stresses are closed using a dynamic turbulent kinetic energy transport model. The sub-grid scale length scale is represented by the minimum of the universal length scale and the grid scale. The universal length scale, which represents the blending of the length scales of cascade of eddies starting from the near wall small scale all the way to the sub-grid scale, is defined on the basis of turbulent Reynolds number in this model. A test filter was used for the dynamic procedure, which is applicable to stretched grid near the body surface. The advantages of such model include resolution of interesting scales, simultaneous modelling of high shear regions and large scale unsteadiness, and use of stretched grids. In the kinetic energy transport equation, dissipation of turbulent energy is defined on the basis of time scale.

Regarding aero-acoustic problem, expansion about incompressible flow (EIF) approach, which splits the direct simulation approach into an incompressible flow problem and a perturbation problem was used. In our work, in order to properly handle the near field wall-bounded shear flow compressibility effect, the perturbed viscous stresses in the momentum equations are included.

Some typical results on aero-acoustic noise for flow past a circular cylinder at Mach number of 0.3 ReD=300, is presented below. In Fig.1 is presented the computational grid. Computational domain is set extending from the cylinder to r=100D and O-type grid with 401X401 mesh points are used. In Fig.2 is presented vorticity distribution. The result reveals a well organized shedding of vortices. Mutual interaction between the two separating shear layers give rise to the alternate formation of vortices which grow, fed by circulation from their connected shear layers, until they are strong enough to draw the opposing shear layer across the near wake. In Fig.3 is presented the instantaneous pressure fluctuation field around the cylinder. The acoustic waves and Karman vortex street can be clearly observed here. The pressure fluctuation field is non-dimensionalized by inlet velocity and density.

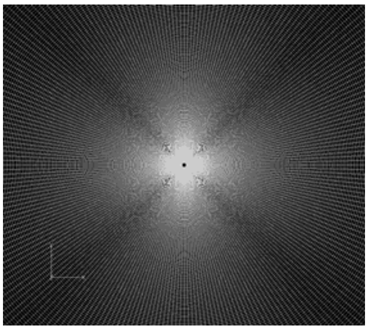
Fig.1 Computation grid

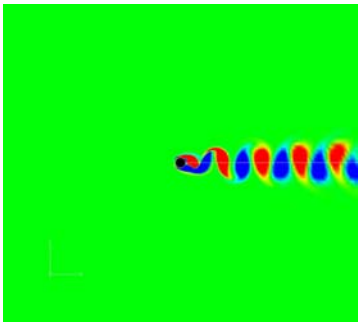
Fig.2 Instantaneous vorticity distribution

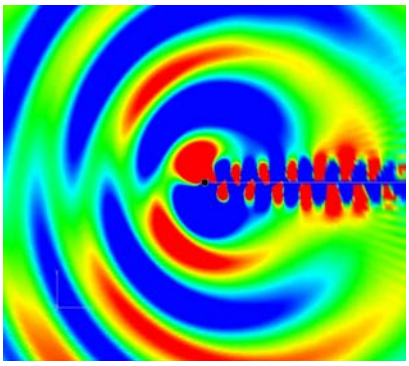
Fig.3 Instantaneous pressure fluctuations

The results of this study indicated that the flow is inherently unsteady due to periodic vortex shedding downstream the cylinder, which results in instability on the structure. The results of this study for some wall bounded shear flow problem will be presented in detail at the congress.

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