

SHEAR LAYER INSTABILITY AND DRAG-CRISIS FOR FLOW PAST A CYLINDER

S. Mittal^a and S.P. Singh^a

^aDepartment of Aerospace Engineering
Indian Institute of Technology
Kanpur, UP 208 016
India
smittal@iitk.ac.in

The flow past a bluff body, and in particular, a circular cylinder is associated with various instabilities [1]. The first one is the wake instability and is also responsible for the onset of vortex shedding. It occurs at $Re \sim 47$ and the flow is two-dimensional. At higher Reynolds numbers, three-dimensional instabilities in the wake set in and beyond $Re \sim 200$ the flow ceases to remain two-dimensional. The shear layer instability sets in at even higher Re . The separated boundary layer from the cylinder surface becomes unstable resulting in the roll-up of the shear layer into vortices that are much smaller than those observed at the onset of vortex shedding. The Re at which the instability is first observed first is still an open issue. At $Re \sim 2 \times 10^5$, a sudden drop in the drag coefficient for the cylinder is observed. This is often referred to as *drag-crisis*.

In the present work we utilize a stabilized finite element formulation to study the flow past a cylinder for $100 \leq Re \leq 10^7$. Close to the cylinder and in the wake region, the finite element mesh has very high resolution. It is shown that at low Re the two-dimensional computations predict the aerodynamic data quite accurately. For Re beyond 1000 the 2D computations overpredict the drag-coefficient (C_D). Shear layer instability sets in at higher Re . It appears that for Re larger than 10^4 the shear layer vortices play a major role in the flow dynamics and overshadow the 3D effects. Consequently, for large Re the 2D computations predict a fairly reasonable value for C_D .

The data for the frequency associated with the shear layer at various Re is compared to that reported by other researchers. Very good agreement is observed between the two. The phenomenon of *drag crisis* is captured by the present, two-dimensional, computations. With an increase in Re the transition point of the shear layer, separated from the cylinder surface, moves upstream. Our computations indicate that at the critical Re the instability reaches the point of flow separation and energizes the local flow causing it to re-attach.

Energy spectra for these highly resolved flows at various Re are computed and the effect of various parameters involved in their calculation is investigated. It is found that despite the high shear in the flow, the kinetic energy shows the same structure as observed for 2D isotropic turbulence. For large Re flows it is found that the energy, $E(k)$, varies as $k^{-5/3}$ below the energy injection wave number and as k^{-3} for higher wave numbers. It is found that the computations with and without the Smagorinsky turbulence model result in virtually identical results.

References

- [1] C. H. K. Williamson, "Vortex dynamics in the cylinder wake," *Annual Review of Fluid Mechanics*, v. 28, p. 477-539, 1996.