World Academy of Science, Engineering and Technology
International Journal of Aerospace and Mechanical Engineering
Vol:9, No:05, 2015

Beyond the “Breakdown” of Karman Vortex Street

Authors : Ajith Kumar S., Sankaran Namboothiri, Sankrish J., SarathKumar S., S. Anil Lal

Abstract : A numerical analysis of flow over a heated circular cylinder is done in this paper. The governing equations, Navier-Stokes, and energy equation within the Boussinesq approximation along with continuity equation are solved using hybrid FEM-FVM technique. The density gradient created due to the heating of the cylinder will induce buoyancy force, opposite to the direction of action of acceleration due to gravity, g. In the present work, the flow direction and the direction of buoyancy force are taken as same (vertical flow configuration), so that the buoyancy force accelerates the mean flow past the cylinder. The relative dominance of the buoyancy force over the inertia force is characterized by the Richardson number (Ri), which is one of the parameter that governs the flow dynamics and heat transfer in this analysis. It is well known that above a certain value of Reynolds number, Re (ratio of inertia force over the viscous forces), the unsteady Von Karman vortices can be seen shedding behind the cylinder. The shedding wake patterns could be seriously altered by heating/cooling the cylinder. The non-dimensional shedding frequency called the Strouhal number is found to be increasing as Ri increases. The aerodynamic force coefficients CL and CD are observed to change its value. In the present vertical configuration of flow over the cylinder, as Ri increases, shedding frequency gets increased and suddenly drops down to zero at a critical value of Richardson number. The unsteady vortices turn to steady standing recirculation bubbles behind the cylinder after this critical Richardson number. This phenomenon is well known in literature as "Breakdown of the Karman Vortex Street". It is interesting to see the flow structures on further increase in the Richardson number. On further heating of the cylinder surface, the size of the recirculation bubble decreases without loosing its symmetry about the horizontal axis passing through the center of the cylinder. The separation angle is found to be decreasing with Ri. Finally, we observed a second critical Richardson number, after which the the flow will be attached to the cylinder surface without any wake behind it. The flow structures will be symmetrical not only about the horizontal axis, but also with the vertical axis passing through the center of the cylinder. At this stage, there will be a "single plume" emanating from the rear stagnation point of the cylinder. We also observed the transition of the plume is a strong function of the Richardson number.

Keywords : drag reduction, flow over circular cylinder, flow control, mixed convection flow, vortex shedding, vortex breakdown
Conference Title : ICFME 2015 : International Conference on Fluid Mechanics and Engineering
Conference Location : Montreal, Canada
Conference Dates : May 11-12, 2015