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Vortex Control by a Downstream Splitter Plate in Psudoplastic Fluid Flow

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Abstract : Pseudoplastic ($n<1$, n is the power index) fluids have great importance in food, pharmaceutical and chemical process industries which require a lot of attention. Unfortunately, due to its complex flow behavior inadequate research works can be found even in laminar flow regime. A practical problem is solved in the present research work by numerical simulation where we tried to control the vortex shedding from a square cylinder using a horizontal splitter plate placed at the downstream flow region. The position of the plate is at the centerline of the cylinder with varying distance from the cylinder to calculate the critical gap-ratio. If the plate is placed inside this critical gap, the vortex shedding from the cylinder suppressed completely. The Reynolds number considered here is in unsteady laminar vortex shedding regime, Re = 100 ($Re = U_\infty a/\nu$, where U_∞ is the free-stream velocity of the flow, a is the side of the cylinder and ν is the maximum value of kinematic viscosity of the fluid). Flow behavior has been studied for three different gap-ratios (G/a = 2, 2.25 and 2.5, where G is the gap between cylinder and plate) and for a fluid with three different flow behavior indices (n =1, 0.8 and 0.5). The flow domain is constructed using Gambit 2.2.30 and this software is also used to generate the mesh and to impose the boundary conditions. For G/a = 2, the domain size is considered as 37.5a × 16a with 316 × 208 grid points in the streamwise and flow-normal directions respectively after a thorough grid independent study. Fine and equal grid spacing is used close to the geometry to capture the vortices shed from the cylinder and the boundary layer developed over the flat plate. Away from the geometry meshes are unequal in size and stretched out. For other gap-ratios, proportionate domain size and total grid points are used with similar kind of mesh distribution. Velocity inlet ($u = U_\infty$), pressure outlet (Neumann condition), symmetry (free-slip boundary condition) at upper and lower domain boundary conditions are used for the simulation. Wall boundary condition ($u = v = 0$) is considered both on the cylinder and the splitter plate surfaces. Discretized forms of fully conservative 2-D unsteady Navier Stokes equations are then solved by Ansys Fluent 14.5. SIMPLE algorithm written in finite volume method is selected for this purpose which is a default solver inculcate in Fluent. The results obtained for Newtonian fluid flow agree well with previous works supporting Fluent's usefulness in academic research. A thorough analysis of instantaneous and time-averaged flow fields are depicted both for Newtonian and pseudoplastic fluid flow. It has been observed that as the value of n reduces the stretching of shear layers also reduce and these layers try to roll up before the plate. For flow with high pseudoplasticity (n = 0.5) the nature of vortex shedding changes and the value of critical gap-ratio reduces. These are the remarkable findings for laminar periodic vortex shedding regime in pseudoplastic flow environment.

Keywords : CFD, pseudoplastic fluid flow, wake-boundary layer interactions, critical gap-ratio
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