Heat Transfer Dependent Vortex Shedding of Thermo-Viscous Shear-Thinning Fluids

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Abstract : Non-Newtonian fluid properties can change the flow behaviour significantly, its prediction is more difficult when thermal effects come into play. Hence, the focal point of this work is the wake flow behind a heated circular cylinder in the laminar vortex shedding regime for thermo-viscous shear thinning fluids. In the case of isothermal flows of Newtonian fluids the vortex shedding regime is characterised by a distinct Reynolds number and an associated Strouhal number. In the case of thermo-viscous shear thinning fluids the flow regime can significantly change in dependence of the temperature of the viscous wall of the cylinder. The Reynolds number alters locally and, consequentially, the Strouhal number globally. In the present CFD study the temperature dependence of the Reynolds and Strouhal number is investigated for the flow of a Carreau fluid around a heated cylinder. The temperature dependence of the fluid viscosity has been modelled by applying the standard Williams-Landel-Ferry (WLF) equation. In the present simulation campaign thermal boundary conditions have been varied over a wide range in order to derive a relation between dimensionless heat transfer, Reynolds and Strouhal number. Together with the shear thinning due to the high shear rates close to the cylinder wall this leads to a significant decrease of viscosity of three orders of magnitude in the nearfield of the cylinder and a reduction of two orders of magnitude in the wake field. Yet the shear thinning effect is able to change the flow topology: a complex K´arm´an vortex street occurs, also revealing distinct characteristic frequencies associated with the dominant and sub-dominant vortices. Heating up the cylinder wall leads to a delayed flow separation and narrower wake flow, giving lesser space for the sequence of counter-rotating vortices. This spatial limitation does not only reduce the amplitude of the oscillating wake flow it also shifts the dominant frequency to higher frequencies, furthermore it damps higher harmonics. Eventually the locally heated wake flow smears out. Eventually, the CFD simulation results of the systematically varied thermal flow parameter study have been used to describe a relation for the main characteristic order parameters.

Keywords : heat transfer, thermo-viscous fluids, shear thinning, vortex shedding
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