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NUMERICAL STUDY OF NON-NEWTONIAN INELASTIC FLUID FLOW IN A 2D BIFURCATION AT NINETY DEGREES

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ABSTRACT

Flow in bifurcations has become a popular case study in fluid mechanics (e.g. [1]), largely because of its relation to hemodynamics and the occurrence of vascular diseases, like the formation of atherostic plaques and thrombi, which are known to occur predominantly near the side branches of such bifurcations. A number of possible mechanisms for the correlation between local disturbances in blood flow and the location of vascular diseases has been advanced: Caro et al. [2] suggested the adhesion of platelets, red cells and lipoids in zones with recirculations in the flow is mainly promoted by the low shear stress; on the other hand, Fry [3] pointed out that the endothelium of the arteries may be damaged due to the presence of high shear stresses, like those occurring on the intersecting corners of a bifurcation or at the re-attachment points of the recirculation zones formed, and thus inducing the formation of plaques in those regions

Since the genesis of vascular diseases is closely related to the recirculation flow zones occurring near bifurcations of blood vessels, a proper assessment of the phenomena and of all variables involved requires an accurate prediction of those recirculations. For non-Newtonian fluids, benchmark data with sufficient accuracy in flow through bifurcations are missing, even for the simplest basic geometry of the 2D diverting flow in a T-junction. That is the purpose of the present work.

A comprehensive computational fluid dynamics study has been carried out for steady-state laminar flow in a planar T-junction, using non-Newtonian Carreau fluids with characteristics close to those of actual blood flow. The calculations were performed for a range of Reynolds numbers, ranging from 50 up to 1000, and for extraction flow ratios varying between 0.1 and 0.9, employing both Newtonian and non-Newtonian fluids. The Newtonian case served to check the present computations by comparison against the recent results of Ref. [1]. For the numerical calculations with the non-Newtonian Carreau fluid, the impact on the results of varying the power law exponent of the Carreau model was investigated. Two sets of calculations were done: Reynolds number varied between 50 and 500 at a constant extracted flow ratio of 0.5;

and flow ratio varied from 0.1 to 0.9 at constant Reynolds number of 102. The present work may thus be viewed as a continuation of that of Miranda et al. [1] who have mainly focussed on steady and unsteady Newtonian in a T-junction.

Shear stress fields and the variation of size and intensity of the two recirculation zones created by the bifurcation were analyzed for the non-Newtonian Carreau model. Lower shear stress fields were obtained for the non-Newtonian fluid when compared with results for a Newtonian fluid, while the recirculation lengths were found to be larger than those for a corresponding Newtonian flow. It was found that the recirculation in the side branch was characterised by a division into two smaller recirculations at a certain value of the Reynolds number, which is lower for than for the parallel Newtonian situation. Simultaneously, an increase of the maximum recirculation intensity was observed for the secondary recirculation in the main branch. An increase of the power law exponent in the Carreau model tends to yield smaller sizes and intensities of the recirculation bubbles, accompanied by a general increase of the level of shear stress values.

Our predictions were based on a finite-volume method employing non-staggered meshes in which all variables are stored at centre of the control volumes forming the mesh. In order to ensure an adequate coupling between the velocity and the stress fields the method described in Oliveira and Pinho [4] was applied. In addiction, and with view to maintain good level of accuracy, the convective terms in the flow equations are represented by the high resolution scheme CUBISTA developed by Alves et al. [5]. Preliminary results for viscoelastic flow in a T-junction were presented recently, see [6].

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