DEVELOPMENT LENGTHS FOR NON-NEWTONIAN FLOWS IN PIPES AND TUBES BASED ON THE WALL SHEAR STRESS

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Knowledge of the length of pipe or channel needed for the flow to become fully developed is very important in many applications. For Newtonian flow, the definition of the development length has been standardised as that length required for the centreline velocity to reach 99% of the fully developed value. However, this definition may not be appropriate for flows of non-Newtonian fluids, such as most biological fluids, since rheological qualities such as shear-thinning and viscoplasticity may cause the flow close to the centreline, where the viscosity is higher, to evolve faster than that closer to the walls. For these cases, various alternative definitions of the development length have been proposed in the literature, all based on the evolution of the velocity field, but none of them has been so useful as to become standard [1,2].

In the present work we propose an alternative definition based on the evolution of the wall shear stress. In fact, for many applications the wall shear stress is more crucial than the flow velocity (e.g., blood flow in arteries), so that this definition will be useful even for Newtonian flows. The flow development of Newtonian and non-Newtonian fluids, such as power-law and Bingham-plastics, is studied in both pipes and channels by means of finite-element simulations for Reynolds numbers up to 2000. The finite-element results demonstrate that in the planar case, the wall-shear stress development is slower than the development of the centreline velocity and this effect becomes more pronounced as the Reynolds number is increased.

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