Numerical Investigation of Non-Newtonian Laminar Flow in a Curved Tube with Insert

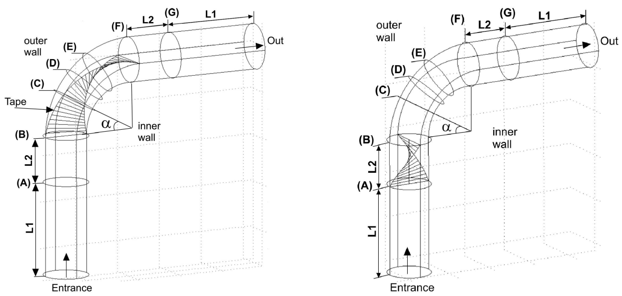
Aydar Kadyyrov[1]

[1]Research Center for Power Engineering Problems, KSC, RAS, Russia

Abstract

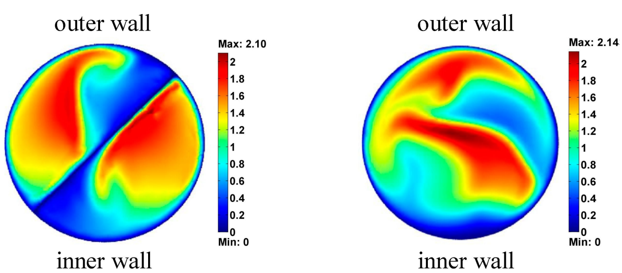
Heat transfer processes are known to depend on hydrodynamic fields. Therefore, the purpose of this research is to study the hydrodynamic fields in curved channels. We consider a steady flow of Non-Newtonian viscous liquids in a curved tube. The mathematical model is developed taking into account a negligibly small gravity force. The steady three-dimensional Navier-Stokes equations are used as the governing equations. The solution domain (Figure 1) consists of three parts. The first part is a part of a straight tube of 0.015m long, L1=0.01 m, L2=0.005 m. The second part is a curved region with rotation angle equals 90 degrees and radius of the curvature R=0.075m. The third part is a part of the straight tube following the curved part. Boundary conditions: in the inlet region of the channel velocity field is fully developed, in the outlet region of the channel normal stress is given (the total stress on the boundary is set equal to a stress vector of magnitude, f0=0, oriented in the opposite normal direction). The no-slip condition is forced on the channel walls. We consider two geometric objects. There is a twisted tape insert in the curved part between B and F in Elbow #1 (Figure 1). Elbow #2 has a twisted tape insert in the straight part of the tube between A and B. The tape is twisted until it reaches an angle of 90 degrees and turns right in both cases. To describe the viscosity behavior we use the Kutateladze model. It is based on the structural theory of viscosity and its parameters have physical meaning. The three-dimensional incompressible Navier-Stokes equations are solved using COMSOL Multiphysics. In our computations we examine Sodium Carboxymethyl cellulose (0.65% NaCMC) (Figure 2). This fluid is one of the widely used as a non-Newtonian fluid. Figure 2 show a comparison between distributions of velocity field in elbow #1 and elbow #2 where red region indicates a higher velocity. The distributions of the velocity field at cross-section D of the curved channels (elbow #1 and elbow #2) are shown in Figure 1. In the plot a red region indicates higher velocity. In the curved channel the fluid particles with different speeds are subjected to different effects of centrifugal forces. Due to these forces maximum speed tends to the outer wall of the curved tube. Numerical results show that due to the twisted tape inserted into the curved part of the channel additional inertial forces appear. The twisted tape before the curved channel considered for elbow#2 reduces the pressure on the outer wall and consequently reduces the force on the pipe wall and increases its longevity. The calculated hydrodynamic parameters can be further used to calculate heat and mass transfer. (The study was supported by the Ministry of Education and Science of the Russian Federation. State contract No. P1212 under The Federal Targeted Programme "Scientific and Scientific-Pedagogical Personnel of the Innovative Russia in 2009-2013")

Figures used in the abstract



Elbow #1 Elbow #2

Figure 1: Geometric objects, (A), (B),…, (G) – cross-sections, where (C) – 30 degrees cross-section, (D) – 45 degrees cross-section, (E) – 60 degrees cross-section.



(a) (b)

Figure 2: Velocity field at cross-section D of the curved channel with insert; (a) Elbow #1; (b) Elbow #2; Re=1039.