Temperature-dependent fluid properties in a turbulent pipe with circumferentially varying thermal boundary conditions

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We report DNS results of a pressure-driven fully developed turbulent flow in a pipe, with sinusoidal heat flux boundary conditions, and with temperature-dependent viscosity and thermal diffusivity, representative of the conditions in the tubes of heat receivers in Solar Power Tower plants. The main objective is to study the influence of variable fluid properties on the mean values and turbulence statistics in the heat transfer fluid. To that end, three different conditions are considered: a case with constant viscosity and two cases with low and high sensitivity to temperature, the latter being representative of the behavior of the molten salts in the Central Solar Receivers.

The simulations are performed using the code Nek5000[1], which uses a spectral-element method, solving the incompressible Navier-Stokes equations on Gauss-Lobatto-Legendre nodes. The computational domain consists of a straight circular pipe of length 25R, discretized with 55440 spectral elements of polynomial order N = 7, with 105 elements in the stream-wise direction and 528 elements in the cross-plane.

We have found that, although the mean temperature on the pipe does not change significantly, both temperature and velocity fluctuations are increased on the cooled wall but damped on the heated wall. We observe the appearance of a secondary flow induced by the variable fluid properties, whose contribution to the heat flux is of the same order as the contribution of the diffusive terms. Finally, the overall friction coefficient increases by up to 2.9%, whilst the heat transfer on the wall, characterized by the Nusselt number, varies only within 1% in all three cases.

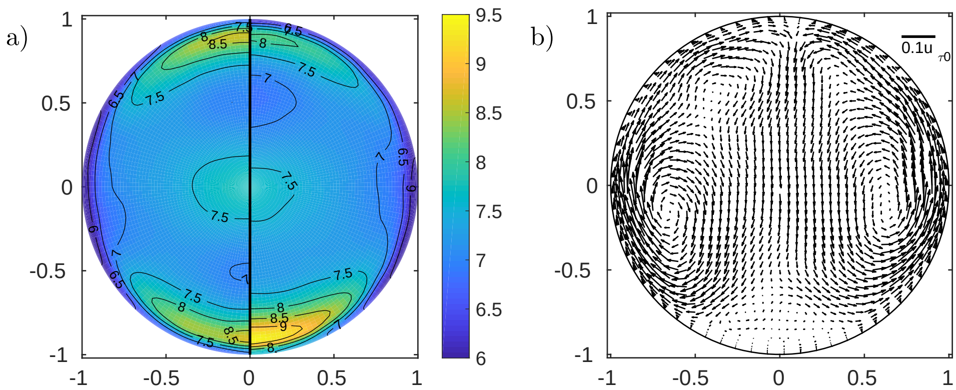

Figure 1: (a) Temperature RMS for the case with constant (left) and temperature-dependent (right) fluid properties. (b) Secondary velocities for the case with variable fluid properties.

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[1]Fischer, *nek5000.mcs.anl.gov* (2008).