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TURBULENT POWER-LAW FLUID FLOW AND HEAT TRANSFER IN ROTATING PIPE

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Large Eddy Simulations (LES) of turbulent forced convection of power-law fluids and heat transfer, flowing in a heated horizontal rotating pipe at isoflux conditions, is carried out, with an extended Smagorinsky model [1], for two power law indices ($n=0.75$ and $n=1$), at various rotation rates ($0 \leq N \leq 3$) and Reynolds and Prandtl numbers $Re_s=4000$ and $Pr_s=1$. The apparent viscosity η of the non-newtonian fluid is modeled by $\eta=K\dot{\gamma}^{n-1}$, where n is the flow index and K the consistency.

The turbulent viscosity, in the non-Newtonian Smagorinsky model [1], is computed by $\nu_t=C_s f_s(f_n \Delta)^2 \overline{S_{ij}}$, where Δ is the computational filter, f_s the van Driest wall damping function and f_n the correction function for the change in viscosity. This model was implemented in a finite difference laboratory code, second-order accurate in space and time. The time advancement was based on a fractional step method. The grid size 65^3 was found to provide an accurate prediction of the turbulence statistics, in agreement with the literature data [2, 3] and to give a good compromise between the required CPU-time and accuracy.

Results indicate a great dependence of the dynamic and thermal fields on the rotation rate: for the shear-thinning fluid, the apparent viscosity is enhanced in the buffer and log regions with increasing rotation rate N (Fig. 1), reducing the turbulent fluctuations. This reduction leads to a depressed RMS of temperature in these regions (Fig. 2). The LES predictions for $n=0.75$ show a decrease of both the friction factor and Nusselt number when N varies from 0 to 0.5 and an increase with increasing N for $N \geq 1$. Contours of the temperature fluctuations at $N=3$ reveals an increase of the turbulent intensities in the core region, meaning that the high speed fluid near the wall transports heat from the wall towards the core region, inducing an augmentation of the Nusselt number when N increases (Fig.3).

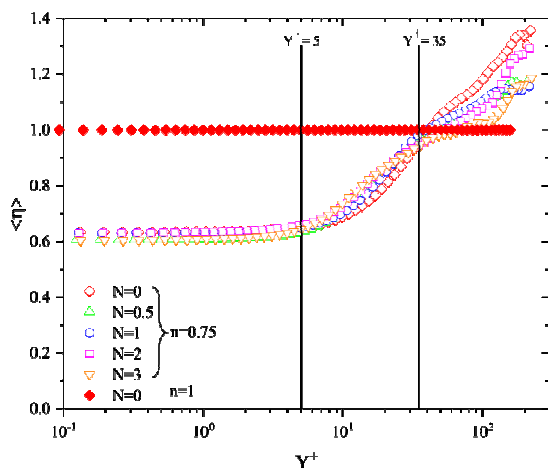


Figure 1: Mean viscosity profiles

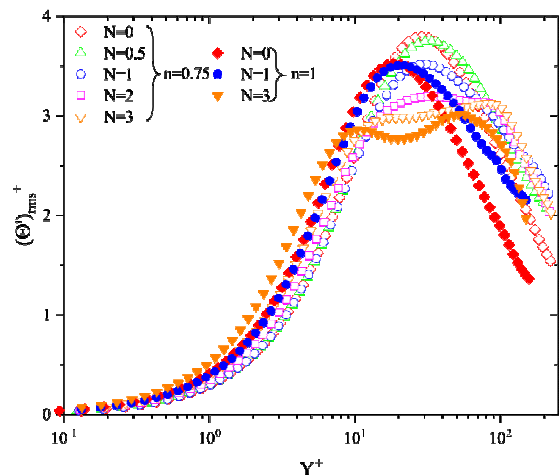


Figure 2: RMS of temperature fluctuations

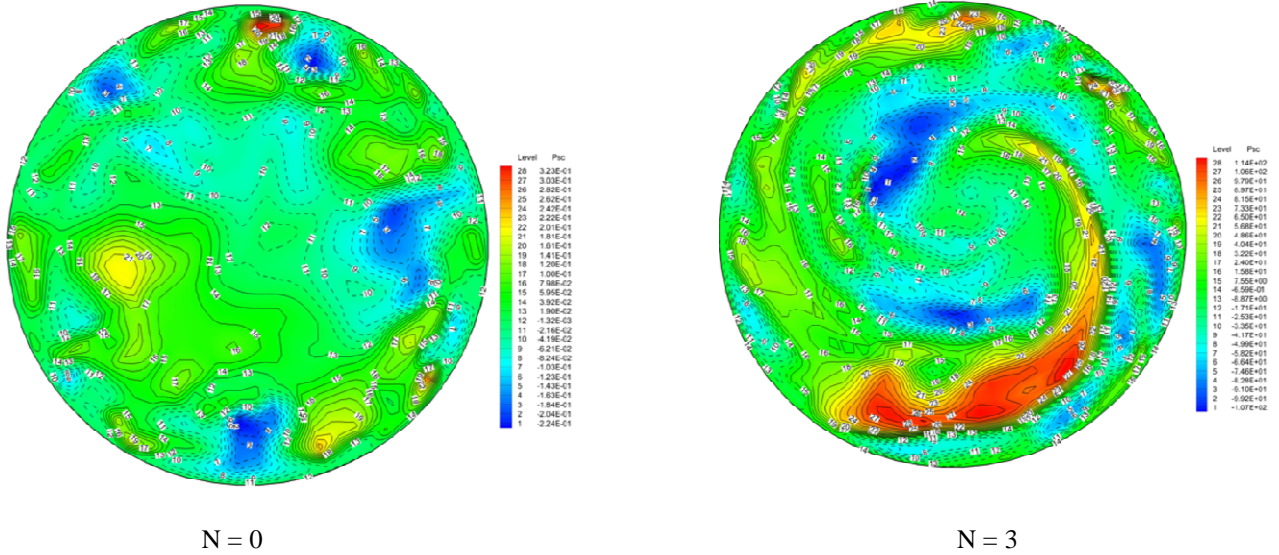


Fig. 3: Contours lines of the temperature fluctuations for $n = 0.75$

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