Analysis of the influence of a sinusoidally varying periodic wall heating on the drag of turbulent pipe flow using direct numerical simulation

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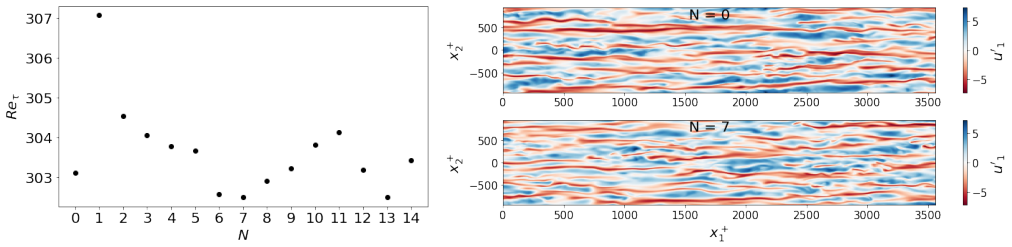
Reliable predictions of turbulent flows with heat transfer are of great importance to many engineering applications. There are several studies of turbulent pipe flow with homogeneous heating have been published, some of them are discussed in the review article by Narasimha and Sreenivasan (1979) who reported that relaminarization in buoyancy aided pipe flows is caused by the damping of turbulent velocity fluctuations which resulted from heating.

To determine the influence of sinusoidally varying temperature boundary conditions in circumferential direction ϕ at the wall of a straight pipe on the turbulent velocity fluctuations, we performed direct numerical simulations at a bulk Reynolds number of $Re_b = 4328$, for a Prandtl number $Pr = 0.71$, a Grashoff number $Gr = 9.5 \cdot 10^5$ and wall temperatures of $\Theta_w = \sin(N \cdot \phi)$, $N = 0, ..., 14$. For an isothermal turbulent pipe flow, Wagner and Friedrich (2012) reported a mean spanwise spacing of velocity streaks in wall coordinates of $\lambda_\phi^+ = 120$ at a wall distance of $y^+ = 15$, which corresponds to the mean width of approximately seven streaks. Figure 1(a) shows a drop in the friction Reynolds number Re_τ for $N = 7$ and 12, which nearly corresponds to streak spacing and half of it. Further it can be seen in Figure 1(b), streaks are longer for the isothermal case. At the conference a detailed analysis by means of instantaneous flow field observations and turbulence statistics will be presented.



(a) (b)

Figure 1: (a): Calculated Friction Reynolds numbers Re_τ for different wall Temperatures $\Theta_w = \sin(N \cdot \phi)$ and the same bulk Reynolds number $Re_b = 4328$, $Pr = 0.71$ and $Gr = 9.5 \cdot 10^5$. (b): Instantaneous velocity fluctuations in u_τ at $y^+ = 15$ for $N = 0$ and $N = 7$.

References

R. Narasimha and K. R. Sreenivasan. *Relaminarization of fluid flows.* Advances in applied mechanics, Vol. 19, 1979.

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