Wall turbulence with rod-like polymers

E. De Angelis[1], E.S C. Ching[2]
1 DIEM, Università di Bologna, 47100 Forlì, Italy
2 Department of Physics and Institute of Theoretical Physics, Chinese University of Hong Kong. Shatin,Hong Kong

It is a relatively a long time since the first simulation of drag reduction by polymers have been reproduced numerically, where velocity field obtained has successfully reproduced the well known drag reducing characteristics of such flows. With respect to the flexible case the simulations for rod-like polymers started only recently due to the higher complexity of the modellization. In particular, the data we will discuss have been obtained by using an appropriate, but very simplified, model for the rod-like polymers. As customary, the total stress tensor is obtained superposing the polymer stress tensor, T^p_{ij}, to the Newtonian contribution. with dynamic viscosity μ, and a part due to Specifically, in this approach each rod is represented by a neutrally buoyant axisymmetric particle, whose configuration is given in terms of the vector n_i. Once introduced the moments $\mathcal{R}_{ij} = \langle n_i n_j \rangle$, $\mathcal{R}_{ijkl} = \langle n_i n_j n_k n_l \rangle$ the field equation for the covariance matrix reads

$$\frac{\partial \mathcal{R}_{ij}}{\partial t} + u_k \frac{\partial \mathcal{R}_{ij}}{\partial x_k} = K_{ir}\mathcal{R}_{rj} + \mathcal{R}_{ir}K_{jr} - 2E_{kl}\mathcal{R}_{ijkl} - 6\gamma_B \left(\mathcal{R}_{ij} - \frac{\delta_{ij}}{3} \right) \quad (1)$$

where K_{ij} and E_{ij} are the velocity gradient and its simmetric part, respectively, and γ_B is the Brownian rotational diffusion of the rods. For the stress tensor instead, again following[1] we have

$$T^p_{ij} = \mu_p \left[E_{kl}\mathcal{R}_{ijkl} + 6\gamma_B \left(\mathcal{R}_{ij} - \frac{\delta_{ij}}{3} \right) \right] \quad (2)$$

μ_p is the rodlike polymers contribution to viscosity depending on the number density, which is proportional to the zero shear viscosity. In the present work we will consider a case where the Brownian diffusion term can be neglected, i.e. $\gamma_B \to 0$. Let's note that in this limit the polymer model depends only on the parameter μ_p. In the simulations the simple closure hypotesis will be used, i.e. $\mathcal{R}_{ijkl} = \mathcal{R}_{ij}\mathcal{R}_{kl}$.

Results obtained by simulations on a channel flow at different Reynolds number and concentrations will be discussed.

References

[1] Doi M., Edwards S.F. *The Theory of Polymer Dynamics*, (Oxford, New York) 1988.