ニュートン流体および非ニュートン流体が共存する抵抗低減チャンネル流れの DNS
DNS of Drag-reducing Turbulent Channel Flow with Newtonian and Non-Newtonian Fluid Coexistence

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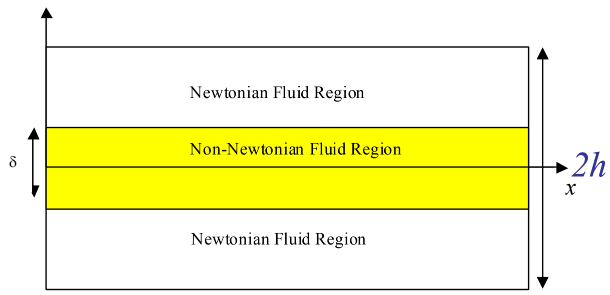
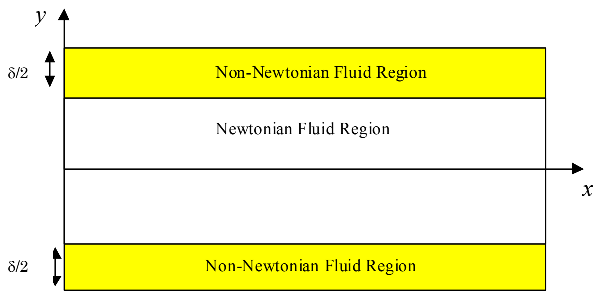
It is generally believed that drag-reduction by addition of a small amount of surfactant additives into liquid is due to the elasticity of the shear-induced- structure (SIS), i.e. the network structures of rod-like micelles. In the previous numerical studies, network structures were assumed to exist in all the flow region and the fluid was assumed to be Non-Newtonian fluid in the whole computational domain. However in practical problems net-work structures are not uniformed distributed, they are sensitive to shear rate and temperature. In this study we assumed that the network structures can be formed either in the region next to the walls or in the center region of the channel to make the solution elastic Non-Newtonian fluid, and at the other regions surfactant additives exist in form of monomers which do not affect the Newtonian properties of the fluid. With this assumption we studied the drag-reducing phenomenon with Newtonian and Non-Newtonian fluid coexistence. Two types of fluid motions, Flow A and Flow B shown in Fig.1 are studied, where Newtonian and non-Newtonian fluid separately flow at different layers with the interface of different fluids parallel to the walls. Net-work microstructures exist at the bulk flow region in Flow A and merely at the near wall region in Flow B. By moving the interface position, how the net-work structures reduce frictional drag at different flow layers can be studied. For Flow A, we did four calculations with the thickness of the non-Newtonian fluid $2\times 0h$, $2\times 0.4h$, $2\times 0.6h$ and $2\times 0.9h$ respectively. For flow B, we carried out three computations with the thickness of the non-Newtonian fluid $2\times 0.2h$, $2\times 0.4h$ and $2\times h$ respectively.



(a) Flow A



(b) Flow B

Figure 1. Flow with Newtonian fluid and Non-Newtonian fluid coexistence

Calculations were performed using a Giesekus model with parameters $\mathrm{Re}_\tau = 125$, $\mathrm{We}_\tau = 25$ and $\alpha = 0.001$ in the Non-Newtonian fluid region and $\mathrm{Re}_\tau = 125$ in Newtonian fluid region. Table 1 lists the obtained mean bulk Reynolds numbers and drag-reduction rate for different cases. From Table 1, we can see that net-work structures are most effective in reducing fractional drag in buffer layer and are essentially not effective in bulk flow region. Table 2 lists the fractional contribution of three components to friction factor. It is seen that drag-reduction by surfactant additives is not only closely associated with the reduction of Reynolds shear stress but also related to the induced viscoelastic shear stress. The well-known onset and post drag-reduction phenomena are also explained.

Table 1 Bulk Reynolds numbers, friction factor and drag-reduction rate

	δ	Re_b	C_f	C_f^D	DR %
Flow A(1)	$2\times 0h$	3653	0.00936	0.00939	0%
Flow A(2)	$2\times 0.4h$	3651	0.00937	0.00939	0%
Flow A(3)	$2\times 0.6h$	3726	0.00900	0.00934	3.63%
Flow A(4)	$2\times 0.9h$	4071	0.00754	0.00914	17.5%
Flow B (1)	$2\times 0.2h$	3848	0.00844	0.00927	8.94%
Flow B (2)	$2\times 0.4h$	4175	0.00717	0.00908	21.0%
Flow B(3)	$2\times h$	4263	0.00688	0.00903	23.9%

Table 2 Fractional contributions of viscous shear stress, Reynolds shear stress and viscoelastic shear stress to friction factor

	V^c	T^c	E^c
Flow A(1)	34.5%	65.5%	
Flow A(2)	34.7%	64.8%	0.453%
Flow A(3)	35.2%	63.2%	1.56%
Flow A(4)	37.7%	57.2%	5.14%
Flow B (1)	36.6%	57.8%	5.62%
Flow B (2)	38.4%	57.2%	4.39%
Flow B(3)	39.9%	54.1%	5.97%