Basic analysis of viscoelastic fluid using MPS method

JST/CREST; Dept. of Applied Physics, Univ. of Tokyo Eisuke Nishitani [1]
Dept. of Applied Physics, Univ. of Tokyo Masao Doi

粘弾性流体は、高分子液体、ゲルなどとして、工業的に非常に重要な用途で使われている。粘弾性流体に関する実験は多くなされているが、粘弾性流体シミュレーションはFDM,FEM,LBMなどのEulerian手法に限られている。本研究で使用したMPS法はLagrange的な手法であり、動的なシミュレーションが可能である。我々はMPS法におけるテンソルモデルを開発し、粘弾性シミュレーションの基礎的な検証を行った。

1 Introduction

Studying viscoelastic flow is very important in a lot of engineering systems (fabrication, gelation of polymer fluid and so on.). Dynamics of viscoelastic fluid is well studied by experimentally. On the other hand, simulation of viscoelastic fluid is limited to statics(using FDM, FEM and LBM etc···). We performed dynamical simulation of viscoelastic fluid using MPS method. Our simulation is very fundamental, but we think this will be very useful for understanding dynamical property of viscoelastic fluid.

2 MPS method

2.1 Basic algorithm

MPS (Moving Particle Semi-implicit) method is one of the particle methods which can solve Navier-Stokes equation. This method is originated by Professor Seiichi Koshizuka[1]. MPS calculation algorithm is separated to two steps.At the first step, the convection term of NS equation (except the pressure term) is calculated and fluid particles are moved by the convection velocity (this step is calculated explicitly). At the next, the pressure term is calculated using incompressibility condition, and the convection velocity is corrected with the pressure term (pressure term is calculated implicitly).

2.2 Tensor model for MPS

If we simulate the viscoelastic fluid using derivative type constitutive equation, the tensor calculation is needed. At first, we developed tensor model for MPS method. This model is based on the MPS gradient model. Details of this model is explained in our poster presentation.

[1]E-mail: nishitani@rheo.t.u-tokyo.ac.jp

3 Results

In the following simulation, we used Doi-Edwards type constitutive equation including solvent viscosity term with a single relaxation time, that is,

$$\frac{D\mathbf{E}}{Dt} = -\frac{\mathbf{E}}{\tau} + 2G(1-\beta)\mathbf{D} - \frac{2}{3G}\mathbf{D} : \mathbf{E}(\mathbf{E} + G\mathbf{I}) \tag{1}$$

$$\sigma = 2G\beta\tau\mathbf{D} + \mathbf{E} \tag{2}$$

where σ and $\mathbf{E}$ are the total stress and polymer stress, β is the degree of solvent contribution, $\mathbf{D}$ is velocity gradient tensor, and G and τ are the elastic shear modulus of polymers and the stress relaxation time.

We first simulated viscoelastic fluid through the straight capillary under pressure gradient. In Newtonian fluid case, the stable velocity distribution becomes Poiseuille flow type. On the other hand, in non-Newtonian fluid case, the distribution becomes plug flow type due to the shear-thinning effect near the wall.(Figure1.) The next, we simulated viscoelastic fluid in contraction flow. Figure2 shows the snapshot of this simulation.

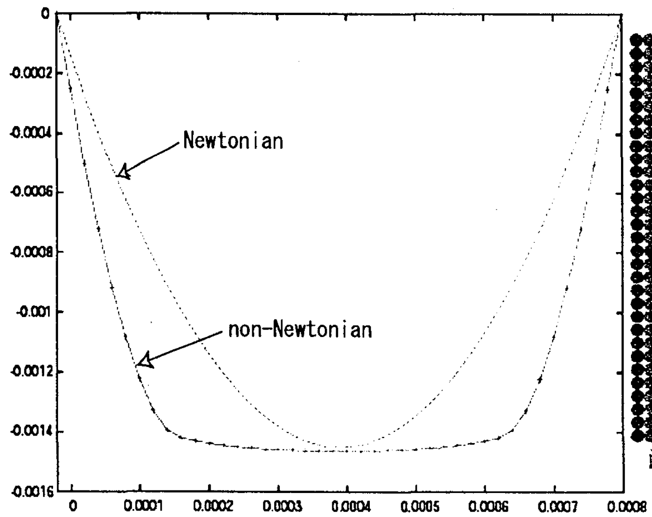

Figure 1: plug flow

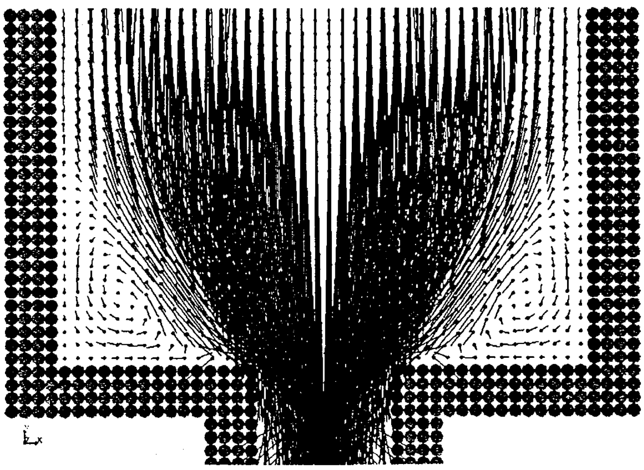

Figure 2: contraction flow

Acknowledgement

This work is supported by Japan Science and Technology/CREST, Japan.

References

[1] Koshizuka, S and Oka, Y, Nucl.Sci,Eng., **123**, (1996), 421-434.