Flow of Newtonian and non-Newtonian Fluids

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1 Introduction

In most polymer processing applications and in lubrication systems the changes of temperature are significant and cannot be ignored.

The well – known equations for the fluid-flow and the heat – transfer are as follows:

Continuity $\nabla . V = 0$

Motion $\rho \frac{DV}{Dt} = \rho g - \nabla p + \nabla \eta \dot{\gamma}$

Energy $\rho C_p \frac{DT}{Dt} = \nabla . k \nabla T + \frac{1}{2} \eta (\dot{\gamma} : \dot{\gamma})$

2 Isothermal case

2.1 The non-Newtonian fluid chosen (CEF Model)

The constitutive equation of the CEF fluid is

$$\tau = -pI + \eta A_1 + (v_1 + v_2) A_1^2 - \frac{1}{2} v_1 A_2$$

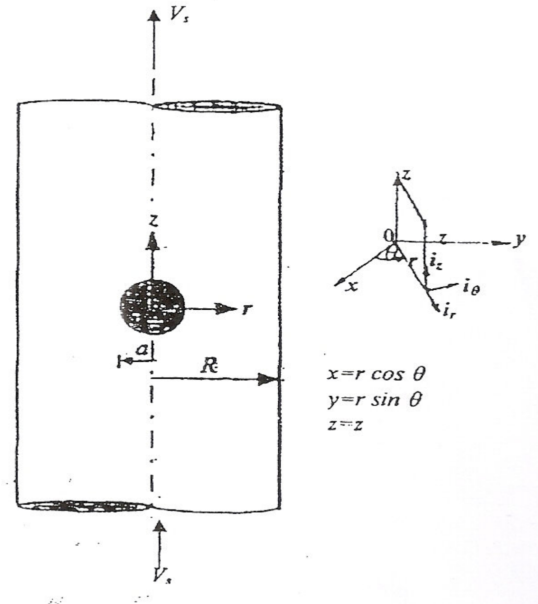

Fig. 1 Schematic diagram of a sphere falling through a fluid in a cylinder.

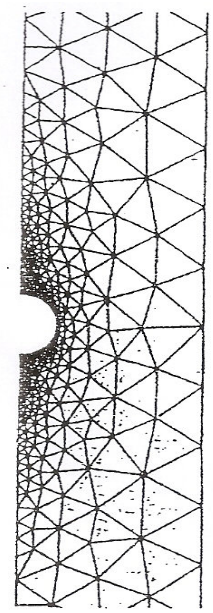

Fig. 2 Mesh pattern around sphere, *a/R* = 0.2

3 Material functions in steady-state shear flows

Viscosity: $\tau_{yx} = \eta(\dot{\gamma})\dot{\gamma}_{yx}$

Carreau formula for the viscosity coefficient:

$$\eta = \eta_0\left(1 + 32.32\mathrm{tr}\ A_1^2\right)^{-0.318}$$

4 Explicit expressions of the dimensionless governing equations

Continuity equation

$$\frac{\partial v_r}{\partial r} + \frac{\partial v_z}{\partial z} + \frac{v_r}{r} = 0$$

Projection of the motion equation on the r and z axes.

5 Nonisothermal case

The energy equation

$$\frac{\partial^2 T}{\partial r^2} + \frac{1}{r}\frac{\partial T}{\partial r} = \frac{v_z(r)}{\chi}\frac{\partial T}{\partial z}$$

6 Temperature effects

According to "Arrhenius dependence

$$a_T = \exp\left[\frac{E}{R}\left(\frac{1}{T} - \frac{1}{T_0}\right)\right]$$

7 Conclusions

We were compelled to resort to the optimisation techniques to resolve the equation system. Fig.3 displays the great distortion of the flow field that is possible due to thermal effects (Morris 1982).

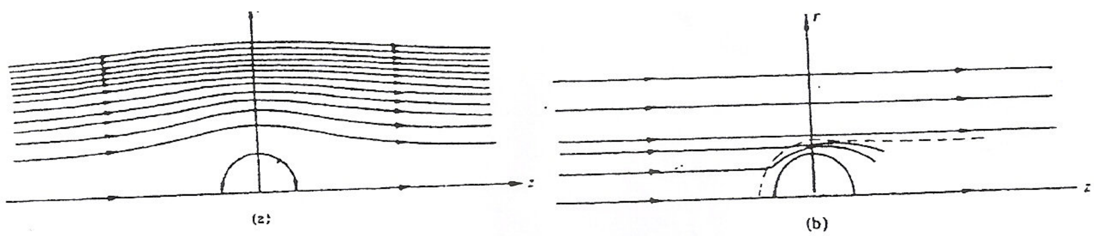

Fig. 3 Effect on streamlines of viscosity – temperature variation in Newtonian, creeping flow.
(a) Isothermal solution. (b) Hot sphere, heat-sensitive viscosity.

References

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