TIME PERIODIC ELECTROOSMOTIC FLOW OF POWER-LAW FLUID IN A CYLINDRICAL MICROCAPILLARY

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Summary: Using the finite difference method, the numerical velocity profile for different parameters is obtained. It is found that the flow behavior index, frequency-dependent oscillation and the value of ratio play an important role and are capable of changing the EOF pattern significantly. In addition, the method of getting higher average velocity or volumetric flow rate is presented by changing the magnitude of parameters mentioned above.

MANUSCRIPT

Electrical potential distribution

According to the electrostatic theory, the electric potential can be expressed as Poisson-Boltzmann equation

$$\frac{1}{r}\frac{d}{dr}\left(r\frac{d\psi}{dr}\right)=k^2\psi\,. \tag{1}$$

$$r=0:\frac{d\psi}{dr}=0,r=R:\psi=\xi\,. \tag{2}$$

The analytical solution which is applicable to both low electric potential and high one is given at the work of Kang Y et al. [1].

Equation of motion

The motion of fluid is governed by the Cauchy momentum equation with the conditions given in this paper which is expressed as

$$\rho\left(\frac{\partial V}{\partial t}+V\nabla V\right)=-\nabla p+\nabla\cdot\tau+E\rho_e\,. \tag{3}$$

In power-law fluids, the shear stress distribution is a non-linear function of velocity gradient. The liquid in the microchannel is assumed to be an incompressible and the flow is only along the *z* direction. Thus there is no pressure gradient along the microchannel. For a single direction EOF in microchannel, the Cauchy momentum equation and given conditions are following as

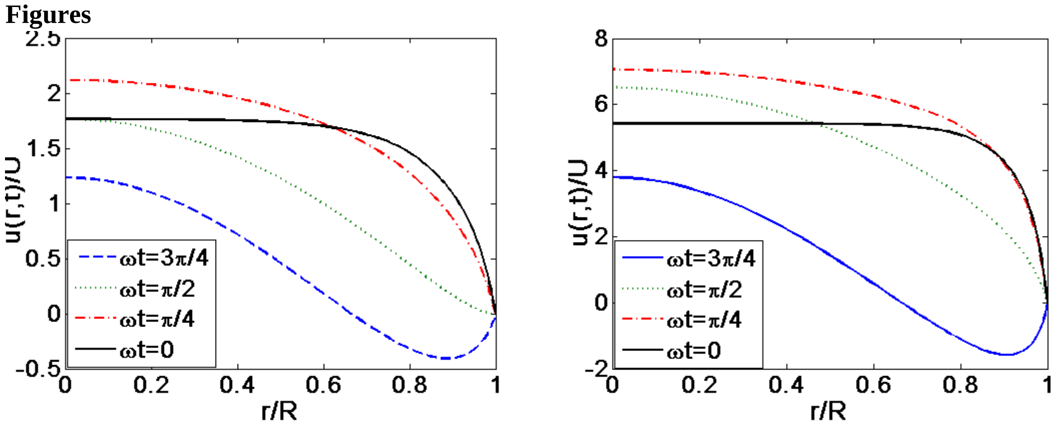
$$\frac{\partial u}{\partial t}=(-1)^{n-1}\nu\left[\frac{1}{r}\left(\frac{\partial u}{\partial r}\right)^n+n\left(\frac{\partial u}{\partial r}\right)^{n-1}\frac{\partial^2 u}{\partial r^2}\right]+\frac{1}{\rho}E_0\exp(i\omega t)\rho_e \tag{4}$$

$$t=0:u(r,t)=0, \tag{5}$$

$$r=0:\frac{\partial u}{\partial r}=0,r=R:u=0\,. \tag{6}$$

We replace Eq. (4) by a discretized version of it, with the finite difference method used at my last work Deng S.Y [2].

Figures



(a) (b)

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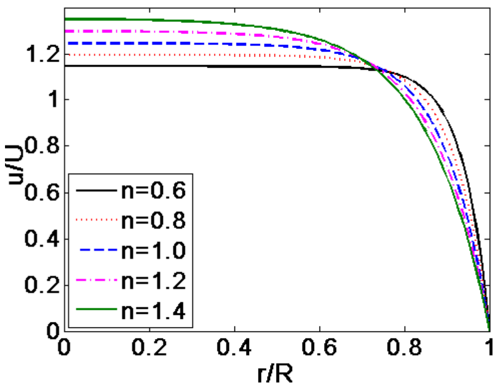
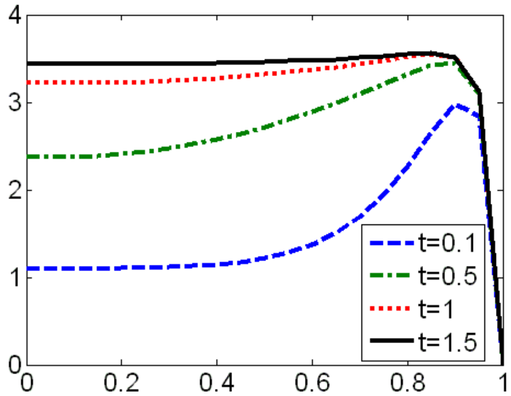


(c)



(d)

Figure. (a) and (b) are steadily oscillating velocity profiles for different times under AC field; figure (c) and (d) are the variation of velocity profiles for different values of power-law fluid and times (n=0.8).

CONCLUSIONS

A numerical solution of the time periodic EOF flow of power-law fluid in a cylindrical microcapillary is presented in this work. The solution involves analytically solving the complete Poisson–Boltzmann equation, together with the Cauchy momentum equation. With the finite difference method, the velocity profiles and the volumetric flow rates for the time periodic one-dimensional EOF flow are obtained numerically. The computational results show that the velocity profiles and the volumetric flow rates of the power-law fluids depend greatly on the value of K, oscillating frequency and normalized relaxation times ωt. The time periodic evolution of the velocity profiles provides a detail insight of the flow characteristic of this flow configuration. Furthermore, as time elapse, the liquid inside the EDL region exist hydrodynamic shear stress on its adjacent liquid, and the liquid outside the EDL region is set in motion layer by layer, finally extending to the entire channel and the velocity reaches its maximum value and tends to steady state. In addition, the method of getting higher average velocity or volumetric flow rate is presented by changing the magnitude of parameters mentioned above. In addition, the shapes of velocity profiles are plug-like (n<1) and bowel-like (n>1) respectively under the transient electric field. Regardless of the power-law index n, the velocity profiles become more plug-like shapes as the value of K transits from 10 to 50 when keeping other parameters unchanged under the transient electric field.

References

[1] Kang Y.J, Yang C, Huang X.Y: Dynamic aspects of electroosmotic flow in a cylindrical microcapillary. *Int. J. Eng. Sci*. 40: 2203–2221, 2002.

[2] Deng S.Y, Jian Y.J, Bi Y.H, Chang L, Wang H.J, Liu Q.S, Unsteady electroosmotic flow of power-law fluid in a rectangular microchannel, *Mech. Res. Commun.* 39: 9-14, 2012.