Electro-magnetohydrodynamics of time periodic electroosmotic flow through microchannels with oscillating boundaries

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INTRODUCTION & OBJECTIVE

For lab-on-chip diveces and micro total analysis systems, study of electroosmotically driven microflows is very much essential. As mixing in microchanels is a very crucial problem for being a low Reynlods number flow, researchers have developed several therotical models as well as experimental models for having better mixing and pumping. Time periodic electric field[1] has been used to initiate mixing by generating vorticity in the flow field but this only works for better mixing. On the other hand some external field such as magnetic field[2,3] has been introduced to enhance the flow rate, which is not appropriate for better mixing. Our main objective through this model is to provide a better mathematical model for both mixing and pumping by incorporating magnetic field on a time periodic electroosmotic flow.

In fig 1. a schematic diagram of the problem has been shown. In this work, we semi-analytically investigate the electro-magnetohydrodynamics of time periodic electroosmotic flow of a Newtonian fluid through microchannels with oscillating boundaries. In this model a constant magnetic field (B_y) and a constant transverse electric field (E_z) have been used along with the time periodic electric field (E_x) to have better control over mixing in the microchannel or to augment the pumping. Poisson-Boltzmann equation has been solved with Debye–Hückel linearization for thin EDL to have the electric potential distribution and with the help of it, we solve the flow field equations for low Hartmann number(Ha) by regular perturbation method. Laplace transformation has been used to solve the flow field for each order. We have obtained the solution of flow field upto $O(Ha)$ and found an excellent match with the complete numerical solution for our range of Ha. The dependence of flow field on dimensionless parameters such as Ha, M and k have been discussed thoroughly, where Ha and M are the strength of applied magnetic field and transverse electric field respectively and k is function of Debye length, kinematic viscosity and frequency of the time periodic electric field.

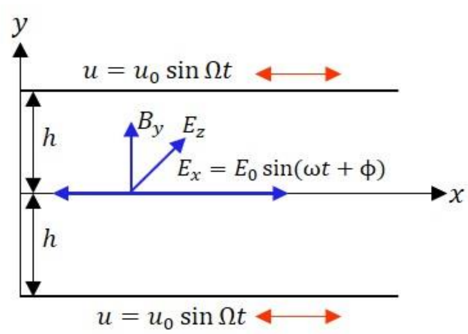
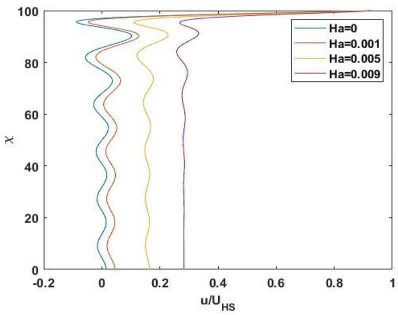
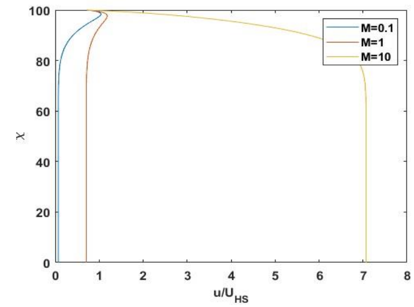


Fig 1. Schematic of the problem

1. RESULTS & HIGHLIGHTS OF IMPOINTANT POINTS

(a)


(b)


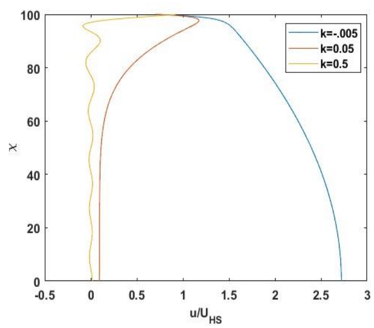
(c)


Fig 2. (a) Variation of velocity with increasing $Ha(k = 0.5, M = 10)$, (b) Variation of velocity with increasing $M(k = 0.1, Ha = 0.009)$, (c) Variation of velocity with increasing $k(M = 0.1, Ha = 0.003)$

In fig 2(a) we see that the dimensionless velocity profiles are more wave like for lower Ha but with increasing Ha it becomes less wavy. This essentintially indicates a better mixing for lower Ha and by increasing Ha we can augment the flow velocity as well as pumping at the expense of mixing. As we see in fig 2(b) the variation of dimensionless velocity with increasing M for fixed Ha and k. We find that for increasing M the velocity profile shows inflection points near the wall for low values of M but at higher values the force due to applied transverse electric field becomes able to overcome the retarding forces cause by magnetic force and viscous stress. Thus we can have a plug like flow by interplaying the values among the dimensionless parametres. In fig 2(c) we find that the dimensionless velocity profile is more like parabolic(except near the wall) for lower values of k but with increasing k the velocity profile becomes more wavy as the diffusion length scale becomes much smaller than the half height of the channel. In a nutshell we can say that lower values of k will help to enhance the mixing on the other hand by increasing the values of Ha and M we can augment the flow rate. Thus by adjusting these paramenters according to our need we can increase the pumping and mixing as well in microchannels.

REFERENCES

1. Dutta, Prashanta, and Ali Beskok. "Analytical solution of time periodic electroosmotic flows: analogies to Stokes' second problem." *Analytical Chemistry* 73.21 (2001): 5097-5102.
2. Chakraborty, Suman, and Dibyadeep Paul. "Microchannel flow control through a combined electromagnetohydrodynamic transport." *Journal of Physics D: Applied Physics* 39.24 (2006): 5364.
3. Wang, Xiaoping, et al. "Effect of magnetic field on electroosmotic flow of viscoelastic fluids in a microchannel." *Electrophoresis* 42.21-22 (2021): 2347-2355.