# EFFECT OF ELECTRICAL DOUBLE LAYER DURING ELECTROOSMOTIC FLOW OF A SECOND GRADE VISCOELASTIC FLUID IN A POROUS MEDIUM

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***Abstract— The oscillatory flow of an incompressible, second grade electrically conducting viscoelastic fluid in a micro channel permeated by a porous medium under the action of a time periodic electric field, is presented. Blood is considered as a second grade non-Newtonian fluid. Analyzing the expressions and computing that using software, the effect of Debye-Hückel parameter is studied. It is found that near the vicinity of the wall a significant change in velocity occurs with the change in Debye-Hückel parameter due to the formation of electrical double layer.***

***Keywords—Electrical Double Layer; Debye-Hückel parameter; Viscoelastic fluid***

## I. INTRODUCTION

Blood exhibits non-Newtonian properties in the region of low shear rate and this low shear rate is dominant if the channel size shrinks. So, Blood flow in microchannel cannot be accurately described by any Newtonian viscous model. The existence of yield stress also does not support the behavior of blood as Newtonian one. Several researchers [1,2] have considered blood as a non-Newtonian fluid. Chandra [3] has drawn attention taking blood a second grade viscoelastic fluid under the aegis of electric field. The flow which is driven by electro kinetic forces, has an advantage of having minute control as per the specific requirement as here the need of moving parts is eliminated. A couple of studies that take into account the electro-osmotically controlled flow of viscoelastic fluid are found in n scientific literatures (cf. [4]-[5]).
In this paper, the study is made especially in a case when blood is flowing through a porous medium. Moreover during the time of contact of an aqueous solution with a solid interface, it is found to be formed a layer of charges of opposite polarity to that polarity of charges at solid-liquid interface. This formation of double layer, in general called as Electrical double layer, affects the flow near the vicinity of the wall. The Debye-Hückel parameter has a relation with the Debye layer and so any kind of effect near the boundary can be well understood by the study of Debye-Hückel parameter. With a view of the above we have formulated a mathematical model to study the effect of Debye-Hückel parameter for a second grade viscoelastic fluid taking into consideration the dynamics of flow is under the influence of an electric field of time periodic nature.

## II MATHEMATICAL FORMULATION AND ANALYSIS

An incompressible, viscous and ionized second grade viscoelastic fluid is considered to flow in the direction of x-axis through a porous medium and driven by an alternating electric field. The microchannel is bounded by two plates at the position, $y = \pm h$ [Fig. 1] that are in a state of oscillation with a velocity $u_s e^{i\omega t}$ . Considering u = u (y,t) , the fluid velocity at time t, the continuity equation reduces to $\frac{\partial u}{\partial x} = 0$.
The flow is considered to be symmetric about the axis y = 0, i.e. the midpoint of the channel and so our study is limited to the region $0 \le y \le h$ only.
Assuming Boussinesq boundary-layer approximations the set of equations that can actually fit and solve our present problem are given by

$$\frac{\partial u}{\partial t} = -\frac{1}{\rho}\frac{\partial p}{\partial x} + \nu\frac{\partial^2 u}{\partial y^2} + K\frac{\partial^3 y}{\partial t\,\partial y^2} - \frac{\nu}{k_p}u + \frac{\rho_e}{\rho}\left(E_x e^{i\omega_e t}\right) \quad \ldots\ldots(1)$$

$$0 = -\frac{1}{\rho}\frac{\partial p}{\partial y} \quad \ldots\ldots(2)$$

$$\frac{\partial^2 \psi}{\partial y^2} = -\frac{\rho_e}{\varepsilon}, \quad \ldots\ldots(3)$$

$\rho_e$ is the net distribution of electric charge density in equilibrium near a charged surface, $w_e$ is the angular velocity of the AC electric field, $E_x$ , the amplitude of the field and $t$ , the time. The symbols $\nu$, $K$, $\rho$, p and $k_p$ denote respectively the kinematic viscosity, viscoelastic co-efficient, density, pressure and porous medium permeability coefficient.
With the use non-dimensional variables and considering $U_{HS}$ as Helmholtz-Smoluchowski electro-osmotic velocity, which is defined by $U_{HS} = -ME_x = -\frac{\zeta\varepsilon E_x}{\mu}$, (in which M stands for the mobility, $\zeta$ for the zeta potential, ε for the dielectric constant of the medium and $u = \rho\nu$, is the dynamic viscosity), the computation is made using the software MATHEMATICA.

With the application of boundary conditions, $\psi^*(0) = 0$ , $\psi^*(\pm 1) = 1$ and $\left(\frac{\partial \psi^*}{\partial y^*}\right)_{y^*=0} = 0$, We obtain from Equation (3)

$$\psi^*(y^*) = -\frac{\cosh(my^*)}{\cosh(m)} \quad \ldots\ldots(4),$$

Where m is called the Debye-Hückel parameter (in non-dimensional form) and is given by the ratio of the height h of the channel and the thickness of the Debye layer λ. Taking the velocity as $u = u_s\, e^{iw_1 t}$ and applying boundary condition $\frac{\partial u}{\partial y} = 0\ at\ y = 0$ and

$u = 0\ at\ y = \pm 1$ , where $u_S$ represents the steady part of the velocity, the solution is obtained and the variation in flow velocity is presented graphically in the section that follows.

## III RESULTS

With the use of software MATHEMATICA, computational work is made. The parameters are chosen in commensurate with that of blood, so that it can be applicable to blood flow in a vessel. The effect of Debye-Hückel parameter m on velocity distribution of blood flow has been investigated and plotted in the graph as follows.

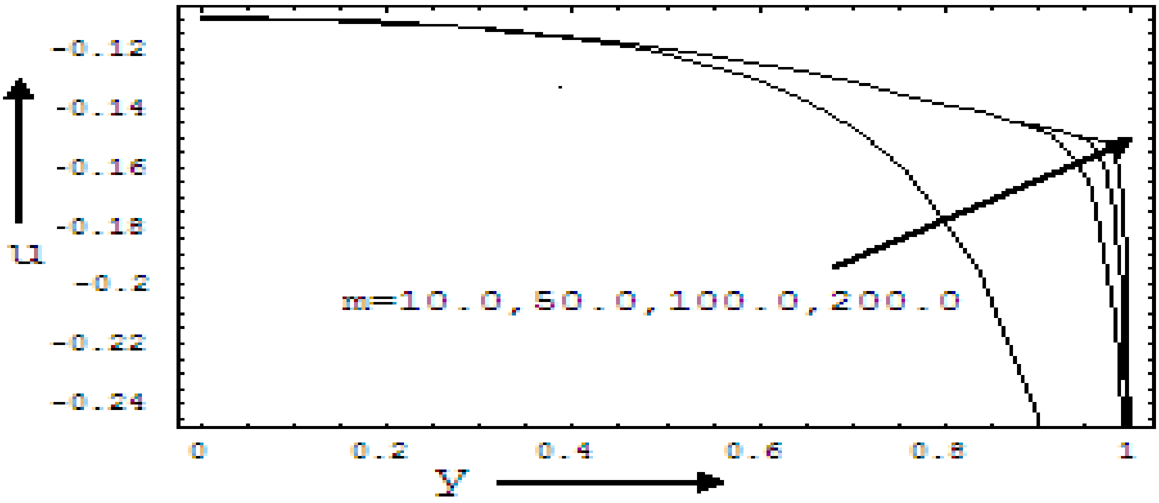


Figure 1 velocity profile with change in Debye-Hückel parameter m, where R=0.1, t=10, D=0.1, B=30, K=0.005, $w_e$ = 500, $w_1$ = 200.

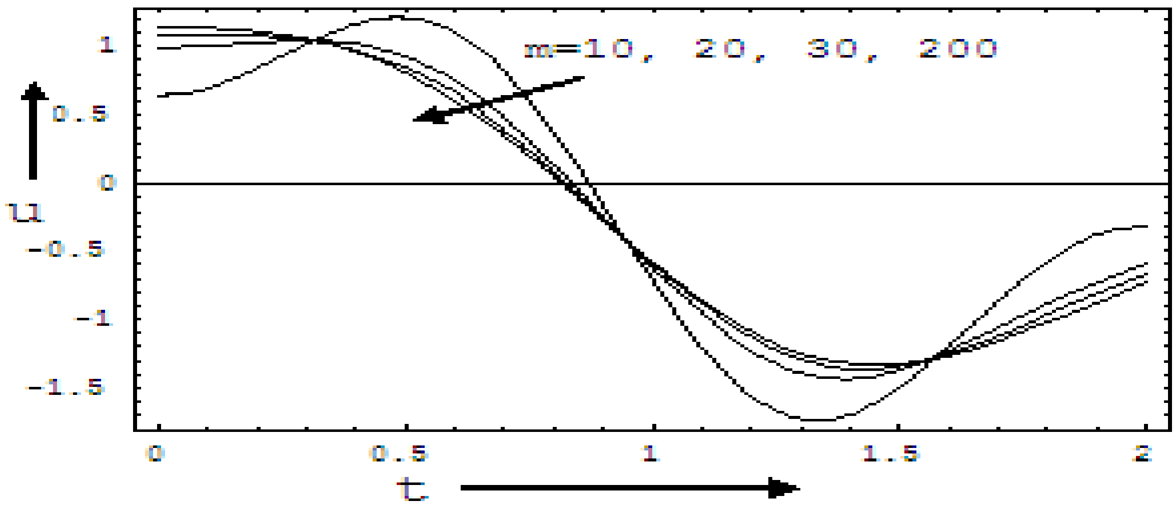


Figure 2 Change in flow velocity with Debye-Hückel parameter (m), when R=0.1, y=0.9, D=0.1, B=30, K=0.005, $w_e$ = 50, $w_1$ = 20.

Figures 1 and 2 illustrate the distribution of velocity for a viscoelastic fluid at different values of non-dimensional Debye-Hückel parameter m. It is observed that the magnitude of blood velocity increases as the value of the parameter m increases at the time specially when y lies between 08 and 0.9. So, it can be inferred that the change in velocity is large after the midpoint of half the channel height. The increase in velocity can be explained in a way that with the increase in Debye-Hückel parameter m, Debye layer thickness reduces, causing thereby increase in velocity. Moreover for the same reason, with the lowering of thickness a sharp profile is obtained near the vicinity of the wall. Figure 2 shows that with the rise in Debye-Hückel parameter m, the amplitude of the velocity decreases and also slight change of phase is observed in the profile. Sharper profile in figure 1 near the wall has been attributed to the formation of electrical double layer (Stern and diffuse layer) at that region of near solid-liquid interface.

## IV CONCLUSION

Due attention is given to the recent progress of bio-sensing technologies meant for sample collection to detect viruses like Dengue Hemorrhagic fever, etc. The problem is prepared with the boundary value approximations in case of a second-grade viscoelastic fluid flowing through porous medium under the action of electro-kinetic forces. The object of this study also lies to the fact of considering blood as a second grade viscoelastic fluid. The parameters are taken keeping in parity with the parameters valid for blood. The effect of Debye-Hückel parameter m is studied and it is also observed that there is a pronounce effect of electrical double layer which is formed near the wall in the solution that is ionized and driven by an electric field.

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