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FLOW OF AN ELECTRICALLY CONDUCTING MICROPOLAR FLUID DOWN A VERTICAL CYLINDER

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ABSTRACT

The problem of flow of an electrically conducting micropolar fluid down a vertical cylinder has been discussed. The axial and micro-rotation velocities functions f and g respectively are expressed in to the power series of the perturbation parameter k (micropolar fluid parameter assumed small). The influences of the parameter k and k_1 (magnetic parameter) on velocity functions f and g have been shown graphically.

Keywords : Flow, Electrically conducting micropolar fluid, Vertical cylinder.

1. INTRODUCTION:

In last few years the theory of micropolar fluid developed by Eringen has attracted the researchers. A lot of work is being done in this field. Deswal, S. & K. K. Kalkal[1], Mahfouz, F.M. [2], Srinivasacharya, D. & M. Upendar [3], Amirat, Y. & K. Hamdache [4] and Singh, K. R, Preeti&Ajit Kumar [5,6] are working in this field actively. Hayat and Sajid[7] have found the solution of thin film flow of fourth grade fluid down a vertical cylinder. Sajid, Ali and Hayat [8] have found on exact solutions for thin film flows of a micropolar fluid. The purpose of the present research work is to study the effects of concentration parameter and magneto-hydrodynamic parameter on the axial velocity function f and the micro-rotation function g.

2. FORMULATION OF THE PROBLEM:

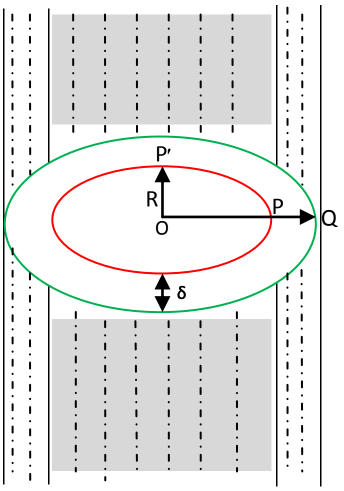
In a three dimensional cylindrical set of co-ordinates the system consists of an infinitely long vertical cylinder of radius R. The incompressible electrically conducting fluid flows on the out side surface of this infinite cylinder. The flow is in the form of a thin, uniform axisymmetric film of thickness δ, in contact with stationary air. The velocity and the microrotation are of the form:

$V=[0, 0, w(r)]$ and $N=N(r)$

The continuity equation

$$\frac{\partial u}{\partial r}+\frac{u}{r}+\frac{\partial w}{\partial z}=0 \tag{1}$$

is being satisfied identically.



PQ=δ
OP=R=OP′
OQ=R+δ
Flow Region:
R≤r≤R+δ

The momentum equation becomes ,

$$\left(\upsilon+\frac{k}{\rho}\right)\left\{\frac{\partial^2 w}{\partial r^2}+\frac{1}{r}\frac{\partial w}{\partial r}\right\}+\frac{k}{\rho}\left(\frac{dN}{dr}+\frac{N}{r}\right)+g-\frac{\sigma B_0^2 w}{\rho} \tag{2}$$

The angular momentum equation becomes ,

$$\left(\upsilon+\frac{k}{2\rho}\right)\left\{\frac{d^2 N}{dr^2}+\frac{1}{r}\frac{dN}{dr}\right\}-\frac{k}{\rho j}\left(2N+\frac{dw}{dr}\right)=0 \tag{3}$$

The boundary condition of the problem are :-

$$w(R)=w'(R+\delta)=N(R+\delta)=0, \quad N(R)=-nw'(R), \tag{4}$$

where R is the radius of the cylinder and δ is the small thickness of the fluid layer.

Introducing the dimensionless variable and function as

$$\xi = \frac{r}{R}, \quad f(\xi) = \frac{R}{\upsilon} w(r), \quad g(\xi) = \frac{R^2}{\upsilon} N(r), \quad m = \frac{g_1 R^3}{\upsilon^2}, \tag{5}$$

Where $\upsilon = \frac{\mu}{\rho}$ is the kinematic viscosity.

Substituting the expressions (5) in equations (2) and (3) , we obtain

$$(1+K)(\xi f'' + f') + K(\xi g' + g) + m\xi - KK_1 \xi f = 0 \tag{6}$$

$$(1+K/2)(\xi^2 g'' + \xi g' - g) - K\xi^2 (2g + f') = 0 \tag{7}$$

where $K = \frac{k}{\mu}$ (micropolar fluid parameter), $K_1 = \sigma B_0^2 R^2 / k$ (magnetic parameter), k is vortex viscosity,μ is dynamic viscosity and j is equal to R^2. Primes indicate differentiation with respect to ξ. The vortex viscosity is assumed to be smaller than the dynamic viscosity.

The transformed boundary conditions are :

f(1)=0, g(1)=-n f'(1)

f(d)=f'(d)= g(d)= 0 (8)

where $d = \left(1 + \frac{\delta}{R}\right)$.

Since the exact solution of the governing equations (6) and (7) subject to the boundary conditions (8) is not possible. We use the perturbation technique taking K (≤0.3 i.e k≤0.3μ)as perturbation parameter assumed small.

3. SOLUTION OF THE PROBLEM :

The axial velocity function f and the microrotation g are expressed into the power series of the perturbation parameter K as:

$$f = \sum_{n=0}^{\infty} K^n f_n \text{ and } g = \sum_{n=0}^{\infty} K^n g_n \tag{9}$$

Substituting the expression (9) in equation (6) and (7) and assuming that the perturbation parameter K is small such that the terms containing K^3 and higher powers of K are neglected and then on comparing the terms independent of K and coefficients of K and $K^2$from both sides, we get the following set of differential equations:

$$\xi f_0''+f_0' = -m\xi \tag{10}$$

$$\xi f_1''+f_1' + \xi f_0''+f_0'-K_1\xi f_0 + (\xi g_0'+g_0) = 0$$

$$\text{or } \xi f_1''+f_1' = m\xi + K_1 f_0 - (\xi g_0'+g_0) = 0 \tag{11}$$

$$\xi f_2''+f_2' + \xi f_1''+f_1'+(\xi g_1'+g_1) - K_1\xi f_1 = 0$$

$$\xi f_2''+f_2' = K_1\xi f_1 - m\xi - K_1 f_0 + (\xi g_0'+g_0) - (\xi g_1'+g_1) \tag{12}$$

$$\xi^2 g_0''+\xi g_0'-g_0 = 0 \tag{13}$$

$$\xi^2 g_1''+\xi g_1'-g_1 + \frac{1}{2}(\xi^2 g_0''+\xi g_0'-g_0) - \xi^2(2g_0 + f_0') = 0$$

$$\text{or } \xi^2 g_1''+\xi g_1'-g_1 = \xi^2(2g_0 + f_0') \tag{14}$$

$$\xi^2 g_2''+\xi g_2'-g_2 + \frac{1}{2}(\xi^2 g_1''+\xi g_1'-g_1) - \xi^2(2g_1 + f_1') = 0$$

$$\text{or } \xi^2 g_2''+\xi g_2'-g_2 = \xi^2(2g_1 + f_1') - \frac{\xi^2}{2}(2g_0 + f_0') \tag{15}$$

The transformed boundary conditions in terms of f_o, f_1, f_2, f_0', f_1', f_2', g_0 and $g_1$are :

$f_0(1)=f_1(1)=f_2(1)=0$,

$f_0'(d)=f_1'(d) =f_2'(d)=0$,

$g_0(d)=g(d)=g_2(d)=0$,

$g_0(1)=-nf_0'(1)$, $g_1(1)=-nf_1'(1)$ and $g_2(1) =-nf_2'(1)$ (16)

The solutions of the differential equations (10) to (15) are determined subject to the boundary conditions (16) which are given as follows:

(17)

(18)

$$f_0(\xi)=\frac{m}{2}(d^2\log\xi+\frac{1}{2}(1-\xi^2)$$

$$f_1(\xi)=\frac{1}{2}(1-n)m(\xi^2/2-d^2\log\xi-\frac{1}{2})+K_{\frac{1}{2}}m[(d^2/2)\{(\xi^2/2)(\log\xi-\frac{1}{2})+1/4-d^2$$

$$\log d\log\xi)\}+(1-d^2)/4(\xi^2/2-d^2\log\xi-\frac{1}{2})-1/8(\xi^4/4-d^4\log\xi-1/4)]$$

$$f_2(\xi)=K_1\left[\frac{1}{2}m(1-n)\left\{\frac{1}{8}\left(\frac{\xi^4-1}{4}-d^4\log\xi\right)-\frac{d^2}{2}\left(\frac{\xi}{2}\log\xi-\frac{\xi^2-1}{4}-d^2\log d\log\xi-\frac{1}{2}\left(\frac{\xi^2-1}{2}-d^2\log\xi\right)\right)\right.\right.$$

$$\left.\left.-\frac{1}{4}\left(\frac{\xi^2-1}{2}-d^2\log\xi\right)\right\}+\frac{K_1m}{2}\left\{\frac{d^2}{4}\left(\frac{1}{4}\left(\frac{\xi^4}{4}\log\xi-\frac{\xi^4-1}{16}-d^4\log d\log\xi\right)-\frac{3}{16}\left(\frac{\xi^2-1}{4}-d^4\log\xi\right)\right)\right.$$

$$+\frac{d^2}{16}\left(\frac{\xi^2-1}{2}-d^2\log\xi\right)-\left(\frac{d^4}{8}\log d\right)\left(\xi^2\log\xi-\frac{\xi^2-1}{2}-2d^2\log d\log\xi-\left(\frac{\xi^2-1}{2}-d^2\log\xi\right)\right)$$

$$+\frac{1-d^2}{32}\left(\left(\frac{\xi^4-1}{4}-d^4\log\xi\right)-4d^2\left(\frac{\xi^2}{2}\log\xi-\frac{\xi^2-1}{4}-d^2\log d\log\xi\right)-2(d^2+1)\left(\frac{\xi^2-1}{2}-d^2\log\xi\right)\right)$$

$$-\frac{1}{192}\left(\frac{\xi^6-1}{6}-d^6\log\xi-12d^4\left(\frac{\xi^2}{2}\log\xi-\frac{\xi^2-1}{4}-d^2\log d\log\xi\right)-6d^4\left(\frac{\xi^2-1}{2}-d^2\log\xi\right)-3\left(\frac{\xi^2-1}{2}-d^2\log\xi\right)\right\}$$

$$\left.-\frac{m}{16}\left\{d^2\left(4\left(\frac{\xi^2}{2}\log\xi-\frac{\xi^2-1}{4}-d^2\log d\log\xi\right)-2\left(\frac{\xi^2-1}{2}-d^2\log\xi\right)\right)+2\left(\frac{\xi^2-1}{2}-d^2\log\xi\right)-\left(\frac{\xi^4-1}{4}-d^4\log\xi\right)\right\}\right]$$

$$+\frac{mn}{2}\left(\frac{\xi^2-1}{2}-d^2\log\xi\right)-mn\left\{\frac{1}{8}\left(\frac{\xi^4-1}{4}-\frac{d^2(\xi^2-1)}{2}\right)-\frac{1}{2}d^2\left(\frac{\xi^2}{2}\log\frac{\xi}{d}+\frac{1}{2}\log d-\frac{\xi^2-1}{4}\right)+d_1\left(d^2\log\xi-\frac{\xi^2-1}{2}\right)\right\}$$

$$-K_1mnd_2\left(d^2\log\xi-\frac{\xi^2-1}{2}\right)-m\left\{\frac{1}{16}\left(d^2\frac{(\xi^2-1)}{2}-\frac{(\xi^4-1)}{4}\right)+\frac{d^4}{4}\left(\frac{\xi^2}{2}\log\frac{\xi}{d}+\frac{1}{2}\log d-\frac{\xi^2-1}{4}\right)+d_3\left(d^2\log\xi-\frac{\xi^2-1}{2}\right)\right\}$$

$$-\frac{m}{2}\left(\frac{\xi^2-1}{2}-d^2\log\xi\right) \tag{19}$$

$$g_0=\frac{mn}{2}(\xi-\frac{d^2}{\xi}) \tag{20}$$

$$g_1(\xi) = mn\left\{\frac{\xi}{8}\left(\xi^2 - d^2\right) - \frac{1}{2}d^2\xi\log\frac{\xi}{d} + d_1\left(\frac{d^2}{\xi} - \xi\right)\right\} + K_1 mnd_2\left(\frac{d^2}{\xi} - \xi\right)$$

$$+ \mathrm{m}\left\{\frac{\xi}{16}\left(\mathrm{d}^2 - \xi^2\right) + \frac{\mathrm{d}^2}{4}\xi\log\frac{\xi}{\mathrm{d}} + \mathrm{d}_3\left(\frac{\mathrm{d}^2}{\xi} - \xi\right)\right\} \tag{21}$$

where,

$$\mathrm{d}_1 = \frac{\mathrm{d}^2}{4\left(1-\mathrm{d}^2\right)} + \frac{1}{8\left(1-\mathrm{d}^2\right)} + \frac{\mathrm{d}^2}{2\left(1-\mathrm{d}^2\right)}\left(\log\mathrm{d} - \frac{1}{2}\right) + \frac{1}{2}(1-\mathrm{n}),$$

$$\mathrm{d}_2 = \frac{1-\mathrm{d}^2}{8} - \frac{1+\mathrm{d}^2}{16} - \frac{\mathrm{d}^4}{4\left(1-\mathrm{d}^2\right)}\log\mathrm{d},$$

$$\mathrm{d}_3 = \frac{\mathrm{d}^2}{16\left(1-\mathrm{d}^2\right)} - \frac{1}{16\left(1-\mathrm{d}^2\right)} - \frac{\mathrm{d}^2}{4\left(1-\mathrm{d}^2\right)}\log\mathrm{d} \tag{22}$$

$$\mathrm{g}_2(\xi) = 2\mathrm{mn}\left\{\frac{1}{8}\left(\frac{\xi^5}{24} - \frac{\mathrm{d}^2\xi^3}{8}\right) - \frac{1}{2}\mathrm{d}^2\left(\frac{\xi^3}{8}\log\frac{\xi}{\mathrm{d}} - \frac{\xi^3}{32} - \frac{\xi^3}{16}\right) + \mathrm{d}_1\left(\mathrm{d}^2\left(\frac{\xi}{2}\log\xi - \frac{\xi}{4}\right) - \frac{\xi^3}{8}\right)\right\}$$

$$+ 2\mathrm{K}_1\mathrm{mnd}_2\left(\mathrm{d}^2\left(\frac{\xi}{2}\log\xi - \frac{\xi}{4}\right) - \frac{\xi^3}{8}\right) + 2\mathrm{m}$$

$$\left\{\frac{1}{16}\left(\frac{\mathrm{d}^2\xi^3}{8} - \frac{\xi^5}{24}\right) + \frac{\mathrm{d}^2}{4}\left(\frac{\xi^3}{8}\log\frac{\xi}{\mathrm{d}} - \frac{\xi^3}{32} - \frac{\xi^3}{16}\right) + \mathrm{d}_3\left(\mathrm{d}^2\left(\frac{\xi}{2}\log\xi - \frac{\xi}{4}\right) - \frac{\xi^3}{8}\right)\right\}$$

$$-\frac{\mathrm{mn}}{2}\left(\frac{\xi^3}{8} - \mathrm{d}^2\left(\frac{\xi}{2}\log\xi - \frac{\xi}{4}\right)\right) + \frac{1}{2}\mathrm{m}(1-\mathrm{n})$$

$$\left(\frac{\xi^3}{8} - d^2\left(\frac{\xi}{2}\log\xi - \frac{\xi}{4}\right) + \frac{1}{2}m(1-n)\left(\frac{\xi^3}{8} - d^2\left(\frac{\xi}{2}\log\xi - \frac{\xi}{4}\right) - \frac{\xi}{4}\right)\right) + \frac{1}{2}K_1 m$$

$$\left[\ \frac{\mathrm{d}^2}{2}\left\{\left(\frac{\xi^3}{8}\log\xi - \frac{\xi^3}{32} - \frac{\xi^3}{16}\right) + \frac{\xi}{8} - \left(\mathrm{d}^2\log\mathrm{d}\right)\left(\frac{\xi}{2}\log\xi - \frac{\xi}{4}\right)\right\}\right.$$

$$\left. + \frac{1-d^2}{4}\left(\frac{\xi^3}{8} - d^2\left(\frac{\xi}{2}\log\xi - \frac{\xi}{4}\right) - \frac{\xi}{4}\right) - \frac{1}{8}\left(\frac{\xi^5}{24} - d^4\left(\frac{\xi}{2}\log\xi - \frac{\xi}{4}\right) - \frac{\xi}{8}\right)\ \right]$$

$$-\frac{m}{4}\left(d^2\left(\frac{\xi}{2}\log\xi-\frac{\xi}{4}\right)+\frac{1}{2}\left(\frac{\xi}{2}-\frac{\xi^3}{4}\right)\right)+\frac{1}{2}C_1\xi+\frac{C_2}{\xi} \tag{23}$$

To find the constants C_1 and C_2 we use the boundary conditions (16) and assume :

$$d_4=-\frac{d^4}{96}+\frac{3d^4}{64}+d_1\left(\frac{d^2}{2}\log d-\frac{3d^2}{8}\right),$$

$$d_5=\frac{d^2}{2}\log d-\frac{3d^2}{8},$$

$$d_6=\frac{d^4}{192}-\frac{3d^4}{128}+d_3\left(\frac{d^2}{2}\log d-\frac{3d^2}{8}\right),$$

$$d_7=\frac{3d^2}{8}-\frac{d^2}{2}\log d,$$

$$d_8=\frac{d^2}{8}\left(\frac{3d^2}{8}\log d-\frac{3d^2}{32}-\frac{d^2}{2}(\log d)^2+\frac{1}{8}\right),$$

$$d_9=\left(\frac{1-d^2}{4}\right)\left(\frac{3d^2}{8}-\frac{d^2}{2}\log d-\frac{1}{4}\right),$$

$$d_{10}=\frac{1}{8}\left(\frac{7d^4}{24}-\frac{d^4}{2}\log d-\frac{1}{8}\right),$$

$$d_{11}=\frac{d^2}{2}\log d-\frac{3d^2}{8}+\frac{1}{4},$$

$$d_{12}=-2mn\,d_4-2K_1mn\,d_2\,d_5-2m\,d_6+\frac{m(2n-1)}{2}d_7$$

$$-\frac{1}{2}K_1m(d_8+d_9-d_{10})+\frac{m}{4}d_{11}, \tag{24}$$

Then on substituting ξ =d in equation (16) and dividing both sides of the obtained equation by d ,we get :

$$\frac{C_1}{2} + \frac{C_2}{d^2} = d_{12} \tag{25}$$

On substituting ξ =1 in equation (6.23) and $f_2'(\xi)$ and taking

$$d_{13} = \frac{1}{8}\left(\frac{1}{24} - \frac{d^2}{8}\right) + \frac{1}{2}d^2\left(\frac{1}{8}\log d + \frac{3}{22}\right) - d_1\left(\frac{d^2}{4} + \frac{1}{8}\right),$$

$$d_{14} = -\left(\frac{d^2}{4} + \frac{1}{8}\right),$$

$$d_{15} = \frac{1}{16}\left(\frac{d^2}{8} - \frac{1}{24}\right) - \frac{d^2}{4}\left(\frac{1}{8}\log d + \frac{3}{32}\right),$$

$$d_{16} = -d_3\left(\frac{d^2}{4} + \frac{1}{8}\right),$$

$$d_{17} = \frac{1}{2}\left(\frac{1}{8} + \frac{d^2}{4}\right),$$

$$d_{18} = \frac{d^2}{2}\left(\frac{d^2}{4}\log d + \frac{1}{32}\right),$$

$$d_{19} = \frac{1-d^2}{4}\left(\frac{d^2}{4} - \frac{1}{8}\right),$$

$$d_{20} = \frac{1}{8}\left(\frac{d^4}{4} - \frac{1}{12}\right),$$

$$d_{21} = \left(\frac{1}{8} - \frac{d^2}{4}\right),$$

$$d_{22} = \frac{1}{8}\left(1-d^4\right) + \frac{d^2}{2}\left(d^2\log d + \frac{1}{2}\left(1-d^2\right)\right) - \frac{1}{4}\left(1-d^2\right),$$

$$d_{23} = -\frac{d^2}{4}\left(\frac{d^4}{4}\log d + \frac{3}{16}\left(1-d^4\right)\right) + \frac{d^2}{16}\left(1-d^2\right) + \frac{d^6}{4}(\log d)^2 - (1-d^2),$$

$$d_{24} = \frac{1-d^2}{32}\left(1 - d^4 + 4d^4\log d - 2\left(1-d^4\right)\right),$$

$$d_{25} = \frac{1}{192}\left(12d^6\log d + 5d^6 - 6d^4 + 3d^2 - 2\right),$$

$$d_{26} = -4d^4\log d + 3d^4 - 4d^2 + 1,$$

$$d_{27} = 1-d^2,$$

$$d_{28} = \frac{1}{8}\left(1-d^2\right) + \frac{1}{2}d^2\log d + d_1(d^2-1),$$

$$d_{29} = d_2(d^2-1),$$

$$d_{30} = \frac{1}{16}\left(d^2-1\right) - \frac{d^4}{4}\log d + d_3(d^2-1),$$

$$d_{31} = 2mnd_{13} + 2K_1 mnd_2 d_{14} + 2m(d_{15}+d_{16}) - mnd_{17}$$

$$+ m(1-n)d_{17} + \frac{K_1 m}{2}\left(d_{18}+d_{19}-d_{20}\right) - \frac{m}{4}d_{21} \tag{26}$$

Hence

$$g_2(1) = d_{31} + \frac{C_1}{2} + C_2 \tag{27}$$

$$-nf_2'(1) = d_{32} = -K_1\left[\frac{1}{2}mn\left(1-n\right)d_{22} + \frac{K_1 mn}{2}\left(d_{23}+d_{24}-d_{25}\right) - \frac{mn}{16}d_{26}\right]$$

$$-\frac{mn^2}{2}d_{27} + mn^2 d_{28} + K_1 mn^2 d_{29} + mnd_{30} - \frac{mn}{2}d_{27} \tag{28}$$

Using the boundary condition $g_2(1)=-nf_2'(1)$ we get

$$d_{31}+\frac{C_1}{2}+C_2=d_{32}$$

$$\frac{C_1}{2}+C_2=d_{32}-d_{31} \qquad (29)$$

On solving (27) and (29), we get

$$C_1=\frac{2}{d^2-1}\left(d^2 d_{12}-d_{32}+d_{31}\right)$$

$$C_2=\frac{d^2}{d^2-1}\left(d_{32}-d_{31}+d_{12}\right)$$

On substituting the values of C_1 and C_2 in equation (23) we get the microrotation function $g_2(\xi)$ in terms of ξ (variable) , d and other parameters.

4. RESULTS AND DISCUSSION :

The variation of the axial velocity function f with ζ at K=0.1, m=1, d=2 and n=0.0 (strong concentration of microelements) for different values of the magnetic parameter K_1=1, 2, 3 is represented through fig. (1). It is evident from this figure that the velocity function f decreases with an increase in the magnetic parameter K_1 throughout the gap length ($1\leq\xi\leq2$).

The value of the function f is zero at the surface of the cylinder and is maximum at the upper surface of the thin film ξ=2. It is also clear from the fig. (3) that the behaviour the velocity function f with K_1 at n=0.5 (indicate vanishing the anti symmetric part of the stress tensor and denotes weak concentration of the microelements) is similar to its behaviour in fig.(1). The only difference is that the magnitude of the velocity function f is smaller in case of n=0.5 than in case of n=0.0.

Fig.(2) exhibits the behaviour of the microrotation function g at K=0.1, m=1, d=2 and n=0.0 for different values of the magnetic parameter K_1=1,2,3. It is clear from the graph that microrotation function remains unchanged approximately with increase in the magnetic parameter K_1 in case of the strong concentration (n=0.0). All the values of g in the region $1\leq\xi\leq2$ are negative and g is minimum at ξ =1 whereas it is maximum (zero) at ξ=2.The microrotation function g start increasing very fast near the surface of the cylinder and after decreasing in the region $1.1<\xi\leq1.4$. It starts increasing again upto to the upper surface of the film. All the branches in this figure are being overlapped.

The behaviour of the microrotation function g with ξ at K=0.1, m=1, d=2 and n=0.5 (weak concentration) for different values of K_1=1,2,3 is shown in fig. (4). It is concluded from this figure that the microrotation function g increases with an increase in K_1 throughout the entire radial region of the thin film. Microrotation function magnitude is maximum at the surface of the cylinder with zero microrotation at the upper surface of the film. The behaviour of the function g with gravitation parameter m shown in fig.(8) is reversed to its behaviour with K_1 shown in fig.(4) for n=0.5.

Figures (5) and (7) represents the variation of the dimensionless velocity function f with ξ at m=1,d=2, K_1=2 in case of n=0.0 and n=0.5 respectively for different values of the parameter k=0.1,0.2,0.3. It is seen in these figures that the function f decreases with an increase in K throughout the entire radial flow region. The value of the axial velocity function is zero (minimum) at the surface of the cylinder whereas attaining maximum value near the upper surface of the film, it starts decreasing (situation does not arise in case of thin film as $1 \leq \xi < 2$ slightly as ξ tends to 2. The influences of the parameters K on the microrotation function g at K_1=2, m=1 d=2,n=0.0 for K=0.1, 0.2, 0.3 in cases of n=0.0 (strong concentration) are shown through figure (6). In this figure the microrotation function g decreases with an increase in K. It is also observed that the variation the microrotation function g with ξ is similar approximately in the two figures (2), (6) through-out the entire radial region $1 \leq \xi \leq 2$.

Fig (8) shows the behaviour of the micro-rotation function g with ξ at n=0.5,m=1,d=2, K_1=2 for different values of K =0.1,0.2,0.3. It is clear from this figure that the micro-rotation is minimum near the surface of the cylinder whereas maximum on the surface of the film .The micro-rotation function g increases with an increase in fluid parameter K throughout the entire radial region.

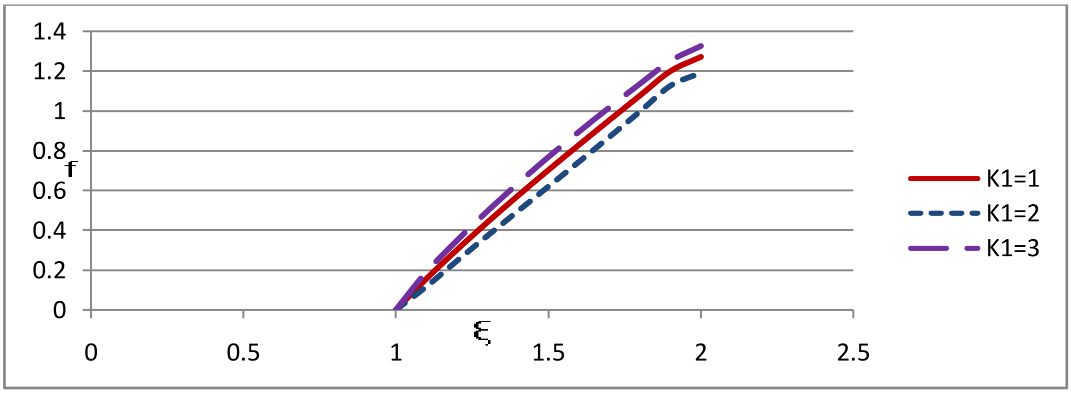


Fig.(1): Influence of parameter K_1 on the axial velocity function f for n=0.0

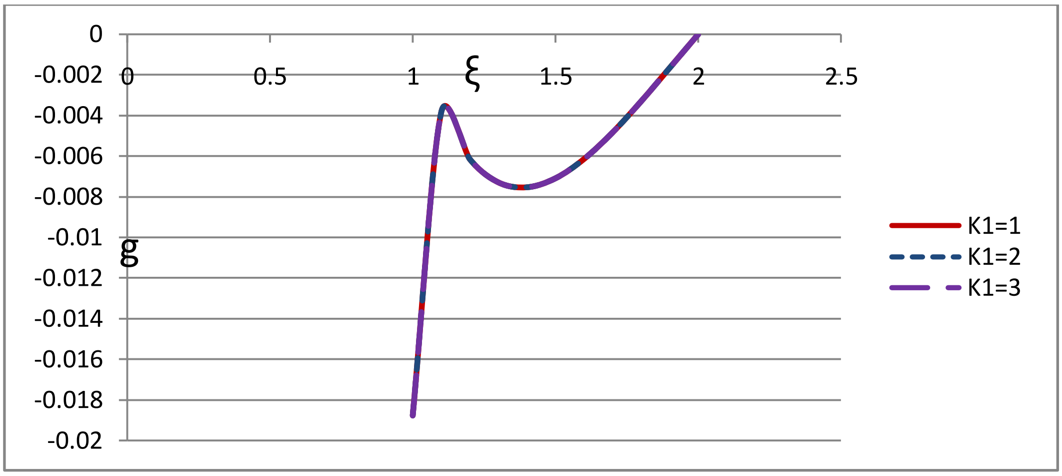


Fig.(2): Influence of parameter K_1 on the micro-rotation function g for n=0.0

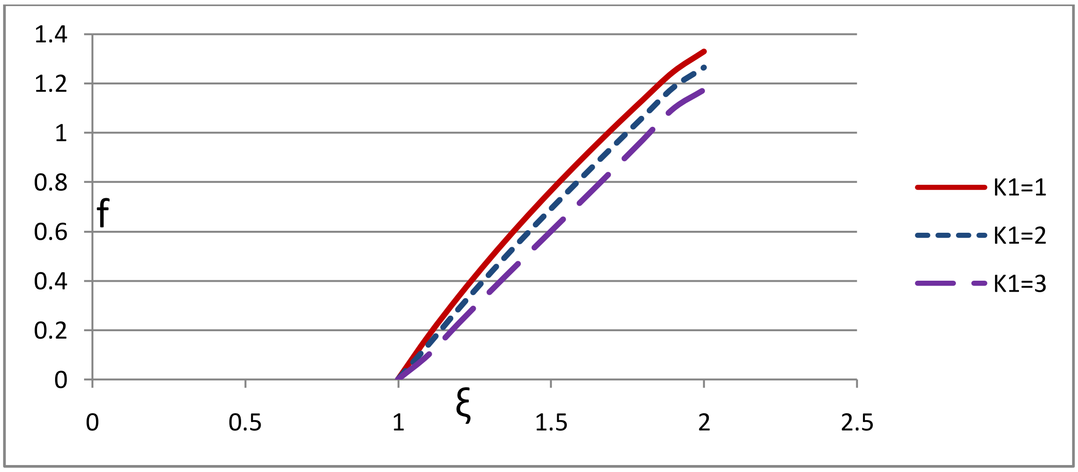


Fig.(3): Influence of parameter K_1 on the axial velocity function f for n=0.5

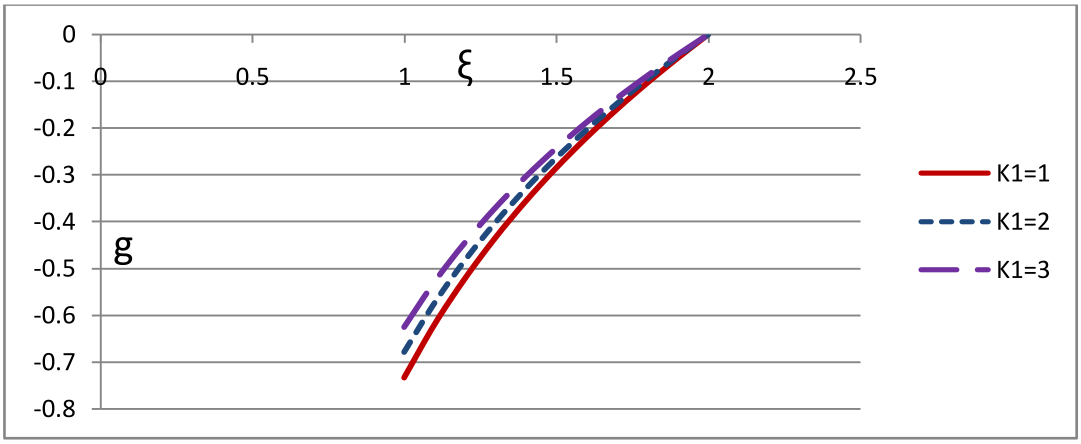


Fig.(4): Influence of parameter K_1 on the micro-rotation function g for n=0.5

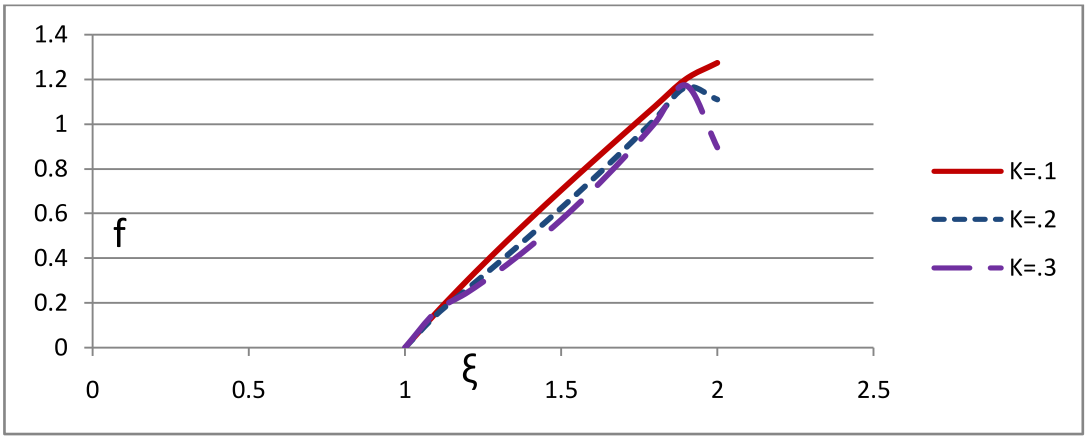


Fig.(5): Influence of parameter K on the axial velocity function f for n=0.0

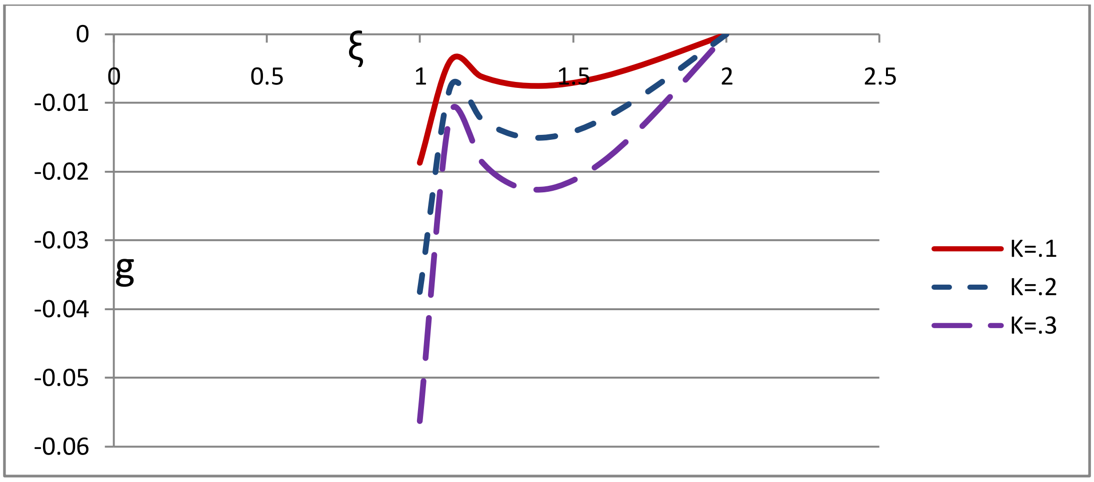


Fig.(6): Influence of parameter K on the micro-rotation function g for n=0.0

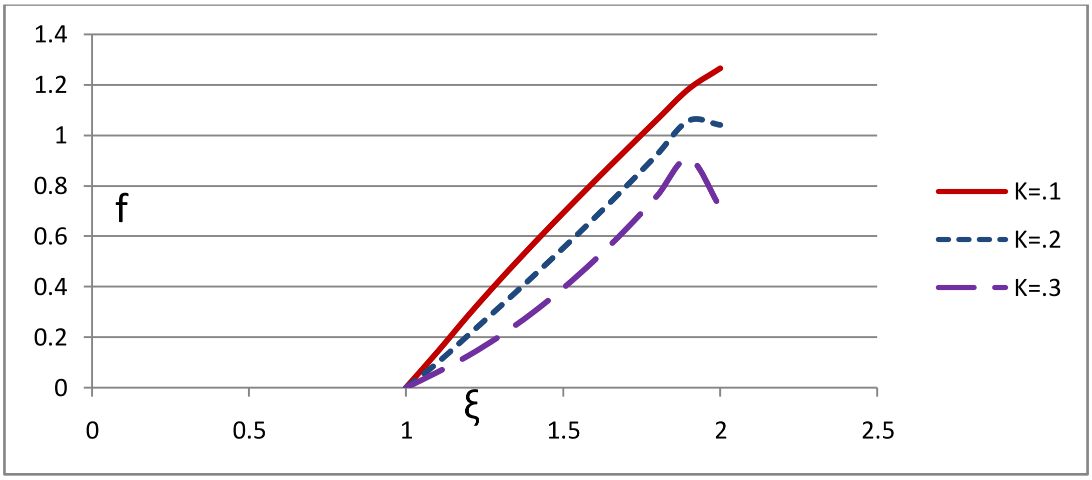


Fig.(7): Influence of parameter K on the axial velocity function f for n=0.5

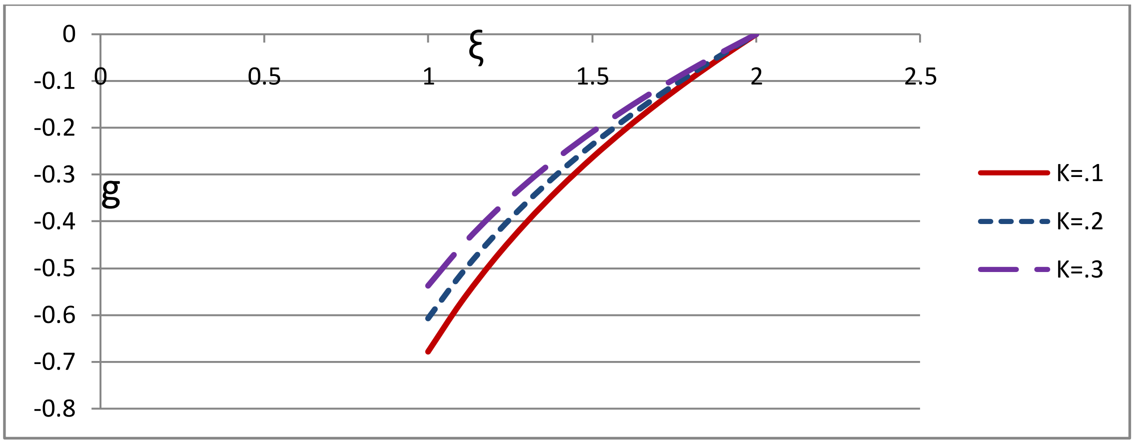


Fig.(8): Influence of parameter K on the micro-rotation function g for n=0.5

5. CONCLUSION :

It is concluded that the axial velocity is zero at the surface of the cylinder and maximum approximately at the upper surface of the film. The axial velocity is increasing very fast from the surface of the cylinder towards the upper surface of the thin film. It is also evident from the graphs of microrotation function g that the magnitude of the microrotation is maximum near the surface of the cylinder and vanishes at the upper surface of the thin film. The microrotation decreases in magnitude very fast near the surface of the cylinder and after increasing in magnitude, it start decreasing in slightly small forward region and start decreasing again in magnitude, in case of n=0.0, whereas in case of n=0.5. It decreases in magnitude linearly from the surface of the cylinder to the upper surface of the thin film.

6. REFERENCES:

[1] Deswal, S. & K.K Kalkal, Fractional order heat conduction law in Micropolar thermo-viscoelasticity with two temperatures, International Journal of heat and mass transfer, 66 (2013) 451.

[2] Mahfouz, F. M., Numerical prediction of buoyancy driven micropolar fluid flow within uniformly heated eccentric annulus, Applied Mathematical Modeling 37 (2013) 6037.

[3] Srinivasacharya, D., J.V Ramana Murty and D. Venugopalam, Unsteady stokes flow of micropolar fluid between two parallel porous plates Int. J. Sci. 39 (2001) 1557-1563.

[4] Amirat, Y. & K.Hamdache, Global weak solutions to the equations of thermal convection in micropolar fluids subjected to hall current, nonlinear analysis 102 (2014) 186.

[5] Singh K.R., Preeti & Ajit Kumar, Thin film flow of an electrically Conducting micropolar fluid down an inclined plane, IJMCA 4 (2012) 1-12.

[6] Singh, K.R., Preeti & Ajit Kumar, Flow of an electrically conducting micropolar fluid flow on a moving belt, International Journal of mathematics and Applied Statistics 3 (2012).

[7] Hayat, T. and M. Sajid, On analytic solution for thin film flow of Fourth grade fluid down a vertical cylinder, Phys Lett A 361 (2007) 316.

[8] Sajid, M., N. Ali and T. Hayat , On exact solution for thin film flows of a micropolar fluid, Science Direct 14 (2009) 451.