International Journal of Engineering &Technology, 7 (4) (2018) 6592-6596

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET
doi: 10.14419/ijet.v7i4.29314
Research paper

Unsteady Rotatory Oscillations of a Vertical Cylinder In Jeffery Fluid With Ion Slip Currents and Porous Medium

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Abstract

The generated flow of a Jeffery fluid due to an infinite circular cylinder's rotatory oscillations is examined. Consideration is given to the effects of Magnetic field, Hall and Ion currents with porous medium. The governing partial differential equations ensuing from the linear momentum equations are determined analytically by the theory of Bessel's functions. The velocity field, tangential drag force, torque and axial force acting on the cylinder are enumerated. The impacts different fluid parameters on transverse and axial velocities are investigated and presented in graph form. It is found that the longitudinal and polar velocity decreases with increasing Reynold number at a distance from the wall. The θ-component and z-component a velocity increase with a raise in Deborah number, also it increases with rising in Ion-slip parameter.

Nomenclature

*P:*Fluid Density
μ:Viscosity
*Σ:*Electrical Conductivity
k_0:Permeability of the Porous Medium
*T:*Cauchy Stress Tensor
*I:*Identity Tensor
*S:*Extra Stress Tensor
*E:*Rate of Strain
λ_1, λ_2:Jeffery Parameters
Q_0:Magnitude of Oscillations
B_0:Angle between the Directions of Transverse Oscillation with Base Vector e_θ
*J:*Current Density
*B:*Magnetic Field
*M:*Magnetic Parameter
*Re:*Reynolds Number
*Da:*Darcy Number
*De:*Debroah Number
β_i:Ion Slip Parameter
β_h:Hall Factor,
$\alpha_e = 1 + \beta_h \beta_i$

Keywords: *Circular Cylinder; Ion-Slip;Jeffery Fluid; Magneto Hydrodynamic; Porous Medium.*

1. Introduction

The primary author to handle the matter of rotatory oscillations of a rod was Stoke[1]. The problem of flow due to axial and rotational oscillations were first initiated by Casarella and Laura[2] by finding an analytical solution to a viscous flow developed due to a cylinder performing rotary oscillations. The practicable problems connected to stimulation of long rods and cables require the expression force performing on the rods. This will have a prominent cause on tension in the rods and subsequently on the reaction of fluids. Few applications of this type flows include:

i) Purification of a hole
ii) Refrigerate and lubricate the bit and drill string
iii) Suspending drill seedling once drilling has blocked (i.e., to alter the drill bit)
iv) Transport of cuttings during drilling to the surface.

Since these flows are very important in oil industry and in design and development of drilling machinery, many papers have ap-

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peared within the literature addressing the issues of transverse and longitudinal oscillations of the cylinder [3-15]. Several researchers have projected the varied models of non-Newtonian fluids so as to investigate completely different rheologic properties, one amongst the models is that the Jeffrey fluid model that uses time derivatives rather than connected derivatives. Many researchers have examined the Jeffrey fluid model underneath completely different geometries. The latest literature on Jeffery fluid can be seen in [16-18].

The Hall and ion currents in Ohm's law are unheeded in most of the MHD flow issues thought-about to this point. However, within the occurrence of a powerful magnetic flux, the influence of Hall current and particle slip is very significant. Ellahi et al [19] examined the consequences of the hall with particle slip for the flow through Jeffrey fluid in an exceedingly non-uniform rectangular channal. Nagaraju et al [20] studied hall and ion-slip, and cross diffusion effects of micropolar flow through the two vertical cylinders. Sara et al [21] examined the peristaltic motion of a hyperbolic tangent fluid with the effects of Hall and ion slip through a non-uniform channel taking the chemical reaction into consideration. Imran Haider Qureshi et al. [22] investigated the heat transfer in Erying-Powell liquid with thermal radiation and Hall and Ion currents. They observed that the width of thermal boundary layer is decelerates as Ion slip parameter increases.

Flow through porous medium may be a subject of general interest and has developed a separate area of study. Numerous usual substances like aquifers, fossil fuel reservoirs, biological tissues (i.e., bones and cork), and manmade equipment like blocks of cement and ceramics will be thought-about as porous media. Various vital properties will solely be rationalized by considering them to be porous media. The thought of porous media is employed in several applications of industries such as Soil mechanics, engineering, geosciences, biology and physical science, material science. Nallapusantosh and Radhakrishnamacharya[23] examined two-fluid representation for Jeffrey fluid through tube with a magnetic field and porous medium. They found that the mean hematocrit decrease with Darcy's parameter. Mohd Zin et al[24] found the exact solution to the unsteady flow through Jeffrey's rotating model with the magnetic field, porous medium and rampedness of a temperature. They identified that the velocity decreases with an raise in Jeffery parameter. A Comprehensive list of latest references with porous media in Jeffery fluid can be found in [25-26].

Motivated and inspiration of the above studies, we have studied the unsteady incompressible electrically conducting Jeffery fluid flow generated by transversely and longitudinally rotating vertical circular cylinder is investigated by considering porous media and Hall and Ion current impacts. The explanations for polar and axial velocity elements, shear stress, drag force, torque, and axial physical phenomenon area unit obtained and their variation with regard to numerous parameters is studied.

2. Mathematical formulation

The conservation mass associated momentum equation that govern the unsteady MHD flow of an incompressible Jeffrey fluid during a vertical cylinder with porous media and Hall currents may be written as [23]

$$\nabla . Q = 0 \tag{1}$$

$$\rho \frac{dQ}{d\tau} = -\nabla P + divT + J \times B - \frac{\mu}{k_o} Q \tag{2}$$

Where

$$T = -PI + S \tag{3}$$

$$S = \frac{\mu}{1+\lambda_1}\left(1 + \lambda_2 \frac{d}{d\tau}\right) E \tag{4}$$

Since we shall investigate the flow generated by circular cylinder is of infinite length, we shall use cylindrical polar coordinates (R, θ, Z) with axis of cylinder along Z-axis and assume the velocity Q is given by

$$Q = \left[0, V(R, \tau), W(R, \tau)\right] \tag{5}$$

The cylinder oscillates with velocity as given by the expression

$$Q_{\Gamma} = Q_{R=a} = q_0 \left(Cos\,\beta_0 e^{i\omega_1 \tau} e_\theta + Sin\,\beta_0 e^{i\omega_2 \tau} e_z\right) \tag{6}$$

Where the cylinder is taking longitudinal oscillations and transverse oscillations with magnitude $q_0 Sin\beta_0$, $q_0 Cos\beta_0$ in conjunction with the individual directions with $\omega_1$as the frequency of the longitudinal oscillations, ω_2 because the frequency of the transverse oscillations. In the lightweight off on top of assumptions and because of tiny magnetic Reynolds's variety the magneto hydrodynamic force in equivalent. (2) is given by

$$J \times B = -\frac{\sigma B_0^2 (1+\beta_h \beta_i) Q}{(1+\beta_h \beta_i)^2 + \beta_h^2} = -\frac{\sigma B_0^2 \alpha_e Q}{\alpha_e{}^2 + \beta_h^2} \tag{7}$$

The subsequent non-dimensional variables are accustomed build the quantities dimensionless

$$q = \frac{Q}{q_0},\ p = \frac{P}{\rho\, q_0^2},\ t = \frac{q_0}{a}\tau,\ r = \frac{R}{a} \text{ and } z = \frac{Z}{a} \tag{8}$$

In sight of (7) and (8), the equations within (1)-(2), for the flow take the subsequent non-dimensional type

$$\nabla \cdot q = 0 \tag{9}$$

$$Re\left(\frac{d\,q}{dt}\right) = -Re\ \nabla p + \frac{1}{1+\lambda_1}\left[1 + De\frac{d}{dt}\right]\left(\nabla q + (\nabla q)^T\right) - \left(\frac{M^2 \alpha_e}{\alpha_e{}^2 + \beta_h^2} + \frac{1}{Da}\right) q \tag{10}$$

Where

$$\frac{d}{dt} = \frac{\partial}{\partial t} + q \bullet \nabla$$

If we put $\lambda_1 \to 0$, we get the equations for classical viscous fluids.

Where

$$Re = \frac{a q_0}{\upsilon},\ De = \frac{q_0 \lambda_2}{a},\ Da = \frac{k_0}{a^2} \text{ and } M^2 = \frac{\sigma a^2 B_0^2}{\mu} \tag{11}$$

Let's select the vector q and pressure in the shape

$$q = v(r) e^{i\sigma_1 t}\, e_\theta + w(r)\, e^{i\sigma_2 t}\, e_z \tag{12}$$

$$p = p_1(r) e^{2i\sigma_1 t} \tag{13}$$

Where

$$\sigma_1 = \frac{\omega_1 a}{q_0} \text{ And } \sigma_2 = \frac{\omega_2 a}{q_0}$$

Substituting (12), (13) in (10) and comparing the coefficients of e_r, e_θ, e_z we get

$$\frac{dp_1}{dr} = \frac{v^2}{r} \tag{14}$$

$$iRe\sigma_1 v = \frac{(1+i\sigma_1 De)}{1+\lambda_1}\left(\frac{d^2u}{dr^2}+\frac{1}{r}\frac{du}{dr}-\frac{u}{r^2}\right)-\frac{M^2\alpha_e}{{\alpha_e}^2+\beta_h^2}v-\frac{1}{Da}v \quad (15)$$

$$iRe\sigma_2 w = \frac{(1+i\sigma_2 De)}{1+\lambda_1}\left(\frac{d^2w}{dr^2}+\frac{1}{r}\frac{dw}{dr}\right)-\frac{M^2\alpha_e}{{\alpha_e}^2+\beta_h^2}w-\frac{1}{Da}w \quad (16)$$

The problem's boundary conditions are:

$$v = Cos\beta_0 \text{ and } w = Sin\beta_0 \text{ at r = 1} \quad (17)$$

$$v, w \to 0 \text{ as } r \to \infty \quad (18)$$

Condition (17) is the classical no-slip boundary condition for the velocity, (18) is the regularity condition far away from the body.

3.1. Solution of the problem

Equation (15) can be rewritten as

$$\frac{d^2v}{dr^2}+\frac{1}{r}\frac{dv}{dr}-\left(\frac{1}{r^2}+S_1^2\right)v = 0 \quad (19)$$

Where

$$S_1 = \left\{\frac{(1+\lambda_1)\left[\frac{M^2(1+\beta_h\beta_i)}{(1+\beta_h\beta_i)^2+\beta_h^2}+\frac{1}{Da}+iRe\sigma_1\right]}{1+iDe\sigma_1}\right\}^{\frac{1}{2}}$$

Since v =0 as $r \to \infty$, the solution of (19) can be taken as

$$v = a_1K_1(S_1r) \quad (20)$$

Using (17), a_1= cosβ0/K1 (S1) (21)
Similarly from equation (16),

$w = a_2K_0(S_2r)$ Where a_2=sinβ0/K0 (S_2) (22)

Where

$$S_2 = \left\{\frac{(1+\lambda_1)\left[\frac{M^2(1+\beta_h\beta_i)}{(1+\beta_h\beta_i)^2+\beta_h^2}+\frac{1}{Da}+iRe\sigma_2\right]}{1+iDe\sigma_2}\right\}^{\frac{1}{2}}$$

Now the constants a1 and a2 can be found out numerically for different values of Jeffery fluid parameters by calculating S_1 and S_2 and by specifying β0. Then velocity components v and w are found analytically.

3.2. Drag calculation

The drag D acting on a cylinder of length L is given by

$$D = aL\int_0^{2\pi}(T_{\theta r}Cos\beta_0 + T_{zr}Sin\beta_0)d\theta \quad (23)$$

Now the stress components T_{zr} and $T_{\theta r}$ on the cylinder (at r = 1) can be calculated as

$$T_{zr} = \frac{\mu q_0}{a(1+\lambda_1)}(1+i\sigma_2 De)a_2[(K_0(S_2)-S_2K_1(S_2)]e^{i\sigma_2 t} \quad (24)$$

$$T_{\theta r} = \frac{\mu q_0}{a(1+\lambda_1)}(1+i\sigma_1 De)a_1[2K_1(S_1)-S_1K_2(S_1)]e^{i\sigma_1 t} \quad (25)$$

Now finally the non–dimensional drag $D'$is given by

$$D' = T_{\theta r}Cos\beta_0 + T_{zr}Sin\beta_0 \text{ on } r = 1 \quad (26)$$

Where $D' = \frac{D}{2\pi L\mu q_0}$

The torque and axial force per unit length are given respectively by

$$M = 2\pi a^2 T_{\theta r} = \frac{2\pi a\mu q_0}{(1+\lambda_1)}(1+i\sigma_1 De)a_1[2K_1(S_1)-S_1K_2(S_1)]e^{i\sigma_1 t} \quad (27)$$

$$F = 2\pi a T_{zr} = \frac{2\pi\mu q_0}{(1+\lambda_1)}(1+i\sigma_2 De)a_2[(K_0(S_2)-S_2K_1(S_2)]e^{i\sigma_2 t} \quad 28)$$

The dimensionless torque and axial force are given by

$$\bar{M} = \frac{1}{(1+\lambda_1)}(1+i\sigma_1 De)a_1[2K_1(S_1)-S_1K_2(S_1)]e^{i\sigma_1 t} \quad (29)$$

$$\bar{F} = \frac{1}{(1+\lambda_1)}(1+i\sigma_2 De)a_2[(K_0(S_2)-S_2K_1(S_2)]e^{i\sigma_2 t} \quad (30)$$

Where

$\bar{M} = \frac{M}{2a\pi\mu q_0}$ and $\bar{F} = \frac{F}{2\pi\mu q_0}$, the over bar denotes dimensionless quantities

3. Results and discussions

The mathematical results are calculated in the form of graphs at M =1, β_i =0.4, β_h = 5, Re=0.25, De = 4, $\lambda_1 = 0.4, \sigma_1 = 1.25$, $\sigma_1 = 1.5, \beta_0 = 0.7$, Da = 5 and $t = \pi$. It can be observed from figure 1 that as Reynolds number increases, the velocity v and w decrease at a distance six times the radius of the cylinder. Figure 2 illustrates that when the Jeffrey parameter λ1 increases, the velocity v decreases at a cylinder far away from cylinder and the same trend is observed for w. Figure 3 shows the effect of Debroah number De on velocity components. It is examined that as De increases the profiles of both velocity components. It is because of the fact that λ1 being the viscoelastic parameter exhibit both viscous and elastic characteristics. Thus, the fluid will always retard whenever viscosity or elasticity decrease. Figure 4 depicts the variation of M on velocity components. It can be identified that M decreases the profiles of velocity components. This is because of an increasing in the magnetic field parameter develops the opposite force of the flow is called Lorentz force. This force has a tendency to reduce the velocity. It reveals from Figure 5 that for large values of Ion-slip parameter βi the velocity increases when β_i increases. The impacts of Darcy's number Da on v and w are shown in figure 6. The Darcy number (Da) represents the relative effect of the permeability of the medium versus its cross-sectional area. The both the components of velocity enchances with the rise in Da. We get the case of viscous fluids from the Jeffery fluid by applying the limit λ1→0. These results are shown in Figure 7 for velocities v and w and our results are in good agreement with the observations of Rao et al. [3] in the case of Newtonian fluids. The dimensionless drag is computed for different values of time and this result is shown in the Fig. 8. It can be seen from this figure that as De increases the amplitude of drag decreases. Table 1 shows a comparison of results. The results are in good agreement with the results of Akyildiz [4].

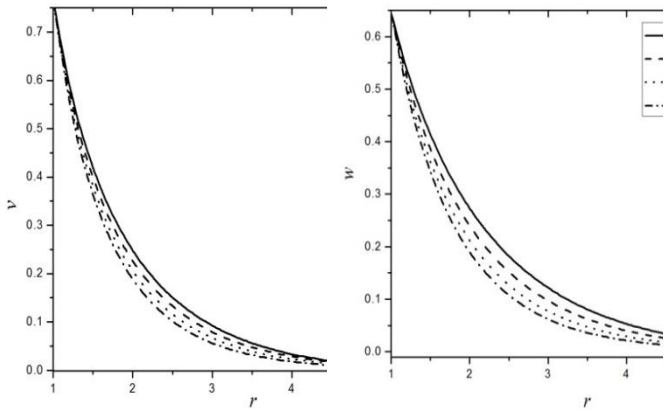


Fig. 1: Response of *Re* on Velocity Components.

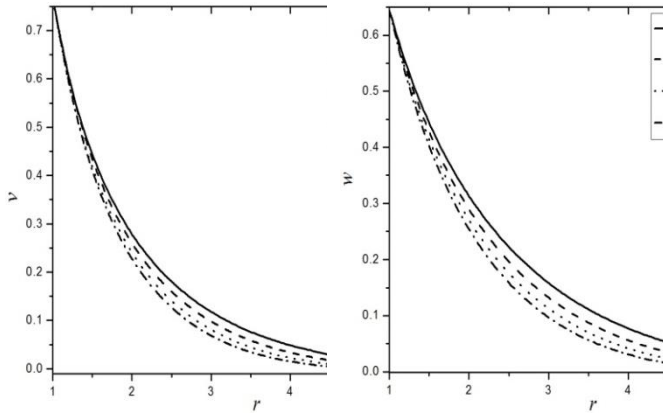


Fig. 2: Response of $\lambda_1$on Velocity Components.

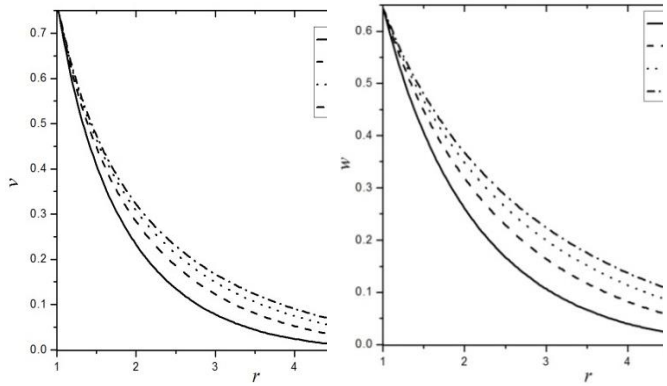


Fig. 3: Response of *De* on Velocity Components.

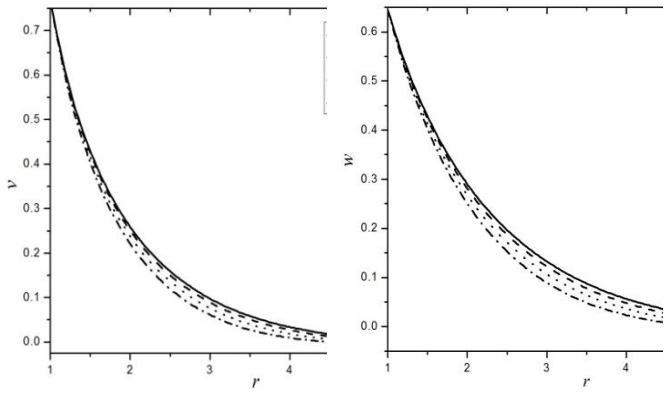


Fig. 4: Response of *M* on Velocity Components.

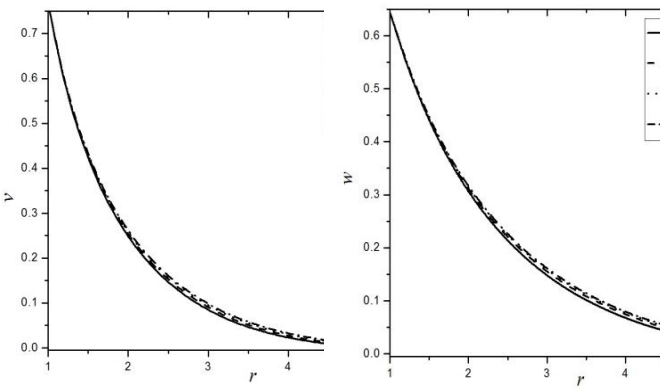


Fig. 5: Response of β_i on Velocity Components.

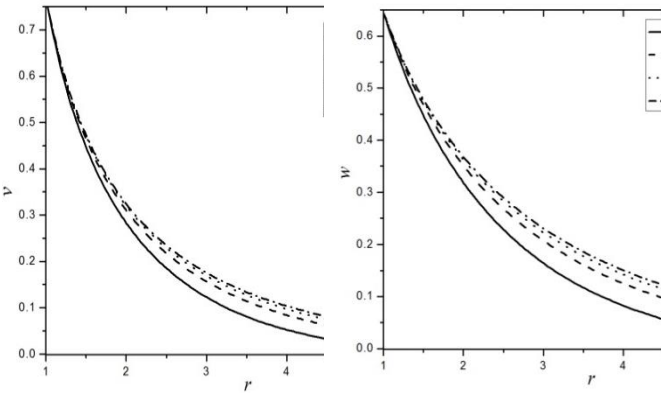


Fig. 6: Response of *Da* on Velocity Components.

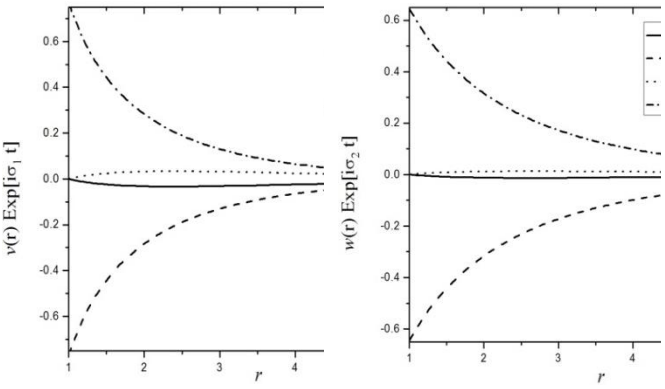


Fig. 7: Response of time(*t*) on Velocity Components.

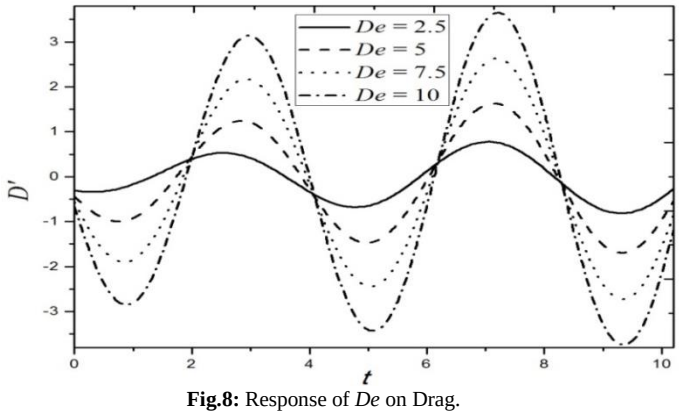


Fig.8: Response of *De* on Drag.

Table 1: Comparison of Results for Axial Force

De	Previous work of Akyildiz [4]	Present work at $\lambda_1 \to 0$.
0.1	0.37434	0.37524
0.3	1.12427	1.12536
0.5	1.87446	1.87548
0.7	2.60987	2.62560
0.9	3.36988	3.37572

4. Conclusion

In this article, we discussed MHD flow generated by performing oscillations about its axis and transversely of a Jeffrey fluid through a porous medium in a vertical cylinder under the influence of a magnetic field and Ion current taking into account. Analytical solutions are presented for the coupled linear ordinary differential equations. The impact of all the pertinent parameters is taken into account with the help of graphs. The major points for the present study are summarized below.

1) The velocity markedly enhances with increasing Ion parameter and decelerates with the magnetic parameter.
2) Both the velocity profiles increase with increasing Darcy parameter and Debroah number.
3) As *De* increasesthe amplitude of dimensionless drag decreases.

Acknowledgement

We are grateful to the esteemed reviewers for their comments and suggestions which led to the improvement of the paper. The authors are very thankful to Prof. J. V. Ramana Murthy, NIT Warangal, for his valuable discussions.

References

[1] Stokes GG (1886), on the effect of rotation of cylinders and spheres about their own axes in increasing the logarithmic decrement of the arc of vibration (Mathematical and Philosophical Papers 5) Cambridge. *Cambridge University Press*, England, pp 207–214.

[2] Casarella MJ & Laura PA (1969), Drag on oscillating rod with longitudinal and torsional motion. *J. Hydronaut*. 13, pp 180–183.https://doi.org/10.2514/3.62823.

[3] Rao PM, Kuwahara K &Tsuboi K (1992), Computational study of unsteady viscous flow around a transversely and longitudinally oscillating circular cylinder in a uniform flow at high Reynolds number. *Comput. Mech.* 10, pp 414–428.https://doi.org/10.1007/BF00363996.

[4] AkyildizFahir T (1998), Longitudinal and torsional oscillations of a rod in a viscoelastic fluid. *Rheol. Acta* 37, pp 508–511.https://doi.org/10.1007/s003970050137.

[5] Calmelet-Eluhu C & Rosenhaus V (2001), Symmetries and solutions of a Micropolar fluid through a cylinder. *Acta. Mech*. 147, pp 59–72.https://doi.org/10.1007/BF01182352.

[6] Owen D &RahamanK (2006), on the flow of an Oldroyd–B liquid through a straight circular tube performing longitudinal and torsional oscillations of different frequencies. *Mathematica* 14, pp 1–9.

[7] Vieru D, Akhtar W, Fetecau C & Corina Fetecau (2007), Starting solutions for the oscillating motions of a Maxwell fluid in cylindrical domain. *Meccanica* 42, pp 573–583.https://doi.org/10.1007/s11012-007-9081-7.

[8] Mehrdad Massoudi & Tran X.phouc (2008), on the motion of a second grade fluid due to longitudinal and torsional oscillations of a cylinder-A numerical study. *Appl. Math. Comput*.203, pp 471–481.https://doi.org/10.1016/j.amc.2008.05.133.

[9] Ramana Murthy JV &NagarajuG (2009), Flow of a Couple stress fluid generated by a circular cylinder subject to longitudinal and torsional oscillations. *Contemporary Engineering Sciences* 2(10), pp 451–461.

[10] Ramana Murthy JV, Nagaraju G & Muthu P (2010), Numerical solution of longitudinal and torsional oscillations of cylinder with suction in a couple stress fluid. Journal of Engg& Appl. Sci.5 (5), pp 51–63.

[11] Ramana Murthy JV, Muthu P &NagarajuG (2010), Finite difference solution for mhd flow of couple stress fluid between two concentric rotating cylinders with porous lining. *Int. J of Appl Math and Mech*.6, pp 1–28.

[12] Ramana murthy JV, Nagaraju G & Muthu P(2012), Micropolar fluid flow generated by a circular cylinder subject to longitudinal and torsional oscillations with suction/injection. *Tamkang Journal of Mathematics* 43(3), pp 339–356.https://doi.org/10.5556/j.tkjm.43.2012.614.

[13] Nagaraju G & Ramana Murthy JV (2013), Mhd flow of Longitudinal and Torsional oscillations of a circular cylinder with suction in a couple stress fluid. *Int.J. of Applied Mechanics and Engineering* 18(4), pp.1099–1114.https://doi.org/10.2478/ijame-2013-0069.

[14] NagarajuG (2014), Unsteady MHD Micropolar Fluid Flow Generated Due to Longitudinal and Torsional Oscillations of Circular Cylinder. *International Journal of Nonlinear Science*.18 (1), pp.22-29.

[15] Nagaraju G & Ramana Murthy JV (2014), unsteady flow of a micropolar fluid generated by a circular cylinder subject to longitudinal and torsional oscillations. *Theoret.Appl.Mech*. 41(1), pp.71-91.https://doi.org/10.2298/TAM1401071N.

[16] Maqbool K, Shaheen S & Mann AB (2016), exact solution of cilia induced flow of a Jeffrey fluid in an inclined tube. *Springer Plus* 5, 1379. https://doi.org/10.1186/s40064-016-3021-8.

[17] OdeluOjjela, Adigoppula Raju & Pravin Kashyap Kambhatla (2017), Influence of thermophoresis and induced magnetic field on chemically reacting mixed convective flow of Jeffrey fluid between porous parallel plates. *Journal of Molecular Liquids*, https://doi.org/10.1016/j.molliq.2017.02.061.

[18] Stanford Shateyi& Gerald T. Marewo (2018), Numerical solution of mixed convection flow of an MHD Jeffery fluid over an exponentially stretching sheet in the presence of thermal radiation and chemical reaction. *Open Physics* 16(1), pp 249–259.https://doi.org/10.1515/phys-2018-0036.

[19] Ellahi R, Bhatti MM &IoanPop (2016), Effects of hall and ion slip on MHD peristaltic flow of Jeffrey fluid in a non-uniform rectangular duct. *International Journal of Numerical Methods for Heat & Fluid Flow* 26(6), 1802 – 1820.https://doi.org/10.1108/HFF-02-2015-0045.

[20] NagarajuGajjela, Anjanna Matta &KaladharK (2017), the effects of Soret and Dufour, chemical reaction, Hall and ion currents on magnetized micropolar flow through co-rotating cylinders. *AIP Advances* 7, 115201 (2017); https://doi.org/10.1063/1.4991442.

[21] Sara I. Abdelsalam& Bhatti MM (2018), the study of non-Newtonian nanofluid with hall and ion slip effects on peristaltically induced motion in a non-uniform channel. *RSC Adv*.8, pp 7904–7915.https://doi.org/10.1039/C7RA13188G.

[22] Imran Haider Qureshi, Nawaz M, & Shahzad A (2019), Numerical study of dispersion of nanoparticles in magnetohydrodynamic liquid with Hall and ion slip currents. *AIP Advances* 9, 025219, https://doi.org/10.1063/1.5084311.

[23] Santhosh Nallapu&RadhakrishnamacharyaG (2014), Jeffrey Fluid Flow through Porous Medium in the Presence of Magnetic Field in Narrow Tubes. *International Journal of Engineering Mathematics* 2014, Article ID 713831, 8 pages. https://doi.org/10.1155/2014/713831.

[24] Mohd Zin NA, Khan I &ShafieS (2017), Unsteady MHD free convection flow of rotating Jeffrey fluid embedded in a porous medium with ramped wall temperature. *IOP Conf. Series: Journal of Physics: Conf. Series* 890 (012043). https://doi.org/10.1088/1742-6596/890/1/012043.

[25] Veera Krishna M, Bharathi K & Ali J. Chamkha(2018), Hall Effects On Mhd Peristaltic Flow Of Jeffrey Fluid Through Porous Medium In A Vertical Stratum. *Interfacial Phenomena and Heat Transfer* 6(3), 253–268.https://doi.org/10.1615/InterfacPhenomHeatTransfer.2019030215.

[26] Eldabe NTM, Shaker MO &MahaSA (2018), Peristaltic Flow of MHD Jeffrey Fluid Through Porous Medium in a Vertical Channel with Heat and Mass Transfer with Radiation. *Journal of Nanofluids* 7(3), pp. 595-602.https://doi.org/10.1166/jon.2018.1466.