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"A Study of The troubles of warmth transfer within the waft of non – Newtonian 2nd Order Fluid"

Rakesh saini
Assistant professor of mathematics
Mdu rohtak

Abstract
The motive of the prevailing paper is an try to have a look at the warm temperature switch inside the go with the go along with the flow of a 2nd-order fluid thru a channel with porous walls below a transverse magnetic trouble by regular perturbation method. The second one-order consequences on the temperature profile are illustrated for awesome values of the Hartman and Reynolds number. The outcomes also are obtained for the Newtonian fluid by taking the second-order parameter to be zero.

Introduction

The study of non-Newtonian fluids (the fluids which do not obey the Newtonian regulation of viscosity) is of huge hobby and significance as it offers with both the biological and non-biological fields. A non-Newtonian fluid is a fluid whose viscosity depends at the force carried out (and occasionally time and temperature as nicely). Fluids like water and fuel behave in line with Newton's version, and are known as Newtonian fluids but ketchup, blood, yogurt, gravy, pie fillings, dust and cornstarch paste don't follow the version. They are non-Newtonian fluids because doubling the speed that the layers slide past every different does not double the resisting force. It may less than double (like ketchup), or it is able to more than double (as inside the case of quicksand and gravy). That's why stirring gravy thickens it, and why struggling in quicksand will make it even harder to break out.

For some fluids (like mud or snow) we can push and get no glide in any respect till we push difficult enough and the substance begins to go with the flow like a normal liquid. This is what reasons mudslides and avalanches. Rheology is defined as the flow of fluids and deformation of solids under stress and strain. Rheometers are the instruments used to measure a material's rheological properties. Hook's low is probably the first recognizable law, which states that deformation, is proportional to the applied force. Newton considered the behaviour of an imaginary fluid when to fill all space, in which resistance to motion was proportional to what has variously been named rate of strain, rate of deformation, velocity strain or flow tensor d_{ij} and is known as Newton-Cauchy-Poisson law. Accordingly,

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$\tau_{ij} = p\delta_{ij} + 2\mu d_{ij} + \lambda d_m{}^m \delta_{ij}$

where

$d_{ij} = (u_{i,j} + u_{i,j})/2,$

p is the pressure, μ and $= -2\mu/3)$ being material constants, also termed as coefficients of viscosity and δ_{ij} is kronecker's delta tensor. The fluids satistfying the relation (1.1), are called Newtonian fluids e.g. honey, glycerin and certain thick oils. For incompressible fluids the relation (1.1) becomes

$\tau_{ij} = -p\delta_{ij} + 2\mu d_{ij}$.

Although certain phenomena like skin-friction, form drag, separation, secondary flows etc., are successfully explained by this classical theory, but it has proved inadequate to explain the rheological properties of certain materials like paints, slurries, ceramics, melts poly-iso-butylene solution in the mineral oils or in tetralin, poly-methylmethacrylate solutions in the dimethyl-pthalate, rubber-toluene solutions etc. certain phenomena like Anmolous viscosity* the Weissenberg effect**, Merrington effect** and spinnability effect**** observed in these fluids could not be explain by the solutions of Navier-Stokes equations and therefore a basic search into the foundations of fluid dynamics had to be undertaken.

MHD is the study of the motion of the electrically conducting fluids in the presence of electric and magnetic fields. When a conducting fluid is under the influence of the electro-magnetic field, it behaves differently than without electromagnetic field. This is mainly because of Lorentz force, which is a cross product of electric field and magnetic field (Sir Flemming's right hand law). Even without the external electric field, flow pattern is altered due to the presence of strong magnetic field.

Magnetic field and the motion of the conducting fluid particles generate electric current. This current and magnetic field interact with each other, and change the flow motion, with a chain reaction, all three fields (velocity, magnetic, electric) are interconnected and reveal very unique features.

Heat transfer is that science, which seeks to predict the energy transfer, which may take place between material bodies as a result of temperature difference. In the simplest of the terms, the discipline of heat transfer is concerned with only two things: temperature and flow of heat. Temperature represents the amount of thermal energy available, whereas heat flow represents the movement of thermal energy from one place to another place.

On a microscopic scale, thermal energy is related to the kinetic energy of the molecules. The greater a material's temperature, The greater the thermal agitation of its constituent molecules (manifested both in linear motion and vibrational modes). It is natural for regions containing greater molecular kinetic energy to pass this energy to regions with less kinetic energy.

SECOND-ORDER FLUIDS:-

A Theory of more general type of incompressible fluid was put forward by Green et. AI., Coleman and Noll. The Theory is based on the hypothesis that the stress is a function of the deformation gradient, that is the stress at the material point depends only on the previous history of the deformation gradient. The materials obeying this theory are termed as simple materials by Noll.

An incompressible simple fluid is an incompressible simple material if it possesses the property that all local states with the same mass density are intrinsically equivalent in response. For a given history g(s) a retarded history $g_c(s)$ can be defined as:

$$g_c(s) = g(s),\ 0 \le s \le \infty, \tag{1.3}$$

where c is the retardation factor $0 \le c < 1$. taking into consideration, this definition of retarded history and assuming that the stress is more sensitive to recent deformation than to deformations which occurred in the distant past, Coleman and Noll proved that the theory of the simple fluids yields the theory of perfect fluids (in which deviatoric stress is independent of strain-rate) for c proved that the theory of the simple fluids yields the theory of perfect fluids (in which deviatoric stress is independent of strain-rate) for $c \to 0$ and yields the theory of the Newtonian fluids (in which deviatoric stress is linearly proportional to deviatoric strain-rate) as the next approximation.

The theory of the Newtonian fluids gives a correction to the theory of perfect fluids, which is complete within terms of order one in c. If we neglect all the terms of order greater than two in c, then the simple fluid is called an incompressible second-order fluid. The constitutive equation of non-Newtonian second-order fluid is

$$\tau_{ij} = -p\delta_{ij} + 2\mu_1 d_{ij} + 2\mu_1 e_{ij} + 2\mu_3 c_{ij} \tag{1.4}$$

On taking $\mu_2 = 0$, we get the constitutive equation for Reiner-Rivlin visco-inelastic fluid as

$$\tau_{ij} = -p\delta_{ij} + 2\mu d_{ij} + 4\mu_3 c_{ij} \tag{1.5}$$

where

$$d_{ij} = {}^1/_2\,[u_{i,j} + u_{i,j}],$$
$$e_{ij} = {}^1/_2\,[a_{i,j} + a_{i,j}],\ u^m{}_{,i}u_{m,j},$$

$$c_{ij} = d_{im}\, d^m{}_j.$$

p is the indeterminate hydrostatic pressure; τ_{ij} is the stress-tensor; and a_i are the velocity and acceleration vector and μ_1, μ_2, μ_3 are called the coefficient of Newtonian-viscosity, the coefficient of elastic-viscosity and the coefficient of cross-viscosity respectively.

Rivlin, Noll, Coleman, Markowitz and others have solved elementary flow problems (steady as well as unsteady in nature) for these fluids. Some evidence favoring the Weissenberg effect etc. were given by Roberts and others, Coleman, Noll, Ericksen and Markowitz contended that the most general type of fluid is characterized by three functions of the rate of shear.

Ting has taken positive values of the elastic-viscosity but later it was confirmed that it should be taken as negative. The problems concerning the behaviour of the second-order fluids have also been discussed by Langlois, Srivastava, Sharma, Gupta, Sharma, Ƅhatia, Sharma, Prakash, Gupta, Singh, Smit, Rita Chaudhary and Alok Das.

Review of Literature

Sharma & Gupta have two infinite torsionally oscillating discs. Thereafter Sharma & Singh extended the same problem for the case of porous discs subjected to uniform suction and injection.

Hayat has considered non-Newtonian flows over an oscillating plate with variable suction.

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Chawla has considered flow past of a torsinonally oscillating plane Riley & Wybrow have considered the flow induced by the torsinally oscillations of an elliptic cylinder. Bluckburn has considered a study of two-dimensional flow past of an oscillating cylinder.

Sadhna Kahre studied the steady flow between a rotating and porous stationary disc in the presence of transverse magnetic field.

Sharma and Agarwal have discussed the heat transfer from an enclosed rotating disc in case of Newtonian fluid. Thereafter Singh K. R. and H.G. Sharma have discussed the heat transfer Singh K. R. and H.G. Sharma have discussed the heat transfer from an enclosed rotating disc in case of Newtonian fluid.

Thereafter in the flow of a second-order fluid between two enclosed rotating discs. The torsional oscillations of Newtonian fluids have been discussed by Rosenblat. He has also discussed the case when the Newtonian fluid is confined between two infinite torsionally oscillating discs· Sharma & Gupta have considered a general case of flow of a second-order fluid between two infinite torsionally oscillating discs. Thereafter Sharma & K. R. Singh have solved the problem of heat transfer in the flow of non-Newtonian second-order fluid between torsionally oscillating plane Riley & Wybrow have considered the flow induced by the torsional oscillations of an elliptic cylinder. Sadhna kahre studied the steady flow between a rotating and porous stationary disc in the presence of transverse magnetic field.

Terrill and Shrestha have discussed the problem of steady laminar flow of an incompressible viscous fluid in a two dimensional channel when the walls are of different permeability and studied the effects of magnetic field when the fluid is electrically conducting. The problem of flow of a second-order fluid with heat transfer in a channel with porous walls has been considered by Agrawal. Sharma & Singh have studied the numerical solution of the flow of second-order fluid through a channel with porous walls under a transverse magnetic field.

Sharma and Agarwal have discussed the heat transfer from an enclosed rotating disc in case of Newtonian fluid. Thereafter Singh K. R. and H.G. Sharma have discussed the heat transfer Singh K. R. and H.G. Sharma have discussed the heat transfer from an enclosed rotating disc in case of Newtonian fluid. Thereafter in the flow of a second-order fluid between two enclosed rotating discs. The torsional oscillations of Newtonian fluids have been discussed by Rosenblat. He has also discussed the case when the Newtonian fluid is confined between two infinite torsionally oscillating discs· Sharma & Gupta have considered a general case of flow of a second-order fluid between two infinite torsionally oscillating discs. Thereafter Sharma & K. R. Singh have solved the problem of heat transfer in the flow of non-Newtonian second-order fluid between torsionally oscillating plane Riley & Wybrow have considered the flow induced by the torsional oscillations of an elliptic cylinder. Sadhna kahre studied the steady flow between a rotating and porous stationary disc in the presence of transverse magnetic field.

Objectives of the Study

In our present problem, we here study the flow pattern of an incompressible second-order fluid between two parallel infinite discs in the presence of transverse magnetic field when one is rotating (called rotor) and other is at rest (called stator). A uniform injection is applied to the stator forming the subject matter of the paper. The Rotor coincides with the plane z = 0 and the stator coincides with the plane z = d. Here the dimensionless parameters $\tau_1(\mu_2/pd^2)$, $\tau_2(\mu_2/pd^2)$

govern the effects of elastic-viscosity and cross–viscosity, while the effect of the injection are governed by a non- dimensional parameter k ($=w_0/2d\Omega$) where w_0 is the uniform suction velocity (negative for injection).

Research Methodology

The governing equations, which will be used in the problems, are as follows:

1. **Equation of Continuity:**

The law of conservation of mass states that fluid mass can be neither created nor destroyed. The equation of continuity aims at expressing the law of conservation of mass in a mathematical form.

Thus in continuous motion, the equation of continuity expresses the fact, the increase in the mass of fluid within any closed surface drawn in the fluid in any time must be equal to the excess of the mass that flows in over the mass that flows out.

$$\partial\rho/\partial t + (\rho u)_{,i} = 0$$

Where u^i and ρ are respectively the velocity vector and density of the fluid. For incompressible fluids this equation reduce to

$$U^i_{,i} = 0 \qquad (1.7)$$

2. **Momentum Equation:**

These equations are based on the Newton's law of motion, which continues to be the basis of all continuum mechanics except relativistic mechanics.

$$\rho(\partial u_i/\partial t + u_m u_{i,m}) = Pf_i + \tau^m_{i,m} \qquad (1.8)$$

Where F is the impressed force per unit mass of fluid and τ^m_i the stress tensor. The Momentum equation for no extraneous force is simply

$$\rho(\partial u_i/\partial t + u_m u_{i,m}) = \tau^m_{i,m} \qquad (1.9)$$

3. **Equation of Energy:**

This equation is based on the first law of Thermodynamics. For incompressible fluid the energy balance is determined by the internal energy, the conduction of the heat, the convection of the heat with the stream and the generation of the heat through friction. In a compressible fluid there is an additional term due to the work of expansion (or compression) when the volume is changed. In all cases radiation may also be present, but its contribution is small at moderate temperatures, and we shall neglect it completely.

$$\rho c_v(\partial T/\partial t + u^m T_{,m}) = kg^{ig} T_{,IJ} + \phi, \qquad (1.10)$$

Where T is the temperature, c_v the specific heat at constant volume, k the thermal conductivity, g^{ij} the associate of metric tensor g_{ij} and ϕ, the dissipation function is given by

$$\phi = \tilde{\tau}^{i}_{j}\, d^j_{i,}$$

$\tilde{\tau}^i_j$ is the mixed deviatoric stress tensor.

4. The equations of electromagnetic field:

Maxwell's equations:

$$\text{div } \mathbf{b} = 0, \qquad (1.11)$$

$$\text{div } \mathbf{D} = \rho_e, \qquad (1.12)$$

$$\text{Curl } \mathbf{E} = -\partial\mathbf{b}/\partial t, \qquad (1.13)$$

$$\text{Curl } \mathbf{H} = \mathbf{J} + \partial D/\partial t. \qquad (1.14)$$

Ohm's law:

$$\mathbf{J} = \sigma(\mathbf{E}+\mathbf{V}\mathbf{x}\mathbf{b})+ \rho_e \mathbf{V}, \tag{1.15}$$

Where

$\mathbf{B} = \mu_e \mathbf{H}$,

$\mathbf{D} = \epsilon_e \mathbf{E}$,

Also the Lorenz force is given by

$$\rho\mathbf{F} = \mathbf{J} \times \mathbf{b} + \rho_e\mathbf{E} \tag{1.16}$$

Where **B** is the electromagnetic induction, **E**is the electric field, **H** is the magnetic field, **D**the density of the electric displacement, **J**is the electric current density, ρ_e the electric charge density, ϵ_e the di-electirc constant, μ_e the magnetic permeability and $\sigma$the electric conductivity.
Thus the equation of energy for incompressible MHD fluid is

$$\rho c_v(\partial T/\partial t + u^m T_{,m}) = \mathbf{J}^2/ \sigma + k g^{ig} T_{,IJ} + \phi \tag{1.17}$$

And the equation of motion will become

$$\rho(\partial u_i/\partial t + u^m u_{i,m}) = \mathbf{J} \mathbf{x} \mathbf{b} + \tau^{m}_{i,m} \tag{1.18}$$

RESULTS AND CONCLUSION

The variation of radial velocity for different elastic-viscous parameter τ_1 = -1.3, -2, -2.6; when cross-viscous parameter τ_1 = 10, injection parameter k = 5 Reynolds number R= 0.05, magnetic field m_1 = 5 is shows that the curve of radial velocity w.r.t ζ is bell shaped with maximum at $\zeta = 0.5$ approximately.
It is also evident that the radial velocity decreases with increase in τ_1 from ζ = 0.0-0.28, then it begins increase with increases in τ_1 upto ζ = 0.72 and then decreases with increase in τ_1 from ζ = 0.8-0.95. The value of radial velocity is approximately equal at ζ =0.28 and ζ – 0.72 for all values of τ_1. The point of maxima is in the middle of the gap length for all values of elastic-viscous parameter τ_1.

Due to complexity of the differential equations and tedious calculations of the solutions of the solutions, no one has tried to solve the most practical problems of enclosed torsionally oscillating discs so far. The authors have considered the present problem of flow of a non-Newtonian second-order fluid over an enclosed torsionally oscillating disc in the presence of the magnetic field and calculated successfully the steady and unsteady part both of the flow functions. The flow functions are expanded in the powers of the amplitude ∈ (assumed to be small) of the oscillations of the disc. The non-Newtonian effects are exhibited through two dimensionless parameters $\tau_1(=n\mu_{2/}\,n\mu_1)$ and $\tau_2(=n\mu_{3/}\,n\mu_1)$, where μ_1, μ_2, μ_3 are coefficient of Newtonian viscosity, elastic-viscosity and cross viscosity respectively, n being the uniform frequency of the oscillation.

The variation of the radial velocity with ζ at τ_2= 2, ξ = 5, R = 5, R_m= 0.05, R_L = 0.049, R_z = 2, m = 2 for different values of elastic-viscous parameter τ_1= 0, -0.3 and phase difference τ= π/3, 2π/3 is shows that τ= π/3, the radial velocity increases with an increase in ζnear the lower disc, attains its maximum value at ζ=0.2then start decreasing, attain its minimum value at ζ=0.8 and increases thereafter near the upper disc. It is clear that the radial velocity increases with an increase in τ_1 near the lower disc then start decreasing with an increase in τ_1 after the point of intersection near the upper disc.

For τ =2π/3, the radial velocity increases with an increase in ζ and start decreasing thereafter at τ_1=0 whenever at τ_1 = -0.3 it decreases first, attains its minimum value at ζ = 0.1then start increasing, attains its maximum value at $\zeta = 0.7$and decreases there after upto the surface of the upper disc. It is also seen that the radial velocity increases with an increase in τ_1 upto the middle of the gap-length and decreases thereafter with an increase in τ_1 upto the surface of the upper disc.

The authors have considered the present problem of heat transfer in the flow of a non-Newtonian second-order fluid over an enclosed torsionally oscillating discs with uniform suction and injection in the presence of the magnetic field and calculated successfully the steady and unsteady part both of the flow and energy functions. The flow and energy functions are expanded in the powers of the amplitude ∈ (assumed to be small) of the oscillations of the disc. The non-Newtonian effects are exhibited through two dimensionless parameters τ_1 (=nμ_2/μ_1) and τ_2(=nμ_3/μ_1), where μ_1, μ_2, μ_3 are coefficient of Newtonian viscosity, elastic-viscosity and cross-viscosity respectively, n being the uniform frequency of the oscillation. The variation of temperature distribution with elastic-viscous parameter τ_1, cross –viscous parameter τ_2 (based on the relation τ_1 =a τ_2, where a = -0.2 as for 5.46% poly-iso- butylenes type solution in cetane at 30^0C (Markowiz[38]) Reynolds number R_1 magnetic field m, suction parameter k at different phase difference τ is shown graphically.

The variation of the temperature distribution with ζ at R = 7, P = 6, ζ = 5, and ϵ =0.02, k =15,m = 10, E = 5 for different values of τ_1= 1, 1.2, 3 when τ = π/3 and 2π/3 is shown in fig (1) and fig (2) respectively. From the result shows that the temperature variation is parabolic with vertex downwards. It is also clear that the temperature is minimum at the middle of the gap-length and remains negative throughout the gap-length except near the surface of the lower disc. It is seen that temperature increases with an increase in elastic-viscous parameter τ in the first half and being overlapped in the second half of the gap-length. It is observed that the temperature decreases with an increase in τ_1 in the middle of the gap-length and is being overlapped thereafter.

The variation of the temperature distribution with ζ at τ_1= 5, P = 6, ζ= 5, ϵ =0.02, k =15,m = 10, E = 5 for different values of R = 1, 1.5, 2 when τ = π/3 and 2π/3 is shows that the temperature variation is parabolic with vertex downwards. It is also evident that the temperature is minimum at the middle of the gap length and remains negative throughout the gap-length except near the surface of the lower disc. It is also clear from these that temperature decreases with an increase in Reynolds number R throughout the gap-length.

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