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A STUDY OF MHD AND POROSITY ON JEFFREY FLUID FLOW

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ABSTRACT

The velocity of Jeffrey fluid flow which is unsteady in nature, over an infinite horizontal porous plate, is considered, and also, the influence of MHD and porosity on the velocity of the fluid is investigated. The major objective of this research paper is to achieve the analytical solution for the incompressible transient flow of MHD (magneto hydrodynamic) Jeffrey fluid above an accelerating porous plate. The fluid flows above the plate at $y > 0$, and the plate is infinite in the x-direction ($y = 0$) and gives an oscillatory motion. For the occurrence of both injection and suction phenomena, porous plate is used. The governing equation of the model becomes dimensionless by using the appropriate set of nondimensional variables. With the help of Laplace transformation and perturbation methods, these nondimensional differential equations of Jeffrey fluid are solved.

Keywords: Mhd, Porosity, Jeffrey Fluid, Flow

1. INTRODUCTION

It is scrutinized since the past limited eras that several scholars are far fascinated in non-Newtonian fluids. The clarification behind such curiosity in non-Newtonian fluid is because of its wide-ranging scope in many fields of life. Non-Newtonian fluids have numerous uses and applications in many fields, for example, chemical industries, biological sciences, geophysics, and petroleum. As we are aware all non-Newtonian fluids have attained the properties of elasticity along with viscosity. The countless models of non-Newtonian fluids are present in our daily life activities, such as oils, ketchup, honey, paints, and toothpaste, and asphalt, and liquid polymers are characterized by some noteworthy phenomena. These fluids are a number of thought-provoking applications and are moreover used in our daily life. The nonlinear relationship between shear stress and shear rate in such types of fluids is verified by many researchers that is not only significant from an academic point of view but also beneficial for production industries like paper construction, polymer, and food processing. It is perceived that a single differential equation is described in the models of Newtonian fluid flows, but in the case of non-Newtonian fluid models, it is not so easy to describe the flow of the model with one and only constitutive differential equation. Usually, the rheological properties of fluids are specified with the help of their hypothetical constitutive conditions. Moreover, it is observed that the Newtonian fluids fulfilled Newton's internal friction law that is "shear stress is proportional to the viscosity of the fluid gradient" and non-Newtonian fluids dissatisfy the Newtonian law of internal friction. The leading flow equations of non-Newtonian fluids are more difficult than the Navier–Stokes equations [1–3]. Generally, non-Newtonian fluids are categorized into three dissimilar categories, namely, first is differential type, second is the integral type, and the third one is rate type. In the current research work, we observed the model of Jeffrey fluid flow, and this sort of fluid flow model indicates the property of the ratio of relaxation and retardation time. It is verified that the non-Newtonian models of fluid flows, with as well as without the magnetic-hydrodynamic field, have countless uses among the different fields of life, for example, biological fluids management, dental amalgam, plasmas, alloys, and metals that are in liquid form, electromagnetic propulsion, and blood [4, 5].

It is observed that the Jeffrey fluid is an extraordinary type of non-Newtonian fluid. Among many other types of non-Newtonian fluid models, it is revealed that the model of Jeffrey fluid flow is one of the substantial models which clearly precise the finest description of properties of the viscoelastic fluids [6–11]. It is presented that, in nature, Jeffrey fluid models are well-defined in linear viscoelastic fluids. As we are familiar with this, Jeffrey fluids have several types of applications in polymer industries and one of them is dilute polymer which is explained by the researchers Farooq et al. and Ara et al. [12, 13]. Due to the viscoelastic behavior of Jeffrey fluid models, the vital and applicable role of such models is found in fluid mechanics and biological aspects. It has been magnificently used in the model of blood flow. As a special case, Jeffrey fluid is interconnected with Maxwell fluid and Newtonian fluid [14].

The main objective of this research work is to observe the behavior of velocity of Jeffrey fluid's transient flow under the influence of different embedded parameters along with MHD and porosity effects. For this purpose, Jeffrey fluid flow is observed over an infinite accelerated plate which is taken to be porous. The governing equations with initial and boundary conditions of the model are transformed to a nondimensional form by using an appropriate set of dimensionless variables.

2. MATHEMATICAL FORMULATION

Consider an incompressible Jeffery fluid-saturated anisotropic porous layer between two infinite parallel plates a distance d apart. Thermal buoyancy is invented to be the cause of fluid motion in the anisotropic porous layer. The lower plate z = 0 is preserved at the regular temperature T0 + ΔT while the top plate z = d is reserved at a temperature T0 as shown in Figure 1.

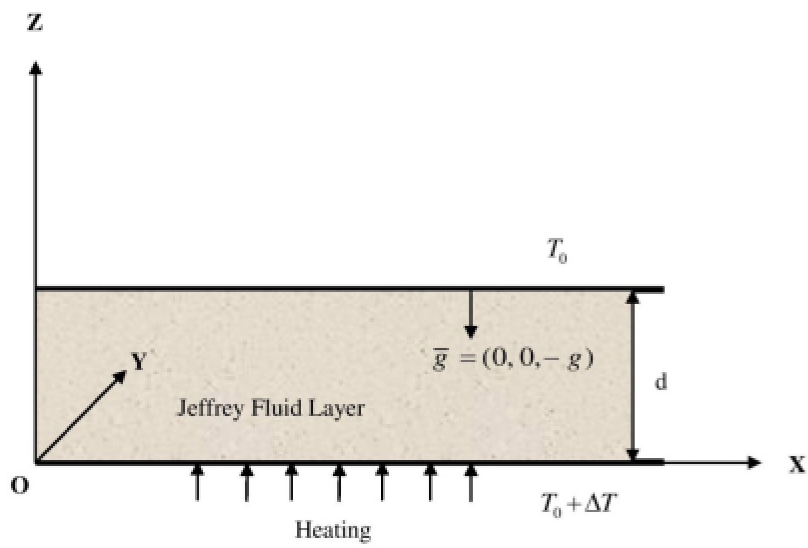

Figure 1 Physical configuration

The Darcy law is adjusted to comprise the Jeffery parameter and the Boussinesq assessment is used for density deviations. The governing equations in non-dimensional form are as follows:

$$\nabla \cdot \bar{q} = 0 \qquad (1)$$

$$\frac{\overline{q}(\xi)}{(1+\lambda)} = -\nabla P - Ra_\rho \overline{e}_z + Ra_T T \overline{e}_z \quad (2)$$

$$\frac{\partial T}{\partial t} + (\overline{q}\cdot\nabla)T = \eta\left(\nabla_H^2 T\right) + \frac{\partial^2 T}{\partial z^2} \quad (3)$$

where the non-dimensional parameters: $\overline{q} = (u, v, w)$ is the velocity vector, $\overline{q}(\xi) = \left(\frac{1}{\xi}u, \frac{1}{\xi}v, w\right)$ is the modified anisotropic velocity vector, $\xi = \frac{K_{mx}}{K_{mz}}$ is the mechanical anisotropic parameter, $Ra_\rho = \frac{\rho_0 g d K_{mz}}{\alpha_{mz}\mu}$ is the temperature, is the thermal anisotropic parameter, is the density Rayleigh number, $Ra_T = \frac{g_0 \beta_T \Delta T K_{mz} d}{\alpha_{mz}\mu}$ $\eta = \frac{\alpha_{mx}}{\alpha_{mz}}$ is the thermal Rayleigh number, $\nabla_H^2 = \frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2}$ and $\nabla^2 = \frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2} + \frac{\partial^2}{\partial z^2}$.

Using linear stability, the expressions for thermal Rayleigh number for stationary and oscillatory convection modes is obtained as follows:

$$Ra_T = \frac{\left(\pi^2 + \xi a^2\right)\left(\pi^2 + \eta a^2\right)}{a^2 \xi (1 + \lambda)} \quad (4)$$

The equations (1)-(3) modeled for the system provides the common expression of thermal Rayleigh number for both stationary and oscillatory modes of instabilities. Thus the oscillatory modes of instability has been ruled out and hence we required to consider only the case of stationary mode of instability.

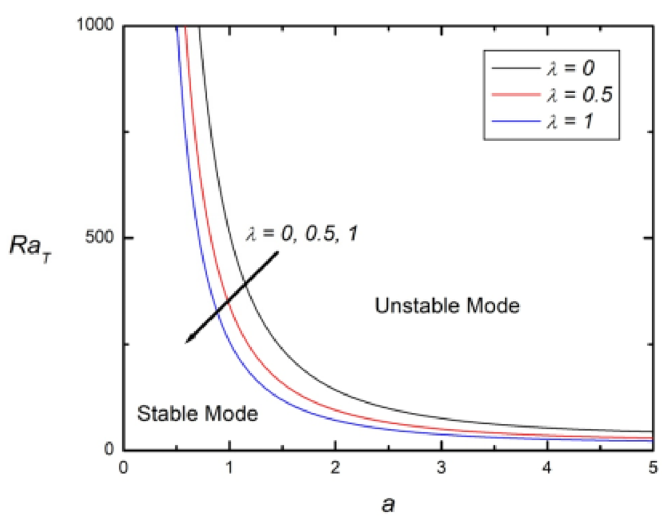

Figure 2 Effect of Jeffery parameter on space

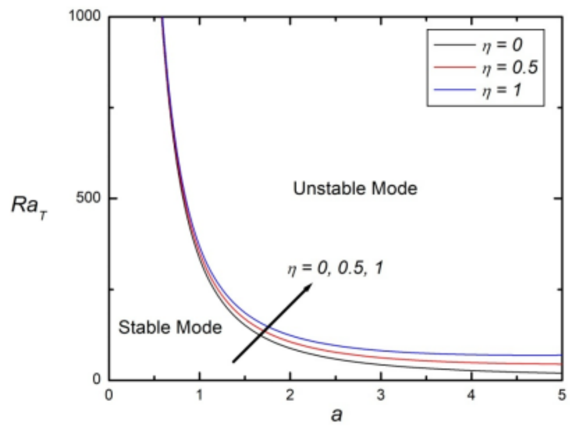

Figure 3 Effect of thermal anisotropy parameter η on space

3. CONCLUSION

This research work presents approximate analytical solutions for the unsteady flows of Jeffrey fluids over a porous, oscillating plate with MHD and porosity effect.

Approximate analytical solutions for the non dimensional velocity field in the transformed domain have been obtained using the Laplace transform and perturbation method.

Graphs have been plotted to examine the effect of embedded parameters on the velocity profile of the fluid. The following observation is perceived by these graphs:

1) The velocity distribution increases with the increasing values of the time.
2) By increasing the parameter ratio of relaxation and retardation time, it leads to decay in retardation time in result the velocity profile is decreasing.

CONFLICT OF INTERESTS

None.

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