EFFECT OF RAMPED WALL TEMPERATURE ON UNSTEADY MIXED CONVECTION FLOW OF ROTATING SECOND GRADE FLUID IN POROUS MEDIUM

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ABSTRACT

The effects of ramped wall temperature, rotation and porosity on mixed convection flow of incompressible second grade fluid are studied. The momentum equation is modelled in a problem of rotating fluid with constant angular velocity subjected to initial and oscillating boundary conditions. The energy equation is also introduced. Some suitable non-dimensional variables are used to write equations into non-dimensional form. Laplace transform method is used to solve these equations in order to obtain the analytical solutions of velocity and temperature profiles. Computations are carried out and presented graphically to analyse the effect of second grade fluid parameter, rotation parameter, porosity parameter, Prandtl number and Grashof number on the profiles. It is found that, for larger values of porosity parameter, the fluid velocity will increase for both primary and secondary velocities. The results also show that, velocity and temperature for ramped wall temperature are lower compared to isothermal temperature. It is worth to mention that, the exact solutions obtained in this study can be used to check correctness of the results obtained through numerical schemes.

Key words: Mixed convection, Second grade fluid, Rotating, Ramped wall, Porous medium

INTRODUCTION

Second grade fluid in a porous medium with the effect of ramped wall temperature has been studied extensively in the literature due to its engineering and industrial applications in food and polymer production, fiber and granular insulation and geothermal systems [1-4]. Further, researchers are focused and contributed new problems on effect of rotation in second grade fluid with ramped wall temperature. For example, [5] has investigated the behavior of velocity of fluid flow that affected by rotation effect and temperature changing. Then, [6] extended the problems of [5] by considering the effects of porosity, magnetic and concentration. They found that, the velocity of fluid flow for ramped wall temperature is always lower compared to isothermal temperature. Recently, [7] solved a new problem of heat transfer in rotating second grade fluid through an oscillating plate. Their results shown that, the effect of oscillation for sine and cosine parts in fluid flow gave a same behavior of embedded parameters except for phase angle. In all the above studies, Laplace transform technique has been used to obtain the solutions of the problems. Motivated by these works, the aim of the present study is to provide the exact solutions for rotating second grade fluid on mixed convection flow in porous medium with the effect of ramped wall temperature. In this study, x-axis is taken along the plate in the upward direction and z-axis is taken normal to plate. Initially, both the fluid and plate are at rest to a constant temperature T_∞. At $t = 0^+$, the plate oscillates and fluid starts to rotates with constant angular velocity Ω. At the same time, the temperature of plate is raised or lowered at $T_\infty + (T_w - T_\infty)t/t_0$ when $t \leq 0$ and thereafter, for $t > t_0$ is maintained at the constant temperature T_w. Therefore, under the usual assumption of Boussinesq approximation, the governing equations of momentum and energy are given as

$$\frac{\partial F}{\partial t} + 2i\Omega F = \upsilon \frac{\partial^2 F}{\partial y^2} + \frac{\alpha_1}{\rho}\frac{\partial^3 F}{\partial y^2 \partial t} - \frac{\mu\phi}{\rho k_1}\left(1 + \frac{\alpha_1}{\mu}\frac{\partial}{\partial t}\right)F + g\beta\left(T - T_\infty\right) \tag{1}$$

$$\frac{\partial T}{\partial t} = \frac{k}{\rho c_p}\frac{\partial^2 T}{\partial z^2}, \tag{2}$$

subjected to initial and boundary conditions

$$\begin{gathered} F(0,t) = UH(t)\cos(\omega_1 t) \text{ or } F(0,t) = \sin(\omega_1 t), \\ F(z,t) = 0 \text{ as } z \to \infty;\ t > 0, \\ F(z,0) = 0\ ;\ z > 0, \end{gathered} \tag{3}$$

and

$$\begin{gathered} T(0,t) = T_\infty + (T_w - T_\infty)\frac{t}{t_0};\ 0 < t \leq t_0, \\ T(0,t) = T_w : t > t_0, \\ T(z,t) \to T_\infty \text{ as } z \to \infty;\ t \geq 0. \\ T(z,0) = T_\infty\ ;\ z \geq 0, \end{gathered} \tag{4}$$

where $F = u + iv$ is the complex velocity, u is a primary velocity, v is a secondary velocity, ρ is the density of fluid, υ is the kinematic viscosity, α_1 is second grade parameter, $\phi(0 < \phi < 1)$ is the porosity and $k_1 > 0$ is the permeability of the porous medium, μ is dynamic viscosity, g is the acceleration due to gravity, β is the volumetric coefficient of thermal expansion, T is the temperature of the fluid, k is thermal conductivity and c_p is the specific heat capacity of the fluid at constant pressure.

MAIN RESULTS

After solving the dimensionless equations, the expressions for velocity and temperature have been obtained. From observations of the plotted graphs, the amplitude of velocity in case of isothermal plate is greater and converges slowly as compare to ramped velocity. On the other hand, the velocity increases with increasing porosity effect. This is because the bigger porosity effect of the fluid will reduce the drag force and hence causes the velocity to increase.

CONCLUSION

In this study, exact solutions for velocity and temperature have been successfully obtained. The effects of important embedded parameters on the fluid flow characteristics have been investigated. It is worth to mention that, the present results satisfy all the boundary conditions and found an excellent aggrement with the published research by [2]. It is interesting to extend this problem by considering the effect of magnetic field in mixed convection flow.

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