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Double diffusive MHD flow of a chemically reacting Alumina nanofluid past a semi-infinite flat plate: Part 2

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ABSTRACT

The study of Double diffusive MHD flow of a chemically reacting Nanofluid is presented in this paper. The solution to the governing equations was obtained by the collocation weighted residual method; mathematical results analyzed showed that for an increase in the chemical reaction and Soret term, the concentration profile increased. Thermal Grashof parameter in terms of concentration together with the Hartmann parameter when increased, lead to a decrease in the velocity profile of the fluid. But the Reynolds parameter when increased brought about an improvement on the velocity of the fluid.

Keywords: Alumina nanofluid, Flate Plate, Double diffusivity, Collocation weighted residual method, Magnetohydrodynamics, Reynolds number

1. INTRODUCTION

In recent years nanofluid has been seen to have a significant impact on the transfer of heat enhancement. They have been applied in different technologies involving turbulent flows [1]. Geothermic [2] porous media solar collector [3,4] propulsion [5] and chemical engineering coating processes [6] and other uses. Nanofluids make-up a significant class of the transfer of heat fluid gotten by dispersing certain nanoparticles (<100 nanometer in diameter) in conventional poor thermal conductivity based fluid. [7], nanofluids are capable of enhancing thermo-physical properties such as thermal conductivity heat transfer coefficients compared to those of the base fluids like water, ethylene or triethylene, glucose and other coolants, biofluids and polymeric solutions as explained by [8] and [9].

[10] Studied the chemically reaction fluid flow induced by exponentially accelerated infinite vertical plate in a magnetic field and variable temperature. From their study they found out that the momentum boundary layer thickness increases for the fluid with Pr<1 and decreases for Pr>1. Also, from their findings temperature decreases on increase in the Pr. As Schmidt number increases, the velocity and concentration decreases. [11] Tackled the group analysis of free convection flow of a magnetic nanofluid with chemical reaction. They found out that nanoparticle volume fractions are decreased with increasing order of chemical reaction and with increasing magnetic field parameter, nanoparticle volume fraction and temperature are enhanced. [12] Investigated variable viscosity effect of Duffor, Soret and thermal conductivity on free convective heat and mass transfer of Non-Dracian flow past porous flat surface using the Runge-Kutta fourth-order method and Newton- Raphison's interpolation Scheme. Their result showed that increase in Duffor and Soret parameter, fluid velocity increases and temperature increases with increase in variation of Dufour while, temperature decreases with increase in Soret.

[13], double diffusive Magnetohydrodynamic heat and mass transfer of nanofluids over a non-linear stretching/shrinking sheet with viscous-ohmic dissipation and thermal radiation. They adopted the non-similarity method for the transformation of the governing equations and used the Runge-Kutta –fehlberg method using shooting technique. This work is a continuation of PART 1 (Ngiangia A.T. and Nwabuzor P.O. Double Diffusive MHD Flow of a Chemically Reacting Alumina Nanofluid Past a Semi-infinite Flat Plate *(World Scientific News*. 119, 168-180).

2. GOVERNING EQUATION

Following from **PART 1**, the transformed governing equation from Part 1 of this work is given as

$$\frac{\partial U}{\partial t} = -\rho_{nf} + \mathrm{Re}_{nf}^{-1}\frac{\partial^2 u}{\partial y^2} + HaU + G_t\theta + G_c C + h\frac{\partial U}{\partial y} \qquad 12$$

$$\frac{\partial \theta}{\partial t} = \left(\frac{1+N}{\mathrm{Pr}}\right)\frac{\partial^2 \theta}{\partial y^2} + Du\frac{\partial^2 C}{\partial y^2} + h\frac{\partial \theta}{\partial y} \qquad 13$$

$$\frac{\partial C}{\partial t} = \frac{1}{Sc}\frac{\partial^2 C}{\partial y^2} - K_0 C + Sr\frac{\partial^2 \theta}{\partial y^2} + h\frac{\partial C}{\partial y} \qquad 14$$

With the boundary conditions also in part 1 given as

$$\begin{matrix} c' = 0 & \theta' = 0 & U = 0 \\ c = 1 + \varepsilon e^{nt} = h & \theta = 1 + \varepsilon e^{nt} & U' = 0 \end{matrix} \quad \text{at } y = 0$$

3. METHOD OF SOLUTION

The method adopted to resolve equations 12-14 is the collocation weighted residual method

Where

$$-\rho_{nf} = 1$$

$$\left(1 + \varepsilon e^{nt}\right) = h$$

From equation 14 we use the

Let

$$C(y) = x_0 + x_1 y + x_2 y^2 + x_3 y^3 + x_4 y^4 + x_5 y^5 + x_6 y^6 + x_7 y^7 + x_8 y^8 \qquad 15$$

Where $\frac{\partial C}{\partial t} = k = 0$

$$\varepsilon_i = -C_{app} + \sum_{k=0}^{\alpha} \alpha_k \phi_k \qquad 16$$

with

$$\phi_1 = y(1-y) \qquad 17$$

Therefor solution to equation 14 which is the concentration equation is

$$C_{app} = \left[-6Sc^{-1} - k_0 - 2h - 2Sr\right]y^3 + \left[\frac{-3h}{7} + 6Sc^{-1} + K_0 + 2h + Sr\right]y^2 + \left[\frac{3h}{7} - 36Sc^{-1} - 6k_0 - 12h - 36Sr\right]y + \left[\frac{-6h}{7} + 12Sc^{-1} + 2k_0 + 4h + 12Sr\right] \qquad 18$$

From equation 13

$$\theta(y) = b_0 + b_1 y^1 + b_2 y^2 + b_3 y^3 + b_4 y^4 + b_5 y^5 + b_6 y^6 + b_7 y^7 + b_8 y^8 \qquad 19$$

Solution to the energy equation is

$$\theta_{app} = \left[-6\Pr^{-1} - 6N\Pr^{-1} - 6Du - 2h\right]y^3 + \left[\frac{-3h}{5} - 12h - 6\Pr^{-1} - 6N\Pr^{-1}\right]y^2 + \left[\frac{3h}{5} + 4h - 42\Pr^{-1} - 36Du\right]y + \left[\frac{-6h}{5} + 12Du + 12\Pr^{-1} + 12N\Pr^{-1}\right] \qquad 20$$

From equation 12 using the collocation weighted residual method

$$U(y) = a_0 + a_1 y + a_2 y^2 + a_3 y^3 + a_4 y^4 + a_5 y^5 + a_6 y^6 + a_7 y^7 + a_8 y^8 \qquad 21$$

The solution to equation 12 after imposing the boundary equation is

$$U_{app} = \left[-6Ra_{nf}^{-1} - Ha - Gt - Gc - 2h\right]y^3 + \left[\frac{3}{5} + 6Ra_{nf}^{-1} + 6Ha + Gt - Gc + 2h\right]y^2 + \left[\frac{-3}{5} - 36Ra_{nf}^{-1} - 6Ha - 6Gt - Gc - 12h\right]y + \left[\frac{6}{5} + 12Ra_{nf}^{-1} + 2Ha = 2Gt + 2Gc + 4h\right] \qquad 22$$

Material Parameters and constant

$$Sc = 1.50, 3.00, 4.50, 6.00, 7.500$$
$$Sr = 1.00, 2.00, 4.00, 5.00, 6.00$$
$$K_0 = 1.25, 2.50, 3.75, 5.00, 6.25$$
$$N = 1.00, 2.00, 3.00, 4.00, 5.00$$
$$\Pr = 0.70, 1.70, 2.70, 3.70, 4.70$$
$$Du = 1.30, 2.60, 3.90, 4.20, 5.50$$
$$\mathrm{Re} = 10.0, 20.0, 30.0, 40.0, 50.0$$
$$Ha = 0.30, 0.60, 0.90, 1.20, 1.50$$
$$Gt = 1.00, 2.00, 3.00, 4.00, 5.00$$
$$Gc = 0.90, 1.80, 2.70, 3.60, 4.4$$

h= 1, n = 1, t = 1

4. PRESENTATION OF RESULTS

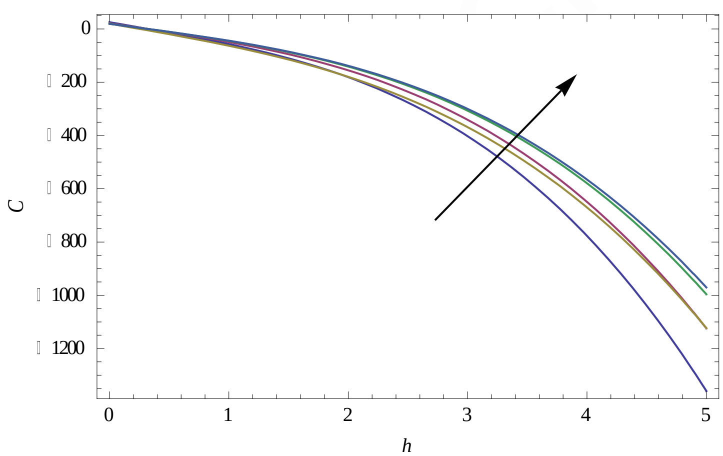

Figure 1 Concentration profile (C) against boundary layer y for varying Schmidt parameter Sc

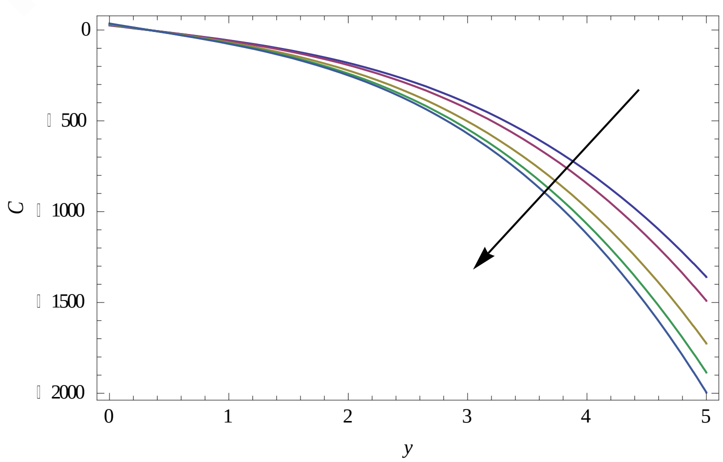

Figure 2 Concentration profile (C)against boundary layer y for varying chemical reaction parameter k_0

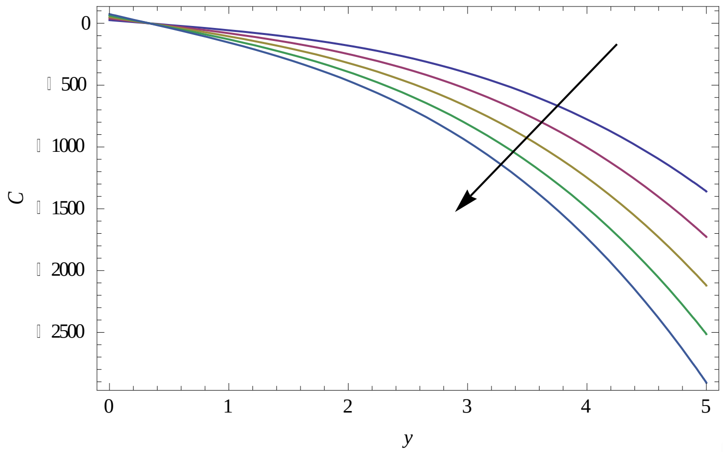

Figure 3 Concentration profile (C) against boundary layer y for varying Soret parameter Sr

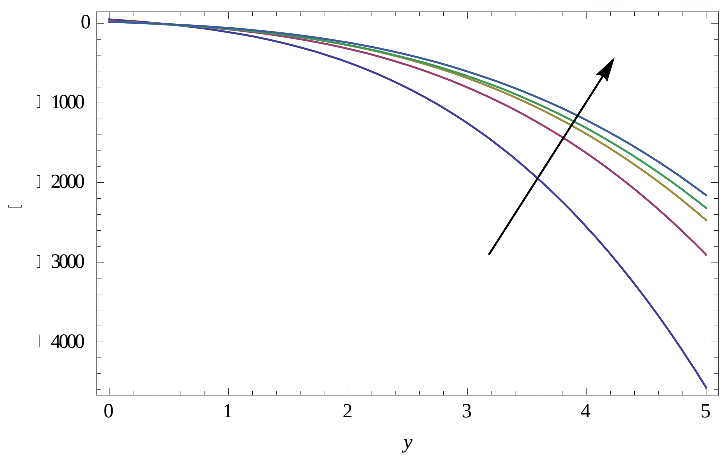

Figure 4 Temperature profile (θ) against boundary layer y for varying Prandtl parameter Pr

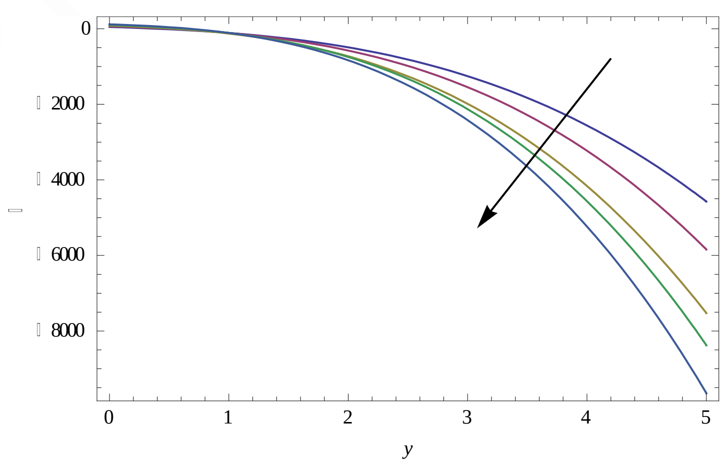

Figure 5 Temperature profile (θ) against boundary layer y for varying Radiation parameter N

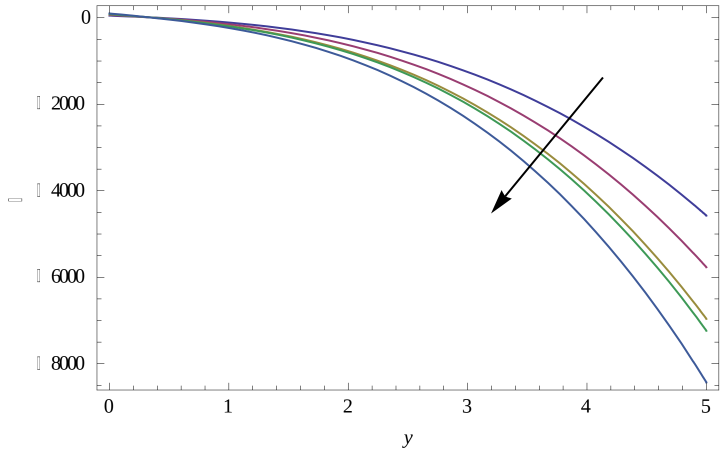

Figure 6 Temperature profile (θ) against boundary layer y for varying Duffor parameter Du

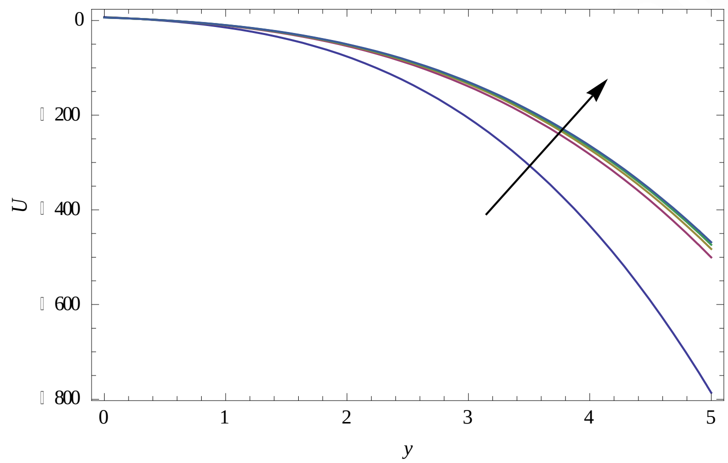

Figure 7 Velocity profile (U) against boundary layer y for varying Reynolds parameter Ra

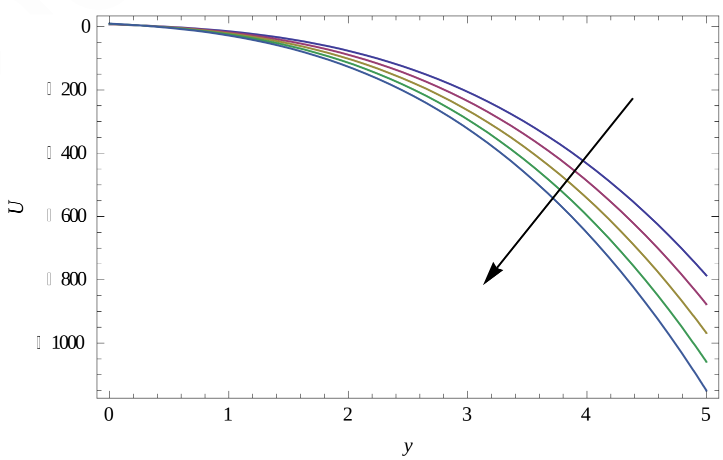

Figure 8 Velocity profile (U) against boundary layer y for varying Hartmann parameter Ha

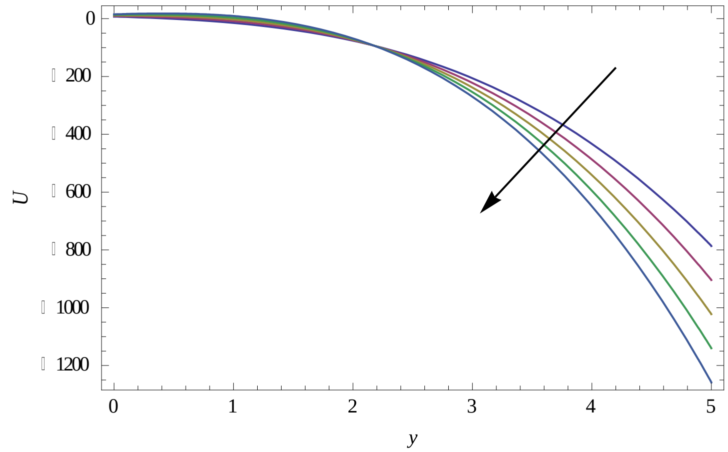

Figure 9 Velocity profile (U) against boundary layer y for varying Grashof parameter in terms of temperature G_t

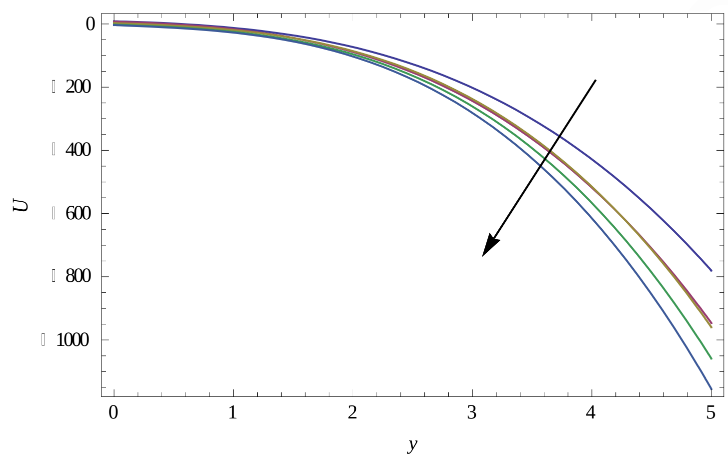

Figure 10 Velocity profile (U) against boundary layer y for varying Grashof parameter in terms of concentration G_c

5. DISCUSSION OF RESULT

The result analyzed showed that for Fig 1. An increase in the Schmidt parameter there is a corresponding is increase in the concentration profile of the fluid. This goes to show that Schmidt term helps to improve on the concentration profile of the fluid. From Fig 2 we see that the chemical reaction term brings about a decline in the concentration profile of the fluid. The result analyzed showed that with an increase in the chemical reaction term the concentration profile drops. The Soret parameter from Fig 3 had the same effect as the chemical reaction term. When the Soret term was increased the concentration decreased.

From Fig 4 an increase in the Prandtl parameter lead to an increase in the temperature profile of the fluid. This indicates that the activities of the Prandtl parameter, increases the temperature of the fluid. These results are in agreement with the results obtained by [7]. The Radiation effect as indicated in Fig 5 shows that when the radiation parameter is increased the temperature profile drops. From Fig 6 Increase in the Duffor term will bring about a decrease in the temperature profile. This result negates the findings of [11]

Also, from Fig 7 an increase in the Reynolds number brings about an increase in the velocity profile of the fluid. This also is in conformity with the result from the part 1 of this work [13]. From Fig 8 indicates that when the Hartman parameter is increases there will be a corresponding decrease in the velocity profile, this goes to show that the magnetic field term impedes on the free flow of the fluid. In Fig 9 the thermal Grahoffs parameter when increase, brought about a decrease in the velocity profile of the fluid. The same was observed in Fig 10 for the Grahofs parameter in terms of concentration. We see that all the activities of the material parameter in the velocity equation bring a decline in the velocity profile of the fluid.

6. CONCLUSIONS

In this work we have examined Diffusive MHD flow of a Chemically Reacting Alumina Nanofluid Past a Semi-infinite Flat Plate. We looked at the effect of several material parameters on the concentration, Temperature and the Velocity profile of the fluid which was ignored in the part one of this work. From the present study, the following conclusion is drawn.

(i). The Schmidt parameter and the chemical reaction term have an opposite effect on the concentration profile of the fluid. The Chemical reaction term and the Soret parameter all improved on the concentration of the fluid.

(ii) The radiation and the Prandtl parameter when increased brought about an increase in the temperature profile of the fluid. But the Dufor parameter brings about a decrease in the temperature profile of the fluid.

(iii) The Hartmann parameter and the Reynolds parameter acted in an opposite fashion on the velocity profile of the fluid. For the Reynolds parameter at values of (10,20,.., 50) leads to an increases in the velocity profile of the fluid.

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