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MHD Mixed Convection Stagnation Point Flow with Binary Chemical Reaction and Activation Energy

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Abstract:
The goal of the present learning is to examine MHD mixed convection stagnation point flow near a vertical plate in a porous medium with Binary chemical reaction and Activation energy. The governing boundary layer equations are distorted into a set of ordinary differential equations using similarity transformations and then are solved by using finite difference method. The obtained numerical consequences for various non-dimensional parameters are illustrated graphically.

Keywords— **MHD, Mixed Convection, Binary chemical reaction, Activation energy.**

1. Introduction

The stagnation point flow of Magneto hydrodynamics is considered towards a vertical plate. It becomes relevant to many Science and industrial applications like paper production and extrusion of plastic sheets etc. Vertical permeable porous plate with Heat source/sink was analyzed by Yih (1998) [1]. Mahapatra and Gupta (2002) have discussed the Stagnation point flow towards a stretching sheet with heat transfer effect [2]. Alam*et al*. (2006) was investigated the mixed convection flow past a porous plate with the effect of Dufour and Soret [3]. Effects of variable and thermal conductivity on MHD flow over a linearly stretching sheet with heat source /sink evaluated by Sharma and Singh (2009)[4]. Singh *et al.*(2010) obtained the Mixed convection stagnation point flow on an iso-thermal vertical plate with the effects of heat generation and absorption[5]. On steady boundary layer stagnation point flow towards a shrinking sheet with the effects of Suction/blowing was examined by Bhattacharyya and Layek (2010) [6]. Postelnicu (2010) was exposed the effects of dufour and soret in Natural convection stagnation point flow with heat and mass transfer [7]. Vempati *et al.*(2010) was studied the soret and Dufour effects on unsteady MHD flow past a vertical porous plate with thermal radiation[8]. Makinde (2011) established MHD stagnation point flow toward a vertical plate with heat and mass transfer [9]. Afify *et al.*(2012) studied MHD stagnation point flow of heat and mass transfer with suction or injection[10].

In this present study, we investigate MHD mixed convection stagnation point flow near a vertical plate in a porous medium with Binary chemical reaction and Activation energy. The non-dimensional parameters are analysed with the help of graphs.

2. Mathematical model

Let us consider the steady, incompressible, two-dimensional MHD stagnation-point flow, heat and mass transfer with electrically conducting fluid through a porous medium along a vertical plate in the presence of magnetic field. Assume that the volumetric heat generation/absorption and first order homogeneous chemical reaction. The magnetic field strength B_o is imposed along the y-axis. The velocity distribution of the flow is $U_\infty = cx$, where c is a positive constant. The Basic equations of continuity, momentum, Energy transfer and concentration are given by,

$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}=0 \tag{1}$$

$$u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}=v\frac{\partial^2 u}{\partial y^2}+g\beta(\mathrm{T}-\mathrm{T}_\infty)+\mathrm{g}\beta^*(\mathrm{C}-C_\infty)-\left(\frac{\sigma_\varepsilon B_0^2}{\rho}+\frac{\nu}{\tilde{\mathrm{K}}}\right)(\mathrm{u}-\mathrm{U}_\infty)+\mathrm{U}_\infty\frac{dU_\infty}{dx} \tag{2}$$

$$u\frac{\partial T}{\partial x}+v\frac{\partial T}{\partial y}=\alpha\frac{\partial^2 T}{\partial y^2}-\frac{\alpha}{k}\frac{\partial q_r}{\partial y}+Q(\mathrm{T}-\mathrm{T}_\infty)+\mathrm{D}_B\frac{\partial^2 C}{\partial y^2} \tag{3}$$

$$u\frac{\partial C}{\partial x}+v\frac{\partial C}{\partial y}=D_B\frac{\partial^2 C}{\partial y^2}+\frac{D_T}{T_\infty}\frac{\partial^2 T}{\partial y^2}-K_r^2(\mathrm{C}-C_\infty)\left(\frac{T}{T_\infty}\right)^n e^{\left(-\frac{E_a}{\kappa T}\right)} \tag{4}$$

We introduce the term $K_r^2(\phi-\phi_\infty)\left(\frac{T}{T_\infty}\right)^n e^{\left(-\frac{E_a}{\kappa T}\right)}$ in equation (4) represents the modified Arrhenius equation where K_r^2 =the reaction rate, E_a =activation energy, κ = 8.61x10^{-5}eV/K the Boltzmann constant and n = fitted rate constant which generally lies in the range -1 < n < 1.

The appropriate boundary conditions are

$$u=0, v=0, T=T_w, \mathrm{C}=C_\omega \text{ as } y=o$$
$$u\to U_\infty=cx, T\to T_\infty, C\to C_\infty \text{ as } y\to\infty \tag{5}$$

The Stefan Boltzmann radiation constant defined as

$$q_r=-\frac{4\sigma^*}{3K'}\frac{\partial T^4}{\partial y} \tag{6}$$

Where σ^* and k′ are the Stefan-Boltzmann constant and the mean absorption coefficient, respectively. Using the Rosseland approximation the temperature term given by

$$T^4=4T_\infty^3 T-3T_\infty{}^4 \tag{7}$$

Equation (7) is substituted in (3) for temperature. We introducing the following dimensionless variable and parameters

$$\eta=y\sqrt{\frac{c}{\upsilon}}, \Psi(\mathrm{x},\mathrm{y})=\sqrt{\upsilon c}\,xf(\eta), \mathrm{C}_r=\frac{\Gamma_0}{c}, \theta(\eta)=\frac{T-T_\infty}{T_\omega-T_\infty}, \phi(\eta)=\frac{C-C_\infty}{C_\omega-C_\infty}, Gr_T=\frac{g\beta(\mathrm{T}_\omega-\mathrm{T}_\infty)\mathrm{x}^3}{\upsilon^2},$$
$$Gr_c=\frac{g\beta^*(\mathrm{C}_\omega-C_\infty)\mathrm{x}^3}{\upsilon^2}, Ri_T=\frac{Gr_T}{\mathrm{Re}_x^2}, Ri_c=\frac{Gr_c}{\mathrm{Re}_x^2}, \mathrm{Re}_x=\frac{U_\infty x}{\upsilon}, Rd=\frac{4\sigma^* T_\infty^3}{kK'}, K=\frac{\upsilon}{c\tilde{K}}, Sc=\frac{\upsilon}{D},$$
$$M=\frac{\sigma_\varepsilon B_0^2}{c\rho}, S=\frac{Q\upsilon}{\alpha c}=\mathrm{Pr}\frac{Q}{c}, D_f=\frac{D_B}{\alpha}\frac{(C_\omega-C_\infty)}{(\mathrm{T}_\omega-\mathrm{T}_\infty)}, E=\frac{E_a}{\kappa T}, \sigma=\frac{K_r^2}{c}, \delta=\frac{T_w-T\infty}{T\infty}, \tag{8}$$

Where ψ is the stream functions which is defined as $u=\frac{\partial\psi}{\partial y}$, $v=\frac{\partial\psi}{\partial x}$, we obtain the following nonlinear ordinary differential equations from the equation(1)- (5) as follows

$$f'''+ff''-f'^2+Ri_T\theta+Ri_c\phi-(\mathrm{K}+\mathrm{M})(f'-1)+1=0 \tag{9}$$

$$(1+\frac{4}{3}\mathrm{Rd})\theta''+\mathrm{Pr}\,f\theta'+S\theta+D_f\phi''(\eta)=0 \tag{10}$$

$$\phi''(\eta)+\mathrm{Sc}\,f\phi'+S_t\theta''-Sc\sigma(1+\delta\theta)^n\phi e^{\left(-\frac{E}{1+\delta\theta}\right)}=0 \tag{11}$$

The corresponding boundary conditions are

$$f=0, f'=0, \theta=1, \phi=1 \text{ as } \eta=0 \tag{12}$$
$$f'=1, \theta=0, \phi=0, \text{ as } \eta\to\infty$$

where Gr_c is solutal Grashof number, Gr_T is thermal Grashof number, K is a porous medium permeability parameter, M is magnetic field parameter, Pr is Prandtl number, Rd is a thermal radiation parameter, Ri_c is the solutal Richardson number, Ri_T is the thermal Richardson number, n is the rate constant, σ is reaction rate, δ is temperature difference parameter .E is Activation energy.

3. Numerical Analysis

In this study, we investigated MHD mixed convection stagnation point flow towards a vertical plate in a porous medium with binary chemical reaction and activation energy. The governing boundary layer equations are transformed into a set of ordinary differential equations using similarity transformation. Then they are solved by finite difference method. From the process of numerical computation, concentration profile is illustrated graphically.

4. Results and discussion

In this part, our focus is to investigate the role of embedded parameters, such as Activation energy E, rate constant *n*, reaction rate σ , temperature difference parameter δ , Schmidt number Sc respectively on concentration profile from the graphical results.

Fig.1 portrays the concentration profile for different values of Activation energy E. Concentration profile enhanced with the increasing values of Activation energy E.

Fig.2 depicts that concentration profile rises when fitted rate constant *n* is increased.

Fig.3 presented the influence of reaction rate σ on concentration profiles. Concentration profile reduces when value of reaction rate σ is incremented.

The behaviour of temperature difference parameter δ on Concentration profile is visualized in Fig.4. Concentration profile destructs with the increasing value of temperature difference parameter δ .

In Fig.5, It is observed that the influence of Schmidt number Sc on concentration profile. It demonstrates that increasing values of Schmidt number thins the Concentration boundary layer.

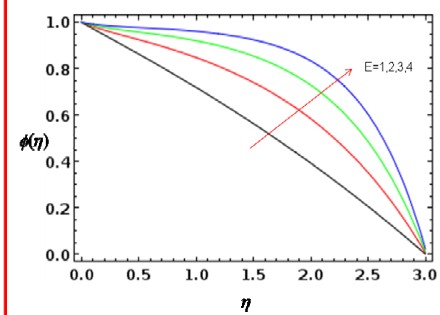

Fig.1 Concentration profiles for different values of E with Sc = 1, n = 0.5, δ = 1,σ=1, S_t =1

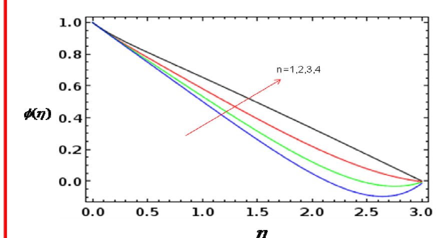

Fig.2 Concentration profiles for different values of E with Sc = 1, E=1, δ = 1,σ=1, St=1

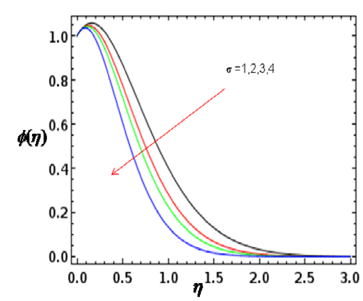

Fig.3 Concentration profiles for different values of σ with Sc = 1, n = 0.5, δ = 1, St =1,E=0.5

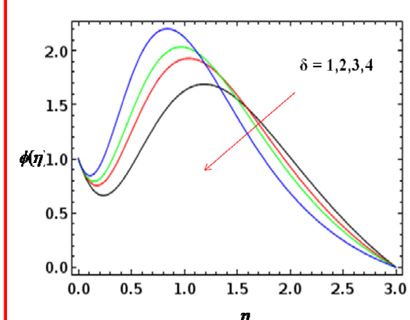

Fig.4 Concentration profiles for different values of δ with Sc = 1, n = 0.5, σ=1, St =1, E=0.5

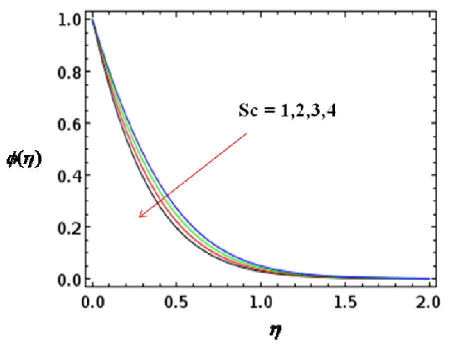

Fig.5 Concentration profiles for different values of Sc with δ = 1, n – 0.5, σ–1, St –1, E–0.5

5. Conclusion

In this paper, we studied binary chemical reaction on MHD mixed convection stagnation point flow near a vertical plate in a porous medium. The main findings are shortened as follows:

- Concentration profile enhanced with the increasing values of Activation energy E.
- Concentration profile rises when fitted rate constant *n* is increased.
- Concentration profile reduces when value of reaction rate σ is incremented.
- Increasing values of Schmidt number thins the Concentration boundary layer.

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