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Computational analysis of magnetohydrodynamic Casson and Maxwell flows over a stretching sheet with cross diffusion

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ABSTRACT

This paper reports the magnetohydrodynamic chemically reacting Casson and Maxwell fluids past a stretching sheet with cross diffusion, non-uniform heat source/sink, thermophoresis and Brownian motion effects. Numerical results are obtained by employing the R-K based shooting method. Effects of pertinent parameters on flow, thermal and concentration fields are discussed with graphical illustrations. We presented the tabular results to discuss the nature of the skin friction coefficient, reduced Nusselt and Sherwood numbers. Dual nature is observed in the solution of Casson and Maxwell fluids. It is also observed a significant increase in heat and mass transfer rate of Maxwell fluid when compared with the Casson fluid.

Introduction

Heat and mass transfer of non-Newtonian fluids past a stretching/shrinking surface plays an important role in fluid dynamics. This study has various applications in chemical engineering and metallurgy. Heat and mass transfer of non-Newtonian flows over a stretching surface has various applications in the modern technology and geothermal engineering as well as other geophysical and astrophysical bio-fluid studies. Also, it has the applications in the field of manufacturing plastic production, cooling of elastic sheets, fiber technology, polymer chemistry and engineering. The heat transfer and flow properties of the Casson fluid are much more essential for many industrial processes [1–3]. Hamad [4] presented the systematic solution by assuming the reaction of magnetic flow for the electrically conducting MHD flow past a shrinking sheet. The convective boundary layer flow over a nano porous stretching surface was discussed by Liao [5]. Anderson et al. [6] analyzed the first order reaction in mass diffusion of chemical reaction past a stretching/shrinking surface. The magnetohydrodynamic convective flow past a stretching sheet under the radiation effect was studied by Seddek and Almushigeh [7]. In this paper, they used two methods namely, secant and Runge-kutta fourth order to solve the initial value problem. Muthucumarasamy [8] discussed the role of chemical reaction on isothermal vertical long stretching surface with suction. The role of MHD boundary layer flow past a stretching/shrinking sheet was discussed by Anjali Devi and Kandasamy [9].

Afify [10] examined the influence of chemical reaction and radiation with magnetic parameter on mass transfer and MHD convective flow of heavy viscous, electrical conducting fluid over an isothermal cone surface. The impact of heat and mass transfer of Casson fluid on over a vertical shrinking sheet is investigated by Kandasamy et al. [11]. Beg et al. [12] analysed the two dimensional convective heat flow in a Darcy porous medium by using numerical difference method. Eldabe and Salwa [13] was studied the Casson fluid flow between two rotating cylinder. The heat and mass transfer of Maxwell fluid past a stretching sheet with chemical reaction was discussed by Mukhopadhyay [14,15] and Chamkha et al. [16] and concluded that thermal and horizontal velocity decreases with increasing convection profiles. Also found that rising the slip parameter deadlines increasing heat transfer. The time dependent of Casson fluid past a stretching surface was investigated by Awais and Hayat [17].

Vyas and Ranjan [18] studied the MHD flow over a non-linear stretching sheet through porous medium. The laminar convective air flow over a vertical plate, occupation of chemical concentration was discussed by Chamkha et al. [19] and found a numerical solution using Blottner difference method. Dursunkaya and Worek [20] investigated the cross diffusion effects on transient free convective

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Nomenclature

a	non-negative constant
B_0	constant magnetic field (kg/(S^2 A))
C_∞, C_f	free stream and surface particle concentrations (kg/m^3)
C	nanoparticle concentration (kg/m^3)
C_p	specific heat (J/(kg K))
D_T	coefficient of thermophoretic (m^2/s)
k	thermal conductivity of the fluid (W/(m K))
D_B	coefficient of Brownian diffusion (m^2/s)
D_m	mass diffusivity
C_{fx}	skin friction coefficient
C_s	concentration susceptibility
v_w	suction/injection velocity
k_T	thermal diffusion ratio
f	similarity variable
Bi	Biot number
Nu_x	local Nusselt number
Pr	Prandtl number
Le	Lewis number
Sr	Soret number
Df	Dufour number
Sh_x	local Sherwood number
M	magnetic field parameter
S	suction/blowing parameter
Nt	thermophoresis parameter
Nb	Brownian motion parameter
T	fluid temperature
T_f, T_∞	surface fluid temperature (K)
T_∞	free stream temperature
k_0	relaxation time
Q_0	heat generation/absorption coefficient
k_1	rate of chemical reaction
x, y	cartesian coordinates (m)
u, v	flow component along x and y directions (m/s)

Greek symbols

σ	fluid electrical conductivity
α	thermal diffusivity (m^2/s)
β	Casson parameter
λ, γ, δ	elastic, chemical reaction and heat generation/absorption parameters
η	similarity independent variable
θ	non dimensional temperature
ν	kinematic viscosity capacity of the nanoparticle material (m^2/s)
μ	dynamic viscosity (kg/(ms))
ρ_f	fluid flow density (kg/m^3)
$(\rho C_p)_f$	fluid heat capacity (J/(m^3 k))
$(\rho C_p)_s$	heat capacity of the surface (J/(m^3 k))
τ	nanoparticle to base fluid heat capacity ratio
ϕ, ψ	non dimensional nanoparticle concentration and stream function

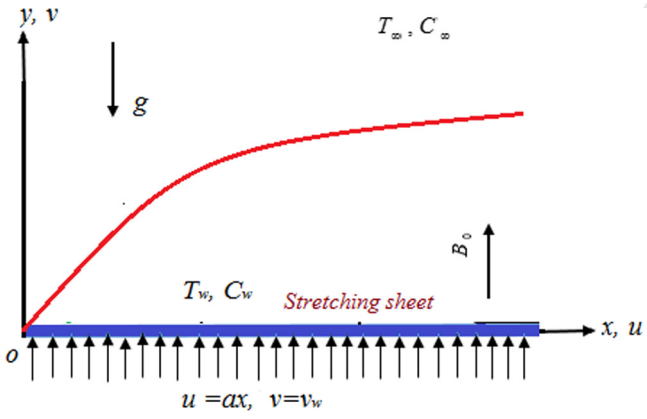

Fig. 1. Physical model of the problem.

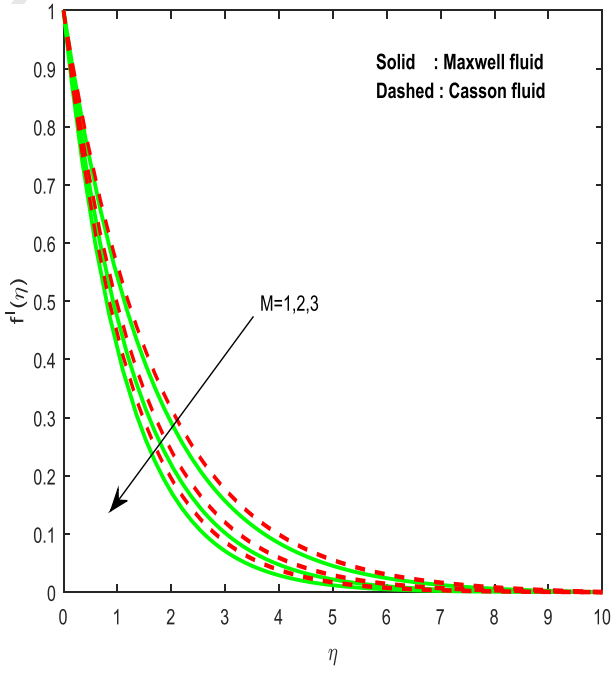

Fig. 2. Effects of M on velocity field.

flow over a vertical stretching surface. Kafoussias and Williams [21] studied the mixed convective boundary layer viscous flow with viscosity variation and cross diffusion. Free convective heat transfer over a semi-infinite stretching surface is numerically investigated by Alam et al. [22]. Alam and Rahman [23] discussed the mixed convective flow on Soret and Dufour effects past a vertical plate and concluded that the velocity and nano particle concentration boundary layer rises with wall suction. The effects of cross diffusion on MHD flow of Casson fluid is investigated by Hayat et al. [24]. Crane [25] studied the two dimensional viscous fluid flow over a stretching sheet and closed form solutions are extended under various physical aspects.

Nadeem et al. [26] discussed the influence of Casson fluid on magnetohydrodynamic boundary layer flow past a stretching sheet and presented analytical solution for the differential system by using Adomain decomposition method (ADM). The boundary layer viscous fluid flow past a stretching sheet was investigated by Muhaimina et al. [27]. The mass diffusion and chemical reaction effects on MHD flow past a stretching surface was studied by Takhar et al. [28]. Recently, the researchers [29–37] studied the heat transfer behavior of magnetohydrodynamic flows by consid-

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