Heat and Mass Transfer Investigation on MHD Casson Fluid Flow past an Inclined Porous Plate in the Effects of Dufour and Chemical Reaction

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Abstract: The impact of heat and mass transfer investigation on MHD Casson fluid flow past an inclined porous plate in the effects of Dufour and chemical reaction is investigated in this study. The velocity, temperature and concentration equations are follow-on as coupled second order ordinary differential equations. The model is non-dimensionalized and shown to be controlled by a number of dimensionless parameters. The resulting dimensionless ordinary differential equations can be solved by analytically using perturbation method. The effects of various governing parameters on the velocity, temperature, concentration profiles are presented graphically and discussed in detail. Numerical results for pertaining parameters, such as Grashof number, Thermal Grashof number, Permeability parameter, Angle of inclination, Heat transfer, Magnetic parameter, Prandtl number, Radiation parameter, Dufour Effects, Heat source parameter, Schmidt number, Chemical reaction parameter, Skin friction, Nusselt number and Sherwood number are shown in the tables and analyzed qualitatively.

Keywords: MHD, Casson Fluid, Dufour Effect, Inclined Plate, Chemical Reaction.

I. INTRODUCTION:

Lately, there has been some renewed attentions in the study of free convective heat and mass transfer in fluid flow through a wavy or irregular channel. Not long ago, there has been increasing interest among the researchers in the theoretical and experimental studies of bio-fluid flows in ducts, in particular, blood flow through larger and narrow diameter arteries. Seeing that Casson fluid model has more advantages than Herschel-Bulkley fluid model in blood flow modeling, it is appropriate to model the blood as Casson fluid model. Hence, this paper performs a mathematical analysis on the Poiseuille flow of viscous incompressible Casson fluid through elastic tube to revise the flow characteristics of blood when it proceed through narrow diameter arteries. It is to be noted that Newtonian fluid model can be obtained as particular case from Casson fluid model when the yield stress is zero.During abundant applications of non-Newtonian fluids in technological improvement and innovation, several engineers and scientists are functioning on individual investigations such as cosmetics, pharmaceuticals, chemicals, oil, gas, food and several others. Even non-Newtonian fluids are not simple to tackle in comparison with Newtonian fluids. This happens due to the non-availability of at least single constitutive equation that can give explanations of all characteristics in non-Newtonian fluids.

Sandhya et al. [1] has been investigated to the impact of heat and mass transfer effects on an MHD flow past an inclined porous plate in the presence of a chemical reaction. In this study, we investigated the heat and mass transfer in Casson fluid flow past an infinite vertical porous plate in the presence of thermal radiation and chemical reaction. The governing equations of the flow, heat and mass transfer are transformed into a system of nonlinear ordinary differential equations and solved analytically by the perturbation technique. In this article it is examined Hall current effect on chemically reacting MHD Casson fluid flow with Dufour effects and thermal radiation. We have examined the unsteady free convective flow on MHD polar fluid with Dufour and chemical reaction effects past a semi-infinite vertical plate are given. We analyze the unsteady MHD free convective flow past an infinite vertical plate in the influence of magnetic induction and first order chemical reaction with Dufour effects is presented. The study of the heat and mass transfer in MHD flow of a Casson fluid involved a moving vertical porous plate are given in references by Vijayaragavan et al. [2-6].Thamizhsudar et al. [7] has been examined a theoretical solution of flow past an exponentially accelerated vertical plate in the presence of Hall current and MHD relative to a rotating fluid with uniform temperature and mass diffusion is presented. The dimensionless equations are solved using the Laplace method. Agarwal et al. [8] explored Two-dimensional heat and mass transfer MHD unsteady and mixed convective flow of an electrically conducting viscous incompressible fluid passes through a semi-infinite vertical porous plate with variable thermal conductivity is investigated. An Unsteady MHD Flow Past a Vertical Porous Plate Under a Variable Suction Velocity with Soret-Dufour and Second-order Chemical Reaction have been studied by Shukla et al. [9]. Najwa Najib et al. [10] analyzed to investigate the effects of Soret and Dufour known as thermo diffusion and diffusion-thermo on moving plate in copper water nanofluid. The set of partial differential equations are converted into set of ordinary differential equations using the appropriate similarity variables before being solved numerically using bvp4c code in Matlab software.

Gbadeyan et al. [11] discussed the effects of dissipation, radiation, Dufor, Soret, heat and mass transfer on a laminar free convective flow of a viscous incompressible, electrically conducting chemically reacting fluid past an impulsively started moving plate adjacent to non-Darcy porous regime in the presence of heat generation. The governing equations are reduced to two-dimensional and two dependent problems involving velocity, temperature, and concentration with appropriate boundary conditions. The Rosseland diffusion approximation was used to analyze the radiative flux in the energy equation which is appropriate for non-scattering media. The governing equations for the model were simplified and non-dimensionalised using dimensionless quantities. The dimensionless governing equations were solved using an implicit finite-difference method of Crank-Nicolson type. Layek et al. [12] have been studied the Dufour and Soret effects on unsteady heat-mass transfer of a viscous incompressible Powell-Eyring fluids flow past an expanding/shrinking permeable sheet are reported. Islam et al. [13] have been analyzed the present an exact analysis the effect of heat generation parameter and Dufour number on the magneto hydrodynamic (MHD) free convection flow of an electrically conducting incompressible viscous fluid over an inclined plate embedded in a porous medium. Rajput et al. [14] have been investigated Dufour effect on unsteady MHD flow through porous medium past an impulsively started inclined oscillating plate with variable temperature and mass diffusion is studied here. Sreenivasa Reddy et al. [15] analyzed the combined influence of Soret and Dufour effects on unsteady heat and mass transfer flow of a viscous incompressible electrically conducting fluid over a stretching sheet with thermal radiation, non-uniform heat source/sink and thermophoresis particle deposition. Sudharsan Reddy et al. [16] depicts the combined effects of Diffuson – Thermo (Dufour), thermal radiation, absorption of radiation and chemical reaction on MHD oscillatory flow of an optically conducting thin fluid in a symmetric wavy channel filled with porous medium. Idowu et al. [17] was probably Heat together with mass transfer of magnetohydrodynamics (MHD) non-Newtonian nanofluid flow over an inclined plate embedded in a porous medium with influence of thermophoresis and Soret-Dufour is studied. The novelty of this study is the combined effects of Soret, Dufour and thermophoresis with nanofluid flow on heat together with mass transfer.The flow is considered over an inclined plate embedded in a porous medium. Seema Tinker et al. (2020) elucidate the effect of chemical reaction on free convection MHD motion of steady, laminar, incompressible liquid under the influence of heat source/sink. The motion is considered over an exponential radiative extending surface with a magnetic field. An appropriate similar transformation is employed to convert the nonlinear system of partial differential equations (PDEs) to a set of ordinary differential equations (ODEs). Manjiul Islam et al. [19] have emphasized of mass transfer flow has attracted the interest of many researchers in view of its important applications of Mass Transfer include the dispersion of contaminants, drying and humidifying, segregation and doping in materials, vaporization and condensation in a mixture, evaporation (boiling of a pure substance is not mass transfer), combustion and most other chemical processes, cooling towers, sorption at an interface (adsorption) or in a bulk (absorption), and most living-matter processes as respiration (in the lungs and at cell level), nutrition, secretion, sweating, etc. In many engineering application, combine heat and mass transformation play a vital role in fluid condensing or boiling at a solid surface. Ramana Reddy et al. [20] was studied the study of thermal radiation and magnetohydrodynamic effects on mixed convection flow of a viscous incompressible electrically-conducting fluid through a porous medium with variable permeability in the presence of oscillatory suction. The influence of a first-order homogeneous chemical reaction, heat source and Soret effects are analyzed.

Shukla et al. [21] was studied in detail The object of this article is to monitor the change of second order chemical reaction and variable suction in MHD (magnetohydrodynamics) flow of viscoelastic fluid over a vertical porous plate immersed in a porous medium with radiation and Soret Dufour effects. The momentum, heat transfer, and mass transfer are set of nonlinear sets of partial differential equations impressed by boundary conditions, these equations are solved using finite difference method namely Crank-Nicolson. Pushpalatha et al. [22] have focused the unsteady free convection flow of a Casson fluid bounded by a moving vertical flat plate in a rotating system with convective boundary conditions. Ramana Reddy et al. [23] delivered the effects of magnetohydrodynamic force and buoyancy on convective heat and mass transfer flow past a moving vertical porous plate in the presence of thermal radiation and chemical reaction. The governing partial differential equations are reduced to a system of self-similar equations using the similarity transformations. The resultant equations are then solved numerically using the fourth order Runge-Kutta method along with the shooting technique. Shukla et al. [24] have mathematically observed the changes of Soret and Dufour effects on MHD (magnetohydrodynamics) flow past a vertical porous plate with second-order chemical reaction. The governing equations of motion are the system of partial differential equations, these equations are nondimensionalized by introducing nondimensional physical quantities. Utpal Jyoti et al. [25] employed the Soret and Dufour effects on an unsteady magneto hydrodynamic oscillatory flow of radiative, visco-elastic fluid through an inclined channel filled with saturated porous medium with nonuniform wall temperature in presence of first-order chemical reaction. the unsteady coupled heat and mass transfer of two-dimensional MHD fluid over a moving oscillatory stretching surface with Soret and Dufour effects. Viscous dissipation effects are adopted in the energy equation. A uniform magnetic field is applied vertically to the flow direction. The governing equations are reduced to non-linear coupled partial differential equations and solved by means of homotopy analysis method (HAM) proposed by Lian-Cun Zheng et al. [26]. Reddy et al. [27] empowered the Soret and Dufour effects on an MHD micropolar fluid flow over a linearly stretching sheet, through a non-Darcy porous medium, where stretching velocity of the sheet varies linearly with distance from the origin, and, temperature and concentration vary non-linearly in the boundary layer region. Rama Krishna Reddy et al. [28] focused on unsteady magentohydrodynamic (MHD) free convective flow of a double diffusive fluid past a moving vertical porous plate in the presence of thermal radiation and first order homogeneous chemical reaction. The temperature of the plate is assumed span wise cosinusoidally fluctuating with time in the presence of heat generation. The effects of Radiation and chemical reaction on unsteady MHD free convection flow in a porous plate fragmented by Sweta Matta et al. [29]. Amos S.Idowu et al. [30] inflected on Cattaneo–Christov heat flux relocation paradox on Casson fluid with MHD and dissipative effects was considered. The buoyancy and heat generation effects were believed to be responsible for the natural convection, while variable properties were perceived as temperature dependent linear function.

On the other hand, in the presence of Dufour impact, none of the studies have well thought-out the Casson model for representing the inclined vertical plate. The main object of the present paper is to the study the transient state convection of fluid from MHD Casson over an inclined layer. Additionally, the effects of the magnetic field, Dufour effects and heat suction / insertion through the porous medium are premeditated in the present study. Partial differential equation has been applied to get exposed the faithful solution of the governing equations. This reproduction can be used for the research of free convection flow in the cooling of nuclear reactor.

II. MATHEMATICAL FORMULATION:

Consider an unsteady MHD free convective flow of a viscous incompressible and electrically conducting fluid past an infinite inclined porous plate with time-dependent variable plate velocity, heat and mass transfer in a saturated porous medium. The x^* - axis is taken along the leading edge of an inclined plate with an angle of inclination α to the vertical direction. The y^* - axis is taken normal to the plate. Initially, both the fluid and the plate were at rest with constant temperature T_∞^* and constant concentration C_∞^* .At time $t^* > 0$, the plate starts moving with a velocity $u^* = u_0\left(\frac{t^*}{t_0}\right)^2$ in its own plane against the gravitational field.

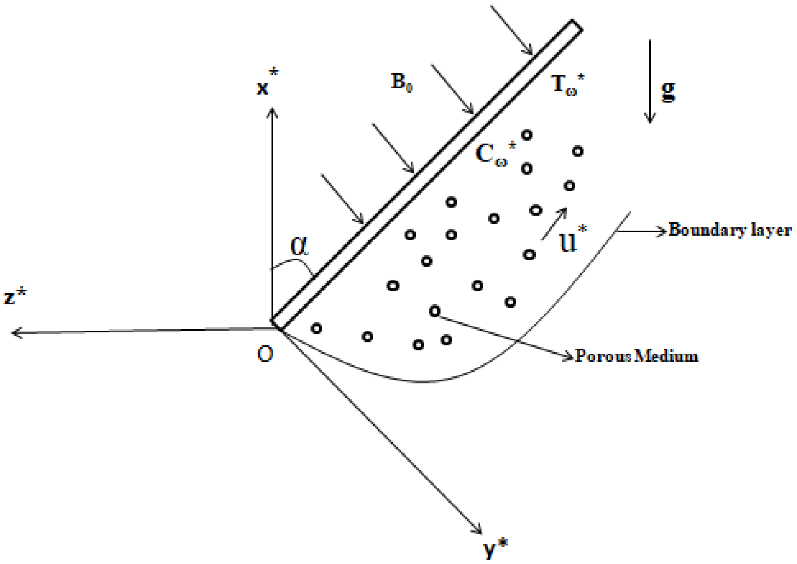

Fig.1.Physical Configuration of the problem

The plate temperature and mass diffusion from the plate into the fluid are increased linearly with reference to time. A uniform magnetic field of strength B_0 is applied transversely to the plate along the y^* - direction. The Reynolds number is assumed to be very small which corresponds to a negligible induced magnetic field when compared to the externally applied force, and hence $B = (0, B_0, 0)$ is the total magnetic field acting on the fluid. Further, it is considered that the viscous dissipation of energy is negligible and that the fluid is an optically thin gray radiating but non scattering medium. All the fluid properties are supposed to be of a fixed value except the density in the buoyancy force term.

In view of the above assumptions, the usual Boussinesq approximation, the governing equations considered are as follows:

Momentum Equation:

$$\frac{\partial u^*}{\partial t^*} = v\left(1+\frac{1}{\beta}\right)\frac{\partial^2 u^*}{\partial y^{*2}} + g\beta(T^* - T_\infty^*)\cos\alpha + g\beta^*(C^* - C_\infty^*)\cos\alpha - \frac{\sigma B_0^2}{\rho}u^* - \frac{vu^*}{K_p^*} \qquad (1)$$

Energy Equation:

$$\frac{\partial T^*}{\partial t^*} = \frac{K_T}{\rho C_p}\frac{\partial^2 T^*}{\partial y^{*2}} + \frac{Q^*}{\rho C_p}(T^* - T_\infty^*) - \frac{1}{\rho C_p}\frac{\partial q_r}{\partial y^*} + \frac{D_M K_T}{C_s C_p}\frac{\partial^2 C^*}{\partial y^{*2}} \qquad (2)$$

Species Equation:

$$\frac{\partial C^*}{\partial t^*} = D_M\frac{\partial^2 C^*}{\partial y^{*2}} - K_c^*(C^* - C_\infty^*) \qquad (3)$$

Where u^* is the component of velocity along the x^* - axis, v is the kinematic viscosity, g is the acceleration due to gravity, β is the volume expansion coefficient for the heat transfer and β^* is the volume expansion coefficient for the mass transfer, K_p^* is the permeability of the porous medium, q_r is the radioactive heat flux, α is the angle of inclination, σ is the electrical conductivity of the fluid, T^* is the fluid temperature, T_∞^* is the far field temperature , K_T is the thermal conductivity, K_C^* is the chemical reaction parameter, Q^* is the heat source parameter, ρ is the density of the fluid, C_P is specific heat at constant pressure , C^* is the species concentration, C_∞^* is the far field concentration, D_M is the coefficient of molecular diffusivity, D_T is the coefficient of thermal diffusion.

Initial and Boundary Conditions of the physical model are presented by,

$$\begin{aligned} t^* \le 0: \quad & u^* = 0,\ T^* = T_\infty^*,\ C^* = C_\infty^* \quad \forall y^*, \\ t^* > 0: \quad & u^* = u_0\left(\frac{t^*}{t_0}\right)^2,\ T^* = T_\infty^* + \frac{T_\omega^* - T_\infty^*}{v}u_0^2\left(\frac{t^*}{t_0}\right), \\ & C^* = C_\omega^* + \frac{C_\omega^* - C_\infty^*}{v}u_0^2\left(\frac{t^*}{t_0}\right) \ at \ y^* = 0, \\ & u^* \to 0, \quad T^* \to T_\infty^*, \quad C^* \to C_\infty^* \quad as \quad y^* \to \infty \end{aligned} \tag{4}$$

Using the Rosseland approximation the rate of radioactive heat flux is obtained by

$$\frac{\partial q_r}{\partial y^*} = -4a^*\sigma^*(T_\infty^{*4} - T^{*4}) \tag{5}$$

Let us assume that the temperature differences are sufficiently small within the flow such that T^{*4} can be represented as a linear function of the temperature. This is accomplished by expanding T^{*4} in a Taylor series about T^{*4} and rejecting the higher order terms. We will get

$$T^{*4} \cong 4T_\infty^{*3}T^* - 3T_\infty^{*4} \tag{6}$$

Using equations (5) and (6) in equation (2), we obtain

$$\frac{\partial q_r}{\partial y^*} = -4a^*\sigma^*(T_\infty^{*4} - T^{*4}) \tag{7}$$

Non- dimensional quantities are defined by

$$\begin{aligned} & y = \frac{y^* u_0}{v},\ u = \frac{u^*}{u_0},\ t = \frac{t^* u_0^2}{v},\ \theta = \frac{T^* - T_\infty^*}{T_\omega^* - T_\infty^*},\ \phi = \frac{C^* - C_\infty^*}{C_\omega^* - C_\infty^*},\ Gr = \frac{g\beta v(T_\omega^* - T_\infty^*)}{u_0^3}, \\ & Gm = \frac{g\beta^* v(C_\omega^* - C_\infty^*)}{u_0^3},\ \Pr = \frac{\mu C_p}{K_T},\ M = \frac{\sigma B_0^2 v}{\rho u_0^2},\ K_p = \frac{u_0^2 K_p^*}{v^2},\ K_r = \frac{vK_c^*}{u_0^2}, \\ & R = \frac{16a^* v^2 \sigma^* T_\infty^{*3}}{K_T u_0^2},\ Q = \frac{Q^* v}{\rho C_p u^2},\ \mu = \rho v,\ Sc = \frac{v}{D_M},\ D_u = \frac{D_M K_T}{vC_s C_p}\frac{(C_\omega^* - C_\infty^*)}{(T_\omega^* - C_\infty^*)} \end{aligned} \tag{8}$$

The equations in non-dimensional form are

$$\frac{\partial u}{\partial t}=\left(1+\frac{1}{\beta}\right)\frac{\partial^2 u}{\partial y^2}+Gr\,\theta\cos\alpha+Gm\,\phi\cos\alpha-Mu-\frac{u}{K_p} \tag{9}$$

$$\frac{\partial \theta}{\partial t}=\frac{1}{\Pr}\frac{\partial^2 \theta}{\partial y^2}-\left(\frac{R-Q\Pr}{\Pr}\right)\theta+D_u\frac{\partial^2 \phi}{\partial y^2} \tag{10}$$

$$\frac{\partial \phi}{\partial t}=\frac{1}{Sc}\frac{\partial^2 \phi}{\partial y^2}-K_r\phi \tag{11}$$

The corresponding initial and boundary conditions are

$$\begin{aligned} t\le 0:&\quad u=0,\ \ \theta=0,\ \ \phi=0\quad \forall y,\\ t>0:&\quad u=t^2,\ \ \theta=t,\ \ \phi=t\quad at\quad y=0,\\ &\quad u\to 0,\ \ \theta\to 0,\ \ \phi\to 0\quad as\quad y\to\infty. \end{aligned} \tag{12}$$

III. METHOD OF SOLUTION:

Equations (9)-(11) are coupled non-linear partial differential equations and these equations can be solved by a closed form method, i-e, the equations can be reduced to a set of ordinary differential equations which can be solved analytically. This can be done by representing the velocity, temperature, concentration of the fluid in the neighborhood of the plate as

$$\begin{aligned} u(y,t)&=u_0(y)\,e^{i\omega t},\\ \theta(y,t)&=\theta_0(y)\,e^{i\omega t},\\ \phi(y,t)&=\phi_0(y)\,e^{i\omega t}. \end{aligned} \tag{13}$$

Substituting (13) in equations (9)-(11) and (12) we get the differential equations

$$\left(1+\frac{1}{\beta}\right)u_0''-k_3^2u_0=-\left[Gr\theta_0\cos\alpha+Gm\phi_0\cos\alpha\right] \tag{14}$$

$$\theta_0''-k_2^2\theta_0=-\Pr D_u\,\phi_0'' \tag{15}$$

$$\phi_0''-k_1^2\phi_0=0 \tag{16}$$

The corresponding boundary conditions are

$$\begin{aligned} t\le 0:&\quad u_0=0,\ \ \theta_0=0,\ \ \phi_0=0\quad \forall y,\\ t>0:&\quad u_0=t^2\,e^{-i\omega t},\ \ \theta_0=t\,e^{-i\omega t},\ \ \phi_0=t\,e^{-i\omega t}\quad at\quad y=0,\\ &\quad u_0\to 0,\ \ \theta_0\to 0,\ \ \phi_0\to 0\quad as\quad y\to\infty. \end{aligned} \tag{17}$$

Solving equations (14)-(15) and using equation (17) the velocity, temperature, concentration fields are as follows

$$\phi(y,t) = t\, e^{-k_1 y} \tag{18}$$

$$\theta(y,t) = A_2\, e^{-k_2 y} + A_1\, e^{-k_1 y} \tag{19}$$

$$u(y,t) = A_7\, e^{-\left(\frac{k_3}{\sqrt{1+\frac{1}{\beta}}}\right) y} + A_3\, e^{-k_2 y} + A_6\, e^{-k_1 y} \tag{20}$$

The skin friction, Nusselt number and Sherwood number are significant parameters for this type of boundary layer flow.

IV. SKIN FRICTION:

Knowing the velocity field, the skin friction on the plate y=0 in non-dimensional form is given by

$$\tau = \left[-\frac{\partial u}{\partial y} \right]_{y=0}$$

$$\tau = \frac{k_3}{\sqrt{1+\frac{1}{\beta}}} A_7 + k_2 A_3 + k_1 A_6 \tag{21}$$

V. NUSSELT NUMBER:

Knowing the temperature field, the rate of heat transfer coefficients can be obtained which is in non-dimensional form in terms of the Nusselt number and is given by

$$Nu = \left[-\frac{\partial \theta}{\partial y} \right]_{y=0}$$

$$Nu = k_2 (t - A_1) + k_1 A_1 \tag{22}$$

VI. SHERWOOD NUMBER:

The rate of mass transfer at that plate in terms of the Sherwood number is given by

$$Sh = \left[-\frac{\partial \phi}{\partial y} \right]_{y=0}$$

$$Sh = t k_1 \tag{23}$$

VII. RESULT AND DISCUSSION:

The influence of the modified Grashof number (Gm) on the velocity profiles is shown in Figure 2. It is observed by modified Grashof number increasing, at the time of velocity profile is also increases. In the case of different values of the thermal Grashof number (Gr), the velocity profiles on the boundary layer are shown in

Figure3. As expected, it is observed that an increases in the Grashof number (Gr) leads to an increasing in the values of velocity due to enhancement in the buoyancy force. Here the positive values of the Grashof number (Gr) represent the surface cooling. Also, as the Grashof number increasing, the peak values of the velocity increases rapidly near the porous plate and then decay smoothly to the free stream velocity. Figure 4 represents the velocity profile for different values of the angle of inclination (α). By observing that the angle of inclination (α) growing, the velocity profile decreases.

Figure 5 demonstrates the effect of the magnetic field on the velocity profiles. While observing the velocity decreases with a rising magnetic parameter (M). This is due to the Lorentz force acting on the fluid flow. This type of resisting force slows down the fluid velocity as shown in figure 5.In figure 6 the effect of the heat transfer (β) on the velocity decreases. During observation velocity profile for different values of the heat transfer (β) increases. The effect of the permeability parameter (Kp) in the velocity profile is depicted in Figure 7. When observing that the velocity increases with a mounting permeability parameter (Kp).

Figure 8 represent the temperature profiles for different values of the Dufour Effects (Du). When capturing the Dufour Effects (Du) increases the temperature profile. Figure 9 represents the temperature profiles for different values of the Prandtl number (Pr). While notifying that the Prandtl number (Pr) increases the temperature profile decreasing due to the thermal boundary layer thickness. Figure 10 the influence of the radiation parameter (R) in the temperature profile.In the observation that the radiation decreases. Figure 11 effect of the heat source parameter (Q) on the temperature fields. It is visible that the increases of the heat source parameter (Q).

Effects of chemical reaction parameters (Kr) on the concentration profiles are presented in Figure 12. It is observed by concentration profiles are decaying functions of summative values of the chemical reaction parameter (Kr). For the growing values of the chemical reaction parameter on the concentration profiles decreases when the molecular diffusivity diminishes. Figure 13 the effect of the Schmidt number (Sc) on the concentration profile. It is observed that as the Schmidt number escalating concentration profile decreases.

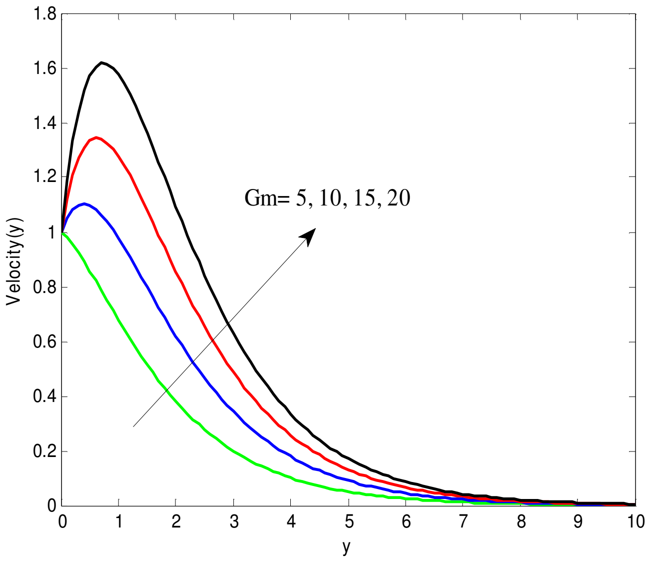

Fig.2.Velocit profile for different values of the Modified Grashof number (Gm)

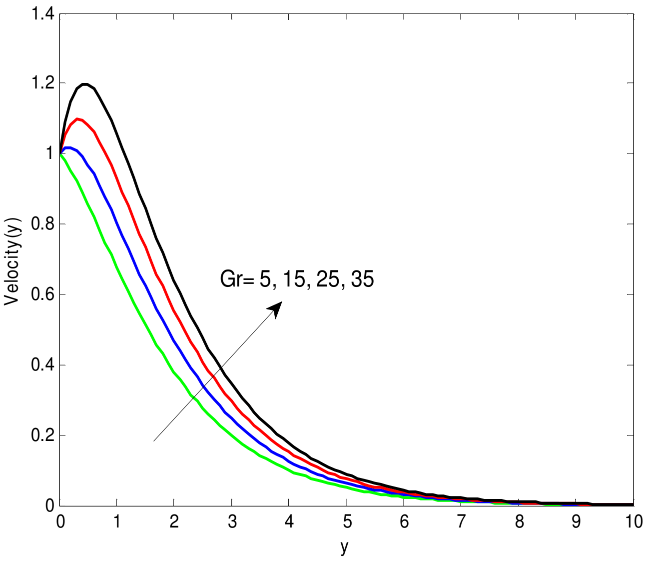

Fig.3. Velocity profile for different values of the Grashof number (Gr)

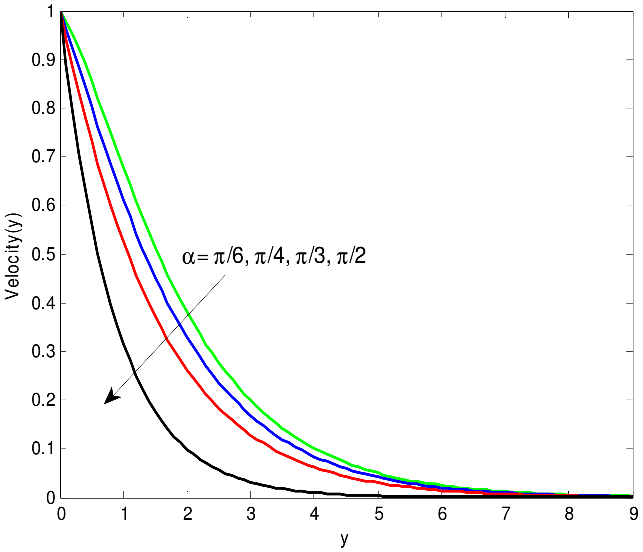

Fig.4.Velocityprofilefor different values of the angle of inclination (α)

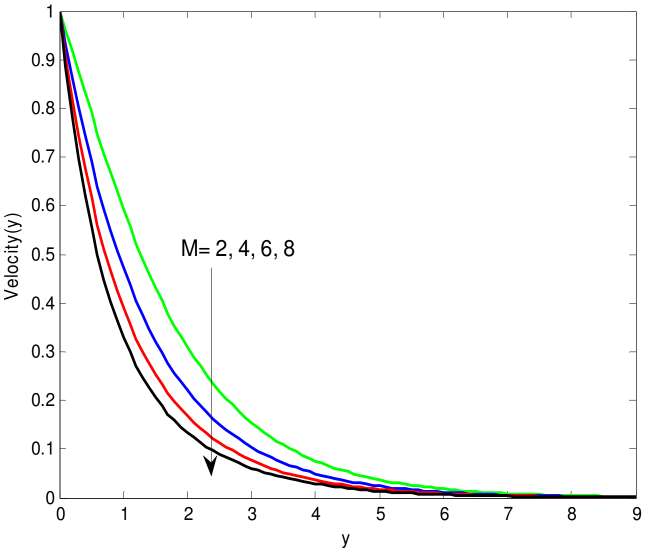

Fig.5.Velocity profile for different values of the magnetic parameter (M)

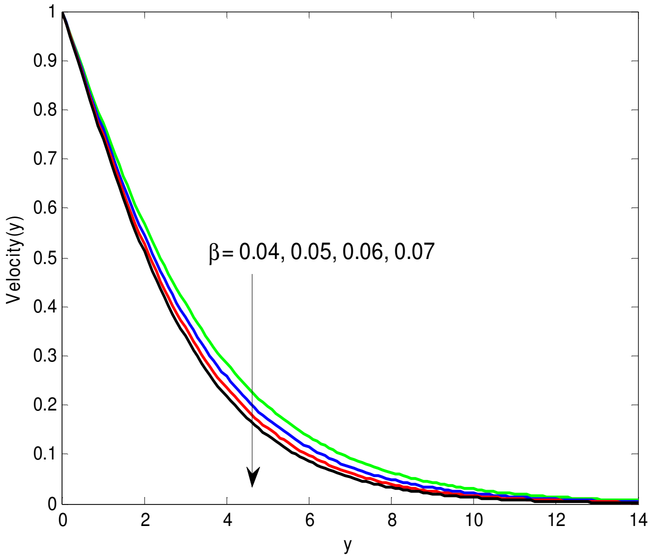

Fig.6.Velocity profile for different values of the heat transfer (β)

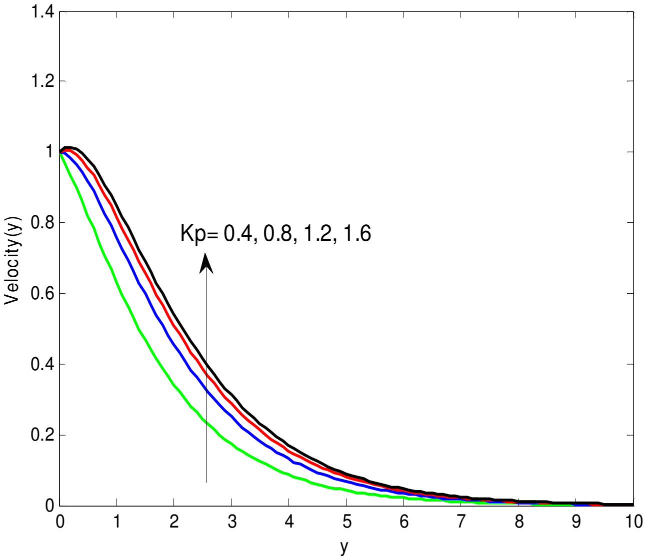

Fig.7.Velocity profile for different values of the permeability parameter (Kp)

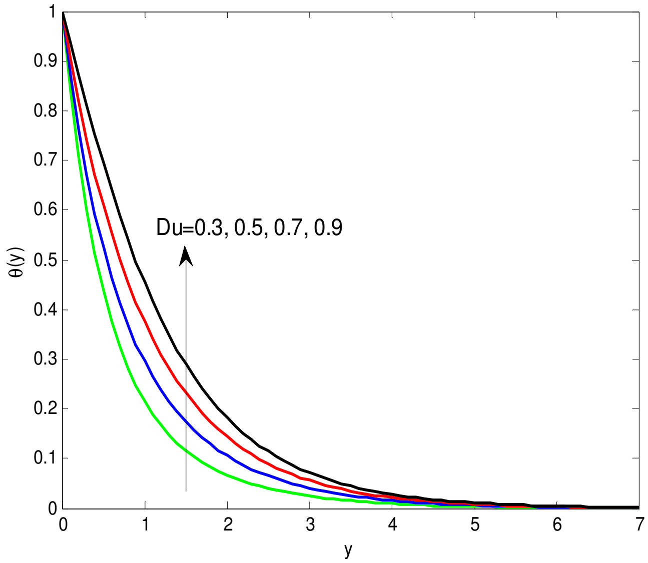

Fig.8.Temperature profile for different values of the Dufour Number $\left(Du\right)$

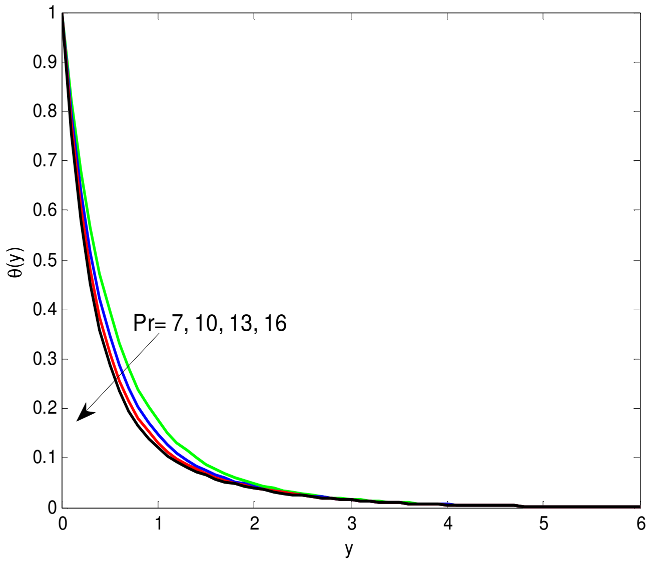

Fig.9.Temperature profile for different values of the Prandtl number $\left(\Pr\right)$

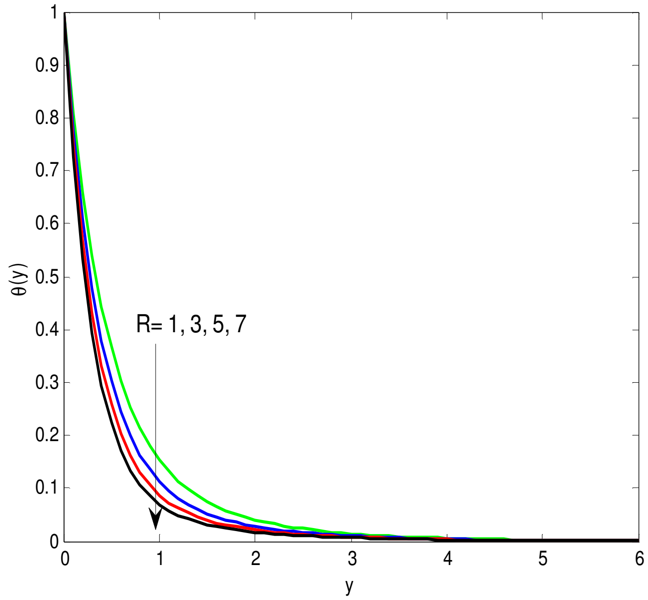

Fig.10.Temperature profile for different values of the radiation parameter $\left(R\right)$

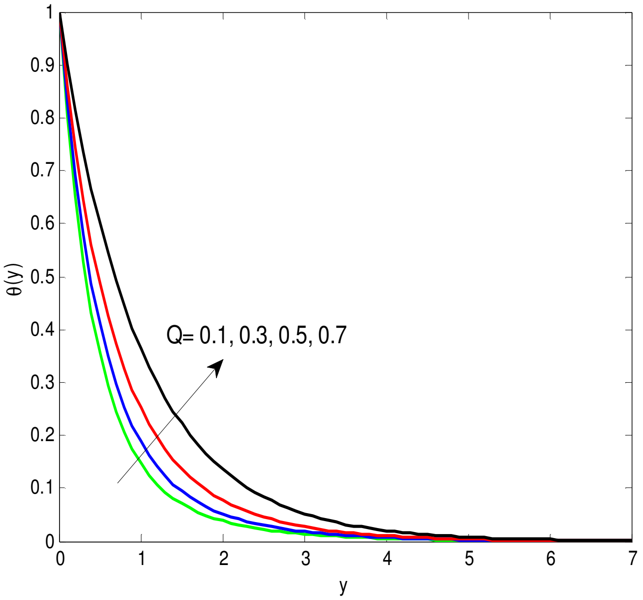

Fig.11.Temperature profile for different values of the heat source parameter $\left(Q\right)$

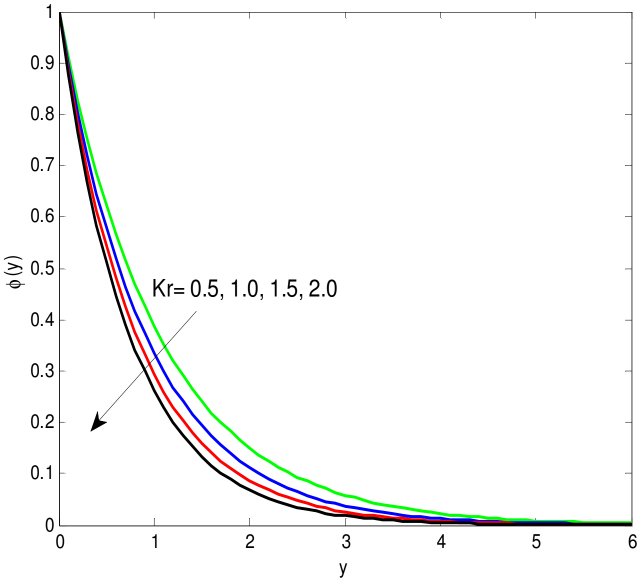

Fig.12.Concentration Profile for different values of the chemical reaction parameter $\left(Kr\right)$

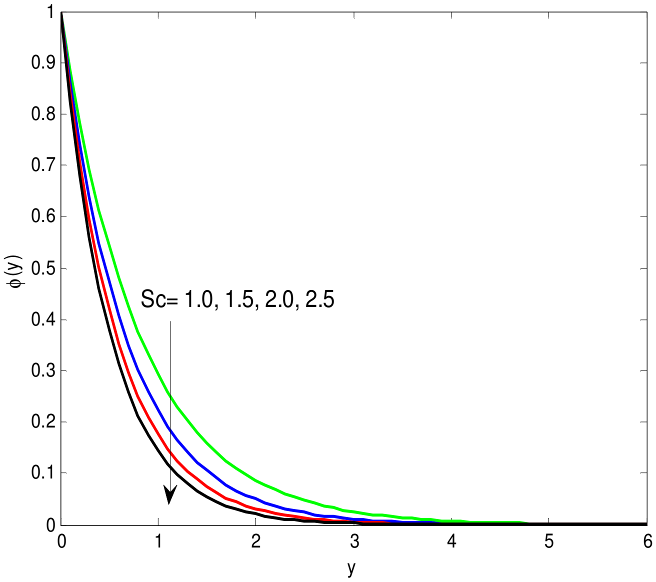

Fig.13.Concentration Profile for different values of the Schmidt parameter $\left(Sc\right)$

Table 4.1. Variation of skin friction for different physical parameters at y=0

Gm	Gr	β	M	Kp	α	τ
5	5	0.5	1	0.5	30	**0.1784**
10	5	0.5	1	0.5	30	**-0.5855**
15	5	0.5	1	0.5	30	**-1.3494**
20	5	0.5	1	0.5	30	**-2.1133**
5	**5**	0.5	1	0.5	30	**0.1784**
5	**15**	0.5	1	0.5	30	**-0.2465**
5	**25**	0.5	1	0.5	30	**-0.6715**
5	**35**	0.5	1	0.5	30	**-1.0964**
5	5	**0.04**	1	0.5	30	**0.2200**
5	5	**0.05**	1	0.5	30	**0.2307**
5	5	**0.06**	1	0.5	30	**0.2385**
5	5	**0.07**	1	0.5	30	**0.2444**
5	5	0.5	**2**	0.5	30	**0.3830**
5	5	0.5	**4**	0.5	30	**0.7217**
5	5	0.5	**6**	0.5	30	**1.0022**
5	5	0.5	**8**	0.5	30	**1.2461**
5	5	0.5	1	**0.4**	30	**0.2845**
5	5	0.5	1	**0.8**	30	**0.0005**
5	5	0.5	1	**1.2**	30	**-0.1108**
5	5	0.5	1	**1.6**	30	**-0.1708**
5	5	0.5	1	0.5	**30**	**0.1784**
5	5	0.5	1	0.5	**45**	**0.3575**
5	5	0.5	1	0.5	**60**	**0.5910**
5	5	0.5	1	0.5	**90**	**1.1547**

Table 5.1. Variation of Nusselt number with Prandtl number, Dufour Effects , radiation parameter and heat source parameter at y=0

Kp	Pr	R	Q	Nu
0.3	7.0	0.25	0.25	**0.8397**
0.5	7.0	0.25	0.25	**0.8721**
0.7	7.0	0.25	0.25	**0.9046**
0.9	7.0	0.25	0.25	**0.9371**
0.3	**7**	0.25	0.25	**0.8234**
0.3	**10**	0.25	0.25	**0.7971**
0.3	**13**	0.25	0.25	**0.7753**
0.3	**16**	0.25	0.25	**0.7567**
0.3	7.0	**1**	0.25	**0.8096**
0.3	7.0	**3**	0.25	**0.7776**
0.3	7.0	**5**	0.25	**0.7508**
0.3	7.0	**7**	0.25	**0.7274**
0.3	7.0	0.25	**0.1**	**0.8044**
0.3	7.0	0.25	**0.3**	**0.8303**
0.3	7.0	0.25	**0.5**	**0.8618**
0.3	7.0	0.25	**0.7**	**0.9027**

Table 6.1. Variation of Sherwood number with Schmidt parameter and Chemical reaction parameter y=0

Sc	Kr	Sh
1.0	0.5	**0.8847**
1.5	0.5	**0.8607**
2.0	0.5	**0.8410**
2.5	0.5	**0.8239**
0.6	**0.5**	**0.9095**
0.6	**1.0**	**0.8962**
0.6	**1.5**	**0.8847**
0.6	**2.0**	**0.8744**

VIII. CONCLUSIONS:

Afterward non- Newtonian property heat and mass transfer investigation on MHD Casson fluid flow past an inclined porous plate in the effects of Dufour and chemical reaction were studied. The fallout of our research study can be summarized as follows:

1] With enhance value of the modified Grashof number (Gm), thermal Grashof number (Gr) and the permeability parameter (Kp) with the fluid velocity is increases.

2] If the enhance value of the angle of inclination (α), the heat transfer (β) and the magnetic parameter (M) with the fluid velocity get decreases.

3] The fluid temperature diminishes with enhance of the Prandtl number $(\Pr)$ and the radiation parameter (R).

4] The fluid temperature enhances with effect of the Dufour Effect parameter (Du) and the heat source parameter (Q).

5] The concentration level of the fluid diminishes when the Schmidt number (Sc) is enhance.

6] The concentration diminishes with enhance of the chemical reaction parameter (Kr).

APPENDIX:

$$k_1 = \sqrt{(K_r + i\omega)Sc}, \qquad k_2 = \sqrt{R - (Q - i\omega)\Pr}, \qquad k_3 = \sqrt{M + \frac{1}{K_p} + i\omega},$$

$$A_2 = (t - A_1), \qquad A_3 = \frac{-Gr\cos\alpha\, A_2}{\left(1+\frac{1}{\beta}\right)k_2^2 - k_3^2}, \qquad A_4 = \frac{-Gr\cos\alpha\, A_1}{\left(1+\frac{1}{\beta}\right)k_1^2 - k_3^2},$$

$$A_5 = \frac{-Gm\cos\alpha\, t}{\left(1+\frac{1}{\beta}\right)k_1^2 - k_3^2}, \qquad A_6 = A_4 + A_5, \qquad A_7 = \left[t^2 - \left(A_6 + A_3\right)\right].$$

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