CHEMICAL ABSORPTION EFFECT ON MAGNETO HYDRODYNAMIC (MHD) CONVECTION FLOW PAST A VERTICAL PLATE WITH MASS TRANSFER

BY

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NOVEMBER 2018

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By

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A Project Submitted to the Department of Mathematical Science Federal University Gusau. Zamfara State.

In partial fulfillment for the requirement of the award of the Degree of Bachelor of Science

(B.sc) in Mathematics Science.

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Declaration

I hereby declare that this project was written by Usman Auwal is a record of my own resech work. It has not been presented before in any previous application for a Bachelor degree. All references cited have been duly acknowledged.

Usman Auwal

21/01/2019

Date

Certification

I certify that this long essay was carried out by Usman Auwal (1410309013) has met the r equirements for the Award of the Degree of Bachelor of Science (mathematics) of the Fede ral University Gusau and is approved for its contribution to knowledge.

14-12-2018

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Dedication

I dedicate this work to Allah whom out of His infinite mercy made it easy for me to comp lete my programme. And to my dearest Father and Mother, Alhaji Usman and Hajiya Fati ma who gave birth to me and trained and guided me in the culture, pattern and system of I slam and its education, and My lovely Brother Alh. Isah Abbakar.

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Nomenclature and Greek symbols

Kr = the chemical reaction parameter

ω =A frequency parameter

Gr = the thermal Grashof number

Gm = the mass Grashof number

M = magnetic parameter

Dc = mass Diffusion term

T = the temperature of the fluid

V= the suction parameter

g = acceleration due to gravity

Cp = Heat capacity at constant pressure

u = the velocity of the fluid

ω = A frequency parameter

ρ = the fluid Density

t = Time

ε = Perturbation parameter

Bo = the magnetic induction

β = the thermal conductivity

Sc = The Schmidt number

M = magnetic parameter

Qo = the heat sink term

k = Thermal conductivity

Abstract

Chemical Absorption Effects on Magnetohyrodynamic (MHD) convection flow through v ertical plate with mass transfer is investigated. As the problem is governed by coupled nonl inear system of partial differential equations (PDEs). Dimensionless quantities were introd uced to transform the partial differential equation into ordinary differential equations(ODE s) and the equations are then solved using the perturbation method. Graphical representatio ns of the numerical results are illustrated in Figure. 1 to Figure. 9 In this study, The influen ce of the effects of physical parameters such as Prandt number, Schmidt number, thermal Grashof number for heat transfer, Grashof number for mass transfer and chemical reaction have been investigated separately in order to clearly observe their respective effects on the velocity, temperature, and concentration profiles of the flow.

CHAPTER ONE

1.0 Background of the Study

1.1 Introduction

Fluid can be defined as a shear thinning which is assumed to have an infinite viscosity at zero rate of shear, a yield stress below which no flow occurs and a zero viscosity at an infinite rate of shear Dorsh *et al.* (2003) fluid flow model was introduce by casson in 1959 for the predictions of the flow behaviors of pigment-oil suspension so for the flow ,the stress magnetic of fluid flow needs to exceed the yields shear stress, or else the fluid behave as rigid body . This type of fluids can marked as a purely viscous fluid with high viscosity .fluid flow is based on structure model of the interactive behaviors' of solid and liquid phases of two phase suspension some famous flow fluids are includes jelly ,honey ,soud,light and concentrated fruits juice. human blood can also be treated as fluid flow due to presence several substance such as fibrinogen .protein, globulin in aqueous based plasma and human red blood cell. Veerech *et* al.(2017). a heat source is anything that can heat up a spacecraft .heat source can be external (from outside the spacecraft) or internal (from the inside the spacecraft) external heats source include the sun, reflected sunlight from planets and moon, heating by frictions when traveling through an atmosphere or gas cloud and released heat from planets .internal heat .internal heat is often generation by crafts propulsion or electrical system . if a craft has parts that move against each other. friction can provided heating as well.Many natural substance like rocks and soil (e.g. aquifers, petroleum reservoice) and man, zeolites,biological tissues(e.g. bones,wood,cork) and manmade materials such as cements and ceramics can seen as porous media .many of their important properties an only be rationalized by considering them to be porous media (Dutta and apati, 2003).

The term perturbation methods refer to a variety of methods to prove existence, uniqueness or regularity for equations that are in senses close to an equation that well understood. if an equations can be written as sum of well understood equations plus an extra term (perturbation that is small with respects to some relevant quantity, then some time a property of the well understood term can be transferred to the original equation. Williams *et al.* (2010).

Convection cannot take place in most solids because neither bulk current flows nor significant diffusion of matter can take place in rigid solids, but that is called heat conduction. Convection, however, can take place in soft solids or mixtures where solid particles can move past each other. Convective heat transfers in one of the major types of heat transfer and convention is also a major mode of mass transfer in fluids .convective heat and mass transfers take place both by diffusion .the random Brownian motion of individual particles in the fluid and by advection in which matter or heat is transported by the large-scale motion of current of fluids .in the context of heat and mass transfer, the term convention is used to refers to some of advection and diffusive transfers. However, mechanics the concept used the word convention is the general senses and different type of convention should be qualified for clarify.

Convention can be qualified in term of being natural, forced, gravitational granular, or thermo magnetic .it may also be said to be due to combustion, capillary action, or Marangoni and Weissenberger effects. Heat transfer by natural convention plays a role in the structure of earth's atmosphere, its oceans and its mantle. Discrete conventions cells in the atmosphere can see as clouds, with stronger convection resulting in thunderstorms .natural convention also play a role in stellar physics (Cengel and Yusus).

1.1 Statement of the problem

The governing equations in this study are the continuity, momentum, energy and diffusion equations, where the velocity, temperature and concentration fields are to be determined. Also the boundary conditions were modified.

1.2 Aim and objectives of the Study

The aim of study is to examine Chemical Absorption Effect on Magnetohyrodynamic (MHD) convection flow througt a vertical plate with mass transfer analytically using perturbation method. The objectives of the study are:

i. To transforms the dimensional governing partial differential equations (PDEs) into non dimensional form using some variable.

ii. To obtain analytical solutions for the velocity, temperature and concentration.

iii. To compute the skin friction, Nusselt and Sherwood number coefficients.

iv. To examines the influence of thermo--physical quantities associated with the flow, with the help of graphs and tables.

1.3 Scope and Delimitation of the Study

This research work mainly focuses on heat source and mass absorption effects on fluid flow and does not extent to other kind's fluid.

1.4 Significance of the Study

This research work help us to examine the influence of thermo-physical quantities associated with fluid flow with the help of graph and table and obtain analytic solution for the velocity temperature and concentration.

1.5 Definition of Basic Term

1.5.1 Radiation:

Radiation is the energy that comes from a source and travels through some material or through space, light, heat and sound are type of radiation.

1.5.2 Heat:

Heat is energy that is in a process of transform between a systems and its surrounding, other than as work or with the transform of matters.

1.5.3 Fluid:

Fluid is a substance, as liquid or gas that is capable of flowing and that changes it shapes at a steady rate when acted upon by a force leading change its shapes.

1.5.4 Fluid flow:

Fluid flow is motion of a fluid subjected to unbalanced force or stresses.

1.5.5 Magnetohyrodynamic (MHD):

Magnetohyrodynamic (MHD) (magneto fluid dynamics or hydro magnetic) is the study of properties of electrically conducting fluids .examples of such magneto-fluids include plasmas, liquid metals, and salt water or electrolytes, the word magneto hydrodynamics (MHD) is derived from magneto-meaning magnetic field, hydro- meaning water , and dynamics meaning movement .

1.5.6 Convection flow:

Convective flow is the motion of fluid due to differences in density. These differences in density commonly occur due to temperature gradients. For example the circulating air flows room with a hot gladiator

1.5.7 Chemical reaction:

Chemical substance to another classically, chemicals reaction encompass changes that only involve the position of electrons in the forming and breaking of chemical bonds between atoms.

CHAPTER TWO

2.0 Review of related literature

The study of radiation and heat absorption effect on MHD convention flow past a vertical plate is attracting the attention of many scholars. Fluid flow is one of such that has distant feature and quite illustration recently. So far the flow, the shear stress or magnetic of fluid needs to exceed the yield shear stress, or else the fluid we have as a rigid body. this kind of fluids can be marked as a purely, viscous fluid with high viscosity flow model is based on a structure model of the interactive behaviors of solid and phase liquid phases of two phases of suspension .so the famous example of fluid fluids flow include jelly sauce, tomato, honey, soup and concentration fruits juice. Human blood can also be treated as a fluid flow due to presence of several substances such as fibrinogen, protein, globulin, in aqueous base plasma and human are either obtained by using approximate methods or by any numerical schemes.

There are many case in which the exact analytical solution of fluid flow are obtained. Vajravelu and Mukhopadyay (2013) studies diffusion of chemicals reactive species on fluid flow over an unsteady permeable stretching surface Das *et al*. (1996) analyzed fluid flow in pipe filled with homogeneous porous medium Hayat *et al*. (2012) investigation effects on magneto hydro dynamic flow of fluid Mustafa *et al*. (2011) analyzed unsteady boundary layer flow of fluid due to an impulsively started moving flat plate, Mustafa *et al*. (2014) discussed stagnation point flow and heat transfer of a fluid towards stretching sheet

The analyses of a boundary layer flow of a unsteady heat and mass transfer fluid has transfer fluids has been the focus of extensive and research by various scientists due to its importance in continuo's casting glass, blowing paper production, polymer extensions and several other one of my refers to recent investigation by *Hayat and Qasim* (2012) influence of thermal radiation and joule heating on MHD flow of max well fluid in presence of thermophoresis fang et al (2010) analyzed a new family of unsteady layer over a stretching surface. *Khan and pop* (2010) considered boundary flow of nano-fluid past a stretching sheet, and Kandaswany *et al.* (2011) researched on scaling group transformation for (MHD) boundary layer flow of a nano-fluid past a vertical stretching surface in presence of suction/injection. on the other hand, mass transfer in impact due to it appearance in many scientific discipline that involve convention transfer of this phenomenon are evaporation of water separation chemicals in distillation process natural or artificial sources e.t.c

Mustafa *et al.*(2011) investigated the boundary layer flow of a fluid due to an impulsively started moving flat plate.rao *et al* (2013) studied the thermal hydrodynamic slip condition on heat transfer flow of fluid past a semi- infinite vertical plate. Heat transfer of a fluids past a permeable shrinking sheet with viscous dissipation was considered by *Qasim and* Noreen (2014) .Chamkha *et al. (2004)* studied the unsteady MHD convective heat and mass transfer past a semi-infinite vertical permeable moving plate with heat absorption.

The study of heat mass transfer with chemical reaction is of considerable importance in chemicals and hydro metallurgical industries. The study of heat generation or absorption in moving fluid is important in many problems with are related with chemicals reaction and these concerned dissociating fluid. The effect of non uniform heat generation effect may change the temperature distribution and consequently rate of particle deposition in nuclear reactors.

Tulukdar *et al* (2010) studied perturbation analysis of unsteady magneto hydrodynamic convective heat and mass transfer in a boundary radiation and chemicals reaction. Ganesan *at el.*

(2001) studied first order chemicals reaction on flow past a vertical permeable plate with thermal radiation and chemicals uniform heat and mass flux. Dulal pal (1999) studied effect of chemicals reaction on the dispersion chemicals physiology of flood flow regulation by red cells was discussed by single and Stemler (2005). Analytical solution for heat and mass transfer by laminar flow of a Newtonian ,viscous, electrically condition and heat generation or absorbing fluid on a continuously vertical permeable surface in the presence of radiation ,a first order homogenous chemicals reaction mass flux are repeated by Ibrahim *et al* (2003).

Wike *et al.* (2001) investigated the effect of chemicals reaction and diffusion .in an isothermal laminar flow along a soluble flat plate. Devika *et al.* (2012) studied the influence of chemicals reaction effect on MHD free convection flow in a irregular channels with porous medium, Raji *et al.* (2017) studied transfer effects on a unsteady MHD free convective flow a vertical plate with chemical reaction using finite element methods . *Raji et al* (2016) found both analytical and numerical solutions of chemical acceleration finite vertical plate in magnetic field and variable temperature via Laplace transform and finite element techniques. Omokhuale *et al.* (2016) studied effect of Heat Absorption on Steady/Unsteady MHD Free Convection Heat and Mass Transfer Flow Past an Infinite Vertical Permeable Plate with Mass Absorption and Variable. Suction.Omokhuale *et al.* (2017) examined Natural Convective Heat Mass Transfer Fluid Flow through a Porous Medium with Variable Pressure and Thermal Radiation.

Motivated by the above studied and applications mentioned, in this study Chemical Absorption Effect on Magnetohyrodynamic (MHD) convection flow past a vertical plate with Mass transfer investigated.

CHAPTER THREE

3.0 Methodology

3.1 Formulation of the problem

Consider the flow of viscous incompressible, electrically conducting, viscco-elastic, second order well-know, non-Newtonian fluid namely Rivlin-Erickson fluid past an impulsively started semi-infinite verticals plate in the presence of homogeneous chemical reaction, thermal radiation ,thermal diffusion, radiation absorption and heat absorption. The x^l-axis is taken along the plate in the vertically upward direct and the y^l-axis is chosen normal to the plate.

Initially the temperature of the plate and the fluid is assumed to be T_∞^l, and the species concentration at plate is C_w^l and in the fluid throughout C_∞^l are assume, At time $t^l>0$, the plate temperature is changed to T_w^l causing convection current to flow near the plate and mass is supply at the costant rate to the plate and they started moving upward due to the impulsive motion, gaining a velocity of u_o.A uniform magnetic field of strength B_O is applied in the y-direction. Therefore velocity and magnetic field are given q= (u, o, o) and B= (o,B_O, o). The flow being slightly conducting the magnetic Reynods number is much less than unity hence the induced magnetic field can be neglected in comparison with the applied magnetic field.

In the absence of any input electric field, the flow is governed by the following equation

Equation of momentum:

$$\frac{\partial u^l}{\partial t^l} + v^l \frac{\partial u^l}{\partial y^l} = gB(T^l - T_\infty^l) + gBc(\, C^l \_ C_\infty^l) + V \frac{\partial^2_{U^l}}{\partial y^{l2}} - \frac{\delta \mu_e^2 B_o^2 u^l}{\rho} \tag{3.1}$$

Equation of energy:

$$\rho CP\left(\frac{\partial T'}{\partial t'} + v' \frac{\partial T'}{\partial y'}\right) = K \frac{\partial 2_{T'}}{\partial y'^2} - Q_o(T' - T'_\infty + Q_1(C' - C'_\infty) \tag{3.2}$$

Equation of concentration:

$$\frac{\partial c'}{\partial t'} + v' \frac{\partial c'}{\partial y'} = Dm \frac{\partial^2 c'}{\partial y'^2} - Kr^*(C' - C'_\infty) \tag{3.3}$$

Where u' is the velocity of the fluid along the plate in x' – direction, t' – is the time, g

Is the acceleration due gravity is the coefficient of volume B^* is the coefficient of thermal

Expansion with concentration, T' is the temperature of fluid near the plate, T'_∞ is the temperature of fluid, c' is the species concentration in fluid near the, c'_∞ is the species concentration in fluid far away from the plate, v is kinematic viscosity, k_0^* is coeffient of kinematic visco-elastic parameter, δ is the electrical conductivity of the fluid μ_e is the magnetic permeability, B_0 is the strength of applied magnetic field p is the density of the fluid, u is the viscosity of fluid D is the molecular diffusivity D_1 is the thermal diffusivity Q_0 is the heat source /sink, Q_1 is the radiation absorption parameter , k_r^* is the chemical reaction paramer,and u_o is velocity of the plate.

The corresponding initial and boundary condition as follows

$$\left.\begin{aligned} &u = 1+\varepsilon e^{int} \ at \ y = 0, \ u \to 0, \ as\ y \to \infty \\ &\theta = 1+\varepsilon e^{int} \ at\ y = 0, \ \theta \to 0\ as\ y \to \infty \\ &c = 1+\varepsilon e^{int} \ at\ y = 0, \ c \to 0 \ as\ y \to \infty \end{aligned}\right\} \tag{3.4}$$

On introducing the following non –dimensional quantities

$$u = \frac{u'}{u_0}, t = \frac{t'u_0^2}{v}, \ y = \frac{y'u_0}{v}, \ \theta = \frac{T'-T'_\infty}{T'_w-T'_\infty}, C = \frac{C'-C'_\infty}{C'_w-C'_\infty} \tag{3.5}$$

In term of the above non dimensional quantities equation (3.1) to (3.3) reduce to the

From (3.1)

$$\frac{\partial u^l}{\partial t^l} + v^l\frac{\partial u^l}{\partial y^l} = gB(T^l - T^l_\infty) + gBc((C^l\_C^l_\infty) + V\frac{\partial_U^2{}^l}{\partial y^{l2}} - \frac{\delta\mu_e^2B_0^2u^l}{\rho}$$

$$\frac{u_0^3\partial u}{v\partial t} + v'\frac{u_0^2\partial u}{v\partial y} = g\beta(T'_\omega - T'_\infty)\theta + g\beta c(C'_\omega - C'_\infty)c\frac{vu_0^3}{v^2}\frac{\partial^2 u}{\partial y^2} - \frac{\sigma\mu_e^2B_e^2uu_0}{\rho}$$

Multiply through by $\frac{v}{u_0^3}$

$$\frac{\partial u}{\partial t} - \frac{v_0}{u_0}\frac{\partial u}{\partial y} = \frac{vg\beta(T'_\omega - T'_\infty)\theta}{u_0^3} + \frac{vg\beta c(C'_\omega - C'_\infty)c}{u_0^3} + \frac{\partial^2 u}{\partial y^2} - \frac{v\delta\mu_0^2\beta_0^2u}{\mu_0^2\rho}, \quad since\ v' = -v_0$$

$$since\ \frac{v_0}{u_0} = \lambda, Gr = \frac{vg\beta(T_\omega^{'} - T_\infty^{'})\theta}{u_0^3}, Gm = \frac{vg\beta c(C_\omega^{'} - C_\infty^{'})c}{u_0^3}, M = \frac{v\delta\mu_0^2\beta_0^2 u}{\mu_0^2\rho}$$

$$\frac{\partial u}{\partial t} - \lambda\frac{\partial u}{\partial y} = \frac{\partial^2 u}{\partial y^2} + Gr\theta + GmC - mu \qquad (3.6)$$

From (3.2)

$$\rho cP\left(\frac{\partial T'}{\partial t'} + v'\frac{\partial T'}{\partial y'}\right) = K\frac{\partial 2_{T'}}{\partial y'^2} - Q_0(T' - T_\infty' + Q_1(C' - C_\infty') \qquad (3.2)$$

$$U_0^2\rho cp\frac{(T_\omega^{'} - T_\infty^{'})}{v}\frac{\partial\theta}{\partial t} - U_0V_o\rho cp\frac{(T_\omega^{'} - T_\infty^{'}}{v}\frac{\partial\theta}{\partial y}$$

$$= u_0^2\kappa\frac{(T_\omega^{'} - T_\infty^{'})}{v^2}\frac{\partial^2\theta}{\partial y^2} - Q_0(T_\omega^{'} - T_\infty^{'})\theta + Q_1(C_\omega^{'} - C_\infty^{'})$$

Multiplying through by $\frac{v}{u_0^2\rho cp}(T_\omega^{'} - T_\infty^{'})$

$$\frac{\partial\theta}{\partial t} - \frac{v_o}{u_o}\frac{\partial\theta}{\partial y} = \frac{k}{\rho cpv}\frac{\partial^2\theta}{\partial y^2} - \frac{v}{u_0^2\rho cp} + \frac{Q_1(C_\omega^{'} - C_\infty^{'})}{u_o^2\rho cp(T_\omega^{'} - T_\infty^{'})}$$

Where $\lambda = \frac{v_0}{u_o}, \frac{1}{pr} = \frac{k}{\rho cpv}, \phi = \frac{v}{u_0^2\rho cp}, \delta = \frac{Q_1(C_\omega^{'} - C_\infty^{'})}{u_0^2\rho cp(T_\omega^{'} - T_\infty^{'})}$

$$\frac{\partial\theta}{\partial t} - \lambda\frac{\partial\theta}{\partial y} = \frac{1}{pr}\frac{\partial^2\theta}{\partial y^2} - \emptyset\theta + \delta c \qquad (3.7)$$

From (3.3)

$$\frac{\partial c'}{\partial t'} + v'\frac{\partial c'}{\partial y'} = Dm\frac{\partial^2 c'}{\partial y'^2} - Kr^*(C' - C_\infty^{'})$$

$$U_o^2\frac{(C_\omega^{'} - C_\infty^{'})}{v}\frac{\partial c}{\partial t} - u_o v_o\frac{C_\omega^{'} - C_\infty^{'}}{v}\frac{\partial c}{\partial y} - u_o^2 Dm\frac{C_\omega^{'} - C_\infty^{'}}{v^2}\frac{\partial^2 c}{\partial y^2} - k^*rc(C_\omega^{'} - C_\infty^{'}$$

Multiplying through by $\frac{v}{u_0^2(C_\omega^{'} - C_\infty^{'})}$

$$\frac{\partial c}{\partial t} - \frac{v_o}{u_o}\frac{\partial y}{\partial x} - \frac{Dm}{v}\frac{\partial y}{\partial x} - \frac{v}{u_o^2}k^*rC$$

where $\frac{v_o}{u_o} = \lambda$, $\frac{Dm}{v} 9 = \frac{1}{sc}$, $\frac{v}{u_0^2} krC = K^* rC$

$$\frac{\partial C}{\partial t} - \lambda \frac{\partial C}{\partial y} = \frac{\partial^2 C}{\partial y^2} - k^* rC \tag{3.8}$$

3.2 Method of solution

Equations (3.6) to (3.8) are coupled non linear partial differential equation and are to be solved by using the initial and boundary condition.

However exact solution is not possible for this set of equation and hence we solve these equation by using perturbation method of solving differential equation.

The equivalence perturbation method scheme of equation for (3.6) to (3.8) is follows

From

$$\frac{\partial u}{\partial t} - \lambda \frac{\partial u}{\partial y} = \frac{\partial^2 u}{\partial y^2} + Gr\theta + GmC - mu \tag{3.9}$$

$$U(y,t) = u_{0(y)} + \varepsilon u_{1(y)} e^{iwt}$$

$$\frac{\partial u}{\partial t} = iwu_{1(y)} e^{iwt}$$

$$\frac{\partial u}{\partial y} = u'_{o(y)} + \varepsilon u'_{1(y)} e^{iwt}$$

$$\frac{\partial^2 u}{\partial y^2} = u''_{o(y)} + \varepsilon u''_{1(y)} e^{iwt}$$

Substituting into (5)

$$inu_{1(y)} e^{int} - \lambda u'_{0(y)} - \lambda \varepsilon u'_{1(y)} = u''_{0(y)} + \varepsilon u''_{1(y)} + Gr\theta_{0(y)} + \varepsilon Gr\theta_{1(y)} e^{int} + GMc_{o(y)} +$$
$$\varepsilon Mu_{1(y)} e^{int} - Mu_{0(y)} - \varepsilon Mu_{1(y)} e^{int}$$

$$\varepsilon^o e^o = -\lambda U''_O = \quad U''_O + Gr\theta_O + GMC_0 - MU_0$$

$$U''_0 + \lambda U'_O - MU_O = -Gr\theta_O - GmC_O \tag{3.10}$$

$$\varepsilon e^{int} = inu_{1(y)} - \lambda u_{1(y)}'' + Gr\theta_{1(y)} + GMc_{1(y)} - Mu_{1(y)}$$

$$U_1'' + \lambda U_1' + (in - m)U_1 = -Gr\theta_1 - GMC_1 \quad \text{since } (in-m) = \Phi$$

$$U_1'' + \lambda U_1' - \Phi U_1 = -Gr\theta_1 - GMc_1 \quad (3.11)$$

... (3.7)

$$\frac{\partial \theta}{\partial t} - \lambda \frac{\partial \theta}{\partial y} = \frac{1}{pr} \frac{\partial^2 \theta}{\partial y^2} - \emptyset \theta + \phi c \quad (3.7)$$

$$\theta(y, t) = \theta_o + \varepsilon \theta_1 e^{int}$$

$$\frac{\partial \theta}{\partial t} = in\varepsilon\theta_{1(y)}$$

$$\frac{\partial \theta}{\partial y} = \theta_o' + \varepsilon \theta_1' e^{int}$$

$$\frac{\partial^2 \theta}{\partial y^2} = \theta_{o(y)}'' + \varepsilon \theta_{1(y)}'' e^{int}$$

Substituting into (3.7)

$$in\theta_{1(y)} - \lambda\theta_o' - \lambda\varepsilon\theta_{1(y)}' e^{int} = \frac{1}{pr}\theta_0'' + \frac{1}{pr}\varepsilon\theta_{1(y)}'' e^{int} + \emptyset\theta_o - \varepsilon\emptyset\theta_{1(y)} e^{int} + \lambda c_0 + \varepsilon\lambda c_{1(y)} e^{int}$$

$$e^o = -\lambda\theta_o' = \frac{1}{pr}\theta_0'' - \emptyset\theta_o + \lambda c_0$$

Multiplying through by pr

$$\theta_o'' + \lambda pr\theta_o' - \emptyset pr\theta_o = -\lambda prc_o \quad (3.13)$$

$$\varepsilon e^{int} = in\theta_1 - \lambda\theta_1' = \frac{1}{pr}\theta_1'' - \emptyset\theta_1 + \lambda c_1$$

Multiplying by pr

$$\theta_1'' + \lambda pr\theta_1' - (\emptyset - in)pr\theta_1$$
$$= -\lambda prc_{1}, \ since \ (\emptyset - in) = \beta$$

$$\theta_1'' + \lambda pr\theta_1' - \beta pr\theta_1$$
$$= -\phi prc_{1}, \qquad (3.14)$$

From (3.8)

$$\frac{\partial C}{\partial t} - \lambda\frac{\partial C}{\partial y} = \frac{\partial^2 C}{\partial y} - k^* rC$$

$$C(y,t) = C_{o(y)} + \varepsilon C_{1(y)}e^{int}$$

$$\frac{\partial C}{\partial t} = in\varepsilon C_1 e^{int}$$

$$\frac{\partial C}{\partial y} = C_o' + \varepsilon C_1' e^{int}$$

$$\frac{\partial^2 C}{\partial y^2} = C_{0(y)}'' + \varepsilon C_{1(y)}'' e^{int}$$

Substituting into (3.8)

$$\varepsilon^0 : -\lambda C_o' = \frac{1}{Sc}C_{1(y)}'' - ScKr^* C_{0(y)}$$

Multiplying through by Sc

$$C_o'' + \lambda ScC_o' + ScK^* r$$
$$= 0 \qquad (3.15)$$

$$\varepsilon e^{int} = inC_{1(y)} - \lambda ScC_{1(y)}' = \frac{1}{Sc}C_{1(y)}'' - K^* rC_{1(y)}$$

Multiplying through by Sc

$$ScinC_1 - \lambda ScC_1' = C_1'' - ScK^* rC_1$$

$$C_1'' + \lambda ScC_1'' - (K^* r - in)ScC_1 \ , Let \ (K^* r - in) = \varphi$$

$$C_1'' + \lambda ScC_1' - \varphi ScC_1 = 0 \quad (3.16)$$

$$U_0'' + \lambda U_0' - MU_O = -Gr\theta_O - GmC_O \quad (3.11)$$

$$U_1'' + \lambda U_1' - \Phi U_1 = -Gr\theta_1 - GMc_1 \quad (3.12)$$

$$\theta_o'' + \lambda pr\theta_o' - \emptyset pr\theta_o = -Ʌprc_o \quad (3.13)$$

$$\theta_1'' + \lambda pr\theta_1' - \beta pr\theta_1 = -Ʌprc_{1,} \quad (3.14)$$

$$C_o'' + \lambda ScC_o' + ScK^*r = 0 \quad (3.15)$$

$$C_1'' + \lambda ScC_1' - \varphi ScC_1 = 0 \quad (3.16)$$

From (3.14)

$$C_o'' + \lambda ScC_o' + ScK^*r = 0$$

Using method solving characteristic equation

a 1 ,b $sc\lambda$. sck^*r

$$M^2 + scM - sck^*r$$

$$\frac{-b \pm \sqrt{b^2 - 4ac}}{2a}, \qquad \frac{-ɅSc \pm \sqrt{(\lambda sc)^2 - 4(sck^*r}}{2}$$

$$\frac{-\lambda sc}{2} \pm \sqrt{\frac{(\lambda Sc)^2 - 4(Sc\lambda)}{4}}$$

Since $\sqrt{\frac{(\lambda Sc)^2 - 4(Sc\lambda)}{4}} = n_1$

$-\lambda sc \pm n_1$, $\quad M_1 = -\lambda Sc + n_{1,} \quad M_2 = -\lambda Sc - n_1$

$$C_{o(y)} = A_1 e^{m_1 y} + A_2 e^{-m_2 y} \quad (3.17)$$

Applying the boundary condition

C = 1, at y = 0

$$1 = A_1 e^0 + A_2 e^0 \qquad it\ implie\ A_1 + A_2 = 1 \quad (3.18)$$

$c \to 0, as\ y \to \infty$

$$0 = A_1 e^{0\infty} + A_2 e^{-\infty},\ it\ implies \quad A_{1=0} \quad (3.19)$$

Substituting A_1 into (3.17)

$$A_2 = 1 \quad (3.20)$$

Substituting (3.18) and (3.19) in (3.17)

$$C_{o(y)} = e^{-m_2 y} \quad (3.21)$$

From (3.13)

$C_1'' + \lambda Sc C_1' - \varphi Sc C_1 = 0$, $a = 1, b = \lambda sc, c = \varphi sc$

$M^2 + \lambda Sc M - \varphi Sc = 0$

$$\frac{-\lambda Sc \pm \sqrt{(\lambda Sc)^2 - 4(\varphi sc)}}{2} \quad , since \quad \sqrt{\frac{(\lambda Sc)^2 - 4(\varphi Sc)}{4}} = n_2$$

$\lambda sc \pm n_2$. $\qquad M_3 = -\lambda Sc + n_2, \qquad M_4 = -\lambda Sc - n_2$

$$C_{1(y)} = A_3 e^{m_3 y} += A_4 e^{-m_4 y} \quad (3.22)$$

Applying the boundary condition

$C = 1$, at $y = 0$

$$1 = A_3 e^0 + A_4 e^0 \qquad , it's\ implies\ \ A_3 + A_4 = 1 \tag{3.23}$$

$$C \to 0, \qquad as\ \ y \to \infty$$

$$0 = A_3 + A_4 \ \ , \Rightarrow A_3 = 0 \tag{3.24}$$

Substituting (3.23) in (3.22)

$$A_4 = 1 \tag{3.25}$$

Substituting (3.23) and (3.24) in (3.21)

$$C_{1(y)} = e^{\ m_4 y} \tag{3.26}$$

From (3.12)

$$\theta_o'' + \lambda pr\theta_o' - \emptyset pr\theta_o = -\lambda prc_o$$

$$\theta_{o(y)}h = \theta_o'' + \lambda pr\theta_o' - \emptyset pr\theta_o = 0$$

Use method solving characteristic equation

$$M^2 + \lambda prM - \emptyset pr = 0 \quad , a = 1 \, , b = \lambda pr, c = \Phi pr$$

$$\frac{-\lambda pr \pm \sqrt{(\lambda pr)^2 - 4(\emptyset pr}}{2} \qquad , since \sqrt{\frac{(\lambda pr)^2 - 4(\emptyset pr)}{4}} = n_3$$

$$\frac{-\lambda pr}{2} \pm n_3 \ , \qquad M_5 = \frac{-\lambda pr}{2} + n_3 \, , M_6 = \frac{-\lambda pr}{2} - n_3$$

$$\theta_{0(y)}h = A_5 e^{m_5 y} + A_6 e^{-m_6 y} \tag{3.27}$$

$$\theta_{0(y)}P_1 = -\lambda prc_0$$

$$\theta_{0(y)}P_1 = -\lambda pre^{\ m_2 y} \qquad since - \ \lambda pr = A_7$$

$$\theta_{0(y)}p = A_7 e^{-m_2 y}$$

$$\theta'_{o(y)}p = -M_2 A_7 e^{-m_2 y}$$

$$\theta''_{o(y)}p = M_2^2 A_7 e^{-m_2 y}$$

Substituting into 3.12)

$$A_7 = \frac{-\lambda pr}{M_2^2 - \lambda prm_2 - \Phi pr} \quad (3.28)$$

$$\theta_{o(y)}h + \theta_{o(y)}p = A_5 e^{m_5 y} + A_6 e^{-m_6 y} + A_7 e^{-m_2 y}$$

$$\theta_{o(y)} = A_5 e^{m_5 y} + A_6 e^{-m_6 y} + A_7 e^{-m_2 y} \quad (3.29)$$

Applying the boundary condition

$$\theta = 1 \ at \ y = 0$$

$$1 = A_5 e^0 + A_6 e^0 + A_7 e^0, it \ implies \ A_5 + A_6 + A_7 = 1 \quad (3.30)$$

$$\theta \to o, as \ y \to \infty$$

$$0 = A_5 e^{\infty} + A_6 e^{-\infty} + A_7 e^{-\infty}, A = 0 \quad (3.31)$$

Substituting (3.30) in (3.28)

$$\theta_{o(y)} = A_6 e^{-m_6 y} + A_7 e^{-m_2 y} \quad (3.32)$$

From (3.13)

$$\theta_1'' + \lambda pr\theta_1' - \beta pr\theta_1 = -\phi prc_1,$$

$$\theta_{1(y)}h = \theta_1'' + \lambda pr\theta_1' - \beta pr\theta_{1=0}$$

$$M^2 + \lambda prM - \beta pr = o \qquad a = 1, b = \lambda pr, c = \beta pr$$

$$\frac{-\lambda pr \pm \sqrt{(\lambda pr)^2 - 4(\beta pr)}}{2}, \quad \text{since} \sqrt{\frac{(\lambda pr)^2 - 4\beta pr}{4}} = n_4$$

$$\frac{-\lambda pr}{2} \pm n_4 \ , M_7 = \frac{-\lambda pr}{2} + n_4, \qquad M_8 = \frac{-\lambda pr}{2} - n_4$$

$$\theta_{1(y)}h = A_8 e^{m_7 y} + A_9 e^{-m_8 y} \quad (3.33)$$

$$\theta_{1(y)}p = -\lambda pr c_1,$$

$$\theta_{1(y)}p = -\lambda pr e^{-m_4 y}$$

$$since -\lambda pr = A_{10}$$

$$\theta_{1(y)}p = A_{10} e^{-m_4 y}$$

$$\theta'_{1(y)}p = -M_4 A_{10} e^{-m_4 y},$$

$$\theta''_{1(y)}p = M_4^2 A_{10} e^{-m_4 y},$$

Substituting into equation (3.13)

$$A_{10} = \frac{-\lambda pr}{M_4^2 - \lambda pr M_4 - \beta pr} \quad (3.34)$$

$$\theta_{1(y)}h + \theta_{1(y)}p = A_8 e^{m_7 y} + A_9 e^{-m_8 y} + A_{10} e^{-m_4 y}$$

$$\theta_{1(y)} = A_8 e^{m_7 y} + A_9 e^{-m_8 y} + A_{10} e^{-m_4 y} \quad (3.35)$$

Applying the boundary condition

$$\theta = 1, \quad at\ y = 0$$

$$1 = A_8 e^0 + A_9 e^0 + A_{10} e^0$$

$$A_8 + A_9 + A_{10} = 1 \quad (3.36)$$

$$\theta \to 0\ , as\ y \to \infty$$

$$0 = A_8 e^{\infty} + A_9 e^{-\infty} + A_{10} e^{-\infty} \quad , it\ implie\ A_8 = 0 \quad (3.37)$$

Substituting (3.37) in (3.35)

From (3.10)

$$U''_0 + \lambda U'_0 - MU_0 = -Gr\theta_0 - GmC_0$$

$U_{o(y)}h = U_0'' + \lambda U_0' - MU_0 = 0$

Use methods of solving characteristic equation

$M^2 + \lambda M - M = 0, a = 1, b = \lambda, c = m$

$\frac{-\lambda \pm \sqrt{\lambda^2 - 4(m)}}{2}$, $\quad since \sqrt{\frac{\lambda^2 - 4m}{4}} = n_5$

$\frac{-\lambda}{2} \pm n_5$, $\quad M_9 = \frac{-\lambda}{2} + n_5, \quad M_{10} = \frac{-\lambda}{2} - n_5$ (3.39)

$U_{o(y)}h = A_{11}e^{m_9y} + A_{12}e^{-m_{10}y}$

$U_{o(y)}p_1 - GmC_0$

$U_{o(y)}p_1 = -Gme^{-m_2y}$, $since - Gm = A_{13}$

$U_{o(y)}p_1 \; A_{13}e^{-m_2y}$

$U'_{o(y)} \; p_1 \; - M_2A_{13}e^{-m_2y}$

$U''_{o(y)}p_1 \; M_2^2A_{13}e^{-m_2y}$

Substituting into (9) and dividing by coefficient of A_{13}

$$A_{13} = \frac{-Gm}{M_2^2 - \lambda m - m} \quad (3.40)$$

$U_{0(y)}p_2 = -Gr\theta_0$

$U_{0(y)}p_2 = -Gr\, A_6e^{-m_6y} - GrA_7e^{-m_2y}$

$since - GrA_6 = A_{14}\; and - GrA_7 = A_{15}$

$U_{0(y)}p_2 = A_{14}e^{-m_6y} \quad and \quad A_{15}e^{-m_2y}$ (3.41)

$U_{0(y)}p_2 = A_{14}e^{-m_6y}$, $\quad U'_{o(y)}p_2 = -M_6A_{14}e^{-m_6y}$, $U''_{o(y)}p_2 = M_6^2A_{14}e^{-m_6y}$

Substituting into equation (9), and dividing by coefficient A_{14}

$$A_{14} = \frac{-GrA_6}{m_6^2 - \lambda m - m} \tag{3.42}$$

$$U_{o(y)}p_2 = A_{15}e^{-m_6y}, \quad U'_{o(y)}p_2 = -M_2A_{15}e^{-m_6y}, \quad U''_{o(y)}p_2 = M_2^2A_{15}e^{-m_6y}$$

Substituting into equation (9) ,and dividing by coefficient of A_{15}

$$A_{15} = \frac{-GrA_7}{m_2^2 - \lambda m - m} \tag{3.43}$$

$$U_{o(y)}h + U_{o(y)}p_1 + U_{o(y)}p_2 = A_{11}e^{m_9y} + A_{12}e^{-m_{10}y} + A_{13}e^{-m_2y} + A_{14}e^{-m_6y} + A_{15}e^{-m_2y}$$

$$U_{0(y)} = A_{11}e^{m_9y} + A_{12}e^{-m_{10}y} + A_{13}e^{-m_2y} + A_{14}e^{-m_6y} + A_{15}e^{-m_2y} \tag{3.44}$$

Applying the boundary condition

$$U = 1 + e^{int} \; at \; y = 0$$

$$1 = A_{11}e^0 + A_{12}e^0 + A_{13}e^0 + A_{14}e^0 + A_{15}e^0 \tag{3.45}$$

$$A_{11} + A_{12} + A_{13} + A_{14} + A_{15} = 1$$

$$U \to 0 \; as \; y \to \infty$$

$$0 = A_{11}e^{\infty} + A_{12}e^{-\infty} + A_{13}e^{-\infty} + A_{14}e^{-\infty} + A_{15}e^{-\infty} \tag{3.46}$$

$$A_{11} = 0$$

Substituting (3.45) into (3.43) (3.47)

$$U_{0(y)} = A_{12}e^{-m_{10}y} + A_{13}e^{-m_2y} + A_{14}e^{-m_6y} + A_{15}e^{-m_2y}$$

From (3.11)

$$U_1'' + \lambda U_1' - \Phi U_1 = -Gr\theta_1 - GMc_1$$

$$U_{1(y)}h = U_1'' + \lambda U_1' - \Phi U_1 = 0$$

Using characteristic method of solving homogeneous equation

$m^2 + \lambda m - \Phi = 0\ , a = 1\ , b = \lambda , c = \Phi$

$\frac{-\lambda \pm \sqrt{\lambda^2 - 4\Phi}}{2}, \quad \frac{-\lambda}{2} \pm \sqrt{\frac{\lambda^2 - 4\Phi}{4}} = n_6$

$\frac{-\lambda}{2} \pm n_6 \quad , \quad M_{11} = \frac{-\lambda}{2} + n_6\ , M_{12} = \frac{-\lambda}{2} - n_6$

$$U_{1(y)}h = A_{16}e^{m_{11}y} + A_{17}e^{-m_{12}y} \tag{3.48}$$

$U_{1(y)}p_1 \quad GMc_1$

$U_{1(y)}p_1 = -Gme^{-m_4 y}, \quad since - Gm = A_{18}$

$U_{1(y)}p_1 = -A_{18}e^{-m_4 y},, \quad U'_{1(y)}p_1 = mA_{18}e^{-m_4 y}, \quad U''_{1(y)}p_1 = -m_4^2 A_{18}e^{-m_4 y}$

Substituting into (10), and dividing by coefficient of A_{18}

$$A_{18} = \frac{-Gm}{m_4^2 - \lambda m - \Phi} \tag{3.49}$$

$U_{1(y)}p_2 = -Gr\theta_1$

$U_{1(y)}p_2 = -GrA_9 e^{-m_8 y} - GrA_{10}e^{-m_4 y}\ , Let - GrA_9 = A_{19,}\ and - GrA_{10} = A_{20}$

$it's\ implie\ A_{19}e^{-m_8 y} \quad and \quad A_{20}e^{-m_4 y}$

$U_{1(y)}p_2 = A_{19}e^{-m_8 y}\ , \quad U'_{1(y)}p_2 = -m_8 A_{19}e^{-m_8 y}\ , \quad U''_{1(y)}p_2 = m_8^2 A_{19}e^{-m_8 y}$

Substituting into (3.11), and dividing by coefficient of A_{19}

$$A_{19} = \frac{-GrA_9}{m_8^2 + \lambda m - \Phi} \tag{3.50}$$

$U_{1(y)}p_2 = A_{20}e^{-m_4 y}\ , \quad U'_{1(y)}p_2 = -m_4 A_{20}e^{-m_4 y}\ , \quad U''_{1(y)}p_2 = m_4^2 A_{20}e^{-m_4 y}$

Substituting into (3.11), and dividing by coefficient of A_{20}

$$A_{20} = \frac{-GrA_{10}}{m_4^2 - \lambda m - \Phi} \tag{3.51}$$

$$U_{1(y)}h + U_{1(y)}p_1 + U_{1(y)}p_2 = A_{16}e^{m_{11}y} + A_{17}e^{-m_{12}y} + A_{18}e^{-m_4y} + A_{19}e^{-m_8y} + A_{20}e^{-m_4y}$$

$$U_{1(y)} = A_{16}e^{m_{11}y} + A_{17}e^{-m_{12}y} + A_{18}e^{-m_4y} + A_{19}e^{-m_8y} + A_{20}e^{-m_4y} \quad (3.52)$$

Apply the boundary condition

$$u = 1 + e^{int}, \qquad y = 0$$

$$1 = A_{16}e^0 + A_{17}e^0 + A_{18}e^0 + A_{19}e^0 + A_{20}e^0$$

$$A_{16} + A_{17} + A_{18} + A_{19} + A_{20} = 1 \quad (3.53)$$

$$U \to o \ as \ y \to \infty$$

$$0 = A_{16}e^{\infty} + A_{17}e^{-\infty} + A_{18}e^{-\infty} + A_{19}e^{-\infty} + A_{20}e^{-\infty}$$

$$A_{16} = 0 \quad (3.54)$$

Substituting (3.52) in (3.51)

$$U_{1(y)} = A_{17}e^{-m_{12}y} + A_{18}e^{-m_4y} + A_{19}e^{-m_8y} + A_{20}e^{-m_4y} \quad (3.55)$$

Velocity

$$U_{(y,t)} = A_{12}e^{-m_{10}y} + A_{13}e^{-m_2y} + A_{14}e^{-m_6y} + A_{15}e^{-m_2y} + \varepsilon(A_{17}e^{-m_{12}y} + A_{18}e^{-m_4y} + A_{19}e^{\pm m_8y} + A_{20}e^{-m_4y})e^{int} \quad (3.56)$$

Temperature

$$\theta_{(y,t)} = (A_6e^{-m_6y} + A_7e^{-m_2y}) + \varepsilon(A_9e^{-m_8y} + A_{10}e^{-m_4y})e^{int} \quad (3.57)$$

Concentration

$$C_{(y,t)} = (e^{-m_2y}) + \varepsilon(e^{-m_4y})e^{int} \quad (3.58)$$

The skin friction, Nusselt number and of mass transfer are important physical parameter for type of boundary layer flow.

The skin-friction at the plate in the non-dimensional give by

$$u(y,t) = m_{10}A_{12} + m_2A_{13} + m_6A_{14} + m_2A_{15} + \varepsilon(m_{12}A_{17} + m_4A_{18} + m_8A_{19} + m_4A_{20})e^{int} \tag{3.59}$$

The Nusselt number is given by

$$\theta(y,t) = m_6A_6 + m_2A_7 + \varepsilon(m_8A_9 + m_4A_{10})e^{int} \tag{3.60}$$

The rate of mass transfer Sh is given by

$$c(y,t) = m_2 + \varepsilon(m_4)e^{int} \tag{3.61}$$

CHAPTER FOUR

4. 0 Result and discussion

The Chemical Absorption Effect on Magnetohyrodynamic (MHD) Convection Flow throgt vertical with Mass transfer has been formulated analyzed and solved analytically. In order to point out the effects of physical parameters namely Visco-elastic parameter λ, magnetic parameter M, Heat parameter Q, Thermal Grashof number Gr, Mass Grashof number Gc, Prandtl number Pr Schmidt number Sc and Chemical reaction parameter Kr, on the flow patterns. The computation of the flow field are carried out.

The Velocity profile has been studied and presented in figure 4.6 to 4.9 the velocity profile are studied for different values of magnetic parameter (M=1.00,2.00,3.00,5.00) and is presented in figure 4.6 From the graph we observed that velocity is increase with decrease in magnetic parameter. The velocity profiles is studied for different values of Mass Grashof number (Gm=2.00, 4.00, 6.00, 8.00) and presented in figure 4.9 it is observed that the velocity increase with decrease in Mass Grashof number the profiles studied for different value of modified Grashof number (Gr=1.00, 2.00, 5.00, Gc=3.00) and is presented in figure 4.8 from the graph its observed that the velocity increase with increase in modified Grashof number. The temperature

Profiles have been studied presented in figure 4.4 to 4.5 the effect temperature for different values of heat sink (Q=1.00, 2.00, 3.00, 5.00) is presented in figure 4.5 from the graph, it is shown that Temperature increase with decrease in. The temperature profiles for different values of Prandtl number (Pr =0.71, 1.00, 3.00, 7.00) is presented in figure 4.4 we observed from the graphs that temperature increase with decrease Prandtl number. The temperature profiles for different value of the heat absorption parameter (Q=1.00, 2.00, 3.00, 5.00) is presented in figure 4.5 from the graph it's observed that the temperature is increasing with decrease in.

The Concentration profile has been studied is presented in figure 4.1 to 4.3 the effects of concentration for different value of Visco-elastic parameter ($\lambda = 1.00, 2.00, 3.00, 4.00$) Is presented in figure 4.1 from the graphs it is observed that the temperature increase with decrease in. The effect of concentration for different value of chemical reaction parameter (Kc=0.50, 1.00, 1.50, 3.00) is presented in figure 4.2 from the graph it is observed that the temperature is increasing with decrease in chemical reaction parameter. The effect of concentration for different value of Schmidt number (Sc=0.30, 0.60, 1.00, 2.00) is presented in figure 4.3 from the graph it is observed that the temperature is increase with decrease in Schmidt number.

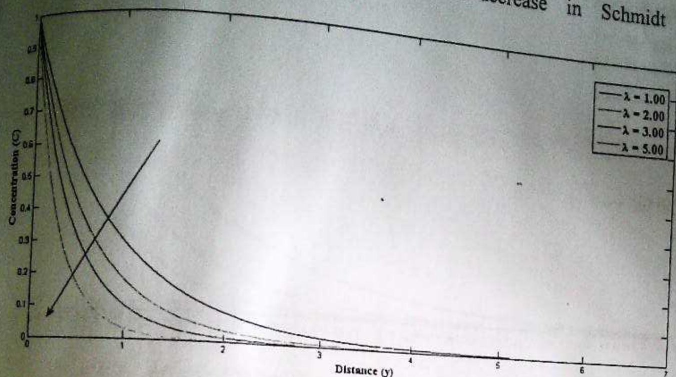

Figure 4.1 effect of visco-elastic parameter on nusselt number

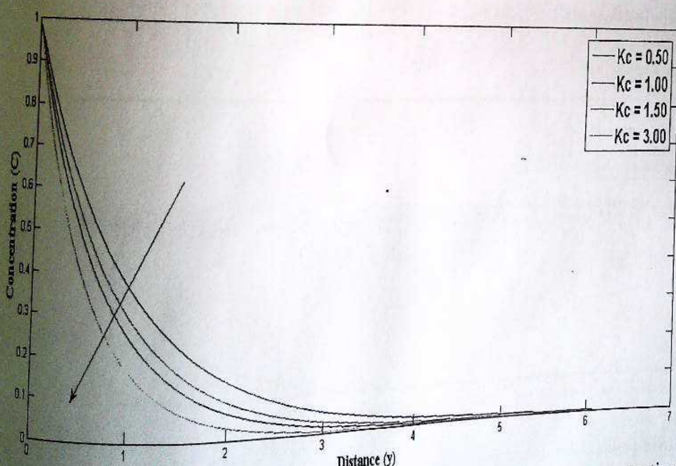

Figure 4.2 effect of increase the values of chemicals reaction on concentration.

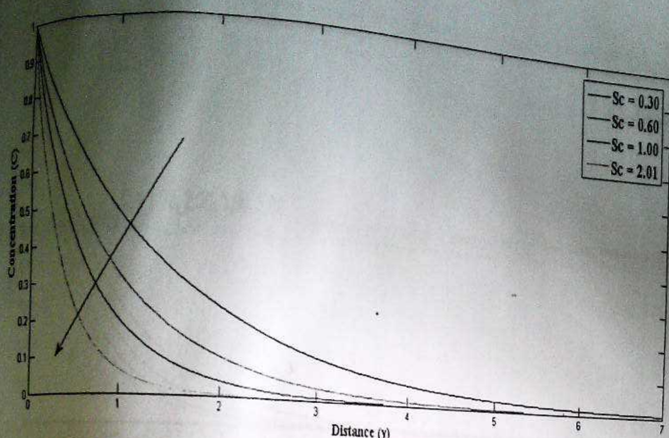

Figure 4.3 effect of Schmidt number on concentration.

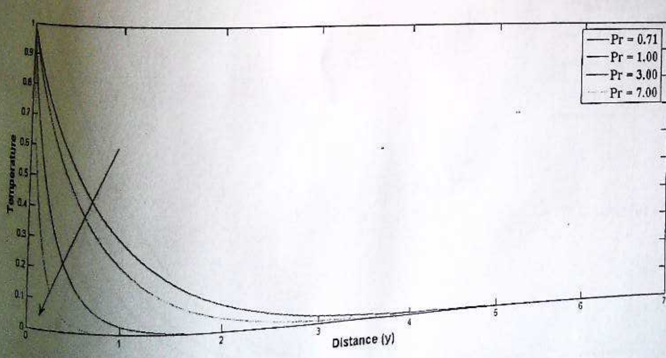

Figure 4.4 effect of Prandtl number on temperature.

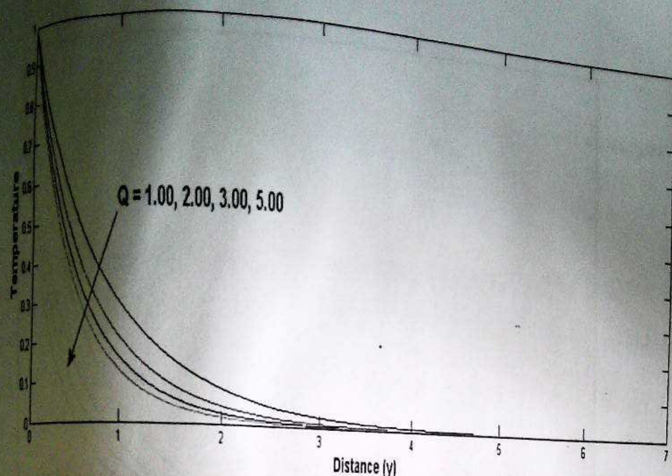

Figure **4.5** effect of heat absorption parameter on temperature.

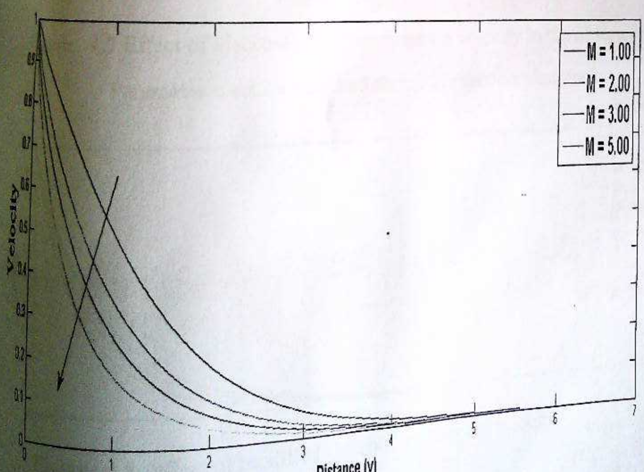

Figure **4.6** effect of magnetic parameter on velocity.

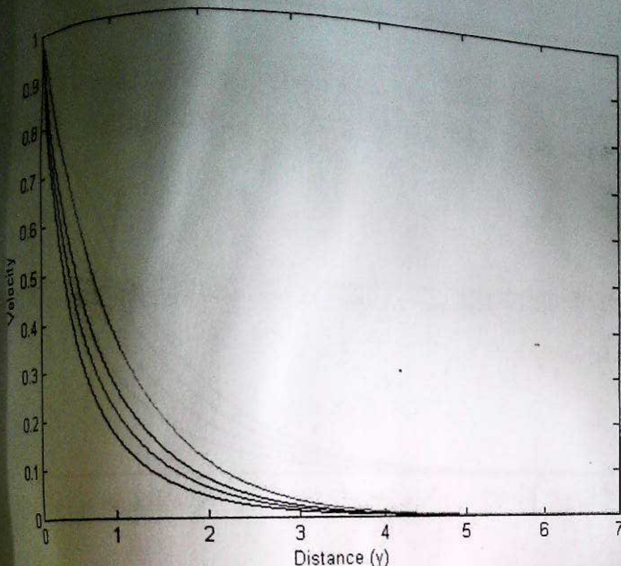

Figure **4.7** Effect of viscco-elastic parameter on velocity in the absence of radiation Parameter soret number and chemical reaction parameter

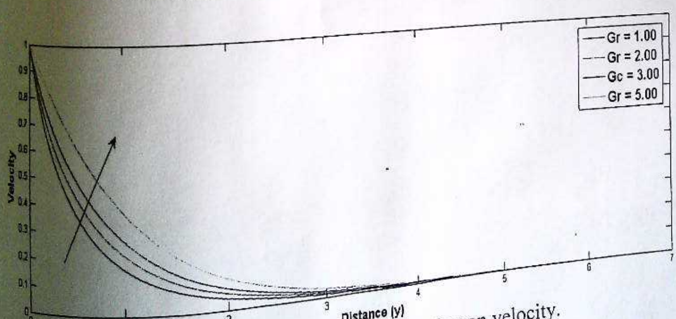

Figure **4.8** effect of modified Grashof number on velocity.

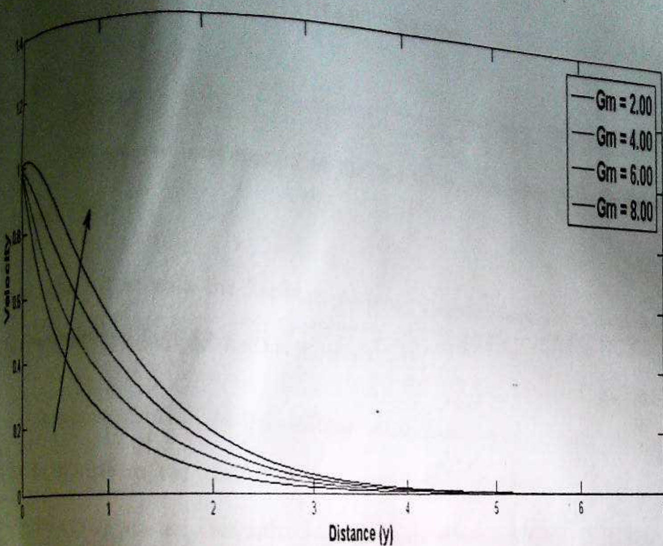

Figure 4.9 effect of the mass Grashof number on velocity

CHAPTER FIVE

5.1 Summary

In chapter one we see the introduction of the. the aims and objective as well as definition of some important terms.

We started chapter two with the literature review. Chapter three we formulated the equation governing the flow. It's the problems is governed by;

Coupled nonlinear systems of partial differential equations (pdes), dimensional quantities were introduced to transform the partial differential equation into ordinary differential equations (odes), and the equations are then solved using the perturbation method. In chapter four we see the numerical representation for different values of velocity, temperature, concentration. In chapter five we see the summary, conclusion, reference.

5.2 Conclusion

We investigated the MHD free convection flow of a non-Newtonian fluid past an impulsively started vertical plate in the presence of chemical reaction, thermal diffusion, radiation absorption, thermal radiation. and heat absorption, with constant mass flux. the governing boundary layer equations are formulated with appropriate boundary conditions. The governing boundary layer equation is simplified and non-dimensionalized. The dimensionless equations are solved by using the finite difference method. the effect of various physical parameter such as Grashof number (Gr), modified (Gc), magnetic field parameter (M), Schmidt number (Sc), Prandtl number (pr), heat absorption parameter (ϕ), chemical reaction parameter (Kr) are considered on the dimensionless velocity ,temperature ,and concentration. Computation on the variation of local skin friction, Nusselt number and Sherwood number are also recorded. From the graphs plotted we discover that:

1. Velocity decrease with an increase in magnetic field parameter, Schmidt number, Prandtl number and visco-elastic parameter while it increases with an increase in Grashof number, modified Grashof number and soret number.

2. Temperature increases with an increase radiation absorption parameter, visceo-elastic parameter, Eckert number while it decreases with an increase in radiation parameter, Prandtl number and heat absorption parameter.

3. Concentration increase with an increase in soret number while it decreases with an increase in Schmidt number and chemical radiation parameter.

References

Bakier A.Y . and Dorsh R.S.R.(1996) ;Thermal radiation and effect on horizontal surfaces in saturated porous medium Transport porous media ,vol,23 pp.357-61.

Chamkha. A J. (2004); MHD flow of a uniformly stretched vertical permeable surface in the presence of heat generation, absorption and a chemical reaction. Int. Commun. Heat Mass Transfer 30 (3) 413-422.

Dorsh M.A. (2004); Combined heat and mass transfer in MHD free convection from a vertical surface with Ohmic heating and viscous dissipation, Int. Eng.Sci.42 (2) 699-713.

Depal, H. Mondal. (2011); Effects of Soret Dufour, chemical reaction and thermal radiation on MHD non-Darcy unsteady mixed convective he T. Hayyat, M. Nawaz,(2011), Soret and Dufour effect on the mixed convection flow of second grade fluid subject to Hall and ionslip current, Int. J Numer meth.vol.3 pp.7-12.

Hayyat, M. Nawaz,(2011), Soret and Dufour effect on the mixed convection flow of second grade fluid subject to Hall and ionslip current, Int. J Numer meth.vol.3 pp.7-12.

Kandasamy. K. Periasamy. K.K.S. Prabhu.(2005) Effects of chemical reaction, heat and mass transfer along a wedge with heat source and concentration in the presence of suction or injection,lnt. J. Heat Mass Transf. 48(7); p 1388-1394

Mostafa A.and Mahmoud A.(2009); Thermal radiation effect on unsteady MHD free convection flow past vertical plate with temperature dependent ; The Canadian journal of Engineerring,vol.87pp-52.

Omokhuale, E., Usman, H. and Altine, M. M. (2016). Effect of Heat Absorption on Steady/Unsteady MHD Free Convection Heat and Mass Transfer Flow Past an Infinite Vertical Permeable Plate with Mass Absorption and Variable Suction. *Journal of the Nigerian Association of Mathematical Physics,* Volume 38 (Nov., 2016). 433 – 442.

Omokhuale, E., Okoro, F. M., Asibor, R. E. and Usman, H. (2017). Natural Convective Heat Mass Transfer Fluid Flow Through a Porous Medium with Variable Pressure and Thermal Radiation. *Journal of the Nigerian Association of Mathematical Physics,* Volume 39 (Jan., 2017). 129 – 138.

Patil,P. S Kulkarni. (2008); Effect of chemical reaction on free convective flow of a polar fluid through a porous medium in the presence of internal heat generation, Int. journal Therm. Sci. 47(8) 1043-1054

Raptis A. (1986); flow through a porous medium in the presence of magnetic field. – International .Jornal. Energy Research vol. 10,pp.97-101.

Raju M.S.Liu X.R.and Law C.K..K.(1982) A formation of combined force and free convection past horizontal and vertical surface. Int. J. Heat Mass Transfer ,vol.27 pp.2215-2224.

Seddeek, A.A Darwish,M.S. Abdelmeguid. (2007) ;Effect of chemical reaction and variable viscosity on hydromagnetic mixed convention heat and mass transfer for Hiemenz flow through porous media with radiation Commun. Nonlinear Sci.Numer Simul 12 (2) 195-21z3.

Vajranvelu M.H.(1990); Radiative and free convection effects on the oscillatory flow past a vertical plate. Astrophysics and space, Science ,vol. 166,pp.26 -75

Appendix

```
...el
...0:0.01:7;
...1 = sqrt(((a*Sc).^2+4.*b*Sc)./4);
...2 = sqrt(((a*Sc).^2+4.*Sc*(b+i*n))./4);
...3 = sqrt(((a*Pr).^2+4.*Q*Pr)./4);
...4 = sqrt(((a*Pr).^2+4.*Pr*(Q+i*n))./4);
...2 = (a*Sc)./2+a1;
... = exp(-m2*y);
...4 = (a*Sc)./2+a2;
... = exp(-m4*y);
...6 = (a*Pr)./2+a3;
...0 = exp(-m6*y);
...8 = (a*Pr)./2+a4;
...1 = exp(-m8*y);
... = sqrt(((a).^2+4.*M)./4);
... = sqrt(((a).^2+4.*(M+i*n))./4);
...10 = (a)./2+a5;
...12 = (a)./2+a6;
...3 = -Gr/(m6^2-a*m6-M);
...4 = -Gm/(m2^2-a*m2-M);
... = 1-B3-B4;
...0 = B2*exp(-m10*y)+B3*exp(-m6*y)+B4*exp(-m2*y);
...7 = -Gr/(m8^2-a*m8-(M+i*n));
...8 = -Gm/(m4^2-a*m4-(M+i*n));
...6 = 1-B7-B8;
...1 = B6*exp(-m12*y)+B7*exp(-m8*y)+B8*exp(-m4*y);

... T0+T1*epsilon*exp(i*nt);
... C0+C1*epsilon*exp(i*nt);
... u0+u1*epsilon*exp(i*nt);

...
... 'k','linewidth',2)
... Distance (y)')
... Velocity ')
...
```