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RESEARCH ARTICLE

ANALYSIS OF TWO IMMISCIBLE MHD THIN LAYER FLOW OF MIXED CONVECTIONTHIRD ORDER FLUID OVER A MOVING VERTICAL BELT WITH CHEMICAL REACTION

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Abstract

This paper examine the slip influence on MHD two immiscible third order thin layer fluid flow in the existence of radiation thermal and transfer mass of first order chemical reaction analysis over a vertical moving belt. we mean immiscible fluids is a superposed fluids with various densities and viscosity. The highly governing non-linear equations are solved by using regular suitable perturbation theory. The different characteristics influential parameters namely, Grashof number of thermal, Magnetic induction, thermal radiation parameter, Grashof number of mass, Non-Newtonian parameter, Brinkman number and chemical reaction are examined flow velocity, temperature field, concentration profile also addressed.

Key words: Third grade fluid, Lifting, Drainage, Magnetohydrodynamics (MHD), Heat transfer, Thin film, Chemical reaction, Thermal radiation, Perturbation method.

Introduction

Theories of non-Newtonian liquids have a extremely effective research field for last few decennium as this third class of liquids represents various important of bio-engineering science and chemical industrial technology for practical applications of processing materials such as slurry fuels, extrusion of polymer fluids, drilling mud, exotic lubricants, products of food, granular suspension, paints, aqueous foams, oil filtration and electrostatic precipitation. Non-Newtonian fluids are not easy compare to Newtonian fluids. Different model types have been suggested to portray the natural characteristics and non-Newtonian fluid properties. Basically, the immiscible fluid has vast application in realistic practical situations. Displacement of non-Newtonian Immiscible fluids ensue in several enhanced oil recovery (EOR) proceeding such as inoculation of non-Newtonian liquids, specifically polymer solutions, micro-emulsions, macro-emulsions, foam solutions and heavy oil displacement by water flooding. Hence an attempt has been made to develop a mathematical model.

The incompressible fluid layer of various immiscible liquid of different heights between two plates and it's have maximum velocity discussed by Kapur *et.al.,* (1961a,b) . Sacheti *et.al.,* (1974) presented the non-Newtonian fluid contact pour of double immiscible homogeneous layer suction impact at the plate is stationary. Flow of non-Newtonian two immiscible liquids is an unbelievably high, impermeable parallel medium brimming with invariable permeable and non-permeable studied by Chamkha Ali (2004). Fundamental aspects of two immiscible pour thermodynamical theory and fluid mechanics in thermal transfer are established by (Ishil and Hibiki 1975).investigated two immiscible stratified viscous liquids in a horizontal plane with respect to the interface surface. Reported the speed flow is maximum from one to another second grade liquid layer between immiscible parallel two plates. Unsteady laminar pour and transmit of thermal double immiscible viscous liquids through a equivalent permeable barrier channel is investigated Chamkha *et.al.,* (2020). Channels are preserved at two varies perpetual temperature and both immiscible fluids are constant obtained by Abdul Mateen *et.al.,* (2013). Umavathi *et.al.,* (2006) analyzed transfer of the thermal and flow of the unsteady two immiscible liquid in a horizontal. [23] Stamenkovic *et al.,* (2010) interpolated the heat flow transfer analysis of MHD two immiscible fluid due to a uphill plates are moving. Petrovic *et.al.,* (2016) developed thermal transfer of magnetohydrodynamic constant density two immiscible liquid pour with parallel permeable. Nikodijevic *et.al.,* (2013) computed two immiscible MHD electrical flow and isothermal fluid betwixt electric field applied in the insulated moving plates. Two fluid transport of magneto convection in a perpendicular cage consisting of double bounded region. One is electrical fluid and another one is non-electrically liquid permeable channel is described Malashetty et.al., (2004; 2006). Time dependent two-immiscible variation liquid between the gradient of pressure and horizontal plated modeled by Bhattacharya (1968). Ramana Murthy and Srinivas (2015) explored the transfer of thermal thermodynamics law of first and second couple stress liquid of two non-miscible inside a parallel medium inferior the process of an imposed transversal magnetic induction.

Mass transfer analysis in two immiscible fluid is a more challenging applications of production of chemical and oil processing. The heat and transfer of flow aspects if immiscible liquid is a specific essential in extraction of petroleum and transport. (Prathap Kumar *et.al.,* 2014; 2015) evaluated the chemical reaction effects on double permeable immiscible liquid passes through a medium with both liquids are different thermal. Influence of thermal and transfer of mass on the unsteady two free convection electrical-conduction immiscible liquid layer via on horizontal channel nether the influence of magnetic induction and chemical reaction solved (Sivakami *et.al.,* 2017; 2018). MHD unsteady two immiscible mixed convection liquid pour with thermal transmission and transfer of species computed (Joseph *et.al.,* 2015). Following many researchers are working in traditional perturbation method. Robert,E and Malley, O. Jr., (2012) established singular perturbation method to solve different ordinary differential equation. (Lebond 2008) gave a powerful reductive perturbation techniques to solve non- linear equations in an effective way and some applications pertaining to it.

In the present of the purpose motivation, we discuss to study MHD third order two immiscible thin layer mixed convection fluid flow with chemical first order homogeneous reaction. This kind of inquiry is proper understanding thermal and characteristics of mass for centrifugal casting of metals and solidification, geophysical problem and petroleum industry. No one have examined electrical conducting thin layer of mixed convection third order two immiscible fluid in the existence of slip sustained boundary conditions. Consider thin layer of two types flows (i) lifting flow, (ii) drainage flow. The analytical employing results are acquired by utilized perturbation regular accurate for small value of. Velocity, thermal field, species concentration and chemical dispersal parameters all are discussed greatly exploration on the flow profile.

Mathematical formulation

(i)Lifting flow:

The physical geometry under assumption depicted in Fig. 1 . Consists both liquid layer are incompressible, steady, laminar and double immiscible liquid flows above a moving vertical belt through a extensive bath of third order liquid. Fluids are conducting electrically in the existence of unvarying magnetic induction and moves belt perpendicular uphill at perpetual speed V. The belt transfer with in a liquid of layer thickness constant h_1 as first layer liquid and second layer liquid of thickness $\delta - h_1$. Since total uniform thickness to be . The axial framework cartesian system is selected, where $x-$ axis is held perpendicular to the belt and $y-$ axis choosing corresponding the belt. Outside atmospheric pressure is all over and then both layer of uniform thickness is h_1 and $(\delta - h_1)$.

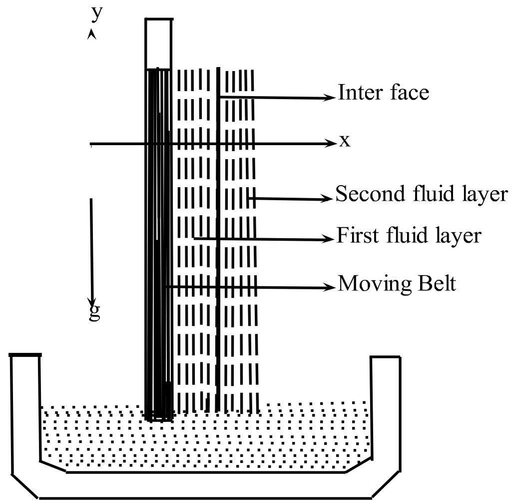

Fig.1 Physical configuration of the lifting flow problem

The conservation equations of third order immiscible liquid can be expressed as,

Conservation of mass

$$\nabla \cdot \boldsymbol{V}^{(i)} = 0 \qquad (1)$$

where, $\boldsymbol{V}^{(i)}$ describes as vector velocity of fluid and Layer $(i) = 1, 2$.

Conservation of momentum

$$\rho^{(i)} \frac{D\boldsymbol{V}^{(i)}}{Dt} = \nabla \cdot \boldsymbol{T}^{(i)} + (\rho \boldsymbol{g} \beta_{\Theta}(\Theta^{(i)} - {\Theta_0}^{(i)}) + \rho \boldsymbol{g} \beta_C (C^{(i)} - {C_0}^{(i)})) + \boldsymbol{J} \times \boldsymbol{B} \qquad (2)$$

where, $\frac{D}{Dt} = \frac{\partial}{\partial t} + (\boldsymbol{V}^{(i)}.\nabla)$ indicates material time derivative, $\rho(i)$ be a constant of density, $\boldsymbol{T}$ denoted as shear stress, $\boldsymbol{J}$ represented as density of current, $\boldsymbol{B}$ be a magnetic induction and $\boldsymbol{g}$ describes as body force of gravitational.

Conservation of energy

$$\rho^{(i)} {c_p}^{(i)} \frac{D\boldsymbol{\Theta}^{(i)}}{Dt} = K^{(i)} \nabla^2 \boldsymbol{\Theta}^{(i)} + tr(\boldsymbol{\tau}^{(i)}.\boldsymbol{L}^{(i)}) \qquad (3)$$

Here, $= \nabla \boldsymbol{V}^{(i)}{}_p$, K are known as thermal conductivity, ${c_p}^{(i)}$ describes as specific heat, Cauchy stress tensor represented as $(\boldsymbol{\tau})$, $\boldsymbol{\Theta}^{(i)}$ be a temperature. Conservation of species

$$\frac{D\boldsymbol{C}^{(i)}}{Dt} = D\nabla^2 \boldsymbol{C}^{(i)} - K\boldsymbol{C}^{(i)} \qquad (4)$$

Where, $\boldsymbol{C}^{(i)}$ be a third grade fluid concentration, K indicates a chemical reaction, D describes the mass coefficient diffusivity.

The magnetic induction $\boldsymbol{B} = (0, B0, 0)$ is transversely applied to the belt and Lorentz external body force(per unit)is given by,

$$\boldsymbol{J} \times \boldsymbol{B} = [0, \sigma^{(i)} B_0{}^2 v^{(i)}(x), 0] \qquad (5)$$

Tensor of stress shear $\boldsymbol{T}^{(i)}$ are described by,

$$\boldsymbol{T}^{(i)} = -p(\boldsymbol{I}) + \boldsymbol{\tau}^{(i)}, \qquad (6)$$

Here $-p\boldsymbol{I}$ is a spherical shear stress and $\tau\,(\boldsymbol{i})$ is denoted as,

$$\tau^{(i)} = \mu^{(i)} \boldsymbol{A}_1{}^{(i)} + \alpha_1{}^{(i)} \boldsymbol{A}_2{}^{(i)} + \alpha_2{}^{(i)} \boldsymbol{A}_1{}^{2(i)} + \beta_1{}^{(i)} \boldsymbol{A}_3{}^{(i)} + \beta_2{}^{(i)} \left(\boldsymbol{A}_1{}^{(i)} \boldsymbol{A}_2{}^{(i)} + \boldsymbol{A}_2{}^{(i)} \boldsymbol{A}_1{}^{(i)} \right) + \beta_3{}^{(i)} (\mathrm{tr} \boldsymbol{A}_1{}^{2(i)}) \boldsymbol{A}_1{}^{(i)} \qquad (7)$$

In which, $\boldsymbol{A}_1{}^{(i)}, \boldsymbol{A}_2{}^{(i)}, \boldsymbol{A}_3{}^{(i)}$ are kinematic tensors and $\alpha_1{}^{(i)}, \alpha_2{}^{(i)}, \beta_1{}^{(i)}, \beta_2{}^{(i)}, \ \beta_3{}^{(i)}$ are the moduli of constant material indicates by,

$$\left. \begin{array}{c} \boldsymbol{A}_1{}^{(i)} = (\nabla \boldsymbol{V})^{(i)} + (\nabla \boldsymbol{V})^{T(i)} \\ \boldsymbol{A}_n{}^{(i)} = \dfrac{D \boldsymbol{A}_{n-1}{}^{(i)}}{Dt} + \boldsymbol{A}_{n-1}{}^{(i)} (\nabla \boldsymbol{V})^{(i)} + (\nabla \boldsymbol{V})^{T(i)} \boldsymbol{A}_{n-1}{}^{(i)}, n \geq 1 \end{array} \right\} \qquad (8)$$

$$\mu^{(i)} \geq 0, \alpha_1{}^{(i)} \geq 0, \left| \alpha_1{}^{(i)} + \alpha_2{}^{(i)} \right| \leq \sqrt{24 \mu^{(i)} \beta_3{}^{(i)}}, \beta_3{}^{(i)} \geq 0 \qquad (9)$$

The conservation of our profile model described as,

$$\boldsymbol{V}^{(i)} = \left[0, v^{(i)}(x), 0\right], \Theta^{(i)} = \Theta^{(i)}(x) \ and \ C^{(i)} = C^{(i)}(x). \qquad (10)$$

Using (10) in equation (1) and (6) - (9) , satisfied continuity equation. Equation (6) produces physical component interpolation tensor of stress

$$\left. \begin{array}{c} T_{xx}{}^{(i)} = -p + \left(2\alpha_1{}^{(i)} + \alpha_2{}^{(i)}\right) \left(\dfrac{dv^{(i)}}{dx} \right)^2, \\ T_{xy}{}^{(i)} = \mu^{(i)} \dfrac{dv^{(i)}}{dx} + 2\left(\beta_2{}^{(i)} + \beta_3{}^{(i)}\right) \left(\dfrac{dv^{(i)}}{dx} \right)^3, \\ T_{yy}{}^{(i)} = -p + \alpha_2{}^{(i)} \left(\dfrac{dv^{(i)}}{dx} \right), \\ T_{zz}{}^{(i)} = -p, \\ T_{xz}{}^{(i)} = T_{yz}{}^{(i)} = 0 \end{array} \right\} \qquad (11)$$

Substitute equations (11) in (2) , (3) and (4) reduced all assumptions, The natural flow of our model described by,

$$\left.\begin{array}{c} 0=\mu^{(i)}\frac{d^2v^{(i)}}{dx^2}+6\left(\beta_2{}^{(i)}+\beta_3{}^{(i)}\right)\left(\frac{dv^{(i)}}{dx}\right)^2\left(\frac{d^2v^{(i)}}{dx^2}\right)-\sigma^{(i)}B_0{}^2v^{(i)}(x)- \\ \left(\rho^{(i)}g\beta_\Theta\left(\Theta^{(i)}-\Theta_0{}^{(i)}\right)-\rho^{(i)}g\beta_C\left(C^{(i)}-C_0{}^{(i)}\right)\right), \\ 0=k\frac{d^2\Theta^{(i)}}{dx^2}+\mu^{(i)}\left(\frac{dv^{(i)}}{dx}\right)^2+2\left(\beta_2{}^{(i)}+\beta_3{}^{(i)}\right)\left(\frac{dv^{(i)}}{dx}\right)^4, \\ 0=D^{(i)}\frac{d^2C^{(i)}}{dx^2}K^{(i)}C^{(i)}. \end{array}\right\} \quad (12)$$

Boundary conditions on flow equation are introduced, to solve the equation n(12),

$$\left.\begin{array}{c} v^{(1)}=U-\gamma T_{xy}{}^{(\mathbf{1})}\ at\ x=0\ and\ \frac{dv^{(2)}}{dx}=0\ at\ x=\delta \\ v^{(1)}=v^{(2)}\ at\ x=0\ and\ T_{xy}{}^{(\mathbf{1})}=T_{xy}{}^{(\mathbf{2})}\ at\ x=h_1 \\ \Theta^{(1)}=\Theta_0{}^{(1)}\ at\ x=0\ and\ \Theta^{(2)}=\Theta_1{}^{(2)}\ at\ x=\delta \\ \Theta^{(1)}=\Theta^{(2)}\ at\ x=0\ and\ k^{(1)}\frac{d\Theta^{(1)}}{dx}=k^{(2)}\frac{d\Theta^{(2)}}{dx}\ at\ x=h_1 \\ C^{(1)}=C_0{}^{(1)}\ at\ x=0\ and\ C^{(2)}=C_0{}^{(1)}\ at\ x=\delta \\ C^{(1)}=C^{(2)}\ at\ x=0\ and\ D^{(1)}\frac{dC^{(1)}}{dx}=D^{(2)}\frac{dC^{(2)}}{dx}\ at\ x=h_1 \end{array}\right\} \quad (13)$$

Solution method

(i) Determination of velocity, temperature and concentration:

Introducing non-dimensional variables:

$$\left.\begin{array}{c} \bar{v}^{(i)}=\frac{v^{(i)}}{U},\bar{x}=\frac{x}{\delta},\bar{\Theta}^{(i)}=\frac{\Theta^{(i)}-\Theta_0}{\Theta_1-\Theta_0},G_r{}^{(i)}=\frac{\rho^{(i)}g\beta_t(\Theta^{(i)}-\Theta_0{}^{(i)})\delta^2}{\mu^{(i)}U} \\ G_C{}^{(i)}=\frac{\rho^{(i)}g\beta_C(C^{(i)}-C_0{}^{(i)})\delta^2}{\mu^{(i)}U},B_r{}^{(i)}=\frac{\mu^{(i)}U^2}{\eta^i(\Theta-\Theta_0)},(\alpha^2)^{(i)}=\frac{K^{(i)}\delta^2}{D^{(i)}}, \\ M^{(i)}=\frac{\sigma^{(i)}B_0{}^2\delta^2}{\mu^{(i)}},\ \beta^{(i)}=\frac{\left(\beta_2{}^{(i)}+\beta_3{}^{(i)}\right)U^2}{\mu^{(i)}\delta^4},\bar{C}^{(i)}=\frac{C^{(i)}-C_0}{C_1-C_0},\eta=\frac{\eta^2}{\eta^1},k=\frac{k^2}{k^1}. \end{array}\right\} \quad (14)$$

Using dimensionless quantities in equations (12) and neglecting bars weobtained,

$$\frac{d^2v^{(i)}}{dx^2}+6\beta^{(i)}\left(\frac{dv^{(i)}}{dx}\right)^2\left(\frac{d^2v^{(i)}}{dx^2}\right)-G_r{}^{(i)}\Theta^{(i)}-G_C{}^{(i)}C^{(i)}M^{(i)}v^{(i)}(x)=0 \quad (15)$$

$$\left(1+N^{(i)}\right)\left\{\frac{d^2\Theta^{(i)}}{dx^2}+B_r{}^{(i)}\left(\frac{dv^{(i)}}{dx}\right)^2+2\beta^{(i)}\left(\frac{dv^{(i)}}{dx}\right)^4\right\}=0 \quad (16)$$

$$\frac{d^2C^{(i)}}{dx^2} - (\alpha^2)^{(i)}C^{(i)} = 0 \tag{17}$$

where, $M^{(i)}$ describes as magnetic parameter, ${B_r}^{(i)}$ indicates Brinkman number, $\beta^{(i)}$ be a effect of non-Newtonian, $N^{(i)}$ represents radiation thermal, $\alpha^{(i)}$ denoted as dimensionless number, ${G_r}^{(i)}$ represented by thermal Grashof number and ${G_C}^{(i)}$ be a Solutal Grashof number.
The dimensionless boundary condition (13) form are:

$$\left.\begin{array}{c} v^{(1)} = \alpha^{(1)} - \wedge\left(\frac{dv^{(1)}}{dx} + 2\beta^{(1)}\left(\frac{dv^{(1)}}{dx}\right)^3\right) \ at\ x = 0\ and\ \frac{dv^{(2)}}{dx} = 0\ at\ x = 1 \\ v^{(1)} = v^{(2)}\ at\ x = 0\ and\ \frac{dv^{(1)}}{dx} + 2\beta^{(1)}\left(\frac{dv^{(1)}}{dx}\right)^3 = \frac{dv^{(2)}}{dx} + 2\beta^{(2)}\left(\frac{dv^{(2)}}{dx}\right)^3\ at\ x = h \\ \Theta^{(1)} = 0\ at\ x = 0\ and\ \Theta^{(2)} = 1\ at\ x = 1 \\ \Theta^{(1)} = \Theta^{(2)}\ at\ x = 0\ and\ \frac{d\Theta^{(1)}}{dx} = k\frac{d\Theta^{(2)}}{dx}\ at\ x = h \\ C^{(1)} = 0\ at\ x = 0\ and\ C^{(2)} = 1\ at\ x = 1 \\ C^{(1)} = C^{(2)}\ at\ x = 0\ and\ \frac{dC^{(1)}}{dx} = \eta\frac{dC^{(2)}}{dx}\ at\ x = h \end{array}\right\} \tag{18}$$

Equations (15) , (16) and (17) are analytically solved, using perturbationtechniques. The velocity, thermal and concentration are noted by,

$$\left.\begin{array}{l} v^{(i)}(x) = {v_0}^{(i)}(x) + \beta^{(i)}{v_1}^{(i)}(x) + 0\left((\beta^2)^{(i)}\right). \\ \Theta^{(i)}(x) = {\Theta_0}^{(i)}(x) + \beta^{(i)}{\Theta_1}^{(i)}(x) + 0\left((\beta^2)^{(i)}\right). \\ C^{(i)}(x) = {C_0}^{(i)}(x) + \beta^{(i)}{C_1}^{(i)}(x) + 0\left((\beta^2)^{(i)}\right). \end{array}\right\} \tag{19}$$

We split the equations (15) to (17) by usual perturbation approach underthe above form (19)
,

Base part of lifting problem:

$$\frac{d^2{v_0}^{(i)}}{dx^2} - {G_r}^{(i)}{\Theta_0}^{(i)} - {G_C}^{(i)}{C_0}^{(i)} - M^{(i)}{v_0}^{(i)} = 0 \tag{20}$$

$$\left(1 + N^{(i)}\right)\frac{d^2{\Theta_0}^{(i)}}{dx^2} + {B_r}^{(i)}\left(\frac{d{v_0}^{(i)}}{dx}\right)^2 = 0 \tag{21}$$

$$\frac{d^2{C_0}^{(i)}}{dx^2} - ((\alpha^2)^{(i)}){C_0}^{(i)} = 0 \tag{22}$$

Applying the boundary conditions for concentration (18) in equation (22) , the base part concentration first order solution is,

$$C_0{}^{(i)}(x) = C_1{}^{(i)} e^{-\alpha^{(i)} x} + C_2{}^{(i)} e^{\alpha^{(i)} x} \tag{23}$$

Perturbation part of lifting problem:

$$\frac{d^2 v_1{}^{(i)}}{dx^2} + 6\left(\frac{dv_0{}^{(i)}}{dx}\right)^2 \left(\frac{d^2 v_0{}^{(i)}}{dx^2}\right) - G_r{}^{(i)} \Theta_1{}^{(i)} - G_C{}^{(i)} C_1{}^{(i)} - M^{(i)} v_1{}^{(i)} = 0 \tag{24}$$

$$\left(1 + N^{(i)}\right) \frac{d^2 \Theta_0{}^{(i)}}{dx^2} + 2B_r{}^{(i)} \left\{\left(\frac{dv_0{}^{(i)}}{dx}\right)^2 \left(\frac{dv_1{}^{(i)}}{dx}\right)^2 + \left(\frac{dv_0{}^{(i)}}{dx}\right)^4\right\} = 0 \tag{25}$$

$$\frac{d^2 C_1{}^{(i)}}{dx^2} - \left(\alpha^{(2)}{}^{(i)}\right) C_1{}^{(i)} = 0 \tag{26}$$

Substitute boundary concentration conditions (18) in equation (26) , perturbconcentration solution as,

$$C_1{}^{(i)}(x) = C_3{}^{(i)} e^{-\alpha^{(i)} x} + C_4{}^{(i)} e^{\alpha^{(i)} x} \tag{27}$$

Boundary conditions for base part:

$$\left.\begin{aligned}
v_0{}^{(1)} = \alpha^{(1)} - \wedge \left(\frac{dv_0{}^{(1)}}{dx}\right) \ at\ x = 0\ and\ \frac{dv_0{}^{(2)}}{dx} = 0\ at\ x = 1 \\
v_0{}^{(1)} = v_0{}^{(2)}\ at\ x = 0\ and\ \frac{dv_0{}^{(1)}}{dx} = \frac{dv_0{}^{(2)}}{dx}\ at\ x = h \\
\Theta_0{}^{(1)} = 0\ at\ x = 0\ and\ \Theta_0{}^{(2)} = 1\ at\ x = 1 \\
\Theta_0{}^{(1)} = \Theta_0{}^{(2)}\ at\ x = 0\ and\ \frac{d\Theta_0{}^{(1)}}{dx} = k \frac{d\Theta_0{}^{(2)}}{dx}\ at\ x = h \\
C_0{}^{(1)} = 0\ at\ x = 0\ and\ C_0{}^{(2)} = 1\ at\ x = 1 \\
C_0{}^{(1)} = C_0{}^{(2)}\ at\ x = 0\ and\ \frac{dC_0{}^{(1)}}{dx} = \eta \frac{dC_0{}^{(2)}}{dx}\ at\ x = h
\end{aligned}\right\} \tag{28}$$

Boundary conditions for Perturbation part:

$$\left.\begin{array}{c} v_1{}^{(1)} = \alpha^{(1)} - \Lambda\left(\frac{dv_1{}^{(1)}}{dx} + 2\left(\frac{dv_0{}^{(1)}}{dx}\right)^3\right) \ at\ x = 0\ and\ \frac{dv_1{}^{(2)}}{dx} = 0\ at\ x = 1 \\ v_1{}^{(1)} = v_1{}^{(2)}\ at\ x = 0\ and\ \frac{dv_1{}^{(1)}}{dx} + 2\left(\frac{dv_0{}^{(1)}}{dx}\right)^3 = \frac{dv_1{}^{(2)}}{dx} + 2\left(\frac{dv_0{}^{(2)}}{dx}\right)^3\ at\ x = h \\ \Theta_1{}^{(1)} = 0\ at\ x = 0\ and\ \Theta_1{}^{(2)} = 0\ at\ x = 1 \\ \Theta_1{}^{(1)} = \Theta_1{}^{(2)}\ at\ x = 0\ and\ \frac{d\Theta_1{}^{(1)}}{dx} = k\frac{d\Theta_1{}^{(2)}}{dx}\ at\ x = h \\ C_1{}^{(1)} = 0\ at\ x = 0\ and\ C_2{}^{(2)} = 0\ at\ x = 1 \\ C_1{}^{(1)} = C_2{}^{(2)}\ at\ x = 0\ and\ \frac{dC_1{}^{(1)}}{dx} = \eta\frac{dC_1{}^{(2)}}{dx}\ at\ x = h \end{array}\right\} \quad (29)$$

Using perturbation approximation split steady and transient state of the lifting problem and solve analytically with sustained *Bcs* (28) and (29) respectively, Graphs are discussed for fluid flow, thermal and concentration of third order fluid utilizing Mathematica software.

Drinage flow

The physical geometry and assumptions of the drainage flow is the equivalent as that analyzed in the prior lifting problem. The liquid drain descending in that gravity above the stationary belt as sketched in fig.2. Axial frame work system is also same as earlier case. Also, flow is steady, laminar, external pressure neglected, gravity balance of shear forces are taken and film thickness remnant stable.

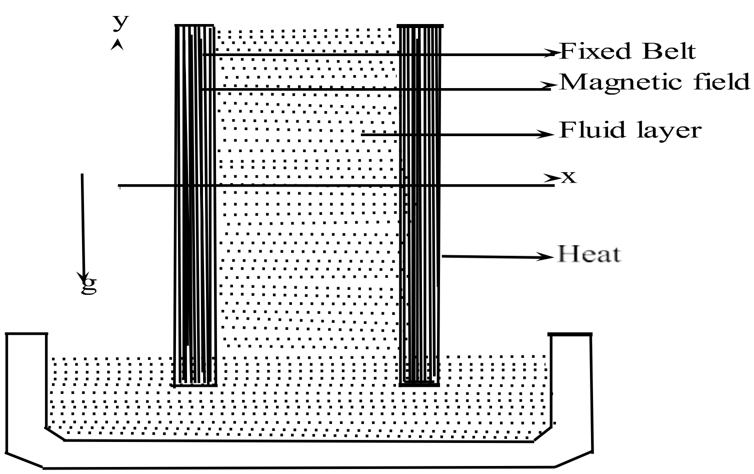

Fig.2 Physical configuration of the drainage flow problem

Using stress component tensor equation (11) and with all assumptions in (2), (3) and (4) of drainage flow reduce to the flow equations made by,

$$\left.\begin{array}{c} 0=\mu^{(i)}\frac{d^2v^{(i)}}{dx^2}+6\left(\beta_2{}^{(i)}+\beta_3{}^{(i)}\right)\left(\frac{dv^{(i)}}{dx}\right)^2\left(\frac{d^2v^{(i)}}{dx^2}\right)-\sigma^{(i)}B_0{}^2v^{(i)}(x)+ \\ \left(\rho^{(i)}g\beta_\Theta\left(\Theta^{(i)}-\Theta_0{}^{(i)}\right)+\rho^{(i)}g\beta_C\left(C^{(i)}-C_0{}^{(i)}\right)\right), \\ 0=k\frac{d^2\Theta^{(i)}}{dx^2}+\mu^{(i)}\left(\frac{dv^{(i)}}{dx}\right)^2+2\left(\beta_2{}^{(i)}+\beta_3{}^{(i)}\right)\left(\frac{dv^{(i)}}{dx}\right)^4, \\ 0=D^{(i)}\frac{d^2C^{(i)}}{dx^2}-K^{(i)}C^{(i)}. \end{array}\right\} \quad (30)$$

Boundary conditions on system of equation are introduced to solve theequation (30),

$$\left.\begin{array}{c} v^{(1)}=-\gamma T_{xy}{}^{(1)}\ at\ x=0\ and\ \frac{dv^{(2)}}{dx}=0\ at\ x=\delta \\ v^{(1)}=v^{(2)}\ at\ x=0\ and\ T_{xy}{}^{(1)}=T_{xy}{}^{(2)}\ at\ x=h_1 \\ \Theta^{(1)}=\Theta_0{}^{(1)}\ at\ x=0\ and\ \Theta^{(2)}=\Theta_1{}^{(2)}\ at\ x=\delta \\ \Theta^{(1)}=\Theta^{(2)}\ at\ x=0\ and\ k^{(1)}\frac{d\Theta^{(1)}}{dx}=k^{(2)}\frac{d\Theta^{(2)}}{dx}\ at\ x=h_1 \\ C^{(1)}=C_0{}^{(1)}\ at\ x=0\ and\ C^{(2)}=C_0{}^{(1)}\ at\ x=\delta \\ C^{(1)}=C^{(2)}\ at\ x=0\ and\ D^{(1)}\frac{dC^{(1)}}{dx}=D^{(2)}\frac{dC^{(2)}}{dx}\ at\ x=h_1 \end{array}\right\} \quad (31)$$

Using dimensionless quantities from (14) in (30) and (31) neglecting bars weobtain,

$$\frac{d^2v^{(i)}}{dx^2}+6\beta^{(i)}\left(\frac{dv^{(i)}}{dx}\right)^2\left(\frac{d^2v^{(i)}}{dx^2}\right)+G_r{}^{(i)}\Theta^{(i)}+G_C{}^{(i)}C^{(i)}-M^{(i)}v^{(i)}(x)=0 \quad (32)$$

$$\left(1+N^{(i)}\right)\left\{\frac{d^2\Theta^{(i)}}{dx^2}+B_r{}^{(i)}\left(\frac{dv^{(i)}}{dx}\right)^2+2\beta^{(i)}\left(\frac{dv^{(i)}}{dx}\right)^4\right\}=0 \quad (33)$$

$$\frac{d^2C^{(i)}}{dx^2}-(\alpha^2)^{(i)}C^{(i)}=0 \quad (34)$$

$$\left.\begin{array}{c} v^{(1)}=-\wedge\left(\frac{dv^{(1)}}{dx}+2\beta^{(1)}\left(\frac{dv^{(1)}}{dx}\right)^3\right)\ at\ x=0\ and\ \frac{dv^{(2)}}{dx}=0\ at\ x=1 \\ v^{(1)}=v^{(2)}\ at\ x=0\ and\ \frac{dv^{(1)}}{dx}+2\beta^{(1)}\left(\frac{dv^{(1)}}{dx}\right)^3=\frac{dv^{(2)}}{dx}+2\beta^{(2)}\left(\frac{dv^{(2)}}{dx}\right)^3\ at\ x=h \\ \Theta^{(1)}=0\ at\ x=0\ and\ \Theta^{(2)}=1\ at\ x=1 \\ \Theta^{(1)}=\Theta^{(2)}\ at\ x=0\ and\ \frac{d\Theta^{(1)}}{dx}=k\frac{d\Theta^{(2)}}{dx}\ at\ x=h \\ C^{(1)}=0\ at\ x=0\ and\ C^{(2)}=1\ at\ x=1 \\ C^{(1)}=C^{(2)}\ at\ x=0\ and\ \frac{dC^{(1)}}{dx}=\eta\frac{dC^{(2)}}{dx}\ at\ x=h \end{array}\right\} \quad (35)$$

Equations (32), (33), (34) and (35) are analytically solved, using perturbation approach. The velocity, temperature and concentration are described by,

Base part of drainage problem

$$\frac{d^2 {v_0}^{(i)}}{dx^2} - {G_r}^{(i)} {\Theta_0}^{(i)} - {G_C}^{(i)} {C_0}^{(i)} - M^{(i)} {v_0}^{(i)} = 0 \tag{36}$$

$$\left(1 + N^{(i)}\right) \frac{d^2 {\Theta_0}^{(i)}}{dx^2} + {B_r}^{(i)} \left(\frac{d {v_0}^{(i)}}{dx}\right)^2 = 0 \tag{37}$$

$$\frac{d^2 {C_0}^{(i)}}{dx^2} - \left({\alpha^{(2)}}^{(i)}\right) {C_0}^{(i)} = 0 \tag{38}$$

Applying the boundary concentration conditions (18) in equation (38), the base solution part is,

$${C_0}^{(i)}(x) = {C_1}^{(i)} e^{-\alpha^{(i)} x} + {C_2}^{(i)} e^{\alpha^{(i)} x} \tag{39}$$

Perturbation part of drainage problem

$$\frac{d^2 {v_1}^{(i)}}{dx^2} + 6 \left(\frac{d {v_0}^{(i)}}{dx}\right)^2 \left(\frac{d^2 {v_0}^{(i)}}{dx^2}\right) - {G_r}^{(i)} {\Theta_1}^{(i)} - {G_C}^{(i)} {C_1}^{(i)} - M^{(i)} {v_1}^{(i)} = 0 \tag{40}$$

$$\left(1 + N^{(i)}\right) \frac{d^2 {\Theta_0}^{(i)}}{dx^2} + 2{B_r}^{(i)} \left\{ \left(\frac{d {v_0}^{(i)}}{dx}\right)^2 \left(\frac{d {v_1}^{(i)}}{dx}\right)^2 + \left(\frac{d {v_0}^{(i)}}{dx}\right)^4 \right\} = 0 \tag{41}$$

$$\frac{d^2 {C_1}^{(i)}}{dx^2} - \left({\alpha^{(2)}}^{(i)}\right) {C_1}^{(i)} = 0 \tag{42}$$

Substitute concentration boundary conditions (18) in (42), the perturbequation part is,

$${C_0}^{(i)}(x) = {C_3}^{(i)} e^{-\alpha^{(i)} x} + {C_4}^{(i)} e^{\alpha^{(i)} x} \tag{43}$$

Boundary conditions for base part:

$$\left.\begin{array}{c} {v_0}^{(1)} = -\wedge\left(\dfrac{d{v_0}^{(1)}}{dx}\right)\ at\ x=0\ and\ \dfrac{d{v_0}^{(2)}}{dx}=0\ at\ x=1 \\ {v_0}^{(1)}={v_0}^{(2)}\ at\ x=0\ and\ \dfrac{d{v_0}^{(1)}}{dx}=\dfrac{d{v_0}^{(2)}}{dx}\ at\ x=h \\ {\Theta_0}^{(1)}=0\ at\ x=0\ and\ {\Theta_0}^{(2)}=1\ at\ x=1 \\ {\Theta_0}^{(1)}={\Theta_0}^{(2)}\ at\ x=0\ and\ \dfrac{d{\Theta_0}^{(1)}}{dx}=k\dfrac{d{\Theta_0}^{(2)}}{dx}\ at\ x=h \\ {C_0}^{(1)}=0\ at\ x=0\ and\ {C_0}^{(2)}=1\ at\ x=1 \\ {C_0}^{(1)}={C_0}^{(2)}\ at\ x=0\ and\ \dfrac{d{C_0}^{(1)}}{dx}=\eta\dfrac{d{C_0}^{(2)}}{dx} at\ x=h \end{array}\right\} \quad (44)$$

Boundary conditions for Perturbation part:

$$\left.\begin{array}{c} {v_1}^{(1)} = -\wedge\left(\dfrac{d{v_1}^{(1)}}{dx}+2\left(\dfrac{d{v_0}^{(1)}}{dx}\right)^3\right)\ at\ x=0\ and\ \dfrac{d{v_1}^{(2)}}{dx}=0\ at\ x=1 \\ {v_1}^{(1)}={v_1}^{(2)}\ at\ x=0\ and\ \dfrac{d{v_1}^{(1)}}{dx}+2\left(\dfrac{d{v_0}^{(1)}}{dx}\right)^3=\dfrac{d{v_1}^{(2)}}{dx}+2\left(\dfrac{d{v_0}^{(2)}}{dx}\right)^3\ at\ x=h \\ {\Theta_1}^{(1)}=0\ at\ x=0\ and\ {\Theta_1}^{(2)}=0\ at\ x=1 \\ {\Theta_1}^{(1)}={\Theta_1}^{(2)}\ at\ x=0\ and\ \dfrac{d{\Theta_1}^{(1)}}{dx}=k\dfrac{d{\Theta_1}^{(2)}}{dx}\ at\ x=h \\ {C_1}^{(1)}=0\ at\ x=0\ and\ {C_2}^{(2)}=0\ at\ x=1 \\ {C_1}^{(1)}={C_2}^{(2)}\ at\ x=0\ and\ \dfrac{d{C_1}^{(1)}}{dx}=\eta\dfrac{d{C_1}^{(2)}}{dx} at\ x=h \end{array}\right\} \quad (45)$$

The flow of drainage non-linear differential equations split steady and transient part by using perturbation analytical approach with sustained boundary conditions (44) and (45) , Graphs are evaluated for the flow velocity, thermal and concentration of third order fluid utilizing Mathematica software.

Results and Discussion

The two immiscible liquid flow studied and transfer of thermal in a belt of vertical in residence if chemical species dispersal is evaluated interpretive by proving regular perturbation techniques. Non-Newtonian characteristic (β) is taken as the perturbation parameter. Thermal field radiation terms are added in the energy system. Magnetic induction, thermal process of Grashof number, Parameter of non-Newtonian, Brikman number, Radiation thermal pertinent, Mass profile Grashof number, Ratio conductivity, Coefficient if diffusion, Chemical rate parameter for first order dispersal in all the computations of results obtained. Figures (3−4) and (19, 20) plotted to describe the magnetic induction of layer $(I,\ II)$. Raises the axial speed in both layer, As falling lifting and rises in drainage. Figures (5, 6) and (21, 22) that as we raises the strength of heat Grashof number, As velocity in both layer enhances in lifting and reduces in drainage flow. Figures (9, 10) and (25, 26) depicts to deserve the effect of $(\beta^{(1)}, \beta^{(2)})$ are enhances, As lift layer (I) raises an declined layer (II) and drainage layer (I) falling an layer (II) raises it is highest predominant coefficient of this types of flow problems. Figures (7, 8) and (23, 24) shows solutal of Grashof number on field speed flow. It is seen that the pour of speed is declined in both lift layer and raises in drainage layer (I, II) . Figures (11, 12) and (26, 27) highlighted the influence of thermal distribution ratio as the ratio escalation Brikman number enhances in both lift layer and decays in drainage layer. Figures (13, 14) and (29, 30) illustrates thermal radiation on temperature profile. It conclude that temperature is rises with raises in layer (I, II) as well as descends in drainage layer (I, II) of thermal effect. The first grade chemical effect parameter $(\alpha^{(1)})$ on concentration profile for lifting and drainage flow of Layer (I) are represents in figures (17) and (31) . These plots revel this $(\alpha^{(1)})$ is based of natural on the physical region. Since, escalation in $(\alpha^{(1)})$ leads to the declined in the solute number of particle undergoing chemical reaction for both lift and drainage profile flow. Effect of ratio width (h) on profile concentration are displace layer (I) for lift and drainage are highlighted in figures (15) and (33) . As (h) escalation concentration descends in both regions. Influence of ratio conductivity (λ) on concentration is scrutinizes in figures (16) and (34) . Dispersal of concentration enhances in layer (1) and layer (2) as raises in $(\lambda^{(1)})$ and $(\lambda^{(2)})$ in both flow problems.

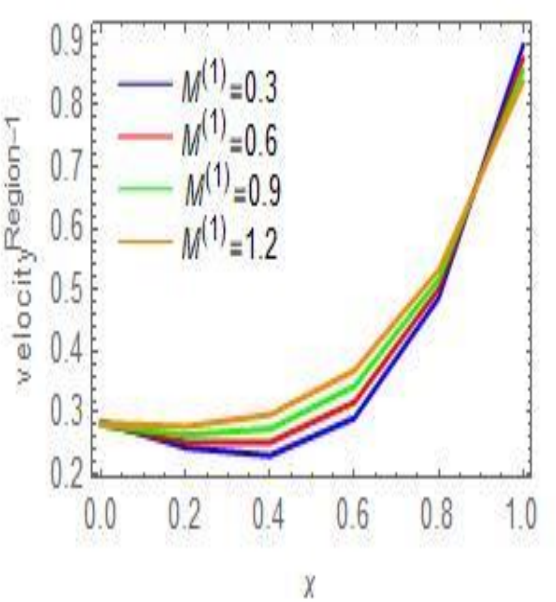

Fig. 3: Influence of first layer $M^{(1)}$ on profile velocity.

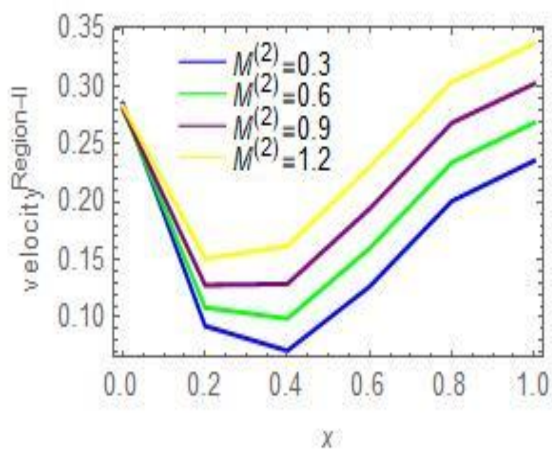

Fig. 4: Effect of second layer $M^{(2)}$ on profile velocity.

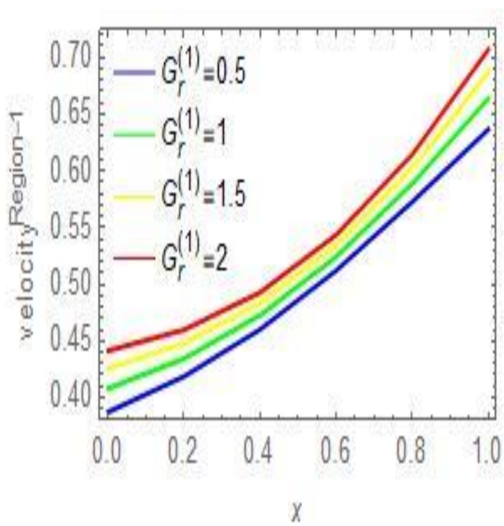

Fig. 5: Effect of first layer $G_r^{(1)}$ on profile velocity

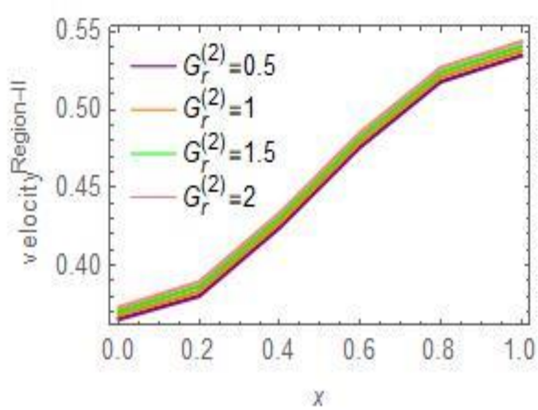

Fig. 6: Effect of second layer $G_r^{(2)}$ on profile velocity.

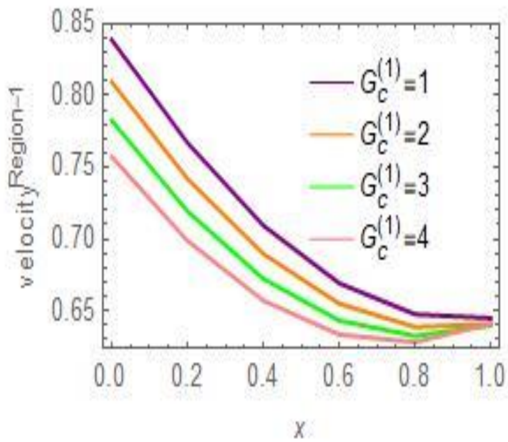

Fig. 7: Effect of first layer $G_c{}^{(1)}$ on profile velocity.

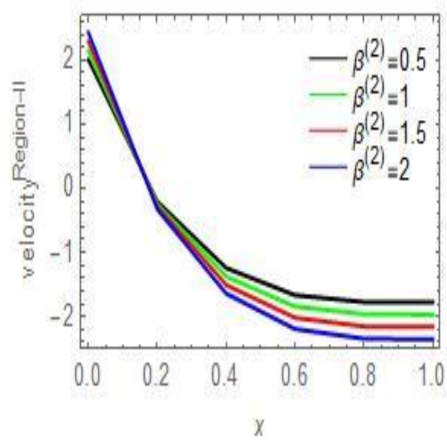

Fig. 10: Effect of second layer $\beta^{(2)}$ on profile velocity

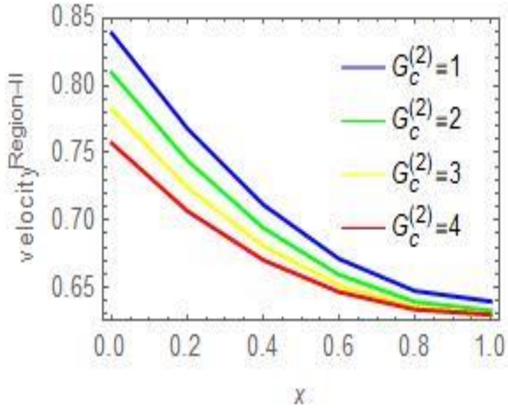

Fig. 8: Effect of second layer $G_c{}^{(2)}$ on profile velocity

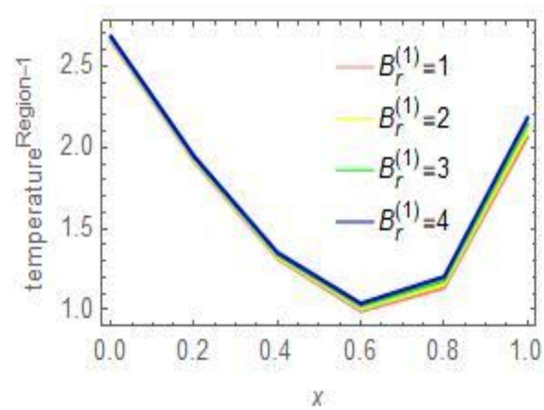

Fig.11: Influence of first layer $B_r{}^{(1)}$ on field thermal

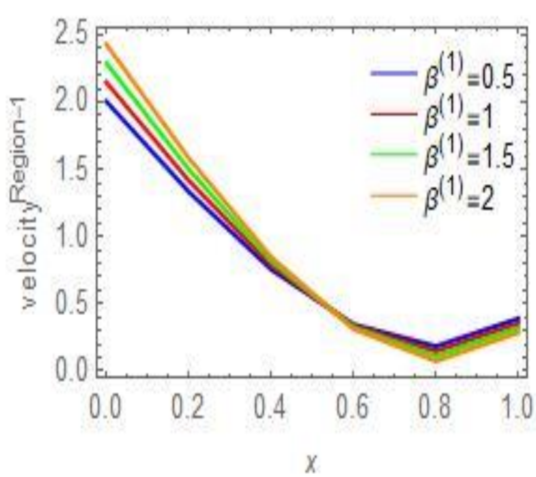

Fig. 9: Effect of first layer $\beta^{(1)}$ on profile velocity.

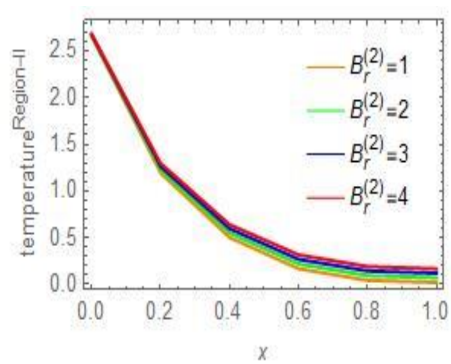

Fig.12: Influence of second layer $B_r{}^{(2)}$ on field thermal.

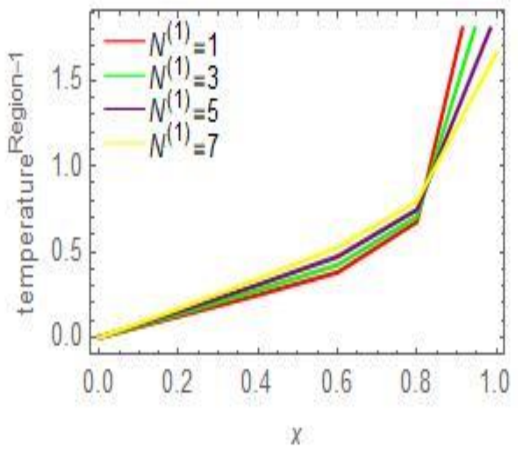

Fig. 13: Influence of first layer $N^{(1)}$ on thermal field radiation.

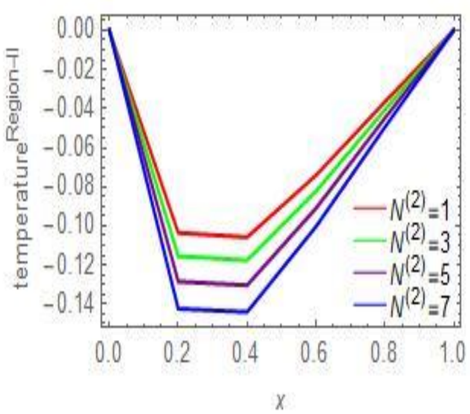

Fig.14: Influence of second layer $N^{(2)}$ on thermal field radiation

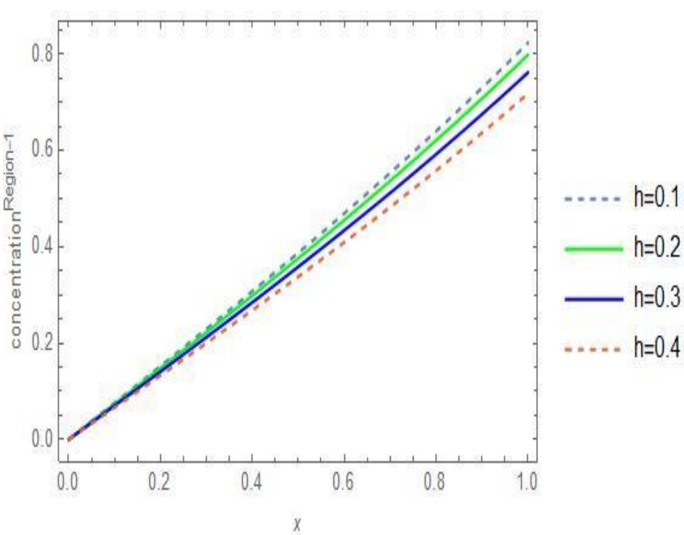

Fig.15: Influence of first layer "*h*" on profile concentration.

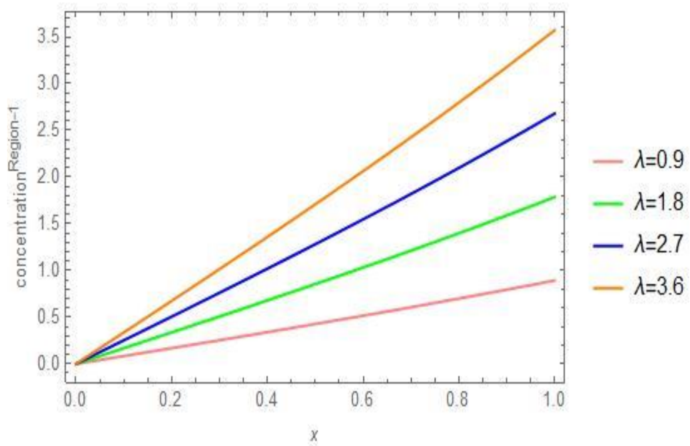

Fig.16: Influence of first layer"λ" on profile concentration

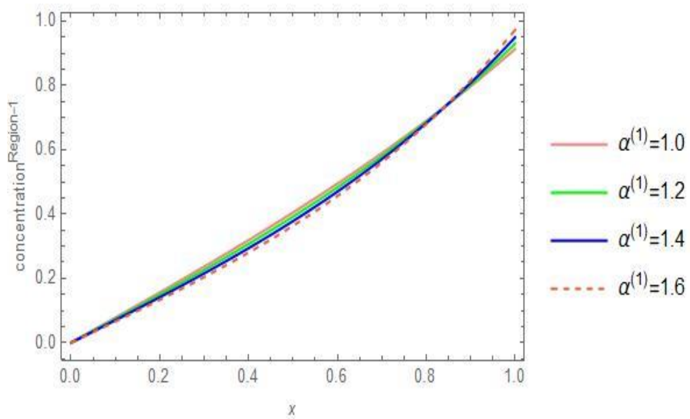

Fig. 17: Influence of first layer"$\alpha^{(1)}$" on profile concentration

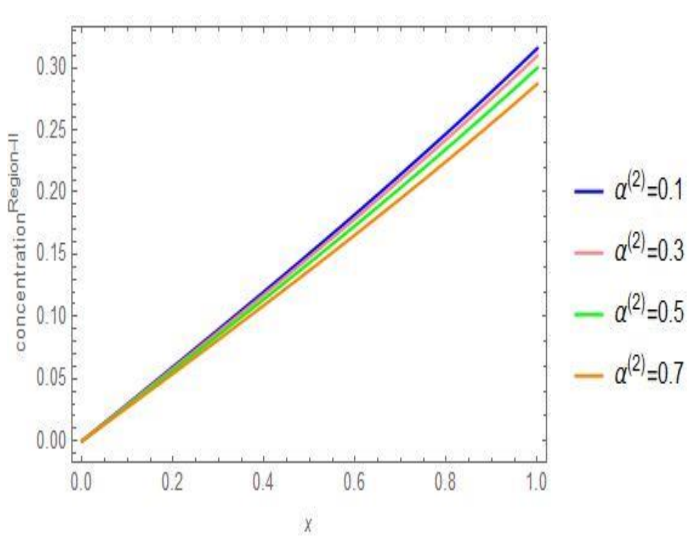

Fig. 18: Influence of first layer"$\alpha^{(2)}$" on profile concentration

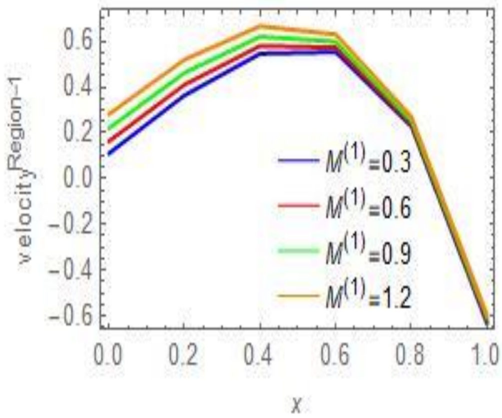

Fig. 19: Effect of first layer"$M^{(1)}$" on profile drainage velocity

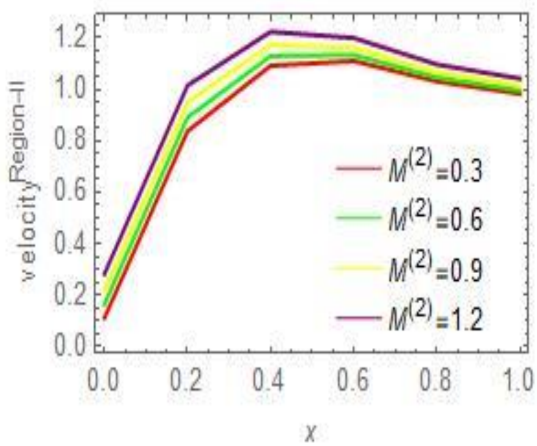

Fig. 20: Effect of second layer "$M^{(2)}$" on profile drainage velocity

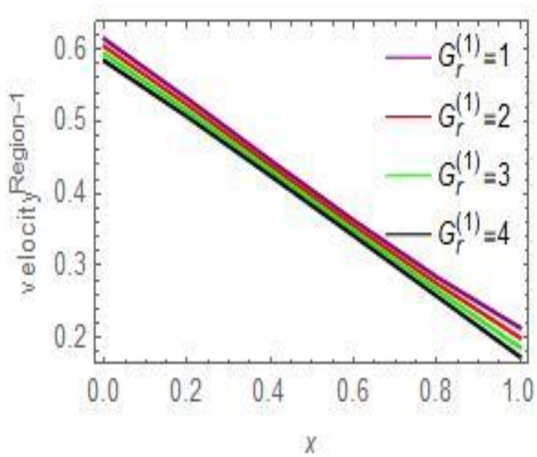

Fig. 21: Influence of first layer "${G_r}^{(1)}$" on profile drainage velocity

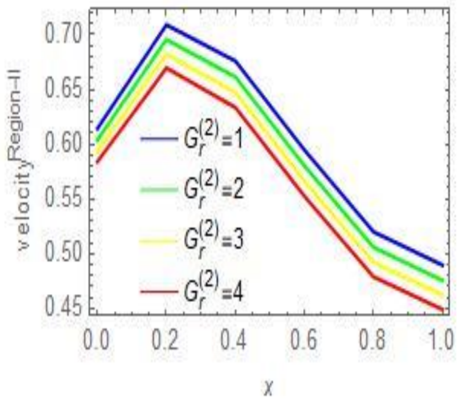

Fig. 22: Influence of second layer "${G_r}^{(1)}$" on profile drainage velocity.

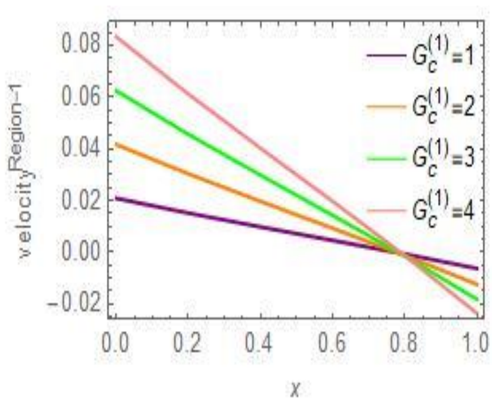

Fig. 23: Influence of first layer "${G_c}^{(2)}$" on profile drainage velocity

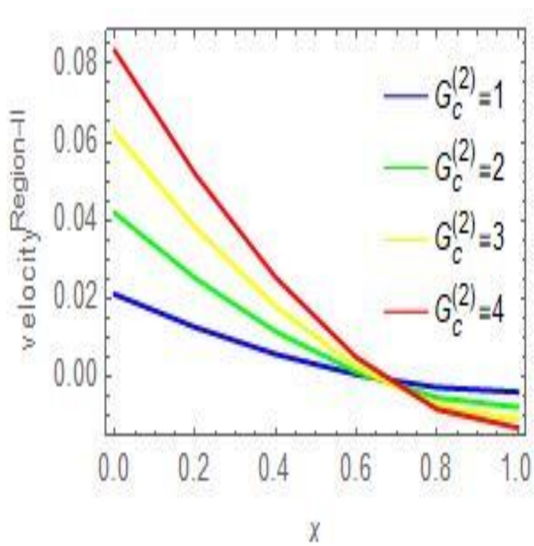

Fig. 24: Influence of second layer "${G_c}^{(2)}$" on profile drainage velocity.

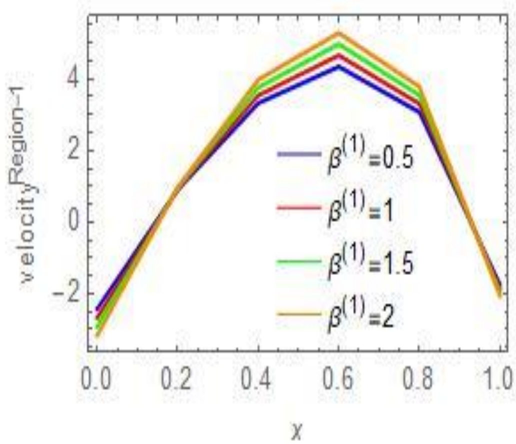

Fig. 25: Influence of first layer "$\beta^{(1)}$" on profile drainage velocity.

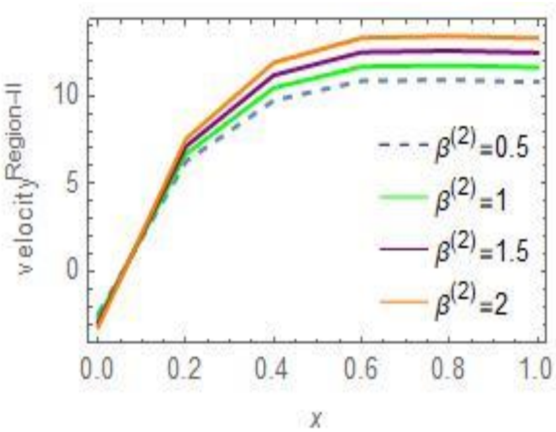

Fig. 26: Influence of second layer "$\beta^{(2)}$" on profile drainage velocity.

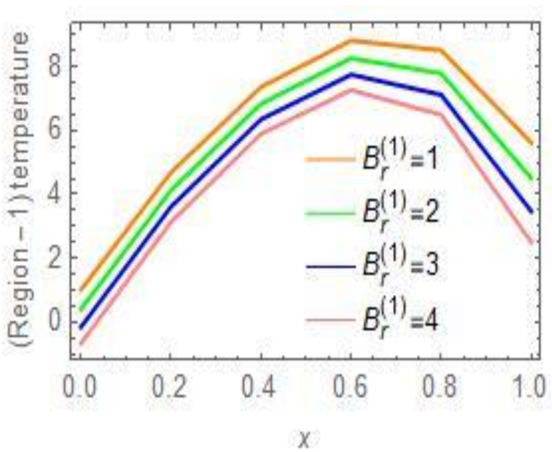

Fig. 27: Influence of first layer "$B_r{}^{(1)}$" filed drainage thermal

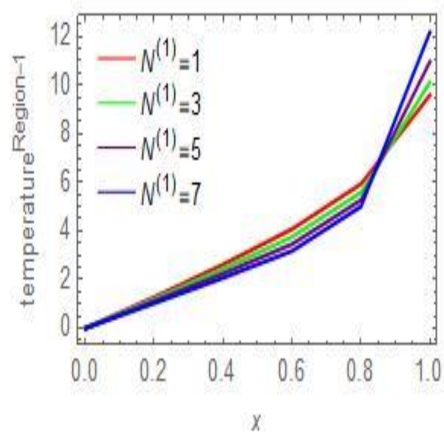

Fig. 28: Influence of second layer "$B_r{}^{(2)}$" on filed drainage thermal.

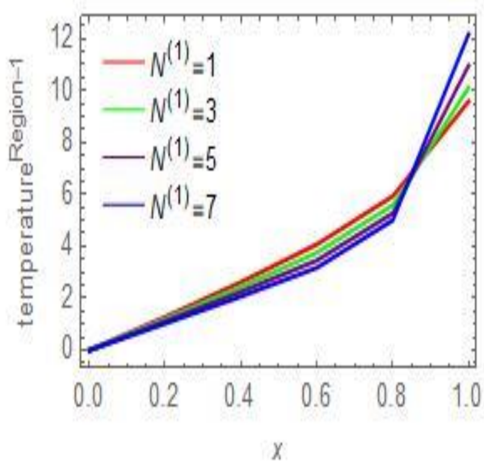

Fig. 29: Influence of first layer "$N^{(1)}$" on filed drainage thermal.

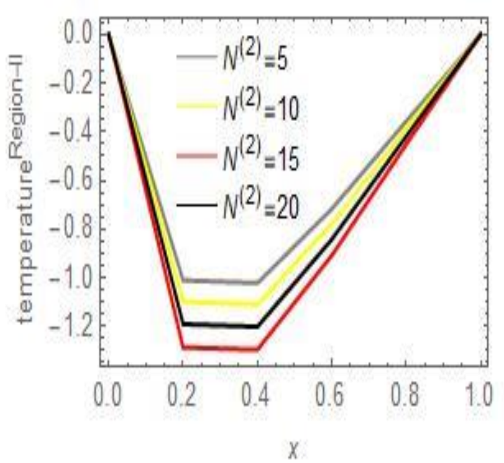

Fig. 30: Influence of second layer "$N^{(1)}$" on filed drainage thermal

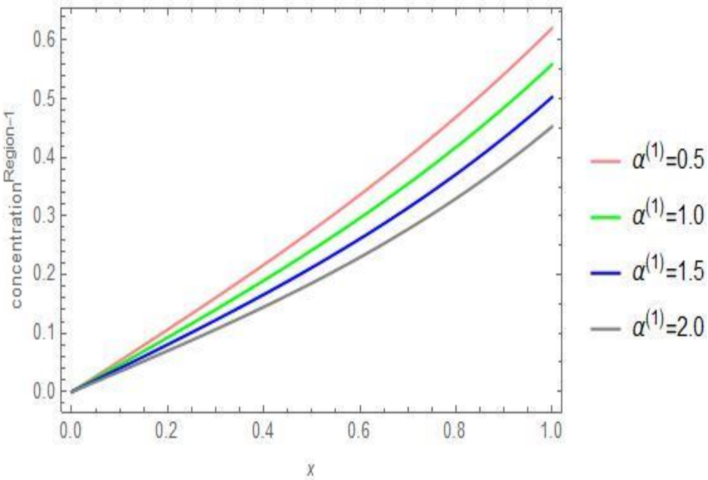

Fig. 31: Influence of first layer"$\alpha^{(1)}$" on concentration drainage profile

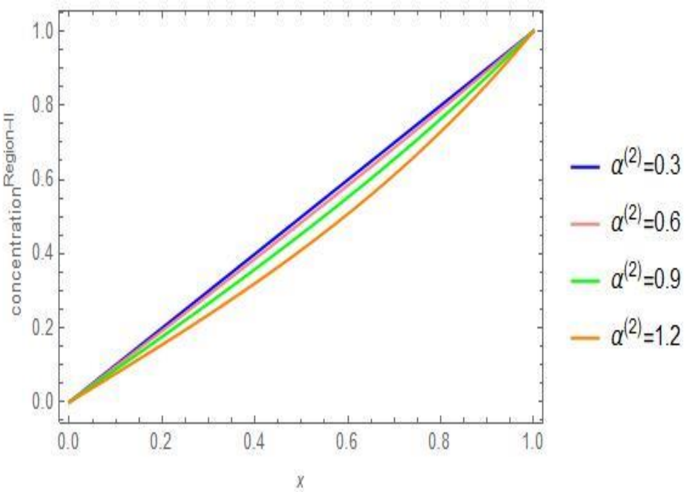

Fig. 32: Influence of second layer"$\alpha^{(2)}$" on concentration drainage profile

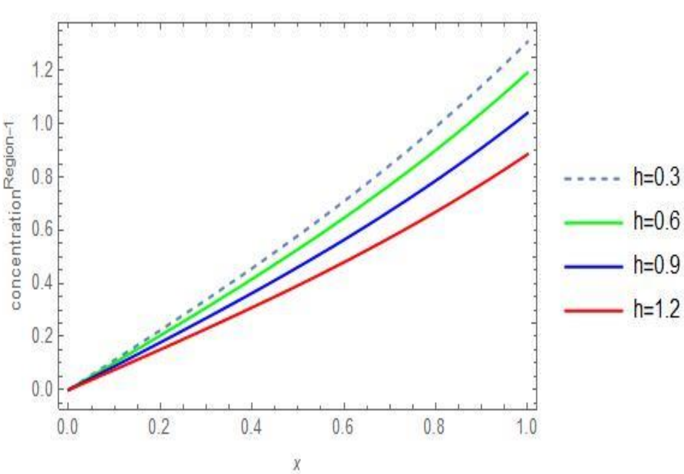

Fig. 33: Influence of first layer "h" on concentration drainage profile

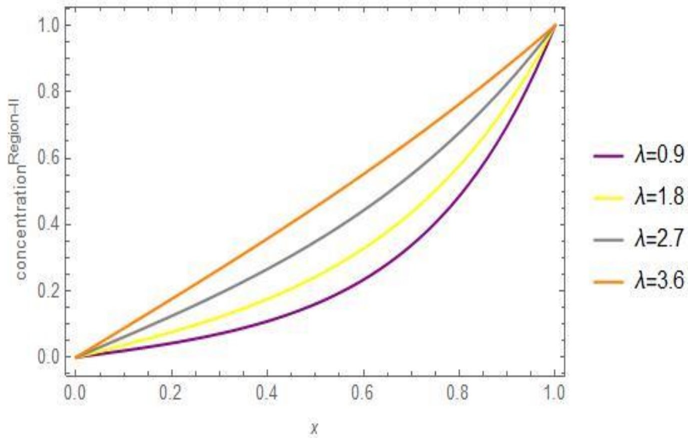

Fig. 34: Influence of second layer" on concentration drainage profile

Conclusion

The problem of thermal and transmit of mass in a perpendicular and moving belt filled with thin layer flow of third order liquid was discussed analytically using perturbation most relevant approach. The following results are drawn:

∗ Thermal effects of Grashof number in layer (I) and (II) escalation of lift velocity and reduces in drainage.

∗ Solutal influence of Grashof number in layer (I) and (II) declined of liftvelocity and raises in drainage field.

∗ Thermal effect radiation and Brikmann influence enhances in both layer oflifting and falling in both layer of drainage.

∗ Chemical dispersal rate characteristics are raises in layer (I) and (II) forlift and drainage flow.

Appendix

$$c_1 = -\frac{\left(e^{h\alpha^{(1)}}+\alpha^{(2)}-h\alpha^{(2)}\right)\left(1+e^{2h\alpha^{(2)}}\right)\alpha^{(2)}\lambda}{\left(1+e^{2h\alpha^{(1)}}\right)\left(-1+e^{2\alpha^{(2)}}\right)\alpha^{(1)}};$$

$$c_2 = \frac{\left(e^{h\alpha^{(1)}}+\alpha^{(2)}-h\alpha^{(2)}\right)\left(1+e^{2h\alpha^{(2)}}\right)\alpha^{(2)}\lambda}{\left(1+e^{2h\alpha^{(1)}}\right)\left(-1+e^{2\alpha^{(2)}}\right)\alpha^{(1)}};$$

$$c_3 = 0;\ c_4 = 0;\ c_5 = -\frac{e^{\alpha^{(2)}}}{\left(-1+e^{2\alpha^{(2)}}\right)};$$

$$c_6 = \frac{e^{\alpha^{(2)}}}{\left(-1+e^{2\alpha^{(2)}}\right)};\ c_7 = 0;\ c_8 = 0;$$

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