MHD Analysis of Casson Fluid through a Vertical Porous Surface with Chemical Reaction

M.Ramanuja[1] V. Nagaradhika[2]
1.Department of Mathematics, Marri Laxman Reddy Institute of Technology & Management (Autonomous) , Dundigal, Medchal Dist .Hyderabad-500043. INDIA
2.Department of Mathematics, Gitam University Bangalore, 562163, INDIA

Abstract
Casson liquid stream over a vertical permeable surface with a synthetic response within the sight of an attractive field has been contemplated. Likeness investigation was utilized to change the arrangement of incomplete differential conditions portraying the issue into customary differential conditions. The decreased construction was illuminated utilizing the Newton Raphson shooting strategy close by the Forth-request Runge-Kutta calculation. The outcomes are introduced graphically and in an unthinkable structure for different domineering parameters. The impact of physical constants resembling Casson liquid (β), Magnetic parameter M, Soret number Sc, Prandtl number Pr, Magnetic Prandtl number, and so forth., on the instigated attractive field, temperature and speed are investigated. An attractive perception of this examination is that the impact of velocity appropriation comply with the physical consideration of notable Newtonian and all other Non-Newtonian liquids.
Keywords: Magnetic Field, Casson Fluid, Mass Transfer, Suction, Non-Newtonian Fluid, Induced magnetic field, MHD, Natural Convection, Slip.
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1. Introduction

At the most severe temperature, the effect of temperate radiation is reflective on the progression of the thick liquid field. These effects are significant in numerous modern territories, for example, sunlight based force novelty, electrical force time, and aeronautical building. A few specialists have likewise examined this field. The effect of the actuated beautiful field on heat and mass exchange of the succession of stagnation point towards the external of the extending sheet was completed. A liquid where in the viscous burdens emerging from its torrent at each point are sprightly corresponding to the pace of progress in its disfigurement after some time is called Newtonian liquid. This implies in a Newtonian liquid, the relationship between the shear pressure and the shear rate is direct with the proportionality steady to allude to as the coefficient of consistency. Then again, a liquid whose flow properties are distinctive in any capability from that of the Newtonian liquid is known as a non-Newtonian liquid. In contrast to the Newtonian liquids, the thickness of the non-Newton liquid is dependent on shear rate the past. In other words, in a non-Newtonian liquid, the connection between the shear pressure and the shear rate is extraordinary and can level be time-subordinate. Along these lines, a consistent coefficient of thickness can't be characterized. A few instances of non-Newtonian liquids are salt arrangements, liquid polymers, ketchup, custard, toothpaste, starch suspensions, paints, blood, and cleanser.

Mustafa et al. [1] are studied strong the variable limit seam waft and heat switch over a Casson fluid upstairs a moving plane fix together with a parallelism fair flow using the Homotopy Analysis Method (HAM). On the vile hand, line bed flows of non-Newtonian fluids triggered by way of a stretching foil hold enormous armed forces into numerous industrial techniques such namely transportation regarding molten polymers through a slit die because of the production regarding plastic sheets, temperate rolling, cable yet filament coating, processing over foodstuffs, metal spinning, glass-fiber production, then delivery note production longevity, Hayat et al.[2] are discussed analyzed the mixed convection stagnation-point flow of a non-Newtonian Casson fluid. Most importantly, Bhattacharyya et al.[3] recently investigated the boundary layer flow of Casson fluid over a porous stretching/shrinking sheet with a magnetic field effect. Rajagopal et al. [4] have developed who considered viscoelastic fluid, Fredrickson. [5] Investigated the steady flow of a Casson fluid in a tube. Khalid et al. [6] studied the impact of oscillating and MHD on the non-Newtonian fluid in a vertical porous plate.Pal and Mandal.[7] examined the impact of an induced magnetic field on a nanofluid at a stagnation point flow for the case of the nonisothermal the surface of stretched sheet, Jayaraman et al. [8] are investigated planned the work of Oka's and steered that the Casson fluid is a lot of much appropriate for blood Oxygenators. The impact of MHD on the free convective the incompressible non-viscous flow of vertical porous flat plate with heat supply and slip has been studied Raju et, al. [9] are given the influence of radiation, heat generation, and thermophoresis on MHD mixed convection Jeffrey fluid flow with inclined leaky moving plate has been elaborate, Anki Reddy [10] studied the smooth, two- MHD Casson fluid flow over a convective boundary layer with an exponentially stretching surface with inclined permeable. The exponentially expanding layer of MHD Casson fluid flow with permeable bed and physical presence of the heat transfer was considered, Imran et al. [11] have described It is seen that the improvement of slip parameters helps the velocity of Casson liquid. It is additionally seen that the effect of slip is a lot of powerful on temperature dispersion in appraisal with velocity dissemination. MHD stagnation point flow of Casson liquid, Raju et al. [12] have examined the impact of slip conditions on non-gooey directing liquid stream over a nonlinearly extending sheet with thick warming in the permeable medium was examined. Watson, [13] contemplated micropolar liquid flow over an extending sheet. Troy et al. [14] have investigated set up the uniqueness of the arrangement of the progression of second-request liquid over an extending sheet. Various experiments performed on blood with varying hematocrits, anticoagulants, temperatures, and the likes, strongly suggest the behavior of blood as a Casson fluid [15] [16].

Because of the novel utilization of MHD blended convection stream in permeable mediums, in the field of the modern building, numerous specialists are pulled in to it. The plan of MHD power generators, atomic waste preparation, and conveyance of concoction squander control are some most prominent applications among all.

From writing, it very well may be discovered that very modest consideration is given to the Casson liquid flow over a permeable vertical surface with a synthetic rejoinder within the view of a smart field. The expanding utilization of a few non-Newtonian liquids in preparing businesses has propelled an investigation to comprehend their conduct in a few vehicle forms. In this manner, right now, consistent incompressible Casson liquid flow and mass exchange towards a permeable vertical extending sheet are contemplated. The administering halfway differential conditions are changed over into frameworks of nonlinear customary differential conditions (ODE) utilizing reasonable likeness changes. The changed self-comparative ODEs are settled by giving technique: a productive numerical strategy for taking care of limit esteem issues. At that point, a graphical assessment is introduced to show the presence and uniqueness of arrangement and to intricately talk about the characters of the flow and mass exchange for the changing parameters.

2. Mathematical Model

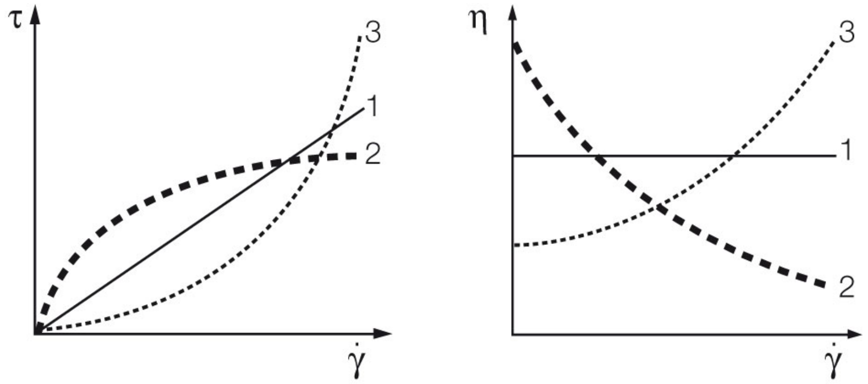
We Consider a two-dimensional steady free convection incompressible Casson fluid flow over a vertical porous plate stretching surface at y = 0 in the presence of a transverse magnetic field, Let the x-axis be taken along the direction of the plate and y-axis normal to the magnetic field of the form $H' = (H_x, H_0, 0)$ it. The fluid occupies the half space y > 0. The mass transfer phenomenon with chemical reaction is also retained. The flow is subjected to a constant practical magnetic field Ho in the y -direction. The magnetic Reynolds number is considered to be very small so that the induced magnetic field is insignificant in comparison to the applied magnetic field. The tangential velocity u, v due to the stretching surface is assumed to vary proportionally to the distance x so that $u = ax$ where is a constant. The rheological equation of state for anisotropic flow of a Casson fluid can be expressed as:

$$\tau_{ij} = \begin{cases} 2\left(\dfrac{\mu_B + P_y}{\sqrt{2\pi}}\right)e_{ij}, & \pi > \pi_c \\ 2\left(\dfrac{\mu_B + P_y}{\sqrt{2\pi_c}}\right)e_{ij}, & \pi < \pi_c \end{cases} \tag{1}$$

In Equation (1) $\pi = e_{ij}e_{ij}$; Where e_{ij} is the $(i, j)^{th}$ constituent of the deformation rate. These resources that π is the invention of the constituent of the turn rate with itself. Also, π_c is the dangerous value of this product based on the non-Newtonian model, μ_B is the plastic active viscosity of the non-Newtonian fluid and P_y is the yield stress of the fluid.

Viscosity values are not normal values as they are affected by many conditions. The problem of this assortment raptly is float behavior under shear at a regular temperature. Flow behavior may be obtainable in two sorts of diagrams Flow curves with shear stress τ and shear rate ˙γ, normally with the latter plot at the x-axis Viscosity curves with viscosity η and shear rate ˙γ(or shear stress τ), generally with the latter plotted at the x-axis. Applying the law of viscosity, every measuring point is calculated as follows: η = τ / ˙γ ideally, viscous flow behavior (Newtonian flow behavior) move toward that the calculated viscosity is self-governing of the shear rate. Characteristic substances from this collection consist of water, mineral oil, silicone oil, salad oil, solvents counting acetone, in addition to viscosity principles.

Shear-thinning behavior (pseudoplastic flow behavior) is characterized by declining consistency with increasing shear rates (Figure-1). Typical materials that show these behavior area component coatings, glues, shampoos, compound solutions, and compound melts. Since consistency is shear-dependent, it must always inclincline with the shear condition. Example: η1 (˙γ1) = 0.5 Pas (at 10 s-1) and η2 (˙γ2) = 0.1 Pas (at 100 s-1). Shear-thinning performance is said to the interior structures of samples.



Flog (1) curves (left) and viscosity curves (right) for (1) preferably viscous, (2) shear-thinning, and (3) shear-thickening flow behavior.

For the present problem, the governing and boundary layer equations are as follows: If u and v are the fluid x, and y –components of velocity correspondingly, and C is being the concentration field; Under these suppositions the administering circumstances for MHD boundary layer flow of Casson fluid are communicated as the complementary situation:

$$\frac{\partial u'}{\partial x'}+\frac{\partial v'}{\partial y'}=0 \tag{2}$$

$$u'\frac{\partial u'}{\partial x'}+v'\frac{\partial u'}{\partial y'}=g\beta_1(\mathrm{T}'-\mathrm{T}'_\infty)+v'\left(1+\frac{1}{\beta}\right)\frac{\partial^2 u'}{\partial y'^2}-\frac{\mu_0}{\rho}H_0\frac{\partial H_x}{\partial y'} \tag{3}$$

$$\frac{K}{\rho CP}\frac{\partial^2 T'}{\partial y'}-\frac{1}{\rho Cp}\frac{\partial q_r}{\partial y'}+\frac{v'}{\rho Cp}\left(1+\frac{1}{\beta}\right)\left(\frac{\partial u'}{\partial y'}\right)^2+\frac{1}{\sigma\rho Cp}\left(\frac{\partial H_x}{\partial y'}\right)^2=v'\frac{\partial T'}{\partial y'} \tag{4}$$

$$v'\frac{\partial H_x}{\partial y'}=H_0\frac{\partial^2 u'}{\partial y'^2}+\frac{1}{\sigma\mu_0}\frac{\partial^2 H_x}{\partial y'^2} \tag{5}$$

where $\beta,\ g,\ \beta_1,\ T', T'_\infty,\ v,\ \mu_0,\ \rho,\ k,\ Cp,\ q_r\ \ and\ \ \sigma$ are parameter of the casson fluid, acceleration due to gravity, coefficient of volume expansion , fluid temperature , temperature of fluid at infinity, kinematic velocity, magnetic permeablebility, fluid density, thermal conductivity, specific heat, constant pressure, radioactive heat flux and electrical conductivity. area under discussion to the following bounder conditions are given by:

$$u'=0\ \ ,v'=-v'_0\ \ \ ,T^1=T^1{}_w\ \ \frac{\partial H_x}{\partial y'}=0\ \ as\ \ y'=0 \tag{6}$$

$$u'=0\ \ ,v'=-v'_0\ \ \ ,T^1=T^1{}_w\ \ \frac{\partial H_x}{\partial y'}=0\ \ as\ \ y'=0 \tag{7}$$

Here the suction velocity v_0 is undeclared to be constant. The temperature at the wall is unspecified to be T'_w, and the constant free stream velocity considered here is U_0. From Eq. (2) it is evident that

$$\frac{\partial q_r}{\partial y'}=-4\,\alpha\,\sigma\,(T_\infty'^4-T'^4) \tag{8}$$

Where σ and α are Stefan-Boltzmann constant and the combination coefficient. Reduce Eq. (4) by using Eq. (8).

$$v'\frac{\partial T'}{\partial y'}=\frac{k}{\rho Cp}\frac{\partial^2 T'}{\partial y'^2}+\frac{4\,\alpha\,\sigma}{\rho Cp}(T_\infty'^4-T'^4)+\frac{v'}{\rho Cp}\left(\frac{\partial u'}{\partial y'}\right)^2+\frac{1}{\sigma\rho\ Cp}\left(\frac{\partial H_x}{\partial y'}\right)^2 \tag{9}$$

Now T'^4 can be expressed as

$$T'^4 \cong 4T_\infty'^3\, T' - 3T_\infty'^4 \tag{10}$$

By using Eq. (10), Eq. (9) becomes

$$v'\frac{\partial T'}{\partial y} = \frac{k}{\rho Cp}\frac{\partial^2 T'}{\partial y'^2} + \frac{16\,\alpha\,\sigma T_\infty'^3}{\rho Cp}(T_\infty' - T') + \frac{v'}{\rho Cp}\left(\frac{\partial u'}{\partial y'}\right)^2 + \frac{1}{\sigma\rho\, Cp}\left(\frac{\partial H_x}{\partial y'}\right)^2 \tag{11}$$

Using these transformations

$$E_c = \frac{U^2{}_0}{C_P(T_w' - T_\infty')},\ G = \frac{\mathrm{vg}\,\beta_1(T_w' - T_\infty')}{U_0 V_0^2},\ S = \frac{16a\sigma T_\infty'^3 v^3}{k\, v^3{}_0},\ p_r = \frac{\rho v c_p}{k},\ M = \left(\frac{\mu_0}{\rho}\right)^{\frac{1}{2}}\frac{H_0}{v_0}$$

$$H = \left(\frac{\mu_0}{\rho}\right)^{\frac{1}{2}}\frac{H_x}{U_0},\ u = \frac{u'}{U_0},\ P_m = v\sigma\mu_0,\ \theta = \frac{T' - T_\infty'}{T_w' - T_\infty'},\ y = \frac{y' v_0}{v}$$

U(x,0)=u , V(x,o)=-v(x), C(X,0)=c(x) u(x,infinite)=0, c(x,0)=c

$$u' = u_x'\ f(\eta)\ ,,\mathrm{v}' = -\sqrt{\frac{v' u_w'}{x}}f(\eta)\ ,\eta = \sqrt{\frac{u_w'}{v_x'}},\phi(\eta) = \frac{c - c_\infty}{c_w - c_\infty} \tag{12}$$

Where $\beta = \mu\frac{\sqrt{2\pi_c}}{p}$ is the non-Newtonian Casson parameter, diffusion, γ is the reaction rate, v_0 is the suction velocity from the surfaces is the kinematic viscosity, ρ is the fluid density, g is gravitational,

Eq(3)-Eq(5) and Eq.(11) reduces to

$$\left(1 + \frac{1}{\beta}\right)\frac{d^2 u'}{dy'^2} + \frac{du'}{dy'} - M\frac{dH}{dy'} + G\theta = 0 \tag{13}$$

$$\frac{d^2 H}{dy'^2} + P_m\frac{dH}{dy'} + MP_m\frac{du'}{dy'} = 0 \tag{14}$$

$$\frac{d^2\theta}{dy'^2} + \Pr\frac{d\theta}{dy'} - S\theta + \Pr E_c\left(1 + \frac{1}{\beta}\right)\left(\frac{du'}{dy'}\right)^2 + \frac{\Pr E_c}{P_m}\left(\frac{dH}{dy'}\right)^2 = 0 \tag{15}$$

The boundery conditions are u=0 , $\frac{dH}{dy'} = 0\ \ ,\theta = 1\ \ at\ \ y = 0$

$$u' \to 1, H \to 0, \theta \to 0\ \ as\ \ y' \to \infty \tag{16}$$

3.Numerical Solution:

The prime symbol denotes differentiation with to the similarity variable η, where $M = \frac{\sigma H_0{}^2}{\rho a}$ is the magnetic field parameter, $B = \frac{\gamma}{a}$ is the chemical reaction paramter $f_w = \frac{v_0(x)}{\sqrt{av}}$ is the suction parameter, $Sc = \frac{v}{D_m}$ is the schmidt number, and $G_c = g\beta(c_w - c_\infty)x / u_w{}^2$ is local solute Grashof number.

The numerical technique was chosen for the respond of the attached standard differential Equations (13)-(14) along with the associated remodeled boundary conditions (16) is that the commonplace Newton-Rap son shooting technique on the ship the fourth-order Runge-Kutta integration formula. From the method of numerical estimate, the plate surface temperature, the countrywide skin-friction constant, the native Nusselt variety and also the native Robert Emment Sherwood assortment, that are strictly, proportional to and computed and their numerical standards given during a tabular type

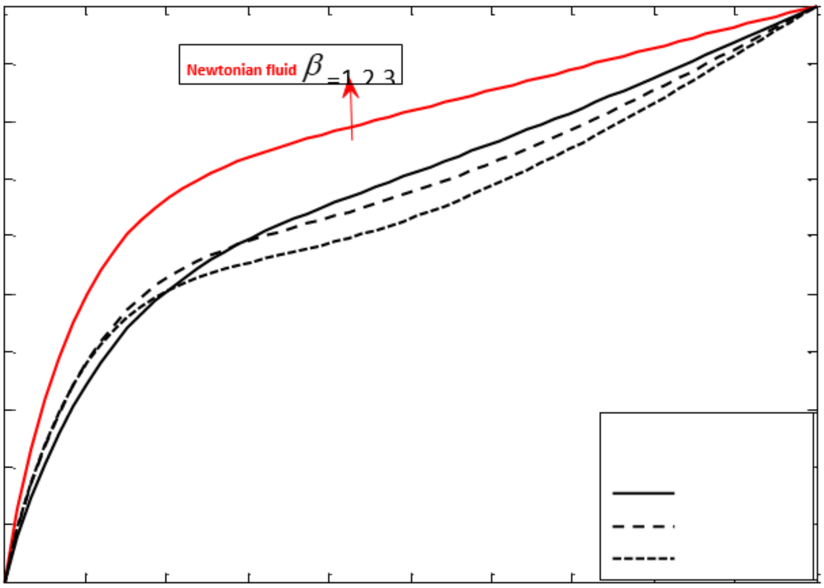


Fig-1 Effect of β distribution on velocity

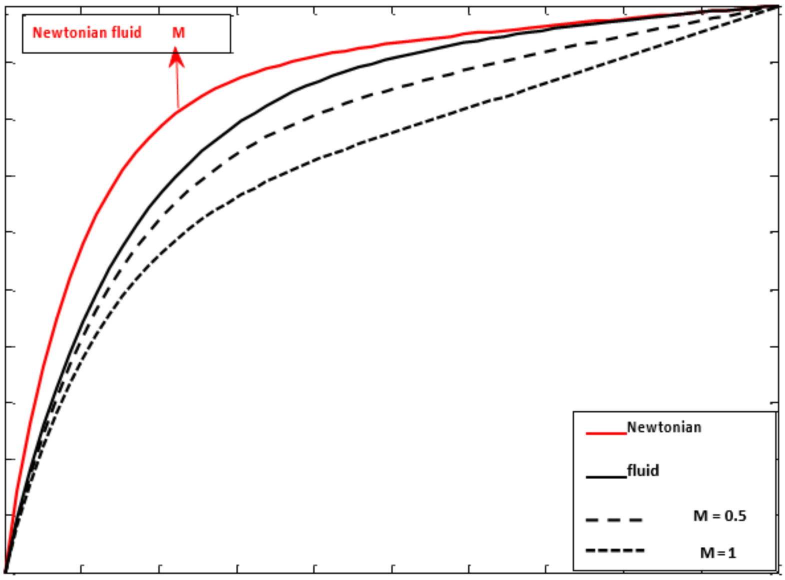
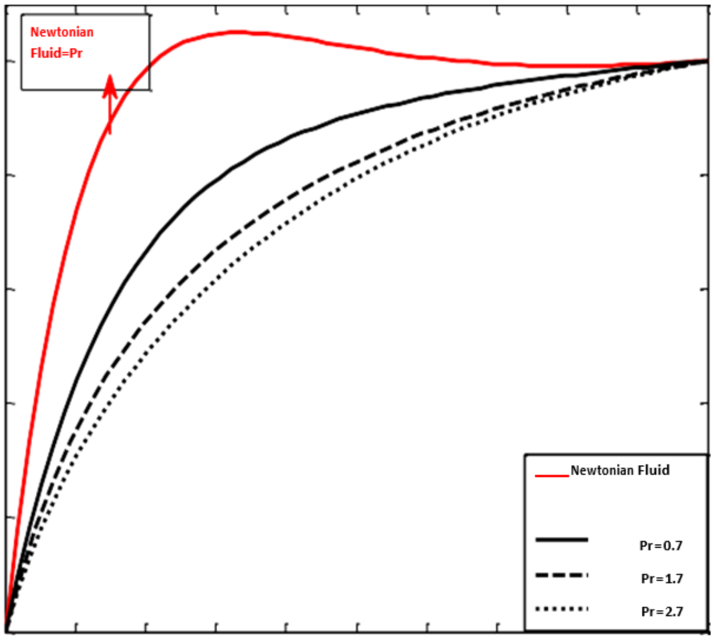


Fig-2 Effect of magnetic M distribution on velocity



Fig—3 The velocity distribution for different values

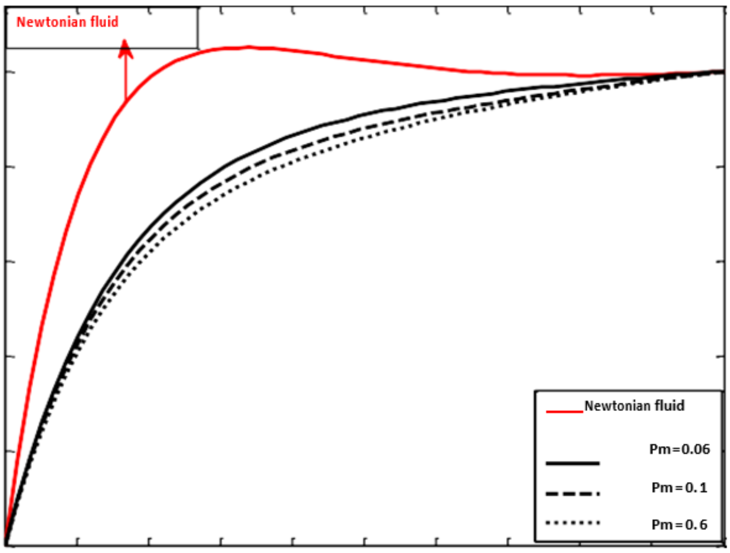


Fig-4 Effect of Magnetic prandtal number Pm on velocity

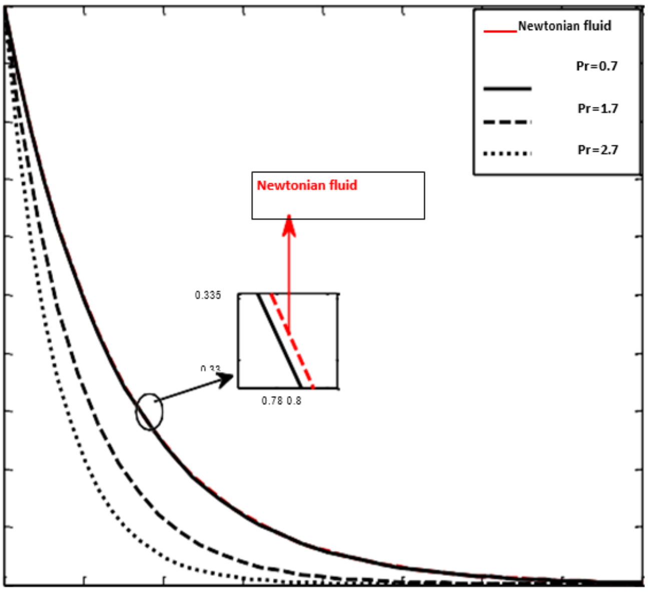


Fig-5 The velocity distribution for different values of Pr

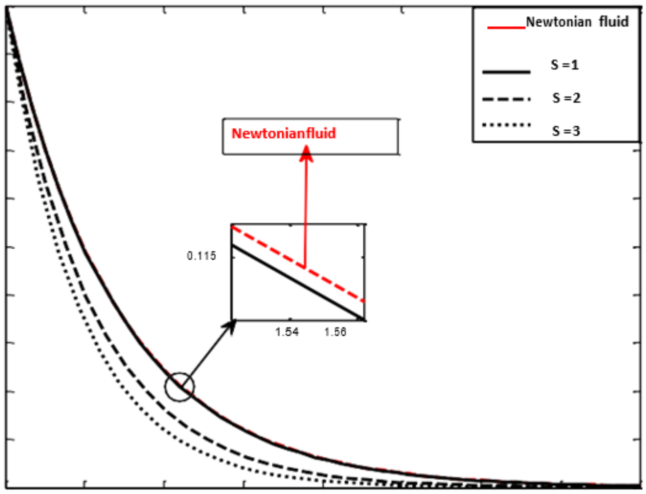


Fig-6 Impact of soret number S on temperature distribution

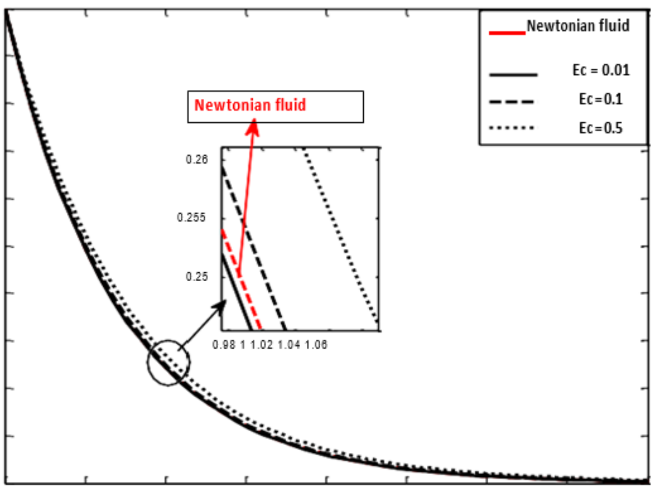


Fig-7 Temperature distribution for various values

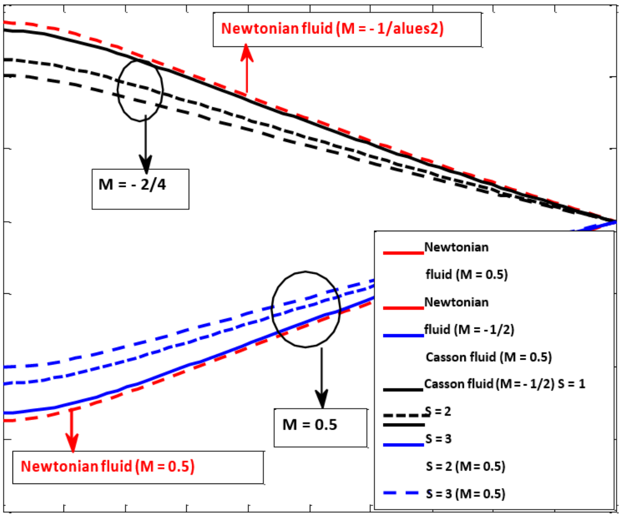


Fig-8 The magnetic induced field for Soret number

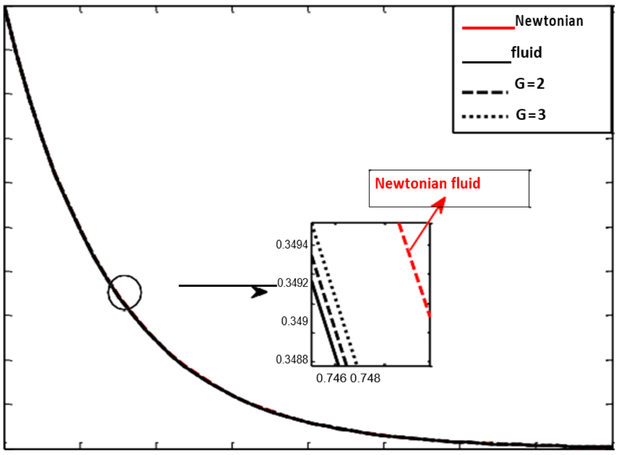


Fig-9 Pr number on temperature distribution

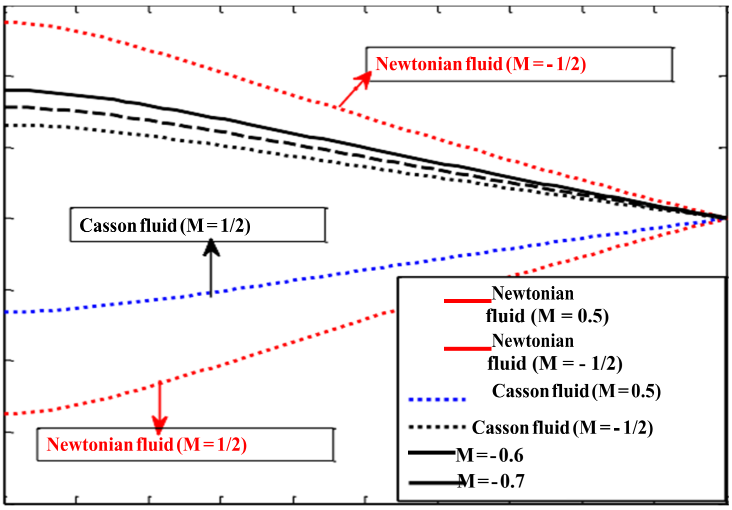


Fig-10 M effect on profile H for distribution value of M

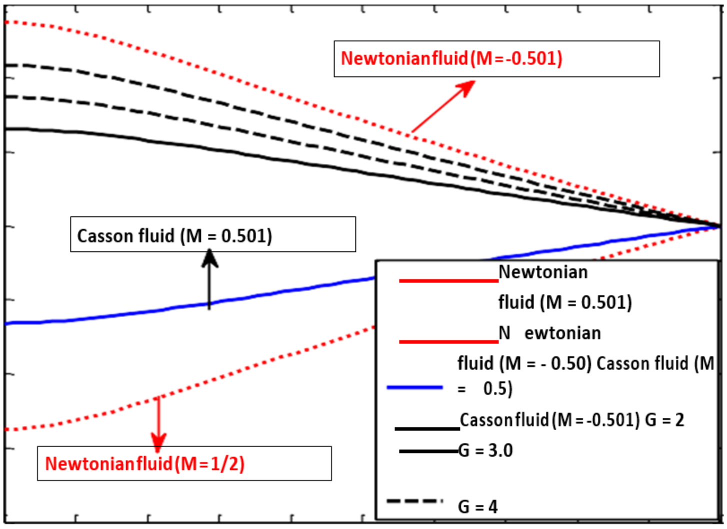


Fig-11 Effect of Gr number on induced M filed

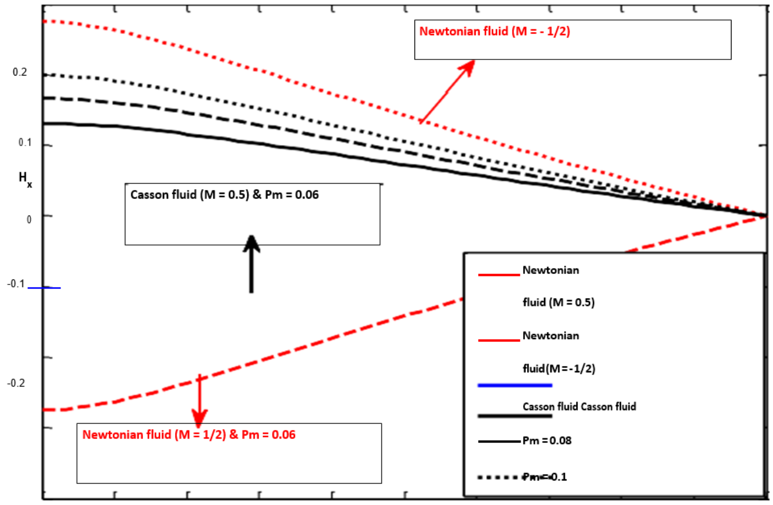


Fig-12The impact of values of Pm on ibduced M filed distribution

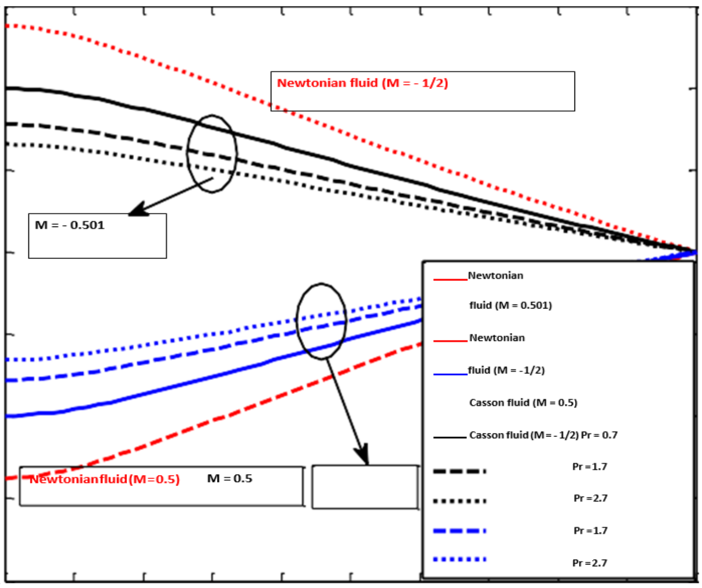


Fig-13 The influence of Pr on magnetic field induced

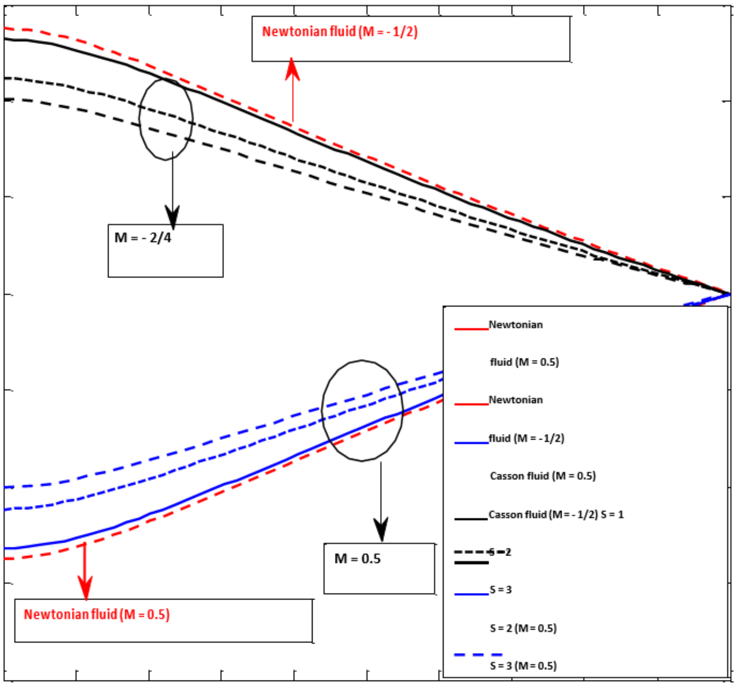


Fig-14 S sorest number the induced magnetic field profile for various value

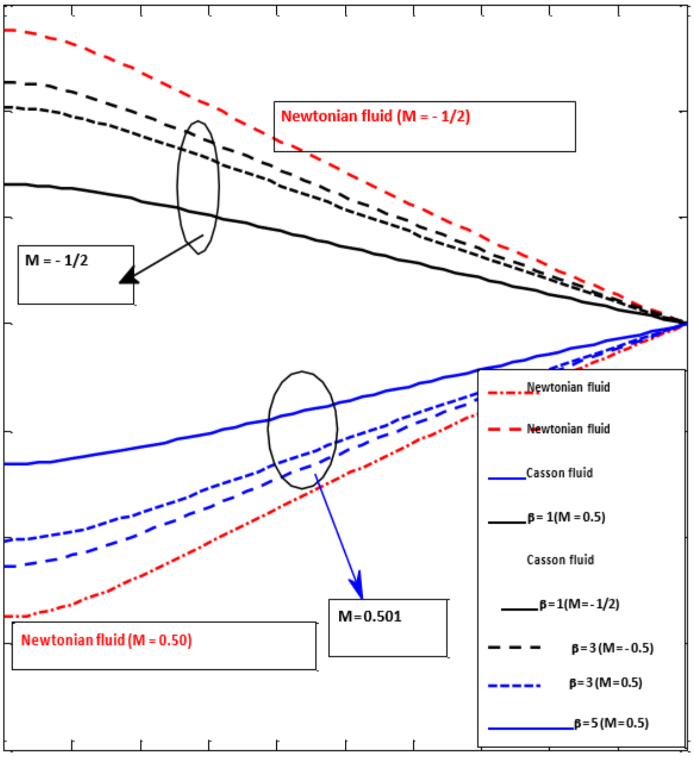


Fig-18 Casson fluid beta on magnetic field

4. Table.1 Numerical results of sikn friction coefficient and Sherwood number

M	B	Gc	Sc	B	fw	− f' (0)	-ϕ′ (0)
0.5	0.5	0.1	0.6	0.3	0.1	0.701894	0.675765
0.7	0.5	0.1	0.6	0.3	0.1	0.747866	0.670528
1.0	0.5	0.1	0.6	0.3	0.1	0.812075	0.663476
1.5	0.5	0.1	0.6	0.3	0.1	0.909246	0.653385
0.5	0.3	0.1	0.6	0.3	0.1	0.584131	0.690091
0.5	1.5	0.1	0.6	0.3	0.1	0.942483	0.650258
0.5	2.0	0.1	0.6	0.3	0.1	0.993805	0.645458
0.5	0.5	0.5	0.6	0.3	0.1	0.615589	0.684487
0.5	0.5	1.0	0.6	0.3	0.1	0.511641	0.694304
0.5	0.5	1.5	0.6	0.3	0.1	0.411199	0.703204
0.5	0.5	0.1	0.5	0.3	0.1	0.700321	0.607036
0.5	0.5	0.1	1.0	0.3	0.1	0.705957	0.911669
0.5	0.5	0.1	1.5	0.3	0.1	0.708792	1.155165
0.5	0.5	0.1	0.6	0.5	0.1	0.703184	0.764950
0.5	0.5	0.1	0.6	1.0	0.1	0.705420	0.949749
0.5	0.5	0.1	0.6	1.5	0.1	0.7069 0	1.102396
0.5	0.5	0.1	0.6	0.3	0.5	0.774640	0.831437
0.5	0.5	0.1	0.6	0.3	1.0	0.874223	1.047186
0.5	0.5	0.1	0.6	0.3	1.5	0.982768	1.281483

5.CONCULESITION

Numerical analysis to observe the effect of the induced magnetic field on the pressure group of Casson fluid through a vertical protect is obtainable. The governing equations are solved numerically all along with shooting technique using the Runge- Kutta method. The numerical consequences for a wide range of the physical parameter values are obtained.

A study of the Casson fluid flow over a vertical porous surface with chemical reaction has been provided in the presence of a transverse magnetic field. Numerical findings were compared with previous consequences published in the literature, and a complete agreement was reached. Our findings show that, amongst others

1) The velocity decreases with the rise in M, fw and β values; and increases with the get higher in Gc.
2) The concentration limit sheet decreases with higher values of fw, Gc, Sc and B; and increase with Higher values of M and β.
3) On the surface, skin friction increases with increasing values of M, fw, β, Sc and B; and decreases with Increasing values of Gc.
4) The rate of mass transfer at the surface increases with increasing values of fw, Gc, Sc and B; and decreases with increasing values of M and β.
5) The Casson fluid velocity decreases with an enlarge of, M, S, Pr, and Pm.
6) Temperature distribution decreases with an augment in the values of Pr and S.
7) Profile H is improved with decreasing of magnetic parameter M.

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