

GSJ: Volume 8, Issue 4, April 2020, Online: ISSN 2320-9186

www.globalscientificjournal.com

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

M. Ramanuja¹ V. Nagaradhika²

¹ Department of Mathematics, Marri Laxman Reddy Institute of Technology & Management (Autonomous), Dundigal, Medchal. Dist . Hyderabad-500043. INDIA.

Email: mramanuja09@gmail.com

²Department of Mathematics, Gitam University Bangalore, 562163, INDIA.

Email: nagaradhika79@gmail.com

ABSTRACT:

Casson liquid stream over a vertical permeable surface with a synthetic response within the sight of an attractive meadow has been contemplated. comparison investigation was utilized in the direction of changing the arrangement of unfinished 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 material constants resembling Casson liquid (β), Magnetic parameter M, Soret number Sc , Prandtl number Pr, Magnetic Prandtl number H, 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 complies with the physical consideration of notable Newtonian and all other Non-Newtonian fluids.

KEYWORDES: Casson Fluid, Mass Transfer, Suction, Non-Newtonian Fluid, Induced magnetic field, Induced magnetic field, MHD, Natural Convection, Slip.

1.Introduction:

At the most extreme temperature, the impact of calm radiation is intelligent in the movement of the thick fluid field. These impacts are noteworthy in various current domains, for instance, daylight based power oddity, electrical power time, and aeronautical structure. A couple of experts have moreover analyzed this field. The impact of the incited lovely field on heat and mass trade of the progression of stagnation point towards the outside of the broadening sheet was finished. A fluid wherein the gooey weights rising up out of its downpour at each point are chipper correspondings to the pace of progress in its distortion after some moment in time is called Newtonian fluid. This suggests in a Newtonian fluid, the connection between the shear pressure and the shear rate is immediate with the proportionality consistent towards insinuate as the coefficient of consistency. Of course, a fluid whose stream properties are particular in any capacity from that of the Newtonian fluid is known as a non-Newtonian fluid. As opposed to the Newtonian fluids, the thickness of the non-Newton fluid is reliant on the shear rate before. As it were, in a non-Newtonian fluid, the association between the shear pressure and the shear rate is remarkable and can level be time-subordinate. Thusly, a reliable coefficient of thickness can't be portrayed. A couple of

occurrences of non-Newtonian fluids are salt courses of action, fluid polymers, ketchup, custard, toothpaste, starch suspensions, paints, blood, and chemical

Mustafa et al. [1] are contemplated solid as far as possible crease float and heat switch over a Casson liquid upstairs a moving plane fix together with a parallelism reasonable stream utilizing the Homotopy Analysis Method (HAM). On the contemptible hand, line bed streams of non-Newtonian liquids activated by method for an extending foil hold gigantic military into various modern systems such to be specific transportation with respect to liquid polymers through a cut kick the bucket as a result of the creation in regards to plastic sheets, calm moving, link yet fiber covering, handling over staples, metal turning, glass-fiber creation, at that point conveyance note creation life span. Hayat et al.[2] are discussed investigated the blended convection stagnation-point stream of a non-Newtonian Casson liquid. In particular, Bhattacharyya et al.[3] as of late examined the limit layer stream of Casson liquid over a porous extending/contracting sheet with an attractive field impact. Rajagopal et al.[4] have developed who considered viscoelastic fluid, Fredrickson. [5] explored the consistent progression of a Casson liquid in a cylinder. Khalid et al.[6] examined 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 the 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] examined the smooth, two-MHD Casson liquid stream over a convective limit layer with an exponentially extending surface with slanted porous. The exponentially growing layer of MHD Casson liquid stream with porous bed and physical nearness of the warmth move was thought of, Imran et al. [11] have depicted It is seen that the improvement of slip parameters helps the speed of Casson fluid. It is moreover observed that the impact of slip is a ton of incredible on temperature scattering in evaluation with speed spread. MHD stagnation point stream of Casson fluid, Raju et al.[12] have analyzed the impact of slip conditions on non-goosy coordinating fluid flow over a nonlinearly broadening sheet through thick warming in the penetrable medium was inspected. Watson, [13] interested over micropolar liquid stream over a broadening sheet. Troy et al.[14] have examined set up the uniqueness of the plan of the movement of second-demand fluid over a broadening sheet. Various assessments performed on blood through fluctuating hematocrits, anticoagulants, temperatures, and the inclinations, solidly prescribe the direction of blood as a Casson fluid [15] [16].

As a result of the novel use of MHD mixed convection flow in penetrable mediums, in the field of the cutting edge assembling, various masters are pulled in to it. The arrangement of MHD power generators, nuclear waste readiness, and movement of blend waste control are some most unmistakable applications among all.

From forming, it may be discovered that inconspicuous idea is given to the Casson liquid pour out over a permeable vertical exterior with a build answer inside the point of view on a wise field. The developing utilization of a couple of non-Newtonian liquids in preparing associations has actuated an assessment to comprehend their lead in a few vehicle structures. At this moment, by and by, consistent incompressible Casson liquid stream and mass exchange towards a vulnerable vertical growing sheet is thought of. The coordinating for the most part differential conditions are changed over into structures of nonlinear standard differential conditions (ODE) utilizing reasonable similitude changes. The changed self-relative ODEs are settled by giving construction: a profitable numerical philosophy for managing limit respect issues. By at that point, a graphical examination is familiar with show the closeness and uniqueness obviously of activity and to complicatedly talk about the characters of the stream and mass exchange for the developing parameters.

2. Mathematical Model:

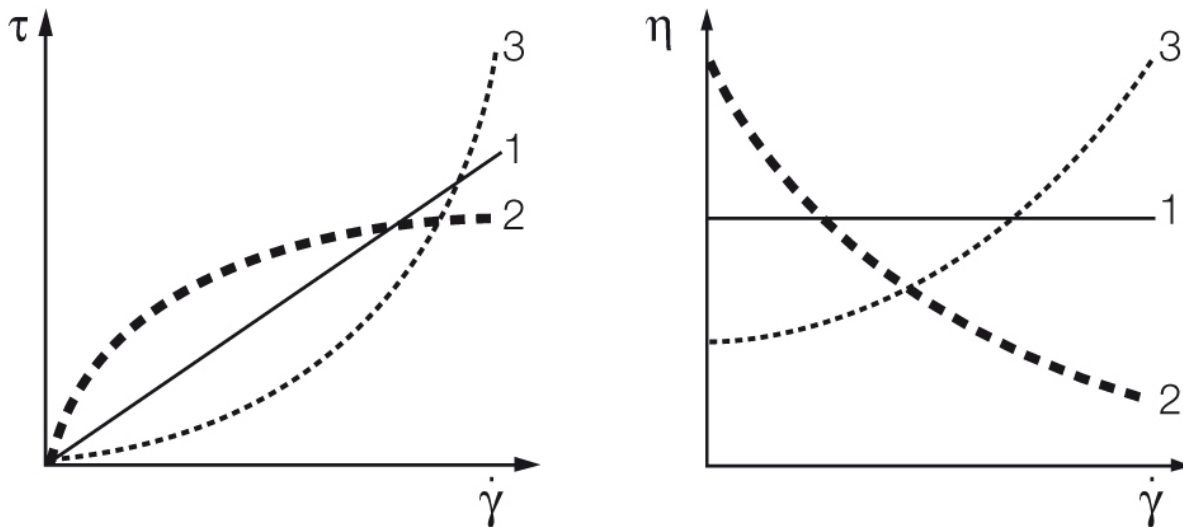
We Consider a two-dimensional steady free convection incompressible Casson fluid flow over a vertical porous plate stretching surface at $y = 0$ in the presence of a transverse magnetic field, Let the x-axis be taken along the direction of the plate and y-axis normal to the magnetic field of the form $H' = (H_x, H_0, 0)$ it. The fluid occupies the half breathing space $y > 0$. The mass exchange wonder with the compound response is likewise held. The stream is exposed to a consistent reasonable attractive field H_0 in the y-course. The attractive Reynolds number is viewed as little with the goal that the prompted attractive field is immaterial in contrast with the applied attractive 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 a is a constant. The rheological equation of state for anisotropic flow of a Casson fluid be capable of be expressed as:

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

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 full of life viscosity of the non-Newtonian fluid and P_y is the give up stress of the fluid.

Viscosity values are no longer ordinary values as they are affected by using many conditions. The problem of this assortment raptly is waft conduct underneath shear at a regular temperature. Flow conduct may also be available in two varieties of diagrams Flow curves with shear stress τ and shear rate $\dot{\gamma}$, normally with the latter plot at the x-axis Viscosity curves with viscosity η and shear rate $\dot{\gamma}$ (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: $\eta = \tau / \dot{\gamma}$ ideally, thick stream conduct (Newtonian stream conduct) advances toward that the determined thickness is self-overseeing of the shear rate. Trademark substances from this assortment comprise of water, mineral oil, silicone oil, serving of mixed greens oil, solvents checking (CH₃CO), notwithstanding thickness standards.

Shear-thinning conduct (pseudoplastic drift behavior) is characterized by declining consistency with increasing shear quotes (Figure-1). Typical substances that show these behavior area element coatings, glues, shampoos, compound solutions, and compound melts. Since consistency is shear-dependent, it should continually inclining with the shear situation. Example: $\eta_1 (\dot{\gamma}_1) = 0.5$ Pas (at 10 s⁻¹) and $\eta_2 (\dot{\gamma}_2) = 0.1$ 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 **existing** 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: For the current issue, the overseeing and limit layer conditions are as per the following: If u' and v' are the liquid x' , and y' – segments of speed correspondingly, and C is being the focus field; Under these suppositions, the directing conditions for MHD limit layer stream of Casson liquid are imparted as the correlative circumstance:

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

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

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

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

where β , g , β_1 , T' , T'_∞ , v , μ_0 , ρ , k , ρC_p , q_r and σ are parameter of the Casson fluid, acceleration due to gravity, coefficient of volume expansion, fluid temperature, the temperature of the fluid at infinity, kinematic velocity, magnetic permeability, fluid density, thermal conductivity, specific heat, constant pressure, radioactive heat flux, and electrical conductivity. The area under discussion to the following boulder conditions are given by:

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

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

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

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

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

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

Now T'^4 can be expressed as

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

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

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

Using these transformations

$$E_c = \frac{U^2_0}{C_p (T'_w - T'_\infty)}, G = \frac{v g \beta_1 (T'_w - T'_\infty)}{U_0 V_0^2}, S = \frac{16 \alpha \sigma T'^3_\infty v^3}{k v^3_0}, p_r = \frac{\rho v c_p}{k}, M = \left(\frac{\mu_0}{\rho} \right)^{\frac{1}{2}} \frac{H_0}{v_0}$$

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

$$U(x,0)=u, V(x,0)=-v(x), C(X,0)=c(x), u(x,\infty)=0, c(x,0)=c$$

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

Where $\beta = \mu \frac{\sqrt{2\pi c}}{p}$ 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 boundary conditions are $u=0, \frac{dH}{dy'} = 0, \theta = 1$ at $y = 0$

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

3. Numerical Solution:

The high 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 parameter $f_w = \frac{v_0(x)}{\sqrt{av}}$ is the suction parameter,

$Sc = \frac{\nu}{D_m}$ is the Schmidt number, and $G_c = g\beta(c_w - c_\infty)x / u_w^2$ is local solute Grashof number.

The numerical method was favored intended for the reaction of the appended standard differential Equations (13)- (14) alongside the related rebuilt limit conditions (16) is that the ordinary Newton-Rap child shooting system on the boat the fourth-request Runge-Kutta mix recipe. From the strategy for numerical estimation, the plate surface temperature, the countrywide skin-contact steady, the local Nusselt assortment and furthermore the local Robert Emmet Sherwood variety, that are carefully, relative to and registered and their numerical norms are given during a forbidden kind

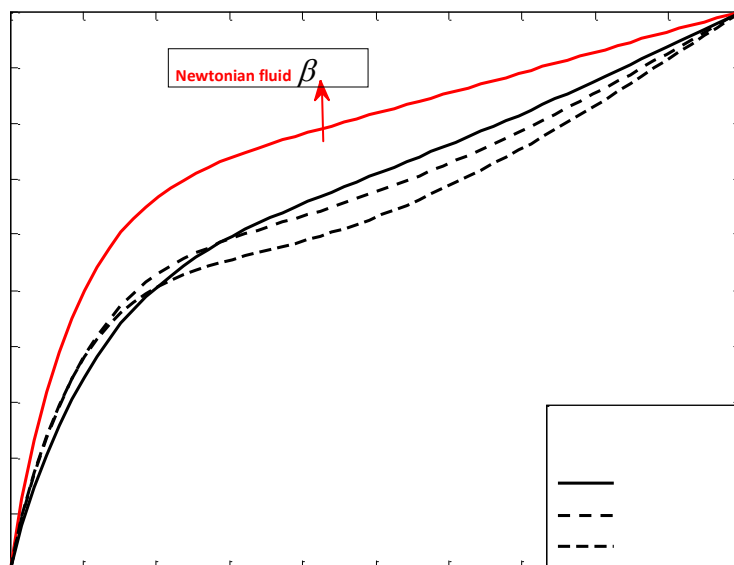


Fig-1 Effect of β allocation resting on velocity

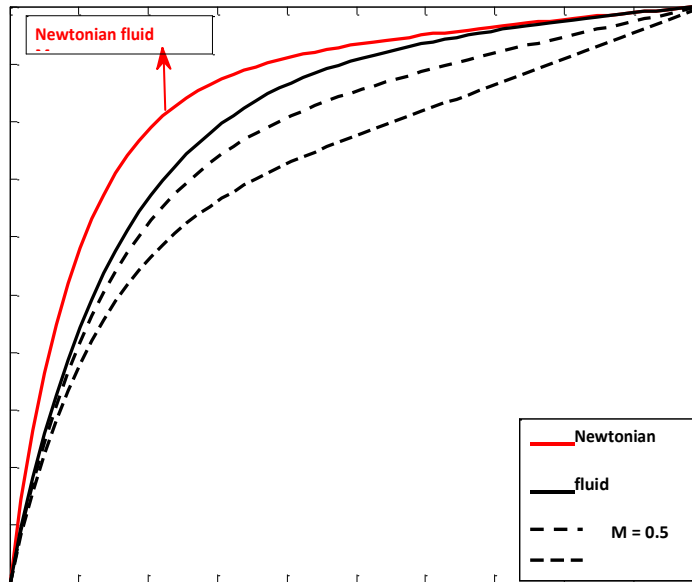


Fig-2 Effect of magnetic M allotment lying on velocity

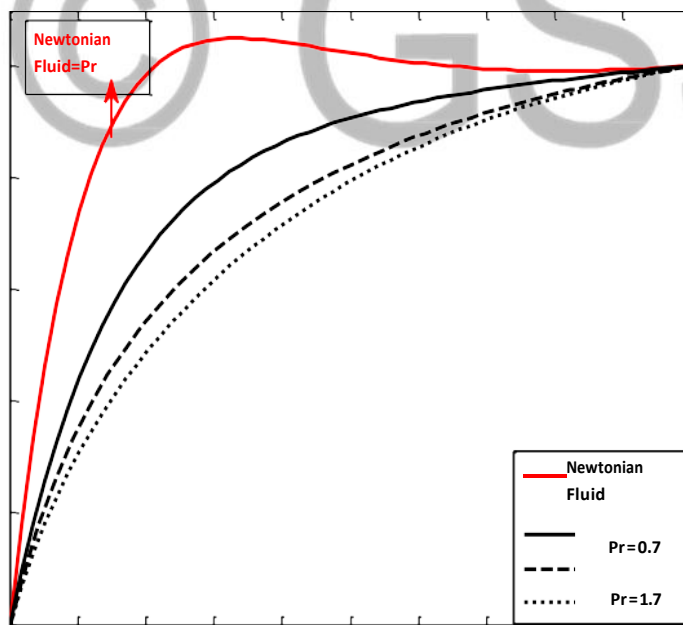


Fig-3 The velocity distribution for different values

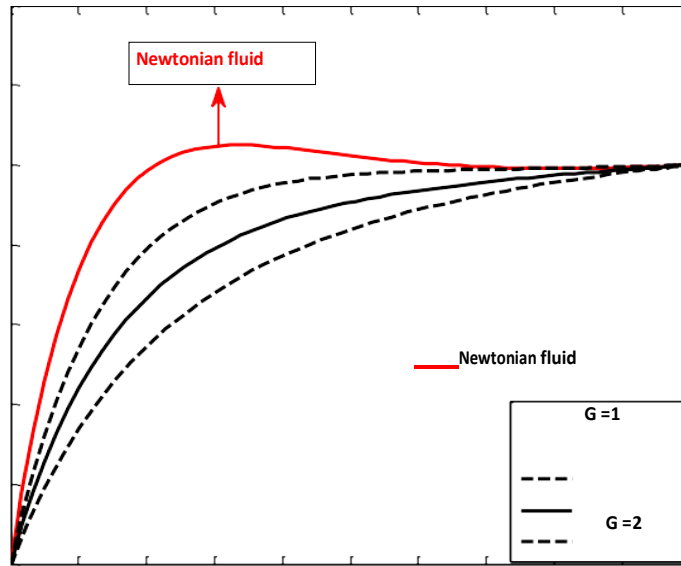


Fig-4 Effect of Magnetic prandtl number P_m resting on velocity

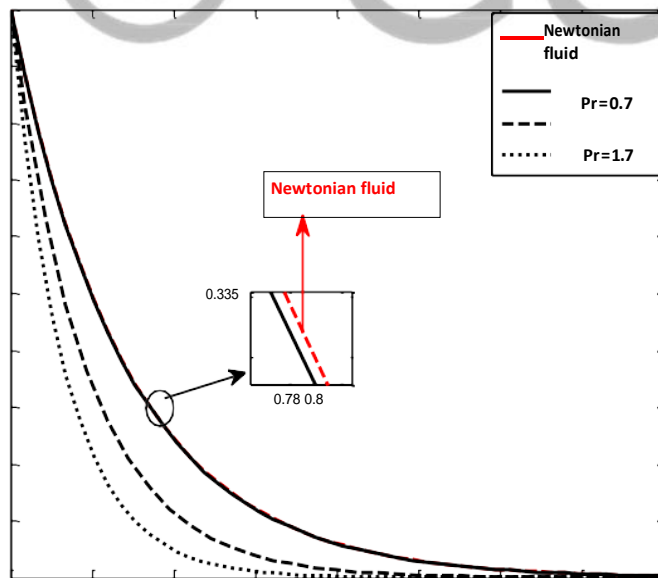


Fig-5 The velocity distribution for dissimilar values of Pr

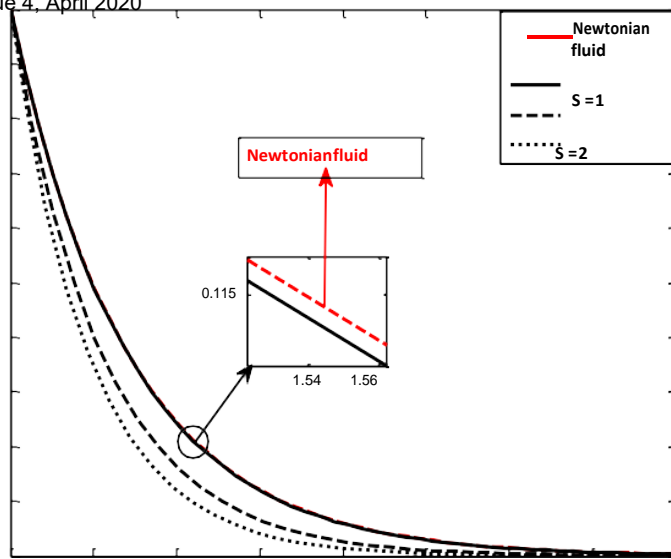


Fig-6 Impact of soret number S on temperature allocation

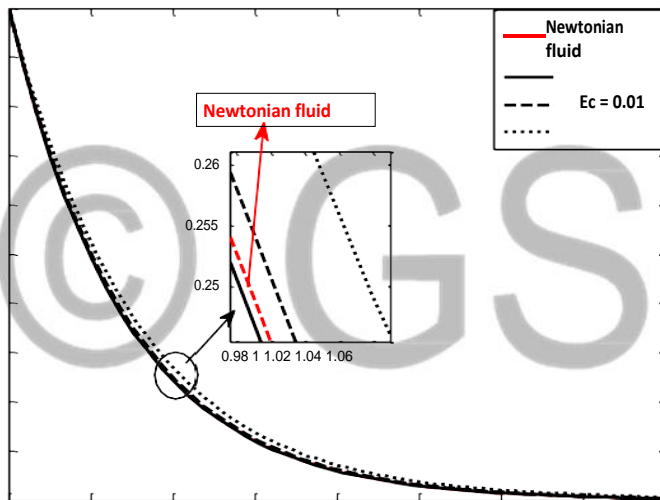


Fig-7 Temperature distribution for a variety of values

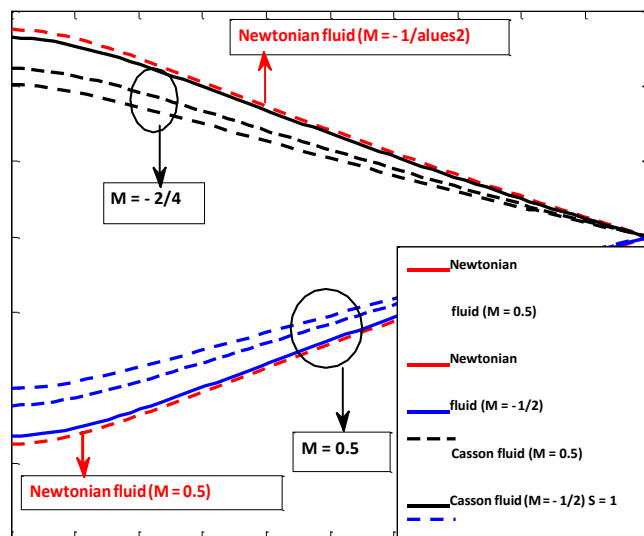


Fig-8 The magnetic induced field for Soret number

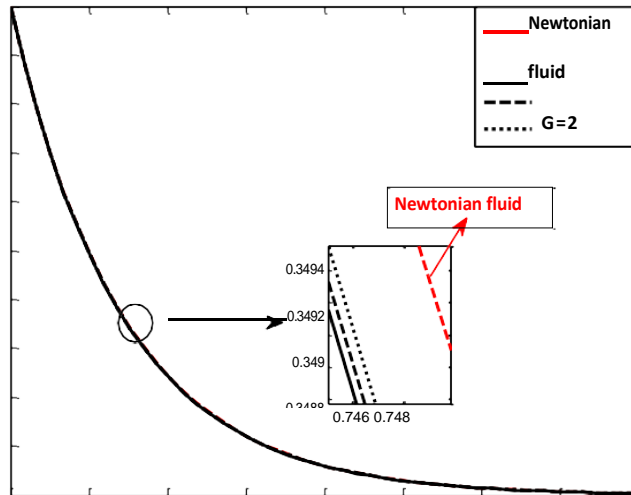


Fig-9 Pr number on temperature allocation

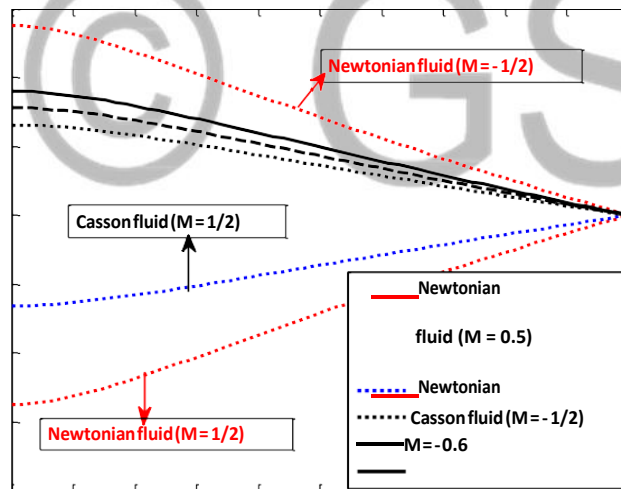


Fig-10 M effect on top of profile H for distribution value of M

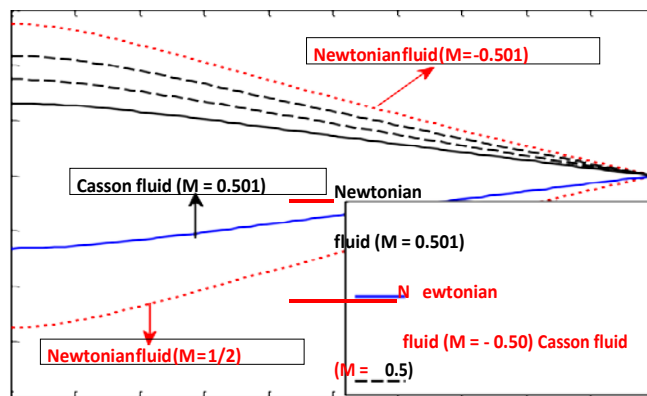


Fig-11 Effect of Gr number lying on induced M filed

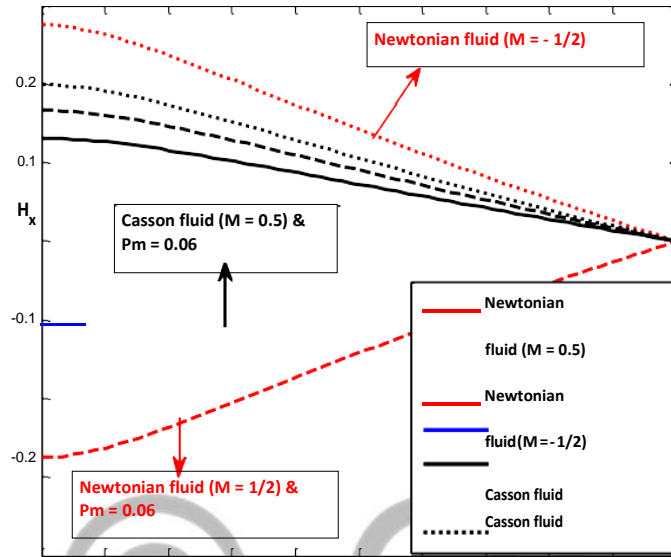


Fig-12 The impact of values of Pm on induced M filed distribution

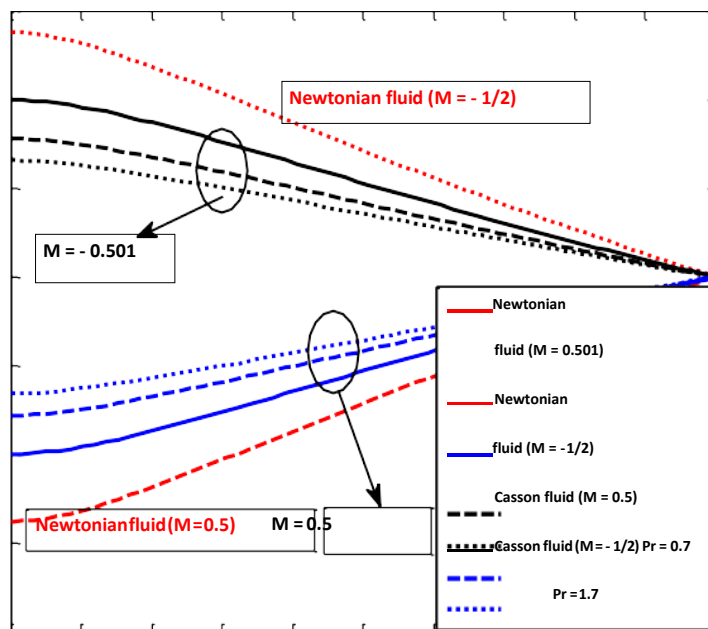


Fig-13 The pressure of Pr on magnetic field induced

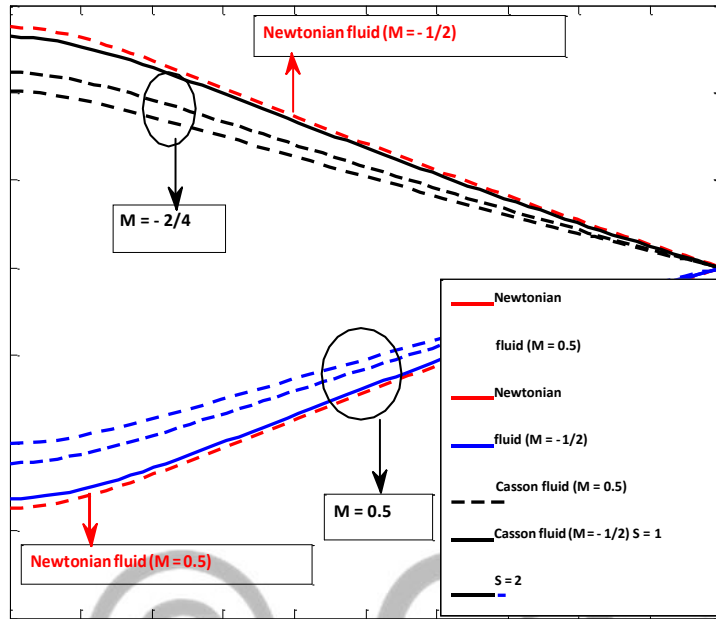


Fig-14 S soresst number the induce magnetic field profile for various values

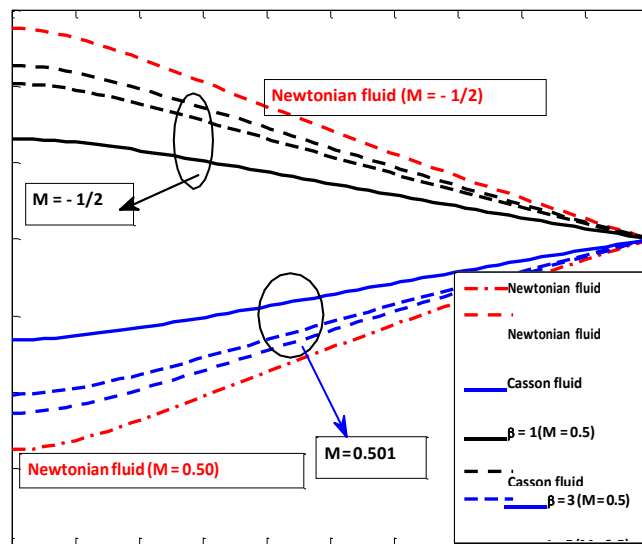


Fig-18 Casson fluid beta on top of magnetic field

4. Table.1 Numerical outcomes of skin friction coefficient and Sherwood range

M	B	G_c	Sc	B	f_w	$-f'(0)$	$-\phi'(0)$
0.5	0.5	0.1	0.6	0.3	0.1	0.701895	0.675764
0.7	0.5	0.1	0.6	0.3	0.1	0.747864	0.670529
1.0	0.5	0.1	0.6	0.3	0.1	0.812076	0.663477
1.5	0.5	0.1	0.6	0.3	0.1	0.909247	0.653386
0.5	0.3	0.1	0.6	0.3	0.1	0.584132	0.690093
0.5	1.5	0.1	0.6	0.3	0.1	0.942482	0.650259
0.5	2.0	0.1	0.6	0.3	0.1	0.993805	0.645457
0.5	0.5	0.5	0.6	0.3	0.1	0.615588	0.684487
0.5	0.5	1.0	0.6	0.3	0.1	0.511644	0.694304
0.5	0.5	1.5	0.6	0.3	0.1	0.411195	0.703205
0.5	0.5	0.1	0.5	0.3	0.1	0.700323	0.607037
0.5	0.5	0.1	1.0	0.3	0.1	0.705958	0.911668
0.5	0.5	0.1	1.5	0.3	0.1	0.708792	1.155166
0.5	0.5	0.1	0.6	0.5	0.1	0.703182	0.764951
0.5	0.5	0.1	0.6	1.0	0.1	0.705420	0.949748
0.5	0.5	0.1	0.6	1.5	0.1	0.706923	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. CONCLUSION:

Numerical investigation to watch the impact of the instigated attractive field on the weight gathering of Casson liquid through a vertical ensures is accessible. The administering conditions are settled numerically from the beginning with shooting approach utilizing the Runge-Kutta technique. The numerical ramifications for a wide scope of the physical parameter esteems are acquired.

An investigation of the Casson liquid flow over a vertical permeable surface with substance response has been given within the sight of a transverse attractive field. Numerical discoveries were contrasted and past results distributed in the writing, and a total understanding was reached. Our discoveries show that, surrounded by others

- 1) The velocity decreases with the upward jab in M , f_w and β values; and will increase with the get greater in G_c
- 2) The attention restrict sheet decreases with higher values of f_w , G_c , Sc , and B ; and amplify with higher values of M and β .
- 3) On the surface, pores and skin friction increases with growing values of M , f_w , β , Sc and B ; and decreases with Increasing values of G_c .
- 4) The charge of mass transfer at the surface increases with increasing values of f_w , G_c , Sc and B ; and decreases with growing 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 a decreasing magnetic parameter M .

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