Unsteady MHD Flow through a Porous Medium in a Parallel Plates

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Abstract: In this article an initial value examination has been prepared for a 2D MHD flow of a 2nd order Rivlin-Ericksen type visco-elastic fluid through a porous medium in a parallel plate channel under externally applied boundary acceleration. The exact solutions for the velocity, accelerations and shear stress have been obtained. Their behaviour for different governing parameters has been discussed computationally based on the available physiological data.

Keywords: Unsteady, visco-elastic fluid flow, porous medium, parallel channel.

1. Introduction:

Flow between porous boundaries is of practical, as well as theoretical interest. The practical interest includes problems of gaseous diffusion, transpiration cooling, lubrication of porous bearing etc. Flow through porous medium under the influence of temperature and concentration differences find great applications in Geothermy, Geophysics and Technology. MHD (magneto hydrodynamic) flows with and without heat transfer in electrically conducting fluids have attracted substantial interest in the context of metallurgical fluid dynamics, re-entry aerothermodynamics, astronautics, geophysics, nuclear engineering, and applied mathematics. Free convective flow in presence of heat source has been a subject of interest of many researchers because of its possible application to geophysical sciences, astrophysical sciences, and in cosmical studies. Such flows arise either due to unsteady motion of the boundary or the boundary temperature. The study of fluctuating flow is important in the paper industry and many other technological fields. During past several years considerable interest has been evinced in the study of the problem of hrodynamic flow in a porous channel with radiative heat transfer be-cause of its various applications in physiology and in engineering devices such as blood flow in arteries, trans- piration cooling of re-entry vehicles and rocket busters, cross-hatching on ablative surfaces. Effects of radiation, chemical reaction and soret on unsteady mhd free convective flow over a vertical porous plate studied by Dharmaiah et al. [1]. Unsteady mhd convective heat and mass transfer flow past an inclined moving surface with heat absorption have been examined by Ramprasad et al. [2]. Chemical reaction and soret effects on casson mhd fluid over a vertical plate proposed by Charan et al. [3].Chemical reaction, radiation and dufour effects on casson magneto hydro dynamics fluid flow over a vertical plate with heat source /sink have reported by Vedavathi et al. [4]. Synthetic response and radiation impacts on unsteady mhd free convective flow over a vertical permeable plate have been explained by Babyrani et al. [5]. Mhd free

convective flow past a semi-infinite vertical permeable moving plate with heat absorption analyzed by Balamurugan et al. [6]. Influence of slip condition on radiative mhd flow of a viscous fluid in parallel porous plate channel in presence of heat absorption and chemical reaction analyzed by Venkateswarlu et al. [7]. An unsteady magneto hydro dynamic heat transfer flow in a rotating parallel plate channel through a porous medium with radiation effect expressed by Dharmaiah [8]. Magneto hydro dynamics convective flow past a vertical porous surface in slip-flow regime experimented by Dharmaiah et al. [9]. Effect of chemical reaction on mhd casson fluid flow past an inclined surface with radiation investigated by Dharmaiah et al. [10]. MHD transient free convection aligned magnetic and chemically reactive flow past a porous inclined plate with radiation and temperature gradient dependent heat source in slip flow regime investigated by Babyrani et al. [11]. The effect of chemical reaction on heat and mass transfer mhd flow ag, tio_2 and cu water nano fluids over a semi infinite surface discussed by Dharmaiah et al. [12]. Influence of radiation absorption, viscous and joules dissipation on mhd free convection chemically reactive and radiative flow in a moving inclined porous plate with temperature dependent heat source concluded by Balamurugan et al. [13]. Influence of radiation on heat and mass transfer in mhd fluid flow over an infinite vertical porous surface with chemical reaction derived by Babyrani et al. [14]. Analysis of heat and mass transfer on mhd flow of nanofluid over a semi infinite moving surface with diffusion thermo have been studied by Dharmaiah et al. [15]. Heat transfer on mhd nanofluid flow over a semi infinite flat plate embedded in a porous medium with radiation absorption, heat source and diffusion thermo effect developed by Vedavathi et al. [16]. Analysis of heat and mass transfer on mhd flow with ag, al2o3 and cu water nanofluids over a semi infinite surface Vedavathi et al. [17]. Effects of chemical reaction and joule heating on mhd heat and mass transfer free on convective radiative flow in a moving inclined porous surface with hall current and alinged magnetic temperature dependent heat source presented by Babyrani et al. [18]. Heat and mass transfer on mhd fluid flow over a semi infinite flat plate with radiation absorption, heat source and diffusion thermo effect used by Dharmaiah et al. [19]. Mhd boundary layer flow and heat transfer of a nanofluid past a radiative and impulsive vertical plate analytically studied by Dharmaiah et al. [20]. Analytical investigations of aligned and hall effects on Unsteady free convection flow past an accelerated inclined plate employed by Vedavathi et al. [21]. Effects of radiation and hall current on unsteady mhd freeconvective flow over inclined porous surface processed by Babyrani et al. [22]. Radiation effect on transient free convection mhd flow with exponentially decaying wall temperature simulated by Babyrani et al. [23]. A study on mhd boundary layer flow rotating frame nanofluid with chemical reaction considered by Vedavathi et al. [24]. A Study on Al_2O_3-H_2O Nanofluid in the presence of Constant heat source have been considered by Ramprasad et al. [25]. Uday kumar et al. [26] has been addressed by analytical study of SiO_2-water based nano fluid flow in a rotating frame with thermo-phoresis. Motivated by the above researches, the present study is aimed to investigate the flow of viscoelastic parameter on unsteady two dimensional hydrodynamic flow and heat transfer of a viscoe- lastic fluid in a porous channel.

2. Formulation and solution of the problem:

We consider an incompressible viscous and electrically conducting two dimensional flow visco-elastic fluid in a parallel plate via porous medium.

The governing equation of the motion to the frame of reference is

$$\frac{\partial u}{\partial t} = -\frac{1}{\rho}\frac{\partial p}{\partial x} + \nu\frac{\partial^2 u}{\partial y^2} + \frac{\alpha_1}{\rho}\frac{\partial^3 u}{\partial y^2 \partial t} - \frac{\sigma\mu_e^2 H_0^2}{\rho}u - \frac{\nu}{k}u \tag{1}$$

with boundary conditions

$$\frac{du}{dt} = g.e^{\text{int}} \qquad \text{at} \qquad y = h \tag{2}$$

$$u = 0 \qquad \text{at} \qquad y = 0 \tag{3}$$

Equation (1) is to be solved subjected to the conditions (2) and (3), In view of Equation (2), we take

$$u = v(y).e^{\text{int}} \tag{4}$$

and the applied pressure gradient

$$\frac{\partial p}{\partial x} = A.e^{\text{int}} \tag{5}$$

Making use of (4) and (5) we solve (1) using the boundary conditions,

$$v = \frac{g}{n}Sinnt \qquad \text{on} \qquad y = h \tag{6}$$

$$v = 0 \qquad \text{on} \qquad y = 0 \tag{7}$$

Where, u is the velocity of the fluid, ρ is the density of fluid, μ is the coefficient of viscosity of the fluid, p is the pressure, A is an amplitude of pressure gradient, α_1 the coefficient of visco-elasticity g is the body acceleration (or) amplitude of the applied acceleration and 'n' its angular frequency in rad. sec $^{-1}$

From (1) and (4) we obtain

$$\frac{d^2 v(y)}{dy^2} - \frac{M_1}{\mu + \alpha_1 in}v(y) = \frac{A}{\mu + \alpha_1 in} \tag{8}$$

Where, $M_1 = \rho in + \sigma\mu_e^2 H_0^2 + \frac{\mu}{k}$

The general solution of Equation (3.2.8) is

$$v(y) = C_1 \cosh\frac{\sqrt{M_1}}{\sqrt{\mu + \alpha_1 in}}y + C_2 \sinh\frac{\sqrt{M_1}}{\sqrt{\mu + \alpha_1 in}}y - \frac{A}{M_1} \tag{9}$$

Now we find the arbitrary constants C_1 and C_2 by using equations (6) and (7) we get

$$v(y) = \frac{A}{M_1}\cosh\frac{\sqrt{M_1}}{\sqrt{\mu + \alpha_1 in}}y +$$

$$+\frac{\frac{A}{M_1}\left(1-\cosh\frac{\sqrt{M_1}}{\sqrt{\mu+\alpha_1 in}}\mathrm{h}\right)+\frac{g}{n}\sin nt}{\sinh\frac{\sqrt{M_1}}{\sqrt{\mu+\alpha_1 in}}\mathrm{h}}.\sinh\frac{\sqrt{M_1}}{\sqrt{\mu+\alpha_1 in}}y-\frac{A}{M_1} \tag{10}$$

Equation (10) is substituted in equation (4) we get

$$u=\left[\frac{A}{M_1}\cosh\frac{\sqrt{M_1}}{\sqrt{\mu+\alpha_1 in}}y+\frac{\frac{A}{M_1}\left(1-\cosh\frac{\sqrt{M_1}}{\sqrt{\mu+\alpha_1 in}}\mathrm{h}\right)+ing}{\sinh\frac{\sqrt{M_1}}{\sqrt{\mu+\alpha_1 in}}\mathrm{h}}.\sinh\frac{\sqrt{M_1}}{\sqrt{\mu+\alpha_1 in}}y-\frac{A}{M_1}\right]e^{\mathrm{int}} \tag{11}$$

Taking the real part of the equation (11) obtained as

$$u=A_1+u_1+u_2+\frac{u_3+u_4}{A_2} \tag{12}$$

The shear stresses on the upper and lower walls at $y = 0$ and h in the non-dimensional form are calculated by

$$\tau=\mu\left(\frac{\partial u}{\partial y}\right)+\alpha_1\left(\frac{\partial^2 u}{\partial y\partial t}\right)$$

3. Results and Discussion:

The profiles (1-6) exhibit the nature of the velocity for variations in the governing parameters S, β, R, G, M and D^{-1}. In all these profiles, we observe that the velocity rapidly increases from zero value on the lower boundary y = 0 to its maximum value on the upper boundary y = h. For fixed R and β the velocity enhances with increase in the visco-elastic parameter and this enhancement in the velocity is plotted in the figure (1) for various values of β and R. For sufficiently large R the magnitude of the velocity is high comparable to smaller R and once again exhibits increase in trend with increase in S. The figure (2) correspond to decrease in β for fixed R and S, we notice that an enhancement in the velocity for reduction in β. Also higher values of R the magnitude of the velocity relatively increases for all β and S. The figure (3) correspond to behaviour of the velocity for variation in R fixing β and S, we once again notice that an increase in R enhances the velocity for fixed β and S while its magnitude exhibits a slight growth for increase in the visco-elastic parameter S at all corresponding values of β and R. Also the figure (4) correspond to behaviour of the velocity for variation in G fixing R, β and S, we once again notice that the velocity enhances increase in for fixed values of R, β and S. From figures (5& 6), the behavior of the velocity always reduces to increase the intensity of the magnetic field M, while the magnitude of the velocity continuously decreases with increase in the inverse Darcy parameter D^{-1}.

The shear stresses (τ) are evaluated for variations in R, S and β at both the lower and upper boundaries. In general, the shear stress in the upper boundary is higher in magnitude compared to its value on the lower boundary at the corresponding sets of the parameters.

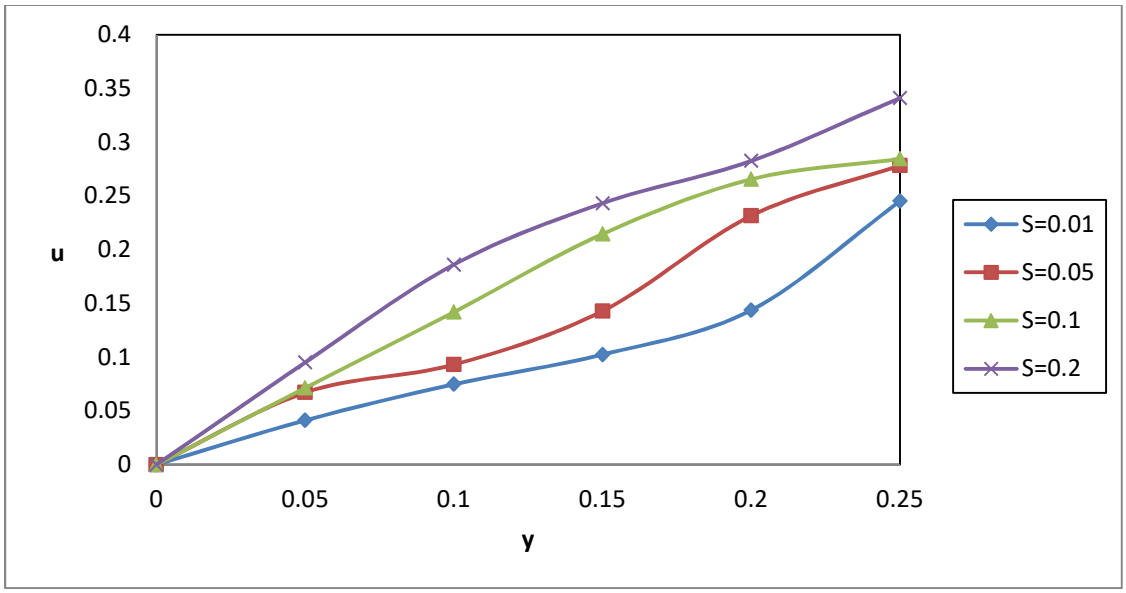

Fig 1: the velocity profile for u against S

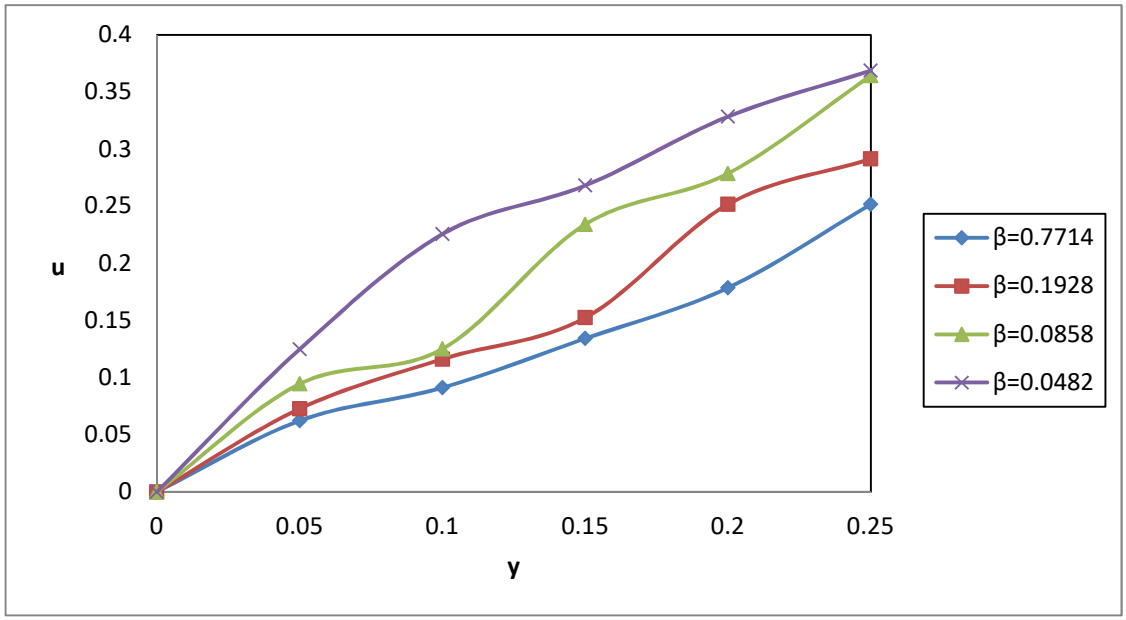

Fig 2: the velocity profile for u against β

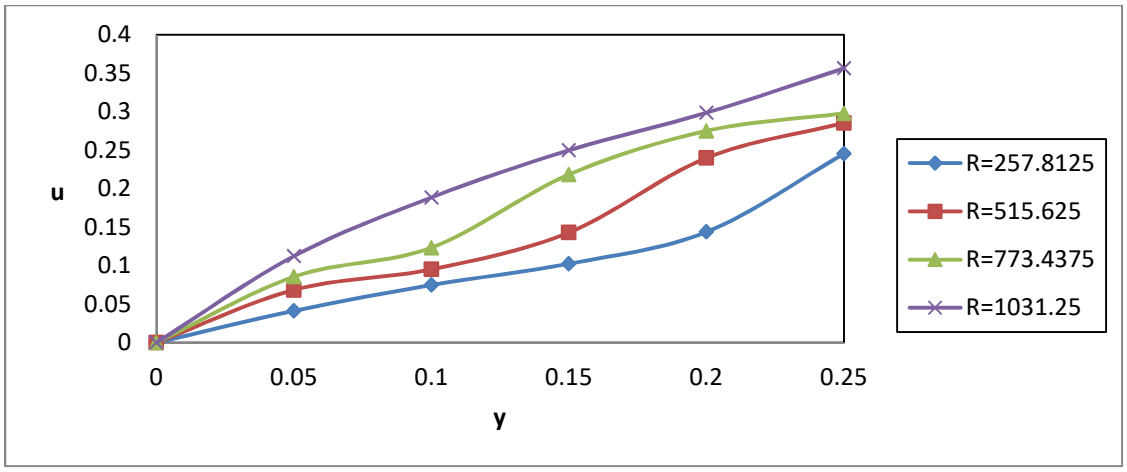

Fig 3: the velocity profile for u against R

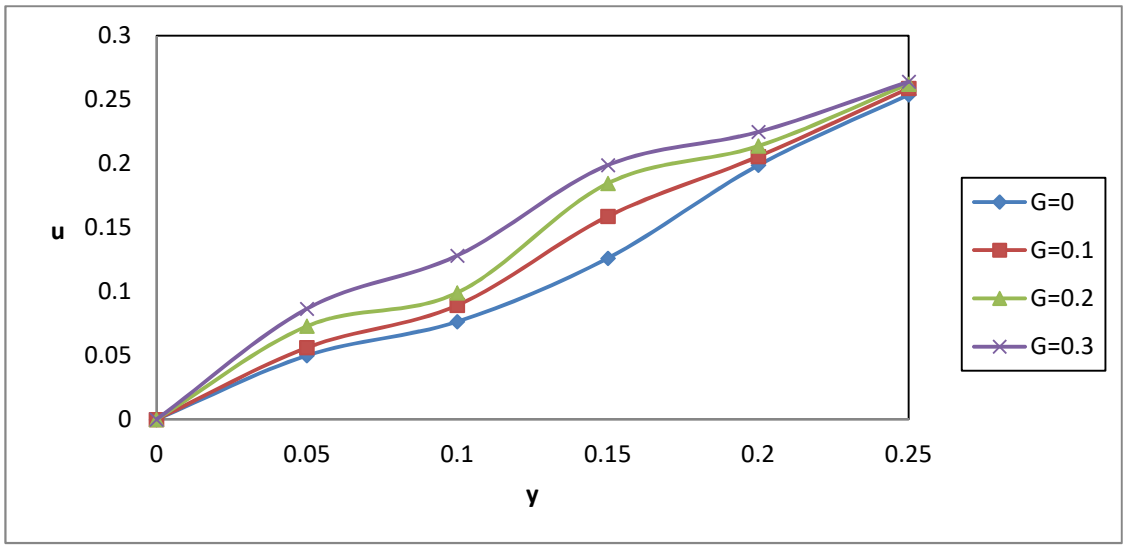

Fig 4: the velocity profile for u against G

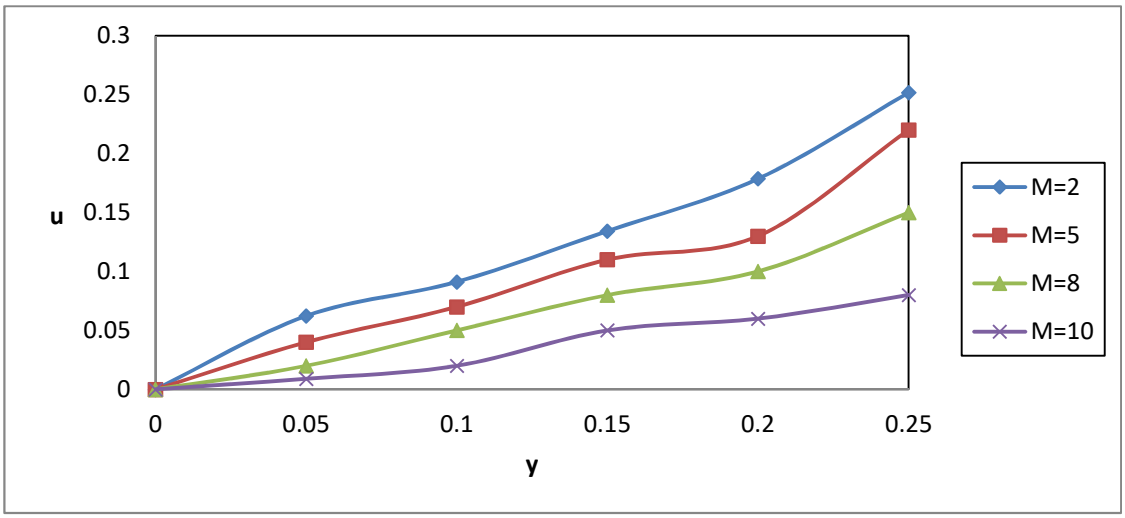

Fig 5: the velocity profile for u against M

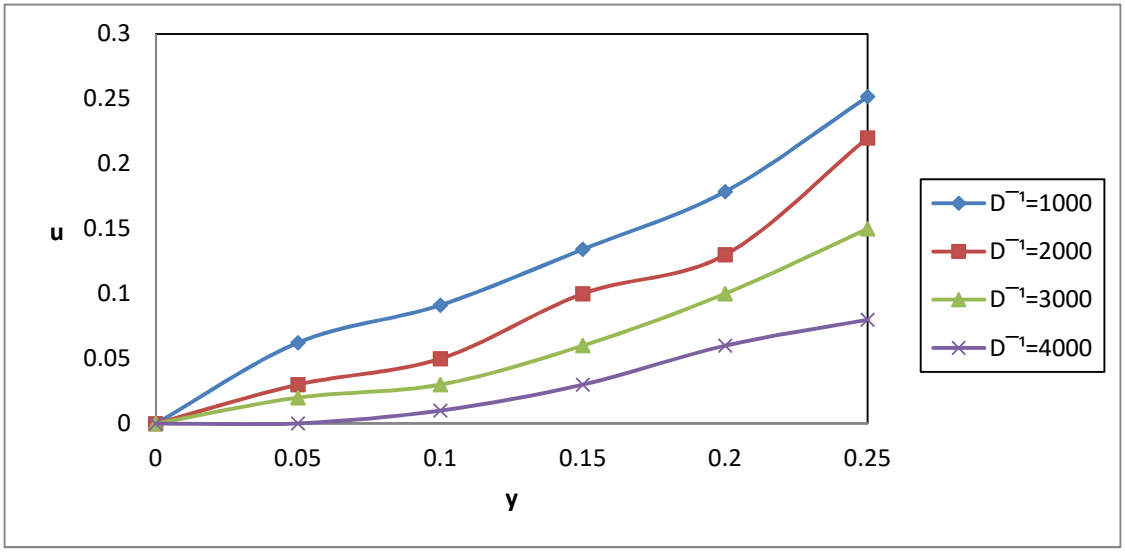

Fig 6: the velocity profile for u against D^{-1}

4. Conclusions:

1. Sufficiently large values of R, the magnitude of the velocity is high comparable to smaller R and once again exhibits increase in trend with increase in S.
2. To decrease in β for fixed R and S, an enhancement in the velocity for reduction in β. Also higher values of R the magnitude of the velocity relatively increases for all β and S.
3. The behaviour of the velocity for variation in R fixing β and S, an increase in R enhances the velocity for fixed β and S while its magnitude exhibits a slight growth for increase in the visco-elastic parameter S at all corresponding values of β and R.
4. The behaviour of the velocity for variation in G fixing R, β and S, the velocity enhances increase in for fixed values of R, β and S.

5. The behavior of the velocity always reduces to increase the intensity of the magnetic field M, while the magnitude of the velocity continuously decreases with increase in the inverse Darcy parameter D^{-1}.

REFERENCES

1) Dharmaiah. G, Vedavathi. N, Balamurugan, K.S. "Effects of Radiation, Chemical Reaction And Soret On Unsteady Mhd Free Convective Flow Over A Vertical Porous Plate", IJSIMR, 3(5), 2015, pp 93-101.
2) Ramprasad, J.L., Balamurugan, K.S., Dharmaiah, G. "Unsteady Mhd Convective Heat And Mass Transfer Flow Past An Inclined Moving Surface With Heat Absorption", JP Journal of Heat and Mass Transfer, 8(1), 2016, pp 33-51.
3) Charan Kumar, G, Dharmaiah. G, Balamurugan, K.S., Vedavathi. N, "Chemical Reaction AndSoret Effects On Casson Mhd Fluid Over A Vertical Plate", Int. J. Chem.Sci.: 14(1), 2016, 213-221.
4) Vedavati. N., Dharmaiah G, Balamurugan, K.S. Charan Kumar. G, "Chemical Reaction, Radiation And Dufour Effects On Casson Magneto Hydro Dynamics Fluid Flow Over A Vertical Plate With Heat Source /Sink", Global Journal Of Pure And Applied Mathematics, 7(1), 2016,pp 191-200.
5) Baby Rani, Ch., Dharmaiah, G., Balamurugan, K.S., Mohiddin Shaw, Sk., "Synthetic Response And Radiation Impacts On Unsteady MHD Free Convective Flow Over A Vertical Permeable Plate", Int. J. Chem.Sci.: 14(4), 2016, pp.2051-2065.
6) Balamurugan, K.S., Dharmaiah, G., Varma, S.V.K., Raju, V.C.C., "MHD Free Convective Flow Past a Semi-Infinite Vertical Permeable Moving Plate with Heat Absorption", International Journal of Engineering & Scientific Research, 4(8),2016, p.p.46-58.
7) Venkateswarlu, M., Venkatalakshmi, D., Dharmaiah, G., "Influence Of Slip Condition On Radiative Mhd Flow Of A Viscous Fluid In Parallel Porous Plate Channel In Presence Of Heat Absorption And Chemical Reaction", J.KSIAM, 20(4), 2016, p.p:333-354.
8) Dharmaiah, G., "An Unsteady Magneto Hydro Dynamic Heat Transfer Flow In A Rotating Parallel Plate Channel Through A Porous Medium With Radiation Effect", Innovare Journal Of Engineering & Technology,vol-5(1),2017,p.p:34-37.
9) Dharmaiah, G., UdayKumar, Y., Vedavathi, N., "Magneto Hydro Dynamics Convective Flow Past A Vertical Porous Surface In Slip-Flow Regime", IJTAM, 12(1), 2017, pp.71-81.
10) Dharmaiah, G., Balamurugan, K.S., Raju, V.C.C., Vedavathi, N., "Effect of chemical reaction on mhd casson fluid flow past an inclined surface with radiation", SKIT Journal, 7(1), 2017, pp:53-59.
11) BabyRani, Ch., Ramaprasad, K., Balamurugan, K.S., Dharmaiah, G., "MHD Transient Free Convection Aligned Magnetic and Chemically Reactive Flow past a Porous Inclined Plate with Radiation and Temperature Gradient Dependent Heat Source in Slip Flow Regime", IOSR Journal of Mathematics, 13(4), 2017, pp.34-45.
12) Dharmaiah, G., Prakash., J., Balamurugan, K.S., Vedavathi, N., "The Effect Of Chemical Reaction On Heat And Mass Transfer Mhd Flow Ag, Tio_2 And Cu Water Nano Fluids Over A Semi Infinite Surface", Global Journal Of Pure And Applied Mathematics, 8(9), 2017,pp.6609-6632.

13) Balamurugan, K.S., Ramaprasad, J.L., Dharmaiah. G., Raju, V.C.C., "Influence of Radiation Absorption, Viscous and Joules dissipation on MHD free Convection Chemically Reactive and Radiative Flow in a Moving Inclined Porous Plate with Temperature Dependent Heat Source", International Refereed Journal of Engineering and Science, 5(12), 2016, PP.20-31.
14) Baby Rani, Ch., Mohiddin Shaw, Sk., Dharmaiah, G., "Influence Of Radiation On Heat And Mass Transfer In Mhd Fluid Flow Over An Infinite Vertical Porous Surface With Chemical Reaction", International Journal of Mathematics and its Applications, 5(4), 2017, pp.731-740.
15) Dharmaiah. G, Balamurugan, K.S., Venkateswarulu, M., "Analysis Of Heat And Mass Transfer On Mhd Flow Of Nanofluid Over A Semi Infinite Moving Surface With Diffusion Thermo", SKIT Journal, 7(2), 2017, 79-86.
16) Vedavathi, N., Dharmaiah, G., Balamurugan K.S., Prakash, J., "Heat Transfer On Mhd Nanofluid Flow Over A Semi Infinite Flat Plate Embedded In A Porous Medium With Radiation Absorption, Heat Source And Diffusion Thermo Effect", Frontiers in Heat and Mass Transfer (FHMT), 9, 38,2017,p.p.1-8.
17) Vedavathi.N, Balamurugan.K.S, Dharmaiah.G, "Analysis of Heat and Mass Transfer on MHD flow with Ag, Al2O3 and Cu Water Nanofluids over a Semi Infinite Surface", Research Journal of Science and Technology, 9(3), 2017,p.p.1-9.
18) Baby Rani, Ch., Dharmaiah, G., Ravi kumar, B.V., "Effects Of Chemical Reaction And Joule Heating On Mhd Heat And Mass Transfer Free On Convective Radiative Flow In A Moving Inclined Porous Surface With Hall Current And Alinged Magnetic Temperature Dependent Heat Source", Int. Journal of Engineering Research and Application, 7(10), 2017, pp.07-21.
19) Dharmaiah, G., Baby Rani, Ch., Vedavathi, N., Balamurugan, K.S., "Heat And Mass Transfer On Mhd Fluid Flow Over A Semi Infinite Flat Plate With Radiation Absorption, Heat Source and Diffusion Thermo Effect", Frontiers in Heat and Mass Transfer, 16, 6, 2018,p.p.1-8.
20) Dharmaiah, G., Vedavathi, N., Baby Rani, Ch., Balamurugan, K.S., "Mhd Boundary Layer Flow And Heat Transfer Of A Nanofluid Past A Radiative And Impulsive Vertical Plate", Frontiers in Heat and Mass Transfer, 11, 14, 2018,p.p.1-7.
21) Vedavathi, N., Ramakrishna, K., Dharmaiah, G., Balamurugan, K.S., "Analytical investigations of aligned and hall effects on Unsteady free convection flow past an accelerated inclined plate", International Journal of Mechanical and Production Engineering Research and Development, 8(4), 2018, pp.661-668.
22) Baby Rani, Ch., Vedavathi, N., Dharmaiah, G., Balamurugan, K.S., "Effects Of Radiation And Hall Current On Unsteady Mhd Freeconvective Flow Over Inclined Porous Surface", International Journal Of Mechanical And Production Engineering Research And Development, 8(4),2018, pp.1177-1186.
23) Baby Rani, Ch., Dharmaiah, G., Kranthi Kumar, K., Sridevi, S., "Radiation Effect On Transient Free Convection Mhd Flow With Exponentially Decaying Wall Temperature", International Journal of Pure and Applied Mathematics, 120(6), 2018, p.p:4139-4152.
24) Vedavathi, N., Dharmaiah, G., Balamurugan, K.S., Ramakrishna, K., "A Study On Mhd Boundary Layer Flow Rotating Frame Nanofluid With Chemical Reaction", Frontiers in Heat and Mass Transfer, 12, 10, 2019, p.p.1-9.

25) Ramprasad, J.L., Balamurugan, K.S., Dharmaiah, G. "A Study on Al_2O_3-H_2O Nanofluid in the presence of Constant heat source", International Journal of Mechanical and Production Engineering Research and Development, 9(2), 2019, pp.399-406.
26) Uday kumar, Y., Dharmaiah, G., Sreenivasa kumar, M., "Analytical study of SiO_2-water based nano fluid flow in a rotating frame with thermo phoresis", International Journal of Mechanical and Production Engineering Research and Development, 9(4), 2019, pp.437-446.