THE EFFECTS OF INCLINED MAGNETIC FIELD AND INCLINED PLATE ON MHD CASSON FLUID

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Abstract

The current note comprises the impact of inclined attractive field and inclined plate on MHD stream of a Casson liquid over a vertical permeable plate. The mathematical analysis is carried out analytically by using the series solution method. The physical highlights of different parameters on the flow have been examined and delineated by the graphs.

Keywords: MHD casson fluidmagnetic field, velocity, temperature.

I INTRODUCTION

During the last few decades, Casson fluid has interesting applications in biological,chemical,medical and engineering applications. It exhibits yield stress.Tomato sauce,honey,soup,jelly,and human blood ,etc. are some examples of Casson fluid.Several researchers have investigated in this direction.Some of them are Raju et.al [1], Jasmine et al.[2], Reddy [3],Rashidi [4], Ajayi [5], Ramana Reddy [6], Eswara Rao [7], Shalini Jain and Amit Parmar [8], Gireesha et.al [9], Kataria and Patel [10], Khalid [11],Animasaun [12], Eegunjobi [13],Biswas [14],Abro et.al [15],Arifuzzaman et.al [16], Umamaheswar [17],Balaji Prakash et.al [18], Manjula et.al [19],Prasad et.al [20].

Spurred by the above writing, we endeavour to examine the consequences of attractive slanted field and slanted permeable plate on MHD Casson fluid over a vertical permeable plate diagnostically and introduce the impacts of fluctuating speed parameters temperature fields with the guide of graphs.

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II MATHEMATICAL ANALYSIS

We study an in-compressible Casson fluid's two-dimensional free convection and mass trade stream past an immense vertical porous plate. The attractions speed typically to the plate is steady and can be composed as,

$$V^{I} = -U_0$$

A course of action of rectangular co-ordinate $O(x^I, y^I, z^I)$ is taken, with the ultimate objective that $y^I = 0$ on the plate and z^I rotate is along its driving edges. All the fluid properties are considered predictable. Besides, the effect of the thickness assortment with temperature is thought of. The effect of the thickness assortment in various terms of the power and essential condition and the augmentation coefficient with temperature is seen as irrelevant. This is the prominent Boussinesq estimate.

The Governing equations are

Continuity equation :

$$\frac{\partial V^I}{\partial y^I} = 0 \qquad (1)$$

Momentum equation:

$$\frac{\partial u^I}{\partial t^I} + V^I \frac{\partial u^I}{\partial y^I} = g\beta(T^I - T^I_\infty)\text{Cos}\,\alpha + \nu(1 + \frac{1}{\beta})\frac{\partial^2 u^I}{\partial y^I} - \left[\frac{\sigma B_0^2 Sin\beta}{\rho} + \frac{\nu}{K^I}\right]u^I \qquad (2)$$

Energy equation:

$$\frac{\partial T^I}{\partial t^I} + V^I \frac{\partial T^I}{\partial y^I} = \alpha\left(\frac{\partial^2 T^I}{\partial {y^I}^2}\right) + Q_0(T^I - T^I_\infty) \qquad (3)$$

Where u^I, V^I, T^I, C^I , α and Q_0 represents velocity, temperature, concentration thermal conductivity and dimensional heat absorption coefficient.

The associated conditions are:

$u^I = 0, T^I = T_w^I, C^I = C_w^I \; at \; y^I = 0$

$u^I = 0\,, T^I = T_\infty, C^I = C_\infty \; at \; y^I \to \infty$ (4)

Let us introduce the non-dimensional variables.

$$u = \frac{u^I}{U_0}, t = \frac{t^I U_0^2}{v}, \; y = \frac{y^I U_0}{v}, T = \frac{T^I - T_\infty^I}{T_w^I - T_\infty^I},$$

$$K = \frac{K^I U_0^2}{v^2}, P_r = \frac{v}{\alpha},, M = \frac{\sigma B_0^2 Sin\beta v}{\rho U_0^2}, \quad B = 1 + \frac{1}{\beta},$$

$$, Q = \frac{Q_0 v}{\rho C_p U_0^2}, G_r = \frac{v g \beta (T_W^I - T_\infty^I)}{U_0^3} \quad (5)$$

Where P_r - Prandtl number, G_r - Grashof number, N - buoyancy ratio, B - Casson parameter, M - inclined magnetic parameter, K - permeability parameter, β - thermal expansion coefficients, β^I - concentration expansion coefficient and Q_0 - dimensional heat absorption coefficient.

$$\frac{\partial u}{\partial t} - \frac{\partial u}{\partial y} = G_r T Cos\alpha + B\frac{\partial^2 u}{\partial y^2} - \left(M + \frac{1}{K}\right)$$

(6)

$$\frac{\partial T}{\partial t} - \frac{\partial T}{\partial y} = \frac{1}{P_r}\frac{\partial^2 T}{\partial y^2} + (Q + R)T \quad (7)$$

and

$u = 0\,, T = 1 \; at \; y = 0$

$u = 0, T = 0 \; at \; y \to \infty$ (8)

III METHOD OF SOLUTION

Assume that u and T as

$u(y,t) = u_0(y)e^{-nt}$,

$T(y,t) = T_0(y)e^{-nt}$ (9)

Using equation (9) in equation(6) and (7) we get

$$Bu_0'' + u_0' - \left[M + \frac{1}{K} - n\right]u_0 = -G_r T_0 \text{Cos}\,\alpha$$

(10)

$$T_0'' + P_r T_0' + P_r(n + Q)T_0 = 0 \quad (11)$$

$u_0 = 0, T_0 = 1 \; at \; y = 0$

$u_0 = 0, T_0 = 0 \quad at \; y \to \infty$ (12)

Solving the equations (10) and (11), using boundary conditions (12), we get the following equations.

$T_0 = e^{-m_1 y}$ (13)

$u_0 = (A_1)e^{-m_2 y} - A_1 e^{-m_1 y}$ (14)

where ,

$$m_1 = \frac{P_r + \sqrt{P_r^2 - 4P_r(n + Q)}}{2}$$

$$m_2 = \frac{1 + \sqrt{1 + 4\left(M + \frac{1}{K} - n\right)}}{2}$$

$$A_1 = \frac{G_r}{Bm_1^2 + m_1 - \left(M_1 + \frac{1}{K} - n\right)}$$

Hence the Solutions of u and T will be as follows

$u = [(A_1)e^{-m_2 y} - A_1 e^{-m_1 y}]e^{-nt}$ (15)

$T = e^{-m_1 y} e^{-nt}$ (16)

$$\tau = \left(\frac{\partial u}{\partial y}\right)_{y=0} = [-m_2(A_1) + m_1 A_1]e^{-nt} \quad (17)$$

Where τ is skin friction

IV RESULTS AND DISCUSSION

This paper has contemplated the inclined plate and magnetic field on MHD Casson fluid with heat absorption/generation. The graphs have concentrated the impact of the parameters β ,Gr, K, Pr, B, α and Q on stream attributes.

To have physical relationships, we pick reasonable estimations of flow parameters. The graphs of speed, temperature and mass focus are taken regarding y.

Velocity profiles: At n = 0.1 and t = 0.1, the Velocity profiles are depicted in Figures 1 – 7.

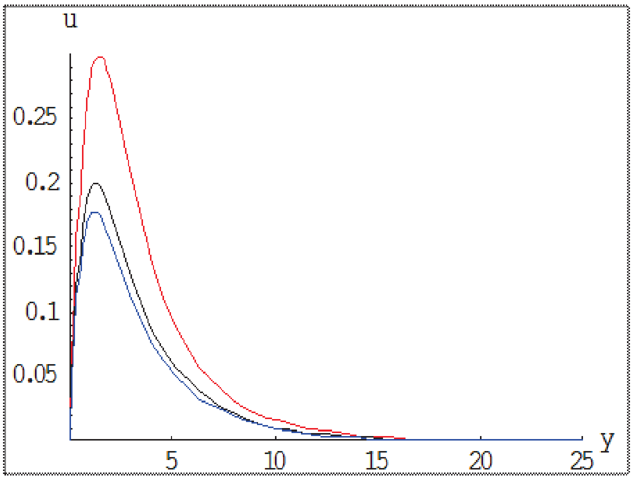

Figure 1

Effects of inclined magnetic field on u profiles

When Pr = 0.71, Gr = 1, Q = 1,B=1 and K = 10

Figure - 1 shows the impact of the inclined Magnetic field on the Velocity profiles. speed diminishes with the expansion in the inclined attractive parameter (β).

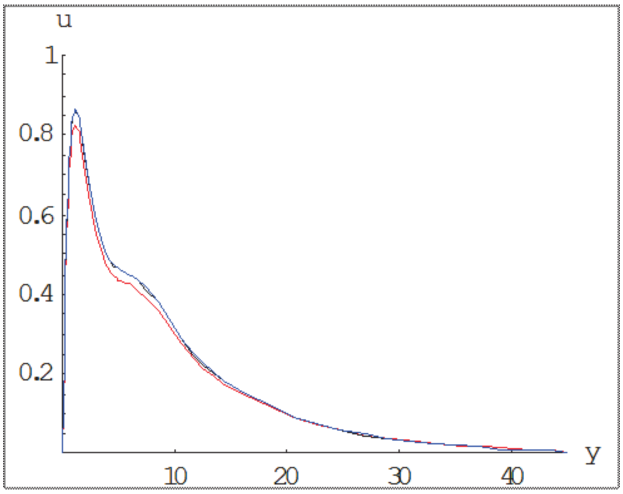

Figure 3

Effects of k on velocity profiles

When Pr = 0.71, Gr = 1, Q = 1,B=1 and M = 2

Figure - 3 shows Changes of Permeability parameter K on the Velocity profiles. Here speed increments with porousness parameter (K).

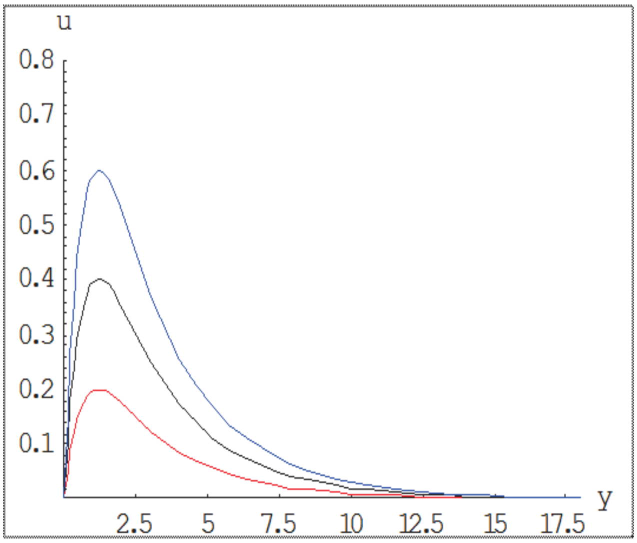

Figure 2

Effects of Gr on velocity profiles

When Pr = 0.71, M = 1, Q = 1, B=1and K = 10

Figure - 2 shows varieties of Grashoff number Gr on the Velocity profiles. It delineates that speed increments with raise in Grashoff number (Gr).

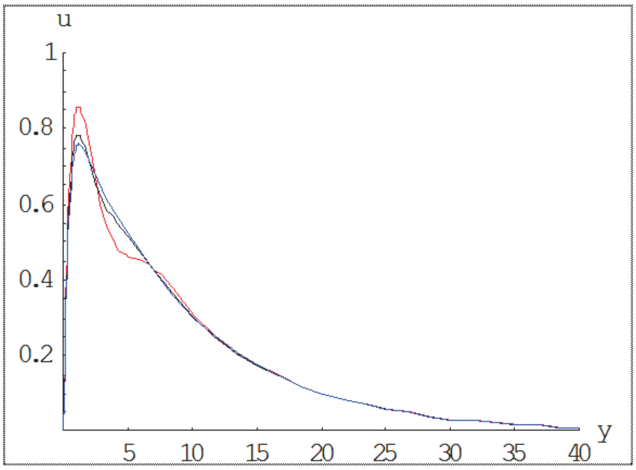

Figure 4

EEffects of Pr on velocity profiles

When Gr = 1, Q = 1,M = 2,B=1 and K = 100

Figure – 4 shows the impact of the Prandtl number Pr on the Velocity profiles. Here, the Prandtl number (Pr) adds to the speed increment close to the beginning and lessening endlessly from the root.

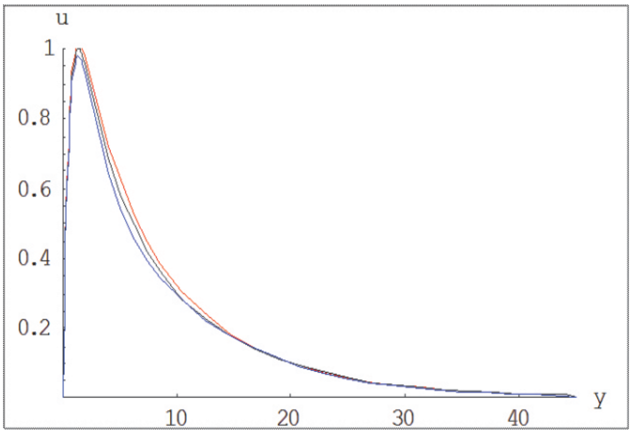

Figure 5

Effects of Q on velocity profiles

When Pr = 0.71, Gr = 1, M = 2,B=1 and K = 10

Figure - 5 shows the Heat assimilation coefficient Q impact on the Velocity profiles. It is seen that an ascent in the warmth ingestion coefficient (Q) adds to decreasing in the speed.

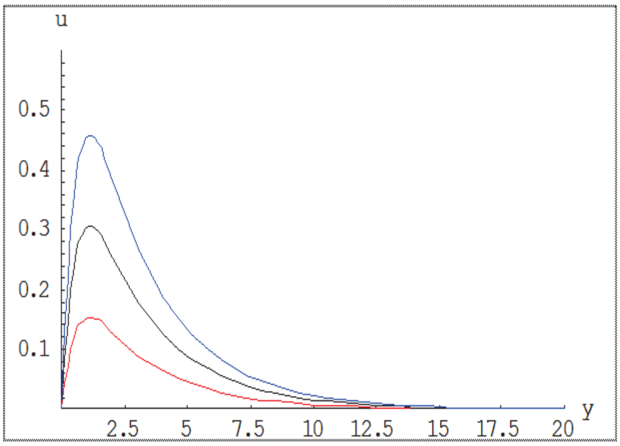

Figure 6

EEffects of inclined porous plate on u profiles

When Pr = 0.71, Gr = 1, M = 2, B=1and K = 10

Figure - 6 shows the slanted permeable plate impact α on the Velocity profiles. It is seen that an ascent in α adds to falls in the speed.

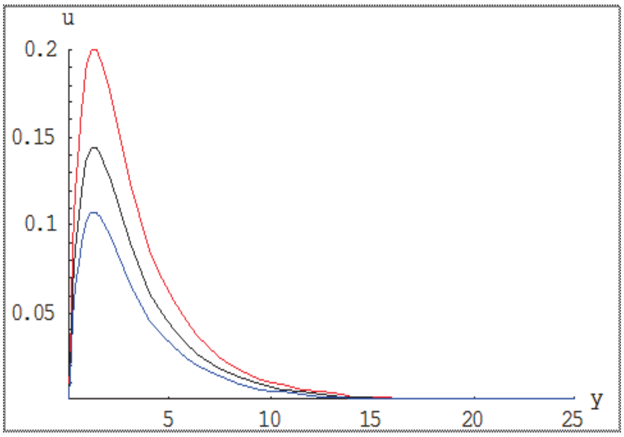

Figure 7

Effects of B on velocity profiles

When Pr = 0.71, Gr = 1, M = 2,B=1 and K = 10

Figure - 7 shows the impact of the Casson parameter B on the Velocity profiles. It is seen that expansion in the Casson parameter B adds to diminish in the speed.

Temperature Profile: At n =0.1 and t = 0.1, the temperature profiles are depicted in figures 8 and 9.

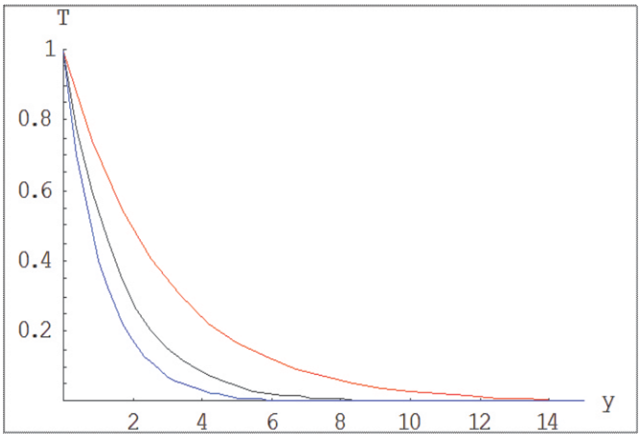

Figure 8

Effects of Pr on Temperature profiles

When Gr = 1, Q = 1, M = 2 and K = 10

Figure - 8 shows the impact of the Prandtl number Pr on the Temperature profiles. It is seen that expansion in the Prandtl number (Pr) adds to diminish the temperature in the liquid medium.

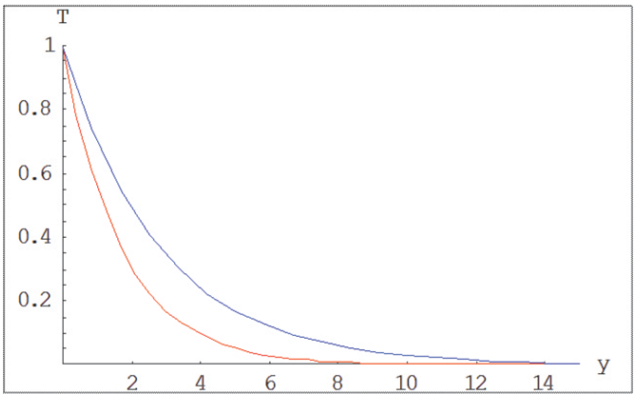

Figure 9

Effects of Q on Temperature profiles

When Pr = 0.71Gr = 1, M = 2 and K = 100

Figure - 9 shows the impact of the Heat retention parameter Q on the Temperature profiles. It is seen that expansion in the Heat ingestion parameter (Q) increases the temperature in the liquid medium.

V CONCLUSION

This paper breaks down the attractive slanted field and slanted permeable plate impacts on MHD Casson liquid stream past a vertical permeable plate with heat assimilation or age. The non-dimensional administering conditions were fathomed by irritation strategy. Finishes of the investigation can be given as follows:

1. Velocity diminished with expanded estimations of slanted attractive parameter M, Heat assimilation coefficient Q, Casson parameter B and Prandtl number Pr.

2. Velocity increased as the parameter of Grashof number Gr, permeability parameter K, inclined porous plate α, and Prandtl number Pr increased.

3. Temperature diminished as Prandtl number Pr expanded and expanded with heat retention coefficient Q expansion.

REFERENCES

[1] Raju, R. S., Reddy, B. M., & R Kumar, B. R., & Sivaraj, R. MHD viscoelastic fluid non-Darcy flow over a vertical cone and a flat plate. International Communications in Heat and Mass Transfer, Volume 40, Page- 1–6. January 2013.

[2] Jasmine Benazir, A., Sivaraj, R., & Makinde, O. D. (2015). Unsteady Magnetohydrodynamic Casson Fluid Flow over a Vertical Cone and Flat Plate with Non-Uniform Heat Source/Sink. International Journal of Engineering Research in Africa,Vol. 21, pp. 69–83. December 2015.

[3] Reddy, P. B. A. Magnetohydrodynamic flow of a Casson fluid over an exponentially inclined permeable stretching surface with thermal radiation and chemical reaction. Ain Shams Engineering Journal, Volume 7, Issue 2, Pages 593-602, June 2016.

[4] Jasmine Benazir, A., Sivaraj, R., & Rashidi, M. M. Comparison Between Casson Fluid Flow in the Presence of Heat and Mass Transfer From a Vertical Cone and Flat Plate. Journal of Heat Transfer, Volume-138, Issue-11, November 2016.

[5] Ajayi, T. M., Omowaye, A. J., & Animasaun, I. L. Effects of Viscous Dissipation and Double Stratification on MHD Casson Fluid Flow over a Surface with Variable Thickness: Boundary Layer Analysis. International Journal of Engineering Research in Africa, Vol. 28, pp.73–89.12 January 2017.

[6] Ramana Reddy, J. V., Sugunamma, V., & Sandeep, N. Enhanced heat transfer in the flow of dissipative non-Newtonian Casson fluid flow over a convectively heated upper surface of a paraboloid of revolution.

Journal of Molecular Liquids, Volume-229, pp-380–388, March 2017.

[7] Eswara Rao, M. The effects of thermal radiation and chemical reaction on MHD flow of a casson fluid over and exponentially inclined stretching surface, Journal of Physics: Conference Series, Volume 1000, National Conference on Mathematical Techniques and its Applications (NCMTA 18),Page-5–6, January 2018.

[8] Shalini Jain, Amit Parmar., Multiple slip effects on inclined MHD Casson fluid flow over a permeable stretching surface and a melting surface, International Journal of Heat and Technology Vol. 36, No. 2, Page-585-594, June 2018.

[9] B.J. Gireesha, K. Ganesh Kumar, M.R. Krishnamurthy, S. Manjunatha, and N.G. Rudraswamy Impact of ohmic heating on MHD mixed convection flow of Casson fluid by considering Cross diffusion effect, Nonlinear Engineering ,Volume 8, Issue 1,Pages-.380-388,October 2018.

[10] Kataria, H. R., & Patel, H. R. Effects of chemical reaction and heat generation/absorption on magnetohydrodynamic (MHD) Casson fluid flow over an exponentially accelerated vertical plate embedded in porous medium with ramped wall temperature and ramped surface concentration. Propulsion and Power Research, Volume 8, Issue 1, Pages 35-46, March 2019.

[11] Khalid, A., Khan, I., Khan, A., & Shafie, S. Unsteady MHD free convection flow of Casson fluid past over an oscillating vertical plate embedded in a porous medium. Engineering Science and Technology, an International Journal, Volume-18 Issue-3, Page-309–317. September 2015.

[12] Animasaun, I. L.Double diffusive unsteady convective micropolar flow past a vertical porous plate moving through binary mixture using modified Boussinesq approximation. Ain Shams Engineering Journal, Volume-7, Issue-2, Page-755–765.June-2016.

[13] Eegunjobi, A. S., & Makinde, O. D. MHD Mixed Convection Slip Flow of Radiating Casson Fluid with Entropy Generation in a Channel Filled with Porous Media. Defect and Diffusion Forum, Volume- 374, Page-47–66,April 2017.

[14]Biswas, R., Mondal, M., Sarkar, D. R., & Ahmmed, S. F. Effects of Radiation and Chemical Reaction on MHD Unsteady Heat and Mass Transfer of Casson Fluid Flow Past a Vertical Plate. Journal of Advances in Mathematics and Computer Science, Volume 23, Issue-2, Pages 1-16, July 2017.

[15]Abro, K. A., & Khan, I. Analysis of the heat and mass transfer in the MHD flow of a generalized Casson fluid in a porous space via non-integer order derivatives without a singular kernel. Chinese Journal of Physics, Volume-55, Issue-4, Page-1583–1595, August 2017.

[16]Arifuzzaman, S. M., Khan, M. S., Mehedi, M. F. U., Rana, B. M. J., & Ahmmed, S. F. Chemically reactive and naturally convective high-speed MHD fluid flow through an oscillatory vertical porous plate with heat and radiation absorption effect. Engineering Science and Technology, an International Journal, Volume- 21, Issue-2, Page-215–228, April 2018.

[17]Umamaheswar. M, Unsteady MHD convective Casson fluid flow past a vertical porous plate in the presence of radiation and thermal diffusion, International Journal of Advanced Scientific Research and Management, Volume 3, Issue 12, December 2018.

[18] G. BalajiPrakash, G. V. Ramana Reddy, W. Sridhar, Y. Hari Krishna and B. Mahaboob, Thermal Radiation and Heat Source Effects on MHD Casson Fluid over an Oscillating Vertical Porous Plate, Journal of Computer and Mathematical Sciences, Volume-10,Issue-5,Page-1021-1031 ,May 2019.

[19] Manjula.V ,Chandra Sekhar.K.V, Effect Of Soret Number And Heat Source On Unsteady Mhd Casson Fluid Flow Past An Inclined Plate Embedded In Porous Medium, ARPN Journal of Engineering and Applied Sciences, Volue-14, Issue-11, June-2019.

[20] Prasad, D. V. K., Chaitanya, G. S. K., & Raju, R. S. Double Diffusive Effects On Mixed Convection Casson Fluid Flow Past A Wavy Inclined Plate In Presence of Darcian Porous Medium. Results in Engineering, Volume 3, September 2019.