Inquisition of Electro-Magnetic Riga Plate for Laminar Flow

Azad Hussain (azad.hussain@uog.edu.pk)
University of Gujrat
Sobia Akbar
University of Gujrat
Muhammad Arshad
National Textile University
Sohail Nadeem
Quaid-i-Azam University

Research Article

Keywords: Computational solution, Electric potential, Magnetic flux, Riga plate, Laminar flow.

Posted Date: January 14th, 2022

DOI: https://doi.org/10.21203/rs.3.rs-1206003/v1

Inquisition of Electro-Magnetic Riga Plate for Laminar Flow

Azad Hussain^{*,a}, Sobia Akbar^{*,a}, Muhammad Arshad^{b}, Sohail Nadeem^{c}

[a]Department of Mathematics, University of Gujrat, Gujrat, 50700, Pakistan

[b]Department of Mathematics, National Textile University, Faisalabad, 37610, Pakistan

[c]Department of Mathematics, Quaid−i−Azam University, Islamabad, 45320, Pakistan

*_(azad.hussain@uog.edu.pk, 18026109−004@uog.edu.pk)

Abstract:

The probation is made to study the stagnation point flow of non-Newtonian fluid for Riga plate. Electric potential and magnetic flux density with time dependent flow is examined. Mesh for electric potential, magnetic flux, laminar flow with physics controlled fine, finer and extra finer option is also represented in details. Inquisition is solved in COMSOL Multi-physics 5.4 to obtain the results of surface magnitude, counter, table surface, magnetic flux, electric potential and coarse mesh for velocity, pressure, magnetic and electric fields. Coarse mesh of electric insulation and magnetic flux of the geometry is created with $6067, 18688$ domain elements and $901, 1448$ boundary elements. Tables for velocity surface, mesh domain, quadrilateral and triangular elements are also presented. Obtained results are discussed with graphs and tables in details.

Keywords: Computational solution; Electric potential; Magnetic flux; Riga plate; Laminar flow.

1. Introduction

The Newtonian fluids can completely be elaborated by the pressure and temperature effects, but the physical aspects of non-Newtonian fluids also consider the forces acting on it per unit time. In the class of these non-Newtonian fluids, third grade non-Newtonian fluids are very important due to their glorious applications. The non-linearity can apparent itself in a variability of ways in various fields, including bio-engineering, drilling operations, and food. Instances of Casson fluid such as determined fruit juices, honey, jelly, blood, paste, etc. Casson fluid give the shear rate-shear stress relation which designates the properties of several polymers over an extensive range of shear stress explored by Mukhopadhyay et al. [1]. According to the literature review researchers did their good effort to probe the steady and unsteady flow of non-Newtonian fluid flow through many geometries $[2-13]$.

In 1995, Casson presented a model for the viscoelastic fluids flow. By fuel engineers this model was cast off in the depiction of glutinous water mixture of insoluble matter. When only transitional shear rate data was attainable, it was improved for predicting high shear rate viscosities. By power manufacturing, electronics and transportation the heating and cooling influences are required.

For high energy devices these heating and cooling techniques are needed. It is very obvious that common fluids have limited potential of heat transferring because of their low heat transferring ability. We observe that some metals have higher thermal conductivity, seems three or four times than common fluids. A substance is required which is made by combining these two fluids, behaving like having higher thermal conductivity metal as well as a fluid. It is achieved from molecular theory of gases instead of empirical correspondence and transform into Newtonian relevance at high and low shear rates. Although mathematically it is more complicated but benefits of this model controls its laboring mathematics. In three disparate cases, couple stress fluid is discussed by Devakar et al. [14]. Also, unsteady description of the couple stress fluid between two parallel plates is presented by Ilani et al. [15].

In the current problem the laminar flow of electro-Magnetic Riga plate with non-Newtonian Casson fluid flow is analyzed with Comsol Multiphysics 5.4. The flow of the fluid is considered as laminar and incompressible. Firstly, the governing equations, magnetic flux, electric potential and Ampere's law are solved. Secondly, mesh description of the domain elements are also described. Then the graphical representation of surface magnitude, counter, pressure table surface, magnetic flux and electric potential are displayed. Also tables of surface velocity, mesh domain, quadrilateral and triangular elements are given.

2. Geometrical Description

The stagnation point flow of non-viscous fluid with magnetic flux and electric insulation of Riga plate has been discussed. In Fig. 1 the geometry of this problem is drawn by taking rectangle. Rectangle 1 is drawn with width $2m$ and height $(l-2)m$ Radian. Rectangle 2 is drawn with width $0.34m$ and height $0.23m$. Circles are drawn by taking solid objects at 360°. An array is also drawn with displacement $3rad$ on x$-$axis and $(l+3)rad$ along y$-$axis.

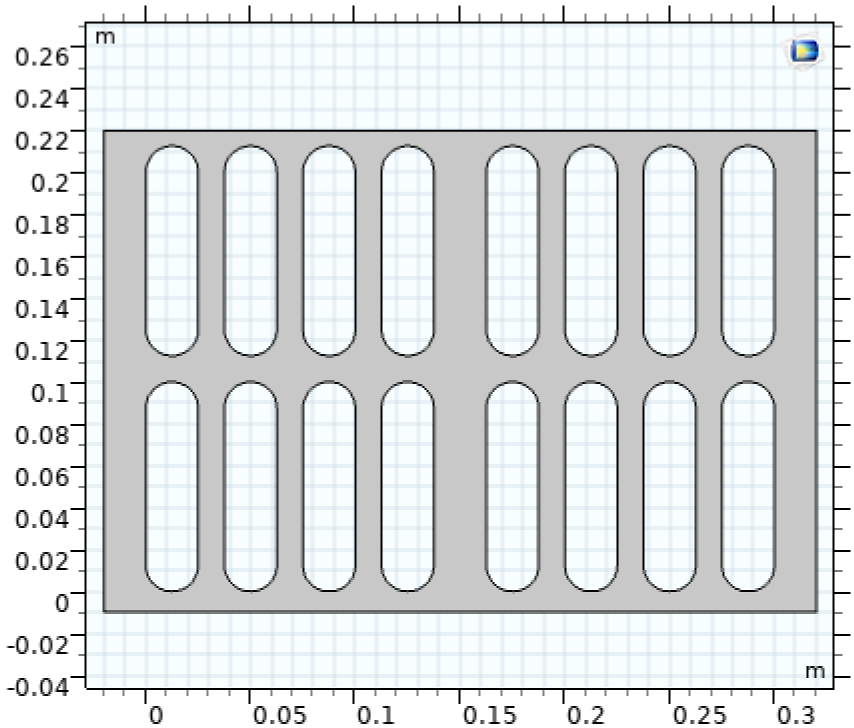

Fig. 1 The geometry of Riga plate.

3. Mathematical Formulation

The governing equations of the model for fluid flow are:

$$\rho \frac{\partial u}{\partial t} + \rho(u.\nabla)u = \nabla.[-PI + K] + F, \tag{1}$$

$$\rho\nabla.(u) = 0, \tag{2}$$

where, $K = \mu(\nabla u + (\nabla u)^T)$, (3)

here, $\mu = m(\gamma^o)^{n-1}$, and $\gamma^o = \max\left(\sqrt{2S:\ \ S},\ \gamma^o_{min}\right),\ S = \ \frac{1}{2}[\nabla u + (\nabla u)^T],$ (4)

The coupled heat transfer equation of the modeled fluid flow is:

$$d_z\rho C_P \frac{\partial T}{\partial t} + d_z\rho C_P u.\nabla T + \nabla.q = d_z Q + q_0 + d_z Q_p + d_z Q_{vd}, \tag{5}$$

where,

$$q = -d_z k\nabla T, Q = 0, q_0 = \frac{q}{A_s\Delta T}, Q_p = \alpha_p T\left(\frac{\partial P}{\partial T} + u\nabla P\right), Q_{vd} = \tau.\nabla u,$$

$$\alpha_p = -\frac{1}{\rho}\ \frac{\partial P}{\partial T}, \tau = -PI - \mu A_1, \qquad \Delta T = T_1 - T_2. \tag{6}$$

Here, Q is heat source, d_z is thickness of the fluid which is equal to 1 $m, \nabla T$ represents temperature gradient and Q_{vd} is viscous dissipation heat source, C_P is specific heat, ρ is density of the fluid.

3.1. Ampere's law

The equation Ampere's law for the magnetic field and magnetic insulation are given below:

$$\nabla \times H = J, \tag{7}$$

$$B = \nabla \times A, \tag{8}$$

$$J = \sigma E + \sigma v \times B + J_e, \tag{9}$$

$$E = -\frac{\partial A}{\partial t}, \tag{10}$$

with magnetization and electric field

$$B = \mu_0(H + M), \qquad D = \epsilon_0 \epsilon_r E, \tag{11}$$

and magnetic insulation is

$$n \times A = 0. \tag{12}$$

Electric field equation is

$$\nabla_T.(s i_s) = i_n, \tag{13}$$

where,

$$i_s = -\sigma \nabla_T \varphi_s, \qquad i_s.n = 0. \tag{14}$$

Where, B, H are magnetic field, J is the total current density (in amperes per square meter, Am^{-2}), ∇ is the curl operator, D is displacement current, ϵ_r is relative static permittivity, ϵ_0 is electric constant.

At wall the no slip boundary condition $u = 0.$ (15)

For Inlet flow $u = -U_0 n.$ (16)

For Outlet flow $[-PI + K]n = -\hat{P}_0 n.$ (17)

Where,

$$\hat{\rho}_0 \leq \rho_0. \tag{18}$$

4. Mesh Representation

In Fig. 2 coarse mesh of electric potential of the geometry is created with 6067 domain elements and 901 boundary elements. In Fig. 3 magnetic mesh is created with 18688 domain elements and 1448 boundary elements.

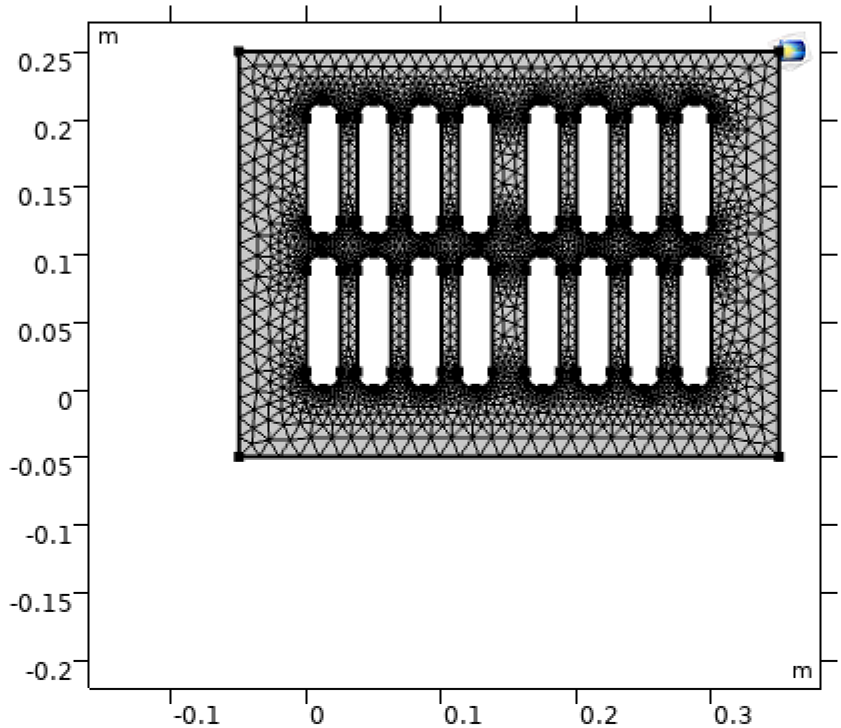

Fig. 2. Coarse mesh of electric potential of the geometry.

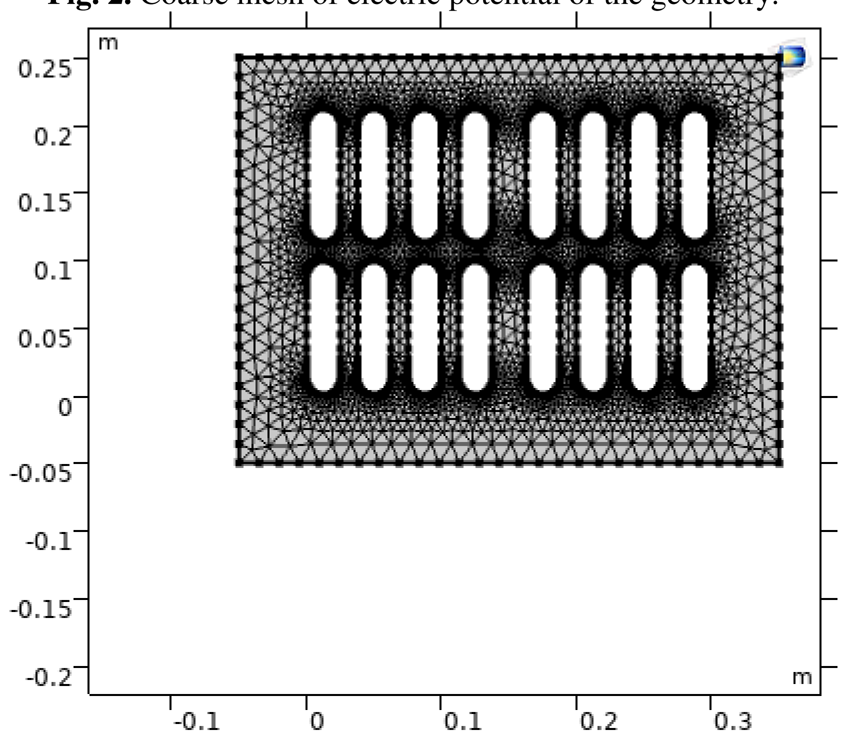

Fig. 3. Coarse mesh of magnetic insulation.

5. Problem Solution

The problem of stagnation point flow of non-Newtonian is discussed in COMSOL Multi-physics 5.4 by taking dependent flow. Mesh is created by using physics controlled fine and finer option. The total number of triangular entities are 8425, edge elements are 1223, Quadrilateral entities 2270, vertex elements 100, with domain statistics that have number of elements 10695, the average element quality is 0.787, the minimum element quality is 0.3047, element ratio area is 0.01569 and mesh area is $0.04041 \ m^2$. The solution is explained by using graphs of COMSOL Multi-physics and obtained results in further sections.

6. Results and Discussion

Fig. 4 shows the surface magnitude for the velocity profile. Fig. 5 indicates the counter portray for pressure field at $t = 1 \ s$. In Fig. 6 counter graph for velocity at $t = 1 \ s$ is presented. Fig. 7 represents the magnetic flux density norm at $t = 0.5 \ s$. In Fig. 8 magnetic flux counter at $t = 0.5$ s examined. Fig. 9 explains electric potential at $t = 1 \ s$. Fig. 10 represents table surface of the velocity field. Table. 1 explains the mesh statistics for triangular and quadrilateral elements. Table. 2 shows mesh description for domain and boundary elements.

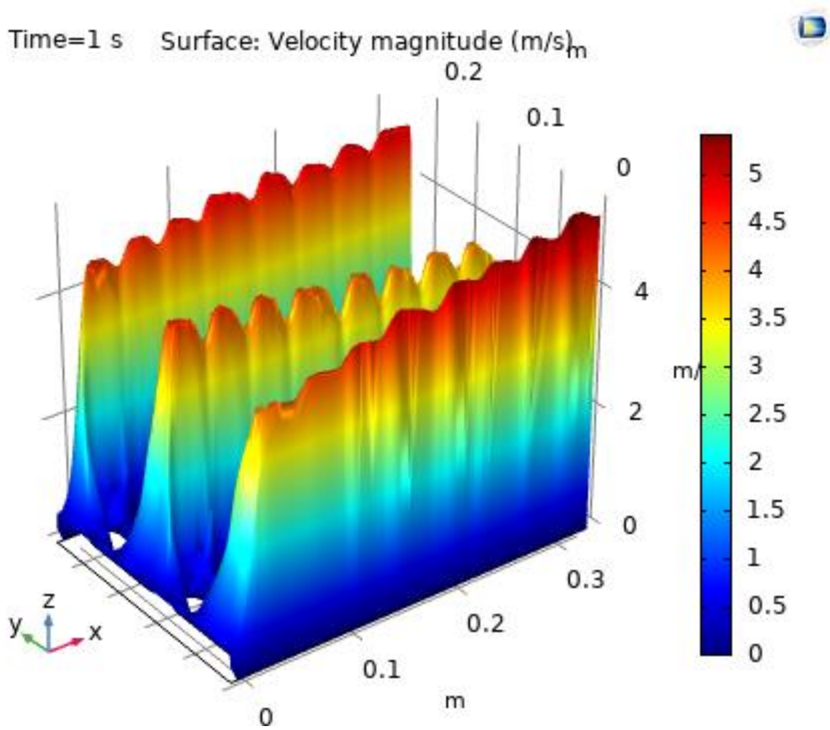

Fig. 4 Surface behavior for the distribution of velocity.

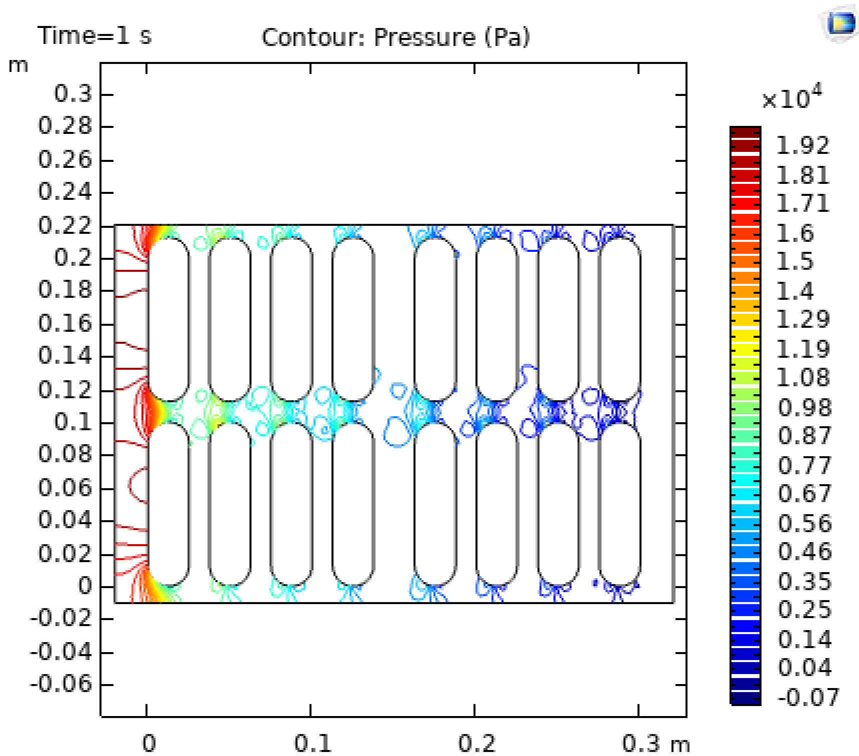

Fig. 5 Counter portray for pressure field at $t = 1$.

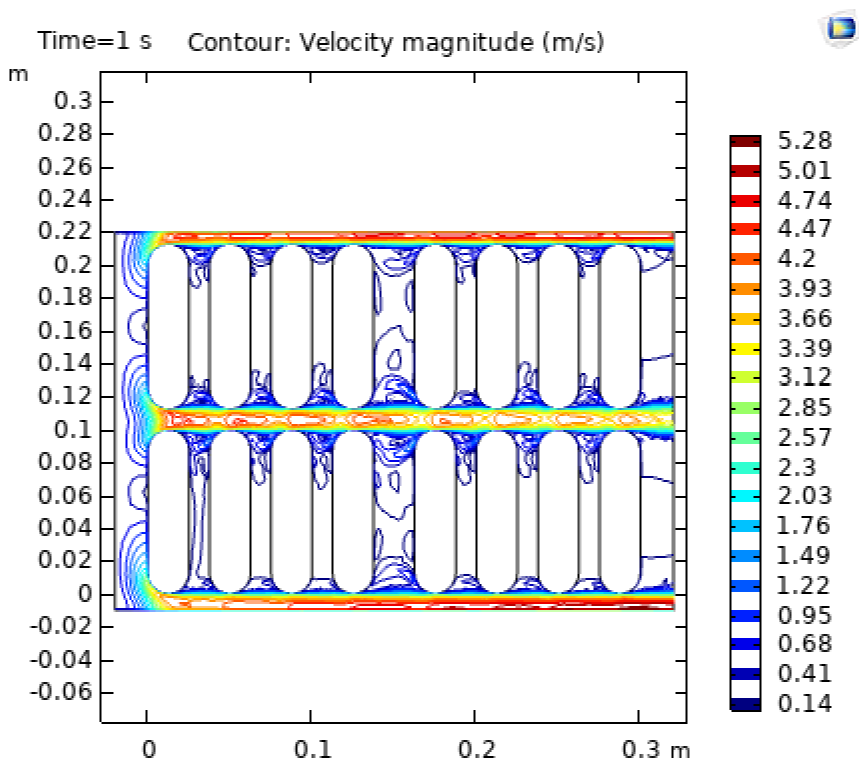

Fig. 6 Counter graph for velocity field.

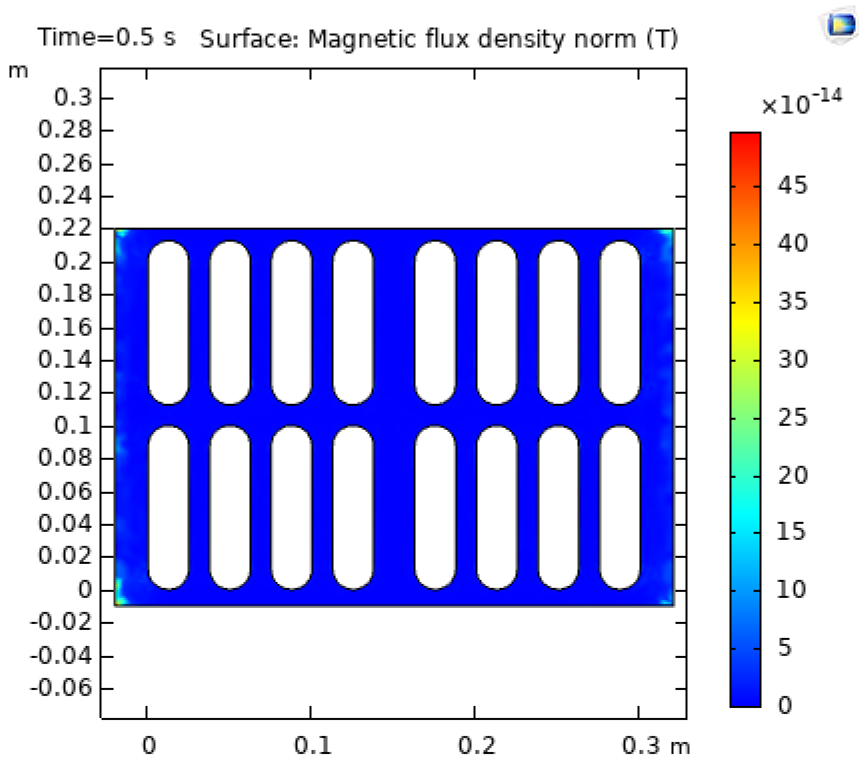

Fig. 7 Magnetic flux density norm for $t = 0.5$.

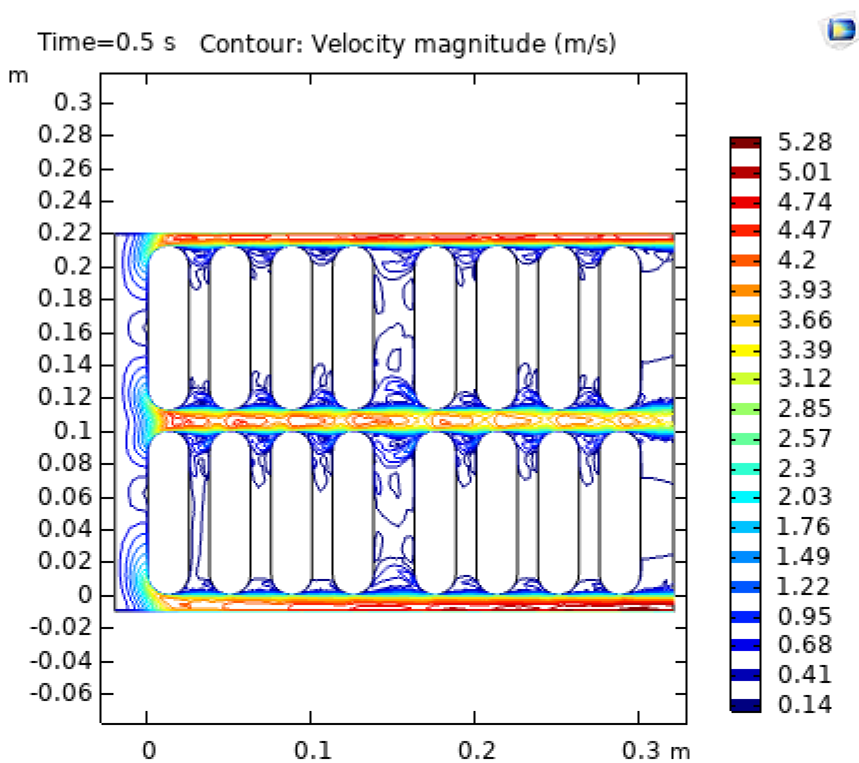

Fig. 8 Magnetic flux counter for $t = 0.5$..

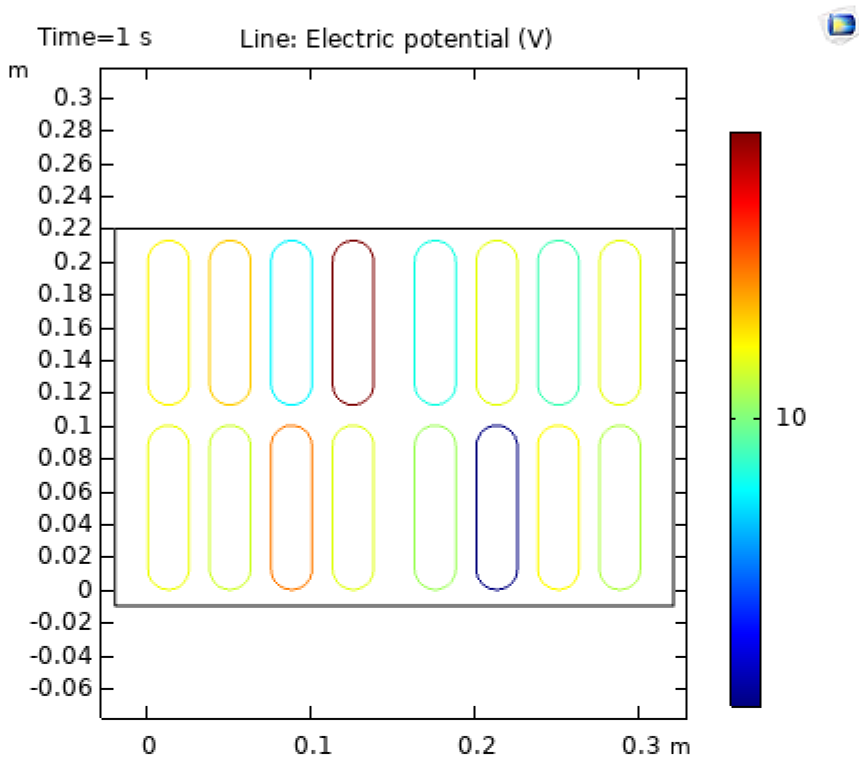

Fig. 9 Electric potential for $t = 1$.

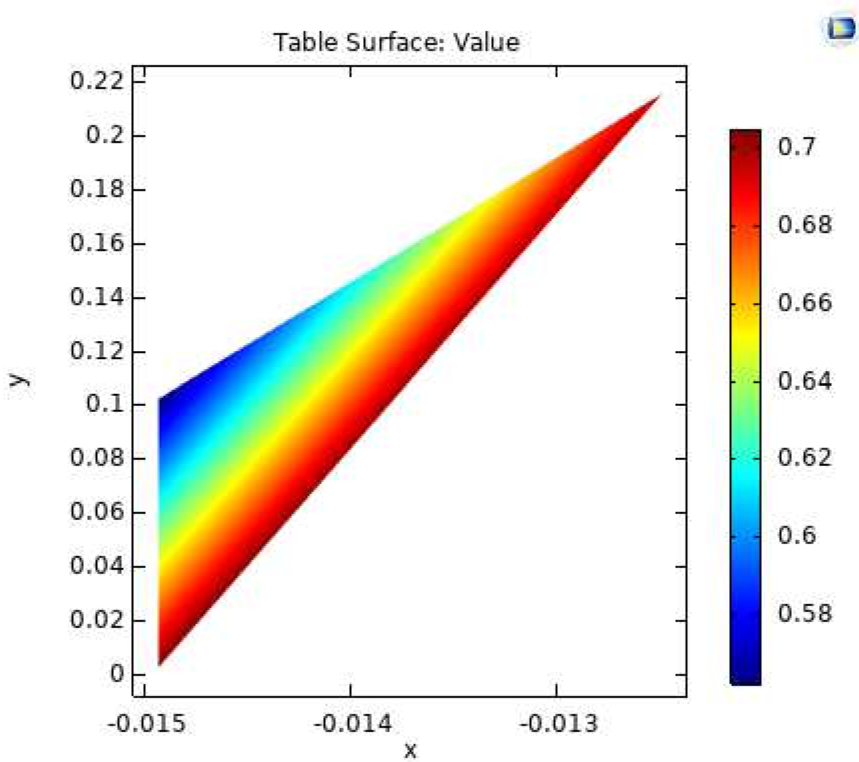

Fig. 10 Table surface for the velocity of the problem.

Table 1. Quadrilateral and triangular elements.

Elements ⟶	Quadrilateral	Triangular
Minimum Element Quality	0.8995	0.3047
Average Element Quality	0.9583	07408
Element Ratio Area	0.1477	0.01569
Mesh Area	0.007401 m^2	0.03301 m^2

Table 2. Mesh domain and boundary elements.

Mesh	Domain Elements	Boundary Elements
Electrode	6067	901
Magnetic flux	18688	1448
Laminar flow	9721	947
Extra Finer	37104	3040
Fine	13404	1588
Finer	10695	1223

7. Concluding Remarks

The problem of stagnation point flow of non-Newtonian is discussed in COMSOL Multi-physics 5.4 by taking incompressible laminar flow. The geometry of the problem is considered as riga plate. Electric and magnetic insulation with heat transfer are examined with graphs. The results obtained by COMSOL multi-physics are given below:

1) Velocity and pressure graphs for counter and surface magnitude with different time values are distinct.
2) Electric potential graph by taking time as unity shows growing behavior.
3) Magnetic flux and counter graph shows positive behavior.
4) Table surface for the velocity of laminar flow shows positive graph.

References

1. Mukhopadhyay, S., De, P. R., Bhattacharyya, K., & Layek, G. C. (2013). Casson fluid flow over an unsteady stretching surface. Ain Shams Engineering Journal, 4(4), 933-938.
2. Azad Hussain, Sobia Akbar, Lubna Sarwara, Sohail Nadeem, Zaffar Iqbal. Effect of time dependent viscosity and radiation efficacy on a non-Newtonian fluid flow. Heliyon 5 (2019) e01203. doi:10.1016/j.heliyon.2019.e01203.
3. M.Y. Malik, Mair Khan, T. Salah Uddin, Imad Khan. Variable viscosity and MHD flow in Casson fluid with Cattaneo-Christov heat flux model: Using Keller box method. Engineering Science and Technology, an International Journal. 19 (2016) 1985-1992.
4. Azad Hussain, Lubna Sarwar, Sohail Nadeem, Sobia Akbar, Sarmad Jamal. Inquisition of combined effects of radiation and MHD on elastic-viscous fluid flow past a pervious plate. Journal of the Brazilian Society of Mechanical Sciences and Engineering (2018) 40:343.
5. Nadeem S, Haq RU, Khan ZH (2014) Numerical solution of non-Newtonian nanofluid flow over a stretching sheet. Appl Nanosci 4(5):625–631.
6. Azad Hussain, Lubna Sarwar, Sobia Akbar, M. Y. Malik, Saadia Ghafoor, Model for MHD Viscoelastic Nanofluid flow with Prominence Effects of Radiation. Heat transfer Asian research 10.1002/htj.21344 (2018).
7. S. Saleem, S. Nadeem, M. M. Rashidi, C. S. Raju (2019), An optimal analysis of radiated nanomaterial ow with viscous dissipation and heat source, Microsystem Technologies, 25:683-689.
8. Azad Hussain, Lubna Sarwar, Sobia Akbar, Sohail Nadeem, Sarmad Jamal, Numerical investigation of viscoelastic nanofluid flow with radiation effects. Proceedings of the Institution of Mechanical Engineers, Part N: Journal of Nanomaterials, Nanoengineering and Nanosystems, 2397791419848957 (2019).
9. Sobia Akbar, Azad Hussain, The Influences of Squeezed Inviscid Flow between Parallel Plates, Hindawi, Mathematical Problems in Engineering, Volume 2021, Article ID 6647708, https://doi.org/10.1155/2021/6647708.
10. Azad Hussain, Lubna Sarwar, Sobia Akbar, Sohail Nadeem, Mathematical model for Blood flow through the stenosed channel in Physica Scripta. https://doi.org/10.1088/1402-4896/ab43ff. (I.F: 2.151)

11. S. Saleem and Mohamed Abd El-Aziz (2019), Entropy generation and convective heat transfer of radiated non-Newtonian power-law fluid past an exponentially moving surface under slip effects, The European Physical Journal Plus, 134:184.
12. Azad Hussain, Sobia Akbar, Lubna Sarwar, M. Y. Malik, Numerical Investigation of Squeezing flow of Walter's B fluid through Parallel Plates in Journal of the Brazilian Society of Mechanical Sciences and Engineering 2019. DOI: 10.1007/s40430-019-1984-4. (I.F: 1.743)
13. Awais M, Malik MY, Bilal S, Salah Uddin T, Hussain A (2017) Magnetohydrodynamic (MHD) flow of Sisko fluid near the axisymmetric stagnation point towards a stretching cylinder. Results Phys 7:49–56.
14. Devakar, M.; Sreenivasu, D.; Shankar, B. Analytical solutions of couple stress fluid Flows with slip boundary conditions. Alexandria Eng. J. 2014, 53, 723–730.
15. Ilani, S.S.; Ashmawy, E.A. A time dependent slip flow of a couple stress fluid between two parallel plates through state space. J. Taibah Univ. Sci. 2018, 12, 1658–3655.