

The Influence Of Key Parameters On Casson MHD Fluid Flow

Posted on March 5, 2025

Abstract

The interesting rheological behaviour of the Casson magnetohydrodynamic fluid has sparked the recent emergence of various hypotheses. While the connection between shear stress and shear rate in Newtonian fluids is linear, it is nonlinear in Casson fluids. Some well-known examples of Casson fluid are “jelly, tomato sauce, honey, soup, concentrated fruit liquids, and even human blood”. Casson MHD fluids exhibit higher viscosity compared to Newtonian fluids, allowing for better flow control. The higher viscosity of Casson MHD fluids results in reducing friction, which is a valuable application in industrial and machinery equipment. Its heat transfer characteristics are mainly used in heat exchangers or cooling systems. Thus, the MHD concept is used by engineers in the design of heat exchangers, pumps, and flow metres, as a propellant, thermal shielding, braking, control, and re-entry of spacecraft, in the development of innovative power generation systems, among other applications. Designers creating applications that try to manage this flow will benefit greatly from a grasp of the behaviour of MHD independent and forced convective flow as well as the different issue parameters that impact it. A significant amount of research has been done recently on the MHD effects of Casson flow, Dufour, absorption, and chemical reaction across permeable plates.

Investigations have been conducted to understand how “second order momentum slip flow and a viscous dissipation magnetic field” affect the flow of [Casson micropolar fluid](#) in a laminar boundary layer over a linear stretching sheet. These factors have been found to have a notable influence on the flow rate of non-Newtonian fluids. The governing equations are solved using the perturbation method, and various parameters such as “skin friction, Nusselt number, and Sherwood number” are also considered. The study closely examines the effects of parameter heterogeneity, including the “Schmidt number, chemical reaction parameter, radiation parameter, Prandtl number, radiation absorption parameter, Dufour parameter, Casson parameter, Grash-of number, and Hall current parameter”. It has been observed that certain parameters like K significantly impact the flow rate of non-Newtonian fluids.

Chapter-1

1. Introduction and Literature Review

Newtonian & non-Newtonian liquids,

Newtonian fluids have a linear relationship between viscosity and shear stress. So, its viscosity remains constant irrespective of the amount of shear applied. On the other hand, the viscosity of the non-Newtonian fluid changes based on the shear applied. So, for Newtonian fluids the shear stress must be directly proportional to the rate of shear strain, called Newtonian law of viscosity. Therefore, solutions of low molecular weight inorganic salts, molten metals and salts, and gases exhibit Newtonian flow characteristics [1].

Non-Newtonian fluids are those that do not have a constant viscosity and have a variable relationship with shear stress. Many substances of industrial significance like foams, emulsions, dispersions and suspensions, and slurries, which do not conform to the Newtonian postulate of the linear relationship between shear stress and strain is, termed as non-Newtonian fluids or also known as rheologically complex fluids [2].

Dilatant, Pseudoplastic, Rheopectic, and Thixotropic are the four popularly classified fluid behaviours based on their shear and viscosity characteristics. All fluids categorized as non-Newtonian present nonlinear behaviours, including shear thinning and shear thickening fluids that exhibit opposite behaviours upon application of stress. So, for non-Newtonian fluids, measuring viscosity is a difficult task to achieve universally. This is further complicated when these fluids also present a time dependency eg: paints. Therefore, processing these materials comes with many challenges due to the complex nature of these flows.

Some of the important behaviour of Non-Newtonian fluids can be classified as below:

Shear-Thickening or Dilatant Behaviour: This class of fluids is similar to pseudoplastic systems in that they show no yield stress, but their apparent viscosity increases with the increasing shear rate and hence the name shear-thickening [3]. Thick granular suspensions present in fluids are known as dilatant fluids. These particles must reorganise when a shear rate is given to them in order to minimise their effects. Thus, the overall shear force is decreased. Particles can reorganise themselves at low shear rates. A significant shear force develops when the shear rate is high enough because the particles are unable to realign themselves in time. A suspension of water and maize starch is a dilatant fluid. Such a suspension becomes almost solid when it is hand-compressed. The suspension reflows when the pressure is released. [15].

Shear-thinning or pseudoplastic behaviour: This is perhaps the most widely encountered type of time-independent non-Newtonian fluid behaviour in engineering practice. It is characterized by an apparent viscosity η which gradually decreases with increasing shear rate.

Time Dependent Behaviour: Many substances, whose viscosities are not only functions of the applied shear stress (σ) or the shear rate ($\dot{\gamma}$), but also of the duration for which the fluid has been subjected to shearing as well as their previous kinematic history [3].

Depending upon the response of a material to shear over a period of time, it is customary to subdivide time-dependent fluid behavior into two types, namely, thixotropy and rheopexy.

Thixotropic Behaviour: A material is classified as being thixotropic if, when it is sheared at a constant rate, its apparent viscosity decreases with the duration of shearing [3].

Rheoplectic Behaviour: The relatively few fluids which show the negative thixotropy, i.e., their apparent viscosity (or the corresponding shear stress) increases with time of shearing are also known as rheoplectic fluids [3].

Visco-plastic Fluid Behavior: This type of non-Newtonian fluid behavior is characterized by the existence of a threshold stress called yield stress, which must be exceeded for the fluid to deform (shear) or flow [4].

1.1.1 Pseudoplastic fluids:

Pseudoplastic fluids, also known as shear-thinning fluids, are a type of non-Newtonian fluid that exhibit a decrease in viscosity as the shear rate increases. In other words, the fluid becomes less resistant to flow when subjected to higher shear rates or stress. This behavior is in contrast to Newtonian fluids, which have a constant viscosity regardless of the shear rate.

In pseudoplastic fluids, the viscosity decreases due to changes in the internal structure or arrangement of the fluid's constituents, such as polymers or particles, under applied shear stress. As the shear rate increases, the fluid's internal structure is disrupted, leading to decreased resistance to flow and smoother flow behaviour.

Common examples of pseudoplastic fluids include various types of polymer solutions, paints, inks, and some food products like ketchup or mayonnaise. The shear-thinning behavior of pseudoplastic fluids is often advantageous in applications such as pumping, spraying, or coating, as it allows for easier flow and application with higher shear rates while maintaining stability when not in motion [8].

Casson fluid

Casson fluid is defined as non-Newtonian fluid due to its characteristic relation in the shear stress-strain relationship. It behaves like an elastic solid if the shear strain is low. Casson acts as a Newtonian fluid when stress is high. Casson fluid is accurately described as fluid with infinite viscosity at shear rate equating to zero and when the shear rate is infinite, the viscosity is infinite [5].

The Casson model was created for liquids containing bar-like solids and is frequently connected to model bloodstream and other practical applications such as modern handling of liquid chocolate and related foodstuff. The flow incited by stretching the boundary in the polymer removal, drawing of copper wires, constant extending of plastic films and recreated strands, hot moving glass fibers,

metal ejection, and metal turning is a segment of the situations where the phenomenon of a stretching boundary develops [6].

MHD Casson fluid

Magnetohydrodynamics (MHD) is a part of fluid dynamics that does incorporate the fluid's magnetization or polarization while studying fluid dynamics in the magnetic field. Similar to a regular Casson fluid, the MHD Casson fluid displays a non-linear relationship between shear stress and shear rate. It requires a certain yield stress to initiate flow, and its viscosity decreases as the shear rate increases. However, the behavior of the MHD Casson fluid is further affected by the presence of a magnetic field.

MHD has a wide range of potential applications in bioengineering and medicine like a controlling agent for blood velocity. The hemodynamics of the MHD peristaltic process of non-Newtonian fluid show that an increase in variable viscosity parameters accelerates the flow hence bolus size increases. Pulsatile flow analysis has gained a lot of attention because of its applications in microelectromechanical systems, reciprocal pumps, internal combustion engines and even also in respiratory systems, circulatory systems, and vascular diseases [7].

The magnetic field can induce additional forces and interactions within the fluid, altering its flow behavior. The MHD principle incorporates the study of the behavior and dynamics of fluids that are electrically conductive in the presence of a magnetic field. The interaction between the fluid's electrical conductivity and the magnetic field gives rise to additional effects such as electromagnetic forces, magnetic field-induced viscosity variations, and flow instabilities [9].

Understanding the behaviour of MHD Casson fluids is crucial in various engineering applications, from industrial and automobile to mechanical and even in the medical domain. Researchers study the MHD influences of Casson flow, as well as factors like Dufour effect, absorption, and chemical reactions via permeable plates to gain insights into the behavior and control of this type of fluid [9].

Hall current is produced when magnetic field becomes strong and this concept was first given by Edwin Hall.

Applications Casson MHD fluids:

Casson magnetohydrodynamic (MHD) fluids offer several advantages in various applications.

Enhanced flow control: Casson MHD fluids exhibit higher viscosity compared to Newtonian fluids, allowing for better flow control. This property is particularly beneficial in applications where precise control of fluid flow is required, such as in microfluidics or industrial processes.

Reduced friction and wear: The higher viscosity of Casson MHD fluids helps in reducing friction and

wear in moving parts. This advantage is especially valuable in applications involving machinery or equipment that experience high levels of stress and friction, leading to improved durability and longer lifespan.

Improved heat transfer: Casson MHD fluids have been found to enhance heat transfer efficiency due to their non-Newtonian behavior. This property is advantageous in applications such as heat exchangers or cooling systems, where efficient heat dissipation is crucial for optimal performance.

Magnetic field manipulation: The presence of a magnetic field can further influence the behavior of Casson MHD fluids. This characteristic opens up possibilities for manipulating the fluid flow using external magnetic fields, enabling precise control and manipulation in various applications.

Versatility in different environments: Casson MHD fluids exhibit versatility in different environments, including high-temperature or high-pressure conditions. This adaptability makes them suitable for a wide range of applications, including aerospace, automotive, and biomedical fields.

The advantages of Casson MHD fluids may vary depending on the specific application, and operating conditions are another important characteristic to consider.

Characteristics of Casson fluid

Few important characteristics of Casson fluids are as follows:

1.2.1 Nonlinear Relationship: Casson fluids exhibit a nonlinear relationship between shear stress and shear rate, in contrast to Newtonian fluids which have a linear relationship.

The Casson equation states that the shear stress (τ) in a Casson fluid is equal to the sum of the yield stress (τ_{yield}) and the square root of the product of a consistency index (K) and the shear rate ($\dot{\gamma}$):

$$\tau = \tau_{\text{yield}} + \sqrt{K * \dot{\gamma}}$$

In this equation, the yield stress (τ_{yield}) represents the minimum stress required to initiate flow in the Casson fluid. It signifies the resistance of the fluid to deformation and acts as a threshold value. Below this yield stress, the fluid behaves as a solid and does not flow.

The consistency index (K) characterizes the fluid's resistance to flow and determines the rate at which the shear stress increases with the square root of the shear rate. As the shear rate ($\dot{\gamma}$) increases, the square root term in the Casson equation causes the shear stress to rise rapidly, resulting in a nonlinear relationship between shear stress and shear rate. This behavior indicates that the Casson fluid requires a certain amount of shear rate to overcome the yield stress and begin flowing smoothly.

In summary, the shear stress and shear rate relationship in a Casson fluid is nonlinear, with a threshold yield stress and an increasing shear stress that is proportional to the square root of the

shear rate once [10,11]

1.2.2 Yield Stress: Casson fluids have a yield stress, meaning that a certain amount of force is needed to initiate flow.

The yield stress of Casson fluids is an important parameter that characterizes the response of these non-Newtonian fluids under applied stress. It indicates the minimum amount of stress required to initiate flow in a Casson fluid. Furthermore, it distinguishes Casson fluids from Newtonian fluids, which have no yield stress and flow continuously under any applied stress. The Casson fluid, which is a type of shear-thinning liquid, exhibits a unique behaviour with regard to its yield stress [12]. When the shear stress applied to the Casson fluid is below the yield stress, it behaves like a solid and does not flow. On the other hand, when the shear stress is greater than the yield stress, the Casson fluid starts to move and exhibits a shear thinning behavior.

The yield stress in the Casson model is widely used to explain the remarkable behavior of blood flow through small blood vessels at low shear rates [13].

1.2.3 Thixotropy: Casson fluids can exhibit thixotropic behavior, which means that their viscosity decreases over time when subjected to continuous shear stress. This allows the fluid to flow more easily with prolonged agitation.

This thixotropic phenomenon is particularly significant in various fluid systems, including the case of Casson fluids, which are shear thinning liquids that exhibit thixotropic behavior [12]. It is defined by its infinite viscosity at zero rate of shear, a yield stress below which no flow occurs, and zero viscosity at an infinite rate of shear. This unique rheological behavior of Casson fluids has important implications for their flow characteristics and practical applications. Understanding the thixotropic behavior of Casson fluids is essential for various fields such as engineering, medicine, and food processing. In the field of engineering, knowledge of Casson fluid thixotropy is crucial for designing efficient systems and predicting the flow behavior of various particle-laden suspensions. In medicine, the study of Casson fluid thixotropy can help in understanding the flow properties of biological fluids such as blood and plasma, which are examples of Casson fluids [14].

1.2.4 Pseudoplasticity: Casson fluids can display pseudoplastic behavior, where their viscosity decreases as the shear rate increases. This results in the fluid flowing more readily when subjected to higher shear rates.

Pseudoplastic fluids, such as the “Maxwell fluid, Williamson fluid, Casson fluid, Jeffrey fluid, and shear-thinning fluids”, exhibit certain characteristics. Examples of pseudoplastic fluids include polymer solutions and high-molecular weight solutions. These fluids experience shear tension at low shear rates, which causes the molecules to rearrange and reduce overall stress. This rearrangement leads to a decrease in shear stress and results in a nonproportional relationship between shear rate and shear force [15]. In conduits, the velocity of pseudoplastic fluids is highest at the center and gradually decreases towards the walls, reaching its lowest magnitude. Additionally, the flow velocity of

pseudoplastic fluids remains constant along the axis of the channel. The temperature of pseudoplastic fluids increases with higher values of the Brinkman number. When considering Rabinowitsch fluid, the pressure gradient graph for pseudoplastic fluids increases in height as the flow rate increases [16].

1.3 Properties of Casson fluid:

The answer is exclusive to the stretching sheet scenario, according to an analysis of Casson fluid across a permeable stretching/shrinking sheet. On the other hand, the Casson parameter affects how the shrinking sheet is solved, therefore each instance may have a different solution or a number of solutions. [6].

An unbounded viscosity with zero rate of shear, a yield stress beyond which flow does not occurs, and there is no viscosity at a boundless rate of shear are all characteristics of the Casson fluid, which is a shear-thinning liquid with changeable plastic dynamic viscosity [17].

Physical Properties of Casson fluid

A Casson fluid's viscosity is a crucial physical characteristic since it affects how the fluid will flow when subjected to various shear rates. Casson fluid behaves in a shear-thinning manner, which means that as the shear rate rises, so does its viscosity. This behavior is crucial because it makes it easier for the fluid to flow at greater shear rates, thus being helpful in a variety of applications including food processing and medicinal [18,19]. Therefore, a Casson fluid is more accurately defined as a fluid with shear thins, limitless viscosity at zero shear rate and zero viscosity at infinite shear rate. "Tomato sauce, honey, soup" and other such popular liquids display the features of Casson fluids. [20].

Another important physical characteristic of a Casson fluid is its yield stress. The minimal tension necessary to start flow in a Casson fluid is known as the yield stress. When the shear stress is smaller than the yield value, the fluid behaves like a solid (plug flow) as a result of the yield stress. Thus, a specific minimum pressure gradient is needed to push the fluid, based on the yield stress the fluid possesses. The fluid and the porous media both affect the measurable yield stress of the fluid. A yield plane is a site within the flow sector in which the shear stress equals the yield value, and a yield plane is the collection of all such locations [21].

The flow behaviour of Casson fluid is a crucial physical characteristic. It's crucial to determine the minimal pressure gradient necessary to drive non-Newtonian fluids with yield stresses. The flow rate significantly decreases with a rise in yield stress and a fall in permeability parameter, indicating a significant increase in frictional resistance [21].

Under low shear rates, Casson fluid behaves like a solid with an infinite viscosity

2. Literature survey

2.1 Literature review on the flow of convective Casson micropolar fluid:

The flow of convective Casson micropolar fluid has been extensively studied in various scenarios by researchers in the field. Many researchers investigated the flow of Casson micropolar fluid at different criteria.

Shah et. al., 2018 studied the effects of thermal radiation with respect to Casson micropolar nanofluid flow in a rotating system between two parallel plates. The effects of “thermal radiation, impact of Hall current, Brownian movement and thermophoresis phenomena” of “micropolar Casson nanofluid” are taken into consideration for this analysis. It is found that, the temperature field enhances with larger values of Brownian motion thermophoresis effect [22]. The flow and heat transfer properties of an electrically conducting Casson fluid through an exponentially expanding curved surface with convective boundary conditions are presented by K. Anantha Kumar et al., 2019. The governing partial differential equations are solved numerically using the “shooting and Runge-Kutta method” after appropriate transformation techniques have been applied to analyse the heat flow and transfer properties of the electrically conducting Casson fluid. The behaviour of temperature-dependent thermal conductivity, temperature owing to radiation, and numerous other irregular heat parameters also changes when the duration of fluid motion is taken into account and the fluid flow is assumed to be laminar. It is thus concluded that the Casson parameter is inversely related to development of curvature parameter and directly related to suppress the distribution of momentum [23].

Sugunamma et al., 2019 provide an important information on the three-dimensional unsteady magnetohydrodynamic flow and entropy generation of the micropolar Casson Cross nanofluid susceptible to nonlinear heat radiation and chemical reaction. It has been shown that a thermal energy source, a dissipation agent, as well as radiative heat transfer, may all raise the temperature of a fluid. Using proper similarity variables and a fourth-order Runge-Kutta-based shooting method, basic partial differential equations are converted. The effects of various physical variables on Casson Cross nanofluid are investigated by considering its “velocity, microrotation, temperature, its friction factor, tension, and local Nusselt numbers”, among other physical aspects [24].

According to the proposal by Patel et al., 2019 the dimensionless equations can be solved using the homotopy analysis approach to get the expression for velocity, micro-rotation, temperature, and concentration profiles. The flow of micropolar fluid is found to increase with an increase in velocity and rotation of the micro-elements present in the fluid after changing the partial differential equation using similarity transformations method. Similar to how skin-friction coefficient values rise when strong and weak concentrations are correlated, a substantial drop in velocity profile is seen when comparing non-linear stretching sheets to linear sheets. The rate of mass transfer decreases with regard to chemical reaction parameter, however the rate of heat transfer improves depending on

Brownian motion and thermophoresis parameter [25].

Nayak et. al., 2019 provide important insights regarding three dimensional unsteady magnetohydrodynamic flow and entropy generation of micropolar Casson Cross nanofluid subject to nonlinear thermal radiation and chemical reaction. Shooting iteration technique together with 4 th order Runge-Kutta integration scheme is the method used in this research. Velocity, Thermal characteristics and microrotation are used in modelling of Nanoparticles concentration. Though Hartmann number shows a negative effect in increasing the axial and transverse velocity, strengthening of Weissenberg number shows a positive effect in this. Also, Brownian motion increases positively with heat and mass transfer rates whereas the thermophoresis drops in the transfer rates. By enhancing temperature ratio there is a significant development in thermal boundary is the secondary result obtained in this study [26].

A method based on KKL was suggested by Yan et al. in 2020 to define the simultaneous dependence of the concentration and temperature of nano-sized particles on the thermal conductivity and viscosity of nanofluids. Within the Lorentz and buoyancy-affected area, a micropolar fluid with modest concentrations of copper oxide nanoparticles flows. The KKL method is used to determine the simultaneous dependence of the concentration and temperature of nano-sized particles on the thermal conductivity and viscosity of the fluid. By using the Galerkin finite element method, governing equations with pertinent boundary conditions expressed in stream function which is dimension less were resolved. Analysis was done on the effects of key control factors on the flow and heat transfer of micropolar nanofluid. It was demonstrated that altering the orientation of the elliptical heater significantly alters the variables under consideration such as isolines along with the exchange of heat rate. The average Nusselt number simultaneously has maximum values of 0 and 1, and lowest value of 2, respectively [27].

In a recent study by Mittal et al. (2020), the influence of thermophoresis and Brownian motion on mixed convection two-dimensional magnetohydrodynamic (MHD) flow of Casson fluid was investigated. The study focused on the flow past an infinite plate in a porous medium, considering the effects of thermophoresis, Brownian motion, non-linear thermal radiation, heat generation, and chemical reaction. The governing differential equations were modified using similarity transformation, and a system of ordinary differential equations (ODEs) was solved using the HAM (Homotopy Analysis Method). The study examined the effects of various important parameters on the velocity, temperature, and concentration profiles, which were presented graphically. Additionally, numerical values of the velocity, temperature, and concentration gradients were obtained and presented in tabular form. The results showed that parameters such as the mixed convection parameter (λ), buoyancy force parameter (N), non-linear thermal radiation parameter (N_r), and heat generation parameter (H) had a positive impact on the fluid motion throughout the flow field. Furthermore, it was observed that the heat and mass transfer processes improved with the presence of Brownian motion (N_b) and thermophoresis (N_t). However, it was noted that Brownian motion and thermophoresis parameters had a negative effect on the temperature gradient [28].

In their study, Jamshed et al., 2021 examined the unsteady flow of a non-Newtonian Casson nanofluid, focusing on its thermal transport and entropy. They thoroughly investigated the influence of slip condition and solar thermal transport on the convection of Casson nanofluid flow. To analyze the flow behavior and thermal transport, a convective heat condition was applied to a slippery surface in the nanofluid. The governing equations for the Casson nanofluid flow and heat transfer were simplified by assuming a boundary layer flow and utilizing Roseland approximations. These equations were formulated as partial differential equations (PDEs). By transforming the equations into ordinary differential equations (ODEs), a self-similar solution was obtained using a numerical technique called the Keller box method. The study considered two types of nanofluids, namely Copper-water (Cu-H₂O) and Titanium-water (TiO₂-H₂O), for analysis. The numerical results were presented graphically, illustrating various flow parameters such as heat transfer, skin friction, Nusselt number, and entropy. It was observed that increasing the Reynolds number and effective Brinkman numbers led to an overall increase in entropy in the system. The thermal conductivity was found to be higher in the case of Casson phenomena compared to conventional fluids. Based on their findings, the (Cu-H₂O) nanofluid demonstrated greater reliability in terms of heat transfer compared to the (TiO₂-H₂O) nanoliquid [29].

The novelty of the present investigation conducted by Mousavi et al. in 2021 lies in the use of experimental relations to approximate the effective thermophysical properties of a water/MgO-Ag hybrid nanofluid. This approach is employed to simulate the two-dimensional magnetohydrodynamic (MHD) Casson flow past a linearly stretching/shrinking sheet, considering the effects of suction, radiation, and convective boundary conditions. The study also takes into account the existence of dual solutions and performs stability analysis. The Tiwari-Das mathematical formulation, coupled with a mass-based hybrid nanofluid model, is utilized to express the governing partial differential equations (PDEs), which are then transformed into a system of dimensionless ordinary differential equations (ODEs) using the similarity transformation technique. A well-known finite difference method with fourth-order accuracy in MATLAB is employed to solve these equations. The study highlights the importance of considering selective experimental relations for effective thermophysical models in the numerical modeling of hybrid nanofluids in the future. Furthermore, the results indicate that the range of the Casson fluid parameter, within which a solution exists, increases with the radiation parameter, suction parameter, and the mass of the second nanoparticle. Additionally, it is demonstrated that the application of a magnetic field normal to the sheet enhances the similarity velocity profiles within the hydrodynamic boundary layer [30].

Khan et al.'s 2022 investigation on the chemical reactions with dynamic micropolar asymmetric transfer of heat that occurs in Casson fluid brought on by a moving wedge submerged in a porous substance. The conversion procedure makes use of the RK4 transformation framework. The unsteadiness factor reduced the temperature as well as concentration boundary layers while thinning the velocity boundary layer. The dimensionless thermal distribution profile was improved by raising Eckert number. The innovative aspect of this research is that it is the first time that under thermal radiation a magnetised Casson fluid has been quantitatively examined across a moving wedge in the presence of a chemical reaction [31].

2.2 Literature review on flow of convective Casson Micropolar fluid:

The study of convective Casson micropolar fluid has gained significant attention in recent years. Researchers have focused on understanding the heat and mass transfer characteristics of Casson micropolar fluids in various flow configurations. However, it is worth noting that the volume of previous studies on both flow and heat convection problems related to micropolar fluids, particularly Casson Micropolar fluids.

The purpose of Hamid et. al., 2019 is to find out the dual solutions of the two-dimensional MHD flow of Casson fluid and heat transfer over the stretching sheet. And concluded that a numerically stable dual solutions are obtained using the proposed model on exploring the “linear thermal radiation effects” for the Casson fluid of steady and unsteady flow controlled by ‘uniform magnetic field’ over the stretching sheet. When analysing with the lower branch the solutions in upper branch model are numerically stable for the Casson fluid profiles, so the implication from the result can be finalized as the MHD flow of Casson fluid for positive Eigen values are more stable when contrasted with negative Eigen values [32].

Kataria et. al., 2019, studies effects of heat generation/absorption and chemical reaction on the unsteady magnetohydrodynamic (MHD) Casson fluid flow past over exponentially accelerated vertical plate embedded in porous medium. The expressions for velocity, temperature and concentration profiles are obtained from the initial and boundary conditions of partial differential equations using Laplace transform technique by assuming bounding plate has ramped temperature and isothermal temperature with ramped surface concentration [33]. Ali et al.’s 2019 investigation into the impact of repeated slip on magnetohydrodynamic instability Casson nanofluid flow through a permeable stretched sheet, sheet embedded within a porous medium having thermo-diffusion impact, as well as thermal source with injection/suction effect. In a system of linked nonlinear ordinary differential equations, the leading nonlinear partial differential equations are converted using the proper transformations, and the changed equations are then numerically solved using the variational finite element technique. To investigate the features of mass and heat transport as well as the effects of various flow parameters, a parametric analysis was conducted [34].

The computational analysis of the heat source influence on an unsteady MHD Casson flow of fluid through a vertically oscillating plate in a porous medium is the subject of Goud et al., 2020. By adding similarity variables, dimensionally irregular coupled differential equations are dimensionally reduced. The Galerkin element method is used to solve the converted dimensionless ordinary differential equations for velocity and temperature. The impact of flow characteristics such as the “Casson fluid, Permeability (K), Magnetic number (M), Phase angle (t), Prandtl number (Pr), Skin friction, Nusselt number”, and other physical variables are investigated. Additionally, raising the thermal source variable results in an increase in temperature and velocity [35].

In their study, Noor et al. (2022) investigated the effects of chemical reaction on the magnetohydrodynamic (MHD) squeeze flow of Casson fluid over a permeable medium in the slip

condition with viscous dissipation. The flow occurs between two plates that are compressed together. To simplify the equations, the researchers transformed the partial differential equations (PDEs) into ordinary differential equations (ODEs) using similarity variables. They employed the Keller-box numerical procedure to solve the dimensionless equations. The obtained numerical results were compared with previous studies to validate the accuracy of the current solutions, and they were found to be in good agreement.

The results of the study indicate that as the plates move closer together, both the velocity and wall shear stress increase. Additionally, an increase in the Hartmann and Casson parameters leads to a decrease in velocity, temperature, and concentration. The presence of viscous dissipation enhances the temperature and the rate of thermal transfer. Furthermore, the mass transfer rate is found to increase in destructive chemical reactions, while adverse effects are observed in constructive chemical reactions [36].

Mishra et al., 2022 investigated the non-newtonian casson fluid hybrid nanofluid flow for the study of entropy across a permeable material. In order to create nanofluid, copper (Cu) and oxide nanoparticles such as Aluminium oxide (Al_2O_3) are dissolved in ethylene glycol (EG), which is regarded as the base liquid. Additionally, the profile is improved by include radiative heat, viscous, and Joule absorption in the energy equation. Suitable similarity transformations are used to derive the dimensionless for the equations that govern them. The primary and secondary velocity distributions, together with the temperature profiles, are solved numerically, and graphs that illustrate the physical relevance of the relevant parameters are also provided. Additionally, the entropy analysis for the thermal system's irreversibility process is performed for a variety of factors together using the Bejan number and carefully considered. Significant increases in the shear rate and heat transfer rate are revealed for the rising magnetic and rotation parameters, however an increased rotation reduces the overall thickness that covers the bounding outermost layer and the main velocity towards the bottom wall [37].

MHD slip flow of casson fluid over a nonlinear permeable stretched cylinder immersed in a medium that is porous with chemical reaction, viscous dissipation, and the generation and absorption of heat is studied by Ullah et al., 2019. The objective of the current investigation is to give regionally equivalent Casson fluid solutions across a non-isothermal cylinder that is being suctioned or blown. Investigations are also conducted into how flow fields are affected by chemical reaction, viscosity dissipation, and heat creation and absorption. Additionally, similarity transformations are used, and the Keller box method is used to solve them. Results show that increasing the Casson parameter suppresses the size of the friction coefficient and the transfer rate of mass while increasing the heat transfer rate. It is observed that with a rise in porosity along with suction/blowing parameters, it is seen that the magnitude of shear stress on the wall is increased [38].

Vellanki et al., 2020 investigate the steady-state impacts of two-dimensional buoyancy, including the effects of radiation and chemical reactions on MHD. When suction or injection occurs, casson fluid flows over a stretched permeable sheet over a porous material. Numerous various parameters are

taken into consideration for the transformation strategies employed in the mathematical expressions and the operating fluid flow. When the magnetic field and the permeability of the porous parameter increase, velocity falls, temperature rises, and concentration rises [39].

Considering “Thermal Diffusion and Diffusion Thermo Effects”, Mouli et al., 2020 investigated the effects of Soret and Dufour on constant, viscous dissipative Casson flow of fluid along a linear stretching surface. The numerical solutions are obtained using the Spectral Relaxation Method. The results are listed with reference to specific physical characteristics, including profiles of “velocity, temperature, concentration, coefficients of skin friction, and Nusselt and Sherwood numbers”. According to the findings, velocity decreases as Casson parameter increases. The Nusselt number increases when the Soret number is increased, but it decreases when the Dufour number is raised. Additionally, the ratio parameter increases the Nusselt number and the Sherwood number. Furthermore, concentration profiles rise for larger “Casson parameter as well as Soret number” values but fall for higher Schmidt and ratio parameter values [40].

The current study by Nayak et al. (2019) examines the effects of thermal-diffusion and diffusion-thermo parameters on a non-aligned stagnation point flow past a stretched horizontal Riga plate, including the “modified Hartmann number, Casson fluid parameter, couple stress parameter, Soret and Dufour numbers, and chemical reaction parameter”. Runge-Kutta-Fehlberg scheme has developed a computing method for the converted momentum, energy, and concentration equations. The current study’s robustness indicates that the fluid motion is enhanced by the “wall-parallel Lorentz force and non-Newtonian parameter”, while the contraction of the concentration boundary layer is facilitated by generative chemical reaction, destructive chemical reaction, and non-reactive species [41].

An investigation by Rajakumar et al., 2022 focuses on the effects of a moving hot vertical permeable plate and a spanwise consinusoidally fluctuating temperature on an unstable magnetohydrodynamic free convective flow with “heat generation, radiation absorption, and chemical reaction”. A multiple regular perturbation approach is used to analyze the governing PDE analytically. Quantitative examples were used to show the effects of different physical estimators on “fluid velocity, temperature, concentration, skin friction, Nusselt number, and Sherwood number”. Eventually, it was discovered that the velocity, concentration, and Sherwood number all decreased as the chemical reaction parameter’s values increased. Incremental Prandtl number values increased velocity and temperature while having the opposite effect on Nusselt number and skin friction. As the “magnetic parameter and Casson fluid parameter values” increased, velocity and skin friction decreased. [42].

Sulochana et. al., 2019 studied the flow of unsteady “MHD non-Newtonian fluid” to examine the impact of pertinent physical constraints over the “velocity, temperature, and concentration profiles of the fluid” through a vertical plate influenced by “Hall current”. All nonlinear differential equations are first modified using similarity transformation techniques, and then they are all solved using perturbation techniques. The magnetic field-derived Lorentz force has a tendency to reduce flow velocity. [43].

Karthikeyan et al., 2019, studied the heat and mass transfer in MHD flow of a Casson fluid with a moving vertical porous plate using the “perturbation method” for solving all the ODE. They came to the conclusion that when the Casson parameter, Grash-of-number, Solutal Grash-of-number, and Heat source parameter rise, the Velocity profiles do as well. Additionally, when the fluid flow velocity falls, the “Inclined Angle parameter, Prandtl number, Magnetic field parameter, Schmidt number, and Chemical reaction” all rise. When the Prandtl and Schmidt numbers rise, the temperature distribution falls. Additionally, when the “Schmidt number and chemical reaction” parameter’s impact increases, the concentration of fluid flow drops [44]. An unstable Casson fluid squeeze flow with magnetohydrodynamic effect that is flowing through a “porous medium channel along with slip” at the borders was examined and simulated by M. Qayyum et al. in 2017. The resultant equations are then analytically solved using the Homotopy Perturbation Method (HPM), also known as similarity transformations. Boundary situations such as slip at upper wall alone, consistent slip for both walls, non-uniform slip at upper wall is higher than that of lower wall, non-uniform slip where slip at lower wall is more than that of upper wall, and slip at lower wall only are examined. ERK-4 is utilized for validation, and the impact of fluid parameter on velocity profile is then examined [45].

The complicated movement of a Casson fluid in a non-uniform conduit when exposed to a radial magnetic field is the subject of Manjunatha et al., 2021. The model is created by taking into account the Casson fluid’s mass as well as its heat transfer characteristics with boundary conditions, the channel’s wall for fluid with variable viscosity, thermal conductivity with changing fluid temperature. The answer is obtained using the perturbation approach [46]. Using the features of heat and mass transport, Admon et al., 2020 examined the unstable squeezing flow of a magnetohydrodynamic (MHD) Casson nanofluid. Examined as well are the effects of viscosity and joule dissipation. Inserting among two opposing plates that are encased in a porous material is what creates the flow. Through similarity transformations, the strongly linked nonlinear PDE are simplified to a set of nonlinear ODE. The Keller-box numerical approach is used to solve the altered equations. Comparisons show that as the plates go closer, the fluid velocity as well as temperature increase. Additionally, a larger concentration of nanoparticles is seen in chemical reactions that are constructive, while the reverse impact is seen in chemical reactions that are destructive [47].

The flow of an unstable MHD of a viscous, impenetrable and fluid that conducts electricity through an inclined porous plate attached to a porous medium of rotating system was explored by Lorenzini et al., 2022. Hall, ion slip, rotation, and Soret effects are the other parameters he considered in this analysis. It is presumed that the fluid is non-Newtonian, whereas its general solution is originally created before being solved using the perturbation technique. According to analysis, the main fluid exhibits a reversal effect for the majority of the taken into account factors, whereas the secondary fluid velocity accelerates [48].

2.3 Literature review on Radiation Absorption sway on Casson MHD

fluid:

In order to comprehend the behaviour of Casson magnetohydrodynamic fluid, radiation absorption is essential. It has an impact on the fluid's flow properties, heat transmission, and mass transfer. A number of experiments have been done to find out how radiation absorption affects Casson MHD fluid.

A semi-infinite vertical porous plate is the object of Rajakumar et al., 2020 study on the effects of radiation absorption in addition to viscous dissipation on "MHD free convective flow of Casson fluid model". The solution of nondimensional governing equations was accomplished by using several regular perturbation laws. Finally, draw the conclusion that an increase in Eckert number causes an increase in velocity, but that temperature had the opposite effects. Additionally, "Sherwood number" decreased as chemical reaction and "Schmidt number" get increased. However, when the "Casson fluid and thermal radiation" parameters get increased, velocity and temperature get decreased [49]. The study of radiation absorption on an unstable MHD free convection Casson fluid flow via an arbitrarily infinite vertical plate through porous media in the presence of thermal radiation and a thermal source/sink is the prime focus for the paper by S. Ramalingeswara Rao et al., 2020. Using the Laplace transform method, the dimensionless equations are regulated and are analytically resolved. The analytical findings are numerically evaluated, and the graphical findings for the velocity, temperature, and concentration profiles inside the boundary layer are shown. Additionally, for various values of the governing parameters, the mathematical representation of the "Skin-friction coefficient, Nusselt number, and Sherwood number" have been calculated and discussed [50].

Vijayaragavan et al., 2018 investigated the impact of heat radiation, Dufour effects, and Hall current on a chemically reactive MHD Casson fluid flow. The perturbation approach is used to resolve this issue for the velocity, temperature, and concentration species. The impacts of numerous physical factors, such as the "Schmidt number, Grash-of-number, Prandtl number, Dufour parameter, Hall current parameter, radiation parameter, and Casson parameter", are also thoroughly examined. [51]. The effects of Dufour, radiation absorption, chemical reaction, and viscous dissipation on the "flow of MHD free convective Casson fluid" with indefinitely perpendicular pulsating porous plate which dependent on time permeability with "Hall as well as Ion-Slip Current" were studied by Rajakumar et al. in 2018. In order to solve the mathematical expression, numerous regular perturbation laws are used. The effects of various factors on the velocity, temperature, and concentration fields are also investigated, and a manifestation for the skin friction, Nusselt number, and Sherwood number profiles was completed. It was discovered that when the Dufour effect and thermal radiation grow, both velocity and temperature rise. However, when both chemical processes increase, the concentration falls (Schmidt number) [52].

C. Venkata Ramudu and colleagues sought to emphasise the effects of "MHD Casson fluid flow" on a convective surface while taking into consideration cross diffusion, chemical reaction, and non-linear radiative heat. Difusive boundary conditions and convection are considered. After using similarity variables, the ODEs are initially solved using the RK-4 and Shooting technique. Decrease temperature

and appreciate concentration are shown with an increase in the Sorret number, but a negative effect is seen with the Dufour number. When the non-linear radiative parameter is intensified, Nusselt number decreases and Sherwood number increases [53]. The impacts resulting from chemical action, radiation, Dufour effects, and Soret effects on “Casson MHD fluid flow” were examined by Reddy et al. in 2017. On a vertical plate with a thermally constant velocity, changing temperature, and concentration, he examined it. The governing expressions are resolved using the finite difference approach. When several known factors on the fields of velocity, temperature, and concentration are increased, it is discovered that velocity decreases. With a drop in Soret number and an increase in chemical parameter, concentration was determined to be declining. When thermal radiation increased and the heat source diminished, temperature fell [54].

Vijayaragavana et.al., 2021 studied the transient state convection in the flow of “MHD Casson fluid” over an inclined layer. Dufour effects and heat suction/injection through the use of porous media are also taken into account while analysing the impact of a magnetic field. When resolving mathematical expressions, the Laplace transformation method is applied. The formulas for the Nusselt number and Sherwood number are also planned utilizing the specific fluid temperature and species concentration. The axial velocity is shown to decrease with an rise in the Dufour number, and it is also reported that the species concentration falls with an in the Dufour number. As the suction parameter increases in all instances of cooling and heating the porous inclined plate, the velocity falls [55].

The “MHD mixed convection flow of Casson fluid” across a vertical plate has been simulated in the presence of the Cross-diffusion effect as well as nonlinear thermal radiation, according to K. Ganesh Kumar et al.’s 2018 research. The mathematical equations are normalized using “similarity transformation together with Runge-Kutta-Fehlberg forth-fifth order.” Additionally, it is discovered that the influence of the Dufour and Soret parameter raises the component’s temperature and concentration in accordance [56]. CP Kumaret.al., 2021 obtained analytical solution of thermal diffusion and diffusion thermo effects on “MHD Casson fluid flow”. It is examined using a porous media in an oscillating inclined plate with a magnetic field to determine its chemical response. Closed form equations are solved using the perturbation method. Due to the fact that the Casson parameter is discovered to be inversely related to yield stress, for large values of the Casson parameter, the fluid is nearer to the “Newtonian fluid” where the velocity is lower than the “non-Newtonian fluid”. A rise in the mass “buoyancy force” is caused by an intensification of Soret number values, which raises the velocity value. [57].

The effects of thermophoresis and soret-dufour on the “flow of MHD non-Newtonian nanofluid” for heat and mass transfer across an inclined plate were investigated by Idowu et al., 2020. In order to solve the modelled equations, a brand-new and precise numerical technique known as the “Spectral Homotopy Analysis Method” (SHAM) was employed. SHAM is a numerical representation of the HAM method. The nonlinear equations must be divided into linear and nonlinear equations. The Chebyshev pseudospectral approach was used to solve the decomposed linear equations. The results showed that the magnetic field which applied produces an opposing force that causes an electrically conducting fluid’s velocity to slow down. The rate of heat and mass transmission is decreased and the

skin friction factor is increased as the non-Newtonian Casson fluid parameter rises [58]. In the presence of a non-uniform magnetic field, Das, 2021 investigates the numerically heating and mass transport on “mixed convective Casson fluid flow” across an inclined plate. Considerations are made for the effects of thermal radiation, viscous dissipation, and Joule heating. PDE is solved using the MATLAB bvp4c technique, and the results are obtained [59].

“Galerkin weighted residual finite element” technique is used to numerically study forced convection of pulsing nanofluid flowing over the curved parallel plate in the presence of slanted magnetic field by Selimefendigil et al., 2019. Analysis is done on the effects of several such parameters on the convective heat transfer characteristics, including the “Reynolds number (between 100 and 500), Hartmann number (between 0 and 15), magnetic inclination angle (between 0° and 90°)” and many more. It has been found that raising a nanoparticle’s “Reynolds number, Hartmann number, magnetic inclination angle” and volume proportion of solid particles improves heat transmission, however in the steady flow situation, corrugation wave parameters have the opposite effect. The heated plate’s with many blocks where each contribute significantly to the total rate of heat transmission, and the impact of the height of the blocks on the distribution of the effects is impressive. The corrugated plate’s heated blocks’ vortices are redistributed by the magnetic field, which also improves heat transmission in both steady-state and pulsing flow [60].

Anusha et al. examined the “Casson fluid” inconsistently moving through a permeable flattened surface where an angled magnetic field and thermal radiation were present. By using the appropriate “similarity transformation, the law of conservation of mass, conservation of momentum”, and heat equations are non-dimensionally inserted into the system of nonlinear ODEs. For velocity, a precise analytical answer is attained. The energy equation, which is an equation of variation with variable coefficients in the presence of an angled magnetic field and radiation, is changed into an incomplete gamma function by adding an additional parameter and applying the “Rosseland approximation” to the radiation. Utilising HNF results in improved pressure drop and heat transmission. Additionally, the stretched sheet’s mass suction and MHD cause the coefficient of skin friction to rise as the rate of heat transmission declines. The findings might be used in liquid-based systems that use flexible materials in technology. [61].

The goal of Tharapatla et al., 2021 study is to use a numerical method to analyse heat and mass transport of “MHD non-Newtonian fluids” flowing through a slanted thermally stratified porous plate. Here, “similarity transformation” is used to produce linked non-linear equations. The non-linear open convection-enhanced term, thermal radiation, nanofluids, and Soret-Dufour effects are all included for the flow equations. The mathematical problems are solved using “SHAM and the spectral relaxation method simply known as SRM”. It is discovered that the velocity profile’s increases as the temperature and concentration parameter increases similarly the thermal radiation’s value also rises, as both the velocity and temperature are elevated. It was discovered that with Lorentz force the applied magnetic field retard the fluid velocity [62]. The goal of Falodun et al., 2022 is to use spectral collocation and statistical analysis to undertake research on “MHD Casson-Williamson nanofluids flow” across a sloped plate under the impact of heat radiation and Soret-Dufour processes.

The converted equations were subjected to a numerical and statistical analysis in order to determine the significant impacts of the flow parameters on the distributions of velocity, temperature, and concentration. The temperature of the fluid, its thermal condition and thickness of boundary layer with respect to its thermal property are found to rise when the value of thermal radiation increases. It was found that a higher value of the magnetic parameter caused a reduction in fluid velocity. The hydrodynamic boundary layer was seen to decrease when the “Casson parameter” increased as a result of the magnetic field and the dynamic plastic viscosity [63].

The mathematical model of the convective circumstances on a “Casson fluid” through a Paraboloid of Revolution (PR) with different parameters, such as “magnetic field parameter, Soret, and Dufour” was examined by Raju et al., 2018. For the profiles of velocity, temperature, and concentration, all the modified governing equations are solved using the “R-K-Felhberg-integration scheme-based shooting technique” and the emergence of intriguing parameters is evaluated for ‘n’ with various values such as “0, 0.5, and 1”. It is discovered that none of these three situations are uniform. For all three examples, it is seen that cross-diffusion aids in the regulation of the thermal, diffusion, and momentum boundary layers. In order to better understand the thermal and mass transportation processes, it is concluded that the mixed convection method is effective [64]. The “MHD stagnation point Casson nanofluid flow” towards stretched surface with velocity slip and convective boundary condition was researched by Thirupathi et al., 2021. They also additionally included the thermal effects of radiation, dissipation due to its viscous behaviour, source of heat, and chemical reaction for this analysis. The “similarity transformation process” is used to yield ODEs, and the outcome is obtained using the “shooting technique” and “Adams-Moulton method of order four.” [65].

On a convective heated stretched sheet, Razaa et al., 2019 investigate the combined impact of radiation from the heat source and slip in velocity. And also close-by stagnation point the NHD impact is also taken into account for this analysis. It shows that thickness of boundary layer concentration width reduces with rising Schmidt number values and grows with increasing chemical reaction parameter. All the ODEs in this analysis are solved using the “Runge-Kutta-Fehlberg method” [66]. In the context of advancements in heat and mass transfer, Rasoola et al., 2020 explore the properties of “Casson type nanofluid” allowed to flow over a porous media across non-linear stretching surface. The Darcy-Forchheimer relation allows an incompressible viscous nanofluid of the Casson type to flow through the specified porous material. They also include slip boundary conditions for this analysis. The thermo-physical properties of the nanofluid are enhanced by an “induced magnetic field” effect. For practical validity, the model includes the formulations for boundary layers as well as modest magnetic Reynolds. The system is numerically solved using the RK-4 technique. Results show that the resistance provided by porous media to fluid flow and the strength of the inertial impact both decrease the momentum boundary layer. The “Brownian motion factor and thermophoresis” are discovered to have a progressive relationship with temperature. For an insignificant rise in slip parameter values, the level of “wall drag factor, heat transfer, and mass transfer rates” shows a decline [67].

Salahuddin et al.’s 2020 study of rotating viscoelastic fluid flow with convective boundary conditions

looks at the steady-state three-dimensional momentum as well as the change in internal energy. While assuming a “Casson fluid model” for temperature-dependent viscosity, the fluid’s velocity is changed exponentially over an exponential three-dimensional surface. It has been discovered that when the local rotation parameter rises, the minimum force needed to start the fluid motion also increases. The velocity profile shows an oddly oscillating pattern for a nominal increase in local rotation parameter. The “viscosity parameter” and the “Casson fluid” have a negative impact on the temperature profile [68].

Sohail et al., 2020 emphasise the importance of energy from radiation and Joule heating impacts while analysing the influence of momentum, entropy production, species, and thermal dispersion on “Casson liquid boundary layer flow (BLF)” across a linearly elongating surface. The model which depends on temperature of mass diffusion coefficient and thermal conductivity are used to provide transportation of both species and heat. ODEs are acquired using OHAM methods. By contrasting the findings, reliability and efficacy of the expected algorithm are determined. It is concluded that a drop in fluid velocity and an improvement in transportation of thermal and species are seen in relation to changing values of the “Hartman number”. Additionally, the reversal behaviour of the “Prandtl number and radiation parameter” is also shown. Additionally, it is said that adding values to the magnetic parameter causes the fluid velocity to condense and the temperature and concentration distributions to increase [69].

A comparison study on the heat transfer properties of an “unstable two-dimensional Casson fluid” squeezing flow across “parallel circular plates ” was proposed by Jasim et al. in 2019. A differential equation’s nth order integration yields coefficients of powers series, which are used in this suggested model’s analysis. Nonlinear ODEs are generated using similarity transformations, and RK-4 is utilized to get the numerical solution. As a result of the investigation, it is found that the temperature distribution reduces as the “Casson fluid” number grows; while the velocity distribution increases. Additionally, it is discovered that as the “Prandtl number and Eckert number” rise, so does the temperature distribution [70].

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