



Research Article

Effects of Magnetized Casson Fluid in the Dynamics of Superhydrophobic Microchannel Flow with Wall Porosity and Asymmetric Wall Heating

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Abstract

This study investigates the magnetohydrodynamic (MHD) flow of a Casson fluid (a non-Newtonian liquid that flows only after a specific yield stress is met) through a superhydrophobic microchannel (a microscopic flow passage with extreme water-repelling walls that create high boundary slip). We analyze the combined physical effects of external magnetic fields, wall suction (drawing fluid inward), and injection (pushing fluid outward) on velocity and temperature profiles. The exact solution of the resultant governing equations is obtained. Particular attention is paid to how variations in the Casson parameter alter the yield stress, flow velocity profiles, and momentum boundary layer thickness. The results show that increasing the Casson parameter increases yield stress and internal resistance, leading to a pronounced reduction in fluid velocity across the microchannel. Furthermore, contrasting the suction and injection parameters reveals that suction stabilizes the boundary layer and suppresses velocity distribution, whereas injection enhances flow displacement near the superhydrophobic walls. The findings provide critical insights for optimizing microfluidic devices, drag-reduction systems, and smart biomedical transport mechanisms.

Keywords: Casson Fluid parameter, Magnetohydrodynamics (MHD), Suction/injection, Superhydrophobic Surface, Microchannel

Received: 15 June 2026

Accepted: 12 September 2026

Introduction

Non-Newtonian fluids offer significant benefits to researchers and engineers due to their complex behavior and widespread applications in engineering, industry, and everyday life (Kataria and Mittal 2017, Sheikholeslammi *et al.* 2017, Patel *et al.* 2019, Mittal and Patel 2020, Mittal *et al.* 2019). Their rheological properties are so diverse that they have to be classified into many groups (Mittal *et al.* 2024). With the development of numerous models, the simulation of viscoelastic fluid dynamics has become more accurate. Because of their high viscosity and nonlinear rheological behavior, non-Newtonian fluids are often processed in laminar flow conditions to ensure stability and predictability. The Casson model, a non-Newtonian fluid model, accurately describes the behavior of viscoelastic materials with shear-thinning properties. This model, which connects shear stress to shear rate, is widely used in a variety of industrial processes involving complicated fluids such as food products (e.g., yogurt, tomato paste), biological substances, and materials treated at numerous stages in manufacturing plants. Casson-type fluids are also used in systems like printing inks, dispensing devices, and paints, where flow behavior is heavily impacted by shear conditions. At low shear rates, these fluids have lower flow velocities, making pseudoplasticity undesirable in particular situations. Among numerous viscoelastic models, the Casson fluid is widely regarded as more dependable because of its congruence with experimental data. It has been used to mimic physiological fluxes, such as blood circulation, demonstrating its importance in biological situations (Ullah *et al.* 2016). Casson originally developed the model while researching pigment mixtures in silicon interruptions and printing inks. Since then, its adaptability has drawn substantial attention from both the scientific and industrial worlds (Ullah *et al.*, 2017). Some notable studies, such as Amaraikannan *et al.* (2021a), Shahzad *et al.* (2021), Amaraikannan *et al.* (2021b), and Ali *et al.* (2021), provide valuable insights to readers on this topic. Hamza *et al.* (2024c) also gave analytical solutions for viscous Casson fluid with heat absorption impacted by uniform wall temperature and concentration conditions using the differential transform method. In addition, Nandeppanavar (2018) described the movement of Casson fluid through a moving plate. Sheikh *et al.* (2020) have presented a study on the implications of the flow of a non-Newtonian fluid across a moving sheet. In addition, Usman and Sanusi (2023) analyzed the MHD flow of Casson nanofluid past a semi-infinite plate embedded in a porous medium under thermal radiation, Soret, and pressure effects, and found that the rate of heat transfer was higher for copper nanoparticles than for titanium oxide, owing to copper's superior thermal conductivity. Ahmad *et al.* (2019) introduced a novel approach to modelling a Casson fluid with fractional derivatives in another study. Further, Sarkar *et al.* (2020), Hamid *et al.* (2019), Das *et al.* (2021), Amjad *et al.* (2021), and Sarkar and

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ISSN: 3043-6087. Science and Education Development Inst., Nigeria

Endalew (2020) have published the flow behavior of the Casson fluid in various physical settings.

Suction and/or injection occur when fluid leaks through pores or gaps in a plane surface or channel wall. Mishra *et al.* (2002), Chaudhary and Jain (2007), and Khalid et al. (2015) provide examples of the phenomenon. Suction/injection is important in boundary layer control, especially in engineering, aerodynamics, space exploration, and medicine. These applications piqued our interest in investigating the role of suction/injection in various types of fluids. In horizontal channel flows of incompressible fluids, the Lorentz force may be used instead of pump pressure to accelerate the channel liquid further or faster. An MHD micropump is a system that uses magnetohydrodynamic (MHD) propulsion. (Jha and Gwandu, 2020). The effects of suction/injection have been described. To this objective, Jha et al. (2022) employed the Laplace transform method to investigate the influence of suction or injection on steady free convection in a vertical channel caused by point or line heat generation or absorption effects. Usman *et al.* (2023) explored the effects of injection/suction on MHD's unsteady natural convection radiative flow of heat and mass transfer with high frequency. The governing partial differential equations are converted to non-dimensional forms before being numerically solved with Crank-Nicolson's efficient, implicit, iterative method. They discovered that increasing injection values causes the temperature profile to rise, whereas increasing suction parameter values causes it to drop. Saeid (2006) conducted a numerical study of free convection flow in a vertical porous layer created by bi-thermal sources. In the presence of a suction effect, raising the temperature of the top element increases heat transfer to the lower element. In another study, Uwanta *et al.* (2014) investigated the effect of suction/injection on hydro-magnetic natural convection flow on vertical plates. It has been discovered that suction or injection can be utilized to regulate fluid flow in the channel. According to Jha *et al.* (2015), increased suction/injection raises the wall-ambient temperature difference, reducing convection in microchannels. Furthermore, Jha *et al.* (2018) explored the impact of suction/injection on natural convection flow in transient magnetohydrodynamics. During chemical processes, suction can be employed to remove reactants and injection to introduce them. Falade *et al.* (2017) investigated how suction and injection influence transient oscillatory magnetohydrodynamic flow. It is important to note that injecting fluid onto the heated surface leads to an increase in skin friction within the channel. Additionally, Jha *et al.* (2019) examined the impact of suction and injection on hydro-magnetic free convection flow. Their findings revealed that an increase in velocity results in a decrease in injection parameters. Furthermore, as shear stress rises, the suction parameters also increase.

The development of microfluidic systems and advanced cooling technologies has

increasingly relied on the manipulation of fluid flow and heat transfer at the microscale. Microfluidics has evolved immensely over the past decade as a consequence of its various applications in material manufacturing, micro-energy pipes, space technology, micro-jet boundary layer cooling, high-performance computing, high-power density transistors, and other devices. Because most of these simulations contain internal micro-channel transport, a sound knowledge of the flow features has become critical for correct flow projections and conceptualization (Jha and Gwandu 2018, Jha *et al.* 2014). In this context, superhydrophobic surfaces that exhibit ultra-repellent properties have become highly relevant due to their ability to reduce drag and modify fluid dynamics in microchannels. Also, the study of heat transfer in superhydrophobic microchannels has garnered significant attention due to their potential applications in microfluidics, thermal management, and energy systems. Several outstanding scholars have greatly contributed to the studies of different effects in microchannels influenced by a superhydrophobic surface (SHS). In view of this, Ibrahim and Ojemeru (2026) recently semi-analytically studied the impact of a non-Newtonian fluid in a microchannel in the presence of viscous dissipation and a magnetic field effect. They concluded from their results that increasing the Jeffrey fluid parameter (which represents the viscoelasticity of the fluid) weakens the velocity gradient, as a result of the fluid resisting deformation more strongly on superhydrophobic surfaces. Hamza *et al.* (2026) investigated the impact of magnetized free flow in a viscous, dissipative, porous fluid in a slit microchannel using the regular perturbation method. Omokhuale *et al.* (2025) recently demonstrated how Arrhenius-controlled heat and mass transfer flow over a superhydrophobic microchannel with a uniform wall concentration is influenced by mixed convection under a constant pressure gradient. While the other parallel plate has a no-slip surface (NSS), one of the plates is purposefully altered to have a superhydrophobic surface (SHS). Hamza *et al.* (2024a, 2024b) reported the influence of electrokinetic effects on free and mixed convection flows in SHO microchannels and the temperature jump scenario. It is concluded from their computational analysis that the function of the SHS and electrokinetic effects is to enhance the fluid velocity in the microchannel. Ojemeru *et al.* (2024) studied the impact of a heat-generating/absorbing fluid on Arrhenius-controlled heat flow in an SHO-heated microchannel using a regular perturbation approach. Yale *et al.* (2023) investigated the impacts of super-hydrophobicity and MHD on a viscous dissipative fluid in a slit microchannel coated with a superhydrophobic surface using a regular perturbation approach. Sharma *et al.* (2020) presented a mathematical model describing pressure-induced flow across a microchannel with textured SHS under constant heat flux. Other interesting research with different thermal boundary conditions in the presence of SHS can be seen in these references (Sia *et al.* (2023), Heidarian *et al.* (2020), and Zhang *et al.* (2019).

Although the mathematical model proposed by Jha and Gwandu (2020) examined the effects of a magnetic field and wall porosity on free convection in a superhydrophobic microchannel, it contains fundamental knowledge gaps that call for extension. They assumed the fluid was entirely Newtonian (having a constant viscosity regardless of stress). This completely omitted non-Newtonian behaviors like yield stress and shear-thinning properties, which are needed to extend the model to real-world biofluids (such as blood) or industrial polymers in microchannels that behave like Casson fluids, requiring a rheological parameter to account for plastic viscosity and yield-stress thresholds. In view of these limitations found in the literature, the model of Jha and Gwandu (2020) is modified to incorporate the Casson fluid effect. This upgraded model presents a unique study that significantly bridges the gap between theoretical magnetohydrodynamics (MHD) and practical micro-engineering applications. Introducing the Casson yield stress parameter alters the velocity profile. Unlike Newtonian fluids, the non-Newtonian Casson fluid requires a threshold shear stress to flow, resulting in a flatter velocity core in the middle of the microchannel and thinner velocity boundary layers near the superhydrophobic walls. Because blood, plasma, and many biological fluids exhibit Casson non-Newtonian traits, this model accurately simulates how microfluidic diagnostic chips handle real patient samples under electromagnetic fields, improving targeted cell separation.

Problem Formulation and Description

Consider an electrically conducting fluid moving steadily upward through a vertical parallel-plate microchannel by convection through heating one of the plates at a time. One of the surfaces is extremely difficult to wet (superhydrophobic) as a result of a special micro-engineering treatment. The other side (no-slip surface) was unaltered. The superhydrophobic surface is kept at a position $y_0 = 0$ while the no-slip surface is at $y_0 = L$, as shown in Figure 1. Different temperature jumps and slips conditions were used for the different plates. The following assumptions were considered in the present research work:

- i. The fluid is laminar, incompressible, and fully developed.
- ii. A magnetic field of uniform strength B_0 is assumed to be applied in the direction perpendicular to the direction of flow.
- iii. It is assumed that one of the surfaces is extremely difficult to wet (superhydrophobic)
- iv. The fluid is believed to be injected and sucked at a constant pace in the microchannel.
- v. It is assumed that there is asymmetric heating of the plates, with one at T_0 and the other at T_h .

- vi. The temperature differential between plates leads to spontaneous convection flow in the microchannel.
- vii. The flow will be considered in terms of the Casson fluid effect.

Following Jha and Gwandu (2020) and invoking the Boussinesq buoyancy approximation, the controlling equations for the present problem in dimensional form can be as follows:

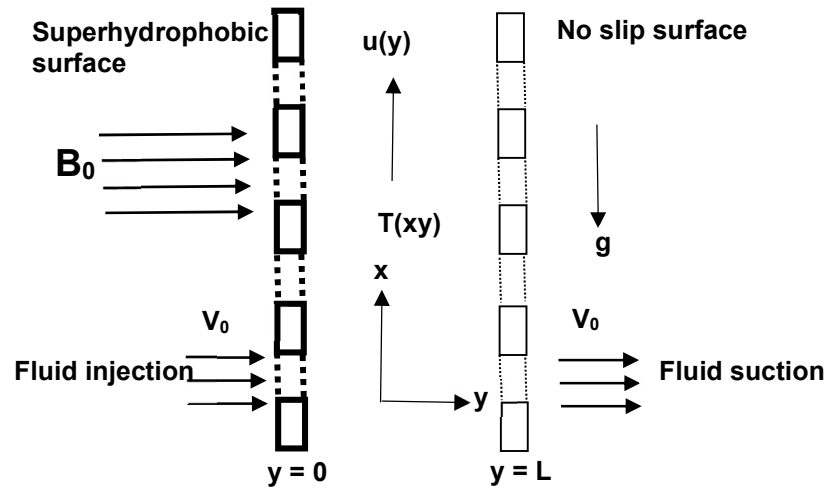


Figure 1: Physical Flow configuration

$$V_0 \frac{du'}{dy'} = \nu \left(1 + \frac{1}{\beta}\right) \frac{d^2 u'}{dy'^2} + g\beta(T' - T_0) - \frac{\sigma B_0^2 u'}{\rho} \quad (1)$$

$$V_0 \frac{dT'}{dy'} = \frac{k}{\rho c_p} \frac{d^2 T'}{dy'^2} \quad (2)$$

The appropriate boundary conditions at the walls are:

$$\left. \begin{aligned} T(y) &= T_0 + A(T_h - T_0) + \gamma' \frac{dT'}{dy} \\ u(y) &= \lambda' \frac{du'}{dy} \end{aligned} \right\} \text{ at } y = 0 \quad (3)$$

$$\left. \begin{aligned} T(y) &= T_0 + B(T_h - T_0) \\ u(y) &= 0 \end{aligned} \right\} \text{ at } y = 1 \quad (4)$$

We employ the dimensionless quantities and parameters:

$$u = \frac{u'}{U}, y = \frac{y'}{h}, \theta = \frac{T' - T_0}{T_w - T_0}, x = \frac{x'v}{Uh^2}, S = \frac{V_0 L}{v}, \xi = \frac{\xi^1}{h}, \quad (5)$$

$$M^2 = \frac{\alpha \beta_0^2 h^2}{\rho \nu}, (Y, \gamma, \lambda) = \frac{Y', \gamma', \lambda'}{h}, \text{Pr} = \frac{\rho c_p v}{k}, \lambda = \frac{\lambda'}{h}, \gamma = \frac{\gamma'}{h},$$

Inserting eqn (5) into eqns (1-4), we have the basic governing equations as:

$$\left(1 + \frac{1}{\xi}\right) \frac{d^2 u}{dy^2} - S \frac{du}{dy} - M^2 u + \theta = 0 \quad (6)$$

$$\frac{d^2 \theta}{dy^2} - SPr \frac{d\theta}{dy} = 0 \quad (7)$$

The boundary conditions in dimensionless forms are:

$$\left. \begin{aligned} \theta(y) &= A + \gamma \frac{d\theta}{dy}, \quad u(y) = \lambda \frac{du}{dy} \quad \text{at } y = 0 \\ \theta(y) &= B, \quad u(y) = 0 \quad \text{at } y = 1 \end{aligned} \right\} \quad (8)$$

Where ξ is the Casson fluid parameter, M is the magnetic field intensity, S is the suction/injection parameter, γ is the temperature jump coefficient and λ is the velocity slip condition.

This study is divided into two cases:

Case I ($A = 1, B = 0$) is when the superhydrophobic surface is heated.

Case II ($A = 0, B = 1$) is when the no-slip surface is heated.

Exact Solution

The governing equations are a system of ordinary differential equations with constant coefficients. The system of linear ordinary differential equations has been determined in closed form by the theory of simultaneous ordinary differential equations. The steady-state velocity and temperature have been obtained as:

$$U(y) = F_1 e^{k_1 y} + F_2 e^{-k_2 y} + F_3 + F_4 e^{-m_2 y} \quad (9)$$

$$\theta(y) = W_1 + W_2 e^{-m_2 y} \quad (10)$$

The overall flow rate is found by integrating the velocity across the channel gap width

$$Q_f = \int_0^1 U dy \quad (13)$$

$$Q_f = \frac{F_1}{k_1} e^{k_1} - \frac{F_2}{k_2} e^{-k_2} + F_3 - \frac{F_4}{m_2} e^{-m_2} - \frac{F_1}{k_1} + \frac{F_2}{k_2} + \frac{F_4}{m_2} \quad (14)$$

The skin friction and Nusselt number is also obtained as

$$\tau_0 = \frac{du}{dy} = m_3 Z_1 - m_4 Z_2 + m_2 Z_4 \quad (15)$$

$$\tau_1 = \frac{du}{dy} = m_3 Z_1 e^{m_3} - m_4 Z_2 e^{-m_4} + m_2 Z_4 e^{m_2} \quad (16)$$

$$Nu_0 = \frac{d\theta}{dy} = -m_2 W_2 \quad (17)$$

$$Nu_1 = \frac{d\theta}{dy} = -m_2 W_2 e^{-m_2} \quad (18)$$

Where the constants W_1, W_2, F_1, F_2, F_3 , and F_4 are indicated in the appendix.

Results and Discussion

The effects of MHD Casson fluid flow in natural convection are investigated in the presence of suction and injection along an isothermally heated microchannel. One surface is intentionally equipped with SHO slip conditions and a temperature jump, while the other has no-slip conditions. The exact solutions for velocity, temperature, volumetric flow, as well as skin friction and heat transfer coefficient have been derived. Several illustrative graphs have also been plotted to showcase and discuss the effects of key parameters on the fluid velocity and temperature components for case I (SHS) and case II (NSS). The reference values taken for the present investigation are $\xi = 0.5$, $\lambda = \gamma = 1$, $S = 0.6$, and $M = 1.5$.

Figure 2 describes the relationship between the present work and the previous one for the limiting case. The comparison confirms a strong agreement, indicating the mathematical soundness and accuracy of the present analysis.

The influence of the Casson fluid parameter on the velocity profile for Case I and Case II is plotted in Figure 3 (a and b). From Figure 3a in Case I, the graph indicates that the flow velocity decreases with an increase in the Casson fluid parameter. In Figure 3b, Case II, the graph shows that heating the no-slip surface causes an equivalent reverse flow. That is, the fluid flows backwards at almost the same speed, while maintaining the same effects of the Casson fluid parameter as in the forward flow. Raising the Casson fluid parameter increases the plastic dynamic viscosity of the non-Newtonian liquid relative to its yield stress. As the Casson fluid parameter tends to infinity, the fluid behavior transitions toward a standard Newtonian fluid, flattening the velocity profile discrepancies near the superhydrophobic walls. However, the superhydrophobic slip features counteract this resistance slightly by elevating local slip velocity, but the dominant dampening trend driven by the Casson fluid remains pronounced.

Figure 4(a and b) illustrates how the magnetic parameter affects the fluid velocity in the microchannel. Figure 4a, Case I, shows that an increase in the magnetic parameter reduces the velocity profile, while in Case II (Figure 4b), there is a reverse flow at a faster rate than in Case I. The effect of magnetism on the velocity is still negative (but to a lesser

degree than in Case I). The Lorentz force generated by the transverse magnetic field creates a drag-like body force opposing the fluid motion. Additionally, increasing the magnetic parameter alongside Casson fluid creates a dual-retardation mechanism, sharply reducing fluid velocity and shrinking the momentum boundary layer thickness.

In Figures 5 (a and b) and 6 (a and b), the effects of fluid injection and suction on the temperature profile are demonstrated, respectively, for both case I and case II. For the suction ($S > 0$) effect, fluid is pulled toward the microchannel walls, thinning the momentum boundary layer and accelerating the fluid near the boundary, which partially offsets the retarding effect of a high Casson parameter. On the other hand, for the injection ($S < 0$) effect, fluid is pushed away from the walls, thickening the boundary layer and compounding the flow resistance caused by high Casson fluid parameters. However, in case II of both injection and suction parametric effects, a similar flow pattern is seen but in a backward manner, which is due to the absence of a superhydrophobic surface that aids faster fluid movement, as in the situation in case I.

The impact of Fluid injection and suction is sketched in Figures 7 (a and b) and 8 (a and b). Similarly, the effect of fluid Injection pushes fluid away from the porous wall, introducing extra momentum that accelerates the fluid and raises the velocity profile across the channel, as depicted in Figure 7a. The injected mass expands the velocity boundary layer, increasing overall flow rates. In contrast to Figure 7a, Suction pulls fluid toward or through the porous boundary, removing kinetic energy and suppressing the velocity profile as displayed in Figure 8a. Further, it thins the boundary layer and prevents flow separation or reversal near the walls. Also, a backward flow behavior is recorded for case II of the injection and suction effects, respectively, as seen in Figures 7b and 8b.

Figure 9 (a and b) describes the effect of Casson and magnetic parameters on volume flow rate, respectively. In the presence of the velocity slip effect, Figure 9a shows that rising values of the Casson parameter lower the fluid flow in Case I, while a contrasting effect occurs in Case II. Similarly, as seen in Figure 9b, the magnetic parameter produces the same effect on the volumetric flow as the Casson parameter.

Skin friction coefficients for the influence of Casson and magnetic parameters are drawn in Figures 10-13. Figure 10 (a and b) showcases the effect of the Casson parameter on the drag force for both lower and upper walls in Case I. It is observed that, for rising values of the velocity slip parameter, the presence of Casson fluid increases the skin friction at the lower plate while producing a similar effect for decreasing values of the velocity slip. Conversely, for Case II (Figure 11 (a and b)), a downward trend occurred as the Casson parameter increases, as illustrated in Figure 10a, whereas a reverse effect happens at the

upper wall (Figure 11b).

Figures 12 (a and b) and 13 (a and b) explain the influence of the magnetic parameter on both cases I and II, respectively. It is observed that the function of MHD is to encourage skin friction at the lower plate ($y = 0$), whereas the reverse case occurs at the upper plate ($y=1$) as plotted in Figure 12. On the other hand, an opposite phenomenon is recorded in Case II for an externally applied magnetic parameter for different values of velocity slip conditions.

Overall, an increase in the Casson parameter typically causes a decrease in the fluid velocity profile inside the core region of a microchannel, but its interaction with a superhydrophobic surface creates a unique balancing act that enhances the velocity slip at the walls. In fluid dynamics and microfluidics, studying how unique fluids move inside tiny channels is highly valuable for designing advanced medical devices and cooling systems.

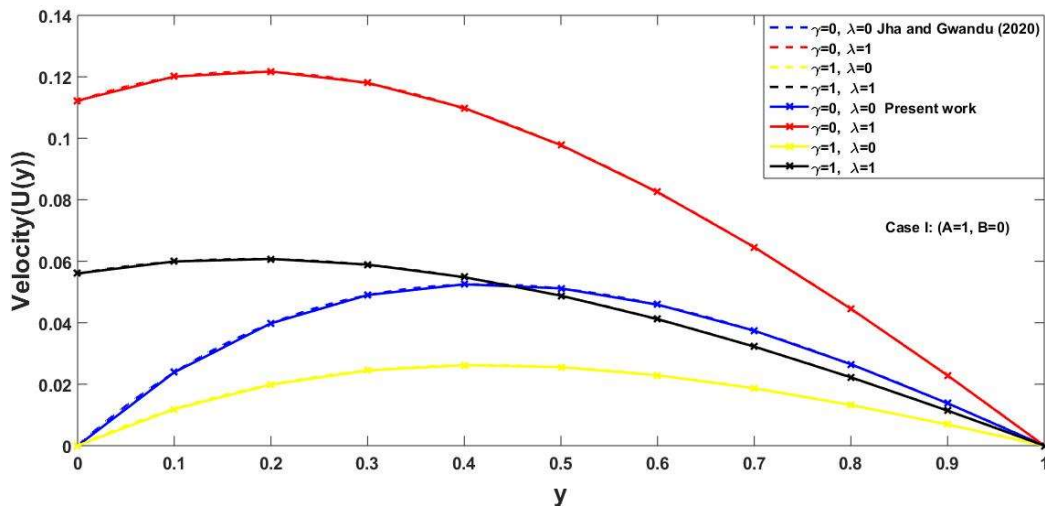


Figure 2: Comparison between the Present work and that of Jha and Gwandu (2020) for the limiting case

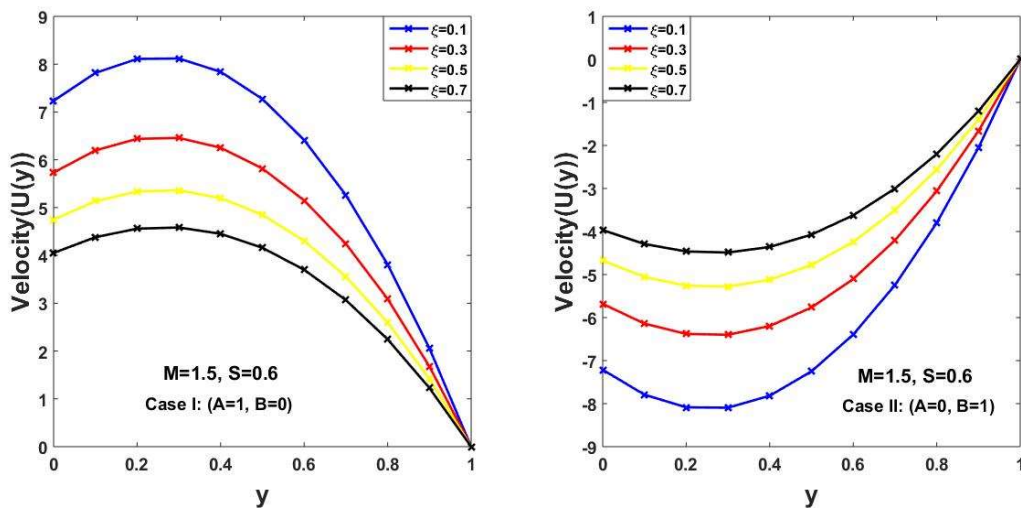


Figure 3: Effect of Casson fluid parameter ξ on Velocity Profile

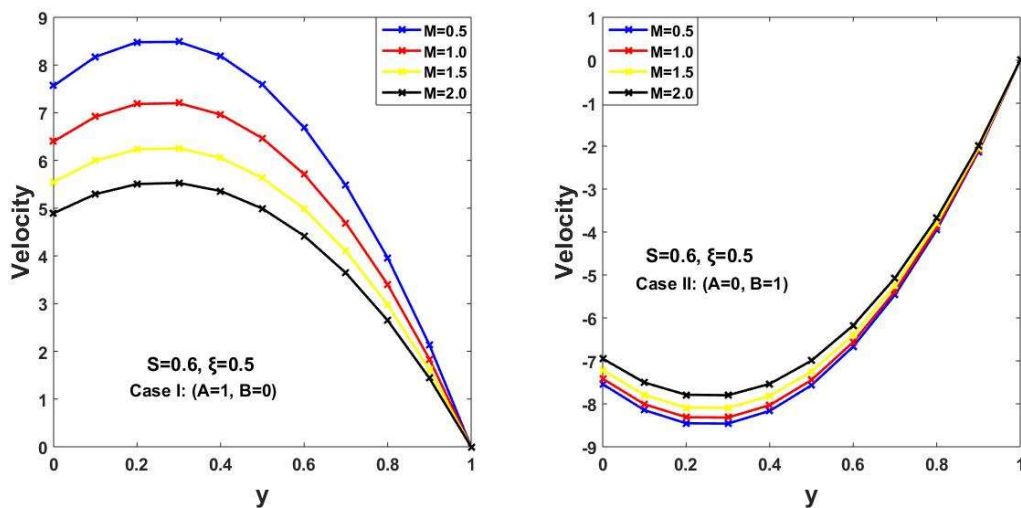


Figure 4: Effect of Magnetic field parameter M on Velocity Profile

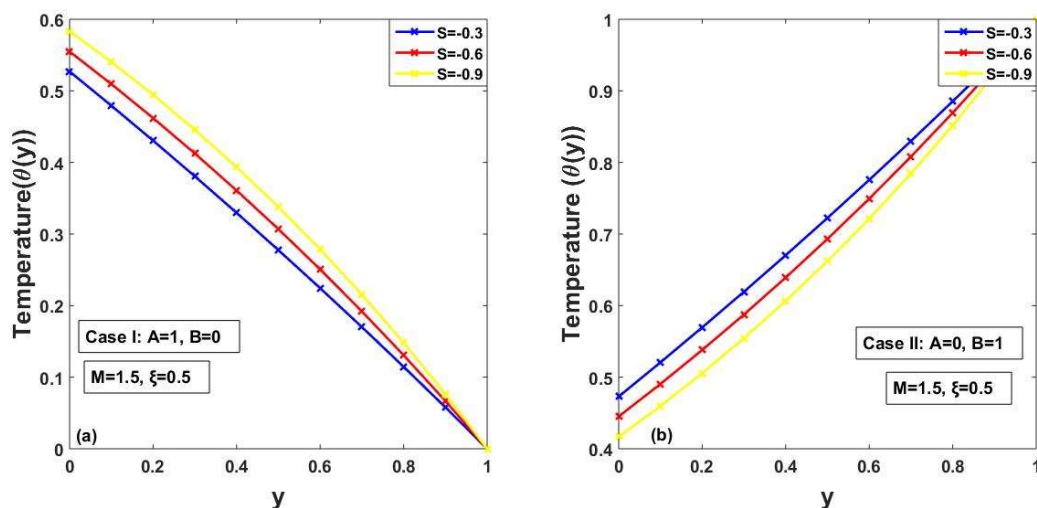


Figure 5: Effect of Injection parameter S on Temperature Profile

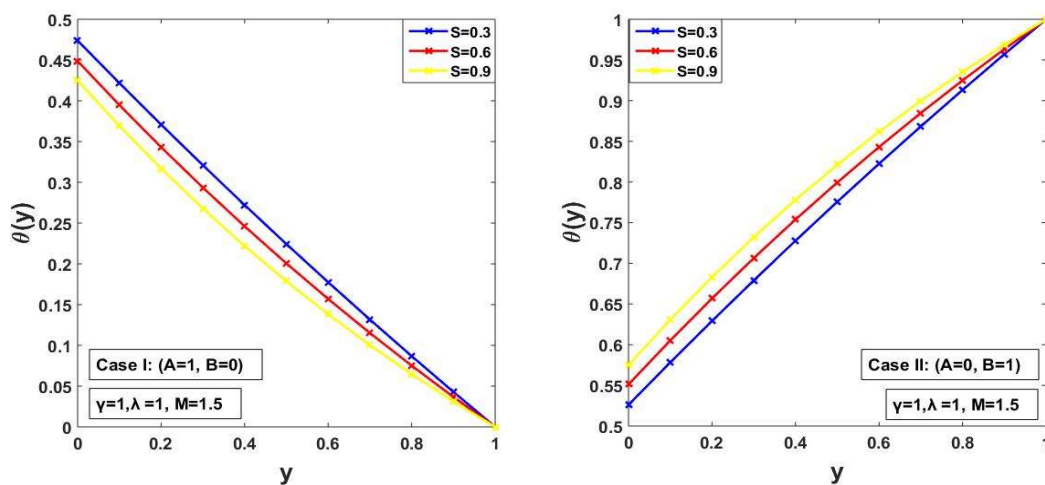


Figure 6: Effect of Suction parameter S on Temperature Profile

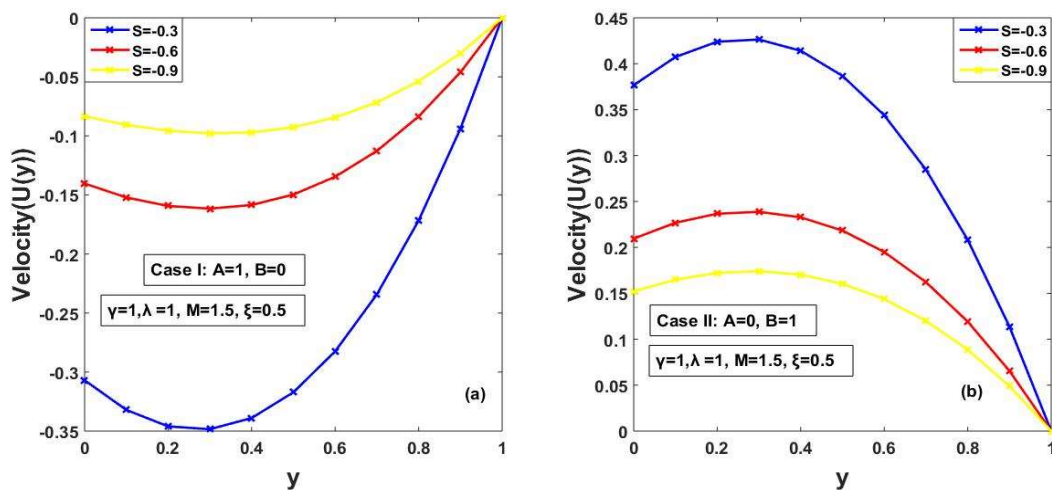


Figure 7: Effect of Injection parameter S on Velocity Profile

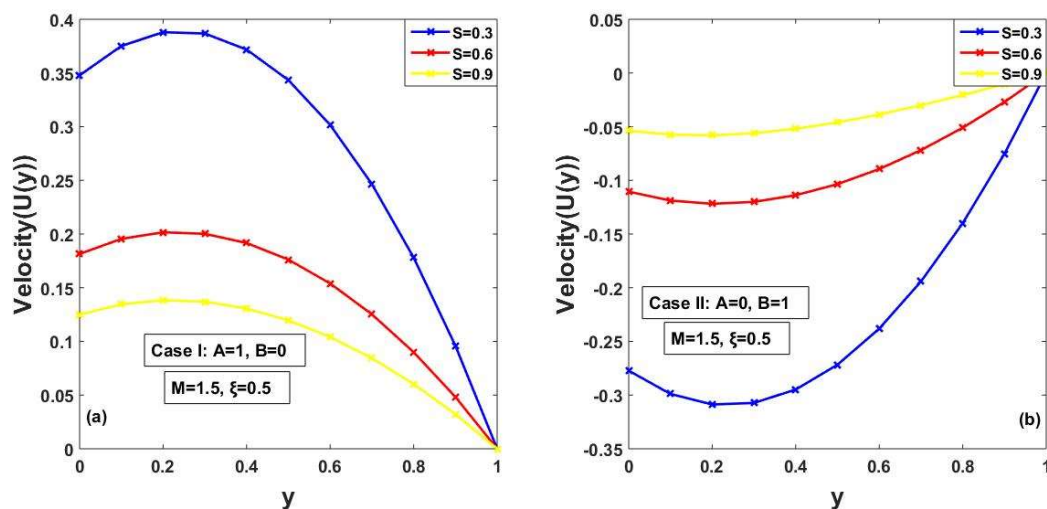


Figure 8: Effect of Suction parameter S on Velocity Profile

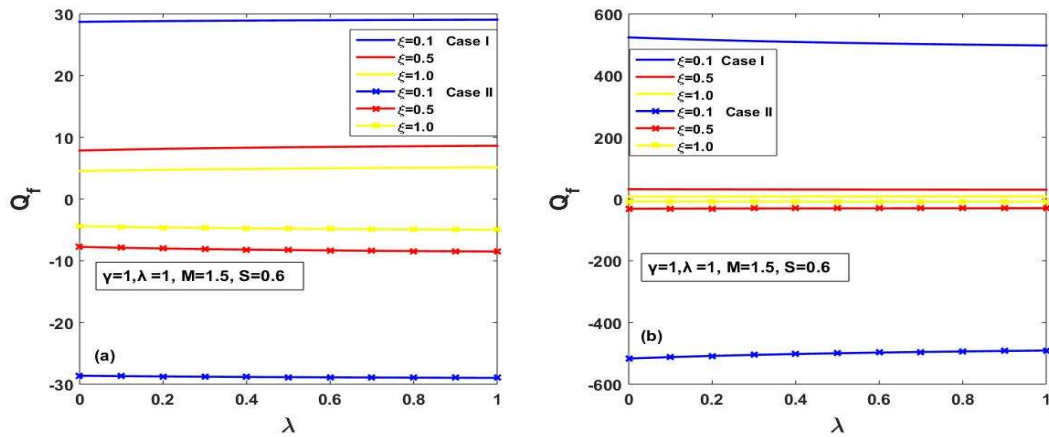


Figure 9: Effects of (a) Casson and (b) Magnetic parameters on Volume Flow Rate

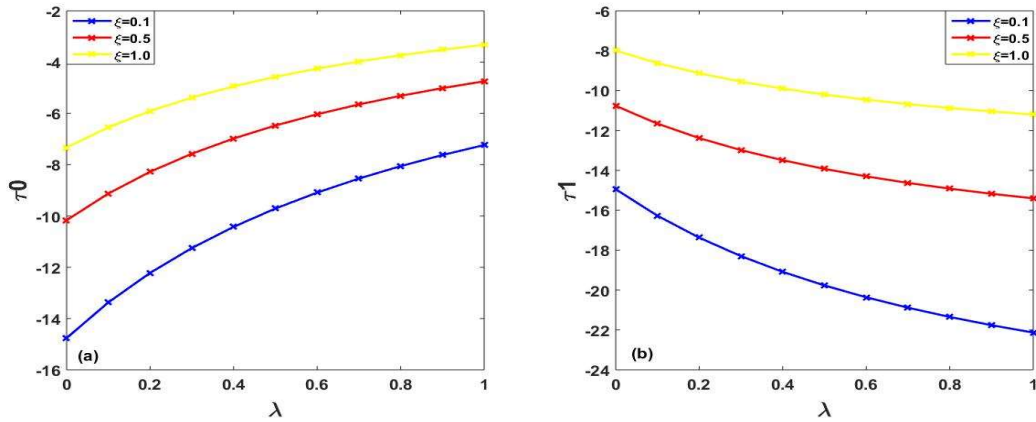


Figure 10: Effects of Casson parameter on Skin friction for (a) lower plate and (b) upper plate) for Case I

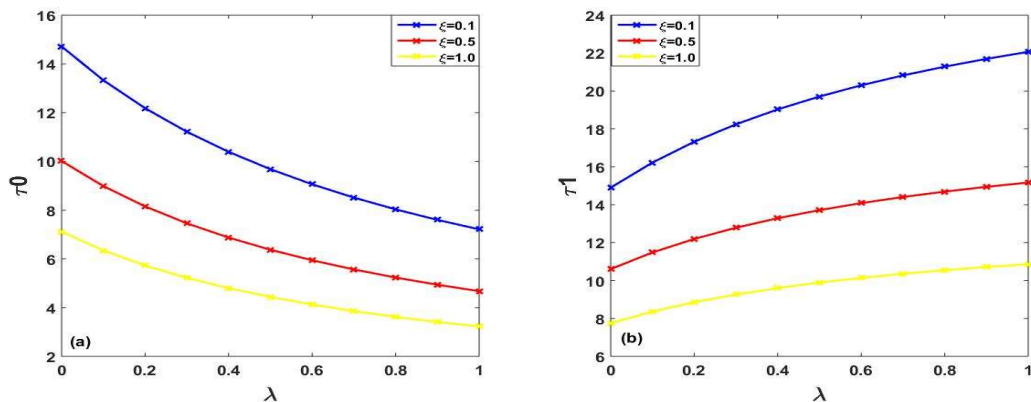


Figure 11: Effects of Casson parameter on Skin friction for (a) lower plate and (b) upper plate) for Case II

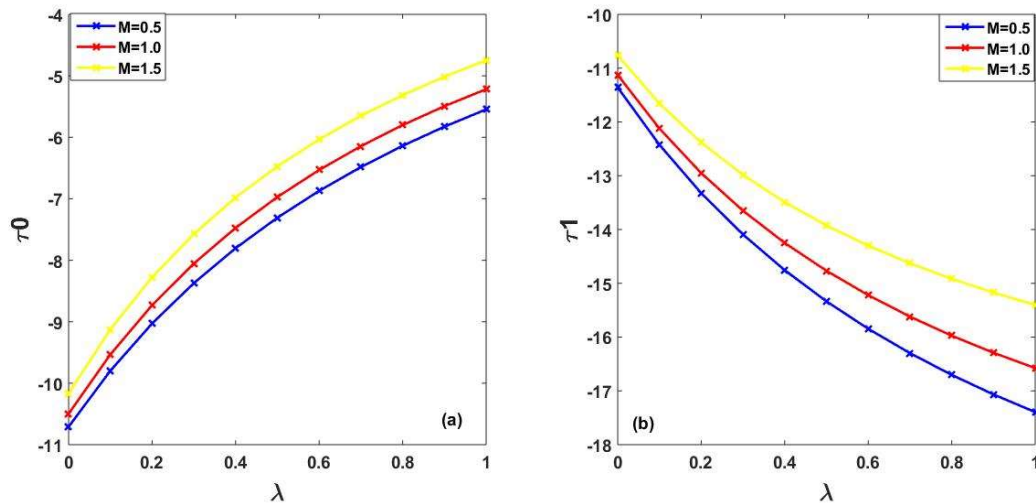


Figure 12: Effects of Magnetic parameter on Skin friction for (a) lower plate and (b) upper plate) for Case I

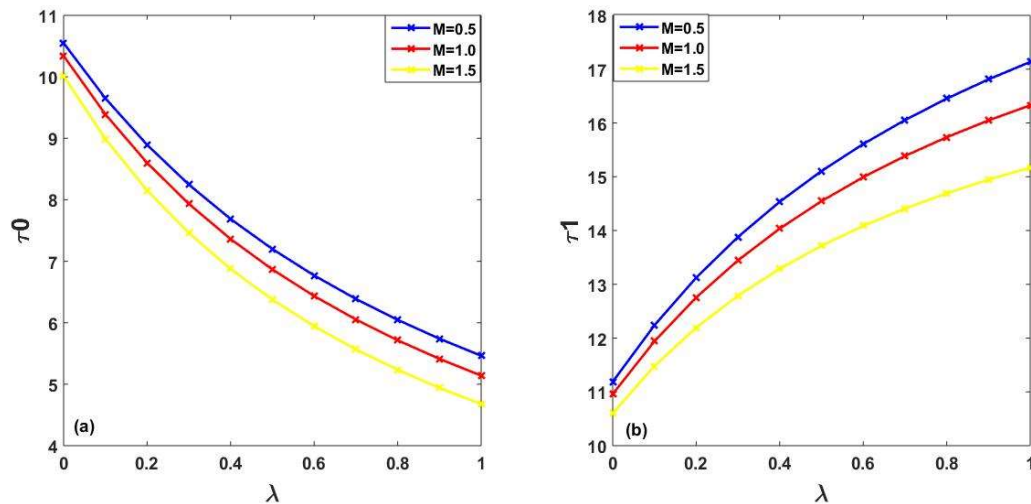


Figure 13: Effects of Magnetic parameter on Skin friction for (a) lower plate and (b) upper plate) for Case II

Conclusion

In this work, the effects of Casson fluid and wall porosity in an MHD free convection flow are investigated via a microchannel controlled by SHO features. A thorough discussion of key parameters controlling the flow, with main emphasis on the Casson fluid effect, is presented. An exact solution of the coupled nonlinear ordinary differential equations describing the velocity and temperature components is achieved. In addition, engineering-related physical factors like the shear stress and the Nusselt number have

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ISSN: 3043-6087. Science and Education Development Inst., Nigeria

been computed. Line graphs are used to illustrate the impact of the main fluid parameters. The yield-stress behavior of Casson fluid acts to resist motion; higher Casson parameter values lower the fluid velocity profile compared to Newtonian fluids. Superhydrophobic slip walls, on the other hand, provide a high effective slip length, which cooperates with injection/suction to drastically reduce overall flow resistance and enhance throughput in microchannel applications. Key findings from this research are outlined below:

- i. Increasing the Casson parameter (which signifies higher plastic dynamic viscosity) generally suppresses core fluid velocity and increases overall flow resistance.
- ii. Suction stabilizes the boundary layer and cools the wall, while injection promotes fluid acceleration.
- iii. The presence of a superhydrophobic surface acts as a counterweight. It ensures that even when the fluid thickens, the microchannel maintains functional flow rates without system clogging.
- iv. Increasing the magnetic parameter directly weakens fluid motion. The Lorentz force drags against the flow direction, which flattens the parabolic velocity profile and lowers the peak speed at the center of the microchannel.
- v. Since the overall velocity profile drops as a result of the Casson parameter, the total volume flow rate through the microchannel decreases.
- vi. Because the magnetic field acts as a drag force, the overall volumetric flow rate of the fluid through the microchannel drops as the magnetic parameter rises.
- vii. When the microchannel walls are heated, a higher magnetic parameter significantly reduces skin friction (frictional drag) on both the superhydrophobic side and the traditional no-slip side.
- viii. Future research will consider the effect of mass transfer with a concentration jump condition.

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Appendix

$$m_2 = SPr, W_1 = \frac{1}{(1-\gamma m_1)}, W_2 = -F_1 e^{-m_2}, k_1 = \frac{\frac{S}{N} + \sqrt{\left(\frac{S}{N}\right)^2 + 4\frac{M^2}{N}}}{2}, k_2 = \frac{-\frac{S}{N} + \sqrt{\left(\frac{S}{N}\right)^2 + 4\frac{M^2}{N}}}{2},$$

$$F_1 = e_4 - F_2 e_5, F_2 = \frac{e_4 e^{k_1} + e_6}{e_5 e^{k_1} - e^{-m_2}}, F_3 = \frac{W_1}{M^2}, F_4 = \frac{-W_2}{(m_2^2 - \frac{S}{N} m_2 - \frac{S}{N} M^2)}, e_1 = 1 - \lambda k_1,$$

$$e_2 = 1 + \lambda k_2, e_3 = -\lambda m_2 F_4 - F_3 - F_4, e_4 = \frac{e_3}{e_1}, e_5 = \frac{e_2}{e_1}$$

Nomenclature

- B_0 = Constant magnetic flux density [kg/s².m²]
 g = Gravitational acceleration [m/s²]
 h = Channel width [m]
 $C_p C_v$ = Specific heats at constant pressure and constant volume [Jkg⁻¹K⁻¹]
 λ = Dimensionless slip length parameter
 γ = Dimensionless temperature jump parameter
 ξ = Casson fluid parameter
 M = Magnetic field
 S = Suction/injection parameter
 Nu = Dimensionless heat transfer rate
 T = Dimensionless temperature of the fluid [K]
 T_0 = Reference temperature [K]
 T_∞^* = The temperature far away from the plate K
 u = Dimensionless velocity of the fluid [ms⁻¹]
 y = Dimensionless distance between plates
 U_0 = Reference velocity [ms⁻¹]
 β = Thermal expansion coefficient [K⁻¹]
 μ = Variable fluid viscosity [kgm⁻¹s⁻¹]
 k = Thermal conductivity [m.kg/s³.K]
 α = Thermal diffusivity [m²s⁻¹]
 σ = Electrical conductivity of the fluid [s³m²/kg]
 ρ = Density of the fluid [kgm⁻³]
 ν = Fluid kinematic viscosity [m²s⁻¹]