1. Introduction

The problem of heat transmission in a thin liquid film flow on a time-dependent stretching sheet has got many applications in various fields, erratic from a meticulous situation of flow in lungs of human beings to problems in lubrication engineering. Also, its significance can be perceived in films of tear in human’s eye, used as a thin layer in bio-physics, varnish of wire, coating streams and fibre, in industrial developments, and in structural and fluid mechanics. Manufacturing of artificial fibres, crystal growing, food stuff processing, manufacturing of plastic fluid and in aerodynamics, and constant casting, rolling and tinning of copper wires are the various renowned uses of liquid films. In the process of extrusion, the extrudate surface quality maintenance is very important. The appearance of the best product should have a smooth surface while coating that requires less friction, strength and transparency. In extrusion processes, the quality of product mainly depends on the momentum and heat transfer of a slender liquid film above a stretched sheet. In the first phase, the study of flow on liquid film was restricted to viscous fluids, later was extended to non-Newtonian fluid.

The thin-film flow on a stretching sheet was first discussed by Wang [1]. In addition, Wang’s work was developed by Andersson et al. [2,3] by taking into account the power-law fluid for various physical properties. Furthermore, heat transfer flow on the thin film over a slendering sheet was discussed by many researchers [4–6]. Quadratic, linear, non-linear and exponential varying of stretching velocity and temperature are considered by many investigators. But Magyari and Keller [7] investigated a slendering sheet with exponential changing of velocity on the flow and thermal boundary layers. Consequently, the flow problems generated by an exponential stretching surface have been created [8–11].

Heat transfer can be enhanced by dispersing non-dimensionalized particles into a conventional fluid and it has got extensive enactment in industries and engineering. The stability of nanofluids lasts for a long period of time. Convective heat transport feature of nanofluids depends on the model of the problem, the shapes of nanoparticle and the volume fraction of the nanoparticles [12]. Electronic gadgets, biomedicine, transportation, lubrication and laser are some of the applications. Besides water-based nanofluids, oil-based nanofluids have significance in many industrial fields with elevated thermal conductivity. Diathermic oils are used in renewable energy systems. It is mostly used at high temperatures or where water and vapour are not favourable to use. As a result, using nanoparticles, thermo-physical properties of diathermic oil can be improved to increase the execution of the systems. The cooling of jet and
rocks is a tough part for mechanical and avionics engineers. Owing to this, a problem is modelled using diathermic oils, particularly, kerosene oil (KO) and engine oil (EO). In various operating machine systems, more heat is produced while in running as a result of frictional forces, and the machine components are unable to continue the functioning and stop working earlier. To decrease the friction inside the machine parts, different lubricants are used for lubrication purpose and for cleaning of the engine. EO takes a dynamic part in the working of machine and acts as blood for the vehicles. The thermal conductivities of lubricants can be enhanced by adding nanoparticles in oils and greases by which the period of time of operations of machine bearings can be enhanced. Kerosene is used as a fuel in semi-cryogenic engine as a regenerative coolant.

Magnetohydrodynamics (MHD) is the analysis of electrically conducting fluids. MHD has major applications in industry and engineering as in MHD sensors, growth of crystals, reactor cooling, geophysics, prediction of climate and so on. In MRI, magnetic drug targeting, cancer treatment, magneto-nanoparticles are widely used. Some motive works on nanofluids with magneto-nanoparticles can be found in the previous studies [13–22].

The analysis of flow-through porous materials such as soil, bones, aquifers, wood, sand, oil reservoirs and others play a significant role in engineering, oil recovery, ground water hydrology, medicine, ignition of coal, growth of warmness pipeline, misappropriation of scattering matter underground. The characteristics of boundary and inertia are included in the non-Darcian porous surface, which is an improved form of the normal Darcy theory. Many researchers with different approaches have been investigated in the previous studies [23–32].

Molybdenum disulphide (MOS₂) is a compound containing alternatively arranged molybdenum and sulphur atoms, and sorted as a metal dichalcogenide semiconductor. It occurs as a solid mineral named molybdenite which is in silvery black colour. As it has little frictional property and robustness, it is broadly used as a solid lubricant and catalyst. It has unique possessions such as high carrier mobility, chemical inertness, photoconductivity, anisotropy, environmental sensitivity, mechanical properties and photo corrosion resistance. Furthermore, MOS₂ materials possess abnormal wetting behaviour, as that of graphene. Dilute acids and oxygen cannot affect MOS₂. MOS₂ nanofluids are water-based fluids dispensed with nano-sized particles of MOS₂. The MOS₂ nanoparticles reduce the heat generated in the grinding parts of the machine. Zhang et al. [33] experimentally prepared a Newtonian molybdenum disulphide nanofluid which is homogeneously stable and has solo and multilayer sheets with huge band gap structure. In logic circuits and devices with amplifier (Das et al. [34] and Dankert et al. [35]) and also in 2D electronic devices (for example, field effect transistors), MOS₂ is widely used because of its unique structure. Moreover, MOS₂ is used in many mechanical applications [36–38] because of its lubrication ability. With the above-mentioned properties, the materials are used for the parting and absorption of oil and some organic toxins from water. A few challenges on nanofluids with MOS₂ are completed by Ilyas Khan [39], Gul et al. [40] and Liu et al. [41].

In heat transfer analysis, heat generation or absorption enacts a foremost role in amending the heat transfer in the boundary. Temperature assimilations are noticed within the boundary layer by applying heat source/sink, and consequently affects the deposition rate of the particles in the system as in nuclear reactors, electronic chips and semiconductor wafers and so on. The temperature distribution can be modified by producing heat in the fluid, as a result, the particle deposition rate is affected. A like studies have different applications in modelling of biomedical instruments. In this study, uneven heat source/sink is considered. Studies related to the above effect have been exemplified in the previous studies [42–48].

Fluids in nature are categorized based on their viscosity into the following two types: Newtonian and non-Newtonian. The shear stress is linear to the shear rate, in the absence of yield stress for Newtonian fluids. H₂O, low-concentrated motor oil, alcohol and air are common Newtonian fluids. Most of the fluids in nature are not Newtonian, that is, their viscous nature alters with strain rate, which results uncertainty in viscosity. Non-Newtonian fluid examples include soaps in liquid form and cosmetics, lubricants, wall paints, toothpastes, slurries, gels, foods, for instance, jam, butter, cheese, mayonnaise and soups, materials in nature, for example, lava, magma and petroleum, and also blood, saliva and synovial fluid (articulation fluid) which are biological fluids and a few types of diffusions. While modelling a non-Newtonian fluid model, highly non-linear terms are produced in governing differential equations. Hence, different fluid models are proposed like Maxwell model, Bingham Herschel-Bulkley, Williamson model, Eyring model, Rivlin Ericksen, Sisko model, Carreau model and so on.

Among these models, Casson model is a real and generally treated fluid model which shows yield stress pseudo plastic properties, and are practically used in bio field, polymer processing and in extraction of crude oil, manufacture of plastic materials. For these fluids, viscosity and heat conductivity are linear with the temperature. Physically, the Casson is a shear-thinning liquid, but it appears as a solid when yield stress is even more when compared with the applied shear stress. It starts to move about when yield stress is below the shear stress. Casson first introduced this model on a flow
of printing ink for pigment oil-suspensions in his work. The commonly used Casson fluids are honey, tomato sauce and some jellies. Casson fluid is well supportive in modelling of blood oxygenators and dialysis as it narrates the properties of the blood flow smartly. At low shear rate, if blood flows through small vessels, then it is expressed by Casson fluid flow model.

Homogeneous and heterogeneous actions take place in several processes like explosions, catalysis and structures in biochemistry. The reactions which take place at two or more stages on the surfaces are heterogeneous and come about at the same phase in the fluid are homogeneous. Iron oxidation, outburst of fireworks, metabolism of foodstuff in body, dispersion and manufacturing of ceramics and polymers are some of the appliances of reactions. The initial studies on the chemical reactions are made by Merkin [49]. This has shown the way for many investigators (Reddy and Suneetha [53]) to spot lights on such types of actions.

Motivated from the above works, an attempt has been made on the diathermic oils ((EO) and (KO)) as the base fluids over a liquid thin film implanted in a porous medium. The fluid is electrically conducting and MOS₂ nanoparticle of tubical shape is suspended in porous medium. The fluid is electrically conducting and has been made on the diathermic oils ((EO) and (KO)) to spot lights on the way for many investigators (Reddy and Suneetha [53]) to spot lights on such types of actions.

Casson parameter β and plastic dynamic viscosity μ₂ are important on which the kinematics viscosity of Casson fluid depends. The graph between μ₂ and thermal conductivity k is a straight line with temperature. The fluid molecules yield stress, μ₂ is the dynamic viscosity of the fluid, π = e₁e₂, where e₁ is the deformation rate in (i, j, k) component and π is the critical value stands on the non-Newtonian model.

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2. Formulation

In this research, it is assumed that a 2D porous nanoliquid film of magnetohydrodynamic Casson nanofluid past an unsteady exponentially stretching sheet. In this work, MOS₂ is treated as base nanoparticle. A fine slot is arranged at the initiating point of a system (x, y). Here, x-axis indicates the sheet-stretching direction with velocity \( U_w = (c/1 - \alpha t)e^\gamma \) wherein c and α are invariable so as to facilitate positive c denotes the rate of stretching and \( \alpha t < 1 \). The stretching surface is upright to y-axis. A magnetic field \( B(t) = (B_0 / (1 - \alpha t)^{1/2})e^{\lambda t} \) is applied vertically to sheet externally, as shown in Figure 1. The sheet thermal profile is designed as \( T_w = T_0 + T_1 (c/2\gamma)(1 - \alpha t)^{-\frac{1}{2}}e^{\lambda t}, \) where \( \nu_1 = \mu_1/\rho \) represents the kinematic viscosity wherein "I" designates the base fluid.

\( A^{**} \) and \( B^{**} \) are the two species taken in the boundary layer flow for homogeneous (or bulk) and heterogeneous (on sheet) chemical reactions

\[ A^{**} + 2B^{**} \rightarrow 3B^{*}, \text{ rate } = k_c ab^2 \]
\[ A^{**} \rightarrow B^{**}, \text{ rate } = k_a b \]

where \( k_c \) (rate constant) and \( k_a \) (rate constant) and \( a, b \) are the concentrations of the chemical species \( A^{**} \) and \( B^{**} \). The reactions are assumed isothermal for both processes.

A different kind of non-Newtonian fluid utilized by Casson in his study known as Casson fluid has a unique feature that it acts as an elastic solid.

The rheological equation of state for an isotropic and incompressible flow of a Casson fluid can be written as (BalaÂñki Reddy and Suneetha [53])

\[ \tau_{ij} = (\mu_b + (P_2 / \sqrt{2\pi}))2e_{ij} \text{ when } \pi > \pi_c, \]
\[ \text{Casson fluid (non-Newtonian) flow} \]
\[ \tau_{ij} = (\mu_b + (P_2 / \sqrt{2\pi}))2e_{ij} \text{ when } \pi < \pi_c, \]
\[ P_2 = \mu_b \sqrt{2\pi / \beta} \text{ is the non-Newtonian fluid yield stress, } \]
\[ \mu_b \text{ is the dynamic viscosity of the fluid, } \pi = e_1e_2, \]
\[ \text{where } e_1 \text{ is the deformation rate in (i, j, k) component and } \pi \text{ is the critical value stands on the non-Newtonian model.} \]

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\[ \rho n f \left( \frac{\partial u}{\partial t} + u \frac{\partial u}{\partial x} + v \frac{\partial u}{\partial y} \right) = \mu n f \left( 1 + \frac{1}{\beta} \right) \frac{\partial^2 u}{\partial y^2} - u \left( \sigma n f B^2(t) + \frac{\mu n f}{k^2} \right), \]
\[ (\rho C_p)n f \left( \frac{\partial T}{\partial t} + u \frac{\partial T}{\partial x} + v \frac{\partial T}{\partial y} \right) = k_n f \frac{\partial^2 T}{\partial y^2} + q", \]
\[ (\frac{\partial a}{\partial t} + u \frac{\partial a}{\partial x} + v \frac{\partial a}{\partial y}) = D_A \left( \frac{\partial^2 a}{\partial x^2} + \frac{\partial^2 a}{\partial y^2} \right) + \frac{DT}{T_\infty} \left( \frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2} \right) - k_1 ab^2, \]
\[ (\frac{\partial b}{\partial t} + u \frac{\partial b}{\partial x} + v \frac{\partial b}{\partial y}) \]
Subject to the boundary conditions (Sulochana et al. [54], Vijaya et al. [56] and Fakour [57])

\[ u = U_w, \quad v = 0, \quad T = T_w, \]
\[ D_a \left( \frac{\partial a}{\partial y} \right) = - D_b \left( \frac{\partial b}{\partial y} \right) = k_s \text{at } y = 0 \]
\[ v = \partial H/\partial t \text{at } y = H(t), H(t): \text{thickness of the fluid film} \]
\[ a = a_0, \quad \frac{\partial u}{\partial y} = \frac{\partial T}{\partial y} = 0, b = 0, \text{ at } y = H. \quad (7) \]

The heat source/sink "q" designates by
\[ q'' = k_f U/w \times \chi \eta(B^* (T - T_0) f' (\eta) + A^* (T - T_0)) \]
where \(A^*\) and \(B^*\) are parameters of space-dependent and temperature-dependent internal heat generation/absorption. It is to be noted that \(A^* > 0\) and \(B^* > 0\) correspond to internal heat generation while \(A^* < 0\) and \(B^* < 0\) correspond to internal heat absorption. Table 1

Practically, nanoparticle concentration of MOS2 is little. The following constant are

\[ \frac{\mu_f}{\mu} = (1 - \chi)^{-2.5}, \quad \frac{\rho_{nf}}{\rho} = 1 - \chi + \chi T, \]
\[ \frac{\rho_{nf}}{\rho} = 1 - \chi + \chi d, \]
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at
\[ \eta = 0 \rightarrow f(\eta) = 0, \quad f'(\eta) = 1, \quad \theta(\eta) = 1, \]
\[ \phi'(\eta) = K_s \phi(0), \quad \delta h'(\eta) = -K_s \phi(0) \] (14)

at
\[ \eta = 1 \rightarrow f(1) = \frac{\beta_1 S}{2}, \quad f''(1) = 0, \]
\[ \theta'(1) = 0, \quad \phi(1) = 1, \quad h(1) = 0 \] (15)

where
\[ \beta = \mu_b \frac{\sqrt{\pi}}{P_r}, \quad \phi_1 = \left(\frac{\mu_f}{\mu_f}\right), \quad \phi_2 = \frac{\rho_f}{\rho_f}, \]
\[ \phi_3 = \frac{\sigma_f}{\sigma_f}, \quad \phi_4 = \frac{k_n}{k_f}, \quad \phi_5 = \frac{P_c}{P_c}, \]
\[ S = \frac{\alpha}{c}, \quad M = \frac{\sigma_B_0^2}{c}, \]
\[ D = \frac{\nu_f}{\rho_f c} \left(1 - \alpha t\right), \quad Pr = \frac{\left(\mu_c\right)}{\left(\mu_c\right)}, \]
\[ K = \frac{a_0^2 k_1}{\left(1 - \alpha t\right)}, \]
\[ K_s = \frac{\kappa_s}{D_{A_0} \theta \left(\nu_f \left(1 - \alpha t\right)\right)^{-\frac{1}{2}}}, \quad \delta = \frac{D_B}{D_A}, \]
\[ N_{AT} = \frac{D_A a_0}{D_{C}} \frac{T_{w} - T_{\infty}}{T_{w} - T_{\infty}}, \quad SC = \frac{\nu_f}{D_A} \]

Thus, \( \delta = 1 \) for the coefficient of diffusions \( D_A \) and \( D_B \) are identical
\[ \phi(\eta) + h(\eta) = 1, \] (16)
Equations (12) and (13) under this assumption reduced to
\[ \frac{1}{Sc} \left( \phi'' + \frac{1}{N_{AT}} \left( \theta + \theta'\right) \right) + f'\phi' - S\phi' \frac{\eta}{2} - K\phi(1 - \phi)^2 = 0 \] (17)

associated boundary conditions
\[ \eta = 0 \rightarrow \phi(0) = K_s \phi(0), \]
\[ \eta = 1 \rightarrow \phi(1) = 1 \]

The surface drag force, and local Nusselt are
\[ C_f = \frac{\tau_w}{\rho_f U_w^2}, \quad Nu = \frac{q_{wx}}{k_f(T_w - T_0)} \] (18)

Where \( \tau_w \) and \( q_{wx} \) are given at \( y = 0 \) as
\[ \tau_w = \mu_{nf} \left(1 + \frac{1}{\beta}\right) \left(\frac{\partial}{\partial y}\right), \quad q_{wx} = -k_{nf} \left(\frac{\partial T}{\partial y}\right) \] (19)

In view of Equations (9) and (19) in Equation (18), we acquire
\[ C_f = (Re_x)^{-0.5} \left(1 + \frac{1}{\beta}\right) (1 - \chi)^{-2.5} f''(0), \]
\[ Nu_x = -(Re_x)^{0.5} \frac{K_{nf}}{k_f} \left(\frac{1}{\beta_1}\right) \phi'(0) \] (20)

where \( Re_x = U_w x (\upsilon_f) \) -1.

Table 2. Comparison of the present results for \(-\theta'(\eta)\) when \( M = A^* = B^* = D = 0 \) and \( Pr = 1 \).

| \( \chi \) | Present results | Sulochana et al. [40] |
|---|---|---|
| 1.0 | 2.677222163 | 2.677222164 |
| 1.2 | 1.999592460 | 1.9995915210 |
| 1.4 | 1.4477543622 | 1.4477543632 |
| 1.6 | 0.9566978342 | 0.9566978660 |

3. Numerical scheme

The PDEs of this model are renovated into ODEs after employing proper transformation. But Equations (10), (11) and (17) are nonlinear and tough to get their analytical solutions. So, solve it numerically by shooting technique with RK4-method (see Figure 2). The system of ODEs which are not linear are converted into differential equations of first order as given below
\[ f = P_1, f' = P_2, f'' = P_3, f''' = P_4, \theta = P_5, \theta' = P_6, \theta'' = P_7, \theta''' = P_8, \]
\[ P_3' = \left(\frac{1}{q_{\phi_1} (1 + \beta)}\right) (-\phi_2 (\beta_1)^2 P_1 P_3 - P_2^2) \]
\[ - S(P_2 + 0.5 \eta P_3)) + \phi_3 MP_2 + \phi_1 DP_2 \]
\[ P_5' = \frac{1}{\phi_6} [-P_1 P_7 + 0.5 S \eta P_5 + K P_6 (1 - P_6)^2] \]
\[ P_7' = \frac{1}{N_{AT}} (P_4 P_5 P_6) \]

Correlated boundary conditions are
\[ P_1(0) = 0, P_2(0) = 1, P_4(0) = 1, P_7(0) = K_s P_6(0), \]
\[ P_1(0) = \frac{\beta_1 S}{2}, P_3(1) = 0, P_5(1) = 0, P_6(1) = 1 \]

This procedure is used for boundary layer flow problems. Introduce initial guesses to \( f''(0) \) and \(-\theta'(0)\) to get approximate solution by assuming the size of the step as 0.001 and the criteria for all cases to converge is \( 10^{-6} \).

4. Validation of numerical method

To decide the meticulousness of the numerical method, we have executed an assessment for the values of heat flux \(-\theta'(0)\) and with \( M = A^* = B^* = D = 0 \), against S with those of Sulochana et al. [54]. Our outcomes are in a good deal with Sulochana et al. [54], as demonstrated in Table 2.

Ali et al. [59] experimentally shown the outcome of MOS2 nanoparticles in EO and concluded that the frequency rate of heat transfer could be improved up to 63.5%. Ali et al. [58] scrutinized in Brinkman-type nanofluid with the sculpt impact of MOS2 nanoparticles in EO and revealed that the heat flux is increased to 13.51% which improves the lubrication properties.

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5. Results proclamation

In this segment, figures are captivated for the parameters involved in the flow region. The calculations have been done numerically by assuming the default values $\phi_1 = 1.0$,

$$\phi_2 = 1.0, \beta = 0.5, S = 0.5, \theta_w = 1.5, M = 0.5, A^* = 0.05, B^* = 0.05, N_{AT} = 1.0, Sc = 0.5, K = 0.5, \beta_1 = 1.0 \text{ and } K_s = 10.0 \text{ until otherwise specified particularly. Here, we examined the following two cases: MOS}_2{+KO \text{ and } MOS}_2{+EO.}

The impact of magnetic flux parameter $M$ on momentum and thermal fields of MOS$_2$ nanofluid is examined for both the base fluids KO and EO and provided in Figures 3 and 4. It can be known from the figure that when a magnetic field is applied in an electrically conducting Casson fluid, it generates an opposing force named as Lorentz force. Both the
momentum and thermal boundary layers are declined by this force. Physically, the magnetic parameter is linked with the Lorentz force which is a resistive force to the fluid flow. An enhancement in magnetic parameter provides more resistive force and as a result velocity diminishes. It is observed from Figure 4 that $M$ and temperature distribution are inversely proportional to each other. This is because the growth in Hartmann number raises the magnetic force, results in the expansion of the magnetic field strength which deprecate the convective heat transfer process. For greater magnetic field strength, the convection effect is declined. Thus, the fluid motion demotes resulting conduction as the leading heat transfer mechanism. It is also pragmatic that MOS$_2$ + KO is very much influenced by the resistive type force when correlated with MOS$_2$ + EO.

The upshot of $S$ on flow, thermal and mass areas is displayed in Figures 5, 6 and 7. It is reported from the figures that the appreciating values of $S$ downgrade the momentum, thermal and species fields for both the cases. Also, it is noticed that the effect of MOS$_2$ + KO is more on the thermal and momentum boundary layer than on the concentration boundary layer. This abides the general physical nature, that is, mounting values of $S$ condense the effect of buoyancy on the flow. This decreases the thermal, momentum and concentration boundary layer.

Figures 8 and 9 show the graphical aspects of the disparity of velocity and temperature allotment for diverse values of the Casson parameter $\beta$. Casson fluid velocity declines near the wall and negligibly decreases far from the vertical wall when $\beta$ enhances. Figure 8 shows that the velocity shrinks with swelling values of $\beta$; that is, the declining yield stress (when Casson parameter raises the fluid behaves as Newtonian fluid) matches up to the viscosity and rate of deformation. The boundary layer
thickness contracts due to the presence of tensile stress caused by the elasticity. It is evident from the sketch that when we upsurge $\beta$ indefinitely, the present situation reduces to the case of Newtonian fluid, the velocity subsides significantly within a layer near the vertical wall. Hence, the magnitude of the velocity is more in Casson fluid when related to viscous fluids. From Figure 9, it is inferred that the thermal boundary layer width and $\beta$ are inversely proportional. The diminution is pronounced for lower $\beta$ compared to higher $\beta$. However, the situation with $\beta$ tends to increase implicating the nature of temperature field line of the Newtonian fluids. The decrement in velocity and temperature for MOS$_2$+KO is more than MOS$_2$+EO.

Figure 10 brings to light about the velocity deviation for porous medium $D$ for thin nanofluid film. The porous media parameter indicates the absorption rate of the fluid when passing through pores. By enlarging $D$, the resistance among the pores and moving liquid shrinks, consequently, the velocity escalates. This signifies that when the fluid passes through the porous medium, fluid transfers with higher velocity. As porosity grows, fraction forces decline between the fluids and the medium resulting the velocity of the fluid to proliferate. From the draft, it is noticed that a growth in $D$ enhances the velocity. The increment in $D$ should be very little as the width of the film is small, towering values of $D$, that is, $D \to \infty$ match to non-porous medium. The upward $D$ responds to the huge gap of the porous opening, which lessen the hindrance of the flow for $D$, and the velocity rises. The dimensionless temperature profile is shown in Figure 11 for different values of $D$, and noticed that with an increase in $D$ the temperature increases.

In Figure 12 the thermal variations for different $Pr$ are shown. It is noted that the temperature and $Pr$ are inversely proportional for both the cases. Prandtl number is a fraction of kinematic viscosity to thermal diffusivity. Therefore, for advanced values of Prandtl number, the thermal diffusivity reduces. Physically, $Pr$ is the ratio of momentum diffusion to thermal diffusion. A fluid with large $Pr$ have large heat capacity, and therefore the heat transfer increases. That is, $Pr$ reduces the temperature distribution due to the raise in heat transfer ability of flow fluid as the $Pr$ enhances. As $Pr$ increases, thermal diffusion drops and the thermal boundary layer becomes thinner. It gives the data about the fluid type, and also thickness of hydrodynamic and thermal boundary layers. The Pr number implies numerous computations of heat transfer in fluid metal reactors. Generally, $Pr$ is used in heat transfer problems that figure out the relative coagulate of the momentum and
the thermal boundary layers. Also, the reduction in temperature is more in MOS₂ + KO than MOS₂ + EO.

Profiles of non-dimensional concentration are plotted in Figures 13 and 14 for homogeneous and heterogeneous reactions \((K, Ks)\) on the species distribution. As the values of \(K\) and \(Ks\) mounted, a decrement in concentration is inferred from the figures. If the strengths of homogeneous and heterogeneous actions are raised, the consumption of chemical reactants also raised which results in a fall in the concentration.

Figure 15 displays the effect of \(Sc\) on concentration. The mass momentum transmission is stated as Schmidt number. \(Sc\) is used to describe the fluid flow where contemporaneous momentum and mass diffusion convection occur. Schmidt number is a dimensionless number defined as the ratio of momentum diffusivity and mass diffusivity. Figure shows a decrement in the concentration as \(Sc\) raises. This is because of the strong diffusion species have higher retarding effect on the concentration. In many heat transfer procedures, Schmidt and Prandtl numbers are related with each other. \(Sc\) is a main tool for thermal and chemical engineers, for developing gas turbine and also in jet flows.

Figure 16 shows fed light on the influence of space-dependent heat source/sink parameter \(A^*\) on temperature distribution. If \(A^* > 0\) (heat source), the boundary layer produces energy, which in turn enhances the fluid temperature. If \(A^* < 0\) (absorption), the boundary layer absorbs energy, which results in a fall in the temperature. The influence of \(B^*\) on temperature profile is shown in Figure 17. It is inferred that the temperature raises as energy is released into the fluid when \(B^* > 0\) and a destructive trend is observed for \(B^* < 0\), that is, a drop in temperature is noticed as the energy is observed by the fluid.
Figure 17. $\theta(\eta)$ for $B^*$.  

Figure 18. $f''(\eta)$ for $D$.  

Figure 19. $f''(\eta)$ for $S$.  

Figure 20. $-\theta'(\eta)$ for $A^*$.  

Figure 21. $-\theta'(\eta)$ for $B^*$.  

Figure 22. $-\theta'(\eta)$ for $Pr$.  

Figure 18 exemplifies the disparity in surface drag force for various $D$. It is noted that an increment of $D$ increases the surface drag force for MOS$_2$+KO and MOS$_2$+EO. The outcome of $S$ on surface drag force is verified in Figure 19. It uncovers that growing values of $S$ grow the surface drag force for both cases.

Figure 20 exemplifies the effect of heat flux on $A^*$. Figure illustrates that a growth in $A^*$ has a drop in the heat flux for the two cases. The effect of $B^*$ on heat flux is defined in Figure 21. It is revealed that mounting of $B^*$ falls down the heat flux for both cases. The increment for MOS$_2$+EO is more than MOS$_2$+KO. Figure 22 exemplifies the effect of heat flux on $Pr$. The outcomes show that a rise in $Pr$ raises the heat flux for both cases.

Table 3 describes the deviations of surface drag force for different values of $M, D, S, \beta$ and $\beta_1$. The surface drag force accelerates with $M, D, S$ and $\beta$ and decelerates with $\beta_1$.

Table 4 exhibits the difference in heat flux for diverse values of $M, Pr, D, S, A^*, B^*$, and $\beta_1$. Declination in heat flux for $M, D, A^*$ and $B^*$ is noted, whereas inclination for $Pr, S$ and $\beta_1$ is observed.

6. Conclusions

Investigation of the flow features imparted to viscous fluid flow over thin liquid film dispensed with molybdenum disulphide (MOS$_2$) in a Casson nanofluid past an unsteady exponentially stretching sheet with a porous medium is done in this section. Diathermic oils with MOS$_2$ nanoparticles reduce the friction among the moving parts of the machine. It also reduces the heat generation caused by the frictional forces. It finds a notable use in mechanics, industrial and engineering fields. The PDEs are renewed into non-linear ODEs.
Table 3. The values of surface drag force and various dimensionless parameters.

| M   | D  | S  | β  | β1 | f′(η) | f″(0) |
|-----|----|----|----|----|-------|-------|
| 0.5 | 0.5| 0.5| 0.5| 0.5| 1.2284| 0.9716|
| 1.0 | 0.5| 0.5| 0.5| 0.5| 1.5398| 1.1278|
| 1.5 | 0.5| 0.5| 0.5| 0.5| 1.7988| 1.2653|
| 2.0 | 0.5| 0.5| 0.5| 0.5| 2.0253| 1.3894|
| 0.5 | 0.7| 0.5| 0.5| 0.5| 1.2699| 1.0234|
| 0.5 | 0.9| 0.5| 0.5| 0.5| 1.3102| 1.0729|
| 0.5 | 1.1| 0.5| 0.5| 0.5| 1.3492| 1.1201|
| 0.5 | 1.0| 0.5| 0.5| 0.5| 1.2602| 1.0131|
| 0.5 | 1.5| 0.5| 0.5| 0.5| 1.2901| 1.0314|
| 0.5 | 2.0| 0.5| 0.5| 0.5| 1.3814| 1.0870|
| 0.5 | 0.5| 0.7| 0.5| 0.5| 1.3398| 1.0486|
| 0.5 | 0.5| 0.9| 0.5| 0.5| 1.4211| 1.1053|
| 0.5 | 0.5| 1.1| 0.5| 0.5| 1.4834| 1.1484|
| 0.5 | 0.5| 1.0| 0.5| 1.0| 0.7967| 0.6901|
| 0.5 | 0.5| 0.5| 1.5| 0.6746| 0.6106|
| 0.5 | 0.5| 0.5| 2.0| 0.6150| 0.5692|

Table 4. Deviations in the heat flux and various dimensionless parameters.

| M   | Pr | D  | S  | A* | B* | f(η) | f′(0) |
|-----|----|----|----|----|----|------|-------|
| 0.5 | 0.27| 0.5| 0.5| 0.05| 0.05| 0.5  | 3.0633| 2.7608|
| 1.0 | 0.27| 0.5| 0.5| 0.05| 0.05| 0.5  | 3.0631| 2.7607|
| 1.5 | 0.27| 0.5| 0.5| 0.05| 0.05| 0.5  | 3.0630| 2.7606|
| 2.0 | 0.27| 0.5| 0.5| 0.05| 0.05| 0.5  | 3.0629| 2.7605|
| 0.5 | 0.8 | 0.5| 0.5| 0.05| 0.05| 0.5  | 3.5172| 3.1812|
| 0.5 | 0.9 | 0.5| 0.5| 0.05| 0.05| 0.5  | 4.0845| 3.7066|
| 0.5 | 1.0 | 0.5| 0.5| 0.05| 0.05| 0.5  | 4.6516| 4.2319|
| 0.5 | 0.72| 0.5| 0.5| 0.05| 0.05| 0.5  | 3.0633| 2.7608|
| 0.5 | 0.72| 0.5| 0.5| 0.05| 0.05| 0.5  | 3.0632| 2.7607|
| 0.5 | 0.72| 1.1| 0.5| 0.05| 0.05| 0.5  | 3.0631| 2.7606|
| 0.5 | 0.72| 1.0| 0.5| 0.05| 0.05| 0.5  | 3.0617| 2.7581|
| 0.5 | 0.72| 1.5| 0.5| 0.05| 0.05| 0.5  | 11.1627| 10.2610|
| 0.5 | 0.72| 2.0| 0.5| 0.05| 0.05| 0.5  | 15.1980| 13.9950|
| 0.5 | 0.72| 0.5| 0.10| 0.05| 0.05| 0.5  | 3.0383| 2.7358|
| 0.5 | 0.72| 0.5| 0.15| 0.05| 0.05| 0.5  | 3.0132| 2.7108|
| 0.5 | 0.72| 0.5| 0.20| 0.05| 0.05| 0.5  | 2.9882| 2.6857|
| 0.5 | 0.72| 0.5| 0.10| 0.05| 0.05| 0.5  | 2.0043| 1.7615|
| 0.5 | 0.72| 0.5| 0.15| 0.05| 0.05| 0.5  | 1.0648| 0.7618|
| 0.5 | 0.72| 0.5| 0.20| 0.05| 0.05| 0.5  | 0.0647| 0.0021|
| 0.5 | 0.72| 0.5| 0.15| 0.05| 1.0| 7.6436| 7.0434|
| 0.5 | 0.72| 0.5| 0.20| 0.05| 1.0| 11.8354| 10.9469|

Abbreviations

- $B_0$: applied magnetic field strength (A/m)
- $q$: dimensionless parameter
- $f(\eta)$: dimensionless velocity
- $EO$: engine oil
- $H(t)$: film size (m)
- $e_{ij}$: $(i,j)$th component of the deformation rate
- $q_w$: heat flux from the surface (W m$^{-2}$)
- $K$: heterogeneous reaction strength
- $K$: homogeneous reaction strength
- $V$: initial stretching velocity along y-axis (m s$^{-1}$)
- $T_0$: initial temperature of the fluid (K)
- $U_w$: initial stretching velocity along x-axis (m s$^{-1}$)
- $KO$: kerosene oil
- $Nu_x$: local Nusselt number
- $C_{fi}$: surface drag force
- $Re_x$: local Reynolds number
- $M$: magnetic field parameter
- $D$: porosity parameter
- $p$: pressure (kg m$^{-1}$ s$^{-2}$)
- $Pr$: Prandtl number
- $T_{ref}$: reference temperature of the fluid (K)
- $Sc$: Schmidt number
- $Cp$: specific heat at constant pressure (J kg$^{-1}$ K$^{-1}$)
- $c$: stretching rate (s$^{-1}$)
- $T$: surface temperature of the fluid (K)
- $k$: thermal conductivity (m$^2$ s$^{-1}$)
- $k^*$: permeability of porous medium
- $S$: unsteadiness parameter
- $u$: velocity component along x-axis (m s$^{-1}$)
- $v$: velocity component along y-axis (m s$^{-1}$)
- $T_w$: wall temperature of the fluid (K)
- $x$: x-axis coordinate (m)
- $y$: y-axis coordinate (m)

Greek symbols

- $\beta$: Casson fluid parameter
- $\alpha$: constant (s$^{-1}$)
- $\pi_c$: critical value of the product of the deformation rate with itself
- $\rho$: density (kg m$^{-3}$)
- $\beta_1$: dimensionless fluid thickness parameter
- $\theta(\eta)$: dimensionless temperature
- $\sigma$: electrical conductivity
- $\nu_f$: kinematic viscosity (m$^2$ s$^{-1}$)
- $\phi_f(i = 1 - 5)$: nanofluids constants
- $\psi$: physical stream function (m$^2$ s$^{-1}$)
- $\mu_b$: plastic dynamic viscosity of the Casson fluid
- $\tau$: shear stress at the surface (kg m$^{-1}$ s$^{-2}$)
- $\tau_{ij}$: shear stress of Casson fluid along $(i,j)$th component (kg m$^{-1}$ s$^{-2}$)
- $\delta$: ratio of diffusion coefficient

by transformations and then disclosed numerically by RK4S method. The numerical outcomes are portrayed in graphs and tables. The concluding statements are as follows:

- Cutback in $\theta(\eta)$ for elevated Pr and D enhances the velocity.
- The velocity, thermal and species are inversely proportional to the unsteadiness parameter for both cases.
- The escalating values of Sc, reaction rate parameter, $K$ and $K_s$, concentration drops.
- $A^*$ and $B^*$ are inversely proportional to the heat flux. Also, the increment for MOS$_2$+EO is more than MOS$_2$+KO.
- The surface drag force and the heat flux are high for large values of the porosity parameter and Pr.
η
similarity variable
χ
volume fraction of the MOS₂ nanoparticles

Subscripts
f
base fluid
∞
fluid properties at ambient condition
d
solid nanoparticles
s
surface
nf
nanofluid

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