https://africanjournalofbiomedicalresearch.com/index.php/AJBR
Afr. J. Biomed. Res. Vol. 27(4s) (December 2024); 17737-17745
Research Article

Impacts of Magnetohydrodynamics and Tangent Hyperbolic Hybrid Nanofluid Flow Through a Stretching Surface: Applications of Biomedical Engineering

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Abstract
The primary objective of the present study is to investigate the role of Silver-Cu nanoparticles mixed in blood with magnetohydrodynamics (MHD) tangent hyperbolic fluid flow over a stretching surface along with thermal radiation. A technique of suitable self-similarity variables has been used to convert PDEs into dimensionless ODEs. Once the ODEs have been solved, both mathematical and graphical results have been obtained via the BVP4c in MATLAB tool. The outcomes of the main active physical parameters are further explained by graphs using energy and velocity profiles. The thermal profile exhibits increasing behaviour when the thermal radiation parameter varies. The velocity graph is decreasing with the variations of the magnetic field parameter. Consistent with earlier research, the results validate the model's correctness and provide light on how to optimize biomedical fluid structures based on nanoparticles.

Keywords: Tangent hyperbolic fluid flow, MHD, Thermal Radiation, Hybrid nanofluid.

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Received - 15/12/2024 *Accepted- 20/12/2024*

DOI: https://doi.org/10.53555/AJBR.v27i4S.8327

1. Introduction

The area of nanotechnology has achieved remarkable progress in recent years, reshaping several scientific and technical disciplines. The word "nanofluid" describes a special kind of fluid that enhances the convectional heat transfer of the fundamental fluids by dispersing nanoparticles less than 100 nanometres in diameter (nm) in the fundamental fluids. There is a lot of potential for improving heat transfer and fluid motion via the use of nanoparticles in moving fluid devices. Scientists have taken an interest in studying particle dynamics in various circulation configurations. This kind of mixed nanofluid

has a maximum heat network and, as a result of mutually beneficial effects, greater stability conducive properties. Researchers are focusing only on studying the characteristics of these hybrid nanostructures in order to draw conclusions about their pros and cons and, ideally, their many applications. As a result of combining two different nanoparticles with a foundation substance, mixed nanofluids provide superior heat results and durable properties. Engine cooling purposes, solar-powered thermal transfer gadgets, medical devices, and many other areas might benefit from hybrid nanoparticles. Numerous technologies, industrial production, process, aircraft engineering, metalworking, oil, treatment of wastewater, and ecological remediation-related domains make extensive use of particles [1-5].

An increasing number of scientists are considering using nanoparticles to conduct biomedical studies, which is a boon to medical technology as a whole. The extraordinary temperature and rheological features of nanoparticles are the reason for this. These attributes made particles an excellent choice for conducting research on the movement characteristics of biological liquids like blood. These investigations demonstrate the increased potential of nanoparticle-enriched algorithms for enhancing diagnostic accuracy and therapeutic efficacy in the treatment of heart conditions, especially a narrowing of through offering comprehensive understanding into the flow dynamics and heat behavior of stenosed artery walls. Due to their immense biomedical use, magnetohydrodynamic (MHD) flow the interplay of a liquid with an imposed magnetic field has lately attracted the attention of biological engineering scholars. The importance of MHD principles in understanding heart disease has been highlighted by several research, which show that these concepts impact the flow dynamics and thermal transfer properties of biological liquids like blood. The investigation confirmed that the magnetic parameter reduced velocities and temperatures, but marginally enhanced the size of the confined bolus because of the fluctuating viscosity; this finding has important implications for medication delivery and surgical blood flow management. The examination of flow across the boundary layer and variations in temperature over a stretched surface has attracted the interest of a substantial number of professionals in the sector owing to the fact that it has a wide range of applications in a variety of business and technological settings. The real-world uses of these studies' results are highly affected by their conceptualization and practical consequences. The wide variety of technical and aesthetic uses it may serve is a major factor in this. When electromagnetic frequencies, especially those in the infrared range, are used to transmit heat, this phenomenon is called thermal radiation. Particularly in hot conditions, when convective and optical heat exchange often take a back seat, this impact becomes important [6-12].

Investigating the aforementioned subjects with further attention reveals various types of deficiencies and holes in the study. To our best knowledge, no prior examinations have investigated blood-based Tangent hyperbolic hybrid nanofluid flow through a stretching surface with thermal radiation and MHD in the present analysis. Therefore, this article's main objective is to conduct a numerical analysis in response to the aforementioned information gap. Computationally determined through the Bvp4c built in function in MATLAB software. The impact of various parameters on the momentum, temperature profiles are plotted graphically.

2. Mathematical flow analysis

The present study a 2D a stretching surface is subjected to Tangent hyperbolic mixed nanofluid flow with thermal radiation. In this cartesian coordinate framework, the fluid is assumed to move along the axial $x-$direction, with the $y-$coordinate and the velocity defined as U=ax, as illustrated in Fig. 1. In the present study, Cu and Silver nanoparticles along with blood as base fluid are considered, as shown in Table 1. The mathematical formulation for the equations relating to continuity, momentum, and energy are as follow [13-15]

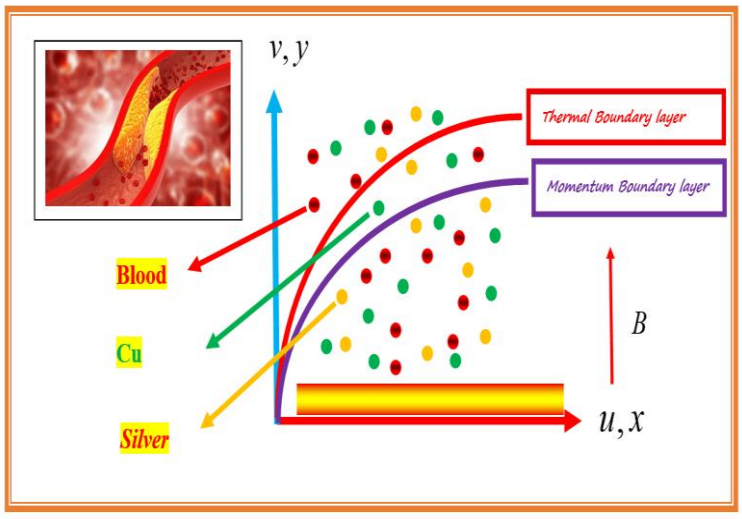

Fig 1. Flow geometry of the model.

$$\frac{\partial \bar{u}}{\partial x}+\frac{\partial \bar{v}}{\partial y}=0, \tag{1}$$

$$\rho_{hnf}\left(\bar{u}\frac{\partial \bar{u}}{\partial x}+v\frac{\partial \bar{u}}{\partial y}\right)=\mu_{hnf}\left(\left(1-S\right)\frac{\partial^2 \bar{u}}{\partial y^2}+\sqrt{2}S\Gamma\frac{\partial \bar{u}}{\partial y}\frac{\partial^2 \bar{u}}{\partial y^2}\right)-\sigma_{hnf}\left(B^2\bar{u}\right), \tag{2}$$

$$\begin{aligned}\bar{u}\frac{\partial \bar{T}}{\partial x}+\bar{v}\frac{\partial \bar{T}}{\partial y}=&\frac{k_{hnf}}{\left(\rho c_p\right)_{hnf}}\left(\frac{\partial^2 \bar{T}}{\partial y^2}\right)+\frac{\mu_{hnf}}{\left(\rho c_p\right)_{hnf}}\frac{S\Gamma}{\sqrt{2}}\frac{\partial u}{\partial y}\left(\frac{\partial u}{\partial y}\right)^2+\frac{\mu_{hnf}}{\left(\rho c_p\right)_{hnf}}\left(1-S\right)\left(\frac{\partial u}{\partial y}\right)^2\\&-\frac{1}{\left(\rho c_p\right)_{hnf}}\left(\frac{\partial q_r}{\partial y}\right)+\frac{\sigma_{hnf}B^2}{\left(\rho c_p\right)_{hnf}}\bar{u}^2.\end{aligned} \tag{3}$$

The Rosseland method based on the employing of Taylor's series expanding the modified energy equation is defined as

$$\begin{aligned}\bar{u}\frac{\partial \bar{T}}{\partial x}+\bar{v}\frac{\partial \bar{T}}{\partial y}=&\frac{k_{hnf}}{\left(\rho c_p\right)_{hnf}}\left(\frac{\partial^2 \bar{T}}{\partial y^2}\right)+\frac{\mu_{hnf}}{\left(\rho c_p\right)_{hnf}}\frac{S\Gamma}{\sqrt{2}}\frac{\partial u}{\partial y}\left(\frac{\partial u}{\partial y}\right)^2+\frac{\mu_{hnf}}{\left(\rho c_p\right)_{hnf}}\left(1-S\right)\left(\frac{\partial u}{\partial y}\right)^2\\&-\frac{1}{\left(\rho c_p\right)_{hnf}}\frac{16T_\infty^3}{3k^*}\frac{\partial^2 \bar{T}}{\partial y^2}+\frac{\sigma_{hnf}B^2}{\left(\rho c_p\right)_{hnf}}\bar{u}^2\end{aligned} \tag{4}$$

The following are the boundary restrictions:

$$\begin{aligned}&\bar{T}=T_f,\bar{v}=0,\bar{u}=U=ax,\ \ at\ y=0\\&\bar{T}\to T_\infty,\bar{u}\to 0\qquad\qquad as\ y\to\infty.\end{aligned} \tag{5}$$

The system is made simpler by introducing the following similarity transformations:

$$\bar{u}=axf'\left(\eta\right),\bar{v}=-\sqrt{a\upsilon_f}f\left(\eta\right),\theta\left(\eta\right)=\frac{\bar{T}-T_\infty}{T_f-T_\infty},\eta=y\sqrt{\frac{a}{\upsilon_f}}. \tag{6}$$

The mixed nanofluid properties are

$$\mathbf{Y}_1=\frac{\mu_{hnf}}{\mu_f},\ \mathbf{Y}_2=\frac{\rho_{hnf}}{\rho_f},\ \mathbf{Y}_3=\frac{\left(\rho c_p\right)_{hnf}}{\left(\rho c_p\right)_f},\mathbf{Y}_4=\frac{k_{hnf}}{k_f},\mathbf{Y}_5=\frac{\sigma_{hnf}}{\sigma_f}.$$

The non-dimensional form of equations

$$\frac{\mathbf{Y}_1}{\mathbf{Y}_2}\left(\left[1-S\right]f'''\left(\eta\right)+SWef''\left(\eta\right)f'''\left(\eta\right)\right)+\mathbf{Y}_2\left(ff''-\left(f'\right)^2\right)-\frac{\mathbf{Y}_5}{\mathbf{Y}_2}Mf'\left(\eta\right)=0, \tag{8}$$

$$\begin{aligned}&\left(\frac{k_{hnf}}{k_f}+\frac{4}{3}Rd\right)\theta''\left(\eta\right)+\mathbf{Y}_3Pr\ f\left(\eta\right)\theta'\left(\eta\right)\\&+\frac{\mathbf{Y}_1}{\mathbf{Y}_3}\left(\left(1-S\right)Ec\left(f''\left(\eta\right)\right)^2+\frac{S}{2}WeEc\left(f''\left(\eta\right)\right)^3\right)+\frac{\mathbf{Y}_5}{\mathbf{Y}_3}M\ Ec\left(f'\left(\eta\right)\right)^2=0.\end{aligned} \tag{9}$$

$$\begin{aligned}&\theta\left(0\right)=1,f\left(0\right)=0,f'\left(0\right)=1\\&\theta\left(\infty\right)=0,f'\left(\infty\right)=0.\end{aligned} \tag{10}$$

Non-dimensional parameters: $M=\frac{\sigma_f B^2}{\rho_f a}$, $Pr=\frac{\mu_f\left(c_p\right)_f}{k_f}$, $Rd=\frac{4\sigma^* T_\infty^3}{k^* k_f}$, $We=\Gamma x\sqrt{\frac{2a^3}{v_f}}$, $Ec=\frac{U^2}{c_p\left(T_f-T_\infty\right)}$ they are defined as Magnetic field parameter, Prandtl number, Radiation parameter, Weissenberg number, Eckert number.

The definition of C_f and Nu dimensional form is

$$C_f=\frac{\tau_w}{\rho_f U^2},\ \tau_w=\mu_{hnf}\left.\frac{\partial \bar{u}}{\partial y}\right|_{y=0} \tag{11}$$

$$Nu=\frac{xq_w}{k_f\left(T_w-T_\infty\right)},\ q_w=-k_{hnf}\left.\frac{\partial \bar{T}}{\partial y}\right|_{y=0} \tag{12}$$

The dimensionless nature of Eqs. transformed are

$$Re_r^{1/2}C_f=\mathbf{Y}_1 f''(0), \tag{13}$$

$$Re_r^{-1/2}Nu_r=-\mathbf{Y}_4\theta'(0). \tag{14}$$

Where Re_r is the local Reynolds number.

Table 1: Hybrid nanoparticles of thermo physical properties [16].

Properties	Blood	Cu	Ag
Density	1063	8933	10,500
Heat Capacity at Constant Pressure	3594	385	235
Thermal Conductivity	0.492	401	429
Electrical conductivity	0.8	5.96×10^7	6.3×10^7
Pr	21		

3. Computational methodology

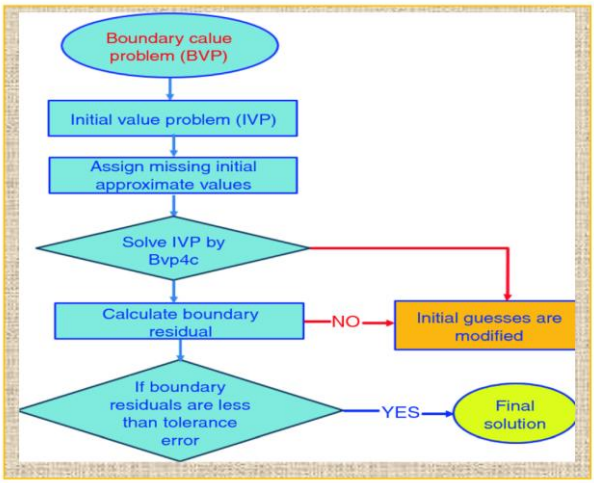

Fig 2. Numerical structure of Bvp4c method.

4. Results and discussion

This section main goal is to study the nature of the relationships that exist between the velocity and energy of hybrid nanoparticles. In addition, the Nusselt number and the skin friction figure structure were examined in BVP4c method in MATLB tool. The procedure of making these profiles includes the identification of mathematical solutions for an extensive different values of the parameters that are accountable for adaptable the system. Many numbers deviate significantly among these defaults for particular reasons, as shown in the following charts and tables.

Figure 3 shows that the magnetic field parameter increases the velocity profile decreased. Physically, this phenomenon results from the Lorentz force, which opposes the velocity of an electrically charged liquid. The larger the magnetic field, the higher the resistive power, which reduces the liquid's speed, while the opposite tendency we noticed on Figure 5. Figure 4 shows that the Weissenberg number increases the velocity profile decreased. Physically, elevating the Weissenberg number amplifies the flow-and deformation-resisting elasticity characteristics. The outcome is a reduced velocity diagram caused by a drop in flow velocity, while the opposite tendency we noticed on Figure 8.

Figure 6 shows that the Eckert number (Ec) increases the temperature profile enhanced. Physically, As Ec grows, the conversion of kinetic energy towards internal power via viscous dissipation gets increasingly noticeable. This process generates extra heat inside the fluid, resulting in a rise in temperature, particularly near places with large velocity gradient. As a result, the variation in temperature grows more apparent, or "enhanced," representing increased internal energy owing to viscous processes. This phenomenon is especially critical in significant-speed movements or liquids with high viscosity, when viscous warming has a substantial impact on the temperature field.

Figure 7 demonstrations the impact of the radiation parameter Rd on the temperature graph. An increase in Rd enhanced the thermal profile for hybrid nanofluid. Physically, an elevated radiation parameter amplifies the role of thermal radiation in heat transmission, resulting in enhanced thermal radiation absorption and, ultimately, elevated temperature profile.

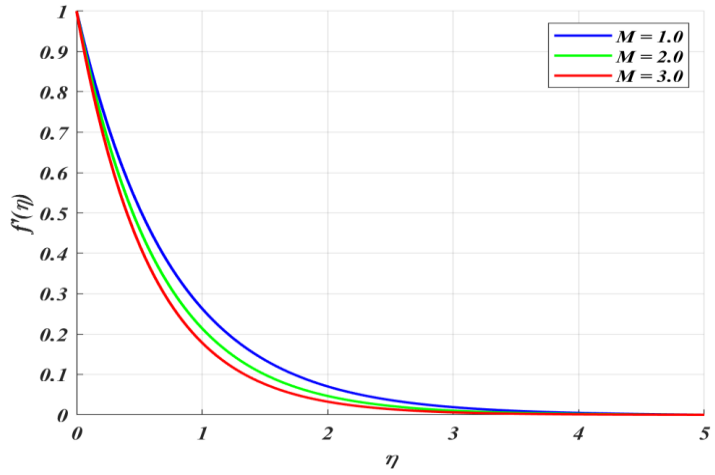

Fig 3. Sway of M on $f'(\eta)$.

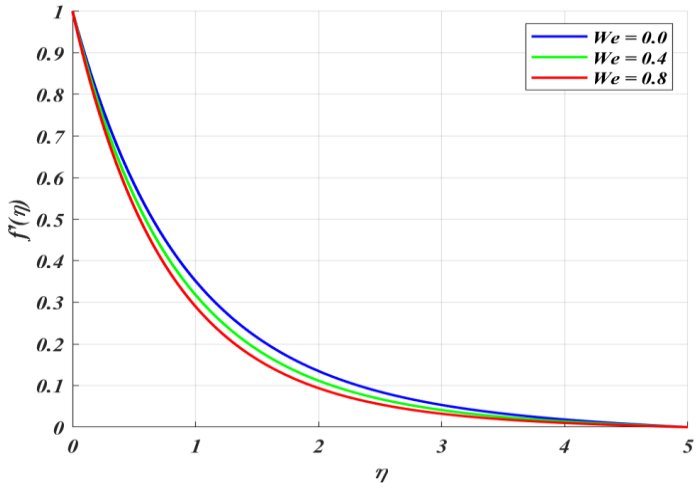

Fig 4. Sway of We on $f'(\eta)$.

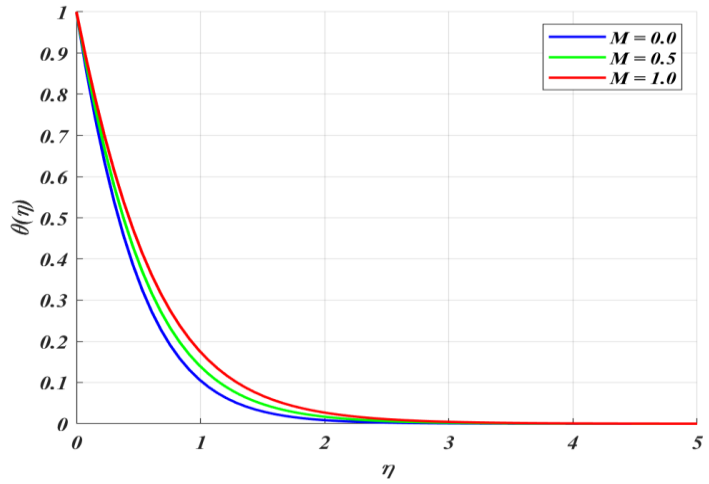

Fig 5. Impacts of M on $\theta(\eta)$.

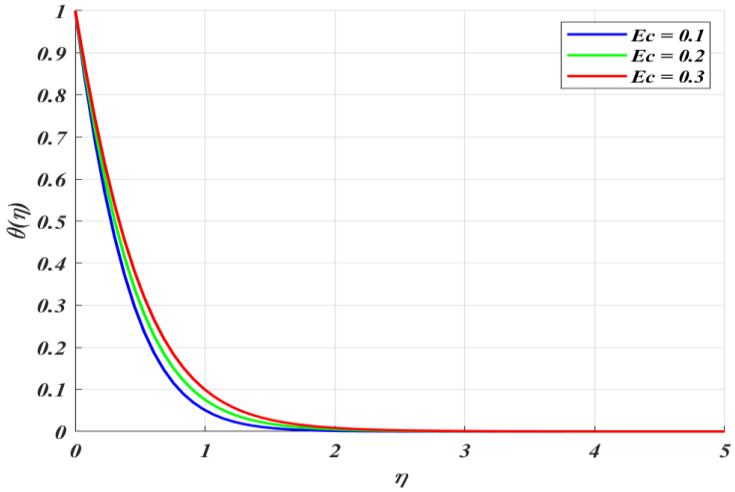

Fig 6. Impacts of Ec on $\theta(\eta)$.

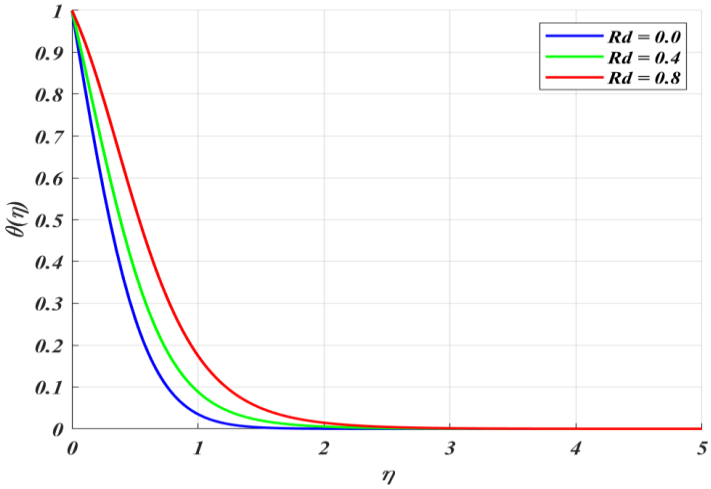

Fig 7. Impacts of Rd on $\theta(\eta)$.

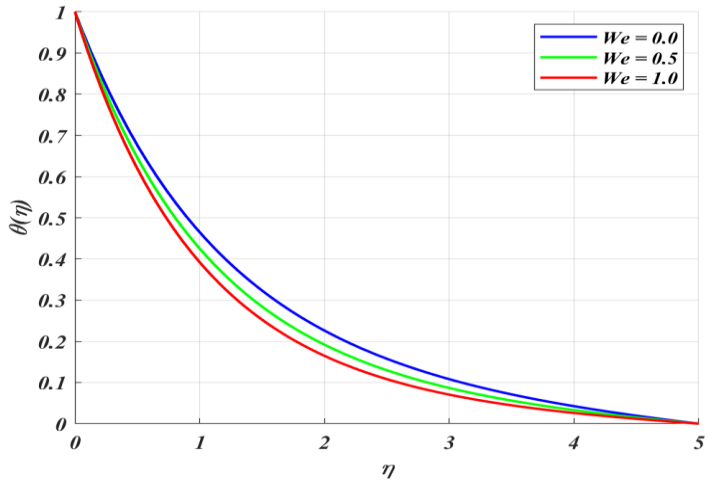

Fig 8. Impacts of We on $\theta(\eta)$.

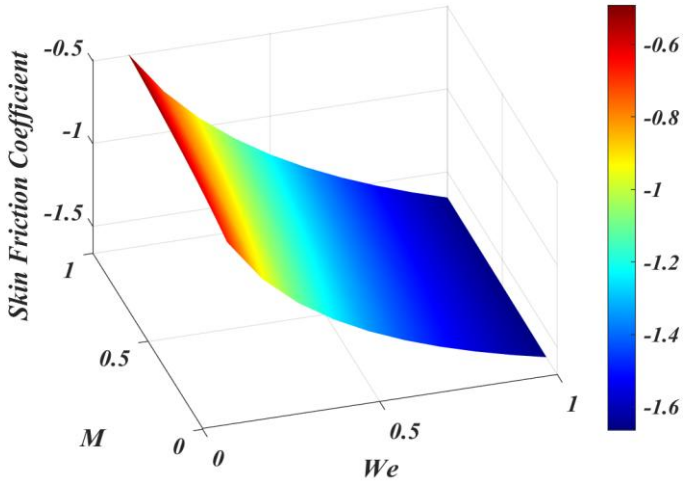

Fig 9. Impacts of M and We on $Re_r^{1/2}C_f$.

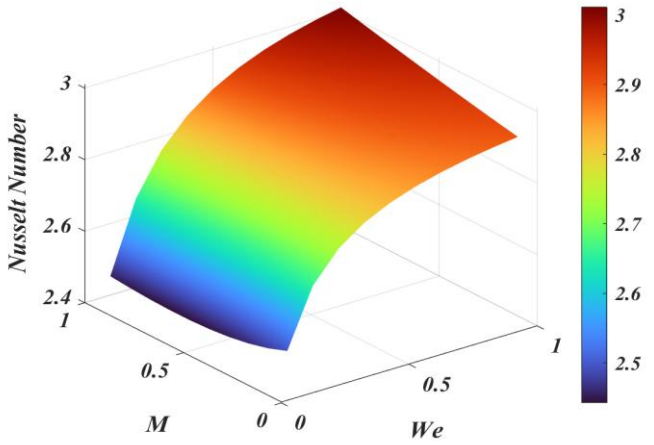

Fig 10. Impacts of M and We on $Re_x^{-1/2}Nu_x$.

Table 2. Tabulated comparison of results for varying Prandtl numbers in the current study.

Pr	Ali et al., [13]	Yahya et al., [17]	Current Findings
0.7	0.4560	–	0.455534
2.0	0.9113	0.9112	0.910615
6.13	–	1.7597	1.759168
20.0	–	3.3540	3.353525
21.0	–	–	3.441600

The current results obtained using the Bvp4c method shows that the excellent agreement with the previous results from Ali et al. and Yahya et al. positive the accuracy of the technique as shown in Table 2.

5. Conclusion

A theoretical study of MHD and thermal radiation optimization was achieved for the goal of the present work. The analysis was executed for the movement of a tangent hyperbolic hybrid nanofluid over a stretching surface. In addition, nanoparticles of Silver and Cu that have been mixed in a blood. As a result of using the Bvp4c in MATLAB tool.

The main following observations are:

- Increasing the magnetic field and We parameter values will cause the fluid's velocity to drop.
- When increasing the Eckert number parameter values the temperature profile increased.
- When increasing the Radiation parameter values the temperature profile enhanced.
- The energy profile enhanced increasing the magnetic field parameter values.
- When increasing the We parameter values the skin friction profile initially increased then after slowly decreased while the opposite tendency noticed in Nusselt number profile.

Data Availability Statement: There is no relevant data available.

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