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EXPLORING THE IMPACT OF MAGNETIC FIELDS AND GOLD NANOPARTICLES ON BLOOD FLOW IN STENOSED ARTERIES

[1]. Dr. T. Sudha, [2].Dr. B. Haritha,[3]. Dr. G. Haripriya,[4]. Dr. C. Umadevi

[1]Designation: Associate Professor

College: Malla Reddy Engineering College for Women, Secunderabad-500100, Telangana

Mail id: sudhathulluri@gmail.com

[2]Associate Professor

College: Santhiram Engineering College, Nandyal, Kurnool (Dist), Andhra Pradesh - 518501

Mail id: haritha.bs@srecnandyal.edu.in

[3]Professor,Dept of mathematics,

Gates Institute of Technology, Gooty, Ananthapuramu (Dist), Andhra Pradesh 515401

Mail ID: hshod@gatesit.ac.in

[4]Designation: Associate Professor

College:TKR College of Engineering and Technology, Hyderabad - 500097, Telangana.

Mail id: uma140276@gmail.com

Abstract

This research paper focuses on the study of magnetic effects on gold nanoparticles suspended in the base fluid through an artery in the presence of overlapping stenosis. The research is conducted on a blood vessel under mild stenosis approximations. The relevant equations are solved to find precise solutions for temperature, speed, and the resistance to the flow. The impact of different factors on the flow is examined using graphs. The analysis also concludes that gold nanoparticles are effective in improving the blood flow dynamics caused by blockages and could be beneficial in medical applications. The findings suggest that nanoparticles can serve as carriers for drugs to lessen the impact of resistance to blood flow.

Keywords: Magnetic field, overlapping stenosis, nanoparticles, resistance to the flow and shear stress.

1. Introduction

The study and simulation of blood circulation in narrowed arteries play a crucial role in the field of biology. The groundbreaking advancements and developments in the medical and health sciences have greatly benefited humanity, yet cardiovascular illnesses remain the leading cause of fatalities, even in affluent nations. Atherosclerosis or Stenosis stands as a

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significant health concern. It's commonly understood that when an artery is narrowed due to atherosclerosis, blood flow is disrupted, leading to serious cardiovascular issues. The way blood behaves in such arteries is markedly different from its normal counterparts due to the accumulation of plaques, which are composed of fatty substances and cholesterol. This condition is medically referred to as atherosclerosis or stenosis.

Stenosis can lead to serious cardiovascular problems by obstructing blood flow. For instance, when an artery that feeds the brain becomes narrowed, it can result in a cerebral stroke. In a similar vein, when there's Stenosis in the arteries that provide blood to the heart, it can trigger a myocardial infarction, which in turn may lead to heart failure. The behavior of blood in both healthy and narrowed arteries differs significantly. The dysfunction of the cardiovascular system is intricately linked to the flow pattern and the physical characteristics of the artery. With a narrowing, the space for blood flow decreases, leading to disruptions in the blood's flow pattern. These disruptions result in fluctuations in the volume of blood flow, shear stress, and resistance. The mathematical analysis of blood flow issues is vital as it offers comprehensive insights into various flow and geometric parameters.

Elastic permeable or moveable artery walls are both possible. Thus, knowledge of the principles governing blood circulation in stenotic arteries is essential. Based on this, a large number of theoretical and experimental models have been put out by different researchers over the past few decades to explore the blood flow during artery stenosis by classifying blood as either Newtonian or non-Newtonian fluids. (Texon [1], Shukla et al., [2], Young [3], Morgan and Young [4],Lee and Fung [5], Padmanabhan [6], Ang and Mazumdar [7], Macdonald [8], , Majhi and Nair [9]). The constrictions in the majority of these theoretical models are taken to be single Stenosis. But Stenosis can form in different shapes such as multiple, overlapping and irregular shapes. A mathematical prototype has been developed by V.P. Srivastava and Shailesh Mishra [10] to examine the effects of overlapping Stenosis by considering blood as non-Newtonian (Casson fluid) fluid . The result of transverse magnetic field and multi-Stenosis on the blood flow in blood vessel was developed by Varshney et al. [11]. Zaman et al.[12] discussed the effects of composite heat and mass transfer on blood flow in arterial segment with overlapping stenosis. Maruthi Prasad et al.[13] studied the effects of an overlapping stenosis in blood vessel by considering blood as couple stress fluid. The unsteady blood flow via an overlapping stenosed artery in the presence of a uniform magnetic field and periodic body acceleration is investigated by Abbas et al. [14].

Nanofluids are very important to researchers and have a lot of applications in all fields like medical, engineering and sciences etc. Heat transfer fluids that contain designed suspension nanoparticles (sizes ranging from 1 to 100 nm) scattered within the fluid are referred to as Nanofluids. These are essential to medical science and therapy in areas such as drug delivery, in vivo therapy and coating medical equipment for better biocompatibility and cancer treatment. They are useful in heat transfer technologies, such as thermal management

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systems and microelectronics cooling, because of their special qualities, which include increased thermal conductivities and convective heat transfer (Shahzadi et al.[15], Hayat et al.[16] and Prasun Choudhary et al.[17]). A.S. Dawood et al.[18] investigated multi effect analysis of nano fluid in narrowed blood vessel. Hassan Waqas et al.[19] inspected the numerical model of hybrid naofluid with nanoparticles such as silver and gold across narrowed artery. Importance of body acceleration and gold nanoparticles through blood flow in an uneven inclined Stenosis blood vessel was developed by C.S.K.Raju et al.[20].

Motivated by the previously mentioned papers, an endeavor has been undertaken in this manuscript to examine the impact of magnetic force on blood flow, employing gold nanoparticles and water as the base fluid. This fluid is thought to flow through an overlapping, stenosed artery (Fig. 1). The examination is done analytically. The influence of diverse significant parameters on flow variables has been detected over the diagrams.

2. Mathematical Formulation

Consider the steady, incompressible and axisymmetric flow of blood through a circular tube of length 'L', in the presence of overlapping stenosis as shown in Fig.1.

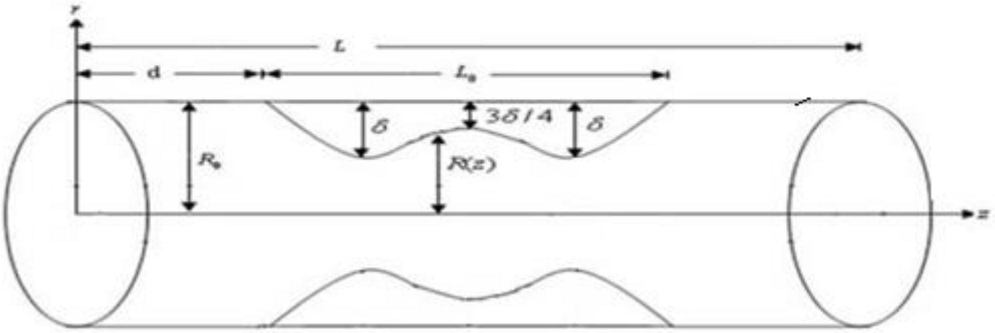

Fig1: Geometry of the Stenosed artery

The geometry of the artery wall is defined mathematically as [6]

$$h = \frac{R(z)}{R_0(z)} = 1 - \frac{3\delta}{2R_0L_0^4}\left[11(z-d)L_0^3 - 47(z-d)^2L_0^2 + 72(z-d)^3L_0 - 36(z-d)^4\right],$$
$$d \le z \le d + L_0,$$
$$= 1, \quad otherwise.$$

(1)

Here $R(z)$ is the tube radius in the stenotic region and $R_0(z)$ represents the radius in the non-stenotic region, d is stenosis location and L_0 it's length , δ is the maximum height of the stenosis located at $z = d + \frac{L_0}{6}, z = d + \frac{5L_0}{6}$. The critical height is taken as $\frac{3\delta}{4}$ at $z = d + L_0/2$, from the origin.

The governing equations for conservation of mass, momentum and temperature for an incompressible nanofluid can be taken as (see ref[11]),

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$$\frac{\partial v}{\partial r}+\frac{v}{r}+\frac{\partial u}{\partial z}=0$$
(2)

$$\rho_{nf}\left(v\frac{\partial v}{\partial r}+u\frac{\partial v}{\partial z}\right)=-\frac{\partial p}{\partial r}+\mu_{nf}\frac{\partial}{\partial r}\left(2\frac{\partial v}{\partial r}\right)+\mu_{nf}\frac{\partial}{\partial z}\left(2\frac{\partial v}{\partial z}+\frac{\partial u}{\partial r}\right) \quad (3)$$

$$\rho_{nf}\left(v\frac{\partial u}{\partial r}+u\frac{\partial u}{\partial z}\right)=-\frac{\partial p}{\partial z}+\mu_{nf}\frac{\partial}{\partial z}\left(2\frac{\partial u}{\partial z}\right)+\frac{\mu_{nf}}{r}\frac{\partial}{\partial r}\left[r\left(\frac{\partial v}{\partial z}+\frac{\partial u}{\partial r}\right)\right]-g\rho_{nf}\alpha(T-T_0)-\sigma B_0^2u$$
(4)

$$\left(v\frac{\partial T}{\partial r}+u\frac{\partial T}{\partial z}\right)=\frac{K_{\eta f}}{(\rho c_p)_{\eta f}}\left(\frac{\partial^2T}{\partial r^2}+\frac{1}{r}\frac{\partial T}{\partial r}+\frac{\partial^2T}{\partial z^2}\right)+\frac{Q_0}{(\rho c_p)_{\eta f}} \quad (5)$$

With the conditions

$$\frac{\partial u}{\partial r}=0,\frac{\partial T}{\partial r}=0 \text{ at } r=0 \quad (6)$$

$$u=0,T=0 \text{ at } r=h \quad (7)$$

In the above equations $u$and v are components of velocity in r and z directions, T is the temperature of fluid, Q_0isthe constant heat absorption or heat generation, $\mu_{\eta f}$ is the dynamic viscosity, ρ_{nf} is the density, $k_{\eta f}$ is the thermal conductivity, $\alpha_{\eta f}$ is the thermal diffusivity and $(\rho c_p)_{nf}$ is the heat capacitance of the nanofluid given as ,

$$\mu_{nf}=\frac{\mu_f}{(1-\varphi)^{2.5}}.k_{nf}=k_f\left\{\frac{k_s+2k_f-2\,\varphi(k_f-k_s)}{k_s+2k_f+2\varphi(k_f-k_s)}\right\}$$

$$\rho_{nf}=(1-\varphi)\rho_f+\varphi\rho_f,(\rho c_p)_{nf}=(1-\varphi)(\rho c_p)_f+\varphi(\rho c_p)_f$$

Introducing the following non-dimensional variables

$$\bar{r}=\frac{r}{R_0},\quad \bar{z}=\frac{z}{L_0},\qquad \bar{\upsilon}=\frac{L_0}{\delta U}\upsilon,\qquad \bar{u}=\frac{u}{U},\qquad \bar{d}=\frac{d}{L_0},\qquad \bar{R}=\frac{R}{R_0}$$

$$M^2=\frac{\sigma B_0^2R_0^2}{\mu_f},G_r=\frac{g\alpha R_0^2T_0\rho_{nf}}{U\mu_f},\bar{\delta}=\frac{\delta}{R_0},\theta=\frac{T-T_0}{T_0}$$

$$\bar{p}=\frac{UL_0\mu}{R_0^2}p,\qquad \beta=\frac{Q_0R_0^2}{k_fT_0},$$

Where U is the velocity averaged over the section of the tube with radius R_0 .

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After using the non-dimensional variables in equations (2)-(5) and also making use of the mild stenosis conditions $\epsilon = \frac{R_0}{L_0} = o(1), \frac{\delta}{R_0} \ll 1$, the reduced equations along with the boundary conditions are (after dropping the bars)

$$\frac{\partial \mathrm{p}}{\partial \mathrm{r}} = 0 \tag{8}$$

$$\frac{\mathrm{dp}}{\mathrm{dz}} = \frac{1}{(1-\varphi)^{2.5}} \frac{1}{r} \frac{\partial}{\partial r}\left(r \frac{\partial \mathrm{u}}{\partial \mathrm{r}}\right) - M^2 u + G_r \theta \tag{9}$$

$$\frac{1}{r} \frac{\partial}{\partial r}\left(r \frac{\partial \theta}{\partial \mathrm{r}}\right) + \beta\left(\frac{k_{nf}}{k_f}\right) = 0 \tag{10}$$

Where M, β and G_r are the Hartmann number, heat absorption parameter and Grashof number respectively.

The no boundary conditions are:

$$\frac{\partial u}{\partial r} = 0, \frac{\partial \theta}{\partial r} = 0 \quad at\, r = 0 \tag{11}$$

$$u = 0, \theta = 0 \quad at\, r = h \tag{12}$$

3. Solution

The exact solutions of equations (9) and (10) are obtained as

$$\text{Velovity, } u = \left\{\frac{\frac{1}{M^2}\frac{dp}{dz} - \frac{G_r\beta}{M^2}\left(\frac{k_f}{k_{nf}}\right)}{I_0\left(Mh\sqrt{(1-\varphi)^{2.5}}\right)}\right\} I_0\left(Mr\sqrt{(1-\varphi)^{2.5}}\right)$$

$$-\frac{G_r\beta}{4M^2}\left(\frac{k_f}{k_{nf}}\right)(r^2 - h^2) - \frac{1}{M^2}\frac{dp}{dz} + \frac{G_r\beta}{M^2}\left(\frac{k_f}{k_{nf}}\right) \tag{13}$$

$$\text{Temperature, } \theta = \frac{-\beta}{4}\left(\frac{k_f}{k_{nf}}\right)(r^2 - h^2) \tag{14}$$

The dimension less flux $q$is

$$q = 2\int_0^h r u dr.$$

$$= \left(\frac{\frac{1}{M^2}\frac{dp}{dz} - \frac{G_r\beta}{M^2}\left(\frac{k_f}{k_{nf}}\right)}{I_0\left(Mh\sqrt{(1-\varphi)^{2.5}}\right)}\right)\left(\frac{hI_1\left(Mh\sqrt{(1-\varphi)^{2.5}}\right)}{M\sqrt{(1-\varphi)^{2.5}}}\right) + \frac{G_r\beta}{16M^2}\left(\frac{k_f}{k_{nf}}\right) + \frac{G_r\beta h^2}{2M^2}\left(\frac{k_f}{k_{nf}}\right)$$

$$-\frac{h^2}{M^2}\frac{dp}{dz}$$

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It implies,

$$\frac{dp}{dz}=\frac{q-\frac{G_r\beta}{16M^2}\left(\frac{k_f}{k_{nf}}\right)-\frac{G_r\beta h^2}{2M^2}\left(\frac{k_f}{k_{nf}}\right)+\frac{G_r\beta}{M^2}\left(\frac{k_f}{k_{nf}}\right)\left(\frac{hI_1\left(Mh\sqrt{(1-\varphi)^{2.5}}\right)}{I_0\left(Mh\sqrt{(1-\varphi)^{2.5}}\right)M\sqrt{(1-\varphi)^{2.5}}}\right)}{\frac{-h^2}{2M^2}+\frac{h}{M^3}\left(\frac{I_1\left(Mh\sqrt{(1-\varphi)^{2.5}}\right)}{I_0\left(Mh\sqrt{(1-\varphi)^{2.5}}\right)\sqrt{(1-\varphi)^{2.5}}}\right)}$$

(15)

The impedance resistance λ is defined as $\lambda=\frac{\Delta p}{Q}=-\int_0^1\frac{dp}{dz}\,dz$

The pressure drop without stenosis $(h=1)$ is defined as $\Delta p_n=\left[-\int_0^1\frac{dp}{dz}\,dz\right]_{h=1}$

The impedance resistance in the normal artery is defined as$\lambda_n=\frac{\Delta p_n}{Q}$

The normalized impedance defined as $\bar{\lambda}=\frac{\lambda}{\lambda_n}$

And the wall shear stressτ_h is defined as $\tau_h=-\frac{h}{2}\frac{dp}{dz}$

4. Results and Discussion:

In this section, the results are interpreted through the graphs. The effects of stenosis height(δ) and heat source or sink parameters (β) on temperature is shown in Figs.2-3. The temperature rises when the stenosis height and heat absorption parameter increases. The temperature is maximum at the center of the tube and minimum near the walls. It is also noted that the temperature variation in Au blood is more than the pure blood.

The variation in velocity against the radial axis for different values of δ,β,G_r,M is presented in Figs.4-7. It is observed that the velocity is high at the center of tube and gradually decreases , the velocity is zero at the wall of the artery. It is also noticed that, the velocity increases with height of stenosis, heat absorption parameter, and Grashof number but decreases with Hartman number. The Au concentrated fluid has more velocity when compared to pure fluid ($\emptyset=0$).

Figs.8-10, depicts the impedance resistance change with respect to stenosis height for different values of heat absorption parameter, Grashof number, Hartman number, flow rate. It seen that the impedance resistance increases with the height of the stenosis, Hartman number, flow rate and decreases as heat absorption parameter, Grashof number increases. In all these figures, we observed that the flow resistance is less in Au blood, when it is compared to pure blood.

The wall shear stress against the axial distance for different values of heat absorption parameter β, stenosis height, Grashof number and Hartman number is plotted in Figs.11-13. It is seen that the wall shear stress is increases with stenosis height and heat absorption parameter and decreases with Grashof number and Hartman number. It is also noticed that, the wall shear stress increases from $z=0$ to $z=0.26$ from there it decreases to $z=0.4$ and

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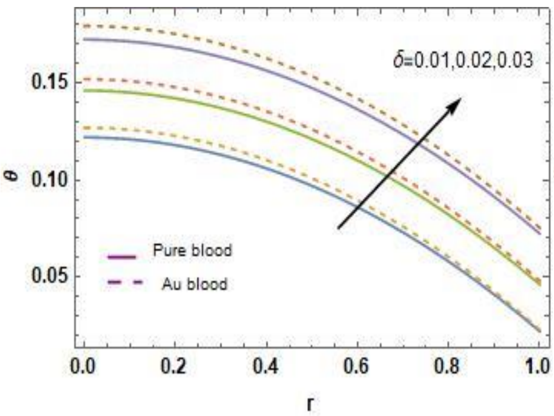
again it increases to $z = 0.53$ from there it gradually decreases and approaches zero. This shows that the walls shear stress is maximum at the throats and minimum at the critical height of the stenosis. It is keenly observed here that the wall shear stress is more for the fluid when the gold concentration is more in the fluid. For pure fluid the shear stress at the walls is low.

The relevant equations are solved to find precise solutions for temperature, speed, and the resistance to the flow. The impact of different factors on the flow is examined through the use of graphs. The analysis also concludes that gold nanoparticles are effective in improving the blood flow dynamics caused by blockages and could be beneficial in medical applications. The findings suggest that nanoparticles can serve as carriers for drugs to lessen the impact of resistance to blood flow.



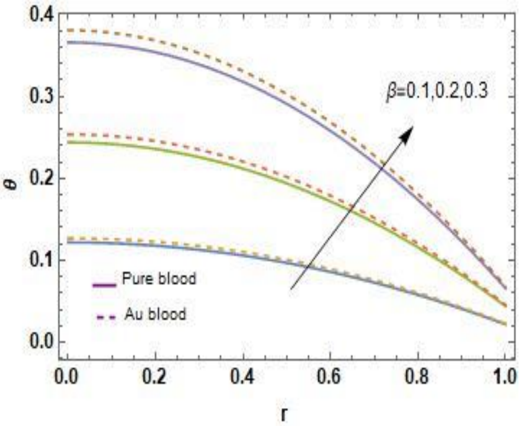
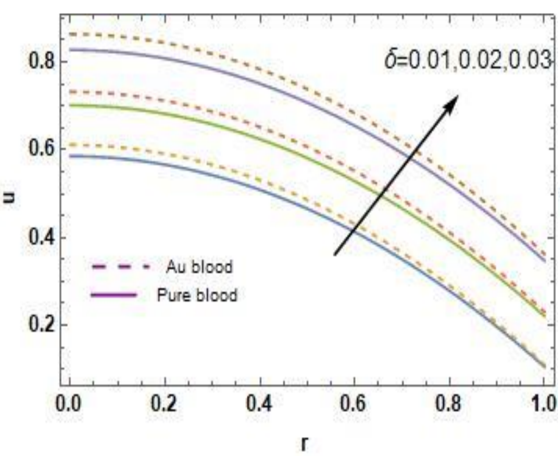


Fig 2: Change in temperature for different values of δ Fig 3: Change in temperature for different values of β $d = 0.2, \mathrm{L}_0 = 0.4, \beta = 0.1, L = 1, z = 0.1$
$d = 0.2, \mathrm{L}_0 = 0.4, \delta = 0.01, L = 1, z = 0.1$



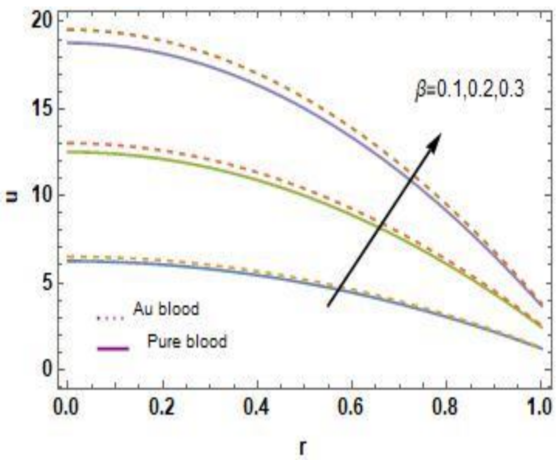


Fig 4: Change in velocity for different values of δ Fig 5: Change in velocity for different values of β

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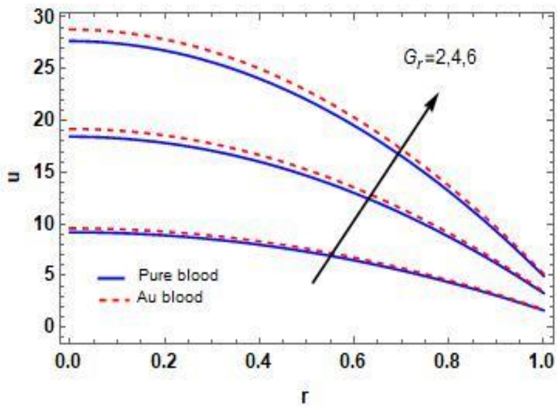
$d = 0.2, \mathrm{L}_0 = 0.4, \beta = 0.1, L = 1, z = 0.1, \mathrm{Gr} = 2; M = 0.1$ $d = 0.2, \mathrm{L}_0 = 0.4, \delta = 0.01, L = 1, z = 0.1, \mathrm{Gr} = 2; M = 0.1$



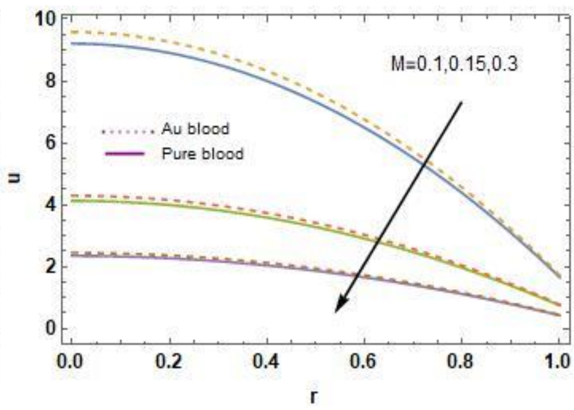
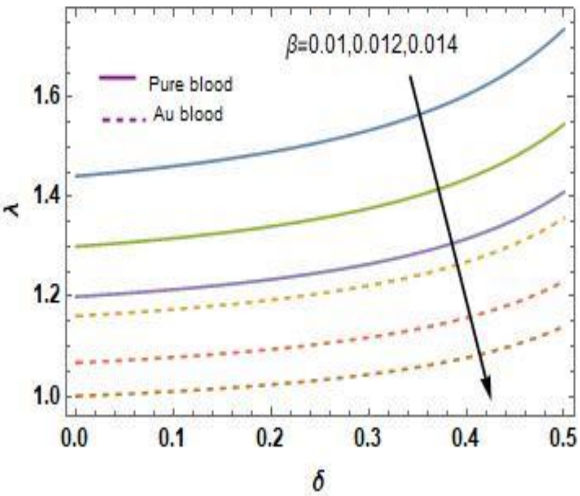


Fig 6: Change in velocity for different values of G_r Fig 7: Change in velocity for different values of M

$d = 0.2, \mathrm{L}_0 = 0.4, \beta = 0.1, L = 1, z = 0.1, \delta = 0.01, M = 0.1$ $d = 0.2, \mathrm{L}_0 = 0.4, \delta = 0.01, L = 1, z = 0.1, \mathrm{Gr} = 2, \beta = 0.1$



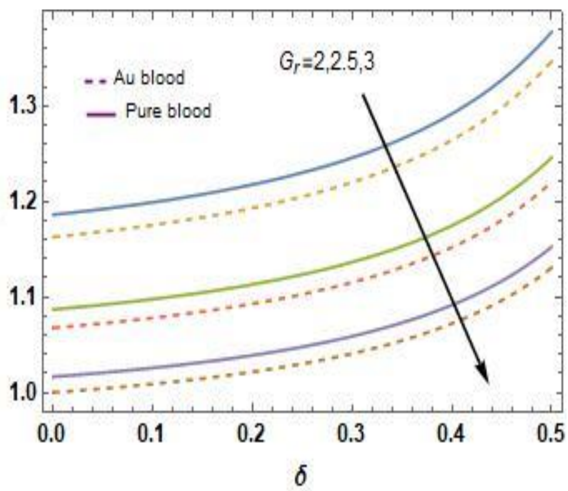


Fig 8: Change in flow resistance for different values of β Fig 9: Change in flow resistance different values ofG_r $d = 0.2, \mathrm{L}_0 = 0.4, L = 1, q = 0.01, \mathrm{Gr} = 2, M = 0.1$ $d = 0.2, \mathrm{L}_0 = 0.4, L = 1, q = 0.01, \beta = 0.1, M = 0.1$

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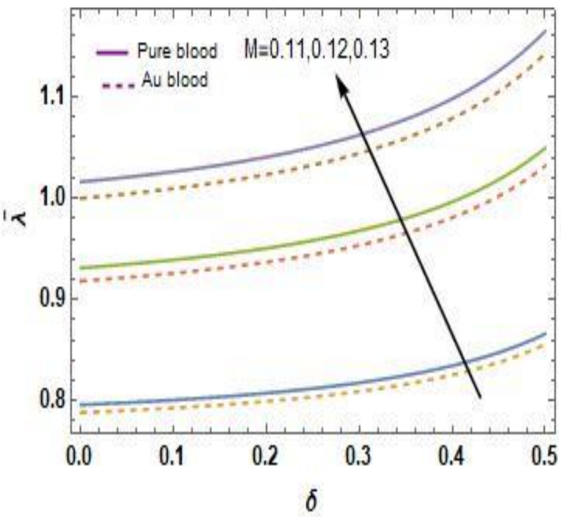


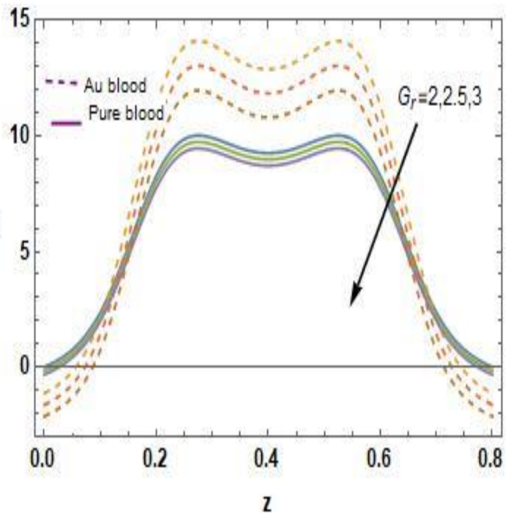
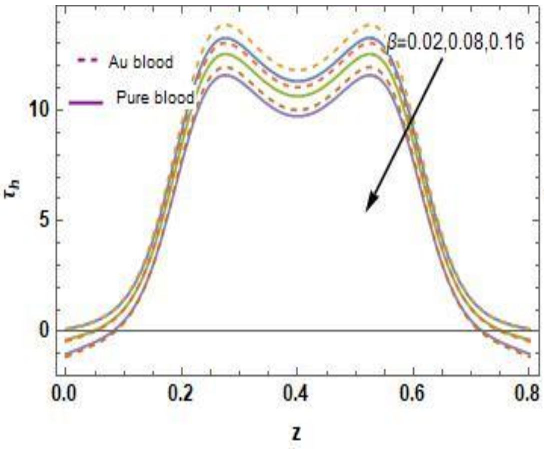


Fig 10: Change in flow resistance for different values of M Fig 11: Wall shear stress for different values of G_r

$d = 0.2, \mathrm{L}_0 = 0.4, L = 1, q = 0.01, \beta = 0.1, \mathrm{Gr} = 2$ $d = 0.2, \mathrm{L}_0 = 0.4, L = 1, q = 1, \delta = 0.1, M = 1, \mathrm{Gr} = 2$



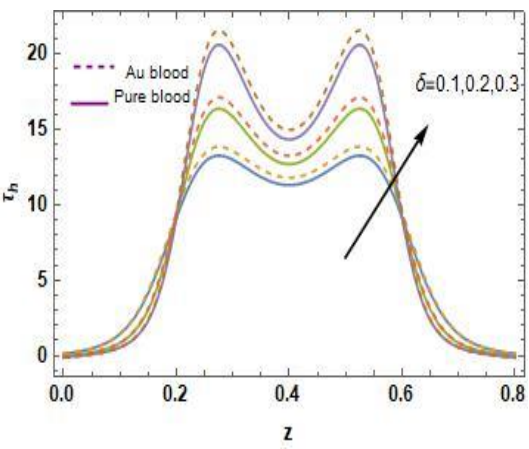


Fig 12: Wall shear stress for different values of β Fig 13: Wall shear stress for different values of δ $d = 0.2, \mathrm{L}_0 = 0.4, L = 1, q = 1, \delta = 0.1, M = 1, \mathrm{Gr} = 2$ $d = 0.2, \mathrm{L}_0 = 0.4, L = 1, q = 1, \beta = 0.02, M = 1, \mathrm{Gr} = 2$

5. Conclusion:

The present analysis is concerned to the gold nanoparticles in the base fluid for the axisymmetric flow through an artery with overlapping stenosis. In this model we studied the effects of various parameters like stenosis height, Grashof number, heat source or sink

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parameter, Hartman number on the flow characteristics velocity, resistance to the flow and wall shear stress.

The main conclusions are given below:

1. The velocity profile increases with height of stenosis, heat absorption parameter, and Grashof number but decreases with Hartman number.
2. It seen that the impedance resistance increases with the height of the stenosis, Hartman number, flow rate and decreases as heat absorption parameter, Grashof number increases.
3. It is observed that the wall shear stress increases with stenosis height and heat absorption parameter and decreases with Grashof number and Hartman number.

References

[1] M.Texon, “A hemodynamic concept of atherosclerosis, with particular reference to coronary occlusion.” AMA archives of internal medicine 99.3(1957):418–427.

[2] J. B. Shukla, R. S. Parihar and B. R. P. Rao. “Effects of stenosis on non- Newtonian flow of the blood in an artery.” Bull. Math. Biol. 42(1980): 283-294,1980.

[3] D.F. Young. “Effects of a time-dependent stenosis on flow through a tube.” J. Eng. Ind., Trans ASME 90(1968): 248-254.

[4] B. E. Morgan and D. F. Young. “An integral method for the analysis of flow in arterial stenosis.” Bulletin of Mathematical Biology 36(1974): 39–53.

[5] J.S. Lee and Y.C. Fung. “Flow in Locally- constricted Tubes and Low Reynolds Numbers.” J. Appl. Mech., Trans ASME. 37(1970): 9-16.

[6] Padmanabhan. “Mathematical model of arterial stenosis.”Med. Biol. Eng. Comput., 18,(1980): 281-286.

[7] K. C. Ang and J. N. Mazumdar. “Mathematical Modelling of Three-Dimensional Flow through an Asymmetric Arterial Stenosis.”Mathl. Comput. Modelling 25.1(1997):19-29.

[8] D.MacDonald. “On steady flow through modelled vascular stenosis.” Journal of Biomechanics 12.1(1979):13–20.

[9] S. N. Majhi and V. R. Nair. “Pulsatile flow of third grade fluids under body Acceleration modeling blood flow.” Int. J. Eng. Sci 32(1994): 839-846.

[10] V.P. Srivastava, Shailesh Mishra et al. "Non-Newtonian arterial blood flow through an overlapping stenosis.” Application and Applied Mathematics. 5.1(2010): 225-238.

ISSN: 1311-1728 (printed version); ISSN: 1314-8060 (on-line version)

[11] Gaurav Varshney, V.K. Katiyar et al. "Effect of magnetic field on the blood flow in artery having multiple stenosis: a numerical study." International Journal of Engineering, Science and Technology2.2(2010) 67-82.

[12] A. Zaman, N.Ali et al. " Numerical simulation of pulsatile flow of blood in a porous-saturated overlapping stenosed artery." Math Comput Simul, 134(2017):1-16.

[13] K. Maruthi Prasad,T. Sudha et al. " Investigation of Blood Flow Through an Artery in the Presence of Overlapping Stenosis." Journal of Naval Architecture and Marine Engineering, 14(2017): 39-46.

[14] Z. Abbas, M.S. Shabbir et al. " Numerical study of magnetohydrodynamic pulsatile flow of Sutterby fluid through an inclined overlapping arterial stenosis in the presence of periodic body acceleration." Results in Physics 9 (2018): 753–762.

[15] I.Shahzadi, S. Nadeem. "Impinging of metallic nanoparticles along with the slip effects through a porous medium with MHD." J Braz Soc Mech Sci Eng 9(2017):2535–2560.

[16] T. Hayat, S. Nadeem. " Heat transfer enhancement with Ag-CuO/water hybrid nanofluid." Results Phys. 7(2017), 2317–2324.

[17] Prasun Choudhary, Sushila Choudhary. "Impacts of unsteady MHD hybrid nanofluid over a non-linear stretchable porous sheet with thermal radiation and gyrotatic microorganisms." International Journal of Thermo fluids 23 (2024): 100788.

[18] A.S Dawood et al. "Multi- Effect analysis of nanofluid flow in stenosed arteries with variable pressure gradient: analytical study." N Applied Sciences 5(2023):382.

[19] Hassan Waqas et al. "Numerical and Computational simulation of blood flow on hybrid nanofluid with heat transfer through a stenotic artery: Silver and gold nanoparticles."Results in Physics 44(2023):106152.

[20] C.S.K.Raju et al. "Significance of body acceleration and gold nanoparticles through blood flow in an uneven/composite inclined stenosis artery: A finite difference computation." Mathematics and Computers in Simulation 215(2024): 399-419.