Finite Element Computations of Stenosed Arterial Blood Flow in the Presence of Transverse Magnetic Field

Dr. Mahesh Chandra
Assistant Professor
Dept. of Mathematics
FS University Sikohabad UP (India).

MS Jharna Goyal
Dept. of Mathematics
FS University Shikohabad UP (India)

Abstract
The present paper deals with the study of flow dynamics of blood with stenosis artery in the presence of transverse magnetic field a computational modelling of blood circulation is carried out and the mathematical equations occurring during the modeling are solved by using Finite Element Method. Various factors like velocity, pressure, wall shear stress, and energy are taken in account. The partial differential equations accounting the complexities are removed by non-dimensional sing them. Boundary conditions are used to simplify the mathematical process. On axis, zero radial gradient condition is applied. The arterial wall is subjected to zero temperature and no-slip conditions.

Keywords: Wall shear stress, magnetic field, radial gradient.

1. Introduction:

The dynamics of blood flow plays an important role in development and progression of various heart diseases. At this time it is worldwide health concern. A large number of researchers have already worked on some similar area. Dabri at el (2013) did work on back group flow. Katiza, K (2014) devote measured quantitatively behavior of flow under water velocimetry. Ruzia (2015) made an investigation on vertex enhanced propulsion. Collin (2016) did work on strength prediction of ecological success. Witlessly at el (2017) did work on vertical axis wind turbine. Breath at el (2018) studied eco system in the pelagicrealm.J.C.et al (2019) did work on the phenotypic plasticity. J.O.et al (2020) worked on vertex pinch of cho.Rosinfield (2021) studied circulation generation and vortex ring. Kartika and Dabril (2022) studied the mechanism of biogenic ocean mixing.

Mathematical Modelling and Governing Equations:-

In the presence of transverse magnetic field M width current density L. the force acted on the blood as we have conceded as non-Newtonian fluid

The motion will be Govern by the following equations

$$L+\frac{We}{ce}(L\times M)=6\left[\square+\square+\square+\frac{APe}{e_n\ e}\right] \quad \ldots\ldots (1)$$

Taking into account Guam Law of Magnetism

A. $\square = 0$ And M= $\square_0\square$ be applied magnetic field

Pressure is constant and E=0. Then

$$L+\frac{L}{\beta\ 0}(r\times\square)=6(\square\times\square) \quad \ldots\ldots (2)$$

Where M=is the Parameter

Using the velocity and current density along axial and radial Co-ordinate system, we have

$Lr=\frac{6M\ \ 0}{1+m^2}(mw+u)$ $Lz=\frac{6M\ \ 0}{1+m^2}(mu-w)$

It results the Momentum and Energy equations are as follows

$$P\left(\frac{du}{dt}+\square\frac{du}{dr}+\square\frac{du}{dz}\right)=-\frac{dp}{dr}+\frac{6M\ \ 0^2}{m^2+1}\left(\square-\square+\square\left(1+\frac{1}{m}\right)\right)\left[\frac{d^2u}{dr^2}+\frac{1}{r}\frac{du}{dr}+\frac{d^2u}{dz^2}-\frac{u}{r^2}\right] \quad \ldots\ldots (3)$$

DOI: https://doi.org/10.5281/zenodo.16916930

$e\left(\frac{du}{dt} + □\frac{du}{dr} + □\frac{du}{dz}\right) = \frac{dp}{dr} + \frac{6M_0}{m^2+1}(□ - □□) + \left(1 + \frac{1}{m}\right)\left[\frac{d^2u}{dr^2} + \frac{1}{r}\frac{du}{dr} + \frac{d^2u}{dz^2} - \frac{u}{r^2}\right]$ ……………………………………………(4)

$\exp\left(\frac{dT}{dt} + □\frac{dT}{dr} + □\frac{dT}{dz}\right) = □\left[\frac{d^2T}{dr^2} + \frac{1}{r}\frac{dt}{dr} + \frac{d^2t}{dz^2}\right] + 2□\left(1 + \frac{1}{m}\right)\left(\frac{du}{dr}\right)^2 + \left(\frac{□}{r}\right)^2 + \left(\frac{d\omega}{dz}\right)^2 + \frac{1}{2}\left(\frac{du}{dz} + \frac{d\omega}{dr}\right)^2 + \frac{6M_0}{(m^2+1)}(□ - □□)^2$………………………(5)

The Pressure gradient is given by

$-\frac{dP}{dZ} = □_0 + □_1□□□□□, \quad □ > 0$ ……. (6)

Since the flow is incompressible axisymmetric and blood as a Non-Newtonian fluid so the equation of continuity will be in the form

$\frac{u}{r} + \frac{du}{dr} + \frac{d\omega}{dz} = 0$……………………………(7)

And Momentum equation will be

$e\left(\frac{du}{dt} + □\frac{du}{dr} + □\frac{du}{dz}\right) = \frac{dp}{dr} + □\left(1 + \frac{1}{m}\right)\left[\frac{d^2u}{dr^2} + \frac{1}{r}\frac{du}{dr} + \frac{d^2u}{dz^2} - \frac{u}{r^2}\right]$ … … (8)

$e\left(\frac{d\omega}{dt} + □\frac{d\omega}{dr} + □\frac{d\omega}{dz}\right) = -\frac{dp}{dz} + □\left(1 + \frac{1}{m}\right)\left[\frac{d^2\omega}{dr^2} + \frac{1}{r}\frac{d\omega}{dr} + \frac{d^2\omega}{dz^2}\right]$………………(9)

in blood flow through a steroid astery in the presence of the Transeverse the Magnetic field. The initial and wall condetios are as

w=0 T=0 atr = 0

$\frac{d\omega}{dr} = 0, \frac{dt}{dr} = 0$ □□□ = 0

…………(10)

□ = 0 □ = □□ atr=R

Wall Shear Strem…………………(11)

$r□ = -□\left(\frac{□□}{□□}\right)$

□□□□□□□□□□ □□□□□□□□□□□ :-

□□□□□□□ □□□□□□□□□ □□□h□□ :–

□ = □₁□₁ + □₂□₂ + ⋯ … … … . . □ₘ□ₘ

□(□) □□ + 1 − □□ / (□□ + 1 − □□) + (□ − □□) / (□□ + 1 − □□) □□ + 1□ ; □□ ≤ □ ≤ □□ + 1

U=Ai Ui+Ai+1 Ui+1

K[q] + [m] [q]=Q(t)

Where A1= 1-s A2=S And Δ= (□ − □□)□□

$\int_e 6□□□□□□ = \int_e □□□□□□□ + \int_e □□□□□□□$

□h□□ □□□□□ □□ □□□□□□ □h□ □□□□□□□□ □□□□□□□ □□□ □□□□□□□

– □□□□□□□□ □□□□□

$F = -□_0 \frac{d^2u}{d+2}$

{u} =[A]q

{u} =[A]{q}

$\int_e □[□]^T[□]□□□(□)$

$= \int_0^e □ [□]^T[□]□□□(□)$

$+ \int_l [□]^T$

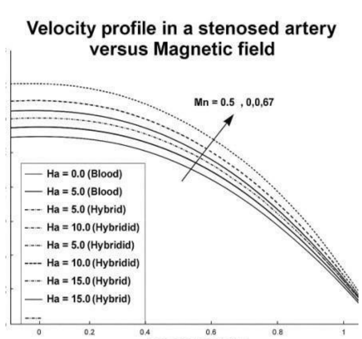
Or [ki] {qi} + {m} I {Q}I = {Q(+) }i

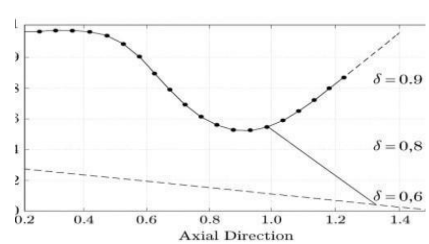
$[K] = \frac{AE}{e}\begin{bmatrix}1 & -1\\ -1 & 1\end{bmatrix}$

$[m] = P_0 Al \int_0^1 (1 - □)[1 - □, □]\, ds = \frac{P0?Al}{6}$

$\{Q\}\ \frac{Alf}{2}$

It proves that magnetic permeability induces changes within the fluid flow that enhance the convective heat transfer along the walls. Cells' fluid temperature profile: it was observed that walls' shear stress decreases as magnetic parameter increases. That causes stress decrement on velocity gradient at the vessel wall thereby decreasing the wall shear stress.





JRE 1.8: Variation of stenosis severity along the axia direction of an artery

DOI: https://doi.org/10.5281/zenodo.16916930

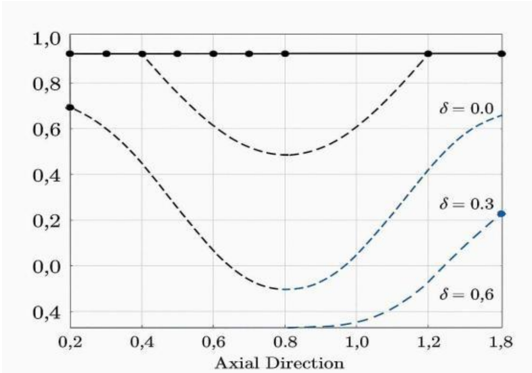
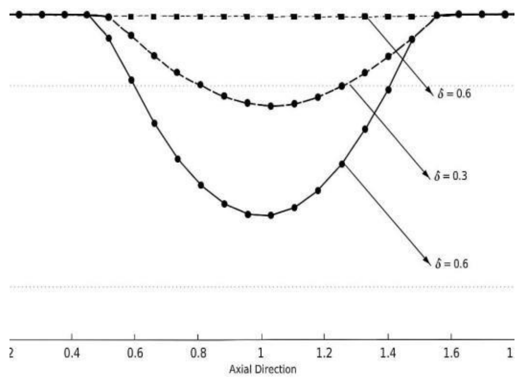


FIGURE 1.8: Variation of stenosis severity along the axial direction of an artery



Results & Discussion

Since the flow is subjected to an applied magnetic field and pulsatile pressure gradient. The applied magnetic field deliberate external force on flow of blood in considered artey. It was observed that increase in magnetic parameter, increase the velocity. The imposed magnetic field poses a force on moving particles within the fluid, which aligns the flow and reduces the velocity gradient. Magnetic parameter plays a significant role in regulating the flow behavior. The influence of magnetic parameter on the temperature. The influence of magnetic parameter generated by the electromotive force transverse to the current in blood corresponds to decrease the temperature. It proves that magnetic parameter induces charge with the fluid flow that enhance the connective heat transfer leading to a coller fluid temperature profile. It was observed that wall shear stress decreases as magnetic parameter increases that causes the reduction of velocity gradient at vessel wall thereby the decreasing the wall shear stresse.

References

1. Dabri,J.O.Koehi,and Mar,L (2013) Simultaneous field measurements of ostracod swimming behaviour and background flow. Lamnology and Oceanography:Fluid andEnvironment1 135-146
2. Colin SP, Costello JH, Dabiri J.O (2014) "Quantitatively measuring in situ using a self-contained underwater velocimetry apparatus (SCUVA)," Journal of Visualized Experiments 56: 2615
3. Whittlesey RW, Dabiri JO (2015) "Vortex-enhanced propulsion," Journal of Fluid Mechanics 668: 5-32.
4. Costello JH, Hansson LJ, Titelman J, Dabiri JO (2016) "Stealth predation: biological mechanisms of the ecological success of the invasive ctenophore Mnemiopsis leidyi," Proceedings of the National Academy of Sciences of the USA 107 (40): 17223-17227.
5. Liska SC, Dabiri JO (2017) "Fish schooling as a basis for vertical-axis wind turbine farm design," Bioinspiration and Biomimetics 5: 035005.
6. Crump BC, Dabiri JO, Gallegos CL (2018) "Ecosystem engineers in the pelagic realm: Habitat alteration by species ranging from microbes to jellyfish," Integrative and Comparative Biology 50 (2): 188-200.
7. Feitl KE, Colin SP, Costello JH, Dabiri JO (2019) "Phenotypic plasticity in hydromedusan jellyfish medusae facilitates effective animal-fluid interaction," Biology Letters 6 (3): 389-393.
8. Colin SP, Katija K, Costello JH (2020) "A wake-based correlate of swimming performance and foraging behavior in seven co-occurring jellyfish species," Journal of Experimental Biology 213 (8): 1217-1225.

DOI: https://doi.org/10.5281/zenodo.16916930

9. Terrell C, Dabiri JO (2021) "A Lagrangian approach to identifying vortex pinch-off," Chaos 20: 017513.
10. Colin SP, Katija K, Costello JH (2022) "A wake-based correlate of swimming performance and foraging behavior in seven co-occurring jellyfish species," Journal of Science. 19,vol 6 pp.178-184.