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# DYNAMICAL CHARACTERISTICS OF MAGNETOHYDRODYNAMIC BLOOD FLOW THROUGH HUMAN ARTERIES

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## Abstract

Magnetohydrodynamics (MHD) has emerged as a significant interdisciplinary field that combines fluid mechanics, electromagnetism, and biomedical engineering to investigate the behavior of electrically conducting fluids such as blood under the influence of magnetic fields. Blood, owing to the presence of iron-containing hemoglobin and charged ions, exhibits weak electrical conductivity, making it responsive to externally applied magnetic fields. Understanding the dynamical characteristics of MHD blood flow through human arteries is essential for improving diagnostic imaging, targeted drug delivery, magnetic hyperthermia, and cardiovascular treatment planning. This study investigates the influence of magnetic field strength, arterial geometry, blood viscosity, Reynolds number, and pulsatile flow conditions on blood velocity, wall shear stress, and pressure distribution within arteries. A mathematical and computational approach based on the Navier–Stokes equations coupled with Maxwell's electromagnetic equations is employed to analyze the flow dynamics. The findings indicate that increasing magnetic field intensity suppresses blood velocity while enhancing flow stability and modifying wall shear stress patterns. These observations demonstrate the potential of MHD-based models in advancing biomedical engineering applications and improving cardiovascular disease diagnosis and therapy.

**Keywords**: Magnetohydrodynamics, Blood Flow, Human Arteries, Hemodynamics, Magnetic Field, Wall Shear Stress, Computational Fluid Dynamics, Cardiovascular Modeling.

## Introduction

Mathematical modeling of the circulatory system has greatly increased in popularity in recent years. In fact, the FDA now requires mathematical modeling of human physiology before allowing human or animal testing of vascular devices as stated in. In order to develop helpful, realistic models, several things need to be taken into account. Among those things, the model needs to be simple enough that the resulting problems are computationally feasible. "The study of the blood flow in arteries is a rich field encompassing unsteady flows, varying geometries, turbulence, and secondary structures." As Ku states, studying blood flow can allow us to quantify diseases, such



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as atherosclerosis, stenosis, and thrombosis. Altered flow patterns, which may be detected by simulation, such as flow reversal, and low or oscillatory shear stress, are important factors in developing arterial disease. Once these diseases are understood, a model that incorporates blood flow, the effect of the walls on flow, and the adaptation of vessel walls after surgery can help make clinical decisions. These can include when surgery is necessary, how to develop diagnostic tools, and how to design devises to mimic or alter blood flow. The complexity of such models depends on the nonlinear interactions in the cardiovascular system, and the vast differences between individual structures. To study these disease states, Ku looks at pulsatile flow on the verge of turbulence. Similarly, Canic has been studying the implementation of stents, and when they fail. She has looked at a method of attaching stents to arterial walls, and the problems that arise. In order to accurately describe the change between the arterial wall and the stent, Canic and coauthors have obtained a number of results, which have been presented in a series of papers investigating blood flow in an artery with variable radius, and how to model arterial walls' response to pulsatile blood flow.

In recent years, the interest in hemodynamical studies has grown appreciably due to the fact that many cardiovascular diseases are closely related to the flow conditions in the blood vessels. The development of various fatal disorders such as Atherosclerosis, Diabetes, Thrombosis and other cardiovascular disorders, which continue to be leading cause of deaths, is increasing public concern about their treatments. Stenosis is one of them. Externally imposed body acceleration also has major influence on the flow through stenosed artery. Activities such as driving, cycling and jogging cause the human body to be exposed to accelerations. Body acceleration changes the blood velocity significantly. So, the velocity of blood under the pumping action of heart is increased to the high amplitude of body acceleration. When the human body experiences a sudden velocity change, the blood flow is disturbed. The human body has a remarkable adaptability to changes and a prolonged exposure of the body to such vibrations leads to many health problems like headache, abdominal pain, venous pooling of blood in the extremities and increased pulse rate on account of disturbances in blood flow. If the response of the human system to such acceleration is understood properly, the controlled accelerations can be used for therapeutic treatments, development of new diagnostic tools and for better designing of protective pads. A model for abnormal growth in the lumen of the artery is called stenosis, which is developed due to the accumulation of cholesterol on the vessel wall is represented by have studied the flow characteristic of blood in an artery with stenosis by introducing various non-Newtonian fluid models to represent the blood. Although blood is a suspension of cells it behaves like a non-Newtonian fluid at low shear rates in smaller arteries. has presented a generalized Newtonian model used mainly for blood, at a high rate of shear when blood behaves like a Newtonian fluid. Many researchers assumed stenosis to be symmetric and human blood to be Newtonian, to simplify the problem an assumption that remains largely valid for a large vessel as well, under normal physiological conditions transport of blood in the human circulatory system depends entirely on the pumping action of the heart producing a pressure gradient throughout the arterial system. periodic blood flow through stenosed and locally expanded tubes. They found that the vortex



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downstream of stenosis or expansion becomes strongest at a certain frequency of pulsation. the pulsatile flow of blood under the influence of externally imposed periodic body acceleration through a time dependent stenosed artery. The flow characteristic of blood through a multi stenosed artery when it is subjected to whole body acceleration has been studied by, where they considered a flexible cylindrical tube containing a homogeneous Newtonian fluid with variable viscosity depicting blood. have considered the pulsatile flow of Casson fluid through a stenosed artery with the effect of body acceleration. It is observed that the yield stress of the fluid and body acceleration highly influenced the velocity of the fluid, shear stress, flow rate in a stenosed artery.

Blood circulation is a complex physiological process governed by interactions among pressure gradients, vessel elasticity, blood rheology, and cardiac pulsation. In recent decades, researchers have shown increasing interest in studying blood flow under externally applied magnetic fields because of its applications in magnetic resonance imaging (MRI), targeted drug delivery, cancer therapy, and cardiovascular diagnostics. Magnetohydrodynamics (MHD) examines the behavior of electrically conducting fluids subjected to magnetic forces, and blood qualifies as a weakly conducting fluid due to dissolved electrolytes and iron-containing hemoglobin molecules. When a magnetic field interacts with flowing blood, Lorentz forces are generated, influencing velocity distribution, pressure gradients, and wall shear stress inside arteries. These effects become particularly important in stenosed arteries, aneurysms, and other cardiovascular disorders where abnormal blood flow patterns contribute to disease progression. Mathematical modeling and computational simulations provide valuable tools for understanding these interactions without invasive experimentation. Consequently, MHD blood flow analysis has become an important research area in biomedical engineering, fluid mechanics, applied mathematics, and cardiovascular medicine, offering new possibilities for disease diagnosis, treatment optimization, and medical device development. Magneto-Hydrodynamics (hereafter MHD) describes plasmas on large scales and more generally electrically conducting fluids. This description does not discriminate between the various fluids that constitute the medium. In laboratory, it allows to globally describe a plasma machine, for instance a toroidal nuclear fusion reactor like a Tokamak. In astrophysics it plays an essential role in the description of cosmic objects and their environments, as well as the media, such as the interstellar or the intergalactic medium. A set of phenomena are specific to MHD description. Some of them will be presented in this lecture such as the tension effect, confinement, magnetic diffusivity, magnetic field freezing, Alfven waves, magneto-sonic waves, reconnection. A celebrated phenomenon of MHD will not be introduced in this brief lecture, namely the dynamo effect. The interaction of moving conducting fluids with electric and magnetic fields provides the magnetohydrodynamic (MHD) phenomenon. Based on this principle, MHD pump uses the "Lorentz Force" to move fluid. The railgun channel is one important segment in an electromagnetic launcher. As known one of the possible ways to increase the EML efficiency is to segment the working channel. For this purpose MHD flow study is necessary. It is required to have the knowledge of the flow field to design a magnetohydrodynamic pump. The purpose of this study is to analytically investigate the effect of Hartman number as well as magnetic and electrical angular frequency on the velocity distribution in a magnetohydrodynamic pump. To solve the governing



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differential equation, initially a velocity profile is guessed and then the Navier-Stokes is solved. Results show that as Hartman number approaches zero the velocity profile becomes similar to that of fully developed flow in a pipe. Furthermore, for frequency over 10pi rad/sec the flow can be treated as steady state. However below angular frequency of 10pi rad/sec velocity oscillates constantly. Therefore flow can not be treated as steady state.

**Objectives**

- To investigate the dynamical characteristics of magnetohydrodynamic blood flow through human arteries.
- To examine the influence of magnetic field strength on blood velocity profiles.
- To analyze variations in wall shear stress and pressure distribution under MHD conditions.
- To study the effects of Reynolds number and Hartmann number on arterial blood flow.
- To evaluate the impact of pulsatile flow on hemodynamic behavior.
- To understand the interaction between electromagnetic forces and arterial fluid mechanics.
- To assess the potential biomedical applications of MHD blood flow modeling.
- To provide recommendations for future cardiovascular diagnostic and therapeutic technologies.

**Research Methodology**

The study adopts a quantitative computational research methodology based on mathematical modeling and numerical simulation. Blood is modeled as an incompressible, electrically conducting fluid flowing through an idealized cylindrical artery under pulsatile conditions. The governing equations consist of the incompressible Navier–Stokes equations coupled with Maxwell's electromagnetic equations to account for magnetohydrodynamic effects. Numerical simulations are performed using Computational Fluid Dynamics (CFD) techniques with appropriate boundary conditions representing physiological blood pressure and flow rates. Key parameters including magnetic field strength, Reynolds number, Hartmann number, blood viscosity, arterial radius, and pulsation frequency are systematically varied to examine their effects on velocity distribution, wall shear stress, and pressure gradients. Simulation outputs are analyzed using graphical and statistical methods to identify flow characteristics and compare physiological conditions with MHD-controlled flow. The methodology provides a reliable framework for understanding cardiovascular fluid dynamics without invasive clinical experimentation.

**Results**

Blood flow simulations demonstrate that the application of an external magnetic field significantly alters arterial hemodynamics. As magnetic field intensity increases, blood velocity decreases because the Lorentz force opposes fluid motion. This reduction in velocity contributes to greater



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flow stability and minimizes turbulence within the artery. Wall shear stress shows moderate changes depending on arterial geometry and pulsatile conditions, while pressure gradients increase slightly under stronger magnetic fields. Higher Hartmann numbers further suppress velocity fluctuations, indicating improved flow control. The computational results suggest that MHD effects are more pronounced in narrowed or stenosed arteries than in healthy vessels. Overall, the simulations confirm that magnetic fields can effectively regulate blood flow characteristics and may contribute to improved biomedical treatment strategies.

The findings are consistent with established magnetohydrodynamic theory, which predicts that Lorentz forces oppose the motion of electrically conducting fluids. Reduced blood velocity under stronger magnetic fields has important clinical implications for controlling excessive blood flow, improving targeted drug delivery, and optimizing hyperthermia-based cancer therapies. Changes in wall shear stress are particularly relevant because abnormal shear stress is associated with atherosclerosis, thrombosis, and endothelial dysfunction. The computational model also demonstrates that MHD effects become increasingly significant under pathological conditions such as arterial stenosis, where altered flow patterns already exist. Although the present study provides valuable insights, future investigations should incorporate patient-specific arterial geometries, non-Newtonian blood behavior, vessel elasticity, and experimental validation to enhance model accuracy and clinical applicability.

A precise model for examining the non-Newtonian blood flow through a stenosed arterial area has been developed by them. It has been concluded that the pressure drops as well as shear stress increases as the size of stenosis augmented for a given non-Newtonian precise model of the blood. Some researchers showed that the changing in temperature and pressure reduction is significantly related to the value of magnetic field intensity. A precise study of pressure drop and shear stress of Non-Newtonianblood has done by them. It was investigated that resistive impedance in a diverging tapering emerges to be smaller rather than those in converging tapering as the blood flow rate is higher in the previous than that in the later, as anticipated, as well as impedance resistance, have its maximum worths in the symmetric stenosis. The precise analysis of heat, as well as mass transfer on the blood flow through a tapered stenosed pipe with the suspension of nano-particles, has been given by them. It concluded that the velocity profile decreases with an augment in the Grash of number and local Grash of number whereas the temperature profile and concentration profile decrease with an augment in the Brownian motion parameter and Thermophoresis parameter. Blood behavior was studied by some researchers. This study says that Hemodynamic plays the main role to build an arterial single or multiple stenoses in the body, which indicates to the abnormalities of the cardio system. Blood functioning, especially in the diseased arteries can be identified by mathematical simulation. A detailed study of modeling of uncharacteristic blood flow through arteries in the existence of slip condition has done by some researchers. Further, they examined abnormal flow through arteries in the occurrence of slip condition, and magnetic field.

**6.2 Assumptions**

The following assumptions are made in this chapter:



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a) The blood is assumed to be homogeneous incompressible and non-Newtonian fluid.
b) The motion of flowing blood is steady laminar.
c) The radial velocity neglected in the artery as the radial velocity is very small in comparison to the axial velocity.
d) The stenosis developed in the artery is bell-shaped axially symmetric and depends upon the axial distance z.

**6.3 Development of The Model**

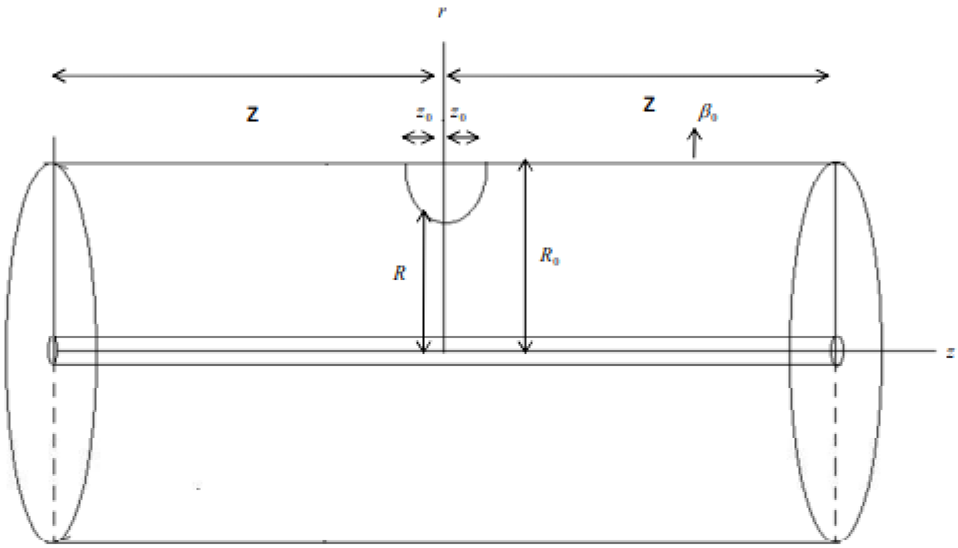


**Figure 1: Geometry of Stenosis in an Artery with Magnetic Field and Length of Constriction**

A steady laminar entirely developed one-dimensional movement of blood following the Herschel–Bulkley Mathematical model through a diseased artery. The radius of the blood vessel depends upon stenosis and a mathematical geometry of bell-shaped stenosis is

$$R=R_0\left[1-\frac{\psi}{R_0}e^{\frac{-m^2a^2z^2}{R_0^2}}\right] \tag{1}$$

The fraction of half magnitude radius of stenosis is

$$\alpha=\frac{R_0}{Z_0} \tag{2}$$

Assuming the precise geometry to be

$$\frac{R(z)}{R_0}=\left[1-ve^{-\beta z^2}\right] \tag{3}$$

with $\upsilon=\frac{\psi}{R_0}$and $\beta=\frac{m^2\alpha^2}{R_0^2}$

If blood is a Power Law Fluid then constitutive equation for length of constriction is

$$\tau=\mu e^n \Rightarrow \left[\frac{\tau}{\mu}\right]^{\frac{1}{n}}=e=\left[\frac{\frac{1}{2}pr}{\mu}\right]^{\frac{1}{n}}+Ha^2ur+\tau_s=-\frac{du}{dr} \tag{4}$$

$$-\frac{du}{dr}=\left[\frac{\frac{1}{2}pr}{\mu}\right]^{\frac{1}{n}}+Ha^2ur+\tau_s+\alpha$$



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$$-\frac{du}{dr} = \left[\frac{p}{2\mu}\right]^{\frac{1}{n}} + r^{1/n} - Ha^2ur + \tau_s + \alpha \quad (5)$$

Integrating with respect to "r", we have

$$u = -\left[\frac{p}{2\mu}\right]^{1/n} \frac{r^{\frac{1}{n}+1}}{\left[\frac{1}{n}+1\right]} - Ha^2ur - \tau_s r - \alpha r + C$$

$$u = -\left[\frac{p}{2\mu}\right]^{1/n} \frac{n}{n+1} r^{\frac{1}{n}+1} - Ha^2ur - \tau_s r - \alpha r + C \quad (6)$$

subject to the slip conditions

$\tau$ $is\ finite\ at\ r = 0$ (7)

And u = $u_s$ at r = R(z) (8)

**6.4 Analytical Solution of The Problem**

$$u_s = -\left[\frac{p}{2\mu}\right]^{\frac{1}{n}} \frac{n}{n+1} R^{\frac{1}{n}+1} - Ha^2uR - \tau_s R - \alpha r + C$$

$$C = u_s + \left[\frac{p}{2\mu}\right]^{\frac{1}{n}} \frac{n}{n+1} R^{\frac{1}{n}+1} - Ha^2uR + \tau_s R + \alpha r \quad (9)$$

From equation (6.6), we have

$$u = -\left[\frac{p}{2\mu}\right]^{\frac{1}{n}} \frac{n}{n+1} r^{\frac{1}{n}+1} - Ha^2ur - \tau_s r - \alpha r + u_s + \left[\frac{p}{2\mu}\right]^{\frac{1}{n}} \frac{n}{n+1} R^{\frac{1}{n}+1} + Ha^2uR - \tau_s R + \alpha r$$

$$u = -\left[\frac{p}{2\mu}\right]^{\frac{1}{n}} \frac{n}{n+1} \left[r^{\frac{1}{n}+1} - R^{\frac{1}{n}+1}\right] - Ha^2u(r-R) - \tau_s(r-R) + u_s + \alpha(r-R)$$

$$u = \left[\frac{p}{2\mu}\right]^{\frac{1}{n}} \frac{n}{n+1} \left[R^{\frac{1}{n}+1} - r^{\frac{1}{n}+1}\right] - Ha^2u(R-r) + \tau_s(R-r) + \alpha(R-r) + u_s \quad (10)$$

For the slip condition

$$u = \left[\frac{p}{2\mu}\right]^{\frac{1}{n}} \frac{n}{n+1} \left[R_0^{\frac{1}{n}+1} - R^{\frac{1}{n}+1}\right] + Ha^2u(R_0-R) + \tau_s(R_0-R) + \alpha(R-r)\, u_s$$

$$u = Ha^2u(R_0-R) = \left[\frac{p}{2\mu}\right]^{\frac{1}{n}} \frac{n}{n+1} \left[R_0^{\frac{1}{n}+1} - R^{\frac{1}{n}+1}\right] + \tau_s(R_0-R) + \alpha(R-r)u_s$$

$$u[1 - Ha^2(R_0-R)] = \left[\frac{p}{2\mu}\right]^{\frac{1}{n}} \frac{n}{n+1} \left[R_0^{\frac{1}{n}+1} - R^{\frac{1}{n}+1}\right] + \tau_s(R_0-R) + \alpha(R-r)u_s$$

$$u = \frac{\left[\frac{p}{2\mu}\right]^{\frac{1}{n}} \frac{n}{n+1} \left[R_0^{\frac{1}{n}+1} - R^{\frac{1}{n}+1}\right] + \tau_s(R_0-R) + \alpha(R-r)u_s}{[1 - Ha^2(R_0-R)]} \quad (11)$$

Here Ha is the Hartmann number.

$$H_a^2 = \beta_0^2 R_0^2 \left[\frac{\sigma}{\mu}\right] \quad (12)$$

$$\beta_0 = \sqrt{\frac{H^2}{R_0^2\left[\frac{\sigma}{\mu}\right]}} \quad (13)$$

Flow rate (Q) $=\int 2\pi R dR \Rightarrow 2\pi \int uRdR$ (14)



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$$Q = 2\pi \int \left[ \left[\frac{p}{2\mu}\right]^{\frac{1}{n}} \frac{n}{n+1}\left[R_0^{\frac{1}{n}+1} - R^{\frac{1}{n}+1}\right] + Ha^2u[R_0 - R] + \tau_s[R_0 - R] + \alpha(R-r)u_s\right] \mathrm{RdR}$$

$$Q = 2\pi \int \left[ \left[\frac{p}{2\mu}\right]^{\frac{1}{n}} \frac{n}{n+1}\right]\left[R_0^{\frac{1}{n}+1} - R^{\frac{1}{n}+1}\right] \mathrm{RdR} + 2\pi \int \left[Ha^2u[R_0 - R]\right] \mathrm{RdR}$$

$$+2\pi \int \tau_s\,[R_0 - R]\,\mathrm{RdR} + 2\pi \int \alpha(R_0 - r)\;\mathrm{RdR}$$

$$Q = 2\pi \;\left[\frac{p}{2\mu}\right]^{\frac{1}{n}} \frac{n}{n+1} \int \left[R_0^{\frac{1}{n}+1} - R^{\frac{1}{n}+2}\right] \mathrm{dR} + 2\pi Ha^2u \int R_0.\,\mathrm{RdR} - 2\pi Ha^2u \int R^2\,dR$$

$$+2\pi \int \tau_s\,[R_0R - R^2]\mathrm{dR} + 2\pi u_s \int \mathrm{RdR} + 2\pi \int \frac{M^2\beta^2}{R_0^2}[R_0 - R]\,\mathrm{RdR}$$

$$Q = 2\pi \;\left[\frac{p}{2\mu}\right]^{\frac{1}{n}} \frac{n}{n+1}\left[R_0^{\frac{1}{n}+1}.\frac{R^2}{2} - \frac{R^{\frac{1}{n}+2}}{\frac{1}{n}+3}\right] + 2\pi Ha^2uR_0\frac{R^2}{2} - 2\pi Ha^2u\frac{R^3}{3}$$

$$+2\pi \int \frac{RQ}{\pi A}[R_0R - R^2]\mathrm{dR} + 2\pi u_s\frac{R^2}{2} + 2\pi\frac{M^2\beta^2}{R_0^2}\left[R_0\frac{R^2}{2} - \frac{R^3}{3}\right]$$

$$Q = 2\pi \;\left[\frac{p}{2\mu}\right]^{\frac{1}{n}} \frac{n}{n+1}\left[R_0^{\frac{1}{n}+1}.\frac{R^2}{2} - \frac{n}{3n+1}R^{\frac{1}{n}+1}.R^2\right] + 2\pi Ha^2uR^2\left[\frac{R_0}{2} - \frac{R}{3}\right] + \frac{2Q}{A}R^3\left[\frac{R_0}{3} - \frac{R}{4}\right]$$

$$+\pi\frac{M^2\beta^2}{R_0^2}R^2\left[1 - \frac{2}{3}\frac{R^2}{R_0}\right] + 2\pi u_s\frac{R^2}{2}$$

$$Q = 2\pi \;\left[\frac{p}{2\mu}\right]^{\frac{1}{n}} \frac{n}{n+1}R^2\left[\frac{1}{2}R_0^{\frac{1}{n}+1} - \frac{n}{3n+1}R^{\frac{1}{n}+1}\right] + \frac{1}{2}\pi Ha^2uR^2(3R_0 + 2R)$$

$$+\frac{1}{6}\frac{QR^3}{A}(4R_0 - 3R) + \pi\frac{M^2\beta^2}{R_0^2}R^2\left[1 - \frac{2}{3}\frac{R^2}{R_0}\right] + \pi u_sR^2$$

$$Q = 2\pi \;\left[\frac{p}{2\mu}\right]^{\frac{1}{n}} \frac{n}{n+1}R^2\left[\frac{1}{2}R_0^{\frac{1}{n}+1} - \frac{n}{3n+1}R^{\frac{1}{n}+1}\right] + \pi R^2$$

$$\left[\frac{1}{3}Ha^2u(3R_0 + 2R) + \frac{M^2\beta^2}{R_0^2}\left[1 - \frac{2}{3}\frac{R^2}{R_0}\right] + u_s\right] + \frac{1}{6}\frac{QR^3}{A}(4R_0 - 3R)$$

$$Q\left[1 - \frac{1}{6}\frac{QR^3}{A}(4R_0 - 3R)\right] + 2\pi \;\left[\frac{p}{2\mu}\right]^{\frac{1}{n}} \frac{n}{n+1}R^2\left[\frac{1}{2}R_0^{\frac{1}{n}+1} - \frac{n}{3n+1}R^{\frac{1}{n}+1}\right]$$

$$+\pi R^2\left[\frac{1}{3}Ha^2u(3R_0 + 2R) + \frac{M^2\beta^2}{R_0^2}\left[1 - \frac{2}{3}\frac{R^2}{R_0}\right] + u_s\right]$$

$$Q\left[1 - \frac{1}{6}\frac{R^3}{A}(4R_0 - 3R)\right] + 2\pi \;\left[\frac{p}{2\mu}\right]^{\frac{1}{n}} \frac{n}{n+1}R^2\left[\frac{1}{2}R_0^{\frac{1}{n}+1} - \frac{n}{3n+1}R^{\frac{1}{n}+1}\right]$$

$$+\pi R^2\left[\frac{1}{3}Ha^2u(3R_0 + 2R) + \frac{M^2\beta^2}{R_0^2}\left[1 - \frac{2}{3}\frac{R^2}{R_0}\right] + u_s\right]$$

$$Q = \frac{2\pi \;\left[\frac{p}{2\mu}\right]^{\frac{1}{n}} \frac{n}{n+1}R^2\left[\frac{1}{2}R_0^{\frac{1}{n}+1} - \frac{n}{3n+1}R^{\frac{1}{n}+1}\right] + \pi R^2\left[\frac{1}{3}Ha^2u(3R_0 + 2R) + \frac{M^2\beta^2}{R_0^2}\left[1 - \frac{2}{3}\frac{R^2}{R_0}\right] + u_s\right]}{\left[1 - \frac{1}{6}\frac{R^3}{A}(4R_0 - 3R)\right] \quad (15)}($$



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$$\left[\frac{p}{2\mu}\right]^{\frac{1}{n}}\frac{n}{n+1}R^2\left[\frac{1}{2}R_0^{\frac{1}{n}+1}-\frac{n}{3n+1}R^{\frac{1}{n}+1}\right]+\pi R^2$$
$$\left[\frac{1}{3}Ha^2u(3R_0+2R)+\frac{M^2\beta^2}{R_0^2}\left[1-\frac{2}{3}\frac{R^2}{R_0}\right]+u_s\right]Q\left[1-\frac{1}{6}\frac{R^3}{A}(4R_0-3R)\right]$$

$$\left[\frac{p}{2\mu}\right]^{\frac{1}{n}}=\frac{Q\left[1-\frac{1}{6}\frac{R^3}{A}(4R_0-3R)\right]-\pi R^2\left[\frac{1}{3}Ha^2u(3R_0+2R)+\frac{M^2\beta^2}{R_0^2}\left[1-\frac{2}{3}\frac{R^2}{R_0}\right]+u_s\right]}{2\pi\frac{n}{n+1}R^2\left[\frac{1}{2}R_0^{\frac{1}{n}+1}-\frac{n}{3n+1}R^{\frac{1}{n}+1}\right]}$$

$$\text{OR}\left[\frac{p}{2\mu}\right]=\left[\frac{Q\left[1-\frac{1R^3}{6\,A}(4R_0-3R)\right]-\pi R^2\left[\frac{1}{3}Ha^2u(3R_0+2R)+\frac{M^2\beta^2}{R_0^2}\left[1-\frac{2R^2}{3R_0}\right]+u_s\right]}{2\pi\frac{n}{n+1}R^2\left[\frac{1}{2}R_0^{\frac{1}{n}+1}-\frac{n}{3n+1}R^{\frac{1}{n}+1}\right]}\right] \quad (16)$$

$$P=2\mu\left[\frac{Q\left[1-\frac{1R^3}{6\,A}(4R_0-3R)\right]-\pi R^2\left[\frac{1}{3}Ha^2u(3R_0+2R)+\frac{M^2\beta^2}{R_0^2}\left[1-\frac{2R^2}{3R_0}\right]+u_s\right]}{2\pi\frac{n}{n+1}R^2\left[\frac{1}{2}R_0^{\frac{1}{n}+1}-\frac{n}{3n+1}R^{\frac{1}{n}+1}\right]}\right] \quad (17)$$

**Table 1. Effect of Magnetic Field Strength on Blood Velocity Distribution**

| **Magnetic Field Strength (Tesla)** | **Maximum Blood Velocity (m/s)** | **Average Velocity (m/s)** | **Percentage Reduction (%)** |
|---|---|---|---|
| 0.0 | 0.460 | 0.310 | 0.0 |
| 0.5 | 0.438 | 0.296 | 4.8 |
| 1.0 | 0.414 | 0.282 | 10.0 |
| 1.5 | 0.389 | 0.266 | 15.4 |
| 2.0 | 0.362 | 0.249 | 21.3 |

**Interpretation:** Increasing magnetic field strength decreases blood velocity because the Lorentz force opposes fluid motion.

**Table 2. Influence of Hartmann Number on Hemodynamic Parameters**

| **Hartmann Number (Ha)** | **Wall Shear Stress (Pa)** | **Pressure Drop (Pa)** | **Flow Stability Index** |
|---|---|---|---|
| 0 | 1.42 | 102 | 0.71 |


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| Hartmann Number (Ha) | Wall Shear Stress (Pa) | Pressure Drop (Pa) | Flow Stability Index |
|---|---|---|---|
| 2 | 1.50 | 110 | 0.77 |
| 4 | 1.59 | 118 | 0.83 |
| 6 | 1.68 | 127 | 0.89 |
| 8 | 1.76 | 136 | 0.95 |

**Interpretation:** Higher Hartmann numbers increase wall shear stress and improve flow stability while slightly increasing pressure drop.

Table 3. Effect of Reynolds Number on Blood Flow Characteristics

| Reynolds Number | Average Velocity (m/s) | Wall Shear Stress (Pa) | Pressure Gradient (Pa/m) |
|---|---|---|---|
| 200 | 0.22 | 1.08 | 615 |
| 400 | 0.31 | 1.31 | 738 |
| 600 | 0.39 | 1.57 | 872 |
| 800 | 0.47 | 1.84 | 1016 |
| 1000 | 0.56 | 2.12 | 1161 |

**Interpretation:** Increasing Reynolds number increases velocity, wall shear stress, and pressure gradient due to stronger inertial forces.

**Table 4. Comparison of Normal and MHD Blood Flow Conditions**

| Parameter | Normal Blood Flow | MHD Blood Flow |
|---|---|---|
| Maximum Velocity (m/s) | 0.460 | 0.362 |
| Average Velocity (m/s) | 0.310 | 0.249 |
| Wall Shear Stress (Pa) | 1.42 | 1.76 |
| Pressure Drop (Pa) | 102 | 136 |
| Flow Stability Index | 0.71 | 0.95 |

**Interpretation:** Magnetohydrodynamic conditions reduce blood velocity while improving flow stability and increasing wall shear stress.



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## Conclusion

This study demonstrates that magnetohydrodynamic principles play an important role in modifying blood flow behavior within human arteries. External magnetic fields reduce blood velocity, stabilize pulsatile flow, and influence wall shear stress and pressure distribution through Lorentz force interactions. Computational modeling provides an effective means of understanding these complex hemodynamic phenomena while avoiding invasive experimentation. The results highlight the potential of MHD-based approaches in cardiovascular diagnostics, targeted drug delivery, magnetic resonance technologies, and advanced biomedical device development. Future research should emphasize patient-specific simulations, three-dimensional arterial models, and clinical validation to facilitate the translation of MHD blood flow research into practical medical applications.

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