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Magnetic Particles Steady State Flow in an Inclined Cylindrical Tube under the Influence of Magnetic Field

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Abstract

In the instant effort fluid flow and magnetic particles over inclined cylindrical vessel displayed to transversal magnetic field has been probably studied. The fluid and magnetic particles motion have been considered under the effect of exterior appealing field. In a sloped cylindrical pipeline the Adomian Decomposition Method has been tested to examine attracted streams. The flowing and magnetic grains have been managed by a vibrating pressure gradient and extraneous magnetic field. A computer software MATHEMATICA was operated to picture the outcomes of distinct motion properties like Hartmann number, definite perpendicular locations, and angle of increment on velocities. Due to the Lorentz effect and the center spiral region velocities decreases by a magnetic field. Concurrently, progressive angle of gradient revised the flow.

Introduction

Magnetic nanomaterial’s mechanical and biological features are basically resolved by their manufacturing manner and chemical distribution. Magnetic particles normally range in size from 1 to 100 nanometers in can showsuperpara-magnetism [1]. Magnetic chemistry’s vow and flexibility stem from the simple and active division of magnetic contents, which highlight the time-exhausting and costly partition techniques generally used in chemistry. Further, magnetic particles may be marked to the convenient area by a magnetic field that could, in particle, bring distinguish awareness in cancer treatment [2]. Magnetic particulates have rare magnetic properties that are not found in other materials. Due to these strange propertiesthese particulates can be used in special medical treatments like Neuroimaging (MRI), medication administration and hyperthermia.

Therefore, its amiably electric surface associate with the adverse charges deoxyribonucleic acid (DNA), the family of cationic magnetic granules that can be used as DNA messenger insidecells. Magnetic granules painted with tumor-explicit immunoglobulin have further tumor-explicit histogram stabilization in MRI, and these can farther be selected as heat thermostat for cancer medicine and magnetism immunoassay.

The flow of fluid through an inclined cylinder tube has several applications in sciences and engineering. For example, to cool a low-velocity position, to cool atomic reactor at the time an emergency shutdown, to cool a solar energy combination, to cool the atmosphere and seas, to cool the flaming chamber wall in a gas turbine and to cool electronic machinery[3]. The magnetism shock on electrostatic induction, magnetic materials and electric currents is stated by a magnetization, which is a vector field. In a magnetosphere, a moving charge makes a force that is crosswise to twain its magnetic field and velocity [4].

Keeping in survey the above history, to the best of our ability researchers did not recognize the magnetic particles completeoutflow an inclined circular tube for the steady-state flow in their subjects by provingAdomian Decomposition Method (ADM). In the ongoing work, under the magnetic effect we have modeled the magnetic particles stream through an inclined cylindrical pipe motivated by the above studies. In the fluid model at different inclination angles magnetic particles and blood both are uncovered to the transversal magnetic field.

For various uses certain experts recently developed ferromagnetic materials. Magnetic particulates have finally become more generally employed in pharmacy and biotechnology. The mood of magnetic nanoparticles to a distant magnetic field is their fastidious impression. Metallic nanoparticles are attracted by higher magnetic flux intensity, which is employed for drugs placement and bio distinction, especially cell disruption. In extraction techniques like as filtering and diagnostics, several magnetic granules have been produced as magnetic mediators [5]. In the context of fermentation operations, secondary processing is expected to account for 40% or over of the additional value of a fermented product [6]. Magnetic particulates have been reported for the removal of particular cytokines such as tumors necrosis agent, the principal inflammatory transmitters in septicemia and multi-organ collapse, in blood purifying [7]. Immune sensors are commonly employed in medical examinations (eg., detection of viruses). Zelepukin*et al*. [8] presented a magnetic spectrum method for detecting magnetic particle (MP) deterioration in real time. The noninvasive nature of the approach allows for a complete analysis of the 1-year destiny of 17 different kinds of iron-oxide elements. Somvanshi*et al*. [9] traced the creation of side brought online magnetic nanoparticles (MNPs) and a viral Ribonucleic Acid (RNA) extraction methodology for COVID-19 identification. Tong *et al* [10] developed a microscopically inscribed electro chemiluminescencewith high stability using magnetic granules. Castelo-Grande *et al* .[11]employed magnetite nanoparticles to remediate real wastewater samples.

Because cylindrical flow has a wide range of implications in science and industry, such as retrieval procedure and manufacture of glass fiber fabrication polymer spheronization plastic sheet, and so on, the researchers are very interested in interpreting fluid flow all throughout the cylinder. Initially, the fluid flow was studied using a stretched cylinder [12]. In the [13] problem, the model was expanded to include suction injection effects. The fluid flow was studied using the velocity slip affects all across the cylinder [14]. It was determined that a reversible flow could be found by expanding the cylinder. The thermal upshots of an incompressible fluid flow via upright skirting cylinder were investigated [15], and the properties of fluid flowing through the cylinder with heat transfer mechanism were described. The nanoliquid flow through spinning cylinder with an inclined magnetic field was scrutinized by Abbas *et al*.[16].Mburu*et al* [17] tested the influence of thermal conduction, condensation, and magnetization on entropy formation in an irregular peristaltic transport across an inclined cylinder using the

Buongiornomodel. Khound*et al.* [18] investigated a visco-elastic fluid flow through an inclined permeable circular tube in a sustained boundary layer. The homotopy survey method was tap by Dawar*et al.* [19] to demonstrate magnetised and semi fluid flow comprising microbes through a multilayer stretchable cylinder. The flow of a ferro-magnetic viscous liquid with particle accumulation alongside of a stretched cylinder under uniform heat sourse/sink circumstances was described by Naveen *et al.* [20]. Physical challenges like this have a lot of applications in the freezing practice of nuclear reactors. The temperature of the stretched standing cylinder as well as the velocity slip effects were investigated [21]. This research uncovered unique numerical and analytical answers [22] investigated the heat transfer parameters in the cylinder with combined influence.

In perspective of hyper geometric equation, the MHD fluid flow analytic solution was achieved utilising the RungeKutta order four techniques and the shooting approach. The effects of Joule's heating and fraction on the MHD flow were investigated using the Riga plate [23]. The MHD flow of Oldroyd-B fluid heterogeneous-homogeneous and the Cattaneo-Christov heat flow are examined [24]. The Laplace transform technique was used to determine the precise solution to the suggested model. [25] examined the MHD flow of an unstable Casson fluid flowing through a porous material. Partial differential equations were used to model the hypothesized phenomena. The viscosity of a third-grade fluid moving across an oscillating plate was examined as a function of temperature. When heat radiations are present and a transverse magnetic field, the research was carried out [26].

The Adomian Decomposition approach is a semi-analytical method that is particularly efficient in solving nonlinear partial and ordinary differential equations. It has a wide range of applications in applied mathematics, engineering, physics, and biology. George Adomian, chair of the University of Georgia's Centre for Applied Mathematics, developed the approach from the 1970s through the 1990s [27]. The symbolic capabilities of the Adomian decomposition approach were investigated by Lu and Zheng [28]. The normal ADM and ADM with integration factors are used by Richard and Zhao [29] in their demonstration to calculate explicit scheme.

Methodology

Fig 1 depicts the flow rate of liquid through a cylindrical tube. A homogenous magnetic field is applied in an axial direction that is orthogonal to the flow direction. The induced magnetic field contribution is omitted since the magnetic Reynolds number is expected to be very low. The blood has zero velocity at the tube's wall at *t=0*, when the fluid motion is stopped and the non-skid situation is applied to the tube's panel. The Maxwell's connections, whichever explain the electromagnetic field, and Never-Stokes calculations, which describe fluid flow, are the governing equations.

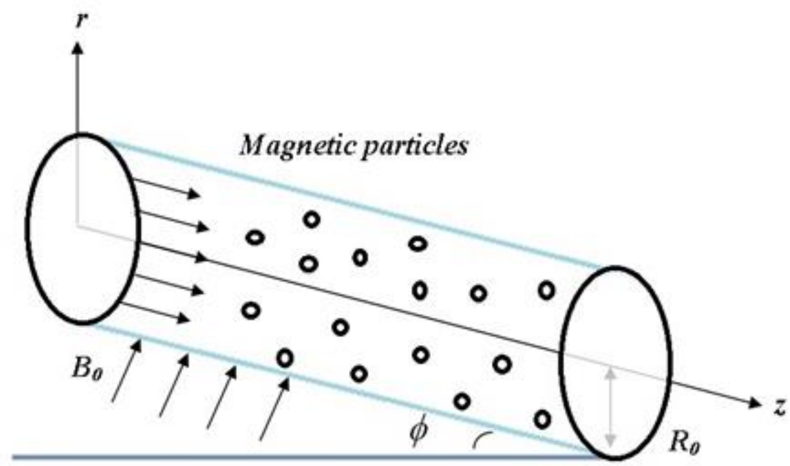

Figure.1,*Blood and magnetic particles flow via an inclined cylindrical channel.*

The issue includes to solve the Navier-Stokes' equations of viscous flow and the Maxwell's equation for magnetic connections at the same time.

The current density $\vec{j}$, according to Ohm′s lawis

$$\vec{J} = \sigma \left(\vec{E} + \vec{V} \times \vec{B}\right). \quad (1)$$

Here$E$iselectrical conductivity alsoσ is the electric field intensity,$\vec{V}$ is the magnetised strength, with momentum trajectory. Hence, thecomparisons ofMaxwell's are:

$$\nabla.\vec{B} = 0, \ \nabla \times \vec{B} = \mu_0 \vec{J}, \ \nabla \times \vec{E} = -\frac{\partial \vec{B}}{\partial t} . \quad (2)$$

In it the μ_0 is the electromagnetism, similarly,Fm stands for electro-magnetic force, which is represented by

$$\vec{F}_m = J \times B = \sigma\left(E + V \times B\right) \times B = -\sigma B_0^2 \mu . \quad (3)$$

Impulse motion inside a spherical duct related to fluid upon radius ‘*r*’ is concern to be effected by uniform diagonal magnetic field. In cylindrical polar coordinates, the modelled momentum equation for fluid flow is:

$$\frac{\partial u}{\partial t}=-\frac{1}{\rho}\frac{\partial p}{\partial z}+v\left(\frac{\partial^2 u}{\partial r^2}+\frac{1}{r}\frac{\partial u}{\partial r}\right)+\frac{KN}{\rho}\left(v-u\right)-\frac{\sigma B_0{}^2\sin\theta}{\rho}+g\sin\phi . \quad (4)$$

Here v is the kinematic viscosity,N isthe number of magnetic particles and v is the velocity of particles, and thus u is the velocity of viscous, respectively, where *p*, here,stands for the fluid’s density, *p* stands for pressure, and*K* is, here, shows the Stokes’ constant.The expression $\frac{KN}{\rho}\left(v-u\right)$ recomended to be the comparative locomotion connecting the fluid and attractive atoms.The relative velocity's Reynolds number is thought to be the smallest. Consequently, the force exerted by magnetic blood particles is proportional to relative velocity.

$-\frac{\partial p}{\partial z}=A_0+A_1\cos\omega t$.(5)

Where A_0 and A_1, are respectively signifying and amplitude and constant part of the pressure gradient.

The dimensionless parameters and variables listed below are introduced as follows:

$$r^*=\frac{r}{a},\ u^*=\frac{ua}{v},\ v^*=\frac{va}{v},\ t^*=\frac{tv}{a^2},\ p^*=\frac{pa^2}{pv^2}. \quad (6)$$

Therefore $R=\frac{KNa^2}{\mu}$ is the particle concentration parameter and $Ha=Ba\sqrt{\frac{\sigma}{\mu}}$ is the Hartmann number.

Eq. (3.4) may be written, using the aforementioned parameters and are dimensionless, as:

$$\frac{\partial u}{\partial t}=\left(A_0+A_1\cos\omega t\right)+\left(\frac{\partial^2 u}{\partial r^2}+\frac{1}{r}\frac{\partial u}{\partial r}\right)+R\left(v-u\right)-Ha^2u+g\sin\phi . \quad (7)$$

In dimensionless form, the starting condition for the velocity field may be stated as: $u(r,0)=1+e^r$.(8)

Equation (7) & (8) can be rewritten as,

$$\frac{\partial u}{\partial t}=\left(A_0+A_1\cos\omega t\right)+\left(\frac{\partial^2 u}{\partial r^2}+\frac{1}{r}\frac{\partial u}{\partial r}\right)+R\left(v-u\right)-Ha^2u+g\lambda\sin\phi\,, \tag{9}$$

$$G\frac{\partial v}{\partial t}=u-v\,, \tag{10}$$

$$L_t u=\left(A_0+A_1\cos\omega t\right)+L_r u+R\left(v-u\right)-Ha^2u+g\lambda\sin\phi\,, \tag{11}$$

$$GL_t=u-v\,. \tag{12}$$

Let us assume that,

$$A_0+g\lambda\sin\phi=a_1,\ \text{and}\ -R-Ha^2=a_2\,. \tag{13}$$

Then,

$$L_t u=a_1+A_1\cos\omega t+L_r u+Rv+a_2u, \tag{14}$$

$$L_t v=\frac{1}{G}\left(u-v\right), \tag{15}$$

$$u_0=dsf\,. \tag{16}$$

$u(r,0)=1+e^r$ *and* $v(r,0)=-1+e^r$.

Where,

$$L_t=\frac{\partial}{\partial t},\ L_r=\frac{\partial^2}{\partial r^2}+\frac{1}{r}\frac{\partial}{\partial r}\ \text{and}\ L_t^{-1}=\int_0^t(.)dt\,. \tag{17}$$

Appling L_t^{-1} on both sides

$$u\left(r,t\right)-1-e^r=a_1\int_o^t dt+A_1\int_o^t\cos\omega t dt+L_t^{-1}L_r u+RL_t^{-1}v+a_2L_t^{-1}u, \tag{18}$$

$$v=-1+e^r+\frac{1}{G}\left(L_t^{-1}u-L_t^{-1}v\right). \tag{19}$$

$$\left.\begin{aligned} &u_o=1+e^r\\ &u_1=a_1t+\frac{A_1}{\omega}\sin\omega t+L_t^{-1}L_r u_0+RL_t^{-1}v_0+a_2L_t^{-1}u_0,\\ &u_{n+1}=L_t^{-1}L_r u_n+RL_t^{-1}v_n+a_2L_t^{-1}u_n, \end{aligned}\right\} \tag{20}$$

$$v_0=-1+e^r,$$

$$v_1 = \frac{1}{G}\left(L_t^{-1}u_0 - L_t^{-1}v_0\right), \qquad (21)$$

$$v_{n+1} = \frac{1}{G}\left(L_t^{-1}u_n - L_t^{-1}v_n\right).$$

Firstly,from eq. (20)finding u_1, we have:

$$u_1 = a_1 t + \frac{A_1}{\omega}\sin\omega t + L_t^{-1}L_r u_0 + RL_t^{-1}v_0 + a_2 L_t u_0 . \qquad (22)$$

Since $u_0 = 1 + e^r$ and $v_0 = -1 + e^r$, so eq. (22) become ,

$$u_1 = a_1 t + \frac{A_1}{\omega}\sin\omega t + \frac{e^r}{r}(r+1)t + R\left(-1+e^r\right)t + a_2\left(1+e^r\right)t . \qquad (23)$$

Secondly, finding v_1 from eq. (21), we have:

$$v_1 = \frac{1}{G}\left(L_t^{-1}u_0 - L_t^{-1}v_0\right), \qquad (24)$$

$$v_1 = \frac{1}{G}\left(\int_0^t\left(1+e^r\right)dt - \int_0^t\left(-1+e^r\right)dt\right), \qquad (25)$$

$$v_1 = \frac{1}{G}\left(1+e^r\right)t\,\Big|_0^t - \left(-1+e^r\right)t\,\Big|_0^t, \qquad (26)$$

$$v_1 = \frac{2t}{G}. \qquad (27)$$

Now, by putting $n = 1$ in eq. (20) and (21), we have u_2 & v_2.

For finding u_2, we have:

$$u_2 = L_t^{-1}L_r u_1 + RL_t^{-1}v_1 + a_2 L_t^{-1}u_1, \qquad (28)$$

$$v_2 = \frac{1}{G}\left[L_t^{-1}u_1 - L_t^{-1}v_1\right]. \qquad (29)$$

Further, u_2 become,

$$u_2 = L_t^{-1}L_r\left[\left(a_1 t + \frac{A_1}{\omega}\sin\omega t + \frac{e^r}{r}(r+1)t + R\left(-1+e^r\right)t + a_2\left(1+e^r\right)t\right)\right]$$
$$+ RL_t^{-1}\left(\frac{2t}{G}\right) + a_2 L_t^{-1}\left[a_1 t + \frac{A_1}{\omega}\sin\omega t + \frac{e^r}{r}(r+1)t + R\left(-1+e^r\right)t + a_2\left(1+e^r\right)t\right]. \qquad (30)$$

From eq. (30) we get:

$$u_2=\frac{e^r t^2}{2}+e^r r^{-1}t^2-\frac{e^r r^{-2}t^2}{2}+\frac{e^r r^{-3}t^2}{2}+\frac{Re^r t^2}{2}+\frac{a_2e^r t^2}{2}+\frac{Re^r r^{-1}t^2}{2}+\frac{a_2e^r r^{-2}t^2}{2}$$
$$+\frac{a_2A_1\cos\omega t}{\omega^2}+\frac{a_2e^r\left(r+1\right)t^2}{2r}+\frac{R\,a_2\left(-1+e^r\right)t^2}{2}+\frac{a_2\left(1+e^r\right)t^2}{2}. \quad (31)$$

Now from eq.(29) we have,

$$v_2=\frac{1}{G}\left[\int_0^t\left(a_1t+\frac{A_1}{\omega}\sin\omega t+\frac{e^r}{r}\left(r+1\right)t+R\left(-1+e^r\right)t+a_2\left(1+e^r\right)t\right)dt-\int_0^t\frac{t}{G}\,dt\right]. \quad (32)$$

And after solving v_2 in eq.(32) we have,

$$v_2=\frac{a_1t^2}{2G}-\frac{A_1\cos\omega t}{\omega^2G}+\frac{e^r\left(-1+e^r\right)t^2}{2rG}+\frac{R\left(-1+e^r\right)t^2}{2G}+\frac{a_2\left(1+e^r\right)t^2}{2G}-\frac{t^2}{G^2}. \quad (33)$$

Finally, our adomian solution for blood velocity $u(r, t)$, become ,

$$u=\sum_{n=0}^{2}u_n=u_0+u_1+u_2\ , \quad (34)$$

$$u=1+e^r+a_1t+\frac{A_1}{\omega}\mathrm{Sin}\,\omega t+\frac{e^r}{2}(r+1)t+R(-1+e^r)t+a_2(1+e^r)t+\frac{e^r t}{2}+e^r r^{-1}t^2$$
$$-\frac{e^r r^{-1}t^2}{2}+\frac{e^r r^{-1}t^2}{2}+\frac{e^r r^{-3}t^2}{2}+\frac{Re^r t^2}{2}+\frac{a_2e^r t^2}{2}+\frac{Re^r r^{-1}t^2}{2}+a_2e^r r^{-1}t^2+\frac{Rt^2}{G}+\frac{a_1a_2t^2}{2}$$
$$-\frac{a_2A_1\,\mathrm{Cos}\,\omega t}{\omega^2}+\frac{a_2e^r(r+1)}{2r}-\frac{Ra_2(-1+e^r)t^2}{2}+\frac{a_2^2(-1+e^r)t^2}{2}, \quad (35)$$

$$u=1+e^r++\frac{A_1}{\omega}\mathrm{Sin}\,\omega t-\frac{a_2A_1\,\mathrm{Cos}\,\omega t}{\omega^2}+\left[a_1+\frac{e^r}{r}(r+1)+R(-1+e^r)+a_2(1+e^r)\right]t$$
$$+\begin{pmatrix}\frac{e^r}{2}+e^r r^{-1}-\frac{e^r r^{-1}}{2}+\frac{e^r r^{-3}}{2}+\frac{Re^r}{2}+\frac{a_2e^r}{2}+\frac{Re^r r^{-1}}{2}+\frac{a_2e^r r^{-1}}{2}\\+\frac{R}{G}+\frac{a_1a_2}{2}+\frac{a_2e^r(r+1)}{2r}+\frac{Ra_2(-1+e^r)}{2}+\frac{a_2^2(1+e^r)}{2}\end{pmatrix}t^2. \quad (36)$$

Finally, we get:

$$u=1+e^r+\frac{A_1}{\omega}\sin\omega t-\frac{a_2A_1Cos\omega t}{\omega^2}+a_3t+a_4t^2. \quad (37)$$

Where ,

$$a_1 = \frac{e^r}{r}(r+1) + R(-1+e^r) + a_2(1+e^r)$$
$$a_2 = \frac{e^r}{2} + e^r r^{-1} - \frac{e^r r^{-1}}{2} + \frac{e^r r^{-3}}{2} + \frac{Re^r}{2} + \frac{a_2 e^r}{2} + \frac{Re^r r^{-1}}{2} + \frac{a_2 e^r r^{-1}}{2} + \frac{R}{G} + \frac{a_1 a_2}{2} \quad . \tag{38}$$
$$+\frac{a_2 e^r (r+1)}{2r} + \frac{Ra_2(-1+e^r)}{2} + \frac{a_2^2(1+e^r)}{2}$$

Now since,

$$v = \sum_{n=0}^{2} v_n = v_0 + v_1 + v_2 \,, \tag{39}$$

$$v = -1 + e^r + \frac{2t}{G} + \frac{a_1 t^2}{2G} - \frac{A_1 \operatorname{Cos}\omega t}{\omega^2 G} + \frac{e^r(r+1)t^2}{2rG} + \frac{R(-1+e^r)t^2}{2G} + \frac{a_2(1+e^r)t^2}{2G} - \frac{t^2}{G^2}\,,$$
$$v = -1 + e^r - \frac{A_1 \operatorname{Cos}\omega t}{\omega^2 G} + \left(\frac{2}{G}\right)t + \left(\frac{a_1}{2G} + \frac{e^r(r+1)}{2rG} + \frac{R(-1+e^r)}{2G} + \frac{a_2(1+e^r)}{2G} - \frac{1}{G^2}\right)t^2\,, \tag{40}$$

$$v = -1 + e^r - \frac{A_1 \operatorname{Cos}\omega t}{\omega^2 G} + a_5 t + a_6 t^2. \tag{41}$$

Where,

$$a_5 = \frac{2}{G},\; a_6 = \frac{a_1}{2G} + \frac{e^r(r+1)}{2rG} + \frac{R(-1+e^r)}{2G} + \frac{a_2(1+e^r)}{2G} - \frac{1}{G^2} \;. \tag{42}$$

Results &Discussion

In the present section, the impacts of various flow parameters on Adomian-based solutions of steady and incompressible magneto-hydrodynamics blood and magnetic particle velocities inside a sloped cylindrical pipe are investigated as well as diagrammatically described here.Considering that, inside Figs.2 toward 4, charts of substantial motion boundaries of significance accommodates separate spiral axis ($0.2 \le r \le 0.5$), exterior electromagnetic field (*Ha = 0.5, 1, 1.5, 2*) and inclination angle ($\phi = Pi/6, Pi/5, Pi/4, Pi/3$). Other constants of liquid movementare $A_0=0.5$, $A_1=0$ (representing the steady state flow),$R=0.5$and $\omega = Pi/4$ .ADM's solution againstvarious flow constraints are plotted in the Fig.2to4, Furthermore, the profiles of *u(r, t)* and *v(r, t)*are displayed against the time variable t, with the impact of the radial axis *r*, external magnetic field *Ha*, and inclination angle. In order to study the steady state flows, the unsteady parameter $A_1 = 0$, for all these plots.

Fig.1 is showing blood and magnetic particles velocities at contrasting radial locations versus *t*. Tube-shapedpassage flow at contrasting radial spotsareexamined. At first, velocity blood motion is about identical near to totally radiating sites, however being$t > 0.1$, as compared to the central point it is higher towards the border. Moreover, blood flow is maximal in the central location than as compared to the edge with time *t*. Then again, magnetic particles flow is progressive with both radial and temporal variable *r* and *t* respectively.

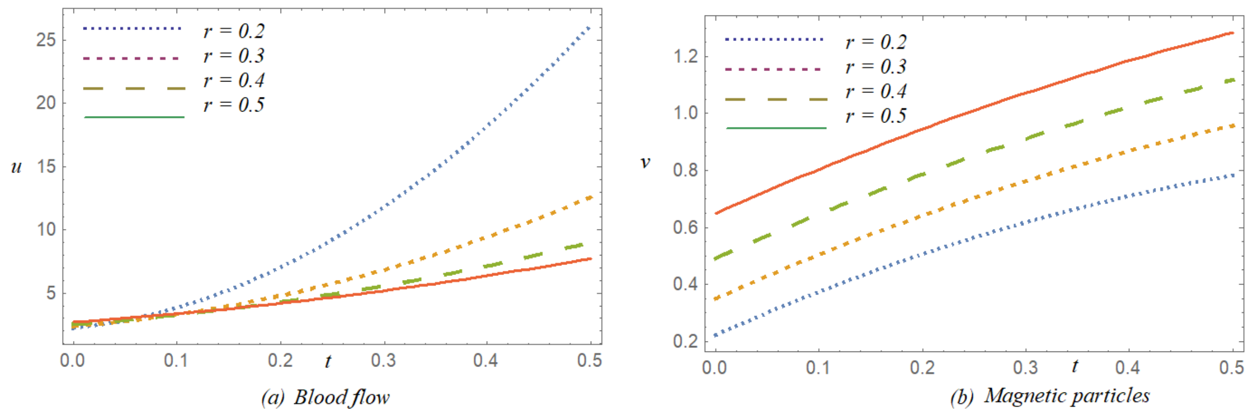

Figure.2: *Velocity plot versus various values of r.*

Fig. 3, indicates that the consequence of magnetic particle flow and an outwardattractive field againstplasma is examined. Because of the steady formation of the resistive force called Lorentz force inhibited flow behavior are recorded in both the cases. Furthermore, it is notice that magnetic particles flow is significantly reduced than as compared to blood flow. It isrealizing that by applying the appropriateoutward magnetic field we can regulate the blood and especially the magnetic particles flows. This judgment might be useful in some therapeutic treatments.

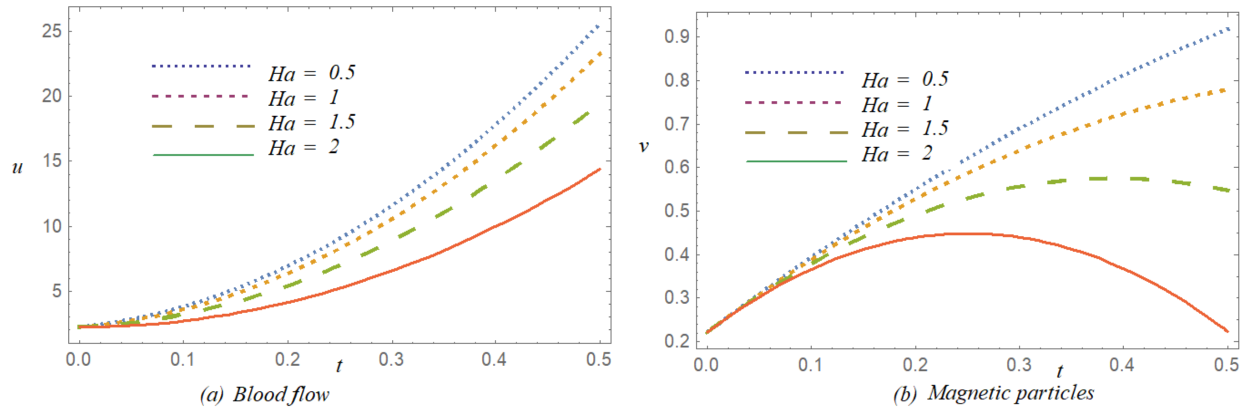

Figure.3: *Various values of Ha besideVelocity plot.*

In Fig.4, profiles of the velocity$u(r, t)$and $v(r, t)$at contrary inclinationsϕ have been intrigued, in order given.It is noted that the fluid and magnetic particles flows are enhanced with the arterial inclinations, as it is convenient to carrying the minerals rich fluidover, when compared to a non-inclined arterial, an inclined artery is more advantageous.

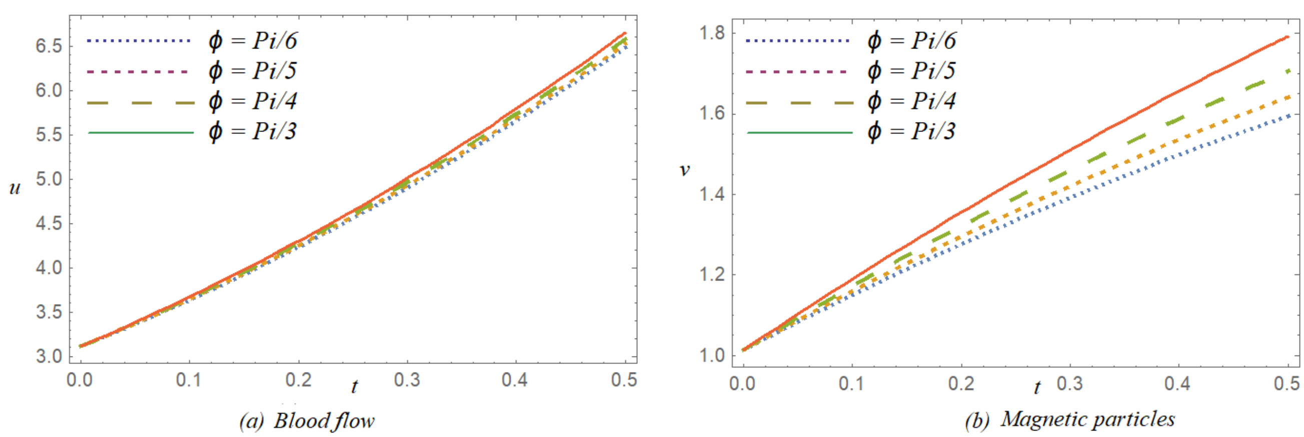

Figure.4: *Various values of* ϕ *compared to velocity plot.*

Conclusions

A mathematical model has been established to examine the steady state blood and magnetic flows in an inclined cylinder-shapedpassageexposed to the transverse magnetic field.

The governing non-dimensional partial differential equation has been solved by a semi-analytical method ADM from the collected works. Velocity profiles for the blood and magnetic particles flows wereaccumulated through ADM scheme.Earlier the mathematical model was solved by using Caputo-fabrizio (CF) fractional order derivative with a non-singular kernel which has the limitations like it fails to fulfill the fundamental theorem of fractional calculus. However, in the current study Adomian Decomposition Method (ADM) which is appropriate for all sorts of linear and non-linear differential equations.The magnetic particles and the velocities of blood drop-off as the Hartmann number increases, according to Adomianbased research. Nevertheless, the velocitiesare enhanced withinclination angles. The graphical resultindicates that the blood and magnetic particleshave opposite flows behaviors inside the tubular artery. The findings might be valuable in the judgment and therapeutic handling of some medical problems. Also, the current outcomes could lead to the better designs of pads and machines.

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