Research Article

Effect of Heat and Mass Transfer and Magnetic Field on Peristaltic Flow of a Fractional Maxwell Fluid in a Tube

F. S. Bayones, 1 A. M. Abd-Alla 2, and Esraa N. Thabet 2

1Department of Mathematics and Statistics, College of Science, Taif University, P.O. Box 11099, Taif 21944, Saudi Arabia
2Department of Mathematics, Faculty of Science, Sohag University, Sohag, Egypt

Correspondence should be addressed to A. M. Abd-Alla; mohmrr@yahoo.com

Received 20 March 2021; Revised 28 April 2021; Accepted 31 May 2021; Published 17 June 2021

Academic Editor: Ahmed Mostafa Khalil

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Magnetic field and the fractional Maxwell fluids’ impacts on peristaltic flows within a circular cylinder tube with heat and mass transfer were evaluated while assuming that they are preset with a low Reynolds number and a long wavelength. The analytical solution was deduced for temperature, concentration, axial velocity, tangential stress, and coefficient of heat transfer. Many emerging parameters and their effects on the aspects of the flow were illustrated, and the outcomes were expressed via graphs. Finally, some graphical presentations were made to assess the impacts of various parameters in a peristaltic motion of the fractional fluid in a tube of different nature. The present investigation is essential in many medical applications, such as the description of the gastric juice movement of the small intestine in inserting an endoscope.

1. Introduction

Numerous implementations have drawn interest of physicists, mathematicians, and engineers on magneto-hydrodynamic flow issues. In some applications and geothermal studies, metal alloy substantiation processes are optimized Sources, management of waste fuel, regulation of underground propagation and pollution of chemicals, waste, the construction of energy turbines for MHD, magnetic equipment for wound therapy and cancer tumour treatment, reduction of bleeding during surgery and transport of targeted magnetic particles as medicines. Several extensive works of literature on that fertile field are now available in [1, 2]. Saqib et al. [3] clarified the nonlinear motion of the non-Newtonian fractional model fluid problem. Rashid and Ahmed [4] produced a numerical solution for dusty nanofluids peristaltic motion in a channel using a shooting method. The slip effect’s problem on a peristaltic flow of the fractional fluid of second-grade over a cylindrical tube was examined by Rathod and Tuljappa [5]. Vajravelu et al. [6] obtained the velocity, temperature, and concentration with a magnetic field of a Carreau fluid in a channel with the heat and mass transfer. Ali et al. [7] discussed magnetic field effects on a blood flow that the blood was characterized as the Casson fluid. Zhao et al. [8] explored the motion natural convection temperature of a fraction with a magnetic field of viscoelastic fluid through a porous medium. Abd-Alla et al. [9] were researching the magnetic field’s impact on a peristaltic motion of the fluid through the cylindrical cavity. Afzal et al. [10] analyzed the effect of the diffusivity convection and magnetic field in nanofluids on the peristaltic motion through the nonuniform channel. Heat and mass transfer’s effects and magnetic field of the peristaltic motion in a planar channel were examined by Hayat and Hina [11]. The impact of the temperature and the magnetic field of peristaltic motion through a porous medium was debated by Srinivas and Kothandapani [12]. Ramzan et al. [13] discussed the heat flux and magnetic field’s influences in Maxwell fluid flow through a two-way strained surface. Rachid [14] calculated the movement of viscoelastic fluid peristaltic transport under the Maxwell fractional model. The impact of a viscosity and a magnetic field of the peristaltic motion of synovial nanofluid in an asymmetric channel was reconnoitered by Ibrahim et al. [15]. Aly and Ebaid [16] inspected the slip conditions’ effects of a peristaltic motion of nanofluids. Carrera et al. [17] checked the extension of a fractional
Maxwell fluid and viscosity to the peristaltic motion. Zhao [18] exhibited the convection flow, the magnetic field, and velocity slip of a peristaltic motion of a fractional fluid. Abd-Alla et al. [19] obtained the solution to the peristaltic motion problem in an endoscope tube. The analytical solution of the transport of viscoelastic fluid through a channel in the fractional peristalsis movement model was presented by Tripathi et al. [20]. The magnetic field effect on peristaltic movement in a vertical annulus was exposed by Nadeem and Akbar [21]. Srinivas et al. [22] were determining the effects movement in a vertical annulus was exposed by Nadeem and Tripathi et al. [20]. The magnetic field effect on peristaltic movement model was presented by Alla et al. [19] obtained the solution to the peristaltic motion velocity slip of a peristaltic motion of a fractional fluid. Abd-

Indeed, the current investigation is firmly believed to receive considerable attention from the researchers towards further peristaltic development with a variety of applications in physiological, modern technology, and engineering.

2. Formulation of the Problem

Take the MHD peristaltic flow through uniform coaxial tubes of a viscoelastic fluid through the fractional Maxwell fluid model. If the flow is transversely subject to a consistent magnetic field, electrical conductivity exists (Figure 1). Furthermore, it is supposed the inner and outer tube temperatures are $T_0$ and $T_1$, and concentrations are $C_0$ and $C_1$, respectively. We picked a cylindrical coordinate $R$ and $Z$. The equations for the tube walls are given by

$$R_1 - a_1 = 0,$$  \hspace{1cm} (1)

$$R_2 - a_2 = +b \sin \left( \frac{2\pi}{\lambda} (Z - c t) \right).$$

The equation of the fractional Maxwell fluid is given by

$$(1 + \lambda_1^{-n} \frac{D_{t}^n}{D_{t}^1}) \frac{\dot{S}}{\dot{S}} = \mu \gamma,$$  \hspace{1cm} (2)

where $0 \leq \alpha_1 \leq 1$.

$D_{t}^n$ is defined as follows:

$$D_{t}^n \frac{\dot{S}}{\dot{S}} = D_{t}^n (\dot{S}) + (\nabla \cdot \mathbf{V}) (\dot{S}) - \mathbf{L} (\dot{S}) - (\dot{S}) \mathbf{L}^T,$$  \hspace{1cm} (3)

where

$$\dot{V} = (\nabla \nabla) (\nabla \nabla) T.$$  \hspace{1cm} (4)

Also, note that $D_{t}^n = \alpha_{n} ^{0}$, of order $\alpha_1$ concerning $t$ and defined as follows:

$$D_{t}^n f (t) = \frac{1}{\Gamma (1 - \alpha_1)} \frac{d}{dt} \int_{0}^{t} (t - \xi)\mu (\xi) d\xi, \hspace{0.5cm} 0 \leq \alpha_1 \leq 1.$$  \hspace{1cm} (5)

Then the equation of motion can be written in the fixed frame which are derived [32, 33] as

$$\rho \left[ \frac{\partial \mathbf{V}}{\partial t} + \left( \mathbf{V} \cdot \frac{\partial \mathbf{V}}{\partial R} \right) + \nabla \left( \frac{\partial \mathbf{P}}{\partial \mathbf{Z}} \right) \right] \mathbf{V} + \frac{\partial \mathbf{P}}{\partial R} = \frac{1}{R} \frac{\partial}{\partial R} \left( R S_{\mathbf{PZ}} \right) + \frac{\partial}{\partial \mathbf{Z}} \left( S_{\mathbf{PZ}} \right) - \frac{S_{\mathbf{PZ}}}{\mathbf{R}},$$

$$\rho \left[ \frac{\partial \mathbf{W}}{\partial t} + \left( \mathbf{W} \cdot \frac{\partial \mathbf{W}}{\partial R} \right) + \nabla \left( \frac{\partial \mathbf{P}}{\partial \mathbf{Z}} \right) \right] \mathbf{W} + \frac{\partial \mathbf{P}}{\partial \mathbf{Z}} = \frac{1}{R} \frac{\partial}{\partial \mathbf{R}} \left( R S_{\mathbf{PW}} \right) + \frac{\partial}{\partial \mathbf{Z}} \left( S_{\mathbf{PW}} \right) + \rho \gamma \frac{\partial \mathbf{V}}{\partial \mathbf{Z}} - \rho \gamma \frac{\partial \mathbf{W}}{\partial \mathbf{Z}},$$

$$\rho \mathbf{C} - C_0 - \sigma B_0^2 \mathbf{W},$$

$$\rho C_P \left[ \frac{\partial \mathbf{C}}{\partial t} + \left( \mathbf{C} \cdot \frac{\partial \mathbf{C}}{\partial R} \right) + \nabla \left( \frac{\partial \mathbf{C}}{\partial \mathbf{Z}} \right) \right] \mathbf{C} = k \left[ \frac{\partial^2 \mathbf{C}}{\partial \mathbf{R}^2} + \frac{1}{R} \frac{\partial \mathbf{C}}{\partial \mathbf{R}} + \frac{\partial^2 \mathbf{C}}{\partial \mathbf{Z}^2} \right] \mathbf{C} + \frac{D_m K_T}{T_m} \left[ \frac{\partial^2 \mathbf{C}}{\partial \mathbf{R}^2} + \frac{1}{R} \frac{\partial \mathbf{C}}{\partial \mathbf{R}} + \frac{\partial^2 \mathbf{C}}{\partial \mathbf{Z}^2} \right] \mathbf{T},$$

$$\frac{\partial \mathbf{U}}{\partial \mathbf{R}} + \frac{\mathbf{U}}{\mathbf{R}} + \frac{\partial \mathbf{W}}{\partial \mathbf{Z}} = 0.$$
The transformation between these two frames can be written as follows:

\[
\begin{align*}
\tau - \bar{\tau} &= 0, \\
\bar{z} - Z &= -c t, \\
\bar{u} - U &= 0, \\
\bar{w} - W &= -c.
\end{align*}
\]  

(7)

The relevant governed boundary conditions for the considered flow analysis can be listed as

\[
\begin{align*}
\bar{w} + c &= 0, \bar{u} = 0 \text{ at } \tau = \bar{\tau}_1, \\
\bar{w} + c &= 0 \text{ at } \bar{\tau} = \bar{\tau}_2 + \beta \sin \left( \frac{2\pi \alpha_1}{\lambda} \right), \\
\bar{T} - T_1 &= 0, \bar{C} - C_1 = 0 \text{ at } \bar{\tau} = \bar{\tau}_1, \\
\bar{T} - T_0 &= 0, \bar{C} - C_0 = 0 \text{ at } \tau = \bar{\tau}_2.
\end{align*}
\]  

(8)

The leading motion equations of the flow for fluid in the wave frame are given by

\[
\begin{align*}
\rho \left[ \frac{\partial \bar{u}}{\partial \tau} + (\bar{w} + c) \frac{\partial \bar{u}}{\partial \bar{z}} \right] \bar{u} + \frac{\partial \bar{p}}{\partial \bar{r}} &= \frac{1}{\bar{r}} \frac{\partial}{\partial \bar{r}} \left( \bar{r} \bar{S}_{\bar{r}r} \right) + \frac{\partial}{\partial \bar{z}} \left( \bar{S}_{\bar{z}\bar{z}} \right) - \frac{\bar{S}_{\bar{w}w}}{\bar{r}}, \\
\rho \left[ \frac{\partial \bar{w}}{\partial \tau} + (\bar{w} + c) \frac{\partial \bar{w}}{\partial \bar{z}} \right] \bar{w} + \frac{\partial \bar{p}}{\partial \bar{r}} &= \frac{1}{\bar{r}} \frac{\partial}{\partial \bar{r}} \left( \bar{r} \bar{S}_{\bar{r}w} \right) + \frac{\partial}{\partial \bar{z}} \left( \bar{S}_{\bar{z}w} \right) + \rho g \alpha (\bar{T} - T_0) \\
&+ \rho g \alpha (\bar{T} - T_0) - \sigma B_0^2 (\bar{w} + c), \\
\rho C_p \left[ \frac{\partial \bar{u}}{\partial \tau} + (\bar{w} + tc) \frac{\partial \bar{u}}{\partial \bar{z}} \right] T &= K \left[ \frac{\partial^2}{\partial \bar{r}^2} + \frac{1}{\bar{r}} \frac{\partial}{\partial \bar{r}} + \frac{\partial^2}{\partial \bar{z}^2} \right] T + Q_0, \\
\left[ \frac{\partial \bar{u}}{\partial \tau} + (\bar{w} + c) \frac{\partial \bar{u}}{\partial \bar{z}} \right] C &= D_m \left[ \frac{\partial^2}{\partial \bar{r}^2} + \frac{1}{\bar{r}} \frac{\partial}{\partial \bar{r}} + \frac{\partial^2}{\partial \bar{z}^2} \right] C + D_m K \frac{C_T}{T_m} \left[ \frac{\partial^2}{\partial \bar{r}^2} + \frac{1}{\bar{r}} \frac{\partial}{\partial \bar{r}} + \frac{\partial^2}{\partial \bar{z}^2} \right] T, \\
\frac{\partial \bar{u}}{\partial \tau} + \bar{u} + \frac{\partial \bar{w}}{\partial \bar{z}} &= 0,
\end{align*}
\]  

(9)

where \( \bar{S} \) depends only on \( r \) and \( t \). After using the initial condition \( \bar{S}(t = 0) \), we find \( \bar{S}_{\bar{r}r} = \bar{S}_{\bar{w}w} = \bar{S}_{\bar{z}r} = 0 \), and

\[
\left( 1 + \lambda \frac{\partial^2}{\partial \bar{r}^2} \right) \bar{S}_{\bar{z}z} = \mu \frac{\partial \bar{w}}{\partial \bar{r}}.
\]  

(10)
We present the following dimensionless parameters for further analysis:

\[ r = \frac{r}{a}, \]
\[ z = \frac{z}{\lambda}, \]
\[ t = \frac{c t}{\lambda}, \]
\[ u = \frac{u}{c}, \]
\[ w = \frac{w}{c}, \]
\[ \lambda_1 = \frac{\lambda_1}{\lambda}, \]
\[ p = \frac{a^2 p}{c \lambda \mu}, \]
\[ \delta = \frac{a_2}{\lambda}, \]
\[ \theta = \frac{T - T_0}{T_1 - T_0}, \]
\[ Pr = \frac{\mu C_p}{K}, \]
\[ Re = \frac{\rho c a_3}{\mu}, \]
\[ Gr = \frac{\rho g a_4 (T_1 - T_0) a_2^2}{\mu c}, \]

wherever \((\varphi = (b/a_2) < 1)\) is the wave amplitude.

### 3. Solution of the Problem

For the abovementioned modifications and nondimensional variables listed earlier, the preceding equations are reduced to

\[ \text{Re}^3 \left[ u \frac{\partial}{\partial r} + (w + 1) \frac{\partial}{\partial z} \right] u + \frac{\partial p}{\partial r} = \frac{\delta}{r} \frac{\partial}{\partial r} (r S_r) + \delta^2 \frac{\partial}{\partial z} (S_z) - \delta \left( \frac{S_w}{r} \right), \]

\( (12) \)

\[ \text{Re} \left[ u \frac{\partial}{\partial r} + (w + 1) \frac{\partial}{\partial z} \right] w + \frac{\partial p}{\partial z} = \frac{1}{r} \frac{\partial}{\partial r} (r S_z) + \delta \frac{\partial}{\partial z} (S_z) + Gr \theta + Br \Theta - M^2 (w + 1), \]

\( (13) \)

\[ \text{RePr} \left[ u \frac{\partial}{\partial r} + (w + 1) \frac{\partial}{\partial z} \right] \theta = \left[ \frac{\partial^2}{\partial r^2} + \frac{1}{r} \frac{\partial}{\partial r} + \delta \frac{\partial}{\partial z} \right] \theta + \beta, \]

\( (14) \)

\[ \text{Re} \left[ u \frac{\partial}{\partial r} + (w + 1) \frac{\partial}{\partial z} \right] \Theta = \frac{1}{Sc} \left[ \frac{\partial^2}{\partial r^2} + \frac{1}{r} \frac{\partial}{\partial r} + \delta \frac{\partial}{\partial z} \right] \Theta + Sr \left[ \frac{\partial^2}{\partial r^2} + \frac{1}{r} \frac{\partial}{\partial r} + \delta \frac{\partial}{\partial z} \right] \theta, \]

\( (15) \)

\[ \frac{\partial u}{\partial r} + \frac{u}{r} + \frac{\partial w}{\partial z} = 0. \]

\( (16) \)

With boundary conditions

\[ w + 1 = 0, u = 0 \text{ at } r = r_1 = \varepsilon, \]
\[ w + 1 = 0 \text{ at } r = r_2 = 1 + \varphi \sin (2\pi z), \]
\[ \theta - 1 = 0, \Theta - 1 = 0 \text{ at } r = r_1, \]
\[ \theta = 0, \Theta = 0 \text{ at } r = r_2. \]

\( (17) \)

### 4. The Analytical Solution

Furthermore, the hypothesis of the long wavelength approach is also supposed. Now, \(\delta\) is very small so that it can be tended to zero. Thus, the \(\delta \ll 1\) dimensionless governing equations \((12)–(15)\) by using this hypothesis may be written as
\[ \frac{\partial p}{\partial r} = 0, \quad (18) \]

Temperature, concentration, and axial velocity solutions can be described as follows:

\[ f \left[ \frac{dp}{dz} - Gr\theta - Br\Theta + M^2(w + 1) \right] = \left( \frac{\partial^2 w}{\partial r^2} + \frac{1}{r} \frac{\partial w}{\partial r} \right), \]

\[ \frac{\partial^2 \theta}{\partial r^2} + \frac{1}{r} \frac{\partial \theta}{\partial r} + \beta = 0, \]

\[ \frac{1}{Sc} \left[ \frac{1}{r} \frac{d}{dr} \left( r \frac{\partial \theta}{\partial r} \right) \right] + \Theta \left[ \frac{1}{r} \frac{d}{dr} \left( r \frac{\partial \theta}{\partial r} \right) \right] = 0, \quad (19) \]

\[ \theta = \frac{\log(r_{r_2})}{\log(r_{r_1}/r_2)} + \frac{\beta}{4} \left[ \frac{r_1^2 \log(r_{r_2}) - r_1^2 \log(r_{r_1})}{\log(r_{r_1}/r_2)} \right], \]

\[ \Theta = \frac{SrSc\beta}{4} r^2 + c_i \log(r) + c_z, \]

\[ w = 4c_2 + 4c_i \log(r) + f \times \left[ (dp/dz)^2 - Gr\left( (r^2 \log(r_{r_2}) - 1)/\log(r_{r_1}/r_2) \right) + (\beta/4) \left( r_1^2 \log(r_{r_2}) - r_1^2 \log(r_{r_1} - 1)/\log(r_{r_1}/r_2) \right) - (\beta/16) r^2 \right], \]

\[ 4 - f M^2 r^2 \]

\[ (20) \]

where

\[ f = (1 + \lambda_{n_i}^n) D_{i}^{n_i}), \]

\[ A = -4 - f \times \left[ \frac{dp}{dz_1} + Gr \left( \frac{r_1^2 \log(r_{r_1}/r_2) - 1}{\log(r_{r_1}/r_2)} \right) + \frac{\beta}{4} \left( \frac{r_1^4 \log(r_{r_1}/r_2) - r_1^4 \log(r_{r_1} - 1)/\log(r_{r_1}/r_2) - \beta}{16 r_1^4} \right) \right], \]

\[ B = -4 - f \times \left[ \frac{dp}{dz_2} + Gr \left( \frac{-r_2^2 \log(r_{r_2})}{\log(r_{r_1}/r_2)} + \frac{\beta}{4} \left( \frac{-r_2^4 \log(r_{r_2}) - r_2^4 \log(r_{r_1} - 1)/\log(r_{r_1}/r_2) - \beta}{16 r_2^4} \right) \right] \]

\[ C_1 = \frac{4 + SrSc\beta (r_2^2 - r_1^2)}{4 \log(r_{r_1}/r_2)}, \]

\[ C_2 = \frac{SrSc\beta \left( r_1^2 \log(r_{r_2}) - r_2^2 \log(r_{r_1}) \right) - 4 \log(r_{r_1}/r_2)}{4 \log(r_{r_1}/r_2)} \]

\[ C_3 = \frac{A - B}{4 \log(r_{r_1}/r_2)}, \]

\[ C_4 = \frac{(B \log(r_{r_1}) - A \log(r_{r_2}))}{4 \log(r_{r_1}/r_2)} \]

The heat transfer coefficient is indicated as follows:

\[ Zr = \frac{\partial \theta}{\partial r} \times \frac{\partial r}{\partial z} \quad (22) \]

\[ Zr = \left[ -\frac{r \beta}{2} + \frac{1}{r \log(r_{r_1}/r_2)} + \frac{(r_1^2 \log(r_{r_2}) - r_2^2 \log(r_{r_1})) \beta}{4 \log(r_{r_1}/r_2)} \right] \times [2 \varphi \pi \cos(2\pi z)]. \quad (23) \]
Using the definition of the fractional differential operator (5) we find the expression of $f$ as follows:

$$f = f(t) = 1 + \lambda_1^{\alpha_1} \frac{\Gamma(1 - \alpha_1)}{\Gamma(1 - \alpha_1)}.$$

(24)

5. Results and Discussion

In this section, the effect of different parameters is shown graphically in Figures 2–7 such as fractional parameter $\alpha_1$, heat source/sink parameter $\beta$, wave amplitude $\phi$, radius ratio $\varepsilon$, Hatman number $M$, Grashof number $Gr$, relaxation time $\lambda_1$, the Soret number $Sr$, and the Schmidt number $Sc$ on the temperature $\theta$, the concentration $\phi$, axial velocity $w$, tangential stress $\tau$, and heat transfer coefficient $Z\tau$. MATLAB software is used to identify the quantitative influences of various physical parameters implicated in the our study. Approximate analytical results are numerically evaluated for temperature, concentration, axial velocity, tangential stress, and the heat transfer coefficient for various values of parameters. For this object, Figures 2–7 are displayed.

Figure 2 has been plotted to clarify the variations of $\beta$ and $\phi$ on the temperature distribution $\theta$. Figure 2 shows that $\theta$ decreases when $\beta$ increases in the range $0 \leq r \leq 0.32$, while $\theta$ increases when $\beta$ increases in the range $0.32 \leq r \leq 1.2$. Moreover, $\theta$ decreases when $\phi$ increases in the range $0 \leq r \leq 0.32$, while $\theta$ increases when $\phi$ increases in the range $0.32 \leq r \leq 1.4$. In addition, the temperature decreases with the radial increase and the boundary conditions are fulfilled.

Figure 3 displays the discrepancy of the concentration with the radial for various values of $\varepsilon, \phi, Sc$ and $Sr$. It is indicated that the concentration increases with increasing $\varepsilon$ and $\phi$. However, $\Theta$ decreases with increasing $Sr$ and $Sc$. In addition, the concentration decreases with the radial increase and the boundary conditions are fulfilled.

The impacts of $Gr, \lambda_1, \phi, \alpha_1, M$, and $Sc$ on the axial velocity $w$ are illustrated in Figure 4. It is indicated that the axial velocity profiles decreases with increasing $Gr, \lambda_1$, and $\phi$ in the range $0 \leq r \leq 0.32$, while it increases in the range $0.32 \leq r \leq 0.45$. In addition to this, the axial velocity profile decreases with increasing $\alpha_1$ in the whole range $0 \leq z \leq 1$, while it increases with increasing $M$ in the whole range $0 \leq z \leq 1$, the axial velocity profiles decreases with increasing $Sc$ in the range $0 \leq z \leq 53$ as well, and it increases in the range $0.53 \leq r \leq 0.88$ and then decreases again in the range $0.88 \leq z \leq 1$. Also, it is observed that the velocity has oscillatory behavior due to peristaltic motion concerned.

The effect of $\alpha_1, M, \beta$ and $Sc$ can be observed from Figure 5, in which the tangential stress is illustrated for the various values of $\alpha_1, M, \beta$, and $Sc$. With the increase of $\alpha_1$ and $Sc$, the tangential stress decreases. Moreover, tangential stress increases with increasing $M$ and $\beta$. It is noticed that one can observe the tangential stress is in oscillatory behavior, which may be due to peristalsis.

Figure 6 explains the influence of $\varepsilon$ and $\phi$ on the heat transfer coefficient $Z\tau$. Obviously, the increase in $\varepsilon$ and $\phi$ increases the amplitude of the heat transfer coefficient in the whole range $z$. From Figure 6, one can observe that heat transfer coefficient is an oscillatory behavior in the whole range, which may be due to peristalsis.

Figure 7 is plotted in 3D schematics concern the axial velocity $w$, the concentration $\Theta$, the temperature $\theta$, and the heat transfer coefficient $Z\tau$ concerning $r$ and $z$ axes in the presence $\alpha_1, Sr, \varepsilon$, and $\phi$. It is indicated that the axial velocity decreases by increasing $\alpha_1$. Also, the concentration decreases by increasing $Sr$, the temperature increases with increasing of $\varepsilon$ as well, otherwise the heat transfer coefficient increases by increasing $\phi$. For all physical quantities, we obtain the peristaltic flow in 3D overlapping and damped when the state of particle equilibrium is reached and increased. The vertical distance of the curves is greater, with most physical fields moving in peristaltic flow.
Figure 3: Discrepancies of the concentration $\Theta$ against the $r$–axis for various values of $\varepsilon$, $\phi$, $Sc$, and $Sr$. 

Figure 4: Continued.
Figure 4: Discrepancies of the axial velocity $w$ against the $r$- and the $z$-axes for various values of $\lambda_1$, $\phi$, $\alpha_1$, $M$, and $Sc$. 

Figure 5: Continued.
Figure 5: Discrepancies of the axial tangential stress $s_{rz}$ against the $z$–axis for various values of $\alpha_1$, $M$, $\beta$, and $\text{Sc}$.

Figure 6: Discrepancies of the heat transfer coefficient $Zr$ against the $z$–axis for various values of $\varepsilon$ and $\phi$.

Figure 7: Continued.
6. Conclusions

The concluding remarks are listed as follows:

1. The axial velocity decreases and increases with the increase of $\alpha_1$, $\varphi$, $\text{Gr}$, $\lambda_1$, and $\text{Sc}$ due to the increase in the Lorentz force.
2. The temperature increases with the increase of the wave amplitude and radius ratio.
3. The concentration decreases with the increase of both $\text{Sr}$, $\text{Sc}$, and it increases with the increase of both $\varepsilon$ and $\varphi$.
4. The tangential stress decreases and increases with the increase of both $\alpha_1$, $\text{Sc}$, and it increases with the increase both $M$ and $\beta$.
5. The study of the phenomenon under effect of $\alpha_1$, $\beta$, $\varphi$, $\varepsilon$, $\text{Gr}$, $\lambda_1$, $\text{Sr}$, and $\text{Sc}$ was performed.
6. This study has indeed been widely applied in many fields of science, such as medicine and the medical industry. Thus, in the field of fluid mechanics, it is considered as extremely essential. When inserting an endoscope through the small intestine, this study describes the movement of the gastric juice.

Nomenclature

$\mathcal{R}_1, \mathcal{R}_2$: Shapes of the wave walls
$t$: Time in a wave frame
$\lambda_1$: Relaxation time
$\alpha_1$: Fractional time derivative parameter
$\gamma$: Rate of the shear strain
$\mathbf{U}, \mathbf{W}$: The components of the velocity in a laboratory frame
$\mathbf{u}, \mathbf{w}$: The components of the velocity in a wave frame
$\rho$: Fluid’s electric conductance
$B_0$: The intensity of the external magnetic field
$P$: The pressure in a laboratory frame
$p$: The pressure in a wave frame
$\sigma$: Fluid’s electric conductance
$\varphi$: Wave amplitude in the dimensionless form
$\varepsilon$: Radius ratio
$\theta$: The distribution of temperature
$\Theta$: The distribution of concentration
$T_0, T_1$: Inner and outer tube temperature
$C_0, C_1$: Inner and outer tube concentration
$\delta$: Wavenumber
$\mu$: Fluid viscosity
$M$: Hartmann number
$\text{Re}$: Reynolds number
$\text{Pr}$: Prandtl number
$\text{Gr}$: Grashof number
$\text{Br}$: Brinkman number
$\text{Sr}$: Soret number
$\text{Sc}$: Schmidt number.

Data Availability

No data were used to support this study.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Acknowledgments

The authors would like to express their gratitude to Taif University for supporting the present study under Taif University Researchers Supporting Project numbered (TURSP-2020/164).

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