Numerical analysis of heat source/sink on peristalsis of MHD carbon-water nanofluid in symmetric channel with permeable space

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Abstract
Nanoparticles of carbon has auspicious uses in a biomedical procedures like energy storage, catalyst supports, biomedical, in drug targeting system, in cancer treatment, in biological therapy, in blood diagnostic and coagulation systems. Motivated from these processes, peristalsis features have been accounted to study the mixed convection of the nanofluid, that is, Carbon-water in a vertical type channel with symmetric walls. Heat transport of magneto-hydro nanoliquid flow inside porous media is scrutinized. Single wall and multiwall Carbon nanotubes with water based nanoparticles are considered. Viscosity is prescribed as variable. The channel boundaries satisfy wall compliant and slip condition. Heat generation or absorption term is present. Assumptions of small Reynolds number along with long wave length are implemented for mathematical modeling. Transformed form of flow equations are evaluated by using numerical scheme. Through different parameters, graphical behaviors of temperature and velocity are displayed and elaborated. Moreover heat transfer rate is computed. Results revealed that for larger $M$, velocity is minimum at upper region and it grows in the lower region. The larger variation in $K$ leads deceleration in the velocity in lower portion and an enhancement is observed in velocity in upper portion. Further, it is seen that the heat transfer rate is larger for the MWCNT nanoparticles case as compared to the case of SWCNT nanoparticles.

Keywords
Peristaltic flow, nanoliquid particles, temperature dependent viscosity, heat generation/absorption, mixed convection, velocity slip

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Introduction
Different studies related to peristalsis phenomenon have been addressed because of its importance in numerous processes of biological and industrial. Additionally, it has its significance due to unique characteristics of asymmetric and symmetric channel walls, that is, compulsion and contraction. In fact, this mechanism has another property in which the channel walls able to push and propagates the substance/material along the tube channel walls. The transport processes such as motion of chyme via gastrointestinal tract, food particles movement through digestive tract, urine via kidneys toward bladder etc. show the importance of peristalsis. Beside that dialysis machine, heart

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lung machines, hose-roller pump etc. are few industrial applications. Such (peristaltic) motions have connection with nano-fluids are utilized in modern system of drug delivery. Due to large utilization of peristalsis phenomenon, Latham1 as well as Shapiro et al.2 are the initiator who formulated peristalsis phenomenon by taking presumption of long wavelength and discussed in detail theoretical and numerically. Abbasi et al.3 disclosed the dissipative effect in peristaltic movement of nanomaterial with Hall effects. Akbar et al.4 discussed the slip features in peristaltic magneto flow of nanomaterial. Hayat et al.5 depicted varying viscosity features in peristaltic nanofluid flow under the magnetic influence. Prakash et al.6 described the peristaltic radiative flow of hydro-magnetic nanoliquid via asymmetric channel. Rafiq et al.7 discussed the slip impact in peristalsis of nanomaterial under the Hall effects. Varying liquid properties in nanfluid motion driven by peristalsis is studied by Abbasi et al.8 The Irreversibility analysis in hydro-magnetic peristalsis considering varying properties is discussed by Farooq et al.9 Asha and Sunitha10 reported the Hall impacts on nanofluid flow under the influence of peristalsis phenomenon. Sheriff et al.11 examined peristalsis propulsion of nano particle flow in a channel having temperature dependent viscosity effects. Imran et al.12 discussed the peristalsis driven chemically reactive flow under the slip phenomenon. Ahmed et al.13 depicted the hydro-magnetic bio-liquid flow in curved geometry with peristalsis.

Nanofluids have gained much significance with the emergence of modern day technology. Among the extensive class of nanofluids, carbon nanotube (CNTs) have special place in it. In the antitumor therapy field, carbon nanotubes play great role in therapy. CNTs behave as a promising material which act as nanocarrier for anticancer drugs. Carbon nanotubes can be characterized as single and multi-walled CNTs. They are able to minimize toxicity, augment the half-life of drug, restrain their activity and stability enhancement in biological environment. CNTs have a properties of being metallic and semi conductivity which make CNTs a suited material for numerous applications like food safety, clinical diagnostic, environmental monitoring. Beside that carbon nanotubes very helpful in rapid enhancement in heat transfer process. Thermo-dynamical features of blood may impact the processes such as hemodialysis and the oxygenation when the blood is taken out from the body. Akbar et al.14 explained the peristaltic darcian flow of tube shaped carbon nanoparticles suspended in copper oxide/water based nanoliquid in porous channel. Shahzadi et al.15 reported the varying viscosity effects in carbon nanotubes (SWCNT) flow driven by peristalsis phenomenon under the wall characteristics impacts. Javed et al.16 suggested the peristaltic transportation of single and multi-walled CNTs radiative nanofluid in asymmetric type channel. Nasir et al.17 examined the convective heat transport in slip flow of radiative single- walled CNT deformed by stretchable disk under magnetic effects. Raza et al.18 examined the hydro-magnetic nanomaterial flow in porous configuration under the peristalsis mechanism with carbon nanotubes. Farooq et al.19 disclosed the Newtonian heating impacts in various CNTs flow caused by peristalsis transport with entropy effects. Anuar et al.20 illustrated the CNT suspended nanomaterial flow deformed by vertical held moving porous sheet. Masood et al.21 discussed the dissipative effects in MHD nanomaterial flow over stretchable sheet. Siddiq and Ashraf22 described the double diffusive impacts in micropolar nanoliquid under bio-convective. Hasona et al.23 discussed the radiative peristaltic transportation in nanofluid under magnetic impacts.

Fluids flow in environmental system either in natural way or in artificial means such as chemical reactors, petroleum reservoirs, flow of water in oceans and lakes, capillaries circulation, composites manufacturing process, filter plants etc., proceeds through porous space. Porous medium be found as a consequence of transmutation of medium structure via deposition, expanding/ shrinkage of land, erosion, sand dunes formation etc. Literature revealed that Darcy24 initiated the work in this direction by considering flow analysis through porous medium. However, very less focus has been paid on the peristalsis analysis via porous medium in channel having symmetric nature. Akbar et al.25 explained flow of magneto suspended carbon nanotubes through porous channel under peristalsis flow phenomenon. Javed et al.26 discussed the peristaltic magneto flow through the permeable-saturated channel. Makinde and Reddy27 described the peristaltic magneto flow of Casson liquid in permeable vertical type channel under slip phenomenon. Hayat et al.28 explained the peristaltic non-darcian motion of magneto Jeffrey liquid including activation energy. Ahmad et al.29 disclosed the darcian reactive flow of convective squeezed fluid with activation energy impacts. Vaidya et al.30 displayed the varying features of fluid in magneto-hydro fluid flow caused by peristalsis through permeable channel. Imran et al.31 disclosed the peristalsis phenomenon in non-Darcy features of permeable channel. Hasona et al.32 suggested the peristalsis driven flow of MHD nanomaterial in asymmetric type porous channel. Riaz et al.33 disclosed the slip features in peristalsis driven nanoliquid through curved permeable channel. Kotnurkar and Giddaiah34 explored the porosity impacts in peristaltic MHD nanomaterial flow under diffusion effects.

The current attempt depicts the peristaltic motion of water based suspended carbon nanotubes with variable viscosity subjected to symmetric channel. The flow kinetics additionally includes magneto-hydrodynamics, and mixed convection effects. Heat generation/
absorption significance is implemented by energy equation. The impact of porous (Darcy) medium is also utilized in flow phenomenon. The slip condition in terms of velocity is retained. The transformed flow model is solved with numeric technique. The flow and temperature fields under the emerging parameters are analyzed through graphs. Moreover, graphical results are also illustrated for heat transfer rate. The objective and notable novelty of this attempt is the application of the carbon nanotubes suspended hydro-magnetic nanomaterial along with the porosity effect for symmetric channel which not yet exist in unfolded literature. This mathematical model has applications in energy storage, chemical reactors, catalyst supports, petroleum reservoirs, biomedical, platelet activation, cancer treatment, tissue regeneration, capillaries circulation, filter plants and many others.

Mathematical description

Peristalsis transport of nanoparticles, that is, carbon nanotubes both single and double-walled emerged in water as base liquid is considered through a symmetric porous channel of width ‘a’. The flow is considered laminar, unsteady and two-dimensional for the incompressible nanofluid. Variable features (viscosity) along with magnetic field are accounted. The expression for varying viscosity with respect to temperature is as follows:

\[
\mu_f(T) = \mu_0 e^{-\lambda(T-T_0)}
\]  

(1)

Here, \(\mu_0\) represent base fluid viscosity, \(\lambda\) represent thermal fluid property, and \(T_0\) represents reference temperature. Heat transport aspect under heat source/sink is scrutinized. Mixed convection and slip concepts are introduced for flow analysis. The flow is assumed two-dimensional and walls of channel propagate in \(X\)-direction and \(Y\)-direction is orthogonal to it. Flow configuration of the current consideration is displayed in Figure 1. The channel wall is described mathematically as:

\[
h(x, \tau) = a + b \cos \frac{2\pi}{\lambda}(x - c\tau),
\]

(2)

here, \(b\) and \(\lambda\) denote amplitude and length of wave respectively, \(c\) the propagating wave velocity, \(a\) denotes the channel’s width, indicates direction of wave propagation, \(h\) represents channel’s walls height and \(\tau\) the time. In fact, fluid motion holds instability in laboratory frame of reference(\(X\), \(Y\)). Therefore, for stability, it appropriates to consider fluid movement in wave frame with wave speed \(c\).

Thus, following transformation is implemented to shift from laboratory to wave frame as:

\[
\tilde{v} = \nabla_x, \tilde{Y} = \tilde{Y}, \tilde{u} = \tilde{U} - c, \tilde{x} = \tilde{x} - c\tilde{t}, \tilde{p}(\tilde{x}, \tilde{y}, \tilde{t}) = \tilde{p}(\tilde{x}, \tilde{Y}, \tilde{t}).
\]

(3)

The conservation laws governing the fluid flow in wave frame are described as:

\[
\frac{\partial \tilde{u}}{\partial \tilde{x}} + \frac{\partial \tilde{v}}{\partial \tilde{y}} = 0,
\]

(4)

\[
\left(\frac{\partial \tilde{u}}{\partial \tilde{t}} + \tilde{u} \frac{\partial \tilde{u}}{\partial \tilde{x}} + \tilde{v} \frac{\partial \tilde{u}}{\partial \tilde{y}}\right) = -\frac{1}{\rho_{nf}} \frac{\partial \tilde{p}}{\partial \tilde{x}} + \frac{1}{\rho_{nf}} \frac{\partial}{\partial \tilde{x}} \left(2\mu_{nf}(T) \frac{\partial \tilde{u}}{\partial \tilde{x}}\right)
\]

\[
+ \frac{1}{\rho_{nf}} \frac{\partial}{\partial \tilde{y}} \left(\mu_{nf}(T) \left[\frac{\partial \tilde{u}}{\partial \tilde{y}} + \frac{\partial \tilde{v}}{\partial \tilde{x}}\right]\right)
\]

(5)

\[
\frac{\partial \tilde{v}}{\partial \tilde{t}} + \tilde{u} \frac{\partial \tilde{v}}{\partial \tilde{x}} + \tilde{v} \frac{\partial \tilde{v}}{\partial \tilde{y}} = -\frac{1}{\rho_{nf}} \frac{\partial \tilde{p}}{\partial \tilde{y}} + \frac{1}{\rho_{nf}} \frac{\partial}{\partial \tilde{y}} \left(2\mu_{nf}(T) \frac{\partial \tilde{v}}{\partial \tilde{y}}\right)
\]

\[
+ \frac{1}{\rho_{nf}} \frac{\partial}{\partial \tilde{x}} \left(\mu_{nf}(T) \left[\frac{\partial \tilde{u}}{\partial \tilde{y}} + \frac{\partial \tilde{v}}{\partial \tilde{x}}\right]\right) - \frac{\nu}{k} \tilde{v},
\]

(6)

\[
\frac{\partial \tilde{T}}{\partial \tilde{t}} + \tilde{u} \frac{\partial \tilde{T}}{\partial \tilde{x}} + \tilde{v} \frac{\partial \tilde{T}}{\partial \tilde{y}} = \frac{k_{nf}}{\rho_{nf} c_{p_{nf}}} \left(\frac{\partial^2 \tilde{T}}{\partial \tilde{x}^2} + \frac{\partial^2 \tilde{T}}{\partial \tilde{y}^2}\right)
\]

\[
+ \frac{Q_0}{\left(\rho_{nf} c_{p_{nf}}\right)},
\]

(7)

Here, \(\tilde{u}\) and \(\tilde{v}\) signify as the components of velocity in axial \(\tilde{x}\)—direction and normal \(\tilde{y}\)—direction respectively, pressure term given by \(\tilde{p}\), temperature of fluid is represented by \(\tilde{T}\), \(Q_0\) represents heat absorption/generation parameter, \(\sigma\) represents electrical conductivity,
magnetic strength is indicated by \( B_0 \), porosity is depicted by \( \nu \), and symbol \( k \) represents permeability of porous media. The expressions \( k_{nf}, \mu_{nf}, \rho_{nf}c_{nf}, \rho_{nf}, \) and \( \alpha_{nf} \) are designated by nano fluid thermal conductivity, dynamic viscosity, heat capacitance of the nanoliquid particles, density, and thermal diffusivity which presented as:

\[
\mu_{nf} = \frac{\mu_j(T)}{(1-\beta)^{1/2}}, \quad k_{nf} = k_f
\]

\[
\left(1 - \phi\right) + \frac{2\phi k_{CNT}}{k_{CNT} - k_f} \log \left( \left( \frac{k_{CNT} + k_f}{2k_f} \right) \right), \quad \alpha_{nf} = \frac{k_{nf}}{\rho_{nf} c_{nf}}.
\]

\[
\rho_{nf} = \left(1 - \phi\right) \rho_f + \phi \rho_{CNT} \rho_{nf} \xi_{nf}
\]

\[
= \left(1 - \phi\right) \left( \rho_f \xi_f \right) + \phi \left( \rho_{CNT} \xi_{CNT} \right) \left( \rho_{nf} c_{nf} \right).
\]

(8)

\[
\text{here,} \quad \mu_{nf}(T) = \frac{e^{-\alpha \theta}}{(1-\beta)^{1/2}} = \left(1 - \alpha \theta \right), \quad \alpha < 1.
\]

(9)

In above mentioned equations, \( \left( \rho_{CNT} c_{nf} \right), \ k_{CNT}, \ k_f, \ \xi_{CNT}, \ \xi_f \) and \( \xi_{nf} \) depict the nanoparticle volume fraction, solid fraction heat capacity, thermal conductivity of nanoparticles, thermal conductivity of base type fluid, thermal expansion coefficient of nanoparticles, thermal expansion coefficient of base fluid and coefficient of thermal expansion.

Thermo-physical characteristics of nanoparticles carbon nanotubes and water are addressed in Table 1.

Now introducing the dimensionless variables:

\[
x = \frac{x}{a}, \quad \bar{x} = \frac{x}{a}, \quad u = \frac{\bar{u}}{c}, \quad \nu = \frac{\bar{v}}{c_0}, \quad p = \frac{\bar{a}^2 \bar{p}}{\alpha_l \mu_0}, \quad \theta = \frac{(T - T_0)}{T_0}, \quad t = \frac{ct}{a}, \quad \phi = \frac{b}{a}, \quad \nu = \frac{\mu_0}{\rho}, \quad \rho = \frac{\mu}{\mu_0}, \quad \beta = \frac{\rho}{\mu_0 c_0}.
\]

(10)

\[
Re = \frac{ac}{\nu}, \quad Pr = \frac{\mu c_{pi}}{\kappa_f}, \quad S = \frac{\mu_0}{\mu_0} = \frac{1}{a}, \quad \alpha = \frac{a}{T_0}, \quad \beta = \frac{\rho c_0}{\mu_0}.
\]

In view of relation (3), dimensionless suitable variables (12), in the term of stream function, the velocity component (13) and low Reynolds number and large wave length assumptions (2) which satisfies automatically, the following dimensionless system under the considered constraint is attained as follows:

\[
\frac{\partial \psi}{\partial x} = \frac{\partial}{\partial y} \left( \frac{1 - \alpha \theta}{(1 - \phi)^{2/3}} \frac{\partial \psi}{\partial y} \right) + \left( \frac{\rho_{nf} \xi_{nf}}{\rho_f \xi_f} \right) G_r \theta
\]

\[-M^2 \frac{\partial^2 \theta}{\partial y^2} + 1 = \frac{1}{K} \left( \frac{\partial \psi}{\partial y} + 1 \right),
\]

(12)

\[
\frac{\partial \psi}{\partial y} = 0,
\]

(13)

In view of equation (14), equation (16) becomes

\[
0 = \left( \frac{1 - \alpha \theta}{(1 - \phi)^{2/3}} \right) \frac{\partial^2 \psi}{\partial y^2} + \frac{\partial}{\partial y} \left( \frac{1 - \alpha \theta}{(1 - \phi)^{2/3}} \right) \frac{\partial \psi}{\partial y} + \frac{\partial^2 \psi}{\partial x^2},
\]

\[\left( \frac{1 - \alpha \theta}{(1 - \phi)^{2/3}} \right) \frac{\partial^2 \theta}{\partial y^2} + \frac{\partial}{\partial y} \left( \frac{1 - \alpha \theta}{(1 - \phi)^{2/3}} \right) \frac{\partial \theta}{\partial y} - \left( M^2 + \frac{1}{K} \right) \frac{\partial^2 \psi}{\partial y^2},\]

(15)

subjected to dimensionless conditions on boundary are:

\[
\frac{\partial^2 \theta}{\partial y^2} + \left( \frac{1 - \phi}{(1 - \phi)} + \frac{2 \phi k_{CNT}}{k_{CNT} - k_f} \log \left( \frac{k_{CNT} + k_f}{2k_f} \right) \right) \beta = 0,
\]

(16)

| Physical properties | \( c_p (\text{j/kgK}) \) | \( \rho (\text{kg/m}^3) \) | \( k (\text{W/mK}) \) | \( \xi \times 10^{-5} (1/\text{K}) \) |
|---------------------|------------------|------------------|------------------|------------------|
| H_2O                | 4179             | 997.1            | 0.613            | 21               |
| SWCNT              | 425              | 2600             | 6600             | 25               |
| MWCNT              | 796              | 1600             | 3000             | 44               |

Table 1. Thermo-physical properties of nano-liquid particles and water.
The imposed conditions $\psi(0) = 0$ and $\psi(h) = F$ have significance due to maintaining constant cross-sectional flow rate. The roughness of surface is strictly correlated to the slip factor and thus, the boundary condition $\frac{\partial \psi}{\partial y} = -1 - S S_{xy}$, established at $y = h$ is described as slip condition which reports different velocities of both wall and fluid while due to symmetric channel, the velocity boundary condition $\frac{\partial^2 \psi}{\partial y^2} = 0$ at $y = 0$ illustrates symmetry condition at the middle of the channel. Moreover, non-dimensional rate of heat transport at the boundary of channel can be acquired through the involvement of temperature as given:

$$Z = \frac{\partial \psi}{\partial y} |_{y = \eta} - \frac{\partial \psi}{\partial y} |_{y = -\eta} .$$

In addition to this, magnetic field effects vanishes when $M = 0$. Further, $\beta > 0$ gives heat generation and $\beta < 0$ gives heat absorption phenomena. When $\phi = 0$, carbon nanotube suspended nanofluid converts to viscous fluid. Moreover, the $\alpha = 0$ illustrates the case for constant viscosity. $S = 0$ corresponds to non-slip condition case where the fluid and wall show same velocity.

**Results and discussion**

A promising class of Nano fluid, that is, carbon nanotubes has been considered in the peristalsis analysis by using water as based fluid. The novel concepts of channel flow like slip at boundary wall, porosity, and symmetric configuration is considered. The transformed dimensionless equations are treated numerically by ND-Solve in Mathematica. This methodology has advantage because it selects appropriate algorithm and automatically track any possible error. Further, such procedure provides better computing outcomes with minimal CPU time (3-4min) per evaluation. In fact, graphical descriptions are directly provided and avoided intricate solution expressions by such method. However, this method incorporates Shooting technique which provides graphical descriptions utilizing minimal to maximal range. For this, we adopted 2nd order of approximation and tolerance $10^{-6}$. The velocity besides with temperature as well as heat transfer rate are sketched and interpreted against involved parameters. Figures 2 to 7 present the involved parameters $(M, K, S, \phi, Gr, \alpha)$ impact on nano-liquid velocity $u$ for both multi and single-wall carbon nanotubes (SWCNT and MWCNT). Axial velocity ($u$) corresponds to diverse Hartmann number $M$ is depicted in Figure 2. For both MWCNTs and SWCNTs cases, this figure of $u$ for $M$ reveals that velocity is minimum at upper region and it declines in the lower region. In fact, for dominant $M$, intensity of Lorentz force enhances that in turn minimizes the nanomaterial deformation and as a consequence velocity decays. Moreover, it is noticeable that velocity field is dominant in MWCNT case in comparison to SWCNT. The description of velocity curves for Darcy number $K$ can be seen through Figure 3. Darcy number $K$ decays the velocity of nanomaterial for the nanoparticles, that is, SWCNT and MWCNT in the below portion of channel whereas it intensifies in channel’s upper part. The axial nano-liquid velocity is more enhanced with the Multi walled-CNT in comparison to single walled-CNT in both lower and upper part of the channel. Actually, growing response of $K$ is responsible for the addition of more pores interior the channel that makes the fluid motion easier and it displays opposite trend for velocity in lower part due to
low percentage of pores. Slip S parameter impact on axial velocity curve $u$ is reported in Figure 4. In Figure 4, it reveals that with the elevation of the slip parameter S, velocity of nano-liquid significantly grows in the bottom portion of channel. While it decays in upper region of channel. Once again the SWCNT-water and MWCNT-water nano-fluids achieve a similar kind of impact on velocity field in both regions. Physically, higher S parameter provides small feeble adhesive forces between particles of fluid and the wall. For this reason, resistance produces which causes partial transfer of wall effects toward the fluid and thus, velocity decrements in upper portion of considered channel.

Figure 5 displays the analysis of velocity field for the variations in nanoparticle volume fraction $\phi$. For higher $\phi$, velocity will elevate in lower part of channel and diminishes in the channel’s upper region. Again the MWCNT nanofluid achieves the similar trend compared with SWCNT nanofluid in the both regions of channel. In fact, dominant $\phi$ produces resistive forces surrounded by the more nanoparticles and liquid and therefore, fluid velocity declines in the lower part.

Figure 6 is displayed to describe the behavior of Grashoff number Gr on nanofluid velocity. Through this figure, it is revealed that velocity is effectively impacted by Gr as it enhances buoyancy forces that grows the velocity around lower portion of the channel whereas it imparts in decaying velocity around channel’s upper region when Gr is dominant. Physically, increased Gr corresponds to dominant buoyancy forces which give assistance to the motion in lower portion and lower in the upper portion of the channel. Further, double-walled CNT have dominant effect over single-walled CNT in both regions. Figure 7 explains the viscosity parameter $\alpha$ impact on velocity for two nanoparticles. This figure depicts growing behavior of velocity with an enlargement in $\alpha$ in channel lower region whereas uniform viscosity gives least velocity in upper portion of channel. Physically, $\alpha$ contributes in enhancing resistive force among the nanoparticles and walls which resultanty enhances the fluid viscosity and as the results the flow velocity decays near lower region. Moreover, in both regions, MWCNT nanofluid is enhancing effect in comparison to SWCNT nanofluid.
Figures 8 to 10 report the nanofluid temperature ($\theta$) variations for ($\beta, \phi, \text{Gr}$) impacts. Figure 8 is depicting the increment in nanofluid temperature for higher heat generation parameter $\beta$. The MWCNT-water nanomaterial achieves greater temperatures than the SWCNT-water nanoliquid. Physically, the case $\beta > 0$ depicts the heat generation phenomenon while the case $\beta < 0$ relates to the heat absorption. Generally, it is revealed that $\beta > 0$ shows increasing trend of temperature. In fact, Temperature field rises because more heat is generated due to friction caused by the increase in $\beta$. Larger impact of volume fraction $\phi$ on field of temperature is exhibited via Figure 9. Here, we found a decrease in temperature subjected to $\phi$. Physically, this figure revealed that for diverse $\phi$, lower concentration of nano-sized particles generates lower effective thermal conductivity inside the fluid and consequently ($\theta$) reduces. Here, MWCNT-water nanoparticles performance stands higher. It should be stated here that the present outcomes are acquired numerical technique not as in$^{34}$ by an exact solutions. For the purpose of comparison, good agreement can be seen between our approximate results demonstrated in Figures 8 and 9 and those which are acquired in Figure 3(a) and (b) by Akbar et al.$^{25}$ at the similar values of the pertinent parameters. Regarding this, it may be pointed out that our approximate outcomes and exact solutions obtained Akbar et al.$^{25}$ are in good agreement. Figure 10 addresses the Grashoff number Gr influence on temperature. Decreasing behavior in temperature is seen corresponding to dominant Gr. Here, higher Gr enhances the buoyancy forces which provide more variation in fluid and as the result, viscosity reduces. Hence, nanofluid temperature decays. Similar trend is noticed here for considered nanoparticles that is (SWCNT and MWCNT). The Heat generation parameter $\beta$ and Grashoff number Gr impacts on rate of heat transfer $Z$ for single-walled CNT and double-walled CNT is described by Figures 11 and 12 respectively. In these figures, $Z$ shows dual behavior of graphs indicating peristaltic wave movement along the boundaries of channel. The heat generation parameter and Grashoff number tend to depict same behavior on heat transfer rate.
Conclusions

Heat transport in mixed convection magneto nanomaterial flow with varying viscosity inside permeable media is communicated here. The mixture of carbon nanotubes in water is incorporated as a working fluid under the slip phenomenon. Here, the notable novelty of this attempt is the application of the carbon nanotubes suspended hydro-magnetic nanomaterial along with the porosity effect for symmetric channel which not yet exist in open literature. The results are reported graphically using NDSolve command. The results report that velocity and temperature against the dominating values of physical parameters are larger for MWCNT-water nanoparticles as comparative in the case of SWCNT-water nanoparticles.

Further, the key points are listed as follows:

- Hartmann number and slip parameter enhance the velocity in lower part of channel and decline is observed in upper part of channel.
- The higher Darcy number improves the velocity in upper part and decays in lower part of channel.
- Temperature is enhanced in case of heat generation and reduces in the situation of heat absorption.
- The reduction in nanoparticles volume fraction values correspond to weaker temperature field.

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