THE EFFECTS OF DIFFUSION ON THE MECHANISM OF PERISTALTIC FLOW AT SLIP BOUNDARIES WHEN INTERNAL JOULE HEATING IS PRESENT

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**Abstract**

This study's primary objective is to demonstrate how diffusion-thermo and thermal diffusion influence of peristaltic flow processes with slip boundaries when joule heating happens from the interior. Several operational factors and their impacts on the system were analysed, along with the corresponding graphs. As slip parameters rise, the axial pressure gradient fluid flow tends to drop. The pressure rate is demonstrated to drop in the backward and peristaltic pumping regions as the quantity of the second order slide parameter rises, whereas it rises in the co-pump zone. As slip parameters rise, fluid temperature and concentration tend to drop. Changes in the thermal diffusion and thermo diffusion factors cause changes in the fluid's temperature and concentration. The Nusselts number can be increased by increasing the Prandtl number, the thermo-diffusion constraint, the dufour number, and the Schmidt number. However, this will result in fewer Sherwood number.

**Keywords:** Thermal radiation, Second order slip boundary condition, Hall current, porous medium, Thermal diffusion, Diffusion-thermo.

**1. Introduction**

Peristalsis has long been acknowledged by physiologists as a fundamental mechanism for fluid movement in a broad range of species. Numerous researches have been undertaken on peristaltic motion in Newtonian fluids. Appropriate for investigating peristalsis in the circulatory system, chyme moment in the digestive tract and spermatozoa transport. Different places throughout the length of a duct in one of these organs contain fluid with varying viscosity. Likewise, the majority of physiological fluids do not behave how one would anticipate a fluid to behave. Considering these factors, it is obvious that viscoelastic rheology provides the most convincing explanation for peristaltic flow.

As discovered by De Vries et al. [1], peristaltic-type motion characterizes endometrium contractions, meaning that uterine wall contractions may occur in either a symmetrical or an asymmetrical manner. Cowling [2] offers a comprehensive description of the hall current concept. When Hall current is added, the absence of an electric field gives biological to this variation of the generalized Ohm's Law. TasawarHayat et al. [3] examined physiological flow under convective boundary conditions. Hayat et al. [4] explored the flow behavior of a Jeffrey fluid and examined how it was affected by rotation and temperature radiation. After doing a search, just a handful of relevant publications [5–12] appear. The study team has shown the superiority of the second-order slip flow model for properly predicting flow parameters. Up order to fill in these information gaps, this work offers the first experimental examination into how heat radiation and hall current affect the physiological fluid over a channel. We would want to address a concern previously raised by Nandeppanavar et al., Turkyilmazoglu, and Rosca and Pop [13], [14], and [15]. The purpose of the research conducted by Asha and Sunitha [16] was to examine the hall and radiation properties in physiological blood flow, specifically in the case of double diffusion. Soret and Dufour features of peristaltic flow were investigated by Nargis Khan et al. [17] using a hall current and a tapered conduit. There are few relevant studies that may be found by searching [18-25].

This study explored the effects of diffusion on the mechanism of peristaltic flow at slip boundaries when internal joule heating is present in a channel at low Reynolds numbers and long wavelengths. According to our knowledge, nobody has previously explored this issue. In order to do this, we employ diagrams to depict the pressure gradient, pumping behaviour, heat distribution, and concentration profile after adjusting a few factors. All of our mathematical calculations are performed using the Mathematica software programme.

**2. Formulation for the problem**

Here we explore the effect of sinusoidal wave trains travelling down the transport of a viscous incompressible fluid along the boundaries of a two-dimensional duct at a consistent speed c. Fig.1 shows the physical model of the problem.

Deformations of the walls are defined by

 (1)

Where b, a, t and are channel width, wave amplitude, time and wavelength.

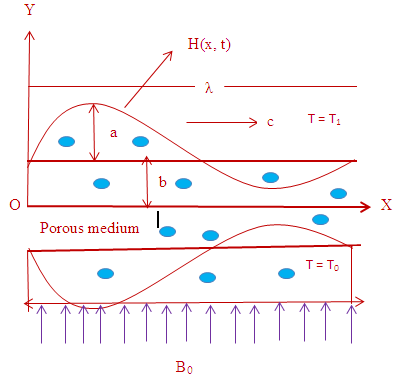


Fig .1. Geometry of the problem

Using a wave-based reference frame, we obtain the flow model equation [26]

 (2)

 (3)

 (4)

 (5)

 (6)

Non-dimensional quantities:

 (7)

Where are non-dimensional amplitude of channel, wave number, Reynolds number, Hartmann number, porosity parameter, hall current parameter, Erect number, thermal radiation parameter, heat source/sink parameter, prandtl number, Soret number, Dufour number and Schmidt number.

**3. Solution of the problem**

Substituting (7) in the equations (2 -6), we get the equations after removing the bars

 (8)



 (9)



 (10)

 (11)

 (12)

Using a long-wavelength approximation while disregarding the wave number and operating under conditions of low Reynolds number. For equations 8-12, we have

 (13)

 (14)

 (15)

 (16)

Where



The boundary conditions:

,, at  (17)

,,at (18)

Solving equations (13-16) using the boundary conditions (17&18), we get

 (19)

 (20)

 (21)

Where





The volumetric flow rate in the wave frame is defined by



 =  (22)

Where  

The expression for gradient the pressure derived from equation (22) as

 (23)

In the laboratory frame, the instantaneous flux Q (x, t) is

 (24)

The typical volumetric flow rate of peristaltic waves is:

 (25)

The pressure gradient is given by, which may be derived from, equations (23) and (25).

 (26)

**4. Discussion of the problem**

The researchers wanted to know how joule heating from the inside and diffusion-thermo and thermal diffusion affected the process of peristaltic flow at slip borders, so they set out to investigate. With Mathematica, we may get numerical answers.

**Pressure Gradient**

Figures (2) and (3) depict pressure gradient as a function of  and m. These figures demonstrate that the pressure gradient decreases as the values of  and m are increased. Figures (4) and (5) depict the results of our inquiry into the impact of dissimilar values of the  and Ω on. It is evident from these maps that the pressure gradient is highest at the wider end of the channel and lowest at its narrowest.

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| --- | --- |
| C:\Users\RAVI KUMAR\Desktop\not published papers\7.png Fig. 2. Significance of  with | C:\Users\RAVI KUMAR\Desktop\not published papers\9.png  Fig. 3. Significance of m with |

|  |  |
| --- | --- |
| C:\Users\RAVI KUMAR\Desktop\not published papers\6.tif  Fig. 4. Significance of  with | C:\Users\RAVI KUMAR\Desktop\not published papers\11.png  Fig. 5. Significance of  with |
|  |  |

**Pressure rise**

The figures (6-9) show how different factors affect the pressure rise. Moreover, the pumping region is divided into the four pumping regions, which are defined as back pumping zone (), peristaltic pumping region (), free pumping region () and co-pumping region (). When shown in figures (6) and (7), as β1and β2 raised, the rate pumping drops in the back and peristaltic pumping zones and increases in the co-pump domain. Figures 8 and 9 demonstrates that when m and Ω are increases, the rate of pumping decreases in the backward, peristaltic, and free pumping domains, while it improves in the co-pumping sector.

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| C:\Users\RAVI KUMAR\Desktop\not published papers\graphs\9.tif  Fig. 6. Significance of  with | C:\Users\RAVI KUMAR\Desktop\not published papers\graphs\10.tif  Fig. 7. Significance of  with |

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| C:\Users\RAVI KUMAR\Desktop\not published papers\graphs\11.tif  Fig. 8. Significance of  with | C:\Users\RAVI KUMAR\Desktop\not published papers\graphs\15.tif  Fig. 9. Significance of  with |
|  |  |

**Temperature Distribution**

Graphical representations of the impact of key variables on the temperature distribution are provided (10-18). The influence of Da, β1, β2 and Rn on the temperature distribution are shown in Figs. (10) to (13). Increasing Da, β1, β2 and Rn all result in a lower fluid temperature, as shown by the graphs. The diffusion impacts on θ are shown in figures 14 and 15, respectively. The plots show that when Pr and Sr concentrations rise, the fluid's temperature drops. The figures 16-18 show how the dufour number, thermal slip parameter, and schmidt number affect the fluid's temperature. Based on these plots, we may deduce that raising Du, γ, and Sc raises fluid temperature.

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| C:\Users\RAVI KUMAR\Desktop\not published papers\graphs\75.png  Fig. 10. Significance of Da with θ | C:\Users\RAVI KUMAR\Desktop\not published papers\graphs\45.png  Fig. 11. Significance of β1 with θ |

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| C:\Users\RAVI KUMAR\Desktop\not published papers\graphs\44.png  Fig. 12. Significance of β2 with θ | C:\Users\RAVI KUMAR\Desktop\not published papers\graphs\41.png  Fig. 13. Significance of Rn with θ |
| C:\Users\RAVI KUMAR\Desktop\not published papers\graphs\38.png  Fig. 14. Significance of Pr with θ | C:\Users\RAVI KUMAR\Desktop\not published papers\graphs\24.png  Fig. 15. Significance of Sr with θ |

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| C:\Users\RAVI KUMAR\Desktop\not published papers\graphs\37.png  Fig. 16. Significance of Du with θ | C:\Users\RAVI KUMAR\Desktop\not published papers\graphs\40.png  Fig. 17. Significance of γ with θ |
| C:\Users\RAVI KUMAR\Desktop\not published papers\graphs\42.png  Fig. 18. Significance of Sc with θ | |

**Concentration Distribution**

Graphical representations (19-27) of the ways in which different factors affect the concentration profile are provided. The effects of Da, β1, β2, and Rn on the concentration distribution are shown in figures (19) to (22). The graphs demonstrate that fluid concentration rises when Da, β1, β2, and Rn values rise. Figures (23) and (24) illustrate the influence of Sr and Du on concentration dispersion. Figures 23 and 24 illustrate that fluid concentration drops when Sr and Du levels increase. The impacts of Pr, γ and Sc on fluid concentration are shown in figures 25-27. These graphs illustrate that the fluid concentration drops as Pr, γ and Sc increase.

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| C:\Users\RAVI KUMAR\Desktop\not published papers\graphs\50.png  Fig. 19. Significance of Da with Φ | C:\Users\RAVI KUMAR\Desktop\not published papers\graphs\69.png  Fig. 20. Significance of β1 with Φ |

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| C:\Users\RAVI KUMAR\Desktop\not published papers\graphs\81.png  Fig. 21. Significance of β2 with Φ | C:\Users\RAVI KUMAR\Desktop\not published papers\graphs\58.png  Fig. 22. Significance of Rn with Φ |
| C:\Users\RAVI KUMAR\Desktop\not published papers\graphs\72.png  Fig. 23. Significance of Sr with Φ | C:\Users\RAVI KUMAR\Desktop\not published papers\graphs\56.png  Fig. 24. Significance of Du with Φ |

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| --- | --- |
| C:\Users\RAVI KUMAR\Desktop\not published papers\graphs\51.png  Fig. 25. Significance of Pr with Φ | C:\Users\RAVI KUMAR\Desktop\not published papers\graphs\74.png  Fig. 26. Significance of ϒ with Φ |
| C:\Users\RAVI KUMAR\Desktop\not published papers\graphs\63.png  Fig. 27. Significance of Sc with Φ | |

The velocity at the wall (y = h) for different selections of the embedded variables has been listed in Table 1. Greater levels of Da, m, β1 and β2 led to a higher fluid velocity, according to the findings. On the other hand, increases in the M and Ω led to a drop in the fluid velocity. In tables 2 and 3, we can see the statistical measures for the Nusselts number and the Sherwood number at the wall y = h. According to these tables, a rise in the Prandtl number, the thermo-diffusion parameter, the dufour number, and the Schmidt number causes the Nusselts number to grow while the Sherwood number decreases. The Sherwood number grows when β1, β2 and Rn are raised, but the Nusselts number shrinks

**Table 1.** Numerical values of velocity profile at the wall (h).

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Da | M | m | Ω | β1 | β2 | Velocity |
| 0.1 | 1.5 | 0.5 | 10 | 0.1 | 0.3 | -0.93372 |
| 0.2 |  |  |  |  |  | -0.88989 |
| 0.3 |  |  |  |  |  | -0.85954 |
| 0.1 | 1.5 |  |  |  |  | -0.93372 |
|  | 3 |  |  |  |  | -0.95388 |
|  | 4.5 |  |  |  |  | -0.96949 |
|  | 1.5 | 0.5 |  |  |  | -0.93372 |
|  |  | 1 |  |  |  | -0.92993 |
|  |  | 1.5 |  |  |  | -0.92726 |
|  |  | 0.5 | 10 |  |  | -0.93372 |
|  |  |  | 20 |  |  | -0.98259 |
|  |  |  | 30 |  |  | -1.07603 |
|  |  |  | 10 | 0.1 |  | -0.93372 |
|  |  |  |  | 0.3 |  | -0.93339 |
|  |  |  |  | 0.5 |  | -0.93313 |
|  |  |  |  | 0.1 | 0.1 | -0.93622 |
|  |  |  |  |  | 0.2 | -0.93458 |
|  |  |  |  |  | 0.3 | -0.93372 |

**Table 2.** Numerical values of Nusselts number at the wall (h).

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Pr | Rn | Sr | Du | Sc | β1 | β2 | γ | Nu |
| 2.5 | 0.5 | 1.5 | 0.2 | 0.6 | 0.1 | 0.3 | 0.3 | 0.482366 |
| 5 |  |  |  |  |  |  |  | 0.667891 |
| 7.5 |  |  |  |  |  |  |  | 0.76611 |
| 2.5 | 0.5 |  |  |  |  |  |  | 0.482366 |
|  | 0.75 |  |  |  |  |  |  | 0.358045 |
|  | 1 |  |  |  |  |  |  | 0.284675 |
|  | 0.5 | 1.5 |  |  |  |  |  | 0.482366 |
|  |  | 2 |  |  |  |  |  | 0.526217 |
|  |  | 2.5 |  |  |  |  |  | 0.578839 |
|  |  | 1.5 | 0.2 |  |  |  |  | 0.482366 |
|  |  |  | 0.3 |  |  |  |  | 0.551275 |
|  |  |  | 0.4 |  |  |  |  | 0.643154 |
|  |  |  | 0.2 | 0.3 |  |  |  | 0.428769 |
|  |  |  |  | 0.6 |  |  |  | 0.482366 |
|  |  |  |  | 0.9 |  |  |  | 0.551275 |
|  |  |  |  | 0.6 | 0.1 |  |  | 0.482366 |
|  |  |  |  |  | 0.4 |  |  | 0.48166 |
|  |  |  |  |  | 0.7 |  |  | 0.48112 |
|  |  |  |  |  | 0.1 | 0.1 |  | 0.487603 |
|  |  |  |  |  |  | 0.3 |  | 0.48166 |
|  |  |  |  |  |  | 0.5 |  | 0.480596 |
|  |  |  |  |  |  | 0.3 | 0.3 | 0.482366 |
|  |  |  |  |  |  |  | 0.5 | 0.515025 |
|  |  |  |  |  |  |  | 0.7 | 0.547843 |

**Table 3.** Numerical values of Sherwood number at the wall (h).

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Pr | Rn | Sr | Du | Sc | β1 | β2 | ϒ | Sh |
| 2.5 | 0.5 | 1.5 | 0.2 | 0.6 | 0.1 | 0.3 | 0.3 | -0.43413 |
| 5 |  |  |  |  |  |  |  | -0.6011 |
| 7.5 |  |  |  |  |  |  |  | -0.6895 |
| 2.5 | 0.5 |  |  |  |  |  |  | -0.43413 |
|  | 0.75 |  |  |  |  |  |  | -0.32224 |
|  | 1 |  |  |  |  |  |  | -0.25621 |
|  | 0.5 | 1.5 |  |  |  |  |  | -0.43413 |
|  |  | 2 |  |  |  |  |  | -0.63146 |
|  |  | 2.5 |  |  |  |  |  | -0.86826 |
|  |  | 1.5 | 0.2 |  |  |  |  | -0.43413 |
|  |  |  | 0.3 |  |  |  |  | -0.49615 |
|  |  |  | 0.4 |  |  |  |  | -0.57884 |
|  |  |  | 0.2 | 0.3 |  |  |  | -0.19295 |
|  |  |  |  | 0.6 |  |  |  | -0.43413 |
|  |  |  |  | 0.9 |  |  |  | -0.74422 |
|  |  |  |  | 0.6 | 0.1 |  |  | -0.43413 |
|  |  |  |  |  | 0.4 |  |  | -0.43349 |
|  |  |  |  |  | 0.7 |  |  | -0.43301 |
|  |  |  |  |  | 0.1 | 0.1 |  | -0.43884 |
|  |  |  |  |  |  | 0.3 |  | -0.43413 |
|  |  |  |  |  |  | 0.5 |  | -0.43254 |
|  |  |  |  |  |  | 0.3 | 0.3 | -0.43413 |
|  |  |  |  |  |  |  | 0.5 | -0.47430 |
|  |  |  |  |  |  |  | 0.7 | -0.53601 |

Conclusions

Diffusion- thermo and thermal diffusion on peristaltic flow mechanism with slip boundaries in the presence of joule heating inside the channel have been analysed. We highlight the most significant findings below.

1. The pressure gradient reduces when the levels of β1, β2, m and Ω are increased.
2. The rate of pumping falls in the retrograde and peristaltic pumping zones, but speeds up in the co-pump zone as a result of an increase in β1, β2, m and Ω.
3. As increase, the fluid's temperature rises, whereas increases in β1, β2,Rn and Ω cause it to fall.
4. As the levels of Sr and Du increase, the fluid temperature goes up.
5. Fluid concentration drops with increase in Sr, Du, Pr, γ and Sc.
6. Increases in the Prandtl, thermo-diffusion, dufour, and Schmidt numbers raise the Nusselts number and lower the Sherwood number.

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