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# COMPUTATIONAL ANALYSIS OF ENTROPY GENERATION AND HEAT TRANSFER ON OSCILLATORY MHD BLOOD FLOW IN THE PRESENCE OF THERMAL RADIATION

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***Abstract***

***Computational analysis of entropy generation and heat transfer on oscillatory magnetohydrodynamic (MHD) blood flow in the presence of thermal radiation was investigated. The modified governing equations are transformed to dimensionless equations using suitable variables. The dimensionless governing equations are solved analytically with the aid of MATLAB. The effects of various parameters on the flow, entropy generation and heat transfer are presented in tabular form and discussed quantitatively. It was observed that the pertinent parameters have significant influences on the flow, entropy generation and rate of heat transfer.***

***Keywords***: Entropy generation, Magnetohydrodynamic, Thermal radiation, Heat transfer, Peristalsis, Oscillation

## 1. INTRODUCTION:

In recent years, attention has been given to the study of fluid in various fields like engineering, environmental sciences and blood flow in arteries. Blood circulate throughout our body system with four basic components which are plasma, red blood cells, white blood cells and platelets. Bio-magnetic fluids are fluids whose flow is influenced by the presence of magnetic field and they contain ions that can interact with an applied magnetic field.

The study of heart rate involves a series of interesting features which arise from pressure oscillation. When person performs hard physical activity, blood flow increases and the circulation cannot remain normal. When the surrounding temperature is more than 20 degrees centigrade, heat transfer takes place from the surface of skin by sweating through the process of evaporation but below 20 degrees centigrade, body loses heat by radiation and conduction. Entropy generation which determines the level of available irreversibility in a process, plays significant role to accurately characterize the system [1].

Several studies have shown that human life processes are actually thermodynamic in nature. Therefore, thermodynamic laws can be used to model human physiology [2-4]. Entropy, in thermodynamics, is a measure of the quantity of energy per unit temperature that is unavailable to do work. Since work is obtained from ordered molecular motion, the amount of entropy can also be viewed as a measure of the molecular disorder (or randomness) of a system. The knowledge of entropy provides useful information on the direction of spontaneous change for everyday processes. In many fields of science and technology, efforts are centred on ways of reducing waste of useful energy which reduces efficiency of thermodynamics system. Transfer of heat in the mammalian body occurs by radiation, conduction, convection and evaporation. Also, in the circulatory system, adjacent tissues lose heat in the form of blood perfusion.

Non-isolated systems like organisms may lose entropy provided their environment's entropy increases by at least that amount so that the total entropy increases. In an ideal reversible process, the entropy does not change; while total entropy is always increase for irreversible processes, which are common in living systems. Entropy is a fundamental quantity as well as energy, but the analysis of the entropy content in radiation is yet to be fully exploited. Although it has been applied in many areas of engineering and sciences, its presence is still generally not well-known especially in the health sector.

Blood flow, which involves fluid transport through the progressive wave of contraction or expansion along the length of a tube or channel containing different types of fluid, has myriad applications [1, 5-8]. Blood motion in physiological sciences has opened a dimension for researchers to manipulate their equipment for minimising the entropy production and hence, for attaining higher output. Blood flow is one of the most important fields in these area. It was pointed out that the rate at which kidney cells regulate the volume of water or salts in the body is affected by using drugs, and the rate at which blood flows through arteries may also be affected or slowed down by the drugs[9]. The analysis of entropy generation was originally formulated by [10, 11] and found various applications, such as two-phase flows, MHD pumps, and electric generators.

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Entropy generation rate in an adiabatic peristaltic pump was investigated by [12]. It was shown that peristaltic pumps generate more entropy than steady walled tubes. This was attributed to flow rate, that is not constant along the tube but increases downstream, and to heat diffusion. Entropy generation impact on peristaltic casson fluid in a rotating frame with consideration of viscous dissipation and slip conditions of velocity with temperature using lubricating approach was studied by [13] and found that entropy is controlled through slip effects.

The effectiveness of entropy generation and energy transfer on peristaltic flow of Jeffery materials with Darcy resistance was examined by [14]. They incorporated velocity, pressure gradient and thermal conditions, and computed the exact solution of the generated system of differential equations with corresponding boundary conditions. They discovered that entropy generation are more pronounced in the vicinity of the channel walls than at the channel centre.

It was pointed out that although the energy function has been vastly studied (taking into the consideration of well-known mode of the energy distribution via Wien's law– and Planck's law), the radiation entropy distribution has not been analysed at the same speed [15]. He further characterised entropy of radiation distribution from a statistical perspective, obtained a Wien's like law for the Mode and integrated the entropy for the Median and the Mean in polylogarithms, and calculated the Variance, Skewness and Kurtosis of the function. He provided the coefficients for a variety of dispersion rules, including wavelength and frequency.

The analysis of entropy generation in the flow of peristaltic nanofluids in channels with compliant walls using Homotopy perturbation techniques was studied by [16]. We modified their work by incorporating oscillatory term, MHD term and thermal radiation in the absence of nanoparticles to study computational analysis of entropy generation and heat transfer on oscillatory MHD blood flow in the presence of thermal radiation. This study examined the impacts of entropy generation and heat transfer in oscillatory blood flow in the presence of thermal radiation on the physiological behaviours and their consequences. It formulated suitable mathematical models for blood flow in human arteries with corresponding entropy generation and heat transfer. This was with a view that the result of the study would help in biomedical sciences.

## 2. MATHEMATICAL FORMULATION:

We consider oscillatory peristaltic blood like flow of a laminar, incompressible and electrically conducting fluid in the presence of thermal radiation. The work studied by [16] was modified to have the following governing equations:

$$\frac{\partial u'}{\partial t'} = -\frac{\partial p'}{\partial x'} + \frac{\partial^2 u'}{\partial x'^2} - \sigma\beta_o^2 u' + g\ell_{fo}\xi(T - T_\infty) \quad (1)$$

$$(\ell_c)_f \frac{\partial^2 T}{\partial y'^2} + (\ell_c)_f D_B \frac{\partial T}{\partial y'} - \frac{\partial q_r}{\partial y'} \quad (2)$$

$$u' = 0, T' = T_\infty + (T_1 - T_\infty)e^{iwt}\ at\ y'a\ ,\ \frac{\partial u'}{\partial y'} = 0, T = T_\infty, at\ y' = \quad (3)$$

According to Roseland approximation, the radioactive heat flux is model as

$$q_r = \frac{4\sigma^*}{3\kappa^*}\frac{\partial T}{\partial y'} \quad (4)$$

Where $\sigma$ is the Steltan-Boltzman constant, $\kappa^*$ is the mean absorption Coefficient

The difference in temperature with the flow is assume to be $T^4$ such that it can be expressed as a linear combination of the temperature. $T^4$ is expand in Tayllor's series about $T_\infty$ as follows:

$$\mathrm{T} \approx T_\infty^4 + 4T_\infty^3(T - T_\infty) + 6T_\infty^2(T - T_\infty)^2 + \cdots \quad (5)$$

Neglecting higher order terms beyond the first degree in $(T - T_\infty)$, we have

$$T \approx -3T_\infty^4 + 4T_\infty^4 T \quad (6)$$

Differentiating equation $(4)$ with respect to $y'$ and using equation $(6)$ gives

$$\frac{\partial q_r}{\partial y'} = \frac{-16T_\infty^3\sigma^*}{3k^*}\frac{\partial^2 T}{\partial y'} \quad (7)$$

Then equation$(2)$, can now be written as

$$(\ell_c)_f \frac{\partial T}{\partial t'} = \frac{\partial^2 T}{\partial y'^2} + (\ell_c)_f D_B \frac{\partial T}{\partial y'} + \frac{16T_w\sigma^*}{3k^*}\frac{\partial^2 T}{\partial y'^2} \quad (8)$$

Introduce the following suitable for transformation;

$$y = \frac{y'}{a}, t = \frac{ct'}{\lambda}, u = \frac{u'}{a}, p = \frac{p'}{a}, w = \frac{\lambda w'}{c}, Q = \frac{T - T_\infty}{T_1 - T_\infty} \quad (9)$$

Using equation $(9)$ to transform $(1)$, $(3)$ and $(8)$ , we have the following dimensionless equations.

$$\frac{\partial u}{\partial t} = -\frac{\partial p}{\partial x} + I\frac{\partial^2 u}{\partial y^2} - M^2 u + G_r Q \quad (10)$$

$$\frac{\partial Q}{\partial t} = \left(\frac{1}{p_r} + R\right)\frac{\partial^2 Q}{\partial y^2} + N_b\frac{\partial Q}{\partial y} \quad (11)$$

$$\frac{\partial u}{\partial y} = 0, Q = 0\ at\ y = 0, u = 0, Q = e^{iwt}\ at\ y = 1 \quad (12)$$

Where

$I = \frac{\lambda}{ca^2}$, $\mathrm{M}^2 = \frac{\partial \mathrm{B}_0 \lambda}{c}$, $G_r = \frac{g \ell_{f0} \xi \lambda (T_1 - T_\infty)}{ca}$

$p_r = \frac{a^2 (\ell_c)_f}{\lambda}$, $R = \frac{16 T_\infty^3 \sigma^* \lambda}{a^2 (\ell_c)_f (T_1 - T_\infty)}$, $N_b = \frac{D_B \lambda (T_1 - T_\infty)}{T_\infty a^2 (P_c)_f}$

## 3. ENTROPY GENERATION ANALYSIS

Entropy generation is derived from the energy and entropy balance. They are as follows according to Mohammad (2016);

$$S_{gen} = \frac{1}{T_\infty^2}\left[(\nabla T)^2 + \frac{16\sigma^* T}{3\kappa^*}(\nabla T)^2\right] + \frac{1}{T_\infty}\frac{\partial u'}{\partial y'} + \frac{1}{T_\infty} B_0^2 u'^2 + \frac{1}{\bar{k} T_\infty} u'^2 \qquad (13)$$

And characteristic entropy generation is given by

$$S_g = \frac{(T_1 - T_\infty)^2}{T_\infty^2 a^2} \qquad (14)$$

Using (9), (13) and (14) we have

$$N_s = (1 + R)\left(\frac{\partial Q}{\partial y}\right) + \frac{B_r}{\mathrm{D}}\frac{\partial u}{\partial y} + B_r \frac{1}{\mathrm{D}} u^2 + M^2 B_r \frac{1}{\mathrm{D}} u^2 \qquad (15)$$

Where $B_r$ is the Brinkman number, $D$ is the dimensionless temperature difference

## 4. SOLUTION OF THE PROBLEM

We assume a solution of the form;

$$u(y,t) = u(y)e^{iwt}, \quad Q(y,t) = Q(y)e^{iwt} \qquad (16)$$

Let take the pressure gradient $-\frac{\partial p}{\partial x} = Pe^{iwt}$ where $P$ is constant (according to [17] )

Using (16), we have the following set of equations

$u'' - Su + K + rQ = 0$

$VQ'' + N_b Q' - \mathcal{Z}Q = 0$

$u' = 0, Q = 0 \ at \ y = 0$

$u = 1, Q = 1 \ at \ y = 1$

Where $s = \frac{(iw - M)}{I}, K = \frac{P}{I}, r = \frac{G_r}{I}, V = \frac{1}{p_r} + R, n = N_b \ and \ z = iw$

The solution obtained with the aid of MATLAB are as follows:

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u=(1/2*exp(s^(1/2)*y)*(2*(n^2+4*z*v)^(1/2)*s^(1/2)*z*r+2*s^2*exp(-1/2/v*(n^2+4*z*v)^(1/2))*v^2*exp(s^(1/2))*exp(-
1/2*n/v)*r+2*s^2*exp(-1/2/v*(n^2+4*z*v)^(1/2))*v^2*exp(s^(1/2))*exp(-1/2*n/v)*k+4*s*exp(s^(1/2))*exp(-
1/2*n/v)*k*exp(1/2/v*(n^2+4*z*v)^(1/2))*z*v+2*s*exp(s^(1/2))*exp(-
1/2*n/v)*r*exp(1/2/v*(n^2+4*z*v)^(1/2))*z*v+2*exp(-1/2/v*(n^2+4*z*v)^(1/2))*z^2*exp(s^(1/2))*exp(-1/2*n/v)*k-
2*s^2*v^2*exp(s^(1/2))*exp(-1/2*n/v)*r*exp(1/2/v*(n^2+4*z*v)^(1/2))-2*z^2*exp(s^(1/2))*exp(-
1/2*n/v)*exp(1/2/v*(n^2+4*z*v)^(1/2))*k-2*s*exp(-(1/2/v*(n^2+4*z*v)^(1/2))*exp(s^(1/2))*exp(-1/2*n/v)*r*z*v-
4*s*exp(-1/2/v*(n^2+4*z*v)^(1/2))*v*z*exp(s^(1/2))*exp(-1/2*n/v)*k-2*s^2*v^2*exp(s^(1/2))*exp(-
1/2*n/v)*k*exp(1/2/v*(n^2+4*z*v)^(1/2))-2*(n^2+4*z*v)^(1/2)*s^(3/2)*v*r+n*s*(n^2+4*z*v)^(1/2)*exp(-
1/2/v*(n^2+4*z*v)^(1/2))*exp(s^(1/2))*exp(-
1/2*n/v)*r+n*s*(n^2+4*z*v)^(1/2)*exp(1/2/v*(n^2+4*z*v)^(1/2))*exp(s^(1/2))*exp(-
1/2*n/v)*r+2*n^2*s*exp(s^(1/2))*exp(-1/2*n/v)*k*exp(1/2/v*(n^2+4*z*v)^(1/2))+n^2*s*exp(s^(1/2))*exp(-
1/2*n/v)*r*exp(1/2/v*(n^2+4*z*v)^(1/2))-n^2*s*exp(-1/2/v*(n^2+4*z*v)^(1/2))*exp(s^(1/2))*exp(-1/2*n/v)*r-
2*n^2*s*exp(-1/2/v*(n^2+4*z*v)^(1/2))*exp(s^(1/2))*exp(-
1/2*n/v)*k)/s/(s^2*v^2*exp(s^(1/2))^2+s^2*v^2+z^2*exp(s^(1/2))^2+z^2-2*s*v*z-2*s*exp(s^(1/2))^2*z*v-
n^2*s*exp(s^(1/2))^2-s*n^2)/(-exp(1/2/v*(n^2+4*z*v)^(1/2))+exp(-1/2/v*(n^2+4*z*v)^(1/2)))/exp(-1/2*n/v)-1/2*exp(-
s^(1/2)*y)/s^(3/2)/(n^2+4*z*v)^(1/2)/(s^2*v^2+z^2-s*n^2-2*s*v*z)*exp(s^(1/2))*(2*s^(5/2)*(n^2+4*z*v)^(1/2)*exp(-
1/2/v*(n^2+4*z*v)^(1/2))*v^2*exp(-1/2*n/v)*r-4*s^(3/2)*(n^2+4*z*v)^(1/2)*exp(-1/2/v*(n^2+4*z*v)^(1/2))*v*z*exp(-
1/2*n/v)*k+2*s^(5/2)*(n^2+4*z*v)^(1/2)*exp(-1/2/v*(n^2+4*z*v)^(1/2))*v^2*exp(-1/2*n/v)*k-
2*s^(3/2)*(n^2+4*z*v)^(1/2)*n^2*exp(-1/2/v*(n^2+4*z*v)^(1/2))*exp(-1/2*n/v)*k+2*s^(1/2)*(n^2+4*z*v)^(1/2)*exp(-
1/2/v*(n^2+4*z*v)^(1/2))*z^2*exp(-1/2*n/v)*k-s^(3/2)*(n^2+4*z*v)^(1/2)*n^2*exp(-1/2/v*(n^2+4*z*v)^(1/2))*exp(-
1/2*n/v)*r+s^(3/2)*n^3*exp(-1/2/v*(n^2+4*z*v)^(1/2))*exp(-1/2*n/v)*r+4*s^(3/2)*n*exp(-
1/2/v*(n^2+4*z*v)^(1/2))*exp(-1/2*n/v)*r*z*v-2*s^(3/2)*(n^2+4*z*v)^(1/2)*exp(-1/2/v*(n^2+4*z*v)^(1/2))*exp(-
1/2*n/v)*r*z*v+2*s^(3/2)*(n^2+4*z*v)^(1/2)*exp(-
1/2*n/v)*r*exp(1/2/v*(n^2+4*z*v)^(1/2))*z*v+2*s^(3/2)*(n^2+4*z*v)^(1/2)*n^2*exp(-
1/2*n/v)*k*exp(1/2/v*(n^2+4*z*v)^(1/2))-2*s^(5/2)*(n^2+4*z*v)^(1/2)*v^2*exp(-
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1/2*n/v)*k*exp(1/2/v*(n^2+4*z*v)^(1/2))+2*s^2*exp(s^(1/2))*v*r*n^2+8*s^2*exp(s^(1/2))*v^2*r*z-2*s^(1/2)*(n^2+4*z*v)^(1/2)*z^2*exp(-1/2*n/v)*exp(1/2/v*(n^2+4*z*v)^(1/2))*k+4*s^(3/2)*(n^2+4*z*v)^(1/2)*exp(-1/2*n/v)*k*exp(1/2/v*(n^2+4*z*v)^(1/2))*z*v-2*s^(5/2)*(n^2+4*z*v)^(1/2)*v^2*exp(-1/2*n/v)*r*exp(1/2/v*(n^2+4*z*v)^(1/2))+s^(3/2)*(n^2+4*z*v)^(1/2)*n^2*exp(-1/2*n/v)*r*exp(1/2/v*(n^2+4*z*v)^(1/2))-2*s*exp(s^(1/2))*z*r*n^2-8*s*exp(s^(1/2))*z^2*r*v+s^(3/2)*n^3*exp(1/2/v*(n^2+4*z*v)^(1/2))*exp(-1/2*n/v)*r+4*s^(3/2)*n*exp(1/2/v*(n^2+4*z*v)^(1/2))*exp(-1/2*n/v)*r*z*v)/exp(-1/2*n/v)/(exp(s^(1/2))^2+1)/(-exp(1/2/v*(n^2+4*z*v)^(1/2))+exp(-1/2/v*(n^2+4*z*v)^(1/2)))+1/2*(-(-k/s^(1/2)/exp(s^(1/2)*y)-r/exp(-1/2*n/v)/(-exp(1/2/v*(n^2+4*z*v)^(1/2))+exp(-1/2/v*(n^2+4*z*v)^(1/2)))/(-s^(1/2)-1/2*n/v+1/2/v*(n^2+4*z*v)^(1/2))*exp(-s^(1/2)*y-1/2*n/v*y+1/2/v*y*(n^2+4*z*v)^(1/2))+r/exp(-1/2*n/v)/(-exp(1/2/v*(n^2+4*z*v)^(1/2))+exp(-1/2/v*(n^2+4*z*v)^(1/2)))/(-s^(1/2)-1/2*n/v-1/2/v*(n^2+4*z*v)^(1/2))*exp(-s^(1/2)*y-1/2*n/v*y-1/2/v*y*(n^2+4*z*v)^(1/2)))*exp(2*s^(1/2)*y)+k/s^(1/2)*exp(s^(1/2)*y)-r/exp(-1/2*n/v)/(-exp(1/2/v*(n^2+4*z*v)^(1/2))+exp(-1/2/v*(n^2+4*z*v)^(1/2)))/(s^(1/2)-1/2*n/v+1/2/v*(n^2+4*z*v)^(1/2))*exp(s^(1/2)*y-1/2*n/v*y+1/2/v*y*(n^2+4*z*v)^(1/2))+r/exp(-1/2*n/v)/(-exp(1/2/v*(n^2+4*z*v)^(1/2))+exp(-1/2/v*(n^2+4*z*v)^(1/2)))/(s^(1/2)-1/2*n/v-1/2/v*(n^2+4*z*v)^(1/2))*exp(s^(1/2)*y-1/2*n/v*y-1/2/v*y*(n^2+4*z*v)^(1/2)))*exp(-s^(1/2)*y)/s^(1/2))*exp(i*w*t)

Q=(-1/exp(-1/2*n/v)/(-exp(1/2/v*(n^2+4*z*v)^(1/2))+exp(-1/2/v*(n^2+4*z*v)^(1/2)))*exp(-1/2*(n-(n^2+4*z*v)^(1/2))/v*y)+1/exp(-1/2*n/v)/(-exp(1/2/v*(n^2+4*z*v)^(1/2))+exp(-1/2/v*(n^2+4*z*v)^(1/2)))*exp(-1/2*(n+(n^2+4*z*v)^(1/2))/v*y))*exp(i*w*t)

**RESULTS:**

**Table 1: Velocity distribution for various values of parameters.**

| M | $P_r$ | R | $G_r$ | $N_b$ | P | u |
|---|---|---|---|---|---|---|
| 0.2 | 0.2 | 0.1 | 0.1 | 0.7 | 0.5 | 6.9112 |
| 0.4 | | | | | | 1.8346 |
| 0.6 | | | | | | 0.8214 |
| 0.8 | | | | | | 0.4630 |
| 0.2 | 0.6 | 0.1 | 0.1 | 0.7 | 0.5 | 7.5796 |
| | 0.8 | | | | | 7.5171 |
| | 1.0 | | | | | 7.3764 |
| | 1.2 | | | | | 7.2191 |
| 0.2 | 0.2 | 0.2 | 0.1 | 0.7 | 0.5 | -6.8961 |
| | | 0.4 | | | | -6.8672 |
| | | 0.6 | | | | -6.8398 |
| | | 0.8 | | | | -6.8136 |
| 0.2 | 0.2 | 0.1 | 0.2 | 0.7 | 0.5 | 9.8622 |
| | | | 0.4 | | | 15.7643 |
| | | | 0.6 | | | 21.6663 |
| | | | 0.8 | | | 27.5683 |
| 0.2 | 0.2 | | 0.1 | 0.8 | | -7.0135 |
| | | | | 1.0 | | -7.1880 |
| | | | | 1.2 | | -7.3229 |
| | | | | 1.4 | | -7.4206 |
| 0.2 | 0.2 | 0.1 | 0.1 | 0.7 | 0.8 | -0.8047 |
| | | | | | 1.0 | 1.1114 |
| | | | | | 1.2 | 1.4181 |
| | | | | | 1.4 | 1.5715 |

**Table 2: Temperature distribution for various values of parameters**

| $P_r$ | $R_i$ | $N_b$ | Q |
|---|---|---|---|
| 0.2 | 0.2 | 0.7 | -1.8536 |
| 0.4 | | | -1.7508 |
| 0.6 | | | -1.6661 |
| 0.8 | | | -1.5956 |
| 0.2 | 0.4 | 0.7 | 1.8580 |
| | 0.6 | | 1.8621 |
| | 0.8 | | 1.8659 |
| | 1.0 | | 1.8695 |
| 0.2 | 0.2 | 0.8 | -1.8372 |
| | | 1.0 | -1.8052 |
| | | 1.2 | -1.7744 |
| | | 1.4 | -1.7447 |

**Table 3: Entropy generation for various values of parameters**

| D | $B_r$ | R | M | G | $P_r$ | $N_b$ | $N_s$ |
|---|---|---|---|---|---|---|---|
| 0.6 | 0.5 | 0.5 | 0.3 | 0.5 | 0.2 | 0.7 | 1.3271 |
| 0.8 | | | | | | | 1.3609 |
| 1.0 | | | | | | | 1.3811 |
| 1.2 | | | | | | | 1.3912 |
| 0.6 | 0.5 | 0.5 | 0.3 | 0.5 | 0.2 | 0.7 | -1.3271 |
| | 0.8 | | | | | | -1.2462 |
| | 1.0 | | | | | | -1.1923 |
| | 1.2 | | | | | | -1.1883 |
| 0.6 | 0.5 | 0.7 | 0.3 | 0.5 | 0.2 | 0.7 | 2.1310 |
| | | 0.9 | | | | | 2.0203 |
| | | 1.1 | | | | | 1.9270 |
| | | 1.3 | | | | | 1.8336 |
| 0.6 | 0.5 | 0.5 | 0.5 | 0.5 | 0.2 | 0.7 | 17.6434 |
| | | | 0.6 | | | | 9.3044 |
| | | | 0.7 | | | | 5.7589 |
| | | | 0.8 | | | | 3.8864 |
| 0.6 | 0.5 | 0.5 | 0.3 | 0.6 | | | 1.8329 |
| | | | | 0.7 | | | 1.7409 |
| | | | | 0.8 | | | 1.2809 |
| | | | | 0.9 | | | 1.1675 |
| 0.6 | 0.5 | 0.5 | 0.3 | 0.5 | 0.3 | | 2.8061 |
| | | | | | 0.4 | | 3.4683 |
| | | | | | 0.5 | | 3.9133 |
| | | | | | 0.6 | | 4.2136 |
| 0.6 | 0.5 | 0.5 | 0.3 | 0.5 | 0.2 | 0.8 | 2.2544 |
| | | | | | | 0.9 | 2.6475 |
| | | | | | | 1.0 | 3.0077 |
| | | | | | | 1.1 | 3.3325 |

**Table 4: Nusselt number variation for various values of parameters**

| $N_b$ | R | $P_r$ | $Nu = -Q'(0)$ |
|---|---|---|---|
| 0.7 | 0.5 | 0.2 | 1.0049 |
| 0.8 | | | 1.0744 |
| 0.9 | | | 1.0840 |
| 1.0 | | | 1.0936 |
| 0.7 | 0.7 | 0.2 | 1.0626 |
| | 0.9 | | 1.0604 |
| | 1.1 | | 1.0584 |
| | 1.3 | | 1.0467 |
| 0.7 | 0.5 | 0.3 | 1.0940 |
| | | 0.4 | 1.1211 |
| | | 0.5 | 1.1465 |
| | | 0.6 | 1.1702 |

## 5. DISCUSSION OF RESULT

Computational analysis of entropy generation and heat transfer on oscillatory blood flow through arteries in the presence of thermal radiation was studied. In order to understand the situation of the problem and hence, manifestation of the various parameters entering the problem, numerical evaluation was performed and the results are presented in Tabular forms. This was done to analyse the influence of various parameters involved. In this study, we chose t = 1 and w = 0.01 while other parameters are varied over range. The effect of magnetic parameter (M), Prandtl number ($P_r$), Radiation parameter (R), Thermal Grashof number ($G_r$), Brownian motion (Nb) and Pressure (P) on velocity profiles are depicted in table1. It is obvious from the table that velocity profile of blood decreases as the magnetic parameter (M) increases which is not surprising because magnetic field gives rise to a resistive type of force called the Lorentz force and the force has the tendency to slow the motion of flow. It is observed from the table that as Prandtl number increases, the velocity profile decreases. The table indicates that the velocity profile of blood increases as the radiation parameter (R) increases. This is expected because when the intensity of hear generated through thermal radiation increases, the bond holding the components of the fluid particle is easily broken and the fluid velocity will increase. Table 1 further shows that the effect of increasing Thermal Grashof number is to increase the velocity profile of the blood while the effect of increasind Brownian motion parameters is to decrease the velocity profile of the blood. It was also shown in the table that pressure rise increases the velocity profile of blood.

Table 2 analysed the effects of Prandtl number ($P_r$), Radiation parameter (R) and Brownian motion parameter ($N_b$) on Temperature profiles. From the Table 2, it was observed that Temperature profile increases when Prandtl number ($P_r$), Brownian motion parameter ($N_b$) and radiation parameter increase.

Table 3 demonstrates the entropy generation for dimensionless temperature difference (D), Brinkman number ($B_r$), Radiation parameter (R), magnetic parameter (M), Thermal Grashof number ($G_r$), Prandtl number ($P_r$) and Brownian motion parameter ($N_b$). The table shows that the entropy generation increases with increase in Brinkman number ($B_r$) while it decreases with increase in dimensionless temperature difference (D). This is because the Brinkman parameter is directly proportional to the square of the velocity profile of the flow while dimensionless temperature difference is inversely proportional to the velocity distribution (Mohammed *et al.*, 2016). It was observed from the table that Radiation parameter (R), magnetic parameter (M), Thermal Grashof number ($G_r$) decreases entropy generation as there are increase in them while Prandtl number ($P_r$) and Brownian motion parameter ($N_b$) increase entropy generation as they increase.

Table 4 displays the effect of Brownian motion parameter ($N_b$), Radiation parameter (R) Prandtl number ($P_r$). The table shows that Brownian motion parameter ($N_b$) and Prandtl number ($P_r$) increase the rate of heat transfer as they increase while radiation decreases the rate of heat transfer as it increases.

## 6. CONCLUSION

The problem of entropy generation and heat transfer on oscillatory MHD blood flow in the presence of thermal radiation has been investigated. The result shows that:

Thermal radiation and pressure rise increases the velocity of blood flow while Brownian motion decreases the velocity

Entropy generation increases with increase in Brinkman number while it decreases with increase in dimensionless temperature difference

Thermal radiation decreases entropy generation and the rate of heat transfer.

## References


[1] Abbas, M.A., Bai, Y.Q., Bhatti, M.M. and Rashidi, M.M. (2016). Three dimensional peristaltic flow of hyperbolic tangent fluid in non-uniform channel having flexible walls. *Elselvier, Alexandria Engineering Journal*, 55: 653-662.

[2] Smith, E. (2008). Thermodynamics of natural selection II: chemical Carnot cycles, *Journal of Theoretical Biology*, 252: 198-212.

[3] Davies, P.C.W, Rieper, E. and Tuszynski, J.A. (2013). Self-organization and entropy reduction in a living cell, *Biosystems*, 111(1): 1-10.

[4] Himeoka, Y and Kaneko, K (2014). Entropy production of a steady-growth cell with catalytic reactions, *American Physical Society*, Physical Review E 90, 042714: 1-8.

[5] Cosmi, F.; Di Marino, F. (2001). Modelling of the mechanical behaviour of porous materials: A new approach. *Acta Bioeng. Biomech*., 3, 55–66.

[6] Rashidi, M.M.; Keimanesh, M.; Rajvanshi,S.C. (2012). Study of pulsatile flow in a porous annulus with the homotopy analysis method. *Int. J. Numer. Method Heat*, 22, 971–989.

[7] Bég, O.A.; Keimanesh, M.; Rashidi, M.M.; Davoodi, M.; Branch, S.T. (2013). multi-step simulation of magneto-peristaltic flow of a conducting Williams on viscoelastic fluid. *Int. J. Appl. Math. Mech.*, 9, 1–24.

[8] Bhatti, M.M., Abbas, M.A. and Rashidi, M.M. (2017). Entropy generation for peristaltic blood flow with casson model and consideration of magnetohydrodynamics effects. Walailak Journal Sci & Tech; 14(6): 451-461.

[9] Rashidi, M.M., Bhatti, M.M., Abbas, M.A. and Ali, M.E. (2016). Entropy generation on MHD blood flow of nanofluid due to peristaltic waves, *Entropy*, 18 (117): 1-16.

[10] Bejan, A. (1980). Second law analysis in heat transfer, *Energy*, 5, 720–732.

[11] Bejan, A. (1995). Entropy generation minimization: the method of thermodynamic optimization of finite-size systems and finite-time processes; *CRC press: Boca Raton, FL*, USA, ISBN 0-8493-9651-4.

[12] Souidi, F., Ayachi, K. and Benyahia, N. (2009). Entropy generation rate for a peristaltic pump, *J. Non-Equilib Thermodyn*, 34:171-194.

[13] Zahir, H., Hayat, T., Alsaedi, A. and Ahmad, B. (2017). Entropy generation impact on peristaltic motion in a rotating frame, *Results in Physics*, 7: 3668

[14] Hayat, T., Farooq, S., Ahmad, B. and Alsaedi, A. (2017). Effectiveness of entropy generation and energy transfer on peristaltic flow of Jeffrey material with Darcy resistance. *International Journal of Heat Mass Transfer*, 106: 244-252.

[15] Delgado-Bonal, A (2017). Entropy of radiation: the unseen side of light, *Scientific Reports*, 1642 (7): 1-11.

[16] Abbas, M.A., Bai, Y., Rashidi, M.M. and Bhatti, M.M. (2016). Analysis of entropy generation in the flow of peristaltic nanofluids in channels with compliant walls, *Entropy*, 18, 90.

[17] Chitra, M., Bhaskaran, R. and Parthasarathy, S. (2018). Effect of oscillatory motion of a visco-elastic dusty fluid (blood) through arteries under the influence of magnetic field with porous medium, *Journal of Physics: Conf. Series* 1139(2018)012004.