7. RESULT AND DISCUSSION:

In this portion we have disclosed the physical interpretation of sundry variables involving into the problem and is about to understand the effects of various non-dimensional physical quantities on the Velocity $f(\eta)$, Heat $\theta(\eta)$, Concentration $\phi(\eta)$ and Density of motile microorganism $\varphi(\eta)$ profiles. The following results with complete details are achieved: Fig. 1 shows geometry of the fluid model for comprehensions of the readers. The h-curves are elaborated in Figs. (2-3). Figs 4,5,6 and 7 represent the influences of squeezing fluid parameter λ on $f(\eta)$, $\theta(\eta)$, $\phi(\eta)$ and $\varphi(\eta)$. When plates are moving apart, then λ takes the positive value in that corresponding case and when plates are coming closer the values are considered negative. Figure.4 clearly shows the influence of the flow when plates are moving away and this is opposite case of when plates coming nearer. With the increase of λ values fluid velocity also increasing. Clearly velocity increases in the channel when fluid sucked inside. On the other hand when fluid injected out, then the plates come closer to one another. This manner brings about a drop in the fluid and consequently decreases the velocity. With varying value of λ parameter the influence of $f(\eta)$ shown in fig. 4. Figs. 5 and 6 show the influence of λ parameter on the heat and concentration distributions respectively. Due to squeezing of the fluid the velocity increases and subsequently falls the temperature of the fluid because warm nanoparticles are escaping rapidly which results in lower temperature and the concentration of the fluid automatically reduces. Fig.7 indicates variation in density of the motile microorganisms for various values of λ. The density of microorganisms $\varphi(\eta)$ illustrates variations. With changing λ values, the $\varphi(\eta)$ is a decreasing factor, when λ parameter changes negatively and it shows increasing function for positive values of λ. Fig.8 demonstrates the impact of velocity field for various values of magnetic field parameter M. It depicts that with an increase in value of M, velocity profile decreases, because Lorentz forces work against the flow and those regions where its influences dominates, it reduces velocity. After a certain distance it increases. Figs.9 demonstrates the characteristics of magnetic parameter M on heat distribution , which is increasing for higher values and drops for the small values of M. Actually Lorentz force decreasing which depend on magnetic field M, so decreasing M leads to decrease Lorentz force and consequently decreases $\theta(\eta)$. The impact of Pr on the $\theta(\eta)$ and $\phi(\eta)$ are shown in Figs. 10 and 11. Clearly it is seen that temperature and concentration distributions vary inversely with Pr, that is temperature distribution drop with large numbers of Pr and rise for lesser values of Pr. Physically, the fluids having a small number of Pr has larger thermal diffusivity and this effect is opposite for higher Prandtl number. Due to this fact large Pr causes the thermal boundary layer to decrease. The effect is even more diverse for the small number of Pr since thermal boundary layer thickness is relatively large. On the other hand increasing behaviour of concentration distribution is shown in fig.11 for increasing Pr values. Figs.12 represents the influence of thermophoretic parameter Nt on heat profile $\theta(\eta)$. It is investigated that $\theta(\eta)$ is increased by varying thermophoretic parameter Nt. According to Kinetic Molecular theory increasing number of particles and increasing number of active particles both can cause to increase in the heat factor. Fig.13 represents the change in the concentration profile $\phi(\eta)$ due to change in parameter Nt. The profile $\phi(\eta)$ decreases in suction and injection cases. In injection case, the decrement in $\phi(\eta)$ is slow as compare to fluid suction case. Figs.14 and15 show the effect of Nb on $\theta(\eta)$ and $\phi(\eta)$ fields.

Heat profile $\theta(\eta)$ is increased by varying values of Nb as shown in fig. 14. Due to Kinetic molecular theory the heat of the fluid increases due to the increase of Brownian motion. So the given result is in good agreement with real situation. Similarly fig.15 highlights the impact of varying Nb parameter with respect to the concentration profile $\phi(\eta)$ on domain, $0 \leq \lambda \leq 1$. An increasing impact of $\phi(\eta)$ is observed for both suction and injection in fig.15. A fast increment has been observed in $\phi(\eta)$ for fluid suction as compared to fluid injection. Fig.16 represents the effect of Peclet number Pe on $\varphi(\eta)$. The values of density field of motile microorganism increase with increase value of Pe. Fig. 17 shows the impacts of on density field of motile microorganism $\varphi(\eta)$.The values of density field of the motile microorganisms decrease with increase in the values of Sc. Actually, Schmidt number is the ratio of kinematic viscosity to the mass flux. So when kinematic viscosity increases, then spontaneously the Sc increases and $\varphi(\eta)$ decreases. Fig. 18 displays the influence of Le on the concentration profile $\phi(\eta)$ where it decreases when number Le increases. Actually, it is the ratio of thermal diffusivity to the mass diffusivity. So, when the thermal diffusivity decreases it automatically decreases Le and also decreases concentration field. Fig. 19 displays the effect of radiation parameter Rd on the heat field $\theta(\eta)$. It is clearly observed that heat profile $\theta(\eta)$ decreases with increase values of Rd. It is a common observation that radiating a fluid or some other thing can cause to reduce the temperature of that particular object.

8. TABLE DISCUSSIONS:

Table.1 displays numerical values of HAM solutions at different approximation using various values of different parameters. It is clear from the table.1 that homotopy analysis technique is a quickly convergent technique. Physical quantities such as skin friction co-efficient, heat flux, mass flux and Local-density number of motile microorganism for engineering interest are calculated through Tables: (2-5). Table: 2 displays the impact of inserting parameters M and λ on Skin friction C_f. It is seen that increasing value of M and λ decreases the skin friction C_f. Table.3 examines the influences of embedding parameters Nb,Nt,Pr and Rd on heat flux Nu. It is seen that increasing values of Pr increase the heat flux Nu where Rd,Nt and Nb decrease the heat flux when it increased. Table.4 inspects the influences of Le,Nb and Nt on mass flux Sh. The increasing values of Le and Nb increase the mass flux where Nt reduces the mass flux .The influences of Sc,λ and Pe on $\varphi'(0)$ are shown in Table.5. The increasing values of Pe increases $\varphi'(0)$, while the higher value of λ and Sc reduce $\varphi'(0)$.

Table 2. Represents numerical values of the Skin-Friction Co-efficient for various parameters where $Nb = 1$,$Nt = Le = 0.6$,$Sc = 0.8$,$Pe = 0.7$ and $\omega = 0.1$.

M	λ	$-(C_f Re_x)^{\frac{1}{2}}$ Hayat et al. [22] result	$-(C_f Re_x)^{\frac{1}{2}}$ Present Results
0.1	1.5	-2.40160	1.1051
0.5		-2.41735	0.9999
1.0		-2.42522	0.9957
0.1	1.5	-2.40788	1.2057
	2.0	-2.40828	1.1947
	2.5	-2.40947	1.1747
	3.0	-2.41426	0.9957

Table 3. Represents Numerical values of Local-Nusselt number for unlike type parameters, where $Pr = 0.7$,$\lambda = 1$,$Le = 0.6$,$Sc = 0.8$,$Pe = 0.7$,$\omega = 0.1$ and $M = 0.5$.

Rd	Nt	Nb	Pr	$-\theta'(0)$ Alsaedi el al [7].Results	$-\theta'(0)$ Present Result
0.5	0.5	0.5	1.0	.....	2.0003
0.1				.....	1.6202
1.5				.....	1.2133
0.5	0.5			0.8167	1.9501
	1.0			0.6971	1.5546
	1.5			0.5735	1.2013
	0.5			0.8943	2.5923
		0.5		0.8011	1.7456
		1.0	1.0	0.7472	1.0072
		0.5	1.5	0.8943	1.1196
			2.0	1.0270	17456

Table 4. Represents Numerical type values of Local-Sherwood number for unlike parameters, where $Le = 0.6$,$Sc = 0.8$,$Pe = Pr = 0.7$,$\omega = 0.1$,$\lambda = M = 0.6$.

Le	Nb	Nt	$-\phi'(0)$ Alsaedi el al [7].Results	$-\phi'(0)$ Present Result
0.1	0.2	0.5	0.4471	0.8518
0.5			0.5878	0.9618
1.0	0.2		0.5878	0.6624
	0.6		0.9582	0.7910
	1.0		1.0320	0.8518
	0.2	0.5	0.5878	0.8615
		1.0	0.8588	0.9020
		1.5	-0.3914	0.8901

Table 5. Represents Numerical values of Local-density number of motile microorganism for various types of parameters, when $Sc = 0.8$,$Pr = 1$,$Pe = 0.7$,$\omega = 0.1$,$\lambda = M = 0.5$.

Sc	λ	Pe	$-\varphi'(0)$ Alsaedi el al [7].Results	$-\varphi'(0)$ Present Result
1.0	0.5	0.5	.....	1.6434
1.5			.....	1.2526
2.0			.....	0.9542
1.0	0.5		.....	2.1053
	1.0		.....	1.8599
	1.5		.....	0.9552
	0.5	0.5	1.3811	1.6864
		1.5	1.4764	1.7801
		2.0	1.5731	2.1053

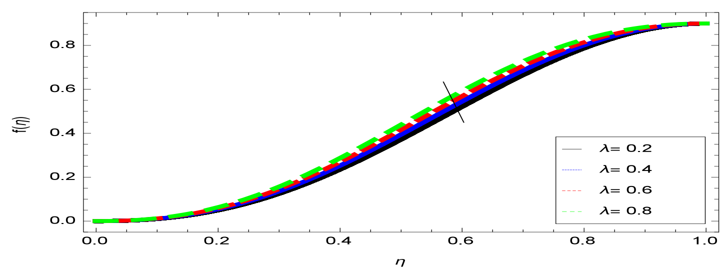

FIGURE 4. Effect of λ on $f(\eta)$, when $\omega = 0.8$ and $M = 1.9$.

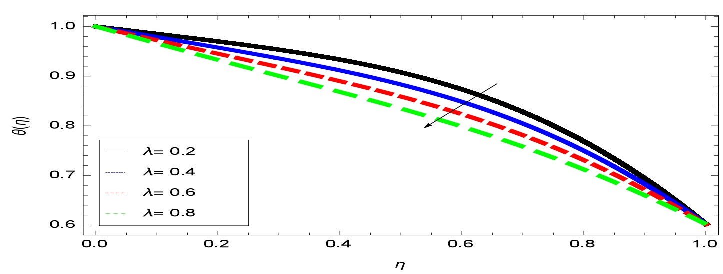

FIGURE 5. Effect of λ on $\theta(\eta)$, when $\omega = 0.8$,$Le = 0.4$,$Nt = 0.1$,$Nb = Rd = 0.4$,$Pr = 0.6$.

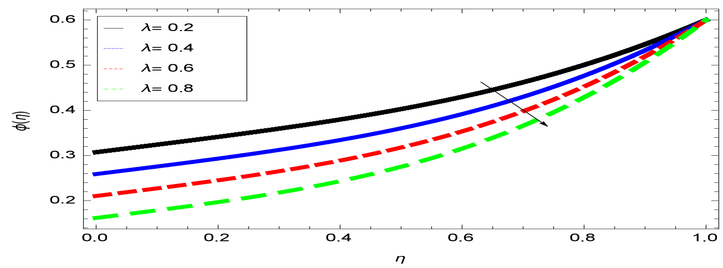

FIGURE 6. Effect of λ on $\phi(\eta)$, when $\omega = 0.8$,$Le = 0.4$,$Nt = 0.1$,$Nb = 0.6$,$Pr = 0.6$ and $M = 0.5$.

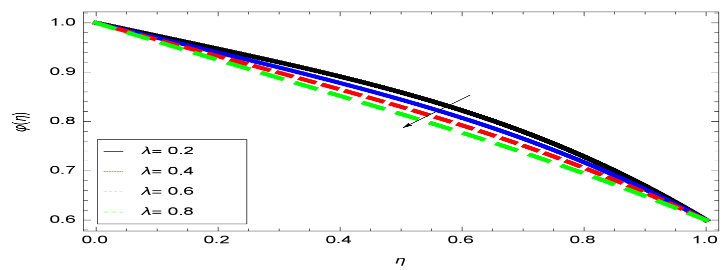

FIGURE 7. Effect of λ on $\varphi(\eta)$, when $\omega = 0.8$,$Le = Sc = 0.4$,$Nt = Pe = 0.1$,$Nb = 0.3$ and $M = 1$.

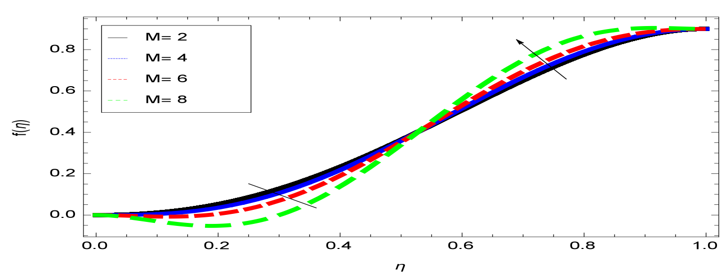

FIGURE 8. Effect of M on $f(\eta)$, when $\omega = 0.8$ and $\lambda = 0.9$.

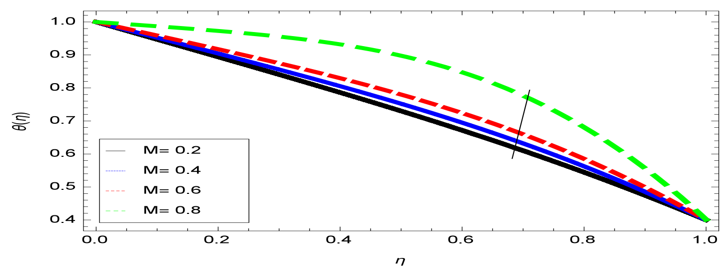

FIGURE 9. Effect of M on $\theta(\eta)$, when $\omega = 0.8$,$Le = 0.3$,$Nt = 0.6$,$Nb = 0.1$,$\lambda = Rd = 1$,$Pr = 0.5$.

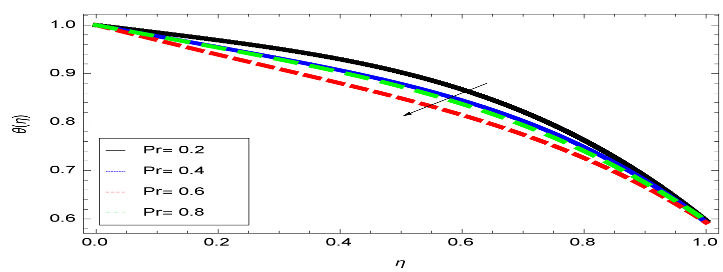

FIGURE 10. Effect of Pr on $\theta(\eta)$, when $\omega = 0.8$,$Le = 0.3$,$Nt = 0.6$,$\lambda = Rd = 0.4$,$Nb = 0.1$,$M = 1$.

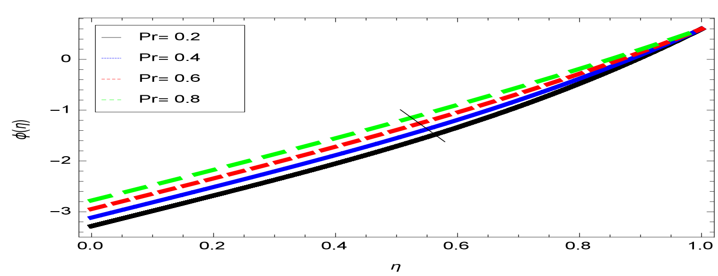

FIGURE 11. Effect of Pr on $\phi(\eta)$, when $\omega = 0.8$,$Le = 0.3$,$Nt = 0.6$,$\lambda = 0.4$,$Nb = 0.1$,$Pr = 0.2$,$M = 1$.

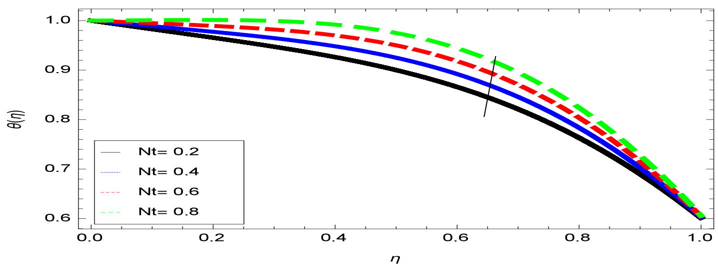

FIGURE 12. Effect of Nt on $\theta(\eta)$, when $\omega = 0.8$,$Le = 0.3$,$\lambda = Rd = 0.4$,$Nb = 0.1$,$Pr = 0.6$,$M = 2$.

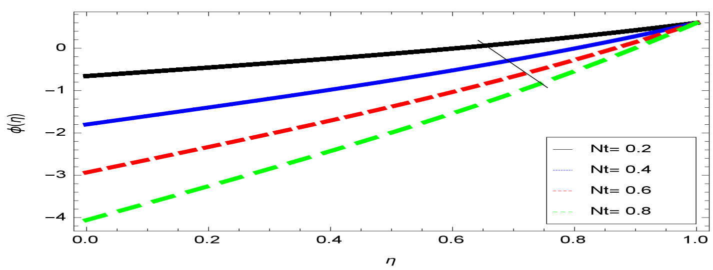

FIGURE 13. Effect of Nt on $\phi(\eta)$, when $\omega = 0.8$,$Le = 0.3$,$\lambda = 0.4$,$Nb = 0.1$,$Pr = 0.6$,$M = 2$.

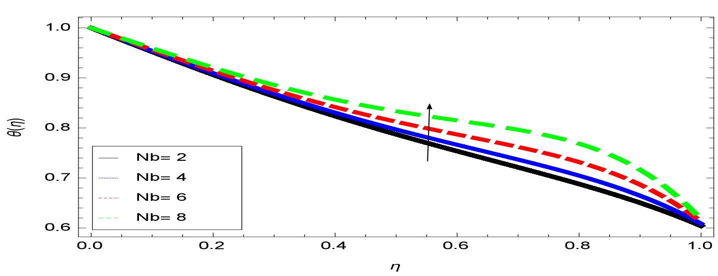

FIGURE 14. Effect of Nb on $\theta(\eta)$, when $\omega = 0.8$,$Le = 0.3$,$\lambda = Rd = 0.4$,$Nt = 0.1$,$Pr = 0.6$,$M = 2$.

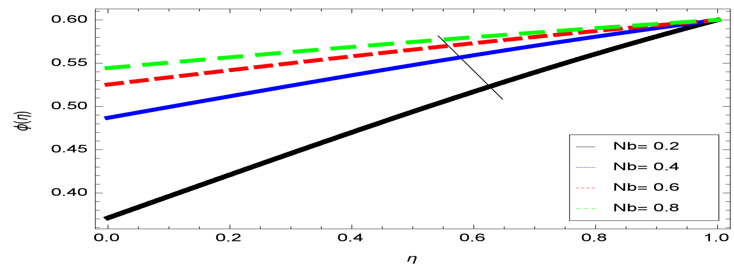

FIGURE 15. Effect of Nb on $\phi(\eta)$, when $\omega = 0.8$,$Le = 0.3$,$\lambda = 0.4$,$Nt = 0.1$,$Pr = 0.6$,$M = 1$.

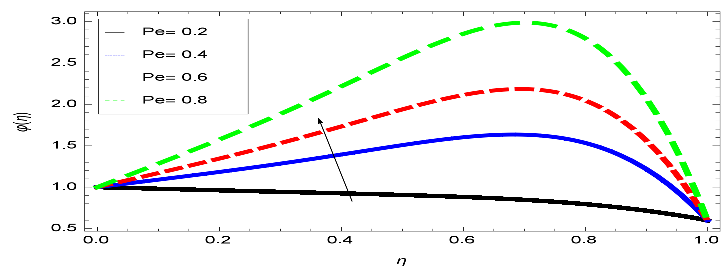

FIGURE 16. Effect of Pe on $\varphi(\eta)$, when $\omega = 0.8$,$Le = 0.3$,$\lambda = Sc = 0.4$,$Nb = 0.1$,$Nt = 0.6$,$M = 2$.

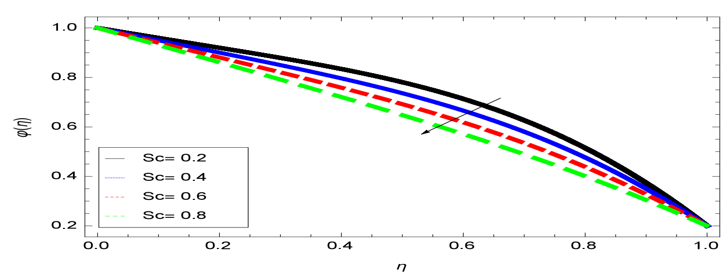

FIGURE 17. Effect of Sc on $\varphi(\eta)$, when $\omega = 0.8$,$Le = 0.3$,$\lambda = 0.4$,$Nb = 0.1$,$Nt = 0.6$,$Pr = 0.5$,$M = 1$.

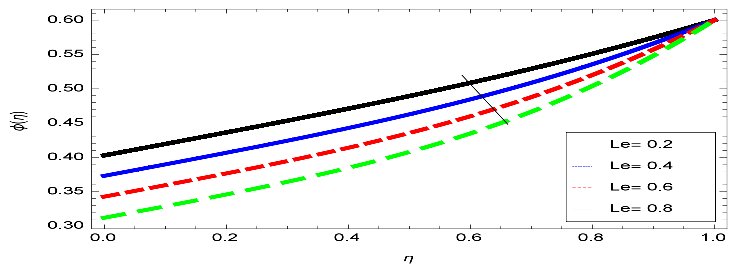

FIGURE 18. Effect of Le on $\phi(\eta)$, when $\omega = 0.8$,$Le = 0.4$,$\lambda = 4$,$Nt = 0.1$,$Nb = 0.3$,$Pr = 0.6$,$M = 1$.

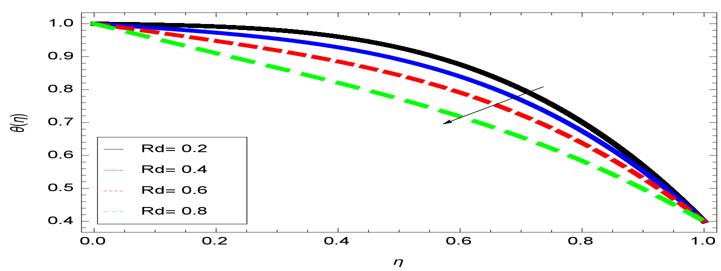

FIGURE 19. Effect of Rd on $\theta(\eta)$, when $\omega = Le = 0.8$,$\lambda = 4$,$Nb = 0.1$,$Nt = 0.6$,$Pr = 0.5$,$M = 1.9$.

9. CONCLUDING REMARKS:

In this research article, bioconvection flow between two parallel plates is under consideration. It is assumed that the plates are capable to expand or contract. The dimensional flow model included the nanofluid and microorganisms transformed into the nondimensional and highly nonlinear system of ordinary differential equations. For this, a defined dimensionless form of the similarity variables is utilized. Also, the supporting boundary conditions are reduced in dimensionless form.Effect of embedding parameters are observed and discussed graphically. Furthermore, the variation of the Skin friction, Sherwood number, Nusselt number and their effects on the velocity, concentration, temperature and motile microorganism profiles are examined. The key points are:

- The larger values of Nb rise the kinetic energy of the nanoparticles, which result an increase in the heat profile.
- When we increase thermal radiation parameter Rd, then it augments temperature of the boundary layer area in fluid layer. This increase leads to drop in the rate of cooling for nanofluid flow.

- It is observed that $\theta(\eta)$ is increased by varying thermophoretic parameter Nt.
- Thermophoretic and Brownian motion parameters affect the concentration field reversely for both the suction and injection case.
- The convergence of the homotopy method along with the variation of different physical parameters has been observed numerically.
- Interesting variations in the density of motile microorganisms φ are analyzed for different values of the bioconvection parameter.
- It is seen that increasing M and λ reduce the skin friction C_f.
- It is seen that increasing values of Pr increases the heat flux Nu while Nb, Nt and Rd reduce the heat flux Nu.
- The increasing values of Le and Nb increase the mass flux where Nt reduces the mass flux.
- For the suction/injection parameter λ, Brownian parameter Nb and thermophoretic parameter Nt the density of motile microorganisms shows very prominent variations throughout the domain of interest.

10. Nomenclature:

The following abbreviations are used in this manuscript:

B_0	Magnetic field strength
Rd	Rediation parameter
M	Magnetic parameter
D_B	Brownian diffusion of nanofluids
Nt	Thermophoretic parameter
Nb	Brownian motion parameter
Sh	Sherhood number
Nu	Nusslet number
Re	Reynold number
Pr	Prandtl number
Sc	Schmidth number
C_{ref}	Reference concentration
T_{ref}	Reference temperature
τ_{ij}	Extra stress tensor
ν	Kinematic viscosity
μ	Dynamic viscosity
T	Temperature
$\widehat{k}$	Thermal conductivity
q_{rd}	Radioactive heat fluctuation
σ^*	Stefan Boltzmann constant
k^*	Mean absorption coefficient
β	Film Thickness parameter
λ	Unsteady squeezing parameter
ρ	Density

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12. AUTHORCONTRIBUTIONS

Conceptualization: Syed Asif Hussain and Gohar Ali, Methodology: Syed Asif Hussain and Sher Muhammad, Software: Mohammad Ishaq and Sher Muhammad, Validation: Syed Asif Hussain, Gohar Ali, Syed Inayat Ali Shah and Mohammad Ishaq, Formal Analysis: Syed Asif Hussain,Mohammad Ishaq Investigation: Syed Asif Hussain,Sher Muhammad, Resources: Syed Asif Hussain, WritingOriginal Draft Preparation: Syed Asif Hussain, WritingReview & Editing: Mohammad Ishaq and Sher Muhammad, Visualization: Syed Inayat Ali Shah and Syed Asif Hussain, Supervision: Gohar Ali, Syed Inayat Ali Shah.

13. Competing Interests

Authors have declared that no competing interests exist.

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