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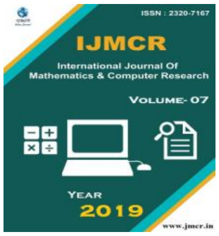

Entropy Generation Analysis of A Magnetized Al_2O_3-H_2O Nanofluid between Viscous Heating Horizontal Internal Rotating Annulus and Joule Heating

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ABSTRACT

The effects of the thermodynamic analysis of the MHD nanofluid flow with horizontal annulus with internal cylindrical rotation are numerically studied in this article. The effects of viscous heating(or dissipation) and ohmic heating are also considered. The momentum, thermal and solutal equations are numerically solved by the RK4 method together with the shooting technique, subject to the associated boundary conditions. The response of various relevant parameters on flow, heat and mass transfer, entropy and bejan numbers are investigated. Results demonstrate that the velocity diminishes with the expansion of Lorentz forces however increments with the increment of Reynolds number. The Bejan number decelerates with the expansion of the Brinkman number and the Brownian parameter.

KEYWORDS: MHD, Nanofluid, Entropy generation, Brownian motion, Thermophoresis, Joule heating, Bejan number

Introduction

As of late, nano science technology has been exhibited as another technique for the improvement of heat transport. Particles of nanofluid are made of oxides, metals, and carbides. Convective heat transfer liquids contain nanofluids that contain nanometer-sized particles. Tentatively, these nanofluids have an essentially more advanced thermal conductivity than the original fluids[1]. These liquids have different operations in microfluidics, micro-electronics, building, biomedical, strong state lighting, high-control X-beams, drug, and preparing of materials. What's more, the investigation into the heat and mass transfer of nanofluid stream between coaxial cylinders has gotten significant consideration because of its distinctive application in the plan of microelectronics and electron cooling gadgets hardware, sun-powered vitality accumulation, and so forth. Izadi et al[2] researched constrained nanofluid laminar convection comprising of Al_2O_3 and water. They found that the coefficient of convective heat transfer increments with the co nanoparticle volume fraction. Sheikhzadeh et al [3] Al_2O_3-water nanofluid has been numerically investigated through the interior coaxial rotating cylinder. Togun et al[4] inculcate a nitty-gritty investigation of the heat transfer of forced, mixed, natural and convective nanofluid course through an assortment of annular section designs. Distinctive researchers [5-12] explored the issues with nanofluid in various base fluids.

In perspective of its applications in geophysics, astronomy and a few engineering applications, the flow issue affected by the magnetic field was additionally an intriguing theme for some scientists. Mozayyeni and Rahimi[13] researched the Newtonian polarized flow through external cylinder rotation in the straight cylinder. Nagaraju and Ramana Murthy[14] talk about the radial magnetic field impact on the flow of the couple stress fluid caused by longitudinal and torsional motions and exposed to a consistent speed of suction on the outside of the cylinder. MHD impacts and Ferro hydrodynamics on convective warmth exchange and ferrofluid flow were dissected by Sheikholeslami and Ganji[15]. Zhang et al [16] numerically researched the thermal transport and MHD flow fluid investigation in a pit with Joule warming impact. Sheikholeslami et al [17] are inspected for the charged Al_2O_3-H_2O nanofluid warm exchange between two pipes.

At the point when the second thermodynamics law happens, the entropy diminishes, for example, Entropy generation obliterates the framework vitality. The framework execution would thus be able to be enhanced by decreasing the entropy generation. The enhancement of entropy generation was produced by Bejan[18, 19] and its applications in science and building were presented. Ratts and Raut[20] explored the augmentation of the entropy decrease exertion generation and demonstrated that it was the best Re for settled mass flow and heat transfer rate. The second law contemplates on thermodynamics and exergy in nanofluid flows started in 2010[21]. Shalchi and Seyf researched numerically the aftereffects of the utilization of Al_2O_3-water nanofluids with disparate molecule distances across and volume portions on produced warm exchange qualities, second law thermodynamics and hydrodynamic execution of a TMHS[22]. Omid et al [23] examined the noteworthiness of the thermal radiation effect on entropy analysis utilizing nanofluid between coaxial cylinders. Govindaraju et al[24] concentrated the magnetohydrodynamic flow of nanofluid from an entropy generation analysis. Kolsi et al [25] Three-dimensional entropy generation was considered in a pit where a precious stone molded body was introduced in the focal point of the depression because of normal convection. In various physical conditions, a couple of pros have theoretically considered entropy generation in heat and mass flow frameworks [26-29].

The essential investigation of this exploration ponder is the investigation of two-stage models for nanofluid warmth and mass exchange and entropy impacts in an annulus affected by connected magnetic field, viscous and Joule heating. The present work concerns the warm improvement of MHD vitality frameworks and magnetic blood streams. The outcomes can be useful in assessing the operational parameters to accomplish the minimum entropy generation extend.

Problem formulation mathematically

The fundamental equations displayed for the two-phase nanofluid flow in cylindrical coordinates and the related boundary conditions are given by

$$[\mu\left(\frac{d^2V}{dR^2}+\frac{1}{R}\frac{dV}{dR}-\frac{V}{R^2}\right)-\sigma V B_0^2=\rho_f V\frac{dV}{dR} \qquad (1)$$

$$\frac{K_T}{R}\frac{d}{dR}\left(R\frac{dT}{dR}\right)+\mu\left(\frac{dV}{dR}-\frac{V}{R}\right)^2+\left(\rho c_p\right)_p\left(D_B\frac{dT}{dR}\frac{dC}{dR}+\frac{D_T}{T_1}\left(\frac{dT}{dR}\right)^2\right)-\left(\rho c_p\right)_f\frac{dT}{dR}V=0 \qquad (2)$$

$$V\frac{dC}{dR}=\frac{D_B}{R}\frac{d}{dR}\left(R\frac{dC}{dR}\right)+\frac{D_T}{T_1}\frac{d}{dR}\left(R\frac{dT}{dR}\right) \qquad (3)$$

$$\begin{aligned}&(i)R=R_1: T=T_1, V=\Omega R_1, C=C_1\\ &(ii)R=R_2: T=T_2, V=0, C=C_2\end{aligned} \qquad (4)$$

The basic equations, Eq. (1) to (3), which currently, ends up in dimensional less form with the associated boundary conditions (4) are:

$$\frac{d^2v}{dr^2}-\left(Ha^2(1-\eta)^{-2}+r^{-2}\right)v-Re\,v\frac{dv}{dr}+\frac{1}{r}\frac{dv}{dr}=0 \qquad (5)$$

$$Br\left(\frac{dv}{dr}-\frac{v}{r}\right)^2+\frac{1}{r}\frac{d}{dr}\left(r\frac{d\theta}{dr}\right)-Pr\,Re\,v\frac{d\theta}{dr}+\left(\frac{d\theta}{dr}\right)^2Nt+Nb\frac{d\theta}{dr}\frac{d\phi}{dr}=0 \qquad (6)$$

$$\frac{Nt}{Nb}\left(\frac{d^2\theta}{dr^2}+\frac{1}{r}\frac{d\theta}{dr}\right)+\frac{1}{r}\frac{d}{dr}\left(r\frac{d\phi}{dr}\right)-Re\,Sc\,v\frac{d\phi}{dr}=0 \qquad (7)$$

$$\begin{aligned}&(i)\ r=1;\ \emptyset=0, \theta=0, v=0 \text{ and}\\ &(ii)r=\eta;\ \phi=1, \theta=1, v=1\end{aligned} \qquad (8)$$

where $v=\frac{V}{R_1\Omega}, r=\frac{R}{R_2}, \eta=\frac{R_1}{R_2}, \ \theta=\frac{T-T_2}{T_1-T_2}, \phi=\frac{C-C_2}{C_1-C_2}, Ha=B_0(\mathrm{R}_2-\mathrm{R}_1)\sqrt{\frac{\sigma}{\mu}}, Re=\frac{\rho_f\Omega \mathrm{R}_1\mathrm{R}_2}{\mu},$

$$\alpha=\frac{K_T}{\left(\rho c_p\right)_f},\ Pr=\frac{\mu}{\alpha\rho_f},\ Nb=\frac{\left(\rho c_p\right)_p D_B\Delta C}{K_T},\ Nt=\frac{\left(\rho c_p\right)_p D_T\Delta T}{K_T T_1},\ Sc=\frac{\mu}{D_B\rho_f},\ Br=\frac{\mu\Omega^2R_1^2}{K_T\Delta T}$$

The dimensionless Rate of heat and mass exchange are taken as

$$Nu=-\eta\frac{d\theta}{dr} \text{ and } Sh=-\eta\frac{d\phi}{dr} \quad \text{at } r=\eta \text{ and } r=1 \qquad (9)$$

Entropy Generation Analysis:

In presence of Joule Heating, the volumetric entropy generation number can be communicated as

$$S_G = \frac{K_T}{T_1^2}(\nabla T)^2 + \frac{\mu}{T_1}\Phi + \frac{R_d D_B}{C_1}(\nabla C)^2 + \frac{R_d D_B}{T_1}\Delta T \bullet \Delta C + \frac{J^2}{\sigma T_1} \qquad (10)$$

In Eq.(10), φ is the viscous heating, J is current density, ΔT is temperature difference, ΔC is Concentration difference, R_d is ideal gas constant.

$$S_G = \frac{K_T}{T_1^2}\left(\frac{\Delta T}{R_2}\right)^2\left(\frac{d\theta}{dr}\right)^2 + \frac{\mu}{T_1}\frac{\Omega^2 R_1^2}{R_2^2}\left(\frac{dv}{dr}-\frac{v}{r}\right)^2 + \frac{R_d D_B}{C_1}\left(\frac{\Delta C}{R_2}\right)^2\left(\frac{d\phi}{dr}\right)^2 + \frac{R_d D_B}{T_1}\frac{\Delta T\,\Delta C}{R_2^2}\frac{d\theta}{dr}\frac{d\phi}{dr} + \frac{\sigma\Omega^2 R_1^2 B_0^2}{T_1}v^2 \quad (11)$$

The non-dimensional scheme of Entropy generation Ns the equation (11) can be given as

$$Ns = \frac{R_2^2 T_1^2}{K_T(\Delta T)^2} S_G$$

$$Ns = \left(\frac{d\theta}{dr}\right)^2 + \frac{Br}{T_d}\left(\frac{dv}{dr}-\frac{v}{r}\right)^2 + \lambda\left(\frac{C_d}{T_d}\right)^2\left(\frac{d\phi}{dr}\right)^2 + \lambda\frac{C_d}{T_d}\frac{d\theta}{dr}\frac{d\phi}{dr} + Ha^2(1-\eta)^{-2}\frac{Br}{T_d}v^2$$

$$N_S = S_T + S_F + S_\emptyset + S_M \qquad (12)$$

Where $T_d = \frac{\Delta T}{T_1}$, $C_d = \frac{\Delta C}{C_1}$ and $\lambda = \frac{R_d D_B C_1}{K_T}$

Bejan Number:

The entropy generation fraction due to heat transport is defined as Bejan number.

$$Be = \frac{S_T}{S_T + S_F + S_\emptyset + S_M} = \frac{1}{1+\emptyset} \qquad (13)$$

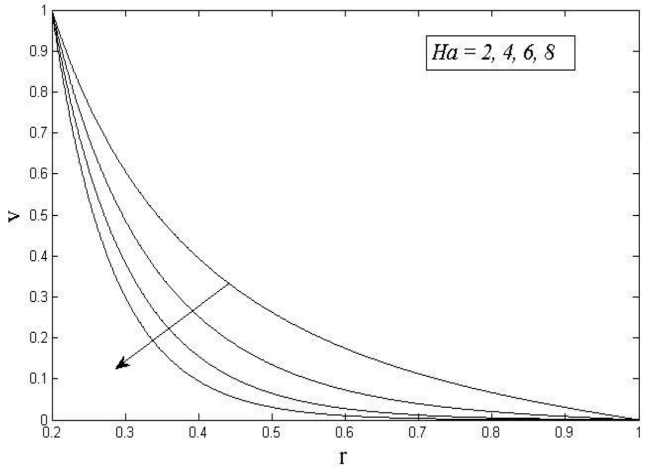
Results and Discussions:

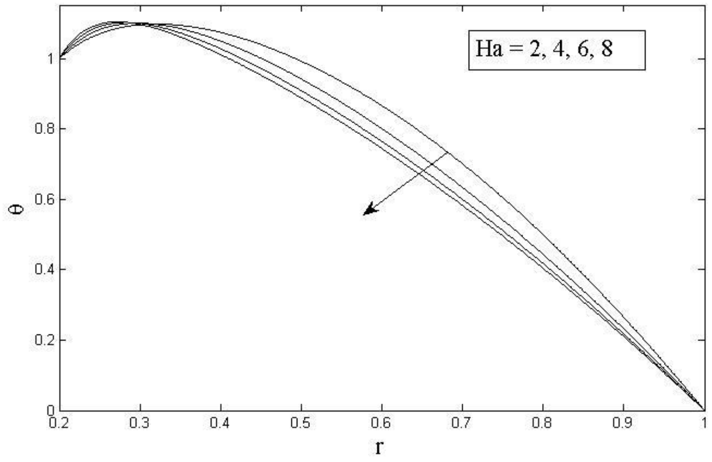
The thermodynamic analysis of the two-phase modeling of Al_2O_3-H_2O nanofluid between horizontal internal rotating annulus is numerically analyzed. The impacts of viscous heating, magnetic field, and joule heating are taken into consideration. Effective parameter influences are shown in graphs. These numeric outputs are checked with Sheikholeslami et al.[17]. Table1 demonstrates the accuracy of this method.

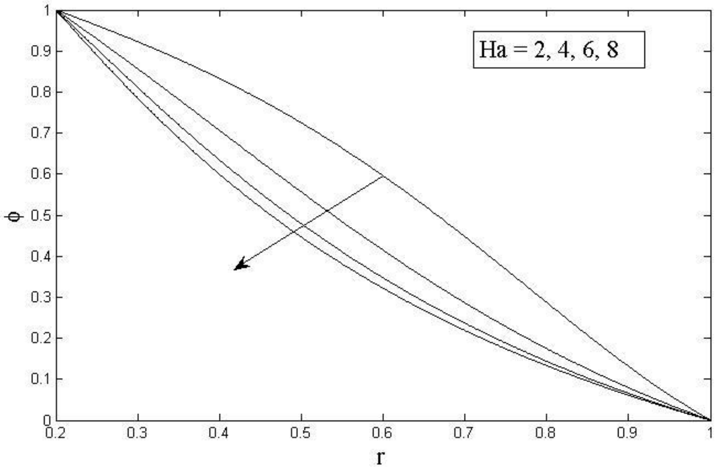
Figure 1 shows the Hartmann number(*Ha*) influence on velocity(v), temperature(θ), concentration(ϕ), Bejan number(*Be*) and entropy number(*Ns*) and As *Ha* increases, transverse velocity(v) decreases. Electromagnetic forces therefore prevail over viscous force. Subsequently, Lorentz forces diminish velocity and produce auxiliary flow; thusly, concentration and temperature decline with an expansion in the Hartmann parameter. As Ha increases, Ns close to the internal cylinder increments. The Bejan number(Be) reductions initially close to the internal cylinder to r= 0.3 and then increments with r. Figure 2 demonstrates Re's reaction to v, θ, ϕ, Ns and Be. As Re expands v, θ, ϕ upgrades yet Ns diminishes. Bejan number(Be) increments in the region of the inner cylinder, however, decelerates outwardly. Figure 3 speaks with the impact of the Brinkman number varieties. The outcome demonstrates an expansion inflow temperature and entropy rate. Be that as it may, in the region of the annulus, a turnaround pattern is watched, for example, ϕ and Be diminishes with an expansion in Brinkman numbers. Since the Brinkman number methods an expansion in temperature because of viscous heating in the flow field in connection to the forced distinction in temperature between the liquid and the pipe. Figures 4 demonstrate that as Nb rises, the temperature and nanoparticle volume fraction increments, however, the turn around the pattern in Ns and Be profiles are watched. As the Nt increases, the temperature increases while the concentration decreases, it can be seen from figure 5. The annulus thickness for concentration is less than the thermal limit layer thickness. While Ns and Be decelerate in the annular region and then rise on the cylinder surface. The impacts of Cd, λ and Td on Ns and Be are shown in figures 6–8. It is recognized that the expansion in Cd and λ raises the Ns close to the internal cylinder and the switching behavior is seen with the upgrading of parameter Td; the Bejan number reduction with expanding estimates of Cd and λ achieves a minimum incentive at r= 0.37 and is improved with Td increment estimates.

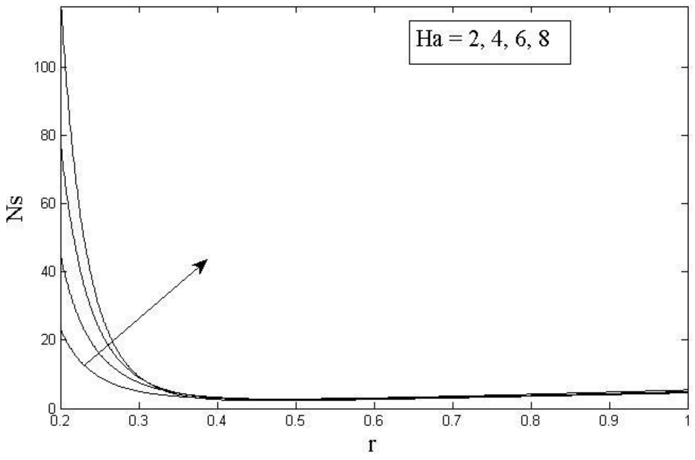
Table 1. Comparison of the current numerical impact of velocity and that of Sheikholeslami et al.[17]

r	Analytical Solution of Sheikholeslami et al.[17]	Present solution(RKSM)
0.2	1	1
0.3	0.8955	0.889254
0.4	0.7469	0.736467
0.5	0.6320	0.627318
0.6	0.5439	0.539237
0.7	0.4198	0.409895
0.8	0.2674	0.257221
0.9	0.1247	0.118242
1	0	0









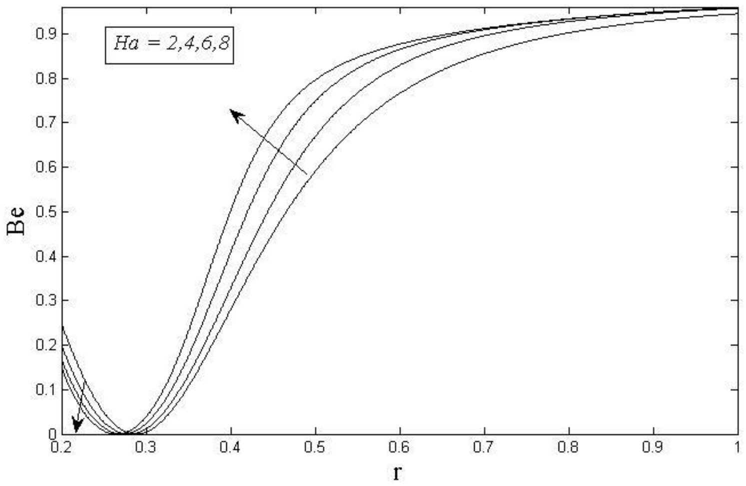
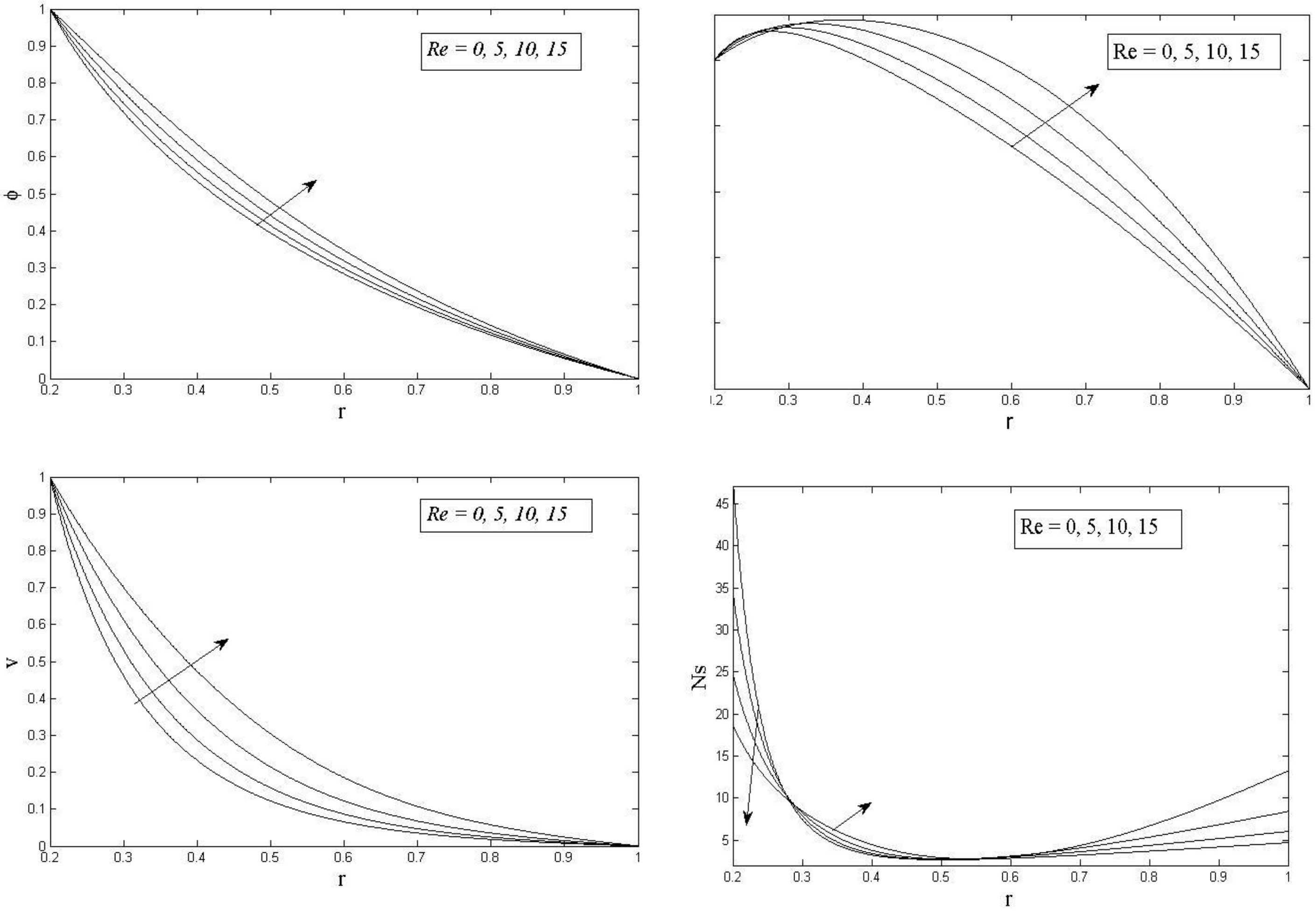


Figure 1: the response of *Ha* on (a) tangential velocity, (b) Temperature, (c) Concentration, (d) Entropy number and (e) Bejan number



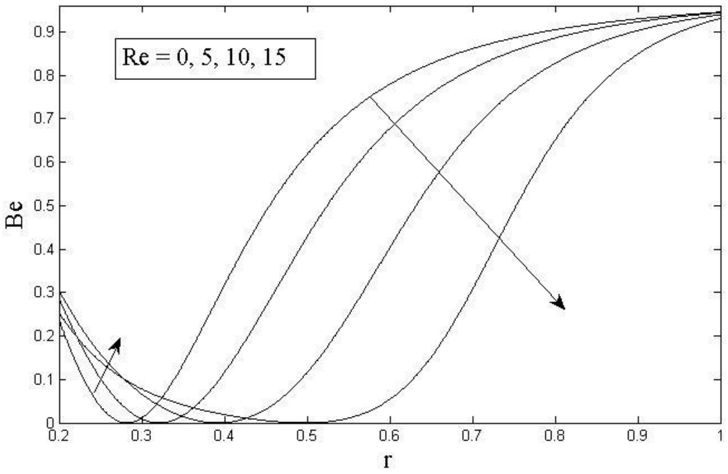


Figure 2: the response of *Re* on (a) Tangential velocity, (b) Temperature, (c) Concentration, (d)Entropy number and (e) Bejan number.

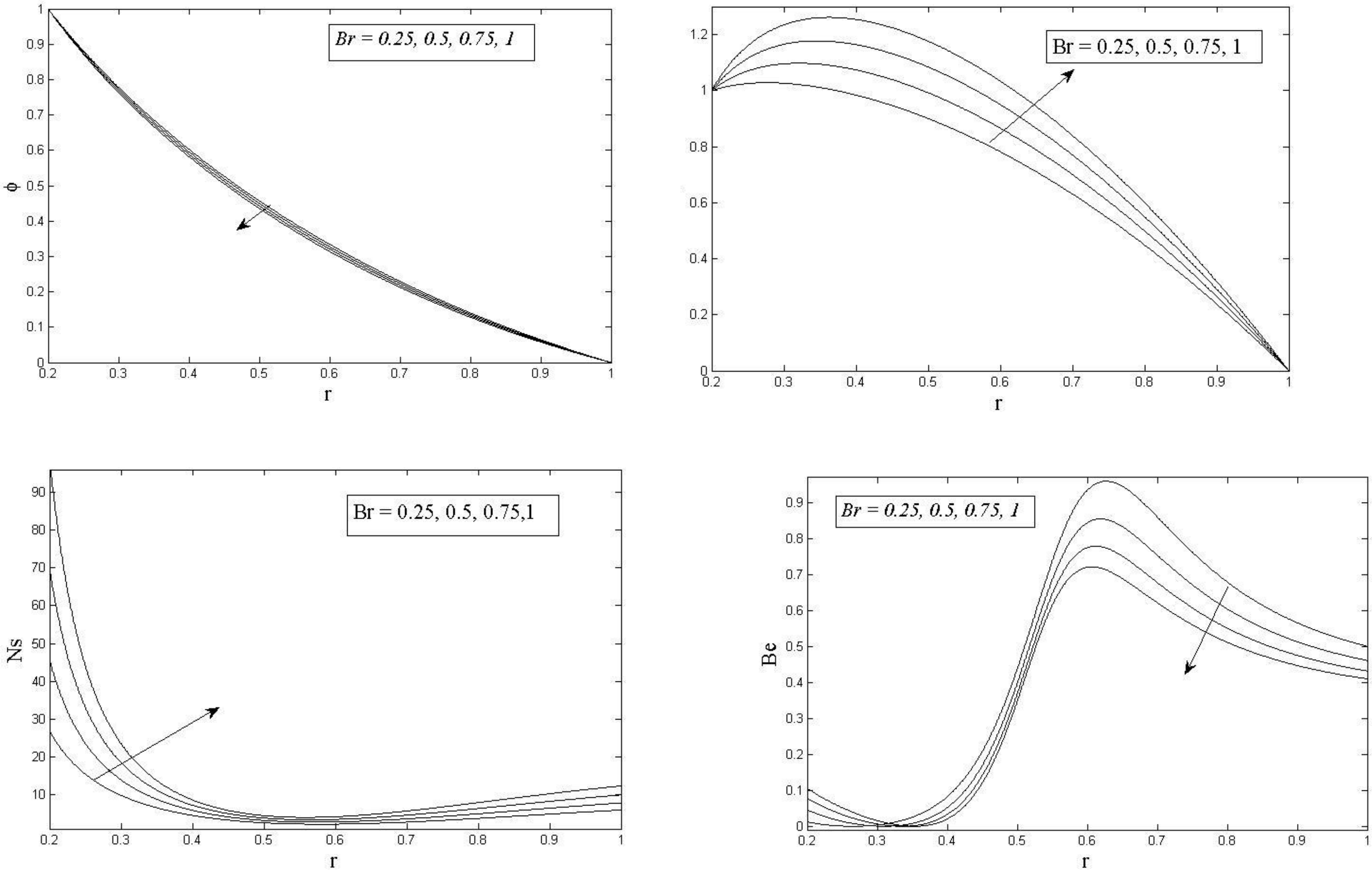


Figure 3: the response of Br on (a) Temperature, (b) Concentration, (c)Entropy number and (d) Bejan number.

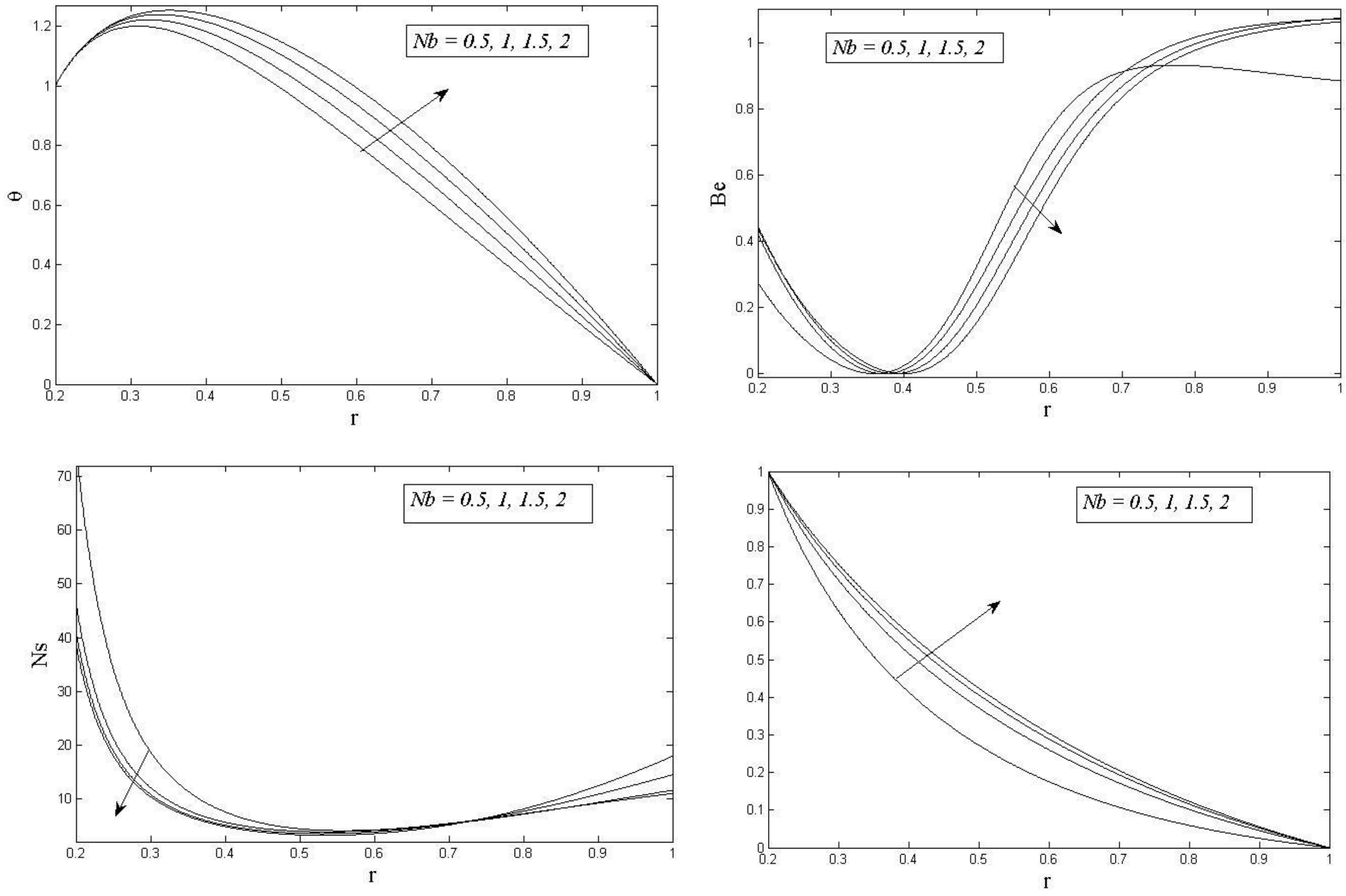
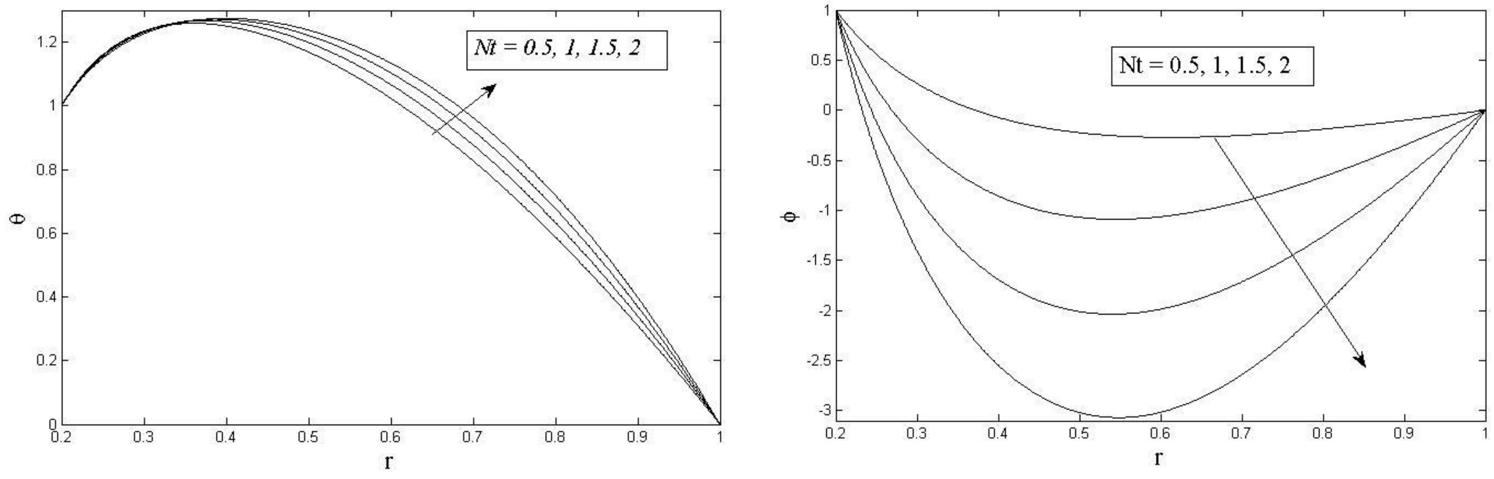


Figure 4: the response of *Nb* on (a) Temperature, (b) Concentration, (c) Entropy number and (d) Bejan number.



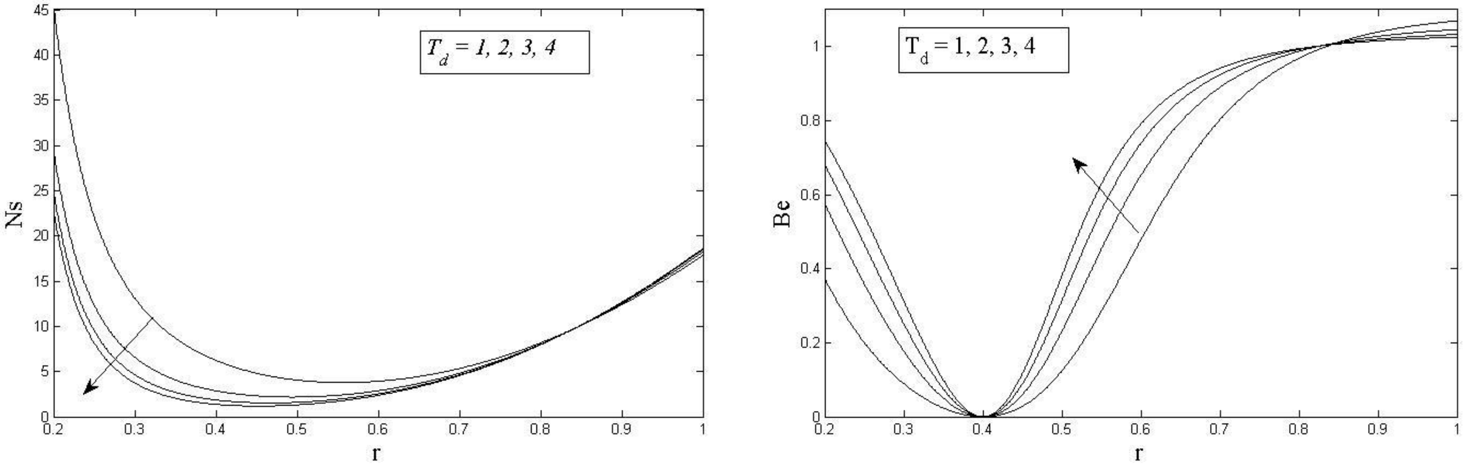


Figure 5: the response of *Nt* on (a) Temperature, (b) Concentration, (c) Entropy number and (d) Bejan number.

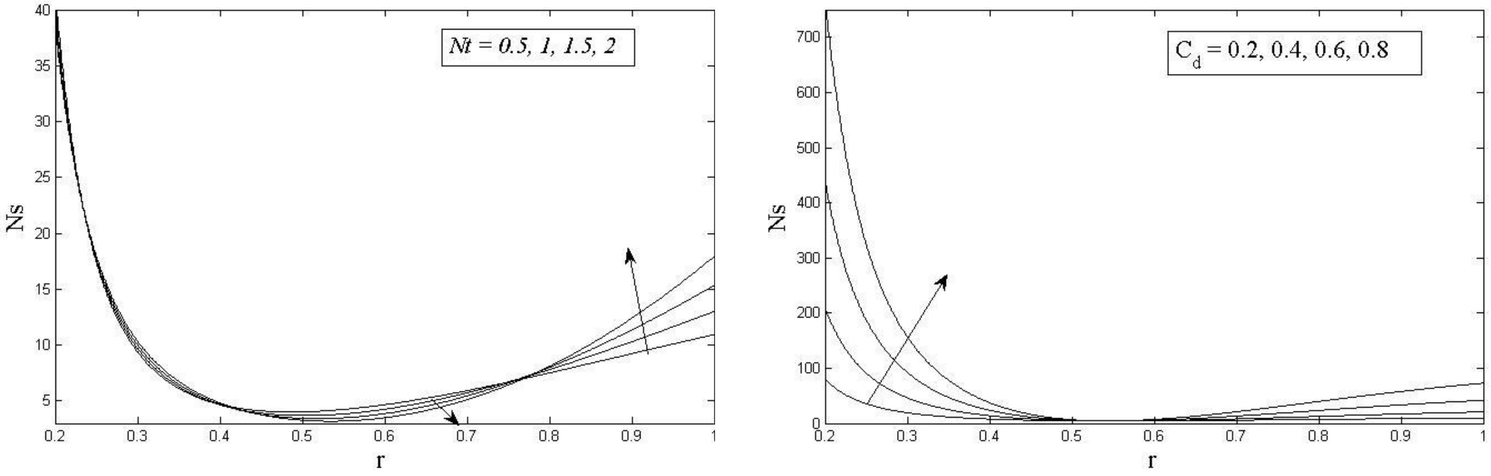


Figure 6, the response of T_d on (a) Entropy generation number and (b) Bejan number.

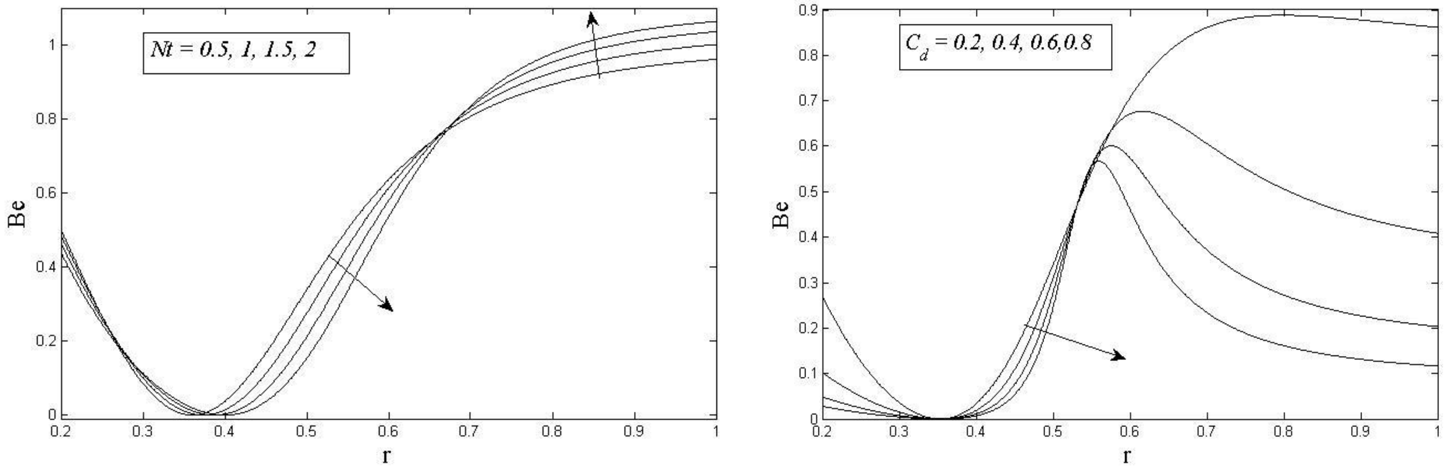


Figure 7: the response of Cd on (a) Entropy number and (b) Bejan number.

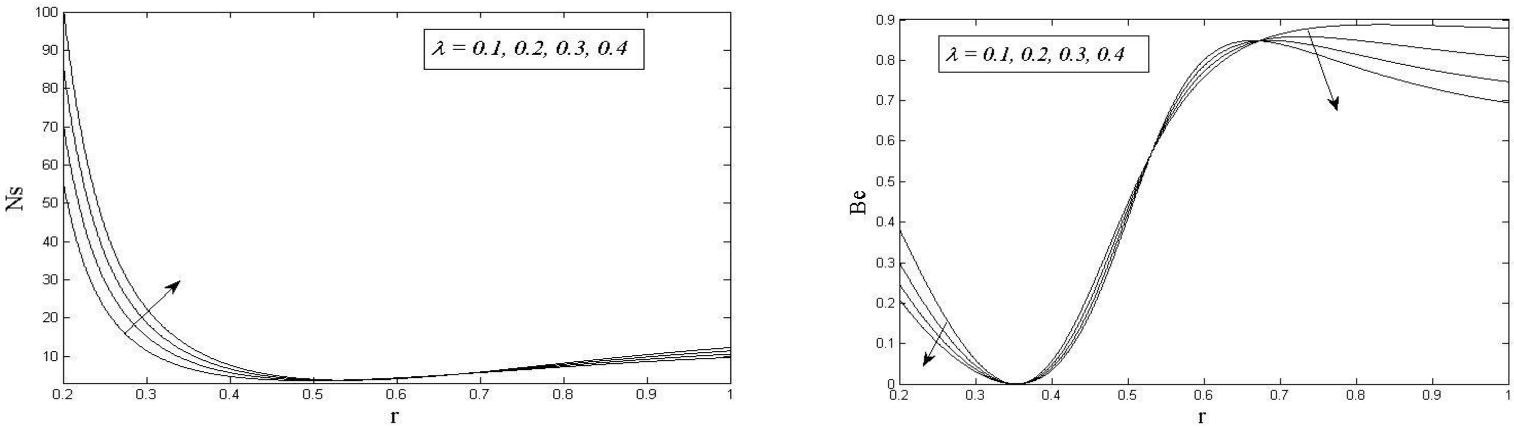


Figure 8: the response of λ on (a) Entropy number and (b) Bejan number

Conclusions

The thermodynamic analysis of magnetized nanofluid Al2O3-H2O between two channels is inspected. Administering equations are settled through RKSM. Roles of Reynold numbers, Hartmann numbers, Brinkman numbers, thermophoresis and Brown parameters, Schmidt numbers, and temperature and concentration difference parameters are shown as graphs. The outcomes demonstrated that the temperature increments with the expansion of the Brownian parameter, the Brinkman number and the Reynolds number, yet with the increment of the Hartmann number it diminishes. Fixation increments with the ascent of Nb, however with the ascent of Lorenz powers and thermophoresis forces, it diminishes. Entropy generation number(*Ns*) of ascents near an inner cylinder with additional estimates of the concentration difference parameter and the diffusive constant parameter, while decelerating with the rise of the temperature difference parameter. Bejan 's number decelerates and achieves a minimum incentive at r= 0.37 with an additional estimate of the concentration difference parameter, diffusive constant parameter; and with the temperature difference parameter increases.

Nomenclature

V,*v* – dimensional and non-dimensional Tangential velocity
D_B -Brownian coefficient
Br-Brinkmann number
c_p- specific heat capacity
D_T- Thermophoretic coefficient
Nb- thermophoresis parameter
Nt- Brownian parameter
Re- Reynolds number
R, *r*- dimensional and non-dimensional radius
σ- Electrical conductivity
μ-Viscosity of fluid
α-Thermal diffusivity
K_T-Thermal conductivity
ρ-Density
H*a*- Hartmann number
Be-Bejan number
B_0-Magnetic flux
Ns-Entropy generation number
S_G-Local volumetric entropy
Pr-Prandtl number
Sc- Schmidt number
S_T - Entropy generation, Heat transfer
S_F- Entropy generation, viscous heating
$S_\emptyset$- Entropy generation, Mean diffusion
S_M- Entropy generation, Magnetic field
λ-Diffusive constant parameter
T_d Temperature difference number.
C_d Concentration difference number.
Φ- Irreversibility ratio
Ƞ-aspect ratio
θ- dimensionless temperature
ϕ-nanoparticle volume fraction

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