International Journal of Engineering Science Invention (IJESI)
ISSN (Online): 2319 – 6734, ISSN (Print): 2319 – 6726
www.ijesi.org ||Volume 7 Issue 4 Ver. III || April 2018 || PP 88-92

Powell-Eyring Nanofluid Flow through a Permeable Stretching Surface with n^{th} Order Chemical Reaction

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Abstract: *Investigation Of non-Newtonian Nanofluid flow through a permeable stretching surface with nth order chemical reaction has been analyzed in this present article. Mathematical modeling has been formulated for continuity, momentum, energy and concentration equations. The governing partial differential equations are transformed into coupled nonlinear ordinary differential equations with the help of similarity transformation and then solved by using MATLAB's built in solver bvp4c. The non-dimensional parameters Prandtl number (pr), Lewis number (Le), Thermophoresis parameter (Nb), Brownian motion parameter (Nt), fluid parameters* $(\boldsymbol{\gamma}, \boldsymbol{\beta})$ *are studied with help of graphs.*

Keywords–*Powell Eyring Nanofluid, Stretching Surface, Chemical Reaction*

Date of Submission: 31-03-2018 Date of acceptance: 16-04-2018

I. INTRODUCTION

Non-Newtonian fluid flow over a stretching surface due to its industrial applicationshas received significant attention. Such interest is fueled by engineering applications in a number of fields as continuous casting of metal, filaments, crystal growing, and extrusion of polymers, glass fiber production, paper production, and process of condensation of metallic plates. Entropy production determines the performance of thermal machines such as heat pumps, and air conditioners, power plants, heat engines, refrigerators,. It also plays a key role in the thermodynamics of irreversible processes. During the recent years of nanotechnology brought out a multidimensional change to its useful applications in industry and engineering process. A nanofluid is a base fluid with a nanometer sized particles. Abolbashari et al. [1] and they investigated entropy analysis of MHD unsteady in nano-fluid flow past a stretching permeable surface. Abbas et al. [2] have described by an entropy generation on nanofluid flow through a horizontal plate. Bhatti et al.[3-9] have purposed a new numerical simulation of MHD stagnation-point flow over a permeable stretching/shrinking sheet in porous media with heat transfer and the various studies to visualized to analyze numerical simulation of entropy generation on MHD towards a effects of thermo-diffusion and thermal radiation on Williamson nanofluid over an boundary layer flow over a permeable shrinking/ stretching sheet and also discussed by Numerical simulation of entropy generation with thermal radiation on MHD Carreau nanofluid on MHD Eyring–Powell nanofluid through a permeable stretching surface. Mohammad et al. [10] examined that the entropy generation of nanofluid due to Peristaltic MHD blood flow as a practical tool of optimization for non-Newtonian flow through a permeable stretching surface using SLM. Munnawaar et al. [11] have investigated the analysis of entropy generation in the flow of peristaltic nanofluids in channels with compliant walls. Muhammad et al [12] studied Entropy generation as a practical tool of optimization for non-Newtonian nanofluid flow through a permeable stretching surface using SLM. Qing et al. [13] have derived an entropy generation on MHD Casson nanofluid flow over a porous stretching/ shrinking surface. Rashidi et al. [14-15] have studied entropy generation in steady MHD flow due to a rotating porous disk in a nanofluid. And also Investigation of entropy generation in MHD and slip flow over a rotating porous disk with variable properties. Sheikholeslami et al. [16] have been discussedMHD free convection of Al2O3– water nanofluid considering thermal radiation. Muhammed MubashirbBhatti et al.[17] studied entropy generation on non-Newtonian nanofluid flow through a permeable stretching surface. This paper is extension of Muhammed MubashirbBhatti et al.[17] for non-Newtonian Eyring-Powel nanofluid through a permeable stretching sheet with nth order chemical reaction. Mathematical modeling has been formulated for continuity, momentum, energy and concentration equations. The governing partial differential equations are transformed into coupled nonlinear ordinary differential equations with the help of similarity transformation and then solved by MATLAB's built in solver bvp4c.

II.MATHEMATICAL FORMULATION

We considered a Mathematical model by Muhammed MubashirbBhatti et al.[17] in which Eyring –Powell nanofluid of boundary layer flow past a permeable stretching surface . This paper investigated nth order chemical reaction for Eyring –Powell nanofluid of boundary layer flow over a stretching surface.In this study also, Cartesian coordinate has been considered as x-axis along the direction of the sheet and y-axis along normal to it and near a stagnation point at y = 0. $\tilde{T}_w$ and $\tilde{C}_w$ are wall temperature and concentration respectively. Ambient temperature and concentration are $\tilde{T}_\infty$ and $\tilde{C}_\infty$ respectively. Assume velocity of the sheet along x-direction as $\tilde{u}_w = ax$.

The governing partial differential equations of Eyring –Powell nanofluid model are as follows:

$$\frac{\partial \tilde{u}}{\partial x} + \frac{\partial \tilde{v}}{\partial y} = 0 \quad (1)$$

$$\tilde{u}\frac{\partial \tilde{u}}{\partial x} + \tilde{v}\frac{\partial \tilde{u}}{\partial y} = \left(\nu + \frac{1}{\rho BC}\right)\frac{\partial^2 \tilde{u}}{\partial y^2} - \frac{1}{2\rho BC^3}\left(\frac{\partial \tilde{u}}{\partial y}\right)^2 \frac{\partial^2 \tilde{u}}{\partial y^2} + \tilde{u}_e \frac{d\tilde{u}_e}{dx} \quad (2)$$

$$\tilde{u}\frac{\partial \tilde{T}}{\partial x} + \tilde{v}\left(\frac{\partial \tilde{T}}{\partial y}\right) = \bar{\alpha}\frac{\partial^2 \tilde{T}}{\partial y^2} + \tau\left(D_B \frac{\partial \tilde{C}}{\partial y}\frac{\partial \tilde{T}}{\partial y} + \frac{D_T}{T_\infty}\left(\frac{\partial \tilde{T}}{\partial y}\right)^2\right) - \frac{\partial q_r}{\partial y}\frac{1}{\rho c_p} + \frac{Q_0}{\rho c_p}(\tilde{T} - \tilde{T}_\infty) \quad (3)$$

$$\tilde{u}\frac{\partial \tilde{C}}{\partial x} + \tilde{v}\frac{\partial \tilde{C}}{\partial y} = D_B \frac{\partial^2 \tilde{C}}{\partial y^2} + \frac{D_T}{T_\infty}\frac{\partial^2 \tilde{T}}{\partial y^2} - Kr(\tilde{C} - \tilde{C}_\infty)^n \quad (4)$$

The corresponding boundary conditions are defined as

$$\tilde{u} = \tilde{u}_w, \tilde{v} = \tilde{v}_w, \tilde{T} = \tilde{T}_w, \tilde{C} = \tilde{C}_w \text{ at } y = 0 \quad (5)$$

$$\tilde{u} = \tilde{u}_e, \tilde{v} = 0, \tilde{T} \to \tilde{T}_\infty, \tilde{C} \to \tilde{C}_\infty \text{ as } y \to \infty \quad (6)$$

Using the similarity transformation variables

$$\zeta = \sqrt{\frac{\tilde{u}_w}{\nu x}}\, y, \tilde{u} = \tilde{u}_w f'(\zeta), \tilde{v} = -\sqrt{\frac{\nu \tilde{u}_w}{x}}\, f(\zeta), \theta = \frac{\tilde{T} - \tilde{T}_\infty}{\tilde{T}_w - \tilde{T}_\infty}, \phi = \frac{\tilde{C} - \tilde{C}_\infty}{\tilde{C}_w - \tilde{C}_\infty}, \quad (7)$$

The radiative flux is defined as

$$q_r = \frac{-4\sigma_1}{3k^*}\left(\frac{\partial T^4}{\partial y}\right) \quad (8)$$

Where σ_1 is the Stefan Boltzmann constant and k^* is Rosseland mean absorption coefficient.

We assume that the temperature differences within the flow are sufficiently small such that T^4 may be expressed as a linear combination of temperature. Expanding T^4 about T_∞ in Taylor's series and neglecting higher order terms yields:

$$T^4 \cong 4T_\infty^3 T - 3T_\infty^4 \quad (9)$$

$$\frac{\partial q_r}{\partial y} = -\frac{16\sigma^* T_\infty^3}{3k_0}\frac{\partial^2 T}{\partial y^2} \quad (10)$$

Using the above, Equations (2) to (6) becomes

$$\left(1+\gamma\right) f''' + 1 - \gamma\beta f''^2 f''' - f'^2 + ff'' = 0 \quad (11)$$

$$\frac{1}{\Pr_{eff}}\theta'' + f\theta' + N_b \theta'\phi' + N_t(\theta')^2 + Q\theta = 0 \quad (12)$$

$$\phi'' + Lef\phi' + \frac{N_t}{N_b}\theta'' - K\phi^n = 0 \quad (13)$$

Their corresponding boundary conditions are

$$f(0)=S,\ f^{'}(0)=\alpha,\ f^{'}(\infty)=1, \tag{14}$$

$$\theta(0)=1, \theta(\infty)=0, \tag{15}$$

$$\phi(0)=1, \phi(\infty)=0, \tag{16}$$

Where the non-dimensional parameters are

$$\Pr_{eff}=\frac{\Pr}{\left(1+\frac{16R}{3}\right)}, Le=\frac{\nu}{D_B}, N_b=\frac{\tau D_B(\tilde{C}_w-\tilde{C}_\infty)}{\nu}, N_t=\frac{\tau D_T(\tilde{T}_w-\tilde{T}_\infty)}{\tilde{T}_\infty \nu}, \gamma=\frac{1}{\rho BC}, \beta=\frac{(ax)^3}{2x\nu C^2} \tag{17}$$

III. RESULTS AND DISCUSSION

Mathematical modeling has been formulated for continuity, momentum, energy and concentration equations. The governing partial differential equations are transformed into coupled nonlinear ordinary differential equations with the help of similarity transformation and then solved by using MATLAB's built in solver bvp4c. The physical parameters involved in the governing flow problem have explained with help of graphs. Figures 1-2 depict velocity profile for various values of fluid parameters γ, β. It is observed that increasing values of γ decreases the velocity profile while the result is reverse with variation of fluid parameter β. It is evident from the figures 3 and 4 that increasing values of thermophoresis parameter Nt increase both temperature and concentration profiles.Thermophoresis parameter Nt enhances thickness of the boundary layer. Figures 5 and 6 shows the variation of Brownian parameter Nb with temperature and concentration profiles. Increment in Brownian parameter Nb enhances temperature profile and reduces the concentration profile. Figures 7, 8 and 9 illustrate velocity, temperature and concentration profiles against various values of Lewis number and nth order chemical reaction parameter. Increasing Lewis number diminish the temperature and concentration profiles. The order of chemical reaction enhances the separation process of species of rarer and lighter particles.

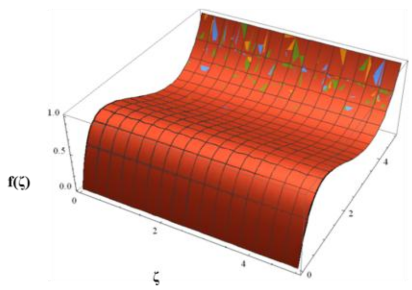

Fig 1 velocity profiles f(ζ) for various values of β =0.2,0.3,0.4,0.5 ; Pr= 10, S=0.3, Nt= Nb=0.5, Le=2, γ=0.5

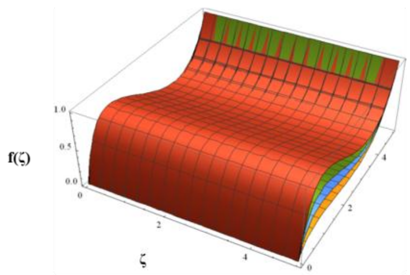

Fig.2 Velocity profiles f(ζ) for various values of γ=0,0.5,1,1.5; Pr= 10, S=0.3, Nt= Nb=0.5, Le=2 β =0.5

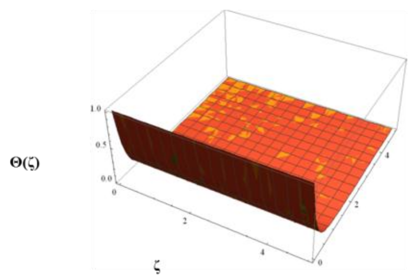

Fig.3 Temperature profiles Θ(ζ) for various values of Nt=0.1,0.15,0.2,0.25, Pr= 10, S=0.3, Nb=0.5, Le=2, γ=0.5 , β=0.5

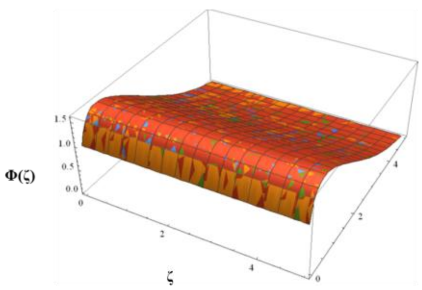

Fig.4 Concentration profiles Φ(ζ) for various values of Nt=0.1,0.15,0.2,0.25, Pr= 10, S=0.3, Nb=0.5, Le=2, γ=0.5 , β=0.5

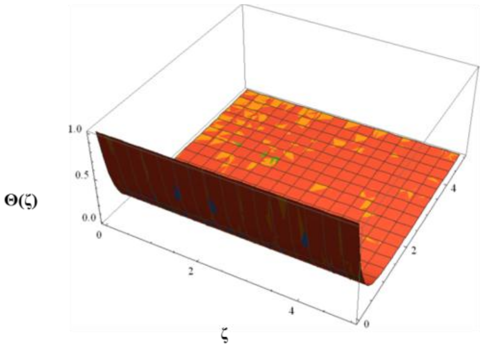

Fig.5 Temperature profiles Θ(ζ) for various Values of Nb=0.1,0.15,0.2,0.25, Pr= 10, S=0.3, Nt=0.5, Le=2, γ=0.5 , β=0.5

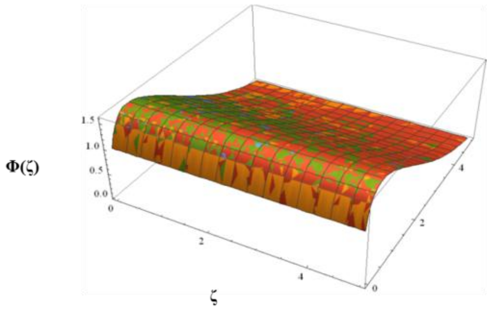

Fig.6 Concentration profiles Φ(ζ) for various values of Nb=0.1,0.15,0.2,0.25, Pr= 10, S=0.3, Nt=0.5, Le=2, γ=0.5 , β=0.5

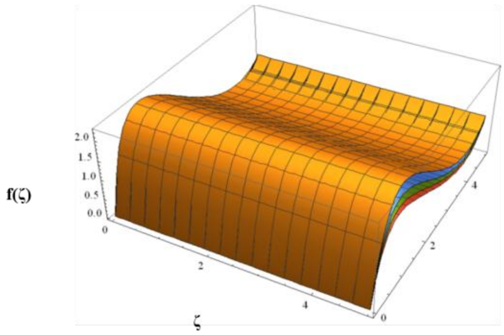

Fig.7 Velocity profiles f(ζ) for Various values of Le =1,2,3,4, Nb=0.5, Pr= 10, S=0.3, Nt=0.5, Le=2, γ=0.5 , β=0.5

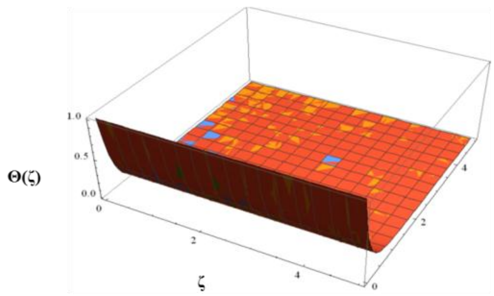

Fig.8 Temperature profiles Θ(ζ) For various values of Le =1,2,3,4, Nb=0.5, Pr= 10, S=0.3, Nt=0.5, Le=2, γ=0.5 , β=0.5

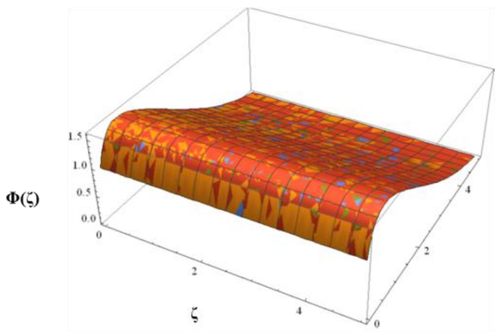

Fig.9 Concentration profiles Φ(ζ) for various values of Le =1,2,3,4, Nb=0.5, Pr= 10, S=0.3, Nt=0.5, Le=2, γ=0.5 , β=0.5

IV. CONCLUSIONS

The nonlinear governing equations are continuity, momentum, energy and concentration which are solved with the help of similarity transformation. The expressions of the emerging parameters analyzed numerically and graphically. It can be concluded as follows:

- Increasing values of γ decreases the velocity profile while the result is reverse with variation of fluid parameter β.
- Increasing values of thermophoresis parameter Nt increase both temperature and concentration profiles.
- Increment in Brownian parameter Nb enhances temperature profile and reduces the concentration profile.
- Increasing Lewis number diminish the temperature and concentration profiles.
- The order of chemical reaction enhances the separation process of species of rarer and lighter particles.

REFERENCES

[1] Abolbashari MH, Freidoonimehr N, Nazari F, Rashidi MM., "*Entropy analysis for an unsteady MHD flow past a stretching permeable surface in nano-fluid",* Powder Technol. (2014); 267:256–67.
[2] Abbas T, Ayub M, Bhatti MM, Rashidi MM, AliMES., "*Entropy generation on nanofluid flow through a horizontal rigaplate",* Entropy (2016); 18(6)223.
[3] Bhatti MM, Abbas T, Rashidi MM., "*A new numerical simulation of MHD stagnation-point flow over a permeable stretching/shrinking sheet in porous media with heat transfer",* Iran. J.Sci. Technol, Trans. A: Sci. (2016); 1–7.
[4] Bhatti MM, Rashidi MM., "*Numerical simulation of entropy generation on MHD nanofluid towards a stagnation point flow over a stretchingsurface",*Int.J.Appl.Comput.Math. (2016); 1–15.
[5] Bhatti MM, Rashidi MM., "*Effects of thermo diffusion and thermal radiation on Williams on nanofluid over a porous shrinking/stretching sheet",* J. Mol.Liq. (2016); 221:567–73.
[6] Bhatti MM, Rashidi MM., "*Entropy generation with nonlinear thermal radiation in MHD boundary layer flow over a permeable shrinking/ stretching sheet: numerical solution",* J. Nanofluids (2016); 5(4)543–8.
[7] Bhatti MM, Abbas T, Rashidi MM, AliMES., "*Numerical simulation of entropy generation with thermal radiation on MHD Carreau nanofluid towards a shrinking sheet",* Entropy (2016);18(6)200.
[8] Bhatti MM, Abbas T, Rashidi MM, AliMES, Yang Z., "*Entropy generation on MHD Eyring–Powell nanofluid through a permeable stretching surface",*Entropy (2016);18(6) 224.
[9] Mohammad Mehdi rashidi, Muhammad Mubashir Bhatti, Munawwar aliabbas, Mohammed el-sayedali., "*Entropy generation on MHD nanofluid blood flow due to peristaltic waves",* Entropy (2016); 18,117; doi:10.3390/e18040117.
[10] Munawwaraliabbas, Yanqinbai, Mohammad Mehdi rashidi, Muhammad MubashirBhatti., "*Analysis of entropy generation in the flow of peristaltic nanofluids in channels with compliant walls",* Entropy (2016); 18, 90;doi:10.3390/e18030090.
[11] Muhammad MubashirBhatti, Tehseen Abbas, Mohammad Mehdi Rashidi., "*Entropy generation as a practical tool of optimisation for non-Newtonian nanofluid flow through a permeable stretching surface using SLM",* Journal of Computational Design and Engineering 4 (2017); 21–28
[12] Qing J, Bhatti MM, Abbas MA, Rashidi MM, AliMES., "*Entropy generation on MHD Casson nanofluid flow over a porous stretching/ shrinking surface",* Entropy (2016); 18(4)123.
[13] Rashidi MM, Abelman S, Freidoonimehr N., "*Entropy generation due to MHD flow insteady rotating porous disk in a nanofluid",* International journal of heat and mass transfer 62(2013) 515-525.
[14] Rashidi MM, Nasser Kaviani, Abelman S., "*Investigation of entropy generation in MHD and slip flow over a rotating porous disk with variable properties*", Int. J.Heat Mass Transf. (2014); 70: 892–917.
[15] Sheikholeslami M, Gorji-bandpy, GanjiDD, Rana P, Soheilsoleimani., "*Entropy generation of nanofluid in presence of magnetic field using Lattice Boltzmann Method",* Physica A: Stat.Mech.Appl. (2015); 417:273–86.

S.Anuradha"Powell-Eyring Nanofluid Flow through A Permeable Stretching Surface with Nth Order Chemical Reaction"International Journal of Engineering Science Invention (IJESI), vol. 07, no. 04, 2018, pp 88-92