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MHD Tangent Hyperbolic Nano-fluid Flow in a Porous Medium with Melting Heat Transfer Near the Stagnation Point

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Abstract

The present work deals with the study of MHD stagnation point of a tangent hyperbolic nano-fluid through a non-Darcy porous medium with melting heat transfer. The basic leading energy, concentration and momentum PDEs are condensed into non- linear ODEs by consuming suitable likeness methodology. Numerical procedure Bvp4c in MATLAB is utilized to resolve ensuing system of ODEs. The measureable effects of non-dimensional physical parameters specifically wall thickness, stretching sheet parameter, Hartmann number, shape parameter, Prandtl number, inverse Darcy parameter, local inertia coefficient and melting parameter on the velocity, temperature and concentration profiles are studied and displayed graphically. Skin friction, Nusselt number and Sherwood number are consequential, considered numerically for discrete guesstimates of physical parameters through graphs. The main findings of tangent hyperbolic fluid are that on increasing the values of local inertia coefficient and Weissenberg number , the velocity profile decreases. Similarly, temperature profile increases with respect to stretching sheet parameter and thermophoresis number . When Prandtl number increases, Nusselt number also increases and skin friction coefficient decreases by increasing shape parameter .

***Keywords**: Hyperbolic Tangent nano-fluid, flow of MHD, Non-Darcy porous medium, Melting heat transfer, Stagnation point, Stretching sheet, BVP4C.*

2. Introduction:

In fluid mechanics, steady flow on a spreading sheet along with heat transfer is a conventional risky. In prior of few years, the boundary layer flow over a broadening sheet turn out to be a greater amount of notoriety since it occurs in diverse fields of engineering and mechanical developments, chemical and metallurgical infrastructures etc. Through the process of polymer sheets in organizations, an unremitting inflammation of polymer separated from mechanical roller succumbs, at that point harsh polymeric sheets are planned by relentless extending of certain polymer that solidified by continuing or cooling by close cooperation with an intrusive fluid.

Non-Newtonian fluid have capacious applications in contrasting search areas such as conveyor belt, aeronautical, aerodynamics, illustration of plastic films, metal spinning processes, insulting materials, agricultural and natural production etc. In current discussion, physical structure of non-Newtonian fluid is an interesting area in investigation and enticement numerous engineers, experts and mathematicians. Tangent Hyperbolic fluid model is one of those models which have an extra ordinary significance in chemical engineering procedures. Malik et al. [1] engraved a framework on hydro magnetic tangent hyperbolic flow around

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moveable cylinder. Kumar et al. [2] scrutinizes on transitory squeezed flow and tangent hyperbolic liquid flows flowing to sensor boundary through inconstant thermal conductivity. Gaffar et al. [3] discovered consequences on boundary layer steady flow of Tangent Hyperbolic fluid with effect of heat transfer using Biot number. They found that by uplifting Weissenberg number causes decline in velocity, Nusselt number and skin friction, while it magnifies the temperature profile. Salahuddin et al. [4] explored the influence of variable conductivity of Hyperbolic Tangent fluid employing transverse magnetic field and viscous dissipation along exponentially varying viscosity. Numerical results of 2-D magneto hydro dynamic boundary layer stream of a Hyperbolic Tangent fluid above a widening surface is investigated by Akbal et al. [5]. Abbas et al. [6] inspected boundary layer peristaltic stream of Tangent Hyperbolic liquid in non-uniform canal with elastic walls. Naseer et al. [7] particularized the boundary layer flow of heat transfer rate past a vertically stretching cylinder. Some studies related to above work is given in [8-10].

The scrutiny of diminuendos of ionized particles and interface with hypnotic and contiguous fields is known as magneto hydro dynamics. It is major significance in cosmological plasmas. In addition, magneto hydro dynamics meters, magneto hydro dynamics pumps, and demeanors are few examples in practical form. In addition, MHD is detected to be very affecting in infection analytical methods; consequently, it has solicitations in bio engineering. Hence, due to broad usage of magneto hydro dynamics investigators scrutinized its stimulus on Newtonian and non-Newtonian fluids. Alfwen [11] naked electromagnetichydro dynamic surfs in their investigate. Perasad et al. [12] deliberated outcomes of changing fluid physiognomies on hydro magnetic stream and heat transfer through nonlinear extending sheet and explained difficult mathematically. Ashorenijad et al. [13] conferred hydro magnetic flow through extending cylinder with unvarying oblique magnetic field and elucidated causing structure numerically RK-4 integration system emphasizing a shooting technique in the presence MAPLE technique. Mukhopadhyay [14] deliberated the significances of the boundary layer flow of viscid fluid with extending cylinder occurrence in the presence of magnetic field. Dassei and Kishan [15] debated magneto hydro dynamics results over Newtonian fluid stream through an extending sheet inserted in permeable medium along varying viscosity and heat sink/source. They precisely utilized technique of Lie group to resolve calculations consuming non-linear expressions. Malik et al. [16] scrutinized results of Hyperbolic Tangent fluid with realistic magnetic pitch through stretchable cylinder and calculated resolution via RK-5 integration structure. Khan et al. [17] premeditated peristaltic crusade of magneto hydrodynamics pseudo plastic fluid flow concluded irregular channel. Ellahi et al. [18] discoursed algebraic explanation of universal Couette flow of magneto hydrodynamics Eyring-Powell liquid along an omission ailment. Bhatti et al. [19] particularized impression of realistic magnetic pitch over peristaltic stream of Jaffrey fluid over a quadrangular tube. Bhatti et al. [20] described thermal contamination demeanor on dense magnetic elements in grimy fluid. Bhatti et al. [21] deliberated agitation explanation of delinquent lecturing peristaltic measure of Sisko nano-fluid over an endoscope. Shekholislemi et al. [22] surveyed impacts of persuaded magnetic field arrange the viscid nano-fluid stream by calculating Kou-Kleenstriuer (KKL) relationship. Khan et al. [23] designated special results of useful magnetic pitch and omission ailment over a peristaltic stream of Walter's B liquefied. Zeishan et al. [24] reviewed boundary layer stream of ferro-magnetic liquid over an extending apparent under outcomes of thermal energy. Majeed et al. [25] discovered demeanor of unsteady ferro-magnetic fluid stream through extending sheet along contributed heat flux. Maqbool et al. [26] analyzed impressions of Hall present on magneto hydrodynamics FENE-P liquid through a strained surface. Hussain et al. [27] and Awais et al. [28] evaluated influence of typically interrupting magnetic pitch on Sisko fluid stream over extending cylinder with various circumstances. Belal et al. [29] deliberated mathematical explanation of three-dimensional flow with magneto hydrodynamics Williamson fluid along with two directional extending surface. Bilal et al. [30] conferred magneto hydrodynamics nano-fluid stream over an extending sheet and investigated the numerical explanation utilizing shooting system. Hayyat et al. [31] scrutinized stressed stream of non-Newtonian Powell-Eyring liquefied through non-linear extending apparent under outcomes of customarily pragmatic magnetic pitch. Lately, magneto hydrodynamics fluid streams are deliberated in innumerable circumstances see Refs. [32-38].

In the look at previously mentioned writing review, it is examined that no endeavor has been done to investigate upgrade of flexible warm conductivity and attractive pitch for stream of hyperbolic digression non Newtonian liquid. Consequently, current undertaking is amassed in this introduction. The natural expectation of this work is to investigate the impact of magneto hydro dynamic and flexible warm conductivity of hyperbolic digression liquid near an extending sheet. The setup of current paper is advanced so that partial differential equations can be remodeled into ordinary differential equations and afterward illuminated by Bvp4c mathematically. The conduct of administering different parameters having no dimensions alike Weissenberg number, Power law index, Hartman number, changeable thickness and Prandtl number have been analyzed for Speed and Temperature fields.

2. Nomenclature:

B_0	Magnetic field		Similarity independent variable
	Viscosity	v	Kinematics viscosity
U_w	Velocity of the stretching sheet	U	Free-stream velocity
Ha	Hartman number	n	Power law index
	Wall thickness parameter	C_f	Skin friction coefficient
C_s	Surface heat capacity		Electrical conductivity
x,y	Cartesian coordinates	Pr	Prandtl number
	Density	T	Temperature
$u,$	Velocity Components	T_m	Melting heat transfer
$_w$	Wall shear stress	T	Temperature at infinity
	Dimensionless temperature	qw	Surface heat flux
Re	Reynolds number	Nu_x	Nusselt number
Da	Inverse Darcy parameter		Latent Heat
	Heat generation parameter	a,b,d	Constants
We	Weissenberg number		Nano-particle concentration
D_B	Brownian motion coefficient	D_T	Thermophoresis coefficient
w	Surface Concentration		Ambient concentration

2.1 Subscripts:

Ambient condition

w Condition at the wall

3. Mathematical Model:

The fluid is thought to be an in-compressible steady two-dimensional magneto hydro dynamic Tangent Hyperbolic fluid with stagnation point in non-Darcy permeable medium. The stream is on the way to an extendable sheet at $y = (x+b)^{\frac{1-n}{2}}$ along x- axis with speed $uw = a(x+b)^n$. However, the speed of outside stream is $ue = d(x+b)^n$. Where a, b and d represents to the dimensionless constants. Assume $y = (x+b)^{\frac{1-n}{2}}$ be wideness of sheet and the quality of magnetic field B_0 connected ordinary to sheet. The non Newtonian stress tensor of Hyperbolic Tangent fluid is characterized as,

$$\bar{\tau} = [\mu_\infty + (\mu_0 + \mu_\infty)\tanh(\Gamma\bar{\gamma})^n]A_1 \quad (1)$$

Here demonstrates shear endless viscosity rate, epitomize index of power law, indicates shear zero thickness, is constant of substantial that rely upon time and is specified by

$$\bar{\gamma} = \sqrt{\frac{1}{2}\sum_i\sum_j\bar{\gamma}_{ij}\bar{\gamma}_{ji}} = \sqrt{\frac{1}{2}\Pi} \quad (2)$$

Where $\Pi = \frac{1}{2}\,\mathrm{tr}(\mathrm{grad}\, V + (\mathrm{grad}\, V)^T)^2$

Taking for simplicity and meanwhile the behavior of Tangent Hyperbolic liquid is shear thinning , $^-$<1 so Eqn. (1)

$$\bar{\tau} = \mu_0[(\Gamma\bar{\gamma})^n]A_1 = \mu_0[(1+\Gamma\bar{\gamma}-1)^n]A_1$$

Consuming binomial expansion, then

$$\bar{\tau} = \mu_0[1+(\Gamma\bar{\gamma}-1)^n]A_1 \quad (3)$$

Afterward resolving above equations by consuming boundary layer approximation, consequential equations of energy, Concentration and temperature are

$$\frac{\partial u}{\partial x} + \frac{\partial u}{\partial y} = 0, \quad (4)$$

$$u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} = \nu(1-n)\frac{\partial^2 u}{\partial y^2} + \sqrt{2}\nu n\Gamma\left(\frac{\partial u}{\partial y}\right)\frac{\partial^2 u}{\partial y^2} - \frac{\sigma B^2}{\rho}(u-u_e) - \frac{\nu\epsilon}{k}(u-u_e) - \frac{C_b\epsilon}{\sqrt{k}}(u^2-u_e^2), \quad (5)$$

$$u\frac{\partial T}{\partial x} + v\frac{\partial T}{\partial y} = \alpha\frac{\partial^2 T}{\partial y^2} + \tau\left(D_B\left(\frac{\partial\phi}{\partial y}.\frac{\partial T}{\partial y}\right) + \frac{D_T}{T_\infty}\left(\frac{\partial T}{\partial y}\right)^2\right), \quad (6)$$

$$u\frac{\partial\phi}{\partial x} + v\frac{\partial\phi}{\partial y} = D_B\frac{\partial^2\phi}{\partial y^2} + \frac{D_T}{T_\infty}\left(\frac{\partial^2 T}{\partial y^2}\right). \quad (7)$$

From Eqns. (4-7), the segments of speed u is taking along x-axis and v is segments of speed taking along y- axis, v symbolizes viscosity of kinematic, is fluid density, represent conductivity, T signifies temperature of fluid and indicates nano-particle concentration.

$$u = u_w(x) = a(x+b)^n, v = 0\ ,\ T = T_m\ ,$$

$$D_B\frac{\partial\phi}{\partial y} + \frac{D_T}{T_\infty}\left(\frac{\partial T}{\partial y}\right) = 0 \ \text{ at } = \ \delta(x+b)^{\frac{1-n}{2}}, \quad (8)$$

$$u \to u_e(x) = d(x+b)^n,\ T \to T_\infty,,\ \phi \to \phi_\infty, \ \text{as } y \to \infty, \quad (9)$$

$$k\left(\frac{\partial T}{\partial y}\right)_{y=\delta(x+b)^{\frac{1-n}{2}}} = \rho\left(\lambda^* + C_S(T_m - T_0)\right) v(x,y)_{y=\delta(x+b)^{\frac{1-n}{2}}}. \quad (10)$$

Here demonstrates thermal diffusivity, is time, k is the permeable of porous medium, * the latent heat of fluid, D_B is Brownian indication coefficient and D_T is thermophoresis diffusion coefficient. Here C_S designates surface heat capacity, T_m is melting temperature and To is orientation temperature, where a,b and d are optimistic constants.

We utilize the transformation to translate above PDE's into ODE's and leading boundary equations are as follows

$$,\zeta = y\sqrt{\left(\frac{n+1}{2}\right)\frac{a}{\nu}(x+b)^{n-1}},$$

$$\psi = \sqrt{\left(\frac{2}{n+1}\right)a\nu(x+b)^{n+1}}F(\zeta), \quad (11)$$

$$\Theta(\zeta) = \frac{T-T_m}{T_\infty - T_m}, \qquad \Phi(\zeta) = \frac{\phi-\phi_m}{\phi_\infty-\phi_m}. \quad (12)$$

Here x represent the stream function, we define by and as ,

$$u = \frac{\partial\psi}{\partial y} \text{ and } v = -\frac{\partial\psi}{\partial x} \text{ as } u = a(x+b)^n F'(\zeta),$$

$$v = -\sqrt{\left(\frac{n+1}{2}\right)a\nu(x+b)^{n-1}}\{F(\zeta)+\zeta\frac{n-1}{n+1}F'(\zeta)\}. \quad (13)$$

By using the Eqs.(11-13), the Eqs.(5-7) becomes

$$\left(\frac{2n}{n+1}\right)F'^2 - FF'' = -(n-1)F''' + \left(\frac{2n}{n+1}\right)WeF''F''' - \left(\frac{2}{n+1}\right)(Ha)^2(F'-\lambda) - \left(\frac{2}{n+1}\right)(Da)(F'-\lambda) - \left(\frac{2}{n+1}\right)\beta(F'^2-\lambda^2), \quad (14)$$

$$\Theta'' + \Pr\left(F\Theta' + Nb\Theta'\Phi' + Nt\Theta'^2\right) = 0, \quad (15)$$

$$\Phi'' + \Pr Le\, F\Phi' + \frac{Nt}{Nb}\Theta'' = 0, \quad (16)$$

The equivalent boundary conditions are

$$F(\alpha) = 0, F'(\alpha) = 1, F'(\infty) = \lambda, \quad (17)$$

$$M\Theta'(\alpha) + \Pr F(\alpha) + Pr\zeta\frac{n-1}{n+1} = 0, \Theta(\infty) = 1, \quad (18)$$

$$Nt\Theta'(\alpha) + Nb\Phi'(\alpha) = 0, \Phi(\infty) = 1. \quad (19)$$

Here $\alpha = \delta\sqrt{\frac{1+n}{2}\frac{a}{v}}$ is the thickness parameter of surface and $\zeta = \alpha = \delta\sqrt{\frac{1+n}{2}\frac{a}{v}}$ is the surface of plate. So we define $F(\zeta) = f(\zeta - \alpha) = f(\xi)$, $\Theta(\zeta) = \theta(\zeta - \alpha) = \theta(\xi)$ and $\Phi(\zeta) = \phi(\zeta - \alpha) = \phi(\xi)$, then the Eqs. (14-19) becomes

$$\left(\frac{2n}{n+1}\right)f'^2 - ff'' = -(n-1)f''' + \left(\frac{2n}{n+1}\right)Wef''f''' - \left(\frac{2}{n+1}\right)(Ha)^2(f'-\lambda) - \left(\frac{2}{n+1}\right)(Da)(f'-\lambda) - \left(\frac{2}{n+1}\right)\beta\left(f'^2 - \lambda^2\right), \quad (20)$$

$$\theta'' + \Pr\left(f\theta' + Nb\theta'\phi' + Nt\theta'^2\right) = 0, \quad (21)$$

$$\phi'' + \Pr Le\, F\phi' + \frac{Nt}{Nb}\theta'' = 0, \quad (22)$$

The equivalent boundary conditions are

$$f(0) = 0, f'(0) = 1, f'(\infty) = \lambda, \quad (23)$$

$$M\theta'(0) + \Pr f(0) + Pr\alpha\frac{n-1}{n+1} = 0, \theta(\infty) = 1, \quad (24)$$

$$Nt\theta'(0) + Nb\phi'(0) = 0, \phi(\infty) = 1. \quad (25)$$

I In above expressions $Ha = \sqrt{\frac{\sigma}{\rho a}}B_0$, $Da = \frac{v\epsilon}{ka(x+b)^{n-1}}$, $Pr = \frac{v}{\alpha}$, $\beta = \frac{C_b\epsilon(x+b)}{\sqrt{k}}$, $\lambda = \frac{d}{a}$, $Le = \frac{\alpha}{v}$ $W_e = \frac{a^{\frac{3}{2}}(x+b)^{\frac{3n-1}{2}}\Gamma}{2\sqrt{v}}$, $Nt = \frac{D_T\tau(T_\infty - T_m)}{vT_\infty}$, $Nb = \frac{\tau C_\infty D_B}{v}$ and $\mathrm{M} = \frac{C_p(T_\infty - T_m)}{\lambda^* + C_S(T_m - T_0)}$. Here H$a$ is Hartman number, *Da* the inverse Darcy number, *Pr* is the Prandtl number, the local parameter of inertia coefficient, is the parameter of stretching sheet, *Le* represent the Lewis number, *We* shows the Weissenberg number, *Nt* is number of thermophoresis, *Nb* parameter of Brownian motion, a is the parameter of surface thickness and M is melting parameter.

The skin friction coefficient is

$$C_f = \frac{2\tau_w}{\rho u_w^2}, \quad (26)$$

After streamlining this term, then

$$\sqrt{R_e x}C_f = 2(1-n)\sqrt{\frac{n+1}{2}}f''(0) + n(n+1)W_e\{f''(0)\}^2. \quad (27)$$

The local Nusselt number is as follows

$$Nu_x = \frac{(x+b)q_w}{k(T_w - T_\infty)}, \quad (28)$$

here $q_w = -k\left(\frac{\partial T}{\partial y}\right)_{y=\delta(x+b)^{\frac{1-n}{2}}}$, the resulting equation is

$$(R_e x)^{-\frac{1}{2}}Nu_x = -\sqrt{\frac{n+1}{2}}\theta'(0). \quad (29)$$

The local "Sherwood number" is as under

$$Sh_x = \frac{(x+b)q_m}{D_B(\Phi_w - \Phi_\infty)}, \quad (30)$$

Here $q_m = -D_B\left(\frac{\partial\Phi}{\partial y}\right)_{y=\delta(x+b)^{\frac{1-n}{2}}}$, the resultant equation is

$$(R_e x)^{-\frac{1}{2}}Sh_x = -\sqrt{\frac{n+1}{2}}\phi'(0). \quad (31)$$

3.1 Numerical Solution:

Since equations (20 22) associative with boundary conditions (23-25) are vastly non-linear ordinary differential equations. Initially, we concealed it into first order ordinary differential equations. Then to novelty the solution of ordinary differential equations, we practice with MATLAB file (BVP4C) technique.

$$f = y(1),$$
$$f' = y(2),$$
$$y'(3) = \left[y(1)y(3) - \left(\frac{2n}{n+1}\right)y^2(2) - \left(\frac{2}{n+1}\right)(Ha)^2(y(2) - \lambda) - \left(\frac{2}{n+1}\right)(Da)(y(2)-\lambda) - \left(\frac{2}{n+1}\right)\beta(y^2(2) - \lambda^2) + \left(\frac{2n}{n+1}\right)\lambda^2\right] / \left[n - 1 - \left(\frac{2n}{n+1}\right)Wey(3)\right],$$
$$\theta = y(4),$$
$$\theta' = y(5),$$
$$y'(5) = -P_r\left[y(1).y(5) + Nby(5).y(7) + Nty^2(5)\right],$$
$$\beta = y(6),$$
$$\beta' = y(7),$$

$$y'(7) = \frac{-NtP_r}{Nb}\left[y(1)y(5) + Nby(5)y(7) + Nty^2(5)\right] + PrLey(1)y(7). \quad (20)$$

4. Results and Discussion:

In the current work, the outcomes of numerous suitable parameters on speed, temperature and concentration fields are considered.

Fig. (1) Suggests the appearance of Hartmann number *Ha* on velocity field. It is noticeable point that the magnitude of speed field decays for growing values of Hartmann number *Ha*. The bodily perceptive behind weakening of velocity field is that an expansion inn attractive field upsurges the contrary force to the stream bearing, which is called Lorentz Force that resistive type force, which moderates speed field. The behavior of shape parameter *n* on the velocity outline ( ) is represented through the Fig. (2). Because on growing the shape parameter *n* the widening speed escalations due to which distortion is formed in the liquid and makes speed of the liquid ascent. Fig. (3) Indicates that velocity outline ( ) decreases when the inverse Darcy parameter increases. Fig. (4) is designed to scrutinize the behavior of stretching sheet parameter on the speed profile ( ), It is decided that the speed circulation increments for heightening benefits of extending sheet parameter. Fig. (5) appearances the stimulus of Weissenberg number *We* on velocityoutline ( ). It is distinguished that the velocity field ( ) lessening due to escalation in number of Weissenberg because number of Weissenberg narratesdirectly through relaxation time and hereafter more confrontation is accessible. Fig. (6) trace the impacts of inertial coefficient parameter on the velocityoutline ( ). It is observed that an inertial coefficient parameter moderatesthe velocity outline ( ) .Figs. ((7) and (8)) shows the effect of inverse Darcy parameter *Da* and Hartman number on the temperature outline ( ) respectively. It is observed that when weincrease the values of inverse Darcy parameter *Da* and Hartman number *Ha* respectively, then the temperature outline ( ) decreases simultaneously. The influence of Brownian diffusion number is shown through Fig. (9). It can be seen that the temperature profile decreases, when we increase the values of Brownian diffusion number *Nb*. Fig. (10) pronounces the stimulus of thermophoresis *Nt* on temperature profile ( ). We bargain that for immense estimation of thermophoresis number *Nt*, the temperature profile ( ) diminishes. Because when we escalation parameter estimation of thermophoresis *Nt*, fluid is altered from warm to taciturn area. Fig. (11) develops the fluxes in temperature field ( ) dissimilar to number of Prandtl *Pr*. Since for giant estimation of number of Prandtl *Pr*, thermal conductivity diminishes. The concentration field that pretentious by Lewis number *Le* is represented through Fig. (12). We discern that the dwindling comportment of concentration field ( ) is owed to proliferation estimation of Lewis number *Le*. Fig. (13) revelations the discrepancies in inattention circulation for inconsistent values of Brownian gesture *Nb*. Since the proportioned crusade of nano-fluid elements is owing to escalation in Brownian motion *Nb*, hence it eventually condemnations the nano-fluid particle fascination. Fig. (14) Commends that the enhancement in thermophoresis *Nt* foremost to upsurge in concentration field ( ). Fig. (15) designates the performance of skin resistance factor $C_f\sqrt{R_e x}$ for miscellaneous values of shape parameter *n*. It is recognizing that coefficient of skin friction $C_f\sqrt{R_e x}$ increases for large values of shape parameter *n*. Fig. (16) Illuminates the comportment of Nusselt number $N_u R_e x^{\frac{-1}{2}}$ for discrete appraisals of Prandtl number Pr. Clearly, Nusselt number $N_u R_e x^{\frac{-1}{2}}$ Condenses for great valuations of Prandtl number Pr.

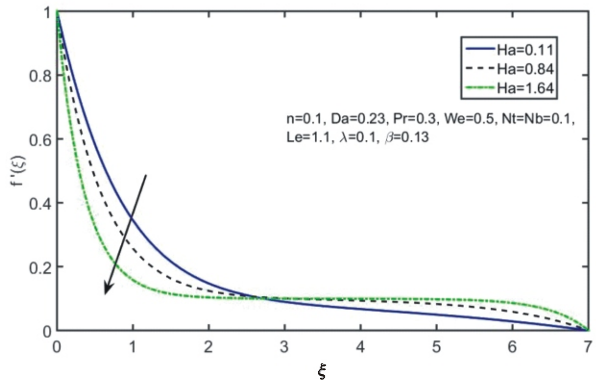

Figure 1: *Impact of Ha on ( ).*

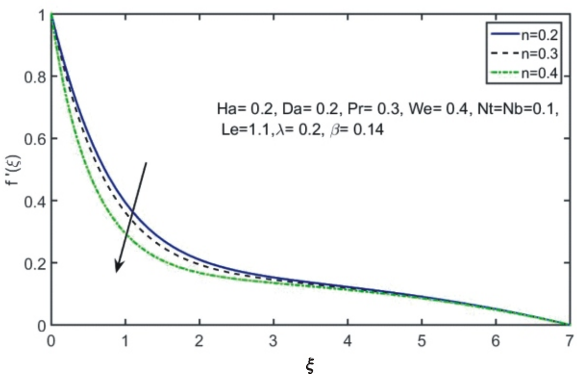

Figure 2: Impact of *n* on ( ).

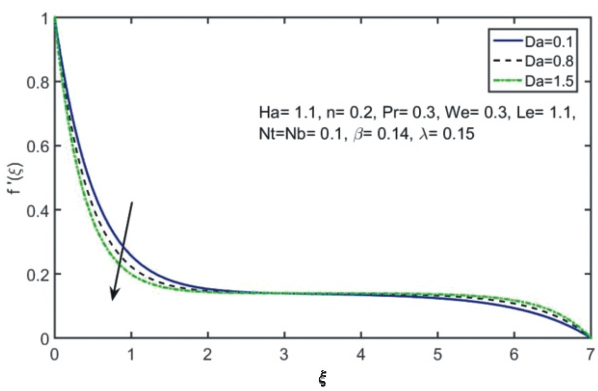

Figure 3: Impact of *Da* on ( ).

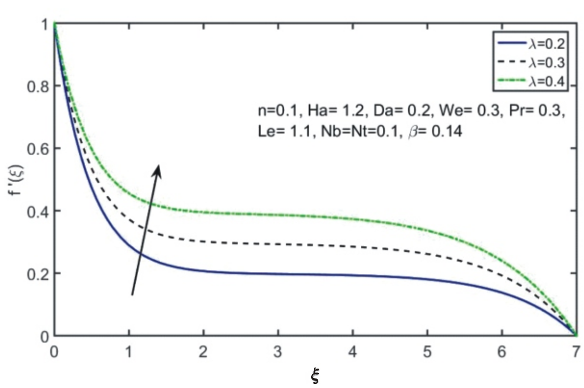

Figure 4: Impact of on ( ).

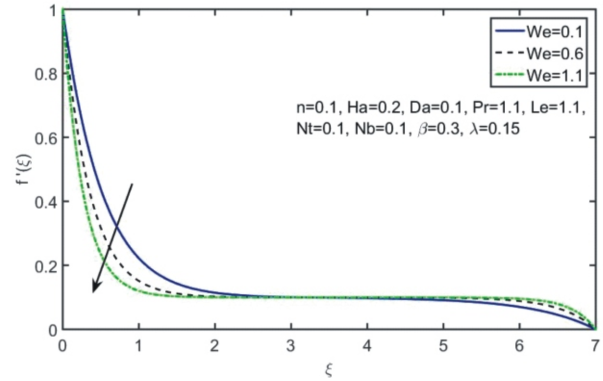

Figure 5: Impact *We* of on ( )..

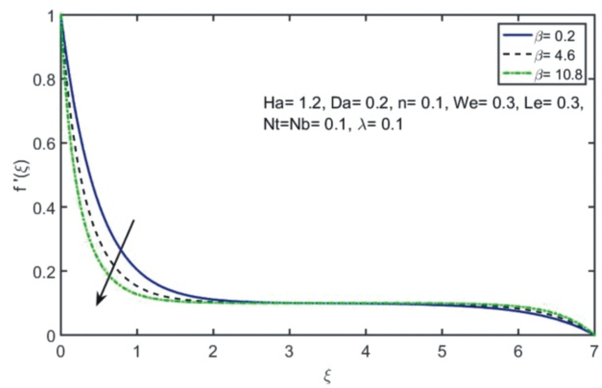

Fig. 6: Impact of on ( )..

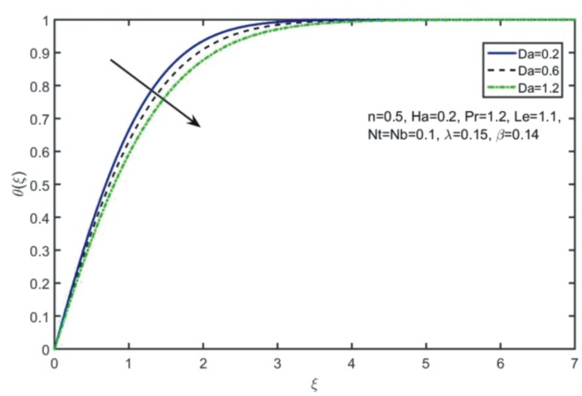

Fig. 7: Impact of *Da* on ( ).

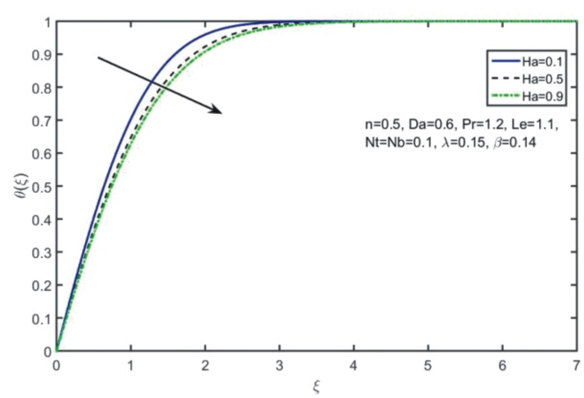

Fig. 8: Impact of *Ha* on ( )...

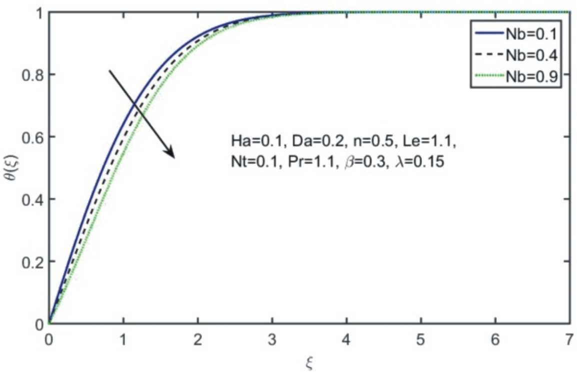

Fig. 9: Impact of *Nb* on ( ).

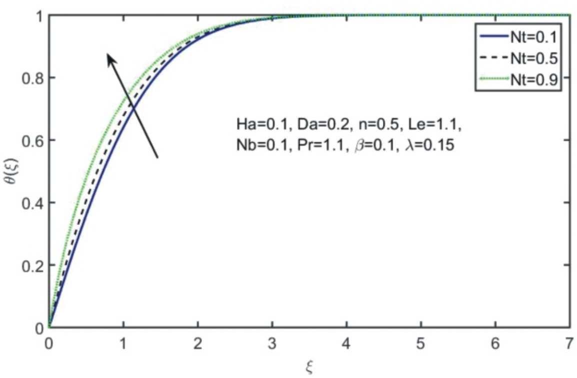

Fig. 10: Impact of *Nt* on ( )...

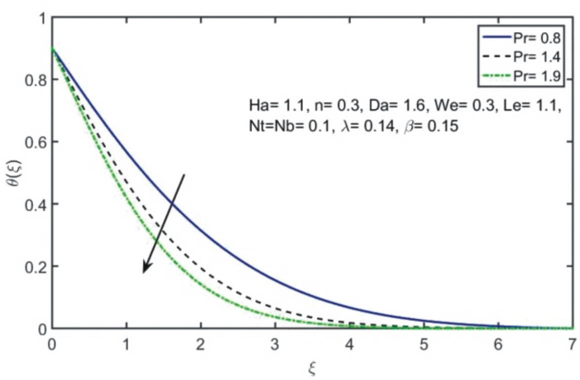

Fig. 11: Impact of *Pr* on ( ).

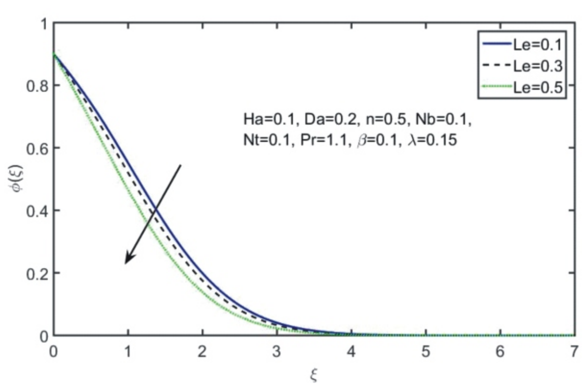

Fig. 12: Impact of *Le* on ( ).

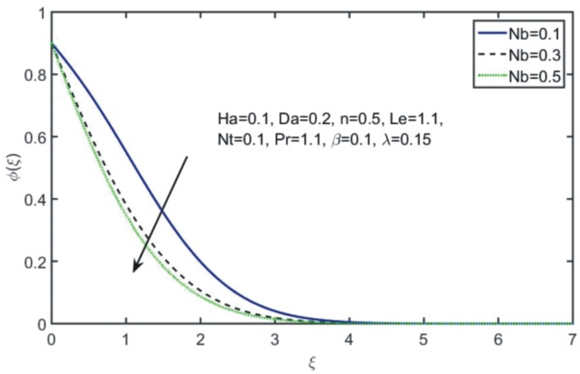

Fig. 13: Impact of *Nb* on ( ).

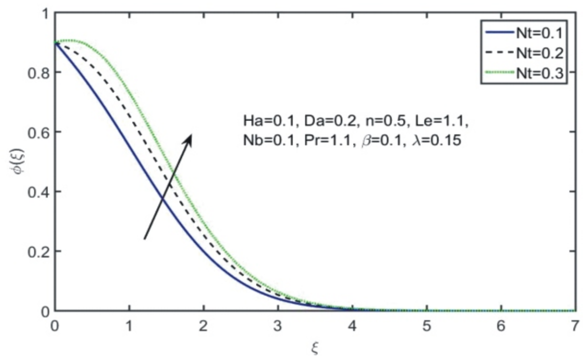

Fig. 14: Impact of *Nt* on ( ).

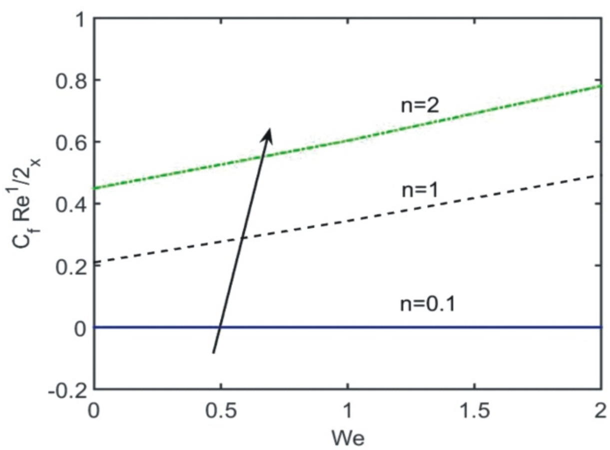

Fig. 15: Impact of *n* on skin friction.

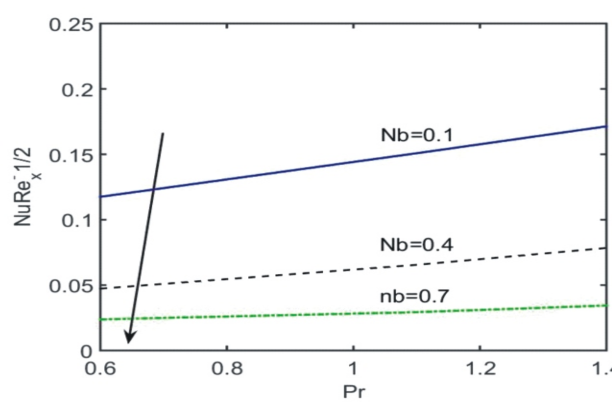

Fig. 16: Impact of *Nb* on Nustle number.

5. Conclusion:

The current study pronounces Bvp4c procedure is utilizing to propose an inaccurate solution for magneto hydrodynamic tangent hyperbolic nano-fluid flow with melting heat transfer in a porous medium. The stimulus of abundant parameters is offered graphically and pondered in detail. The foremost finding keys of numerical outcomes are:

- Velocity distribution ( ) diminishes for greater estimations of Hartman number *Ha* and inverse Darcy number *Da*.
- Velocity profile ( ) reduces for the variation of local inertial coefficient parameter and Weissenberg number *We*.
- The behaviour of velocity profile ( ) magnify for exceeding values of stretching sheet parameter .
- Temperature field ( ) upsurges with respect to stretching sheet parameter and thermophoresis number *Nt*.
- Temperature distribution ( ) decreases with the large values of Prandtl number *Pr*, Brownian motion *Nb* and Lewis number *Le*.
- Coefficient of skin friction declines by elevating the estimations of shape parameter *n*.
- Nusselt number - (0) augments for escalating estimations of Prandtl number *Pr*.

References:

1 M.Y. Malik, T. Salahuddin, A. Hussain, S. Bilal. MHD flow of tangent hyperbolic fluid over a stretching cylinder: Using Keller box method J Magnet Magnet Mater, 395 (2015), pp. 271-276.

2 K.G. Kumar, B.J. Gireesha, M.R. Krishnamurthy, N.G. Rudraswamy. An unsteady squeezed flow of tangent hyperbolic fluid over a sensor surface in the presence of variable thermal conductivity Results Phys, 3 (2017), pp. 3031-3036.

3 S.A. Gaffar, V.R. Prasad, O.A. Beg. Numerical study of flow and heat transfer of non-Newtonian Tangent Hyperbolic fluid from a sphere with Biot number effect Alex Eng J, 54 (2015), pp. 829-841.

4 T. Salahuddin, M.Y. Malik, A. Hussain, M. Awais, I. Khan, M. KhanAnalysis of Tangent Hyperbolic nanofluid impinging on a stretching cylinder near the stagnation point. Results in Physics, 7 (2017), pp. 426-434.

5 N.S. Akbar, S. Nadeem, R.U. Haq, Z.H. Khan. Numerical solutions of magneto hydrodynamic boundary layer flow of tangent hyperbolic fluid towards a stretching sheet. Indian Journal of Physics, 87 (2013), pp. 1121-1124.

6 M.A. Abbas, Y.Q. Bai, M.M. Bhatti, M.M. Rashidi. Three-dimensional peristaltic flow of hyperbolic tangent fluid in non-uniform channel having flexible walls. Alex Eng J, 55 (2016), pp. 652-662.

7 M. Naseer, M.Y. Malik, S. Nadeem, A. Rehman. The boundary layer flow of hyperbolic tangent fluid over a vertical exponentially stretching cylinder. Alexandria engineering journal 53 (3), 747-750 (2014).

8 S. Nadeem, N.S. Akbar. Stagnation flow of a Jeffrey fluid over a shrinking sheet. Zeitschrift für Naturforschung-A 65 (6), 540 (2010).

9 N.S. Akbar, S. Nadeem, R.U. Haq, Z.H. Khan. Numerical solutions of Magneto hydrodynamic boundary layer flow of tangent hyperbolic fluid towards a stretching sheet. Indian Journal of Physics 87 (11), 1121-1124 (2013).

10 S. Nadeem, E.N. Maraj. The Mathematical Analysis for Peristaltic Flow of Hyperbolic Tangent Fluid in a Curved Channel. Communications in Theoretical Physics 59 (6), 729 (2013).

11 H. Alfven. Existence of electromagnetic-hydrodynamic waves. Nature, 150 (1942), p. 405-406.

12 K.V. Prasad, K. Vajravelu, P.S. Datti. The effects of variable fluid properties on the hydro-

magnetic flow and heat transfer over a non-linearly stretching sheet. International Journal of Thermal Science, 49 (2010), pp. 603-610.

13 H.R. Ashorynejad, M. Sheikholeslami, I. Pop, D.D. Ganji. Nanofluid flow and heat transfer due to a stretching cylinder in the presence of magnetic field. Heat Mass Transfer, 49 (2013), pp. 427-436.

14 S. Mukhopadhyay. MHD boundary layer slip flow along a stretching cylinder. Ain Shams Eng J, 4 (2013), pp. 317-324.

15 H. Dessie, N. Kishan. MHD effects on heat transfer over stretching sheet embedded in porous medium with variable viscosity, viscous dissipation and heat source/sink. Ain Shams Eng J, 5 (2014), pp. 967-977.

16 M.Y. Malik, T. Salahuddin. Numerical solution of MHD stagnation point flow of Williamson fluid model over a stretching cylinder. International Journal of Nonlinear Science Numerical Simulation, 16 (2015), pp. 161-164.

17 A.A. Khan, Saima Muhammad, R. Ellahi, Q.M. Zaigham Zia. Bionic study of variable viscosity on MHD peristaltic flow of Pseudoplastic fluid in an asymmetric channel. Journal of Magnetism, 21 (2016), pp. 273-280.

18 R. Ellahi, E. Shivanian, S. Abbasbandy, T. Hayat. Numerical study of magneto hydrodynamics generalized Couette flow of Eyring-Powell fluid with heat transfer and slip condition. International Journal of Numerical Methods Heat Fluid Flow, 26 (2016), pp. 1433-1445.

19 M.M. Bhatti, R. Ellahi, A. Zeeshan. Study of variable magnetic field on the peristaltic flow of Jeffrey fluid in a non-uniform rectangular duct having compliant walls. Journal of Molecular Liquid, 222 (2016), pp. 101-108.

20 M.M. Bhatti, A. Zeeshan, R. Ellahi. Study of heat transfer with nonlinear thermal radiation on sinusoidal motion of magnetic solid particles in a dusty fluid. J Theor Appl Mech Bulg, 46 (2016), pp. 75-94.

21 M.M. Bhatti, A. Zeeshan, R. Ellahi. Endoscope analysis on peristaltic blood flow of Sisko fluid with titanium magneto-nanoparticles. Comput Biol Med, 78 (2016), pp. 29-41.

22 M. Sheikholeslami, Q.M. Zaigham Zia, R. Ellahi. Influence of induced magnetic field on free convection of nanofluid considering Koo-Kleinstreuer (KKL) correlation. Applied Sciences, 6 (2016).

23 A. Khan, H. Usman, K. Vafai, R. Ellahi. Study of peristaltic flow of magneto hydrodynamic Walter's B fluid with slip and heat transfer. Science Iran, 23 (2016), pp. 2650-2662.

24 A. Zeeshan, A. Majeed, R. Ellahi. Effect of magnetic dipole on viscous ferro-fluid past a stretching surface with thermal radiation. Journal of Molecular Liquid, 215 (2016), pp. 549-554.

25 A. Majeed, A. Zeeshan, R. Ellahi. Unsteady ferromagnetic liquid flow and heat transfer analysis over a stretching sheet with the effect of dipole and prescribed heat flux. Journal of Molecular Liquid, 223 (2016), pp. 528-533.

26 K. Maqbool, A. Sohail, N. Manzoor, R. Ellahi. Hall effect on Falkner-Skan boundary layer flow of FENE-P fluid over a stretching sheet. Commun Theor Phys, 66 (2016), pp. 547-554.

27 A. Hussain, M.Y. Malik, S. Bilal, M. Awais, T. Salahuddin. Computational analysis of magneto hydrodynamic Sisko fluid flow over a stretching cylinder in the presence of viscous dissipation and temperature dependent thermal conductivity. Results in Physics, 7 (2017), pp. 139-146.

28 M. Awais, M.Y. Malik, S. Bilal, T. Salahuddin, A. Hussain. Magneto hydrodynamic (MHD) flow of Sisko fluid near the axisymmetric stagnation point towards a stretching cylinder. Results in Physics, 7 (2017), pp. 49-56.

29 S. Bilal, K.U. Rehman, M.Y. Malik, A. Hussain, Mair Khan. Effects of temperature

dependent conductivity and absorptive/generative heat transfer on MHD three-dimensional flow of Williamson fluid due to bidirectional non-linear stretching surface. Results in Physics, 7 (2017), pp. 204-212.

30 S. Bilal, K.U. Rehman, M.Y. Malik, A. Hussain, M. Awais. Effect logs of double diffusion on MHD Prandtl nano fluid adjacent to stretching surface by way of numerical approach. Results in Physics, 7 (2017), pp. 470-479.

31 T. Hayat, R. Sajjad, T. Muhammad, A. Alsaedi, R. Ellahi. On MHD nonlinear stretching flow of Powell-Eyring nanomaterial. Results in Physics, 7 (2017), pp. 535-543.

32 K.U. Rehman, M.Y. Malik, S. Bilal, M. Bibi, U. Ali. Numerical analysis for MHD thermal and solutal stratified stagnation point flow of Powell-Eyring fluid induced by cylindrical surface with dual convection and heat generation effects. Results in Physics, 7 (2017), pp. 544-552.

33 A.Hussain, M.Y. Malik, M. Awais, S. Bilal, T. Salahuddin. Computational and physical aspects of MHD Prandtl-Eyring fluid flow analysis over a stretching sheet. Neural Comput Appl (2017).

34 M.M. Bhatti, A. Zeeshan, R. Ellahi. Simultaneous effects of coagulation and variable magnetic field on peristaltically induced motion of Jeffrey nanofluid containing gyrotactic microorganism. Microvasc Res, 110 (2017), pp. 32-42.

35 R. Ellahi, M.H. Tariq, M. Hassan, K. Vafai. On boundary layer magnetic flow of nano-ferroliquid under the influence of low oscillating over stretchable rotating disk. Journal of Molecular Liquid, 229 (2017), pp. 339-345.

36 M.M. Bhatti, A. Zeeshan, R. Ellahi, N. Ijaz. Heat and mass transfer of two-phase flow with electric double layer effects induced due to peristaltic propulsion in the presence of transverse magnetic field. Journal of Molecular Liquid, 230 (2017), pp. 237-246.

37 A.Hussain, M.Y. Malik, T. Salahuddin, S. Bilal, M. Awais. Combined effects of viscous dissipation and Joule heating on MHD Sisko nanofluid flow over stretching cylinder. Journal of Molecular Liquid, 231 (2017), pp. 341-352.

38 M. Hassan, A. Zeeshan, A. Majeed, R. Ellahi. Particle shape effects on ferrofluids flow and heat transfer under influence of low oscillating magnetic field. J Magn Magn Mater, 443 (2017), pp. 36-44.