Journal of Naval Architecture and Marine Engineering
December, 2023
http://dx.doi.org/10.3329/jname.v20i2.66824 http://www.banglajol.info

STIMULUS OF CROSS DISPERSION ON WILLIAMSON LIQUID FLOW OWING TO STRETCHED SHEET WITH CONVECTIVE-DIFFUSIVE SITUATIONS

Y. Masthanaiah[1,2*] G. Viswanatha Reddy[1]

[1]Dept. of Mathematics, Sri Venkateswara University, Tirupati, Pin: 517502, A.P., India.
[2]Dept. of Humanities and Sciences, Annamacharya Institute of Sciences and Technology, Tirupati, Pin: 517507, A.P., India. Email: masthan.svu@gmail.com, gvr.svu@gmail.com

Abstract:

The current research wishes to scrutinize the heat and mass transmission features on magnetohydrodynamic stream of Williamson liquid owed to stretching surface with cross dispersion impacts. The stimulus of radiative heat, mutable heat sink/source, dissipation, Joule's heat and chemical reaction is taken. With the support of similarities the original PDEs are transmuted into ODEs and then obtain a numerical solution by the well-known numerical method R.K. with shooting procedure. The impact of dissimilar dimensionless constraints on the flow fields are conversed over displays and the same parameters on skin friction coefficient, local heat plus mass transport rates are deliberated through table. An improvement in thermal field is perceived for thermic heat constraint and Eckert number. On the other hand, it is witnessed that escalating the values of Dufour number augments the distribution of heat, while a contrary result is perceived in the distribution of concentration.

***Keywords*:** Cross dispersion, Joule heating, heat plus mass transport, stretching surface.

1. Introduction:

The analysis of boundary layer due to stretched surface has notable tenders in my trades which enclose fabrication of elastic sheets, wire cartoon, nonstop icy of fibre solidification, consolidation and receding of metallic ropes and hot progressing. Sakidas (1965) was the topmost boffin to identify the convective shear coagulating flow through a strained surface. This work was protracted by Crane (1970). Chen (2000) and Abel *et al.* (2004) argued the flow owed to stressed surface in the appearance of emotion conveyance claims. The diverse convective hydrodynamic flow past a vertical stretching surface with mutable fluid belongings was examined by Prasad *et al.* (2010). The time-independent, incompressible convective shear condensing liquid stream owed to elongating of an absorbent sheet was elucidated by Aswinkumar *et al.* (2021). They opined that the stretching ratio parameter has a propensity to control liquid hotness.

Presently, Sundry boffins are used non-Newtonian supplies for their extensive every day and industrial needs like food refining, coal slurries, manufacture of paper, nutritional provision, oil retrieval and crystal development. Banana juice, shampoos, chilli sauce, jells and paints are specific instances of shear thickening liquids. A critical explanation for boundary level stream of Williamson liquid over a stretched sheet was reported by Nadeem *et al.* (2013). Further, Nadeem and Hussain (2014) extended this work on the shear condensing fluid pour due to extending of an exponential surface. Kumar *et al*. (2019), Salahuddin *et al*. (2021) and Dadheech *et al*. (2022) have paid their interest on shear thickening liquid flows across solid surface with various heat transport aspects and found that shear thickening constraint has an affinity to declaim the velocity. Reddy *et al*. (2017) examined the characteristics of non-Newtonian fluid flows over a stretching sheet with various effects.

The acuity of MHD is to regulate fluid crusade. It shows a vigorous charm in the arenas of physics, medical and some manufacturing fields. For the presentation of chilly resolutions, larger heat broadcast rate is only in the manifestation of attractive strength. Some of the noteworthy presentations of attractive significances are brain treatment, malevolent tumour, stiffness and blood pressure. In sight of these claims, Nawaz *et al.* (2019) debated the bearing of magnetic variable on convection flow of shear condensing liquid due to stretching of an external in the presence of thermic transport. A computational analysis is conducted by Akarm and Afzal (2020) to examine the various heat transport aspect in the assistance of magnetic force and found that the liquid swiftness drops owing to Lorentz force. Further, Nawaz and Sadiq (2021), Almaneea (2022) focused to probe the flow and mass transport stimuli of non-Newtonian fluids in the appearance of thermo-diffusion. Newly, Kumar *et al*. (2022) reported a scientific scrutiny to scrutinize

 Received on: June, 2023

the flow and thermal transmission features of non-newtonian liquid in the company of drag strength and irregular hear constraints.

The influence of biochemical response in the stream owing to extending of surface which is beneficial in sundry manufacturing bids like ventilation, threatened, built-up of tiles, diet indulgence, energy transmission in a cooling turret and polymer fabrication. Hayat *et al.* (2017) argued the aspects of thermic heat and biochemical response on conducting fields. The mass plus heat conveyance structures of non-Newtonian fluid over a nonlinear exterior were reported by Jena *et al*. (2018). Further, Panigrahi *et al.* (2021), Nagaraja and Gireesha (2021), Nandi and Kumbhakar (2022) reported a numerical scrutinization for MHD flow of shear thickening liquid over a solid sheet and they conclude that the chemical response constraint diminishes the rate of mass conveyance. The consequent dissipation parameter on convection stream of micropolar liquid above a twisting surface with jagged heat constraints and drag force was reported by Kumar *et al*. (2020) and found that an augmentation in liquid hotness for swelling values of asymmetrical heat basis/droplet constraints. Ramadevi *et al*. (2019) examined the impact of irregular heat source/sink on MHD flow due to strained sheet with heat plus mass transport.

Dispersal of substance caused by incline of heat is known as thermo dispersion consequence and dispersal of heat caused by incline of absorption is definite as Dufour consequence. These influences have noteworthy part for too huge heat and absorption grades. Typically these two belongings are preserved as second order singularity. It has solicitations such as the solidification of twofold alloys, relocation of pulverized water impurity, biochemical devices and geosciences. Several academics are involved in the area heat and mass transmission owing to massive solicitations in numerous castigations. Hayat *et al.* (2015) scrutinized the flow and heat transfer performance of Shear thickening liquid through a solid surface in the appearance of cross diffusion. The stimulus of cross dispersion on non-Newtonian liquid flow past two unlike solids with resistive force was explored by Raju and Sandeep (2016). Kumar *et al*. (2020) and Ramadevi *et al*. (2020) studied the impact of Dufour on MHD stream of shear thickening fluid through a strained sheet.

To the greatest of our gen, no writer made an effort to examine the primary chemical reaction on MHD Williamson liquid through a perpendicular sheet in the being of thermic heat irregular heat constraints. By spending appropriate appraisal alterations, the governing equations are transmuted into ODEs. The rehabilitated flow equalities are preserved by R-K procedure and also inspected the influence related to numerous flow restraints with vividly and by chart.

2. Formulation:

Let us take a steady 2D mixed convective Williamson fluid flow past an extending external with cross dispersion belongings. The fluid flow is laminar and incompressible. The impacts of Joule heating, thermic hot, bumpy heat sink/source and dissipation are taken. Convective –diffusive boundary conditions are taken. Assume that the stretching velocity of the surface is $u_w(x) = ax$ (where a is rate of stretching initially) acting along the $x-$axis as exposed in Fig-1. A constant magnetic force $B = B_0$ is applied horizontally. Here B_0 is the strength of transverse attractive force.

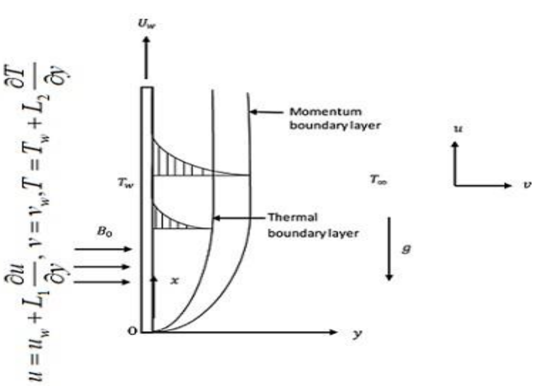

Fig. 1: Flow Geometry

The flow directed by the classical fluid is (see Nadeem et al., 2013, Akram and Afzal, 2020) is represented by:

$$\frac{\partial v}{\partial y}+\frac{\partial u}{\partial x}=0, \tag{1}$$

$$u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}=\upsilon\frac{\partial^2 u}{\partial y^2}+\sqrt{2}\upsilon\Gamma\frac{\partial^2 u}{\partial y^2}\frac{\partial u}{\partial y}+(T-T_\infty)g\rho\beta_T+g(C-C_\infty)\rho\beta_C-\frac{\sigma B_0{}^2 u}{\rho}, \tag{2}$$

$$\left(u\frac{\partial T}{\partial x}+v\frac{\partial T}{\partial y}\right)\rho C_p=k\frac{\partial^2 T}{\partial y^2}+\sigma B_0^2 u^2-\frac{\partial q_r}{\partial y}+q'''+\mu\left(\frac{\partial u}{\partial y}\right)^2+\frac{\rho D_m K_T}{C_s}\frac{\partial^2 C}{\partial y^2}, \tag{3}$$

$$u\frac{\partial C}{\partial x}+v\frac{\partial C}{\partial y}=D_m\frac{\partial^2 C}{\partial y^2}-k^*(C-C_\infty)+\frac{D_m K_T}{T_m}\frac{\partial^2 T}{\partial y^2} \tag{4}$$

The boundary conditions of the present study is (see Nadeem et al., 2013, Akram and Afzal, 2020)

$$\left.\begin{array}{ll} u=\frac{\partial u}{\partial y}L_1+u_w,\ v=v_w,\frac{\partial T}{\partial y}=(T-T_w)\frac{h_1}{k},\frac{\partial C}{\partial y}=(C-C_w)\frac{h_2}{D} & at\ y=0 \\ u\to 0,\ T\to T_\infty, C\to C_\infty, & at\ y\to\infty \end{array}\right\} \tag{5}$$

Where $\Gamma>0$ is a time constant, υ is kinematic viscosity of the fluid, g is the gravitational force, $T\,\&\,T_\infty$ respectively, near and far away temperature of the fluid, ρ is density, $\beta_T\,\&\,\beta_C$ are the thermic and solutal expansion coefficients, $C\,\&\,C_\infty$ respectively, close and far-off concentrations, σ is the electrical conductivity, k is the updraft conductivity of the fluid, C_p is the heat capacitance, D_m is the mass diffusivity, K_T is the thermic diffusition ratio, C_s is the solutal vulnerability, and T_m is the mean fluid temperature, L_1 is the velocity slip factor, $h_1\,\&\,h_2$ are the coefficients related to convective and diffusive heat transfer, v_w is the suction velocity.

Consider

$$q_r=-\frac{4}{3}\frac{\partial T^4}{\partial y}\frac{\sigma^*}{k^*}, \tag{6}$$

$$T^4=4TT_\infty{}^3-3T_\infty{}^4, \tag{7}$$

$$q'''=[(T-T_\infty)B^*+(T_w-T_\infty)f'A^*]\frac{ku_w}{x\upsilon}, \tag{8}$$

3. Solution of the Problem:

Ponder the following alterations to change the Eqns. (1)-(4) into a set of ODEs.

$$\eta=\sqrt{\frac{a}{\upsilon}}\,y \tag{9}$$

$$\left.\psi=\sqrt{a\upsilon}\,xf(\eta),\ \theta(\eta)=\frac{T-T_\infty}{T_w-T_\infty},\phi(\eta)=\frac{C-C_\infty}{C_w-C_\infty},\right\} \tag{10}$$

Here η,ψ are the similarity variable and stream function.

The distorted reckonings are

$$f'''(1+\lambda f'')+Gr_T\theta+Gr_C\phi-Mf'+ff''-(f')^2=0, \tag{11}$$

$$(1+R)\theta''+\Pr MEc(f')^2+\Pr Ec(f'')^2+\Pr f\theta'+A^*f'+\Pr Du\phi''+B^*\theta-\Pr f'\theta=0, \tag{12}$$

$$\phi''+Scf\phi'-Scf'\phi-KrSc\phi+SrSc\theta''=0 \tag{13}$$

The resultant BCs are

$$f'(0)=1+k_1f''(0),\ f(0)=S,\theta'(0)=-Bi_T(1-\theta(0)),\phi'(0)=-Bi_C(1-\phi(0))\quad at\ \eta=0, \tag{14}$$

$$f' \to 0, \theta \to 0, \phi \to 0, \qquad as\ \eta \to \infty, \tag{15}$$

Here Williamson fluid parameter is $\lambda = \Gamma x \sqrt{\frac{2a^3}{\upsilon}}$, the thermal and solutal Grashof numbers $Gr_T = \frac{g\beta_T (T_w - T_\infty)}{a^2 x}, Gr_C = \frac{g\beta_C (C_w - C_\infty)}{a^2 x}$, the Magnetic field parameter $M = \frac{\sigma B_0^{\ 2}}{a\rho}$, the Radiation parameter $R = \frac{16\sigma^* T^3_{\ \infty}}{3kk^*}$, the Eckert number $Ec = \frac{u_w^{\ 2}}{C_p (T_w - T_\infty)}$, the Prandtl number $\Pr = \frac{\upsilon\rho C_p}{k} = \frac{\mu C_p}{k}$, the dimensionless chemical response parameter $Kr = k^*(C_w - C_\infty)$, the suction/injection parameter $S = \frac{-v_w}{\sqrt{a\upsilon}}$, $Bi_T = \sqrt{\frac{\upsilon}{a}}\frac{h_1}{k}$ & $Bi_C = \sqrt{\frac{\upsilon}{a}}\frac{h_2}{D_m}$ respectively, the thermal and solutal Biot numbers.

The physical quantities of manufacturing importance are given by,

$$\left(f''(0)\frac{\lambda}{2} + 1 \right) f''(0) = \mathrm{Re}_x^{\frac{1}{2}} C_f, \tag{16}$$

$$\theta'(0)(Rd + 1) = -\mathrm{Re}_x^{\frac{-1}{2}} Nu, \tag{17}$$

$$\phi'(0) = -\mathrm{Re}_x^{\frac{-1}{2}} Sh \tag{18}$$

Where $\mathrm{Re}_x = \frac{x u_w}{\upsilon}$ is the local Reynold's number.

4. Results and Discussions:

The set of coupled and non-linear ODEs (10)-(12) with the boundaries (13-14) are resolved arithmetically using bvp4c method. The results attained validate the influences of $M, Sr, Du, \Pr, Gr_T, Gr_C, Sc, Ec, Kr, R, Bi_T$, Bi_C, A^* & B^* on the flow fields and physical quantities are thoroughly scrutinized and bestowed via graphs and table.

Figures 2 and 3 are sketched to see the stimulus of Soret number on heat and mass functions respectively. It can be understood that the concentration upsurges with the growth in Soret number while the inverse result is detected in the case of temperature. The Soret impact is the reciprocal phenomenon to the Dufour effect. Hence fluid concentration increases in the boundary layer due to Soret effect. Figures 4 and 5 are delineated to apprehend the influence of Dufour number on heat and mass functions respectively. It can be understood that the heat upsurges with the growing values of Dufour number while the converse consequence is saw in the situation of mass contour. Really, the Dufour word that seems in the heat equivalence dealings the aid of mass gradient to thermic heat fluxes in the flow province. Hence it plays a vigorous character in augmenting the fluid momentum and has the capacity to upsurge the thermic heat in the boundary. As a consequence, the temperature distribution rises with the surge in Du, whereas the contrary result is perceived in the situation of absorption distribution.

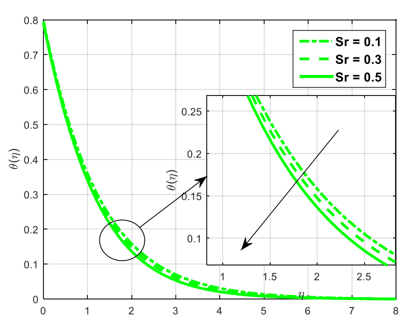

Fig. 2: Sr on $\theta(\eta)$

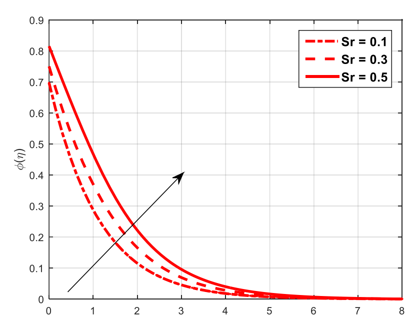

Fig. 3: Sr on $\phi(\eta)$

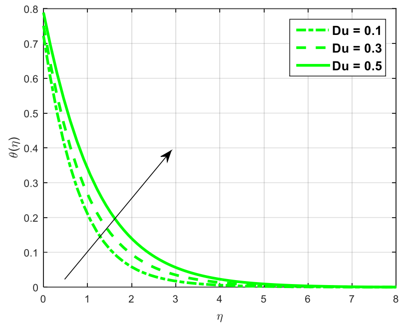

Fig. 4: Du on $\theta(\eta)$

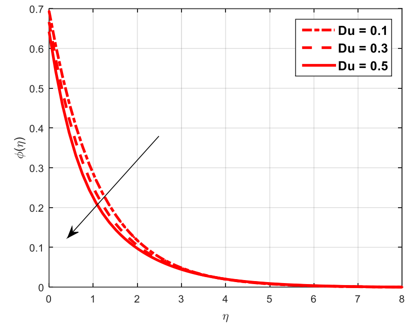

Fig. 5: Du on $\phi(\eta)$

Figs. 6-8 discern the consequence of attractive field constraint (M) on the flow fields. It is witnessed that, an upsurge in M consequences a reduction in momentum and the consistent boundary layer width. An augmentation in M , an opposed type of strength called drag force is produced in the flow which origins a decrease in the distribution of velocity.

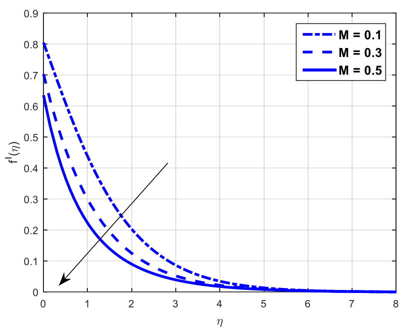

Fig. 6: M on $f'(\eta)$.

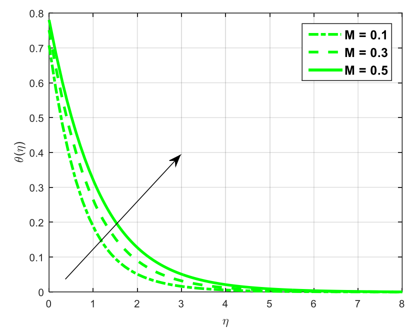

Fig. 7: M on $\theta(\eta)$.

Figs. 9 and 10 show the effect of heat and mass Biot numbers on the fields ($\theta(\eta)$ & $\phi(\eta)$) correspondingly. From Figure 9, we see that a raise in Bi_T results an enhancement in the distribution of temperature. It is discerned from Figure 10 that the distribution of concentration id an increasing factor of solutal Biot number (Bi_C).

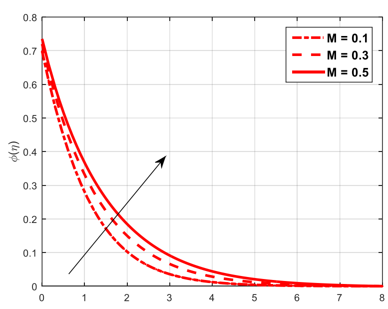

Fig. 8: M on $\phi(\eta)$.

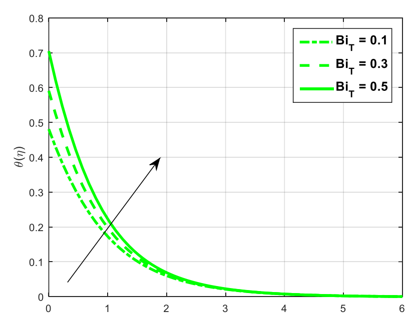

Fig. 9: Bi_T on $\theta(\eta)$.

Figure 11 indicates the influence of Eckert number (Ec) on temperature. By swelling values of Eckert number enhances the distribution of temperature. Really, Eckert quantity is the proportion of advective transport and the heat indulgence potential. Hence, the dispersal of concentration and the consistent layer thickness augments for increase in Ec .

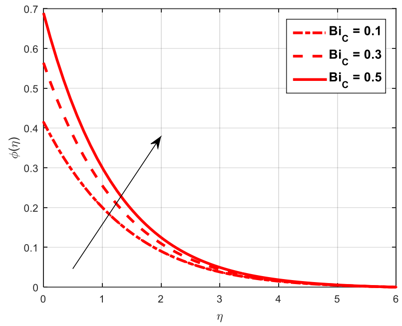

Fig. 10: Bi_C on $\phi(\eta)$

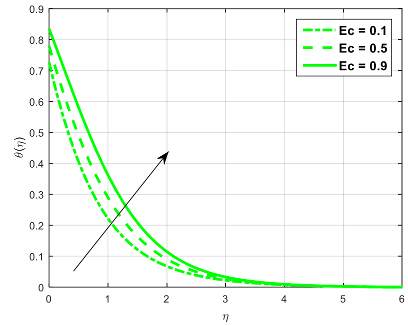

Fig. 11: Ec on $\theta(\eta)$

Figure 12 is plotted to understand the sway of thermic heat parameter (R) on the distribution of heat. It is witnessed from chart that an improvement in thermal radiation constraint escalations the distribution of heat and the equivalent boundary layer width. Figs. 13 and 14 are to analyse the inspiration of Gr_T & Gr_C on ($\theta(\eta)$ & $\phi(\eta)$) correspondingly. From Fig. 13, we see that a raise in Gr_T diminishes the distribution of temperature. A decrement in the dispersal is noticed for swelling values of solutal Grashof number (See Fig. 14).

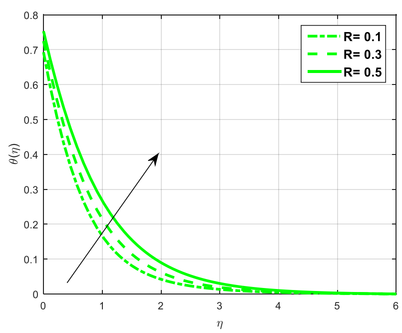

Fig. 12: R on $\theta(\eta)$

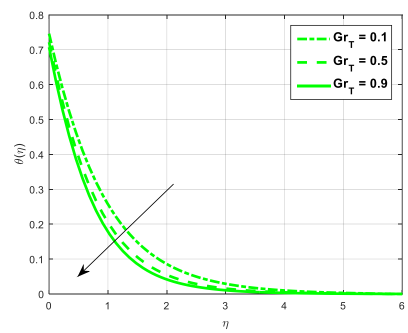

Fig. 13: Gr_T on $\theta(\eta)$.

Figs. 15 and 16 are delineated to know the impact of A^* & B^* on the dispersal of heat. It is witnessed from the charts that temperature is an increasing function of bumpy heat basis/bowl constraints. Tangibly, an enhancement in A^* & B^* acts as heat source in the flow and hence we detect an enhancement in the distribution of temperature and the consistent layer width.

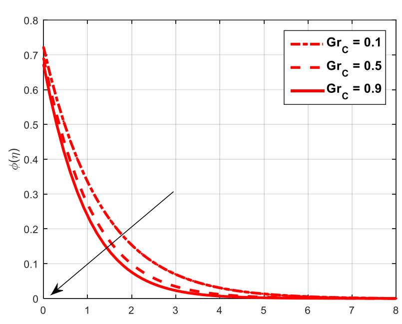

Fig. 14: Gr_C on $\phi(\eta)$.

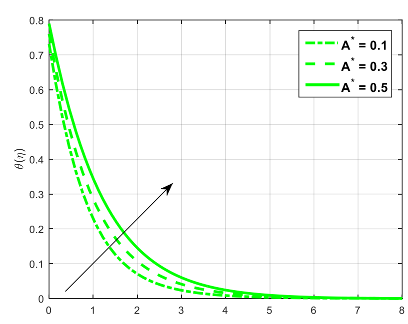

Fig. 15: A^* on $\theta(\eta)$.

Figure 17 is drawn to understand the stimulus of K_r on $\phi(\eta)$. For increasing values of K_r drops the absorption and the consistent boundary width. Figure 18 is plotted to know the effect of Sc on $\phi(\eta)$. It was perceived from the chart that the distribution of heat is a decreasing function of Schmidt number. Actually, Schmidt number is the proportion between momentum and mass diffusivities. Hence, the distribution of concentration and the corresponding boundary layer width shrinkage for snowballing values of Sc .

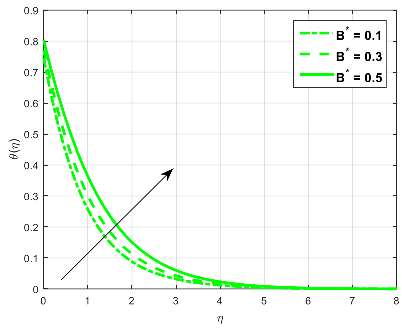

Fig. 16: B^* on $\theta(\eta)$.

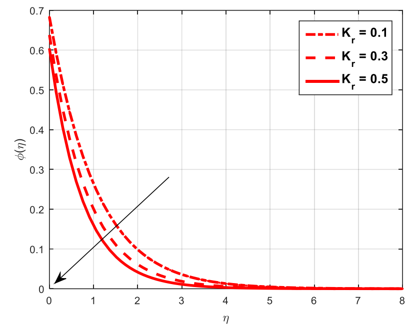

Fig. 17: K_r on $\phi(\eta)$..

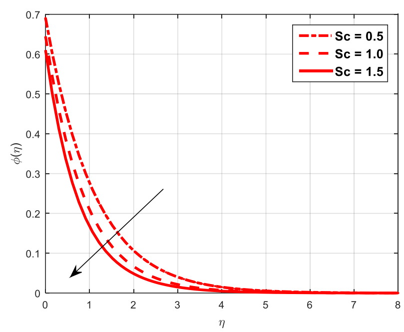

Fig. 18: Sc on $\phi(\eta)$

5. Conclusions

The key findings of the work are

- An enhancement in thermal field is detected for R, Ec, A^* & B^*.
- By expanding the values of Dufour number enhances the heat while the distribution of concentration decreases.
- A decreasing in velocity while a heightening in thermal and solutal fields is detected for snowballing values of M .
- Increasing values of Sr reduces $\theta(\eta)$ while $\phi(\eta)$ enhances.
- Concentration is an increasing factor of Sc and chemical reaction parameter.
- Local heat and mass transport rates are reduce for swelling values of Sr & Du .
- An extension in friction factor is sensed for raising values of thermal and solutal Grashof numbers.

References

Abel, S., Veena, P. H., Rajgopal, K., and Pravin, V. K. (2004): Non-Newtonian magnetohydrodynamic flow over a stretching surface with heat and mass transfer, International journal of Non-linear Mechanics, Vol. 39, No. 7, Pp. 1067-1078. https://doi.org/10.1016/S0020-7462(03)00097-0.

Akram, S., and Afzal, Q. (2020): Effects of thermal and concentration convection and induced magnetic field on peristaltic flow of Williamson nanofluid in inclined uniform channel, The European Physical Journal Plus, Vol. 135, No. 10, 857. https://doi.org/10.1140/epjp/s13360-020-00869-9

Almaneea, A. (2022): Numerical study on heat and mass transport enhancement in MHD Williamson fluid via hybrid nanoparticles, Alexandria Engineering Journal, Vol. 61, No. 10, Pp. 8343-8354. https://doi.org/10.1016/j.aej.2022.01.041

Ashwinkumar, G. P., Samrat, S. P., and Sandeep, N. (2021): Convective heat transfer in MHD hybrid nanofluid flow over two different geometries, International Communications in Heat and Mass Transfer, Vol. 127, 105563. https://doi.org/10.1016/j.icheatmasstransfer.2021.105563

Chen, C. H. (2000): Mixed convection cooling of a heated, continuously stretching surface, Heat and Mass Transfer, Vol. 36, Pp. 79-86. https://doi.org/10.1007/s002310050367

Crane, L. J. (1970). Flow past a stretching plate, Zeitschrift für angewandte Mathematik und Physik ZAMP, Vol.21, Pp. 645-647. https://doi.org/10.1007/BF01587695

Dadheech, A., Parmar, A., Agrawal, K., Al-Mdallal, Q., and Sharma, S. (2022): Second law analysis for MHD slip flow for Williamson fluid over a vertical plate with Cattaneo-Christov heat flux, Case Studies in Thermal Engineering, Vol. 33, 101931. https://doi.org/10.1016/j.csite.2022.101931

Hayat, T., Rashid, M., Imtiaz, M., and Alsaedi, A. (2017): MHD convective flow due to a curved surface with thermal radiation and chemical reaction, Journal of Molecular Liquids, Vol. 225, Pp. 482-489. https://doi.org/10.1016/j.molliq.2016.11.096.

Hayat, T., Saeed, Y., Alsaedi, A., and Asad, S. (2015): Effects of convective heat and mass transfer in flow of Powell-Eyring fluid past an exponentially stretching sheet, PloS one, Vol. 10, No. 9, e0133831. https://doi.org/10.1371/journal.pone.0133831

Jena, S., Dash, G. C., and Mishra, S. R. (2018): Chemical reaction effect on MHD viscoelastic fluid flow over a vertical stretching sheet with heat source/sink, Ain Shams Engineering Journal, Vol. 9, No. 4, Pp. 1205-1213. https://doi.org/10.1016/j.asej.2016.06.014.

Kumar, K. A., Ramudu, A. C.V., Sugunamma, V., and Sandeep, N. (2022): Effect of non-linear thermal radiation on MHD Casson fluid flow past a stretching surface with chemical reaction, International Journal of Ambient Energy, Vol. 43, No. 1, Pp. 8400-8407. https://doi.org/10.1080/01430750.2022.2097947

Kumar, K. A., Reddy, J. R., Sugunamma, V., and Sandeep, N. (2019): Simultaneous solutions for MHD flow of Williamson fluid over a curved sheet with non-uniform heat source/sink, Heat Transfer Research, 50(6). Vol. 50, No. 6, 2019, pp. 581-603. https://doi.org/10.1615/HeatTransRes.2018025939

Kumar, K. A., Sandeep, N., Sugunamma, V., and Animasaun, I. L. (2020): Effect of irregular heat source/sink on the radiative thin film flow of MHD hybrid ferrofluid, Journal of Thermal Analysis and Calorimetry, Vol. 139, Pp. 2145-2153. https://doi.org/10.1007/s10973-019-08628-4

Kumar, K. A., Sugunamma, V., and Sandeep, N. (2018): Impact of non-linear radiation on MHD non-aligned stagnation point flow of micropolar fluid over a convective surface, Journal of Non-Equilibrium Thermodynamics, Vol. 43, No. 4, PP. 327-345. https://doi.org/10.1515/jnet-2018-0022

Kumar, K. A., Sugunamma, V., and Sandeep, N. (2020): Effect of thermal radiation on MHD Casson fluid flow over an exponentially stretching curved sheet, Journal of Thermal Analysis and Calorimetry, Vol. 140, Pp. 2377-2385. https://doi.org/10.1007/s10973-019-08977-0

Nadeem, S., and Hussain, S. T. (2014): Heat transfer analysis of Williamson fluid over exponentially stretching surface, Applied Mathematics and Mechanics, Vol. 35, No. 4, Pp. 489-502. https://doi.org/10.1007/s10483-014-1807-6

Nadeem, S., Hussain, S. T., and Lee, C. (2013): Flow of a Williamson fluid over a stretching sheet, Brazilian Journal of Chemical Engineering, Vol. 30, Pp. 619-625. https://doi.org/10.1590/S0104-66322013000300019

Nagaraja, B., and Gireesha, B. J. (2021): Exponential space-dependent heat generation impact on MHD convective flow of Casson fluid over a curved stretching sheet with chemical reaction, Journal of Thermal Analysis and Calorimetry, Vol. 143, Pp. 4071-4079. https://doi.org/10.1007/s10973-020-09360-0

Nandi, S., and Kumbhakar, B. (2022): Viscous dissipation and chemical reaction effects on tangent hyperbolic nanofluid flow past a stretching wedge with convective heating and Navier's slip conditions, Iranian Journal of Science and Technology, Transactions of Mechanical Engineering, Vol. 46, No. 2, Pp. 379-397. https://doi.org/10.1007/s40997-021-00437-1

Nawaz, M., and Sadiq, M. A. (2021): Unsteady heat transfer enhancement in Williamson fluid in Darcy-Forchheimer porous medium under non-Fourier condition of heat flux, Case Studies in Thermal Engineering, Vol. 28, 101647. https://doi.org/10.1016/j.csite.2021.101647

Nawaz, S., Hayat, T., and Alsaedi, A. (2019): Analysis of entropy generation in peristalsis of Williamson fluid in curved channel under radial magnetic field, Computer methods and programs in biomedicine, Vol. 180, 105013. https://doi.org/10.1016/j.cmpb.2019.105013

Panigrahi, L., Kumar, D., and Panda, J. P. (2021): Impact of chemical reaction, hall current, and radiation on MHD flow between vertical walls, Journal of Engineering Thermophysics, Vol. 30, Pp. 122-144.

Prasad, K. V., Vajravelu, K., and Datti, P. S. (2010): Mixed convection heat transfer over a non-linear stretching surface with variable fluid properties, International Journal of non-linear Mechanics, Vol. 45, No. 3, Pp. 320-330. https://doi.org/10.1016/j.ijnonlinmec.2009.12.003

Raju, C. S. K., and Sandeep, N. (2016): Heat and mass transfer in MHD non-Newtonian bio-convection flow over a rotating cone/plate with cross diffusion, Journal of Molecular Liquids, Vol. 215, Pp. 115-126. https://doi.org/10.1016/j.molliq.2015.12.058

Ramadevi, B., Kumar, K. A., Sugunamma, V., and Sandeep, N. (2019): Influence of non-uniform heat source/sink on the three-dimensional magnetohydrodynamic Carreau fluid flow past a stretching surface with modified Fourier's law, Pramana, Vol. 93, Pp. 1-11. https://doi.org/10.1007/s12043-019-1847-7

Ramadevi, B., Kumar, K. A., Sugunamma, V., Reddy, J.V.R., and Sandeep, N. (2020): Magnetohydrodynamic mixed convective flow of micropolar fluid past a stretching surface using modified Fourier's heat flux model, Journal of Thermal Analysis and Calorimetry, Vol. 139, Pp. 1379-1393. https://doi.org/10.1007/s10973-019-08477-1

Reddy, J. V., Sugunamma, V., and Sandeep, N. (2017). Dual solutions for heat and mass transfer in chemically reacting radiative non-Newtonian fluid with aligned magnetic field, Journal of Naval Architecture and Marine Engineering, Vol. 14, No. 1, Pp. 25-38. http://dx.doi.org/10.3329/jname.v14i1.25907

Sakiadis, B.D. (1965): Boundary-layer behavior on continuous solid surfaces: II. The boundary layer on a continuous at surface. AIChE Journal Vol. 7, No. 2, pp. 221-225. https://doi.org/10.1002/aic.690070211

Salahuddin, T., Khan, M., Saeed, T., Ibrahim, M., and Chu, Y. M. (2021): Induced MHD impact on exponentially varying viscosity of Williamson fluid flow with variable conductivity and diffusivity, Case Studies in Thermal Engineering,Vol. 25, 100895. https://doi.org/10.1016/j.csite.2021.100895