**Effect of Soret Number on Axis Symmetric Flow Using Successive Linearization Method**

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**Abstract**

In this research, the radially increasing axisymmetric discharge of an electrically conducting fluid across a surface is accurately evaluated mathematically using the influence of Soret number. The surface is extended at an exponential speed in a radial direction, which causes flow trends. New similarity transformations are discussed in order to transform the governing, transform nonlinear partial differential equations into standard derivatives. The Successive Linearization Method is used to perform mathematical analysis for flow performing. The Chebyshev spectral technique is utilized to resolve the linear system in order to provide accurate solutions that converge effectively to the whole numerical solution. Comparisons with earlier research are conducted to evaluate the validity of the results on the distribution of velocity, temperature and concentration. Verify convergence and accuracy of the solution, the impacts of a few fluid factors are identified and explained.

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1. **Introduction**

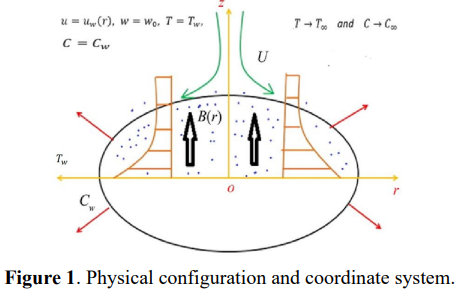
Recent years have seen a greater focus on heat transmission and boundary-layer flow in viscous fluid over extended surfaces because of its usefulness in engineering. Such flows are particularly fascinating for cooling melt-down sheets or electronic chips, plastic sheet extrusion aerodynamics, boundary layer accompanying liquid film in upgrading techniques, and other applications. In the industry that makes fiber, cools, dries off papers, evaporates polymers, etc. These processes differ significantly at the expanding surface depending on the mass transfer. J.Ahmed et al. [1] have examined the power law fluid's axisymmetric flow and heat transmission. Examine on the heat transfer of a sticky substance across a horizontally extended nonlinear sheet has been explored by Shahzad A et al. [2]. Bhattacharyya et al. [3] a stretched sheet with suction or blowing to impart reactive solute transfer. Najib et al. [4] Discuss on chemical processes past an expanding or contracting cylinder, mass transfer, and stagnation point flow. Further, Abbas et al. [5] a third-grade fluid's stagnation-point flow was studied using a hybrid numerical method to examine the impact of chemical reaction. Fairbanks and Wike [6] A chemical reaction's impact on an isothermal laminar flow across a flat plate has been investigated. H.Andersson et al. [7] A chemically reactive substance's diffusion from a stretched sheet is investigated. G.C.Dash et al. [8] investigated a arithmetical method for boundary layer flow over a sheet that is elongation and contracting. Nayak B et al. [9] investigated the effect of axisymmetric flow on a radially extended sheet's chemical reaction. B. Malga et al. [10] said the impact of Soret numbers on the MHD flow of Jeffrey fluid using a finite elements vertical permeable moving plate. Pramod P et al. [11] explained the effects of heat emission and the magnetic field created on the convection of viscous dissipative fluid flowing naturally over an inclined plate. Mishra et al. [12] examined the mass and heat transfer in an MHD micropolar fluid with a heat source present. Azeem Shahzad et al. [13] investigated a numerical approach for axisymmetric flow with heat transfer over an increasingly stretched sheet.  Ibrahim and Makinde et al. [14] explored the effects of magnetic fields, wall suction, heat, and mass transfer on boundary layer flow over an accelerating vertical plate. Recently, Bala Siddulu.M et al. [15] examined the consequences of chemical reactions and viscous dispassion on axisymmetric flow across a radially extended surface. Several recent investigations (see [16-20]) have employed the SLM. They proved the sequential linearization technique is precise and converges fast in numerical results while comparing with other existing semi-analytical strategies like the Adomian decomposition method. C. Mangamma et al. [21] explored impact of Dufour and chemical reactions on the hydrodynamic flow of an unstable magneto past a plate moving exponentially. Ch. Mangamma et al. [22] used the galerkin method to examine the effects of radiation and viscous dissipation on a vertical porous panel with temperature change. P Pramod kumar et al. [23] researched the mass transfer and unstable free convection flow of a viscous fluid at finite element analysis across an accelerating vertical permeable plate having chemical reaction & suction.

In this paper, we aim to expand the work of Bala Siddulu.M et al. [15] examined the chemical reaction effects and viscous dispassion on axisymmetric flow across a radially extended surface. The nonlinear equations been transformed into a system of linear differential equations using the successive linearization technique (SLM). We will use the Chebyshev pseudospectral technique to work out the higher order deformation on linear differential equations. According to the Chebyshev spectral collocation differentiation matrix presented in [16], the auxiliary linear operator is described. Several recent researches (see [16–20]) have used the SLM. They revealed that the sequential linearization method converges fast and accurately into the numerical results, while comparing with the current semi-analytical techniques, including the Adomian decomposition technique. In place of more conventional numerical techniques like finite differences and R-K methods, the SLM methodology may be applied to handle highly nonlinear systems of boundary value problems.

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1. **Mathematical model**

Consider a continuous, axisymmetric, two-dimensional MHD flow across an extending surface that corresponds with the plate z=0, containing an electrically conducting viscous fluid, viscous dispassion, and chemical reaction. Conducting fluid flows when the sheet is stretched along the route with U(r) =r, where is a dimensional constant. The sheet's surface concentration is known to be, and its fluid concentration is. The temperature of the sheet is kept constant.The surrounding fluid's temperature is indicated by. In figure 1, the flow geometry is displayed.



Considering preceding statement, the governing stable two-dimensional boundary layer calculations of an electrically performing viscous fluid for momentum and heat transmission follows B.S. Malga et al. [15]

++ = 0 (1)

uw = ) - (r) (2)

= (3)

= +-C (4).

Velocity coefficients along axial, transverse axes are represented by u nd w, respectively. Fluid properties include fluid density (), temperature (T), thermal diffusion coefficient (), and specific heat (), fluid concentration(C), diffusion coefficient (D),ambient concentration ( and changing magnetic field) and electrical conductivity (. The following is the corresponding boundary for the elements of concentration and velocity:

(5)

The following new similarity transformations were proposed in order to nondimensionalize equations (2), (3), and (4):

Φ (ƞ) (6)

Where the change in solute amount in the r-direction is represented by the Power law coefficient n, is the changing surface concentration, and is a constant.

We analyze the electrically conducting incompressible viscous flow engaged across an extended sheet in a steady axisymmetric MHD flow. Figure 1 shows how the issue's geometry is constructed. The stretching sheet in the direction of, here ṟ is the direction of surface stretching and is a dimensional constant, affects the flow of conductive fluids. In addition, it is assumed that and represents temperature, solute concentration of the extended sheet, respectively. At the infinity, the ambient temperature, solute concentration are given by the variables, and, respectively. The strength of the field is recaptured in the current investigation by the formula, where denotes the uniform magnetic field strength. The magnetic field exerts a positive Z-direction along the sheet's normal. Since the divergence should be zero, the magnetic field differs in both the radial and vertical directions when it does so. The boundary layer technique may be used to get the equation for the continuity, linear momentum, energy. Maintaining visibility while eq. (1) is satisfied, eqs. (2), (3), (4), and (5) along with the boundary condition are reduced to the following.

(ƞ) (ƞ) (7)

(ƞ) (8)

(9)

Where Prandtl number, Schmidt number, Chemical reaction parameter and magnetic parameter,

Is the Eckert number, is the Soret number.

Following physical boundary constraints are necessary for the governing equations mentioned below

(ƞ) ƞ (10a)

(10b)

Fundamental mechanism governing the transfer of flow, mass and heat transfer are characterized by key parameter as the skin friction, Nusselt number, Sherwood number S defined as:

, S

The wall mass flux, wall heat flux, and wall shear stress are represented by the terms, respectively, with the corresponding formulas

|z=0

Utilizing Eqs. (6)– (12), the mass transfer, drag, and heat provide the following results.

, , S

1. **Method of Solution**

To explore, the application of successive linearization, for Eqs. (7), (8) and (9) assuming that solutions f(դ), ϴ ( and 𝞥 ( may be extended to

=+

(= (+ (11)

Φ (= () +

Where’s,’s,’s unidentified values while, and (m< i) are known functions that are obtained by solving the linear portion of the system of equations repeatedly that arises from modifying the governing equations.

Where’s,’s,’s unknown function and the known functions, and (m< i) are derived by iteratively solving the linear part of the system of equations that results from changing the governing equations. The basic concept of the SLM is that as grow larger, get less and lesser.

i.e.

So let’s start with the initial assumptions made by

=1-, ( = () = (12)

They are selected in order to meet the boundary constraints Once equation (11) is substituted within the regulating formulas, linearized form of equations solved consecutively, yielding,,, i 1. Only the linear terms are taken into consideration. The given linearized equations need to be solved by substituting the assumptions (11) in the system (7)-(9) and neglecting the non-linear term gives

= (13)

(14)

(15)

Depending on he border circumstances

() = 0; () = () = 0 (16)

Where = - []

= -[]

=]

After finding each solution for (i by repeatedly completing equations the approximate solutions are found to be

, (17)

In the SLM approximation, M represents the order. Once the RHS of Eqs (13)–(15) For i=1, 2, 3... And the coefficient parameter are known (from earlier iterations), equations may be easily solved using any conventional numerical technique. In this work, the successive linearization approach was utilized to solve Equations (13) - (15). This method's intention is to estimate the dependent functions by utilizing Chebyshev's interpolating polynomials to collocate them at the Gauss-Lobatto point, which is given as

, j=0, 1……N (18)

Using any domain truncation technique, the physical area [0, ∞] is translated into the region [-1, 1] in order to perform the strategy. The total number of collocation points employed is N+1, where, as opposed to [0, ∞], the issue is addressed on the interval. The approximate representations of the unknown functions fi, θi, φi at the collocation points are

,=0,1,2…. (19)

Chebyshev polynomial is:

(20)

At the collocation locations, the derivatives of the variables are shown as

,

k =1, 2… (21)

Where the chebyshev spectral differentiation matrix is D and differentiation order is r whose entries are

j ,=0,1,.. (22)

,N

Equation (21) may be substituted into the equation system (13)–(15) to obtain the following algebraic equation system.

Hence, above equations written as

(23)

The matrix is a (3N+3) × (3N+3) square, while the column vectors are 3N+1, given by

= , =, (24)

Where

,

,

,

-

The result is as follows:

1. **Results and Discussion**

The numerical solution of the set of boundary conditions (10a & 10b) and the collection of ordinary differential equations with nonlinear (7–9) can be obtained from successive linearization approach. We present the findings for the key variables impacting the flow in this chapter. In this study, all results were acquired using MATLAB program. Comparison with results from the literature was done to ensure the proposed successive linearisation technique (SLM) was accurate. Unless otherwise stated, the graphs and tables in this study were produced using the N = 30, L= 15, n=1, Sc=0.5, gamma=0.3, Ec=0.8, 0.1, Pr=0.7, M=1andSr=0.1 Parameters, which provided the SLM results with enough precision.



Figure2(A) Effect of M on the Velocity Profile

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Figure 2(B) Effect of M on the Temperature Profile

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figure 2(C) Effect of M on the Concentration Profile

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Fig3(A) Effect of Prandtl number-Pr on the Temperature Profile

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Fig 3(B) Effect of Viscous dissipation-Ec on the Temperature Profile



fig 4(A) Effect of on mass distribution



Fig 4(B) Effect of on mass rate distribution



fig 5(A) effect of Sc on mass distribution



Fig 5(B) Effect of Sc on rate of mass distribution.



Fig 6(A) effect of Sr on mass distribution.



Fig 6(B) Effect of Sr on rate of mass distribution.

**Velocity**

Figure 2(A) shows the impact of the similarity variable ƞ on magnetic parameter M, velocity. The figure shows that a drop in the velocity profile is caused by a rise in magnetic parameter M.

**Temperature**

Figure 2(B) demonstrates that ᴍagnetic field M affects the temperature distribution θ(ƞ) in relation to variable ƞ. From the Fig, It is evident to us that the temperature distribution grows as the magnetic parameter M becomes higher.Fig3(A) impact of the Prandtl number on the dimensionless temperature distribution is discussed. We observed the thermal boundary layer decreased with increasing dissipation. The Prandtl number defines the ratio between diffusivity of momentum and thermal diffusivity.The thickness of the boundary layer increases with decreasing Prandtl numbers, which further reduces heat transfer. Fig3(B) displays the temp. distribution for various values of the eckert number (Ec).Because frictional heating retains heat energy in the fluid, it is clear that a rise in the Eckert number improves the temperature profiles. The association between internal energy and kinetic energy is expressed by this physical parameter.

**Concentration**

Figure 4(A) illustrates that the stretching parameter, or power-law coefficient, effects the concentration and mass transfer rate,accordingly. The concentration boundary layer's breadth and the concentration profile both slow down as the power-law factor rises. fig 4(B) demonstrates that increasing the stretching parameter-n value causes the rate of mass transfer to drop across a region of variance, after which a reversal trend appears.By raising the stretching value n, we looked into the possibility of reducing the concentration on the boundary layer. Figure 5(A) shows that the concentration profile is affected by the Schmidt number.It has been shown that the concentration profile decreases for heavier responding species when the Schmidt number Sc increases. Thus, it can be concluded that for high values of Sc concentration profile, species with low diffusivity and reactive species with positive reaction rate coefficient will decrease. Figure 5((B) displays the profile of the mass transfer rate for various Schmidt number values. The profile is found to be almost linear at n=0, and it subsequently declines as n increases up to a specific point before the mass flux improves. Figure 6(A) illustrates that soret affects the concentration field.As the soret number increases, the thickness of Concentration boundary layer also expand. figure 6(B) displays the mass transmission profile rate for various Soret number values. It is clear that the boundary layer contains a variation point. Additionally, it is seen that the rate of mass transmission significantly drops up to the variation region, beyond which an increase in the Soret number indicates the opposite outcome. Thus, It is found that the magnetic parameter and the addition of stronger species are the causes of the twofold character on the profile.

From fig7(),7()the Nusselt number coefficient is depicted againest the power law coefficient(n),magnetic parameter(M) respectively.It is clear from observation that Nusselt number exhibits a decreasing with respect of both the prandtl number, magnetic parameter. Fig 8 displays Sherwood number in relation to the magnetic parameter.The Sherwood number drops in proportion to the rise in the Soret number.

Top of Form

Fig 7(a): Effect of M on Nusselt number profile

Fig 7(b): Effect of Pr On Nusselt Number Profile

Fig 8ffect of M on herwood number profile

**Table 1 Calculation of Skin Friction, Nusselt & Sherwood number**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  |  |  |  |  |  |  |  |  | **(0)** |
| 1 | 0.0 | 0.7 | 0.8 | 0.0 | 0.05 | 0.0 | 0.0 | -1.0000 | 0.2975 | 0.1216 |
| 2 | **1.0** | 0.7 | 0.8 | 0.0 | 0.05 | 0.0 | 0.0 | -1.4142 | 0.0205 | 0.1160 |
| 3 | **2.0** | 0.7 | 0.8 | 0.0 | 0.05 | 0.0 | 0.0 | -1.7321 | -0.1143 | 0.1133 |
| 4 | **3.0** | 0.7 | 0.8 | 0.0 | 0.05 | 0.0 | 0.0 | -2.0000 | -0.2206 | 0.1117 |
| 5 | 0.0 | **2.0** | 0.8 | 0.0 | 0.05 | 0.0 | 0.0 | -1.0000 | 0.2975 | 0.1216 |
| 6 | 0.0 | **4.0** | 0.8 | 0.0 | 0.05 | 0.0 | 0.0 | -1.0000 | 0.2748 | 0.1216 |
| 7 | 0.0 | **6.0** | 0.8 | 0.0 | 0.05 | 0.0 | 0.0 | -1.0000 | 0.1953 | 0.1216 |
| 8 | 0.0 | 0.7 | **1.0** | 0.0 | 0.05 | 0.0 | 0.0 | 1.0000 | 0.1511 | 0.1216 |
| 9 | 0.0 | 0.7 | **2.0** | 0.0 | 0.05 | 0.0 | 0.0 | 1.0000 | -0.1523 | 0.1216 |
| 10 | 0.0 | 0.7 | **3.0** | 0.0 | 0.05 | 0.0 | 0.0 | 1.0000 | -0.4556 | 0.1216 |
| 11 | 0.0 | 0.7 | 0.8 | **1.0** | 0.05 | 0.0 | 0.0 | 1.0000 | 0.2118 | 0.1611 |
| 12 | 0.0 | 0.7 | 0.8 | **2.0** | 0.05 | 0.0 | 0.0 | 1.0000 | 0.2118 | 0.1992 |
| 13 | 0.0 | 0.7 | 0.8 | **3.0** | 0.05 | 0.0 | 0.0 | 1.0000 | 0.2118 | 0.2361 |
| 14 | 0.0 | 0.7 | 0.8 | 0.0 | **0.1** | 0.0 | 0.0 | 1.0000 | 0.2118 | 0.1452 |
| 15 | 0.0 | 0.7 | 0.8 | 0.0 | **0.2** | 0.0 | 0.0 | 1.0000 | 0.2118 | 0.1966 |
| 16 | 0.0 | 0.7 | 0.8 | 0.0 | **0.5** | 0.0 | 0.0 | 1.0000 | 0.2118 | 0.3572 |
| 17 | 0.0 | 0.7 | 0.8 | 0.0 | 0.05 | **0.1** | 0.0 | 1.0000 | 0.2118 | 0.1372 |
| 18 | 0.0 | 0.7 | 0.8 | 0.0 | 0.05 | **0.3** | 0.0 | 1.0000 | 0.2118 | 0.1657 |
| 19 | 0.0 | 0.7 | 0.8 | 0.0 | 0.05 | **0.6** | 0.0 | 1.0000 | 0.2118 | 0.2033 |
| 20 | 0.0 | 0.7 | 0.8 | 0.0 | 0.05 | **1.0** | 0.0 | 1.0000 | 0.2118 | 0.2464 |
| 21 | 0.0 | 0.7 | 0.8 | 0.0 | 0.05 | 0.0 | **0.1** | 1.0000 | 0.2118 | 0.1175 |
| 22 | 0.0 | 0.7 | 0.8 | 0.0 | 0.05 | 0.0 | **0.2** | 1.0000 | 0.2118 | 0.1134 |
| 23 | 0.0 | 0.7 | 0.8 | 0.0 | 0.05 | 0.0 | **0.3** | 1.0000 | 0.2118 | 0.1093 |

**The following results are concluded from the table 1.**

* Skin-friction coefficient, Nusselt and Sherwood numbers, and the Magnetic parameter (M) all show concurrent decreases as M increases.
* The Nusselt number falls as the Prandtl number (Pr) rises.
* Eckert number Ec increases, the local Nusselt decreases while there is no alteration observed in the Sherwood numbers.
* Sherwood, Nusselt, and Skin-friction coefficient improve when the magnetic parameter (M) evolves..
* sherwood number rising as the power-law factor decreases.
* Sherwood number grows as it rises chemical reaction parameter.
* While the Sherwood number falls, the Soret number (Sr) rises.

1. Top of Form
2. **Conclusion**

In this study, we solve a highly systemic nonlinear boundary value problem using successive linearization technique. The approach is applied to MHD free convective mass and heat transport via the soret affect. An ordinary differential equation with appropriate boundary conditions replaces the collection of governing equations and boundary conditions. The shooting iteration technique and Runge-Kutta integration were used to compare the accuracy and convergence of the results to other techniques in the literature. The impacts of different physical factors on the fluid characteristics were displayed in graph form. The following are the primary conclusions drawn from this paper.Since any initial estimate that meets the boundary constraints is acceptable, For choosing linear operators and initial approximations, the SLM proposed a standard procedure. Alternatively, one can select an initial guess using HAM or HPT, It will allow the higher order deformation equations to be integrated.In this investigation, it was discovered that a few iterations of the Successive Linearization Method was sufficient to produce good agreement with the precise answer. SLM converges rapidly and with great accuracy and efficiency. Couple of iterations are required to ensure that the numerical results are accurate. The Temperature and Concentration components grow as M increases, while velocity Profile decreases. Ϲoncentration profile rises with a higher Soret number, while the rate of mass distribution decreases until it reaches the variation region, and vice versa.

Lastly, compared to R-K, Finite Difference, and Keller-Box methods, the Successive Linearization Method solves nonlinear boundary value problems with great accuracy and simplicity.

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**Journal : International Journal of Heat and Mass Transfer**