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Cross-diffusion effects on an exponentially stretching sheet in a doubly stratified viscous fluid

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ABSTRACT

This article analyses the influence of double stratification and cross-diffusion effects on the viscous fluid flow over a porous sheet stretching exponentially by applying the velocity slip at the boundary. The numerical solutions to the governing equations are evaluated using successive linearisation procedure and the Chebyshev collocation method. The results obtained are compared with the existing results in the literature for special cases. The influence of the pertinent parameters on the physical quantities are displayed through graphs.

1. Introduction

The analysis of flow, heat and mass transfer over elongating surfaces is one of the important research area due to its significant use in various chemical, polymer industries and other engineering disciplines. Applications include wire drawing, crystal growth, filaments spinning, paper production, glass fiber, food processing, continuous casting. Sakiadis [1,2] was the first to study the flow due to a stretching sheet. Since then several researchers, to mention a few Aziz [3], Bikash and Sebastien [4], Rohni et al. [5], Nadeem et al. [6], Bhattacharyya and Layek [7], Lare [8], Othman et al. [9] analyzed this flow problem for different stretching surfaces under different physical conditions.

The influence of stratification is an important in the thermal and solutal transport phenomena. Stratification of fluid occurs as a result of the differences in the temperature or concentration or the occurrence of diverse fluids of dissimilar densities. Mukhopadhyay et al. [10] analyzed the solutal transport over a sheet strtching exponentially entrenched in porous medium. Srinivasacharya and Surender [11] examined the impact of thermal and solutal stratification and cross diffusion on a vertical plate in a non-Darcy mixed convection flow. Chandrasekhar [12] investigated the impact of magnetic field and suction on a sheet stretching exponentially embedded in a thermally stratified medium. Lare [13] concluded that an increase in the stratification parameter results in reduction of velocity and temperature profiles. Influence of MHD, radiation and suction over a sheet stretching exponentially, embedded in a thermally stratified nanofluid medium is analyzed by Loganthan and Vimala [14]. Recently, Hayat et al. [15] studied effect of viscous dissipation and radiation on the unsteady flow over an inclined stretching sheet in a thermally and solutally stratified nanofluid.

The Soret effect (thermal diffusion), the existence of a diffusion flux inview of a temperature gradient, become very noteworthy when the thermal gradient is very large. Whereas the energy flux caused by a concentration gradient is termed as the Dufour effect (diffusion-thermo). Generally, these effects are considered as second-order phenomenon and may become significant in areas such as petrology, hydrology, geosciences, etc. Eckert and Drake [16] studied the importance of these effects. Srinivasacharya and Ramreddy [17–19] investigated the influence of cross-diffusion effects over an exponentially stretching under various physical conditions. Srinivasulu and Reddy [20] conformed from their investigation that the rate of heat transfer is decreasing and rate of mass transfer is increasing with increasing values of the dufour number or simultaneous decreasing values of the soret number. Khidir and Sibanda [21] in their investigation, it is concluded that with an increase in both viscous dissipation and radiation parameter, the temperature found to be increase and this investigation is carried out using the successive linearization method. Raju et al. [22] concluded that increasing the value of soret number, skin-frictionis increasing and rate of heat and mass transfers

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are decreasing for both the suction and injection cases. Recently, Sulochana et al. [23] reported that the concentration and heat transfer rate reduces with increasing values of the chemical reaction parameter while it has no much influence on skin-friction coefficient.

Motivated by the above investigations, due to the importance and numerous applications discussed above, and no effort has been made to investigate the effects of slip on boundary layer flow, heat and mass transfer with double stratification over an exponential stretching surface subjected to suction or injection, it is considered in this article.

Table 1
Comparative analysis for $-T'(0)$ by the present method for $\epsilon_1 = 0, \epsilon_2 = 0, \lambda = 0$, $D_f = 0, S = 0$ and $S_r = 0$.

	Nusselt number $-T'(0)$	
Pr	Present	Magyari and Keller [27]
0.5	0.59436352	0.594338
1	0.95478270	0.954782
3	1.86907354	1.869075
5	2.50013157	2.500135
8	3.24211881	3.242129
10	3.66037218	3.660379

2. Mathematical formulation

Consider a stretching sheet in a laminar slip flow of viscous incompressible fluid with a temperature and concentration as T_∞ and C_∞, respectively. The Cartesian framework is selected by taking positive $\tilde{x}-$axis is along the sheet and $\tilde{y}-$axis is orthogonal to the sheet. The stretching velocity of the sheet is assumed as $U_*(\tilde{x}) = U_0\ e^{\frac{\tilde{x}}{L}}$where $\tilde{x}$ the distance from the slit. The sheet with temperature$T_w(\tilde{x})$ and concentration $C_w(\tilde{x})$ is embedded in a stratified medium with ambient temperature $T_\infty(\tilde{x})$ and concentration $C_\infty(\tilde{x})$. $(\tilde{u}_x, \tilde{u}_y)$ is the velocity vector, $\widetilde{C}$ is the concentration and $\widetilde{T}$ is the temperature. The suction/injection velocity of the fluid through the sheet is $V_*(\tilde{x}) = V_0\ e^{\frac{\tilde{x}}{2L}}$, where V_0 is the strength of suction/injection. Further, the slip velocity of the fluid is assumed as $N(\tilde{x}) = N_0\ e^{\frac{-\tilde{x}}{2L}}$, where N_0 is the velocity slip factor. Hence, the following are the equations which governs the present flow

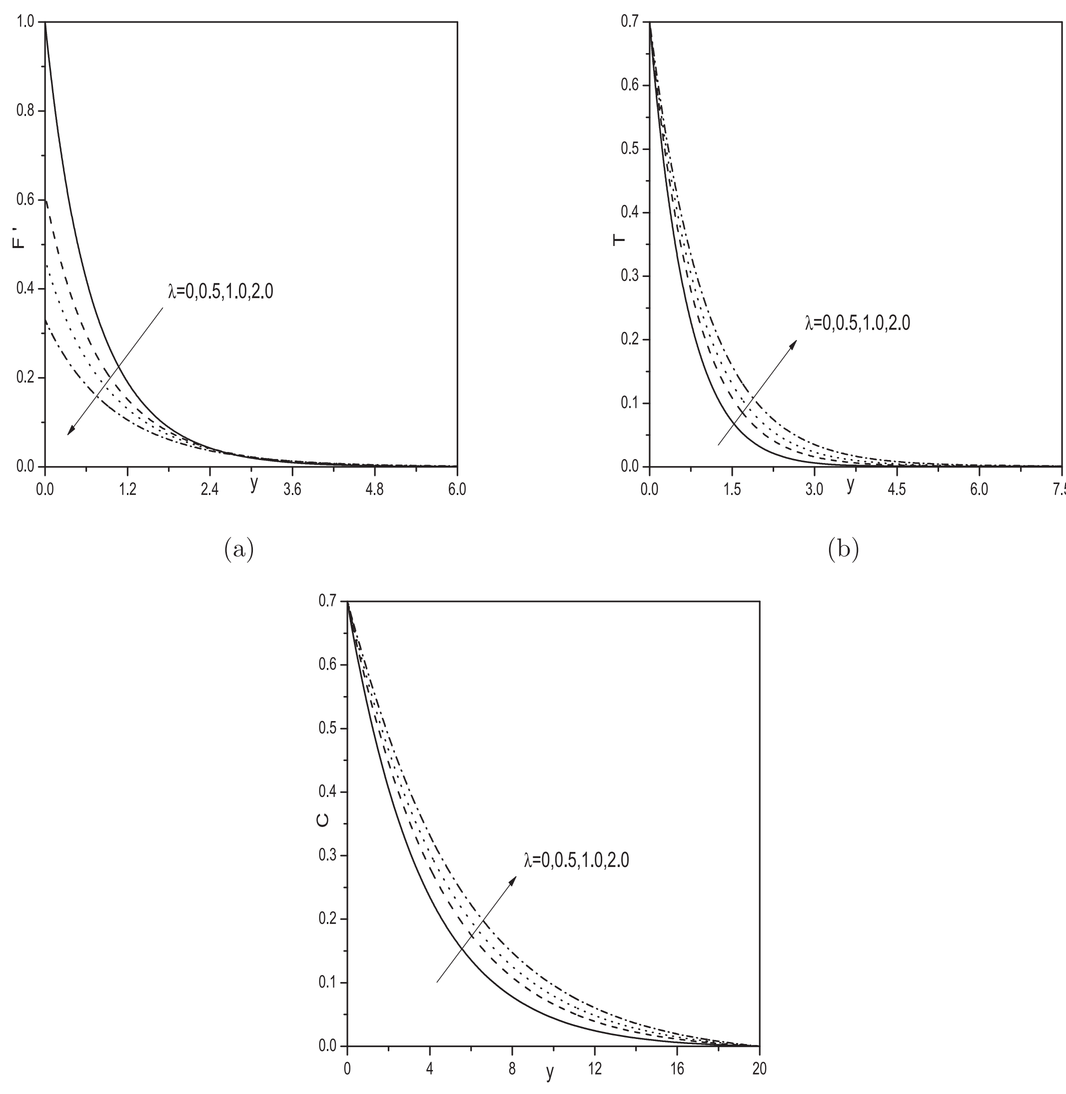

Fig. 1. Influence of λ on (a) F', (b) T and (c) C.

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