Stagnation Point Flow Of Nan fluid Over a Linear Stretching Surface with the Effect of Non Uniform Heat Source/Sink.

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Abstract: The present study is totally concentrated on the numerical solution of stagnation point flow of nano fluid due to a linear stretching surface with the effect of non uniform heat source/sink. A system of coupled ordinary differential equations was obtained by applying similarity transformation on the governing partial differential equations. The system of coupled ordinary differential equations was solved using the fourth order Runge-Kutta method with shooting technique. The role of various parameters involved in the system such as the velocity ratio parameter $\lambda$, the Prandtle number Pr, the Lewis number Le, the Brownian motion parameter $Nb$, the thermophoresis parameter $Nt$, the space dependent heat source/sink parameters $A$ and temperature dependent heat source/sink parameter $B$ are sketched graphically and discussed. The skin friction $Cf$, the local Nusselt number $Nu$, the local Sherwood number $Sh$, were determined for different cases and analyzed.

Key Words: Linear stretching surface, Stagnation point flow, Nanofluid and non uniform heat source/sink.

Nomenclature

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
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<tbody>
<tr>
<td>$Re$</td>
<td>Local Reynolds number</td>
</tr>
<tr>
<td>$Sh$</td>
<td>Local Sherwood number</td>
</tr>
<tr>
<td>$Nu$</td>
<td>Local Nusselt number</td>
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<tr>
<td>$Cf$</td>
<td>Skin friction</td>
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<tr>
<td>$\lambda$</td>
<td>Velocity ratio parameter</td>
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<td>$Pr$</td>
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<td>$Le$</td>
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<td>$Nb$</td>
<td>Brownian motion parameter</td>
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<td>$Nt$</td>
<td>Thermophoresis parameter</td>
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<tr>
<td>$A$</td>
<td>Space dependent heat source/sink parameter</td>
</tr>
<tr>
<td>$B$</td>
<td>Temperature dependent heat source/sink parameter</td>
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</tbody>
</table>

I. Introduction

Nano fluids are two phase fluids involving base fluid and nano sized (1-100 nm) particles (nano particles) suspended within them. Some of the base fluids are water, oil, glycol, polymeric solutions etc. Examples of the materials used for nanoparticles are like alumina, silica, diamond graphite, AlO3 CuO, Ag, and Cu. A properly and efficiently synthesized nanofluid provides high specific surface area that allows to have more heat transfer surface between particles and fluids, more stable dispersions of the nanoparticles, minimized particles clogging, adjustable properties such as thermal conductivity by varying particle concentration, the collision and interaction among particles, the surface of the flow passage and base fluids are intensified.

The stagnation point flow of nanofluid over a linear stretching surface is the most applicable study in technology and manufacturing industries. Some of the applications are saving power using nanofluid in closed loop cooling cycles, in the extraction of Geothermal power nanofluids used to cool the pipes exposed to high temperature, extrusion, melting spinning, the hot rolling, wire drawing, glass fiber production, manufacturing of plastic and rubber sheets, cooling of large metallic plate in bath, polymer sheets and filaments are manufactured by continuous extrusion of the polymer from a die to a mind up roller.

Khan and Pop [1] have investigated the effect of stretching flat surface on a laminar fluid flow of nanofluid numerically. Hazem [2] has studied the role of heat generation/absorption on the steady hydro magnetic laminar three dimensional stagnation point flow of an incompressible viscous fluid impinging on a permeable stretching sheet numerically. Makinde and Aziz [3] have analyzed the numerical study on the boundary layer flow induced in a nanofluid over a linearly stretching sheet with the influence of various parameters involved. Krishnendu [4] has reported the contribution of non uniform heat flux on heat transfer in a
boundary layer stagnation point flow over a shrinking sheet. Mohanty et al. [5] have presented the combined effect of heat and mass transfer in Jeffreys fluid due to a stretching sheet to transverse magnetic field in the presence of heat source/sink. Thommaandru et al. [6] have explored the role of MHD and heat source/sink on free convection boundary layer flow of nanofluid over a non linear stretching sheet. Vijendra and Shweta [7] have explained the contribution of non uniform heat source/sink with variable thermal conductivity on MHD flow and heat transfer for Maxwell fluid over exponentially stretching sheet through a porous medium. Gireesha et al. [8] have examined the influence of non uniform heat generation/absorption and chemical reaction on MHD casson fluid boundary layer flow over a permeable stretching sheet. Sarojamma and Vendabai [9] have analyzed the effect of magnetic field and heat source/sink on the steady boundary layer flow and heat transfer of Casson nano fluid over an exponentially stretching vertical cylinder a long its radial direction. Ramesh [10] has investigated the role of temperature dependent heat generation/absorption on the flow of Jeffrey nanoliquid near stagnation point towards a permeable stretching sheet. Chenma and Shankar [12] have presented the influence of radiation and internal heat generation/absorption on heat transfer in a nano fluid stagnation point flow over a stretching/shrinking sheet embedded in a porous medium. Madasi et al. [26] have explained the role of temperature dependent heat generation/absorption on the mixed convection flow over a vertical stretching/shrinking sheet with suction/injection. Sreenivasulu et al. [17] have explored the effect of viscous dissipation on MHD boundary layer flow of a radiating nanofluid over a non linear stretching sheet with uniform heat source. Hayat et al. [18] have presented the contribution of thermal radiation and heat source/sink on the mixed convection flow of Non Newtonian nano fluid over a stretching surface. Elsayed et al. [19] have examined the effect of thermal radiation on a steady two dimensional boundary layer MHD stagnation point flow and heat transfer of incompressible micro polar fluid over stretching sheet. Saidulu and Venkata [20] have presented the influence of thermal radiation, suction/blowing, viscous dissipation, heat source/sink and chemical reaction on the boundary layer flow of a nan Newtonian casson fluid with heat and mass transfer towards a porous exponentially stretching sheet with velocity slip and thermal slip conditions. Raju et al. [21] have studied the role of heat source/sink on MHD two dimensional ferro fluid flows past a cone and a vertical plate in the presence of volume fraction of ferrous nano particles. Kishan et al. [22] have investigated the steady MHD boundary layer flow of an electrically conducting nano fluid due to an exponentially permeable stretching sheet with heat source/sink in the presence of thermal radiation. Mohan et al. [23] have explored the effect of non linear thermal radiation on MHD casson fluid flow over a non-linearly stretching sheet. Dodda et al. [24] have examined the influence of velocity, temperature concentration slips on the steady two dimensional flows of a viscous nano fluid MHD and heat transfer for the boundary layer flow over non-linear stretching sheet. Mohamed and Tarek [25] have reported the effect of nonlinear thermal radiation and convective boundary conditions on the hydro magnetic nanofluid boundary layer flow over a moving surface with variable thickness. Madasi et al. [26] have explained the role of non-uniform heat source/sink on a stagnation point flow of MHD casson nano fluid over exponentially stretching sheet with heat and mass transfer. Mahatha et al. [27] The influence of nonuniform heat generation/absorption and Newtonian heating on the steady two dimensional laminar stagnation point boundary layer nano fluid flow past a stretching sheet in the presence of an external uniform magnetic field is investigated. Auralda and Yegammal [28] The influence of the n-order chemical reaction on the free convective unsteady MHD boundary layer flow of nano fluid over a permeable shrinking sheet is studied. Shakhaaasot et al. [29] explored the effect of magnetic field of thermal radiation-diffusion, heat generation and viscous dissipation on a two dimensional flow of an incompressible Williamson fluid of Cattaneo-christov heat flux type over a linearly stretched surface. Jain et al. [30] have clearly put the different numerical methods specifically the Runge-Kutta method.

On the bases of above literatures, it is known that a number of investigations have been conducted on the stagnation point flow of nanofluid over a linear stretching surface. However to the best of the author’s knowledge the problem of stagnation point flow of nanofluid over a linear stretching surface with the effect of non uniform heat source/sink has not yet addressed. Therefore in the present paper, we have dealt with the stagnation point flow of nanofluid over a linear stretching surface with the effect of non uniform heat source/sink. The governing equations are transformed into Non-linear ordinary differential equations using suitable similarity transformation and the results are solved numerically using the fourth Runge-Kutta method. We investigated the effect of the relevant parameters using several set of values of the parameters and the results are analyzed for the flow and heat transfer characteristics.
II. Mathematical Formulation:

Let us assume that the flow is steady two dimensional stagnation point flow of nanofluid due to a linear stretching sheet. Consider the velocity of the stretching sheet to be \( u(x) = ax \) and the velocity of the free stream flow to be \( u(x) = bx \), where \( a, b \) are constants and \( x \) is the coordinate measured along the stretching sheet. The flow is carried out at \( y \geq 0 \), where \( y \) is the coordinate measured normal to the stretching sheet. Assume that \( T_w \) is the temperature at the stretching sheet while \( T_{\infty} \) to be the temperature of the nanofluid. Moreover it is assumed that the base fluid and the nano particles are in thermal equilibrium and no slips occur between them.

\[ \text{Figure 1 physical sketch of the problem} \]

With the above assumptions the governing equations for the boundary layer motion, energy and concentration in the presence of non uniform heat source/sink and viscous dissipation are as follows.

\[
\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = 0 \tag{1}
\]

\[
u \frac{\partial u}{\partial x} + v \frac{\partial u}{\partial y} = -\frac{\partial p}{\partial x} + \frac{\partial^2 u}{\partial y^2} + u \frac{\partial u}{\partial x} \tag{2}
\]

\[
u \frac{\partial T}{\partial x} + v \frac{\partial T}{\partial y} = \frac{\partial^2 T}{\partial y^2} + \tau \left[ D_p \frac{\partial c}{\partial y} + \frac{D_c}{T} \left( \frac{\partial T}{\partial y} \right)^2 \right] + \frac{q^m}{\rho c_p} \tag{3}
\]

\[
u \frac{\partial c}{\partial x} + v \frac{\partial c}{\partial y} = D_n \frac{\partial^2 c}{\partial y^2} + \frac{D_c}{T} \frac{\partial T}{\partial y} \tag{4}
\]

\( q^m \) is the space and temperature dependent heat source/sink that is given \[8\] as;

\[ q^m = \frac{KN}{M^2} \left[ A(T_w - T_{\infty}, f' + B(T - T_{\infty}) \right] \]

Boundary conditions are

\[
\begin{align*}
u &= U_w = ax, \ v = 0, \ T = T_w, \ c = C_w \ & \text{at} \ y = 0 \\
u &= U_w = bx, \ T \rightarrow T_{\infty}, \ c \rightarrow C_{\infty} \ & \text{as} \ y \rightarrow \infty
\end{align*} \tag{5}
\]

Where \( u \) and \( v \) are the velocity components along \( x \) and \( y \) directions respectively, \( \nu \) is the kinematic viscosity, \( \alpha \) is the thermal diffusivity, \( \tau \) is the effective heat capacity of nanoparticle to the heat capacity of the fluid i.e.

\[
\tau = \frac{(\rho c)_p}{(\rho c)_f}
\]

\( D_b \) is the Brownian motion coefficient, \( D_p \) is the thermophoresis diffusion coefficient.

With the help of the similarity transformation below, we have transformed the coupled partial differential equations into a system of ordinary differential equations.

\[
\begin{align*}
\psi &= (ax)^2 \frac{\partial \eta}{\partial \eta}, \ \theta(\eta) = \frac{T - T_{\infty}}{T_w - T_{\infty}}, \ \phi(\eta) = \frac{c - C_w}{C_{\infty} - C_w} \\
\eta &= \left( \frac{ax}{D_n} \right)^2 \frac{\eta}{\eta}, \ u = \frac{\partial \psi}{\partial \eta} = axf', \ v = -\frac{\partial \psi}{\partial \eta} = -(ax)^2 f'(\eta)
\end{align*} \tag{6}
\]

Substituting equation (6) in Equations (2), (3) and (4) we have

\[
\begin{align*}
f'' + \frac{ff'}{\alpha^2} + \frac{f'}{\alpha^2} + \lambda^2 &= 0 \tag{7}
\end{align*}
\]

\[ \theta'' + Pr[Nb \theta' f' + f \theta' + Nt \theta'^2] + [A f' + B' \theta] = 0 \]

\[ \phi'' + Le \phi' + \frac{Nt}{Nb} \theta'' = 0 \tag{8} \]

With associated boundary conditions;

\[
\begin{align*}
f(0) &= 0, \ f'(0) = 1, \ \theta(0) = 1, \ \phi(0) = 1 \ & \text{at} \ \eta = 0 \\
f'(-\infty) &= \lambda, \ \theta(-\infty) \rightarrow 0, \ \phi(-\infty) \rightarrow 0, \ & \text{as} \ \eta \rightarrow -\infty
\end{align*} \tag{9}
\]

\[ \text{Figure 1 physical sketch of the problem} \]

With the above assumptions the governing equations for the boundary layer motion, energy and concentration in the presence of non uniform heat source/sink and viscous dissipation are as follows.
Where $Pr$ is the Prandtl number, $Le$ is the Lewis Number, $Nb$ is the Brownian motion parameter, $A^*$ and $B^*$ are the space dependent, temperature dependent heat source/sink parameters respectively, $A^*>0$ and $B^*>0$ represent heat source and $A^*<0$ and $B^*<0$ indicate heat sink. We know that $Nb$ and $Nt$ involve the x-coordinate and therefore we look for the variability of the local similarity solution that gives chances to investigate the behavior of these parameters at affixed location above the sheet. The skin friction coefficient $Cf_1$, the local Nusselt number $\text{Nu}_x$, and the local Sherwood number $Sh_x$ are given by

$$
Cf_1 = \frac{\mu \left( \frac{\partial u}{\partial y} \right)_{y=0}}{\rho u'\nu}, \quad \text{Nu}_x = -x \left( \frac{\partial T}{\partial y} \right)_{y=0}, \quad Sh_x = -x \left( \frac{\partial C}{\partial y} \right)_{y=0}
$$

(11)

Substituting equations (6) into equations (11), the reduced form will be

$$
Re_x^2 Cf_1 = f''(0), \quad \frac{\text{Nu}_x}{Re_x^2} = \theta'(0), \quad \frac{Sh_x}{Re_x^2} = -\phi'(0)
$$

(12)

### III. Method Of Solution

Using the fourth order Runge-Kutta method along with shooting technique, we solve the coupled ordinary differential equations (7) (8) and (9), with their respective boundary condition equations (10). The system of the ordinary differential equations (7) (8) and (9) are highly non linear higher order differential equations. To solve these equations using the indicated method, first we transform them into a system of first order differential equations by applying the following notations.

Let

$$
\begin{align*}
& f = f(1), \quad f' = f(2), \quad f'' = f(3) \\
& \theta = f(4), \quad \theta' = f(5) \\
& \phi = f(6), \quad \phi' = f(7)
\end{align*}
$$

(13)

Using equations (13) in equations (7), (8) and (9) we have

$$
\begin{align*}
& f'' = -f' f'' + f'^2 - \lambda^2 \\
& \theta'' = -Pr\{Nb\theta' + f'\theta' + Nt\theta''\} - [A^* f(2) + B^* f(4)] \\
& \phi'' = -Le\phi' - \frac{\text{Nu}_x}{Re_x^2} \phi''
\end{align*}
$$

(14)

The boundary conditions are

$$
\begin{align*}
& f_x(1) = 0, \quad f_x(2) = 1, \quad f_x(4) = 1, \quad f_x(6) = 1 \\
& f_x(2) \to 0, \quad f_x(4) \to 0, \quad f_x(6) \to 0 \\
& \text{where} \quad a = 0 \quad \text{and} \quad b = \infty
\end{align*}
$$

(15)

The boundary conditions $f''(0), \theta'(0)$ and $\phi'(0)$ are not included in the system of the ordinary differential equations. Therefore, we calculate the approximate values $f''(0), \theta'(0)$ and $\phi'(0)$ using the shooting technique first and then we apply the fourth order Runge-Kutta method to get $f, \theta$ and $\phi$ as it is clearly indicated in Jain et al. [30]. We choose the step size to be $\Delta h = 0.01$ with accuracy of $10^{-5}$.

### IV. Results And Discussions

The role of various parameters involved in the coupled ordinary differential equations such as the velocity ratio $\lambda$, the prandtl number $Pr$, the Brownian motion parameter $Nb$, the thermophoresis parameter $Nt$, the space dependent and temperature dependent heat source/sink parameters respectively $A^*$ and $B^*$ and the Lewis number $Le$ on the stagnation point flow of nano fluid over a linear stretching surface have been drawn their graphs and discussed.

#### Table 1 Comparison of results for the reduced Nusselt number - $\theta'(0)$

<table>
<thead>
<tr>
<th>$Pr$</th>
<th>Present result of - $\theta'(0)$</th>
<th>Khan and Pop [1] results of - $\theta'(0)$</th>
</tr>
</thead>
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<tr>
<td>0.7</td>
<td>0.4544</td>
<td>0.4540</td>
</tr>
<tr>
<td>2.0</td>
<td>0.9114</td>
<td>0.9113</td>
</tr>
<tr>
<td>7.0</td>
<td>1.8954</td>
<td>1.8954</td>
</tr>
<tr>
<td>10.0</td>
<td>3.3540</td>
<td>3.3536</td>
</tr>
<tr>
<td>70.0</td>
<td>6.4823</td>
<td>6.4821</td>
</tr>
</tbody>
</table>

#### Table 2 Variation of $\text{Nu}_x$ with $Nb$ and $Nt$ where $Pr=Le=10$
Table 3 Variation of $Sh_x$ with $Nb$ and $Nt$, for $Le=Pr=10$

<table>
<thead>
<tr>
<th>$Nt$</th>
<th>Present</th>
<th>Khan and Pop [1]</th>
</tr>
</thead>
<tbody>
<tr>
<td>$Nb=0.1$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.1</td>
<td>2.199E-1</td>
<td>2.191E-1</td>
</tr>
<tr>
<td>0.2</td>
<td>2.754E-1</td>
<td>2.728E-1</td>
</tr>
<tr>
<td>0.3</td>
<td>3.730E-1</td>
<td>3.663E-1</td>
</tr>
<tr>
<td>$Nb=0.2$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.1</td>
<td>2.199E-1</td>
<td>2.191E-1</td>
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<td>0.2</td>
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</tr>
<tr>
<td>0.3</td>
<td>3.730E-1</td>
<td>3.663E-1</td>
</tr>
<tr>
<td>$Nb=0.3$</td>
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<td></td>
</tr>
<tr>
<td>0.1</td>
<td>2.199E-1</td>
<td>2.191E-1</td>
</tr>
<tr>
<td>0.2</td>
<td>2.754E-1</td>
<td>2.728E-1</td>
</tr>
<tr>
<td>0.3</td>
<td>3.730E-1</td>
<td>3.663E-1</td>
</tr>
<tr>
<td>$Nb=0.4$</td>
<td></td>
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</tr>
<tr>
<td>0.1</td>
<td>2.199E-1</td>
<td>2.191E-1</td>
</tr>
<tr>
<td>0.2</td>
<td>2.754E-1</td>
<td>2.728E-1</td>
</tr>
<tr>
<td>0.3</td>
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<td>3.663E-1</td>
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<tr>
<td>$Nb=0.5$</td>
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<tr>
<td>0.1</td>
<td>2.199E-1</td>
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<tr>
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<td>0.3</td>
<td>3.730E-1</td>
<td>3.663E-1</td>
</tr>
</tbody>
</table>

The present results for the considered Prandtl numbers in table 1 agree to three decimal places with the results of Khan and Pop [1]. The results of table 1 clearly illustrate that the Nusselt number increases as the prandtl number increases and this is analogous to the result obtained in a natural convection from a vertical plate in a regular fluid.

In tables 2 and 3 above, for the given values of the Brownian motion parameter $Nb$ and the thermophoresis parameter $Nt$ the present result coincides with the results presented by Khan and Pop [1].

Table 4 Numerical results of $f''(0), -\theta'(0), and -\phi'(0)$ for different values of $\lambda$, $Pr$, $Nb$, $Nt$, $A^*$, $B^*$ & $Le$

As $Nb$ varies from 0.1 to 0.5 taking $Nt$ constant the reduced Nusselt number decreases. Because increasing Brownian motion enforces a large extent of the fluid to wedge together so that the thermal boundary layer thickness increases however the Nusselt number diminish. The Sherwood number increases considerably with the increase of $Nb$ from 0.1 to 0.3 and approaches to plateau beyond $Nb=0.3$. Table 2 and 3 show that the thermophoresis parameter has the same contribution as the Brownian motion parameter on the Nusselt number but the Sherwood number increases with the increase thermophoresis. This due to the fact that the thermophoresis diffusion perforates deeper in to the fluid and makes to move nano particles from hot to cold areas as $Nt$ increases. This cause both the thermal boundary layer and concentration boundary layers thicken and hence the Nusselt number decreases as well as the Sherwood number increases.

In the first part of table 4 above one can easily understand that as the velocity ratio $\lambda = \frac{b}{a} < 1$ (i.e. the velocity of the stretching surface is greater than the free stream velocity) increases then the velocity of the fluid and the boundary layer thickness increase. The second, third and fourth parts of table 4 have analogous results for $Pr$, $Nb$ and $Nt$ as table 1, 2, 3. In the fifth and sixth parts of table 4 increasing $A^*$ and $B^*$ result in the increase of the generation of thermal energy. So that the nano fluid temperature enlarged and this causes the reduced Nusselt number to descend and the Sherwood number to ascend. In the last part of table 4 the Nusselt number decreases and the Sherwood number increases with the increase of Lewis number. Because the larger the Lewis number the weaker molecular diffusivity and the thinner concentration boundary layer.

Figure 2 the effect of $\lambda$ on the velocity profile. Figure 3 the influence of $Pr$ on the temperature profile.
Figure 4 the contribution of Nb on the temperature profile.  
Figure 5 the effect of Nt on the temperature profile.

Figure 6 the influence of $A^*$ on the temperature profile.  
Figure 7 the contribution of $B^*$ on the temperature profile.

Figure 8 the effect of Pr on the concentration profile.  
Figure 9 the influence of Nb on the concentration profile.

Figure 10 the contribution of Nt on the concentration profile.  
Figure 11 the effect of $A^*$ on the concentration profile.
Figure 12 illustrates the influence of $B^*$ on the concentration profile. Figure 13 shows the contribution of $Le$ on the concentration profile.

Figure 2 indicates that the velocity of the fluid and the boundary layer thickness increase with the increase of $\lambda$ as the velocity of the stretching surface is greater than the free stream velocity (i.e., $\lambda = \frac{b}{a} < 1$), where as the flow velocity increases and the boundary layer thickness decreases with the increase of $\lambda$ when the free stream velocity is larger than the velocity of the stretching surface (i.e., $\lambda = \frac{b}{a} > 1$).

In the case where the velocity of the stretching surface is equal to the free stream velocity, there is no boundary layer thickness of the nanofluid near the surface. Increasing the Prandtl number as in Figure 3 reduces the thermal boundary layer thickness; it is because of the smaller the thermal diffusivity for the larger the Prandtl number. In Figure 4 the enhancement of the Brownian motion parameter makes the thermal boundary layer thicken due to the increased Brownian motion that transfers a larger extent of fluid to wedge together and make the thermal boundary layer thicken. Figure 5 shows that the increment of the thermophoresis parameter makes the thermal boundary layer thicken. Because as $Nt$ increases the thermophoresis diffusion transfers the nanoparticles to move from the hot to cold area which enlarges the thermal boundary layer thickness. In Figures 6 and 7, it is revealed that the thermal boundary layer thickness increases with the enlargement of the space and temperature dependent of non-uniform heat source/sink parameters $A^*$ and $B^*$ which corresponds to the internal heat generation that raises the temperature profiles.

Figure 8 indicates that as Prandtl number increases the boundary layer thickness of the concentration increases. The concentration boundary layer reduces as the Brownian motion parameter increases that is revealed in Figure 9, as $Nb$ increases the Brownian motion of the nanoparticles transfers the surface heat to the fluid and the nanoparticles gain higher kinetic energy that contributes to the thermal energy of the fluid and cause the movement of the nanoparticles from the hot to the cold region. However, the concentration boundary layer thickness increases with the increase of $Nt$ as it is shown in Figure 10, increasing the thermophoresis diffusion creates the movement of the nanoparticles from a region of high temperature to a region of low temperature. Figures 11 and 12 show that as the space dependent $A^*$ and the temperature dependent $B^*$ heat source/sink parameters increase the concentration boundary layer decreases; as the nanofluid temperature increases with the increase of $A^*$ and $B^*$ diffusion of the nanoparticles takes place from high to low temperature regions and hence the concentration boundary layer decrease. The molecular diffusivity becomes weaker as the Lewis number increases and the concentration boundary layer becomes thinner as it is illustrated in Figure 13 so that as $Le$ increases the concentration boundary layer decreases.

**V. Conclusions**

Stagnation point flow of nanofluid over a linear stretching surface is studied in the presence of non-uniform heat source/sink. Numerical solutions of the governing equations are obtained that permit the computation of the flow, heat and mass transfer behaviors for various values of the velocity ratio $\lambda$, the Prandtl number $Pr$, the Brownian motion parameter $Nb$, the thermophoresis parameter $Nt$, the non-uniform heat source/sink space and temperature dependent parameters $A^*$ and $B^*$ as well as the Lewis Number $Le$. The results have been found that

1. The velocity boundary layer thickness increases with the increase of the velocity ratio parameter $\lambda$.
2. Increasing Prandtl number reduces the thermal boundary layer thickness.
3. The thermal boundary layer thickness increases with the increase of the space dependent ($A^*$) and temperature dependent ($B^*$) parameters and similar results have been found for the Brownian motion and thermophoresis effects.
4. The concentration boundary thickness increases with the increase of the prandtl number $Pr$ and the thermophoresis parameter $Nt$. 
5. The enhancement of the space dependent (A’) parameter and the Brownian motion parameter Nb reduces the concentration boundary layer thickness.

6. The concentration Boundary layer thickness decreases as the Lewis number increases.

References
