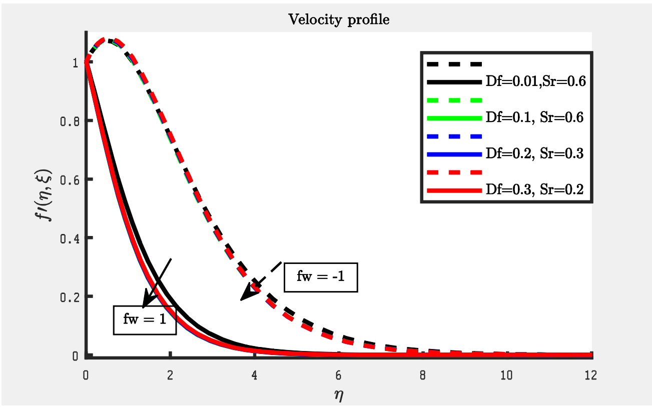
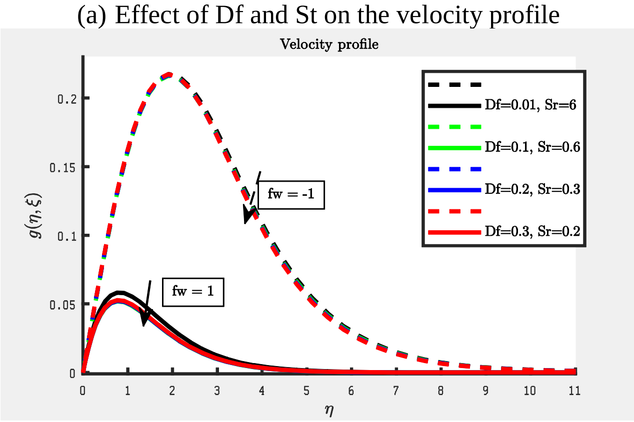
when multiplied. The specified values of the other parameters are p=0.1, $\beta=\infty$, M=0.5, $\delta$=1, n=0.1, K=4, q=0.1, Pr=0.7, Sc=0.22, and m=2.

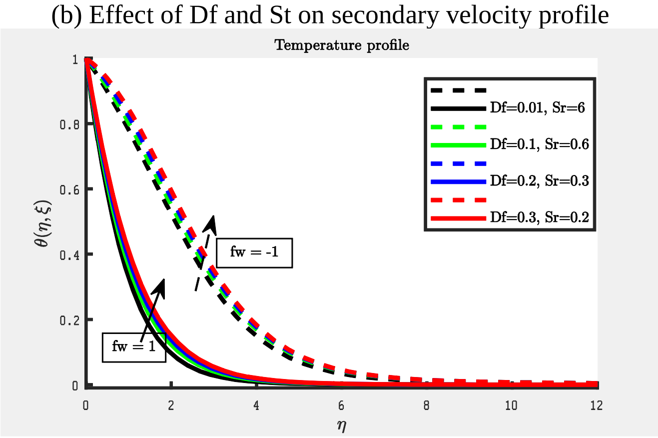
The available studies on the Dufour and Soret effects show that Df and St are arbitrary constants, which provides that their product is constant. It is observed from Figures 5a and 5b that both primary and secondary velocities increase when there is an increase in the Dufour number and a corresponding decrease in the Soret number. An increase in Df causes a concentration gradient, and this concentration gradient plays an important role in the transportation of the heat energy from the solid boundary into the fluid, which results in an increase in the temperature as shown in Figure 5c. The effect of Dufour and Soret numbers on the concentration field is found in Figure 5d. Increasing the Dufour number (while decreasing the Soret number) leads to a decrease in the concentration boundary layer thickness.



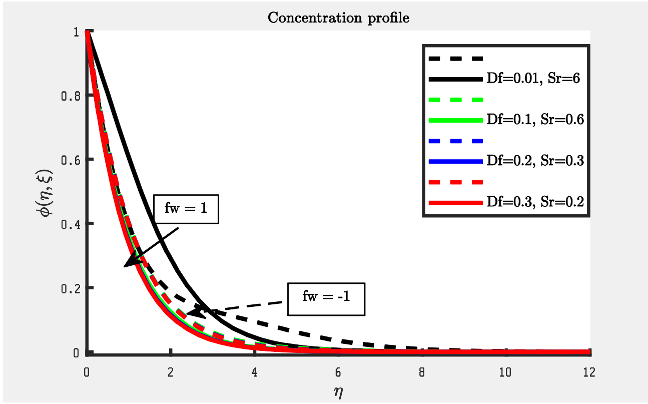

(a) Effect of Df and St on the velocity profile




(b) Effect of Df and St on secondary velocity profile




(c) Effect of Df and St on temperature profile

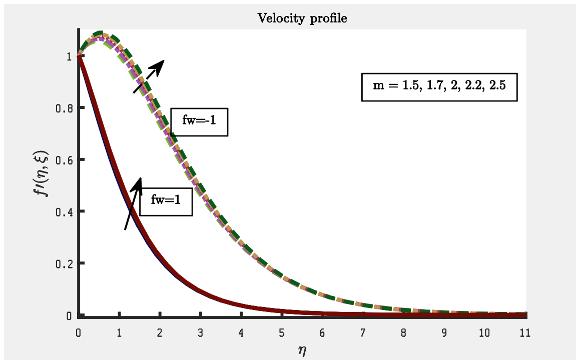



(d) Effect of Df and St on concentration profile

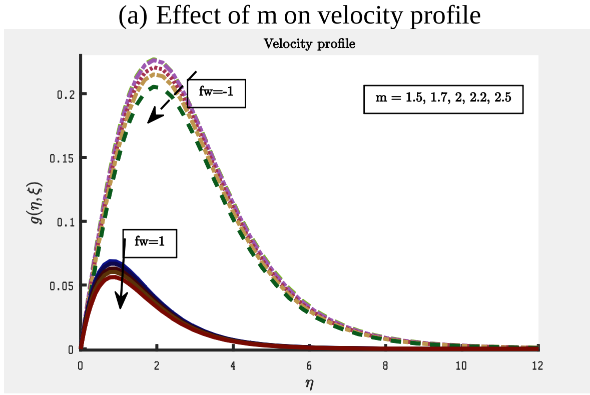
**Figure 5.** Effect of K

4.2.3 With varying of Hall parameter m

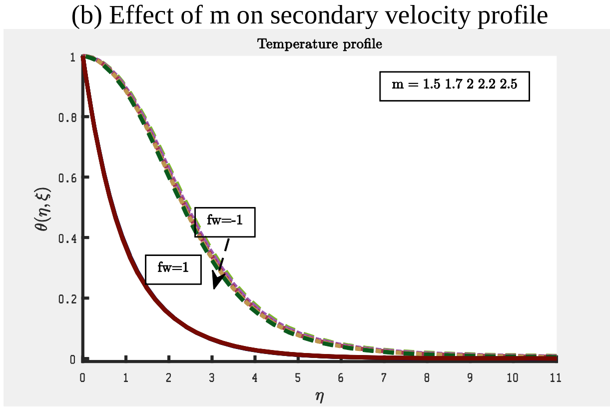
Figures 6a to 6d display the effect of the Hall parameter m on the various profiles when p=0.1, $\beta=\infty$, M=0.5, $\delta$=1, n=0.1, Df=0.4, q=0.1, Pr=0.7, St=7.5, Sc=0.22, and K=4.



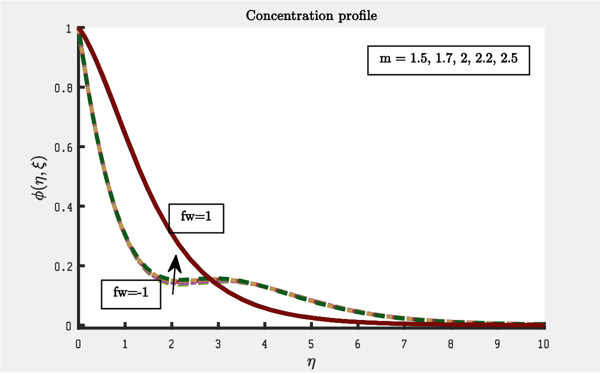

(a) Effect of m on velocity profile




(b) Effect of m on secondary velocity profile




(c) Effect of m on temperature profile



(d) Effect of m on concentration profile

**Figure 6.** Effect of m

We observe that an increase in the Hall parameter increases the primary velocity but decreases the secondary velocity as shown in Figures 6a and 6d. In Figures 6c and 6d, we observe that blowing has no effect on the temperature and concentration profiles as the Hall parameter is increased. During suction, however, we observe that the temperature cools down while concentration increases when the Hall parameter is increased.

## 5. CONCLUSION

In this paper, investigation was conducted on the combined effect of Hall, suction/blowing parameter, chemical reaction parameters, Dufour and Soret number on flow over a stretching/shrinking sheet. The PQLM was used to obtain some useful results needed to illustrate the flow characteristics of the fluid and their dependence on some certain parameters.

- It was observed that increasing the chemical reaction parameter and Dufour number has a retarding effect on the velocity of flow field as well as concentration distributions.
- The hydrodynamic and concentration boundary layer thickness were observed to decrease as a result of increasing chemical reaction or Dufour effect.
- Velocity and temperature profiles with suction parameter (fw) were greater than velocity and temperature profiles of blowing parameter whereas the reverse effect is seen for concentration profile.
- Increasing the Hall parameter retards the secondary velocity and temperature profiles while enhancing the primary velocity and concentration profiles.
- The hydrodynamic and concentration boundary layer thickness were observed to decrease as a result of increasing chemical reaction.

Future studies will consider the porous medium flow and deception effects where the fluid is polar fluids (fluids with local rotary inertia and couple stresses). The governing equations will be solved by a new numerical approach and numerical simulations will be performed.

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## NOMENCLATURE

| | |
|---|---|
| u, v, w | Velocity components |
| CP | specific heat, J. $kg^{-1}$. $K^{-1}$ |
| $g^*$ | gravitational acceleration, $m.s^{-2}$ |
| Nu | local Nusselt number along the heat source |
| Sh | Sherwood number |
| T | Temperature |
| C | Concentration |
| n, p, q, A, B | are positive constants |
| x, y, z | axes |
| D | species diffusivity |
| M | magnetic parameter |

**Greek symbols**

| | |
|---|---|
| $\alpha$ | thermal diffusivity, $m^2$. $s^{-1}$ |
| $\beta_T$ | thermal expansion coefficient, $K^{-1}$ |
| $\beta$ | Casson parameter |
| $\phi$ | solid volume fraction |
| $\Theta$ | dimensionless temperature |
| $\mu$ | dynamic viscosity, kg. $m^{-1}.s^{-1}$ |
| $\rho$ | fluid density |
| $\beta_C$ | coefficient of expansion with concentration |

**Subscripts**

| | |
|---|---|
| p | nanoparticle |
| f | fluid (pure water) |
| fw | nanofluid |
| $Gr_x$ | local Grashof number |
| Df | Dufour number |
| St | Soret number |
| $Re_x$ | Local Reynolds number |
| $B_0$ | strength of the magnetic field |
| $T_m$ | mean fluid temperature |