Research Article

A Parametric Analysis of the Effect of Hybrid Nanoparticles on the Flow Field and Homogeneous-Heterogeneous Reaction between Squeezing Plates

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Different strategies have been utilized by investigators with the intention of upgrading the thermal characteristics of ordinary liquids like water and kerosene oil. The focus is currently on hybrid nanomaterials since they are more efficient than nanofluids, so as to increase the thermal conductivity of fluids and mixtures. In a similar manner, this investigation is performed with the aim of breaking down the consistent mixed convection flow close to a two-dimensional unstable flow between two squeezing plates with homogeneous and heterogeneous reaction in the presence of hybrid nanoparticles of the porous medium. A sustainable suspension in the ethylene glycol with water is set by dissolving inorganic substances, iron oxide (Fe_3O_4) and cobalt (Co), to form $\text{Fe}_3\text{O}_4 - \text{Co}/\text{C}_2\text{H}_6\text{O}_2 - \text{H}_2\text{O}$ hybrid nanofluid. The numerical and analytical model portraying the fluid flow has been planned, and similitude conditions have been determined with the assistance of the same transformations. The shooting technique has been used to solve nonlinear numerical solution. To check the validity of the results obtained from the shooting mode, the Matlab built-in function BVP4c and Mathematica built-in function homotopy analysis method (HAM) are used. The influence of rising parameters on velocity, temperature, skin friction factor, Nusselt number, and Sherwood number is evaluated with the help of graphs and tables. It has been found in this work that to acquire a productive thermal framework, the hybrid nanoparticles should be considered instead of a single sort of nanoparticles. In addition, the velocities of both the hybrid nanofluids and simple nanofluids are upgraded by the mixed convection boundary, whereas they are decreased by the porosity. An augmentation in volumetric fraction of nanoparticles correlates to an increment in the heat transmission rate. It is also found that heat transfer rate for $\text{Fe}_3\text{O}_4 - \text{Co}/\text{C}_2\text{H}_6\text{O}_2 - \text{H}_2\text{O}$ hybrid nanofluids (HNF) is better than that of the $\text{Fe}_3\text{O}_4 - \text{C}_2\text{H}_6\text{O}_2 - \text{H}_2\text{O}$ of single nanofluids (SNF). This research shows that hybrid nanofluids play a significant part in the transfer of heat and in the distribution of nanofluids at higher temperatures.

1. Introduction

Pressure flows have many engineering, scientific, and technical applications in the industry such as lubrication system, moveable pistons, hydrodynamic engines, hydraulic

lifts, scattering and formulation, chemical equipment processing, food processing, film damage, and frost damage syringes and nasogastric tubes. The initial study of squeezing flow was published by Stefan [1] who reported the lubrication method in his research. New doors were opened by

Stephen's rewarding work for researchers on squeezing flows. Different researchers studied the flow of compression and followed him. From different research perspectives, this study has been pushed forward in recent years to compress the flow. Hayat et al. [2] have examined the squeezed flow of MHD fluid between two horizontal disks using homotopy analysis. The result of their investigation was found to be an increase in the velocity field of for augmenting values of micropolar parameter. Mustafa et al. [3] analyzed the fluid flow with magnetic effects upon thermal and mass transmission behavior of an incompressible viscous Casson fluid flow amid parallel plates. They have noticed in this work that flow has been augmented with escalating values of squeezing parameter. The two-dimensional magnetized laminar constant Marangoni convection of the incompressible viscous fluid was explored by Mahanthesh et al. [4] by implementing the Runge-Kutta-Fehlberg technique. The authors have found that the boundary layer thickness and the increasing meridian convection have increased the fluid velocity within the flow area.

Ferrolíquids are magnetic nanofluids suspended in nondirecting liquids such as water, hydrocarbons, and kerosene. These ferrofluids have various applications in medical science like cell partition, focusing of drug medication, and imaging of magnetic characters. The thermal and magnet functions of the ferrofluid flow were investigated by Neuringer [5]. Khan et al. [6] examined the influence of a homogeneous heat stream on flat-surface slip flows with heat transfer. They evaluated three distinct ferrofluids with two distinct basic fluids (CoFe_2O_4 , Fe_3O_4 , and $\text{Mn} - \text{ZnFe}_2\text{O}_4$) (water and kerosene). Rashad [7] examined the magnetic slip-flow function containing nonisothermal convection and radiation wedge kerosene based cobalt ferrofluid. Zaib et al. [8] investigated a mixed convective flow entropy of a vertical plate of magnetite ferrofluid. Ali et al. [9] recently discussed the magnetic dipole impact on micropolar fluid consisting of the EG and the water-based ferrofluids Fe and Fe_3O_4 from a stretched sheet.

Hybrid nanolíquids, however, are deliberately captured by blending several different nanoparticles with better thermal and rheological characteristics. The introduction of hybrid ferrofluids is to increase heat transfer efficiency in fluid flow. It has several scientific applications such as dynamic sealing, naval sealing, dampening, and microfluidics. Suresh et al. [10] investigated the effect of dissipation on time-based flux comprising a rounded pipe of hybrid nanoliquid. They have achieved a lower friction factor for nanolytes than for hybrid nanol. The pressurization decline in the volume percentage of the water-based Cu - TiO_2 hybrid nanolic was examined by Madhesh and Kalaiselvam [11]. Minea [12] revealed the association with the date of the temperature gradient of alumina hybrids and nanofluids. The fluid flow characteristics of hybrid nanolíquids from water-based Ag-CuO were evaluated by Hayat and Nadeem [13]. Mebarek-Oudina [14] examined the thermal and hydrodynamic parameters of Titania nanolíquids that satisfy a cylinder annulus, the impact of annulus, Mahanthesh et al. [15] An exponential spatially dependent magneto slip heat source flow from an extendable rotation consisting of carbon

nanofluids. Marzougui et al. [16] investigated the surface effects. $\text{Al}_2\text{O}_3 - \text{CuO}$ stability roughness and radiation nanolic hybrid through the widespread use of the model. Recently, Wakif et al. [17] examined the entropy examination through convective flow including nanoliquid by means of MHD with chamfers in a hole. The investigation of the attractive capacity has significant sales in MHD orientation; topography, astronomy, siphons, generators, medication, control of limit layer, and so on are many noticeable MHD applications. Alshomrani and Gul [18] inspected the slight film flow of water-based Al_2O_3 and Cu nanofluid through an extended chamber under the effect of attractive capacity. The characteristics of magneto thermal transport, comprising a time dependent flux of liquid nanofluid thin film flow to a starched surface, were examined by Sandeep and Malvandi [19]. Sandeep [20] examined the characteristics of the hybrid nanolytic flux with various heat and drag forces. Ahmad and Nadeem [21] examined the magnetic effects of hybrid nanofluid with a heat sink/source on micropolar fluid and achieved numerous findings for hybrid nanofluid and micropolar fluid. Hamrelaine et al. [22] examined the magnetic effect of Jeffery-Hamel flow between nonparallel permeable walls or permeable plates. The attractive impact on the radiative progression of the hybrid nanoliquid thin film with sporadic warmth sink/source was examined by Anantha Kumar et al. [23]. Zaib et al. [24] got the comparability of various outcomes from magnetite ferrofluid passing on non-Newtonian blood stream with entropy age. Wakif et al. [25] assessed the impact of the magnetic field on progressions of Stokes' second issue with entropy generation. Recently, Kameswaran et al. [26] investigated homogeneous-heterogeneous reactions in nanofluid flow due to a microscopic stretch sheet. They showed that the velocity profiles decrease with an increasing volume of the nanoparticles, while the liquid concentration is reversed by the volume of the nanoparticles for both Cu-water and Ag-water nanofluids.

The cited literature and similar other works show that no study is conducted to examine the combined effects of unstable flow between two squeezing plates in the presence of hybrid nanoparticles. Therefore, using all the studies mentioned above, we analyzed the multifaceted and homogeneous chemical reaction effects on the flow between two compression plates in the presence of hybrid nanoparticles. Navier-Stokes equations, heat transfer, and homogeneous and multifaceted reactions are solved by the HAM and BVP4c. In this work, we analyzed, discussed, and obtained the effects of different parameters on velocity, temperature, concentration, skin friction coefficient, and Nusselt and Sherwood numbers through graphs and tables.

2. Mathematical Formulation

Figure 1 shows a laminar, unsteady incompressible, and two-dimensional and hybrid nanofluid flowing between horizontally parallel and squeezing plates with homogeneous and heterogeneous reactions. Hybrid nanoparticles comprise Fe_3O_4 and $\text{Fe}_3\text{O}_4 + \text{Co}$ in the ethylene glycol with water as base fluid suspension. The plates are separated by a

FIGURE 1: Geometrical view of flow problem.

gap of $h(t) = l\sqrt{1 - \alpha t}$ with α as squeezed parameter. For $\alpha > 0$, the plates are squeezing but when $t = (1/\alpha)$ and $\alpha < 0$, the two plates are separated. The velocity field is often impacted by a uniform magnetic field $B(t) = B_0/\sqrt{1 - \alpha t}$ distributed along the y -axis. The upper and lower plates are held at steady temperature T_u and T_l , respectively. The proposed model of Chaudhary and Merkin [27] for homogeneous as well as heterogeneous reaction has been used in this study as described below.

The homogeneous reaction for cubic autocatalyst surface is

The heterogeneous reaction upon catalyst surface is

The quantities of the chemical sorts $N1$ and $N2$ are signified by a and b , respectively, while the initial conditions

are denoted by k_c . The reaction rate vanishes in exterior flow and beyond the boundary layer bottom, as shown by the equations above. The equations that governed the flow system are presented as [28, 29].

Continuity equation is as follows:

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = 0. \quad (3)$$

Navier-Stokes equation is as follows:

$$\begin{aligned} \frac{\partial u}{\partial t} + u \frac{\partial u}{\partial x} + v \frac{\partial u}{\partial y} &= -\frac{1}{\rho_{hnf}} \frac{\partial p}{\partial x} + \frac{\mu_{hnf}}{\rho_{hnf}} \left(\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} \right) - \sigma_{hnf} B^2 u, \\ \frac{\partial v}{\partial t} + u \frac{\partial v}{\partial x} + v \frac{\partial v}{\partial y} &= -\frac{1}{\rho_{hnf}} \frac{\partial p}{\partial y} + \frac{\mu_{hnf}}{\rho_{hnf}} \left(\frac{\partial^2 v}{\partial x^2} + \frac{\partial^2 v}{\partial y^2} \right). \end{aligned} \quad (4)$$

Energy equation is as follows:

$$\frac{\partial T}{\partial t} + u \frac{\partial T}{\partial x} + v \frac{\partial T}{\partial y} = \frac{k_{hnf}}{(\rho c_p)_{hnf}} \left(\frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2} \right) + \frac{1}{(\rho c_p)_{hnf}} \frac{16\sigma^* T_0^3}{3\kappa^*} \frac{\partial^2 T}{\partial y^2} + \frac{Q^*}{(\rho c_p)_{hnf}} (T - T_0). \quad (5)$$

Homogeneous and heterogeneous equations are as follows:

$$\begin{aligned} \frac{\partial a}{\partial t} + u \frac{\partial a}{\partial x} + v \frac{\partial a}{\partial y} &= D_A \frac{\partial^2 a}{\partial y^2} - K_c a b^2, \\ \frac{\partial b}{\partial t} + u \frac{\partial b}{\partial x} + v \frac{\partial b}{\partial y} &= D_B \frac{\partial^2 b}{\partial y^2} + K_c a b^2. \end{aligned} \quad (6)$$

In the above equations, T represents temperature, P represents pressure, ρ_{hnf} represents effective density, $(\rho c_p)_{hnf}$ represents effective heat power, and σ_{hnf} represents electrical conductivity of nanofluid. The quantities (u, v) denote the fluid's nanofluid velocity component, T is the temperature, and D_A and D_B are the respective diffusion constants of the chemical sorts a and b . The permeability is provided by K^* . k_{hnf} nanofluid thermal conductivity, Q^*

heat generation, k_{hnf} nanofluid thermal conductivity, k_{hnf} nanofluid thermal conductivity, k_{hnf} nanofluid thermal conduct.

2.1. Boundary Conditions. The squeezing flow under consideration has the undermentioned conditions at boundaries:

$$\begin{aligned} u = 0, v = 0, T = T_l, D_A \frac{\partial a}{\partial y} &= k_3 a, D_B \frac{\partial b}{\partial y} = -k_3 a \text{ at } y = 0, \\ u = 0, v = \frac{-\alpha D}{2\sqrt{1 - \alpha t}}, T = T_u, a = a_0, b = 0 &\text{ at } y = h(t). \end{aligned} \quad (7)$$

Use the transformations [2]

$$\begin{aligned} u &= \frac{\alpha x f'(\eta)}{2(1-\alpha t)}, \\ v &= \frac{-\alpha l f(\eta)}{(1-\alpha t)}, \end{aligned} \quad (7a)$$

$$\begin{aligned} T &= \theta(\eta)T_H, \\ \eta &= \frac{y}{l\sqrt{1-\alpha t}}, \\ a &= a_0 H(\eta), \\ b &= a_0 G(\eta), \\ B(t) &= \frac{B_0}{\sqrt{1-\alpha t}}, \\ \theta &= \frac{T - T_u}{T_l - T_u}. \end{aligned} \quad (7b)$$

Implementing equations (7a) and (7b), we have the following system of equations:

$$f''' - S\left(\frac{A_1}{A_4}\right)\left(\eta f''' + 2f'' + f''f' - ff'''\right) - \left(\frac{A_5}{A_4}\right)Ha^2 L f'' = 0, \quad (8)$$

$$\theta''\left(1 + \frac{4}{3}R\right) + P_r S(f\theta' - 2\eta\theta + Q\theta) = 0, \quad (9)$$

$$H'' - S_c K_1 H G^2 - S_c S(\eta H' - fH) = 0, \quad (10)$$

$$G''\delta - S_c K_1 H G^2 - S_c S(\eta G' - fG') = 0, \quad (11)$$

and the boundary conditions are reduced to

$$\begin{aligned} f(0) &= 0, f'(0) = 0, \theta(0) = 1, H'(0) \\ &= K_2 H(0), \delta G'(0) = -K_2 H(0), \\ f(1) &= 0.5, f'(1) = 0, \theta(1) = 0, H(1) = 1, G(1) = 0. \end{aligned} \quad (12)$$

Here, $S = (\alpha l^2 / 2\nu_f)$ is the squeezed Reynolds number, $P_r = (\mu c_p / K)$ is the Prandtl number, $Ha = l B_0 \sqrt{\sigma_{mf} / \mu_f}$ is the Hartmann number, $R = (4\sigma^* T_0^3 / K K^*)$ is the radiation parameter, $Q = 2Q^* (1 - \alpha t) / \alpha (\rho c_p)_{mf}$ is the heat generation parameter, $L = (\alpha \sigma_{nf} / x)$ is the length parameter, $S_c = (\nu_f / D_A)$ is the Schmidt number, $K_1 = 8k_c a_0^2 (1 - \alpha t) / \alpha^3$ is the homogeneous reaction strength, $K_2 = (k_s / D_A)$ is the heterogeneous reaction strength, and $\delta = (D_A / D_B)$ is the ratio of the diffusion coefficients. Here, it is considered that A and B diffusion coefficients of chemical species are of comparable size. The other hypothesis is that D_A and D_B are equivalent, so $\delta = (D_A / D_B) = 1$, and $G(\eta) + H(\eta) = 1$ [30].

2.2. Coefficients of Interest. The local Nusselt number (Nu), Sherwood number (Sh), and skin friction coefficient (Cf) are some of the coefficients of interest in engineering.

$$\begin{aligned} C_f^* &= \frac{S}{h} C_f = f''(0), \\ -\theta'(0) &= \text{Nu}, \end{aligned} \quad (13)$$

$$-G'(0) = -H'(0) = \text{Sh}.$$

By using A_i for the dimensionless constant, the result will be as follows:

$$\begin{aligned} A_1 &= \frac{\mu_{nf}}{\mu_f} = \frac{1}{(1-\phi)^{2.5}}, \phi = \phi_1 + \phi_2, \\ A_4 &= \frac{\rho_{nf}}{\rho_f} = (1-\phi) + \phi_1 \left(\frac{\rho_1}{\rho_f}\right) + \phi_2 \left(\frac{\rho_2}{\rho_f}\right), \\ A_5 &= \frac{\sigma_{nf}}{\sigma_f} = \left(1 + 3(\sigma_1 \phi_1 + \sigma_2 \phi_2) \sigma_f^{-1} - \phi\right) \\ &\quad + \left((\sigma_1 + \sigma_2) \sigma_f^{-1} + 2\right)^{-1} - \left((\sigma_1 \phi_1 + \sigma_2 \phi_2) \sigma_f^{-1} + \phi_1\right)^{-1}. \end{aligned} \quad (14)$$

The total volume fraction of nanoparticles is represented by ϕ . The volume fractions of the discrete nanoparticles are represented by the symbols ϕ_1 and ϕ_2 ; the density of first, second, and base fluids of nanoparticles is ρ_1 , ρ_2 , and ρ_f ; and the electrical conductivity of 1st, 2nd, and base fluids of nanoparticles is σ_1 , σ_2 and σ_f .

3. Approximate Analytical Solution

To solve system of equations (8)–(11), the analytic method HAM is used. Due to HAM, the functions $f(\eta)$, $\theta(\eta)$, $H(\eta)$, and $G(\eta)$ can be stated by a set of base functions q^c , $c \geq 0$ as

$$f_\Psi(\eta) = \sum_{\xi=0}^{\infty} a_\xi q^\xi, \quad (15)$$

$$\theta_\Psi(\eta) = \sum_{\xi=0}^{\infty} b_\xi q^\xi, \quad (16)$$

$$H_\Psi(\eta) = \sum_{\xi=0}^{\infty} c_\xi q^\xi, \quad (17)$$

$$G_\Psi(\eta) = \sum_{\xi=0}^{\infty} d_\xi q^\xi, \quad (18)$$

where a_ξ , b_ξ , c_ξ , and d_ξ are the constant coefficients to be determined. Initial approximations are chosen as follows:

$$f_0(\eta) = \frac{3}{2}q^2 - q^3, \quad (19)$$

$$\theta_0(\eta) = (S_r - 1)q + 1, \quad (20)$$

$$H_0(\eta) = 1 - q, \quad (21)$$

$$G_0(q) = 1 - q. \quad (22)$$

The auxiliary operators are chosen as

$$\begin{aligned} \ell_f &= \frac{\partial^4}{\partial q^4}, \\ \ell_\theta &= \frac{\partial^2}{\partial q^2}, \\ \ell_H &= \frac{\partial^2}{\partial q^2}, \\ \ell_G &= \frac{\partial^2}{\partial q^2}, \end{aligned} \quad (23)$$

with the following properties:

$$\ell_f(\xi_1 q^3 + \xi_2 q^2 + \xi_3 q + \xi_4) = 0, \quad (24)$$

$$\ell_\theta(\xi_5 q + \xi_6) = 0, \quad (25)$$

$$\ell_H(\xi_7 q + \xi_8) = 0, \quad (26)$$

$$\ell_G(\xi_9 q + \xi_{10}) = 0, \quad (27)$$

where $\xi_1, \xi_2, \xi_3, \xi_4, \xi_5, \xi_6, \xi_7, \xi_8, \xi_9$, and ξ_{10} are arbitrary constants.

The zeroth order deformation problems can be obtained as

$$(1; \omega) \ell_f [\bar{f}(q; \omega) - f_0(q)] = q \hbar_f N_f [\bar{f}(q; \omega), \bar{\theta}(q; \omega), \bar{m}(q; \omega), \bar{n}(q; \omega)], \quad (28)$$

$$(1; \omega) \ell_\theta [\bar{\theta}(q; \omega) - \theta_0(q)] = q \hbar_\theta N_\theta [\bar{f}(q; \omega), \bar{\theta}(q; \omega), \bar{m}(q; \omega), \bar{n}(q; \omega)], \quad (29)$$

$$(1; \omega) \ell_H [\bar{H}(q; \omega) - H_0(q)] = q \hbar_H N_H [\bar{f}(q; \omega), \bar{H}(q; \omega), \bar{G}(q; \omega)], \quad (30)$$

$$(1; \omega) \ell_G [\bar{G}(q; \omega) - G_0(q)] = q \hbar_G N_G [\bar{f}(q; \omega), \bar{H}(q; \omega), \bar{G}(q; \omega)]. \quad (31)$$

The nonlinear operators of (17)–(20) are defined as

$$\begin{aligned} N_f[\bar{f}(q; \omega), \bar{\theta}(q; \omega)] &= \frac{\partial^4 \bar{f}(q; \omega)}{\partial q^4} - S \left[q \frac{\partial^3 \bar{f}(q; \omega)}{\partial q^3} + 2 \frac{\partial^2 \bar{f}(q; \omega)}{\partial q^2} + \frac{\partial^2 \bar{f}(q; \omega)}{\partial q^2} \frac{\partial \bar{f}(q; \omega)}{\partial q} - f \frac{\partial^3 \bar{f}(q; \omega)}{\partial q^3} \right] \\ &\quad - Ha^2 L \frac{\partial^2 \bar{f}(q; \omega)}{\partial q^2}, \end{aligned}$$

$$N_\theta[\bar{f}(q; \omega), \bar{\theta}(q; \omega)] = \frac{\partial^2 \bar{\theta}(q; \omega)}{\partial q^2} \left(1 + \frac{4}{3} R \right) + Pr S \left[f \frac{\partial \bar{\theta}(q; \omega)}{\partial q} - 2 q \bar{\theta}(q; \omega) + Q \bar{\theta}(q; \omega) \right], \quad (32)$$

$$N_H[\bar{f}(q; \omega), \bar{H}(q; \omega), \bar{G}(q; \omega)] = \frac{\partial^2 \bar{H}(q; \omega)}{\partial q^2} - S_c K_1 \bar{H}(q; \omega) \frac{\partial^2 \bar{G}(q; \omega)}{\partial q^2} - S_c S \left[q \frac{\partial \bar{H}(q; \omega)}{\partial q} - f \bar{H}(q; \omega) \right],$$

$$N_G[\bar{f}(q; \omega), \bar{H}(q; \omega), \bar{G}(q; \omega)] = \frac{\partial^2 \bar{G}(q; \omega)}{\partial q^2} \delta - S_c K_1 \bar{H}(q; \omega) \frac{\partial^2 \bar{G}(q; \omega)}{\partial q^2} - S_c S \left[q \frac{\partial \bar{G}(q; \omega)}{\partial q} - f \frac{\partial \bar{G}(q; \omega)}{\partial q} \right],$$

where ω is an embedding parameter; $\hbar_f, \hbar_\theta, \hbar_H$, and $\hbar_G$ are the nonzero auxiliary parameter; and N_f, N_θ, N_H , and N_G are the nonlinear parameters.

For $\omega = 0$ and 1, we have

$$\begin{aligned}\bar{f}(\varrho, 0) &= f_o(\varrho), \bar{f}(\varrho, 1) = f(\varrho), \\ \bar{\theta}(\varrho, 0) &= \theta_o(\varrho), \bar{\theta}(\varrho, 1) = \theta(\varrho), \\ \bar{H}(\varrho, 0) &= H_o(\varrho), \bar{H}(\varrho, 1) = H(\varrho), \\ \bar{G}(\varrho, 0) &= G_o(\varrho), \bar{G}(\varrho, 1) = G(\varrho),\end{aligned}\quad (33)$$

so we can say that as ω varies from 0 to 1, $\bar{f}(\varrho, 0)$, $\bar{\theta}(\varrho, 0)$, $\bar{H}(\varrho, 0)$, and $\bar{G}(\varrho, 0)$ vary from initial guesses $f_o(\varrho)$, $\theta_o(\varrho)$, $H_o(\varrho)$, and $G_o(\varrho)$ to exact solutions $f(\varrho)$, $\theta(\varrho)$, $H(\varrho)$, and $G(\varrho)$, respectively.

Taylor's series expansion of these functions yields

$$\begin{aligned}f(\varrho; \omega) &= f_o(\varrho) + \sum_{\Psi=1}^{\infty} \omega^{\Psi} f_{\Psi}(\varrho), \\ \theta(\varrho; \omega) &= \theta_o(\varrho) + \sum_{\Psi=1}^{\infty} \omega^{\Psi} \theta_{\Psi}(\varrho), \\ H(\varrho; \omega) &= H_o(\varrho) + \sum_{\Psi=1}^{\infty} \omega^{\Psi} H_{\Psi}(\varrho), \\ G(\varrho; \omega) &= G_o(\varrho) + \sum_{\Psi=1}^{\infty} \omega^{\Psi} G_{\Psi}(\varrho), \\ f_{\Psi}(\varrho) &= \frac{1}{\Psi!} \left. \frac{\partial^{\Psi} f(\varrho; \omega)}{\partial \omega^{\Psi}} \right|_{\omega=0}, \\ \theta_{\Psi}(\varrho) &= \frac{1}{\Psi!} \left. \frac{\partial^{\Psi} \theta(\varrho; \omega)}{\partial \omega^{\Psi}} \right|_{\omega=0}, \\ H_{\Psi}(\varrho) &= \frac{1}{\Psi!} \left. \frac{\partial^{\Psi} H(\varrho; \omega)}{\partial \omega^{\Psi}} \right|_{\omega=0}, \\ G_{\Psi}(\varrho) &= \frac{1}{\Psi!} \left. \frac{\partial^{\Psi} G(\varrho; \omega)}{\partial \omega^{\Psi}} \right|_{\omega=0}.\end{aligned}\quad (34)$$

The convergence is strongly supported by $\hbar_f$, $\hbar_{\theta}$, $\hbar_H$, and $\hbar_G$.

For $\omega = 1$, we have

$$f(\varrho) = f_o(\varrho) + \sum_{\Psi=1}^{\infty} f_{\Psi}(\varrho), \quad (35)$$

$$\theta(\varrho) = \theta_o(\varrho) + \sum_{\Psi=1}^{\infty} \theta_{\Psi}(\varrho), \quad (36)$$

$$H(\varrho) = H_o(\varrho) + \sum_{\Psi=1}^{\infty} H_{\Psi}(\varrho), \quad (37)$$

$$G(\varrho) = G_o(\varrho) + \sum_{\Psi=1}^{\infty} G_{\Psi}(\varrho). \quad (38)$$

Differentiating the deformation equations (25)–(28) Ψ – times with respect to ω and putting $\omega = 0$, we have

$$\ell_f[f_{\Psi}(\varrho) - \chi_{\Psi} f_{\Psi-1}(\varrho)] = \hbar_f R_{f,\Psi}(\varrho), \quad (39)$$

$$\ell_{\theta}[\theta_{\Psi}(\varrho) - \chi_{\Psi} \theta_{\Psi-1}(\varrho)] = \hbar_{\theta} R_{\theta,\Psi}(\varrho), \quad (40)$$

$$\ell_H[H_{\Psi}(\varrho) - \chi_{\Psi} H_{\Psi-1}(\varrho)] = \hbar_H R_{H,\Psi}(\varrho), \quad (41)$$

$$\ell_G[G_{\Psi}(\varrho) - \chi_{\Psi} G_{\Psi-1}(\varrho)] = \hbar_G R_{G,\Psi}(\varrho), \quad (42)$$

subject to the boundary conditions

$$\begin{aligned}f_{\Psi}(0) &= 0, f'_{\Psi}(0) = 0, \theta_{\Psi}(0) = 1, \\ H'_{\Psi}(0) &= k_2 H(0), \delta G'_{\Psi}(0) = -k_2 H(0), \\ f_{\Psi}(1) &= 0.5, f'_{\Psi}(1) = 0, \theta_{\Psi}(1) = 0, \\ H_{\Psi}(1) &= 1, G f'_{\Psi}(1) = 0,\end{aligned}\quad (43)$$

where

$$R_{f,\Psi}(\varrho) = f''_{\Psi-1}(\varrho) - S \left(\frac{A_1}{A_4} \right) \left[\varrho f''_{\Psi-1}(\varrho) + 2 f''_{\Psi-1}(\varrho) + 2 \sum_{j=0}^{\Psi-1} f_j(\varrho) f'''_{\Psi-j-1}(\varrho) - \sum_{j=0}^{\Psi-1} f_j(\varrho) f''_{\Psi-j-1}(\varrho) \right] - \left(\frac{A_5}{A_4} \right) H a^2 L f''_{\Psi-1}(\varrho), \quad (44)$$

$$R_{\theta,\Psi}(\varrho) = \theta''_{\Psi-1}(\varrho) \left(1 + \frac{4}{3} R \right) + Pr S \left[\sum_{j=0}^{\Psi-1} f_j(\varrho) \theta'_{\Psi-j-1}(\varrho) - 2 \varrho \theta_{\Psi-1}(\varrho) + Q \theta_{\Psi-1}(\varrho) \right], \quad (45)$$

$$R_{H,\Psi}(\varrho) = H''_{\Psi-1}(\varrho) + S_c K_1 \sum_{j=0}^{\Psi-1} H_j(\varrho) G'_{\Psi-j-1}(\varrho) - S_c S \left[\varrho H'_{\Psi-1}(\varrho) - \sum_{j=0}^{\Psi-1} f_j(\varrho) H_{\Psi-j-1}(\varrho) \right], \quad (46)$$

$$R_{G,\Psi}(\varrho) = G''_{\Psi-1}(\varrho) \delta - S_c K_1 \sum_{j=0}^{\Psi-1} H_j(\varrho) G^2_{\Psi-j-1}(\varrho) - S_c S \left[\varrho G'_{\Psi-1}(\varrho) - \sum_{j=0}^{\Psi-1} f_j(\varrho) G'_{\Psi-j-1}(\varrho) \right], \quad (47)$$

and $\chi_{\Psi} = \{1, \text{if } \Psi > 1, \text{ and } 0, \text{if } \Psi = 1\}$.

Finally, the general solution of (36)–(39) can be written as

$$f_{\Psi}(\varrho) = \int_0^{\varrho} \int_0^{\varrho} \int_0^{\varrho} \int_0^{\varrho} \hbar_f R_{f,\Psi}(z) dz dz dz dz + \chi_{\Psi} f_{\Psi-1} + \xi_1 \varrho^3 + \xi_2 \varrho^2 + \xi_3 \varrho + \xi_4, \quad (48)$$

$$\theta_{\Psi}(\varrho) = \int_0^{\varrho} \int_0^{\varrho} \hbar_{\theta} R_{\theta,\Psi}(z) dz dz + \chi_{\Psi} \theta_{\Psi-1} + \xi_5 \varrho + \xi_6, \quad (49)$$

$$H_{\Psi}(\varrho) = \int_0^{\varrho} \int_0^{\varrho} \hbar_H R_{H,\Psi}(z) dz dz + \chi_{\Psi} H_{\Psi-1} + \xi_{11} \varrho + \xi_{12}, \quad (50)$$

$$G_{\Psi}(\varrho) = \int_0^{\varrho} \int_0^{\varrho} \hbar_G R_{G,\Psi}(z) dz dz + \chi_{\Psi} G_{\Psi-1} + \xi_{13} \varrho + \xi_{14}, \quad (51)$$

and so the exact solutions $f(\varrho)$, $\theta(\varrho)$, $H(\varrho)$, and $G(\varrho)$ become

$$\begin{aligned} f(\varrho) &\approx \sum_{n=0}^{\Psi} f_n(\varrho), \\ \theta(\varrho) &\approx \sum_{n=0}^{\Psi} \theta_n(\varrho), \\ H(\varrho) &\approx \sum_{n=0}^{\Psi} H_n(\varrho), \\ G(\varrho) &\approx \sum_{n=0}^{\Psi} G_n(\varrho). \end{aligned} \quad (52)$$

4. Optimizing the Convergence of Control Parameter

It is important to note that the series solutions (46)–(49) include $\hbar_f$, $\hbar_{\theta}$, $\hbar_H$, and $\hbar_G$ nonzero auxiliary parameters that define the convergence area as well as rate of the homotopy series solutions. The residual error to obtain the maximum values of $\hbar_f$, $\hbar_{\theta}$, $\hbar_H$, and $\hbar_G$ was used as

$$\begin{aligned} \epsilon_{\Psi}^f &= \frac{1}{\xi+1} \sum_{j=0}^{\xi} \left[N_f \sum_{i=0}^{\Psi} \bar{f}(\varrho), \sum_{i=0}^{\Psi} \bar{\theta}(\varrho) \right]^2 d\varrho, \\ \epsilon_{\Psi}^{\theta} &= \frac{1}{\xi+1} \sum_{j=0}^{\xi} \left[N_{\theta} \left(\sum_{i=0}^{\Psi} \bar{f}(\varrho), \sum_{i=0}^{\Psi} \bar{\theta}(\varrho) \right) \right]_{n=jD_u n}^2 d\varrho, \\ \epsilon_{\Psi}^H &= \frac{1}{\xi+1} \sum_{j=0}^{\xi} \left[N_H \left(\sum_{i=0}^{\Psi} \bar{f}(\varrho), \sum_{i=0}^{\Psi} \bar{H}(\varrho), \sum_{i=0}^{\Psi} \bar{G}(\varrho) \right) \right]_{n=jD_u n}^2 d\varrho, \\ \epsilon_{\Psi}^G &= \frac{1}{\xi+1} \sum_{j=0}^{\xi} \left[N_G \left(\sum_{i=0}^{\Psi} \bar{f}(\varrho), \sum_{i=0}^{\Psi} \bar{H}(\varrho), \sum_{i=0}^{\Psi} \bar{G}(\varrho) \right) \right]_{n=jD_u n}^2 d\varrho. \end{aligned} \quad (53)$$

Due to Liao

$$\epsilon_{\Psi}^t = \epsilon_{\Psi}^f + \epsilon_{\Psi}^{\theta} + \epsilon_{\Psi}^H + \epsilon_{\Psi}^G, \quad (54)$$

where ϵ_{Ψ}^t is the total squared residual error.

5. Analysis of Error

An error analysis is conducted to ensure a minimum residual error for the efficiency of the analysis. HAM and BVP4c solve the problem analytically and numerically. The analysis is conducted using an approximation order of the 40th order. For this analysis, the validity of HAM techniques is also evaluated using the Mathematica software BVPh 2.0 for maximum residual error 10^{-40} . The results are compared with the numerical solution of BVP4c using Matlab for the authentication and consistency of the HAM solution. The reliability of the two methods for various concerning physical parameters is investigated by error analysis in Figure 2 and Tables 1–12. Figure 2 shows that up to the 16th transition series, the maximum average residual errors of $f''(\eta)$, $-\theta'(\eta)$, $-H'(\eta)$, and $-G'(\eta)$ are almost gradually decreased. The cumulative residual error for the various approximation orders of fixed $P_r = -0.5$, $S = -0.5$, $L = 0.01$, $Q = 5$, $R = 0.7$, $\delta = 1$, $Sc = 2.5$, $K1 = 0.1$, $K2 = 1$, and $Ha = 0.1$ values is shown in Table 1. Table 2 shows various orders of approximation with distinct average squared residual error for $f''(\eta)$, $-\theta'(\eta)$, $-H'(\eta)$, and $-G'(\eta)$ with fixed values as $P_r = 0.5$, $S = -0.5$, $L = 0.01$, $\delta = 1$, $Q = 0.01$, $R = 0.1$, $Sc = 2.5$, $K1 = 0.3$, $K2 = 0.1$, $Ha = 0.2$, $\phi = 0.02$, $\phi1 = \phi2 = 0.01$, $\rho1 = 5180$, $\rho2 = 8900$, $\rho3 = 1056$, $\sigma1 = 0.74 \times 10^6$, $\sigma2 = 1.602 \times 10^7$, $\sigma3 = 0.00509$. The comparison of the analytical and numerical values by HAM and BVP4c is shown in Table 3 for various values of η and fixed values of other parameters, $P_r = 0.5$, $S = -0.5$, $L = 0.01$, $\delta = 1$, $Q = 0.01$, $R = 0.1$, $Sc = 2.5$, $K1 = 0.3$, $K2 = 0.1$, $Ha = 0.2$, $\phi = 0.02$, $\phi1 = \phi2 = 0.01$, $\rho1 = 5180$, $\rho2 = 8900$, $\rho3 = 1056$, $\sigma1 = 0.74 \times 10^6$, $\sigma2 = 1.602 \times 10^7$, and $\sigma3 = 0.00509$.

6. Results and Discussion

For various values of parameters S , Ha , P_r , Q , R , Sc , $K1$, $K2$, and ϕ , the system of nonlinear equations (8)–(11), resulting in the boundary conditions equation (12), is numerically

FIGURE 2: Error analysis on $f(\eta)$, $\theta(\eta)$, $G(\eta)$, and $H(\eta)$ with $P_r = -0.5$, $S = -0.5$, $L = 0.01$, $Q = 5$, $R = 0.7$, $\delta = 1$, $Sc = 2.5$, $K1 = 0.1$, $K2 = 1$, and $Ha = 0.1$.

TABLE 1: Thermophysical properties of iron oxide, cobalt, and ethylene glycol with water at 20°C [7].

Physical properties	ρ (kg/m ³)	c_p (J/kgK)	k (W/mK)	$\beta \times 10^{-5}$ (K ⁻¹)	σ (sm ⁻¹)
Fe ₃ O ₄	5180	670	9.7	1.3	0.74×10^6
Co (cobalt)	8900	420	100	1.3×10^{-5}	1.602×10^7
C ₂ H ₆ O ₂ - H ₂ O	1056	3630	0.387	58	0.00509

TABLE 2: Total residual error of $f(\eta)$, $\theta(\eta)$, $G(\eta)$, and $H(\eta)$ with $P_r = -0.5$, $S = -0.5$, $L = 0.01$, $Q = 5$, $R = 0.7$, $\delta = 1$, $Sc = 2.5$, $K1 = 0.1$, $K2 = 1$, and $Ha = 0.1$.

n	$\epsilon^f n$	$\epsilon^\theta n$	$\epsilon^G n$	$\epsilon^H n$
1	0.186129	2.4373×10^{-7}	3.17987×10^{-7}	2.30094×10^{-9}
5	2.936895×10^{-10}	2.30705×10^{-17}	7.84948×10^{-18}	8.67775×10^{-20}
10	1.34057×10^{-20}	1.16169×10^{-27}	3.02765×10^{-28}	6.44809×10^{-30}
15	1.3174×10^{-30}	3.18812×10^{-34}	3.27408×10^{-35}	1.86574×10^{-36}
16	3.64848×10^{-31}	3.20099×10^{-34}	3.17778×10^{-35}	1.86574×10^{-36}
20	3.64848×10^{-31}	3.20099×10^{-34}	3.17778×10^{-35}	1.86574×10^{-36}
25	3.64848×10^{-31}	3.20099×10^{-34}	3.17778×10^{-35}	1.86574×10^{-36}
30	3.64848×10^{-31}	3.20099×10^{-34}	3.17778×10^{-35}	1.86574×10^{-36}
35	3.64848×10^{-31}	3.20099×10^{-34}	3.17778×10^{-35}	1.86574×10^{-36}
40	3.64848×10^{-31}	3.20099×10^{-34}	3.17778×10^{-35}	1.86574×10^{-36}

resolved using HAM and BVP4c numerical routines. The local skin friction coefficient as well as the local rates of heat and mass transfer at the surface of the squeezing plates, both of which are extremely important in terms of physical properties, is also computed. Because there are so many physical parameters in the current problem, a wide range of results can be obtained. The distributions of temperature, velocity, pressure, and mass transfer are obtained by solving

(8)–(11) and are shown in Figures 1–10 for various physical parameters. The impact of the squeeze number S on the velocity and temperature distribution for both heating and cooling surfaces is plotted on $f(\eta)$, $f'(\eta)$, $\theta(\eta)$, $H(\eta)$, and $G(\eta)$ in Figure 5 in the case of both Fe₃O₄ - C₂H₆O₂ - H₂O single nanofluids (SNF) and Fe₃O₄ - Co/C₂H₆O₂ - H₂O hybrid nanofluids (HNF). The values of the squeeze number have been set to be higher than zero in this case, indicating

TABLE 3: Computation of nanoparticles (iron oxide, cobalt) and ethylene glycol for $f(\eta)$, $\theta(\eta)$, $H(\eta)$, and $G(\eta)$ with $P_r = 0.5$, $S = -0.5$, $L = 0.01$, $\delta = 1$, $Q = 0.01$, $R = 0.1$, $Sc = 2.5$, $K1 = 0.3$, $K2 = 0.1$, $Ha = 0.2$, $\phi = 0.02$, $\phi_1 = \phi_2 = 0.01$, $\rho_1 = 5180$, $\rho_2 = 8900$, $\rho_3 = 1056$, $\sigma_1 = 0.74 \times 10^6$, $\sigma_2 = 1.602 \times 10^7$, and $\sigma_3 = 0.00509$.

η	HAM results				Numerical results			
	$f(\eta)$	$\theta(\eta)$	$H(\eta)$	$G(\eta)$	$f(\eta)$	$\theta(\eta)$	$H(\eta)$	$G(\eta)$
0.0000	0.0000	1.0000	1.0193	0.1242	0.0000	1.0000	1.0193	0.1242
0.1001	0.0146	0.9229	1.0308	0.1106	0.0146	0.9229	1.0308	0.1106
0.2002	0.0542	0.8441	1.0447	0.0966	0.0542	0.8441	1.0447	0.0966
0.3003	0.1122	0.7621	1.0602	0.0825	0.1122	0.7621	1.0602	0.0825
0.4004	0.1820	0.6752	1.0757	0.0685	0.1820	0.6752	1.0757	0.0685
0.5005	0.2570	0.5822	1.0892	0.0550	0.2570	0.5822	1.0892	0.0550
0.6006	0.3310	0.4820	1.0980	0.0422	0.3310	0.4820	1.0980	0.0422
0.7007	0.3978	0.3736	1.0986	0.0301	0.3978	0.3736	1.0986	0.0301
0.8008	0.4517	0.2567	1.0865	0.0189	0.4517	0.2567	1.0865	0.0189
0.9009	0.4873	0.1315	1.0560	0.0088	0.4873	0.1315	1.0560	0.0088
0.0000	0.5000	0.0000	1.0000	0.0000	0.5000	0.0000	1.0000	0.0000

TABLE 4: Convergence of homotopy solution for different orders of calculation of nanoparticles (iron oxide, cobalt) and ethylene glycol for $f''(\eta)$, $-\theta'(\eta)$, $-H'(\eta)$, and $-G'(\eta)$ with $P_r = 0.5$, $S = -0.5$, $L = 0.01$, $\delta = 1$, $Q = 0.01$, $R = 0.1$, $Sc = 2.5$, $K1 = 0.3$, $K2 = 0.1$, $Ha = 0.2$, $\phi = 0.02$, $\phi_1 = \phi_2 = 0.01$, $\rho_1 = 5180$, $\rho_2 = 8900$, $\rho_3 = 1056$, $\sigma_1 = 0.74 \times 10^6$, $\sigma_2 = 1.602 \times 10^7$, and $\sigma_3 = 0.00509$.

η	$f''(0)$	$-\theta'(0)$	$-H'(0)$	$-G'(0)$
0.0000	3.1331	0.7679	-0.1019	0.1019
0.1001	2.4908	0.7758	-0.1279	0.0911
0.2002	1.8362	0.8006	-0.1486	0.0800
0.3003	1.1779	0.8413	-0.1576	0.0689
0.4004	0.5255	0.8963	-0.1490	0.0579
0.5005	-0.1106	0.9637	0.1166	0.0472
0.6006	-0.7555	1.0459	0.0484	0.0362
0.7007	-1.2931	1.1247	0.0492	0.0268
0.8008	-1.8216	1.2101	0.2020	0.0173
0.9009	-2.2987	1.2912	0.4208	0.0082
1.0000	-2.7161	1.3595	0.7259	0.0000

TABLE 5: Computation of nanoparticles (iron oxide and ethylene glycol) and hybrid nanoparticles (iron oxide, cobalt, and ethylene glycol with water) for skin friction $f''(0)$.

Different fluid model parameters			Nanoparticles	Hybrid nanoparticles
S	Ha	ϕ	$f''(0)$	$f''(0)$
-0.5	1	0.1	0.057180	3.083700
-1			0.053850	3.077570
-1.5			0.050680	3.072110
-2	1		3.057180	3.028170
	3		3.057180	3.028170
	5		3.057180	3.028170
	7	0.1	3.019960	3.029040
		0.2	3.019620	3.028170
		0.3	3.019160	3.026870

that the upper plate is moving away from the lower stationary plate and the opposite inequality of the squeeze number indicating that the lower plate is moving away from the upper plate. Effect of S on $f(\eta)$ and $f'(\eta)$ is depicted in Figure 3 in the case of both SNF and HNF. In reality, for larger S , the upper plate slides downward, which puts more stress on nanoparticles, and consequently velocity components $f(\eta)$, $f'(\eta)$ are amplified. Effect of S on $\theta(\eta)$ is demonstrated in Figure 3. For bigger S , the top plate shift downwards, and interatomic collision nanoparticles increase; hence, the temperature increases. The influence on

concentration profiles $H(\eta)$ and $G(\eta)$ of the parameter S can be observed in Figure 3 in both SNF and HNF. The concentration profile $H(\eta)$ decreases and $G(\eta)$ increases. It has been discovered that as S increases, the homogeneous chemical reaction increases, resulting in a decrease in viscosity. However, the $H(\eta)$ indicates the reverse of the $G(\eta)$ above can seen in Figure 3. The impact of Hartmann number Ha show in Figure 3 on $f(\eta)$ against the similarity variable η for the phenomenon of both SNF and HNF are decreases. When the HNF flow is applied, the fluid velocity is reduced by moving down the horizontal axis and the SNF flow

TABLE 6: Computation of nanoparticles (iron oxide and ethylene glycol) and hybrid nanoparticles (iron oxide, cobalt) and ethylene glycol with water for Nusselt number $-\theta'(0)$.

S	Different fluid model parameters				Nanoparticles	Hybrid nanoparticles
	P_r	Q	R	ϕ	$-\theta'(0)$	$-\theta'(0)$
-0.5	1	1	1	0.1	1.101390	1.101380
-1					1.201800	1.201760
-1.5					1.301230	1.301160
-2					1.201810	1.201790
	2	1	1	0.1	1.399750	1.399710
	3				1.593820	1.593760
	4				1.008540	1.008530
		2			1.039600	1.039590
		3			1.070550	1.070540
		4	1		1.094100	1.094100
			2	0.1	1.079550	1.079550
			3		1.064990	1.064990
			4		1.054580	1.054580
				0.2	1.054580	1.054580
				0.3	1.054580	1.054580

TABLE 7: Computation of nanoparticles (iron oxide and ethylene glycol) and hybrid nanoparticles (iron oxide, cobalt) and ethylene glycol with water for Sherwood numbers (homogeneous-heterogeneous) $H''(0)$ and $G''(0)$.

S	Variation in parameters				Nanoparticles		Hybrid nanoparticles	
	Sc	k1	k2	ϕ	$-H''(0)$	$-G''(0)$	$-H''(0)$	$-G''(0)$
-0.5	1	0.1	1	0.1	-0.333233	0.167006	-0.333230	0.167016
-1					-0.332977	0.167346	-0.332968	0.167332
0.5					-0.332720	0.167686	-0.332700	0.167680
-2					-0.333233	0.167006	-0.333230	0.167005
	2	0.1	1	0.1	-0.333135	0.167346	-0.333129	0.167345
	3				-0.333038	0.167688	-0.333029	0.167686
	4				-0.333283	0.166396	-0.333286	0.166396
		0.2			-0.332976	0.166531	-0.332979	0.166532
		0.3			-0.332669	0.166531	-0.332672	0.166667
		0.4	1		-0.499141	0.249089	-0.499141	0.249089
			6	0.1	-0.852392	0.430977	-0.852392	0.430977
			11		-0.911060	0.460473	-0.911060	0.460473
			4		-0.333387	0.166454	-0.333387	0.166454
				0.2	-0.333387	0.166454	-0.333387	0.166454
				0.3	-0.333387	0.166454	-0.333387	0.166454

TABLE 8: Computation for $f''(0)$, $-\theta'(0)$, $-H'(0)$, and $-G'(0)$ with $P_r = 0.5$, $S = -0.5$, $L = 0.01$, $\delta = 1$, $Q = 0.01$, $R = 0.1$, $Sc = 2.5$, $K1 = 0.3$, $K2 = 0.1$, $Ha = 0.2$, $\phi = 0.02$, $\phi_1 = \phi_2 = 0.01$, $\rho_1 = 5180$, $\rho_2 = 8900$, $\rho_3 = 1056$, $\sigma_1 = 0.74 \times 10^6$, $\sigma_2 = 1.602 \times 10^7$, and $\sigma_3 = 0.00509$ and varied values of S.

S	HAM results				Numerical results			
	$f''(0)$	$-\theta'(0)$	$-H'(0)$	$-G'(0)$	$f''(0)$	$-\theta'(0)$	$-H'(0)$	$-G'(0)$
-1.1	3.1283	0.8762	-0.1209	0.1209	3.1283	0.8762	-0.1209	0.1209
-1.2	3.1357	0.8641	-0.1324	0.1324	3.1357	0.8641	-0.1324	0.1324
-1.3	3.1443	0.8519	-0.1411	0.1411	3.1443	0.8519	-0.1411	0.1411
-1.4	3.1540	0.8395	-0.1515	0.1515	3.1540	0.8395	-0.1515	0.1515

TABLE 9: Computation for $f''(0)$, $-\theta'(0)$, $-H'(0)$, and $-G'(0)$ with $P_r = 0.5$, $S = -0.5$, $L = 0.01$, $\delta = 1$, $Q = 0.01$, $R = 0.1$, $Sc = 2.5$, $K1 = 0.3$, $K2 = 0.1$, $Ha = 0.2$, $\phi = 0.02$, $\phi_1 = \phi_2 = 0.01$, $\rho_1 = 5180$, $\rho_2 = 8900$, $\rho_3 = 1056$, $\sigma_1 = 0.74 \times 10^6$, $\sigma_2 = 1.602 \times 10^7$, and $\sigma_3 = 0.00509$ and varied values of P_r .

P_r	HAM results				Numerical results			
	$f''(0)$	$-\theta'(0)$	$-H'(0)$	$-G'(0)$	$f''(0)$	$-\theta'(0)$	$-H'(0)$	$-G'(0)$
0.5	3.1059	1.2983	-0.0996	0.0398	3.1059	1.2983	-0.0996	0.0398
0.6	3.1059	1.3545	-0.0996	0.0398	3.1059	1.3545	-0.0996	0.0398
0.7	3.1059	1.4096	-0.0996	0.0398	3.1059	1.4096	-0.0996	0.0398
0.8	3.1059	1.4638	-0.0996	0.0398	3.1059	1.4638	-0.0996	0.0398

TABLE 10: Computation for $f''(0)$, $-\theta'(0)$, $-H'(0)$, and $-G'(0)$ with $P_r = 0.5$, $S = -0.5$, $L = 0.01$, $\delta = 1$, $Q = 0.01$, $R = 0.1$, $Sc = 2.5$, $K1 = 0.3$, $K2 = 0.1$, $Ha = 0.2$, $\phi = 0.02$, $\phi_1 = \phi_2 = 0.01$, $\rho_1 = 5180$, $\rho_2 = 8900$, $\rho_3 = 1056$, $\sigma_1 = 0.74 \times 10^6$, $\sigma_2 = 1.602 \times 10^7$, and $\sigma_3 = 0.00509$ and varied values of δ .

δ	HAM results				Numerical results			
	$f''(0)$	$-\theta'(0)$	$-H'(0)$	$-G'(0)$	$f''(0)$	$-\theta'(0)$	$-H'(0)$	$-G'(0)$
1	3.1059	1.2983	-0.0994	0.0994	3.1059	1.2983	-0.0994	0.0994
2	3.1059	1.2983	-0.0996	0.0398	3.1059	1.2983	-0.0996	0.0398
3	3.1059	1.2983	-0.0996	0.0332	3.1059	1.2983	-0.0996	0.0332
4	3.1059	1.2983	-0.0996	0.0249	3.1059	1.2983	-0.0996	0.0249

TABLE 11: Computation for $f''(0)$, $-\theta'(0)$, $-H'(0)$, and $-G'(0)$ with $P_r = 0.5$, $S = -0.5$, $L = 0.01$, $\delta = 1$, $R = 0.1$, $Sc = 2.5$, $K1 = 0.3$, $K2 = 0.1$, $Ha = 0.2$, $\phi = 0.02$, $\phi_1 = \phi_2 = 0.01$, $\rho_1 = 5180$, $\rho_2 = 8900$, $\rho_3 = 1056$, $\sigma_1 = 0.74 \times 10^6$, $\sigma_2 = 1.602 \times 10^7$, and $\sigma_3 = 0.00509$ and varied values of Q .

Q	HAM results				Numerical results			
	$f''(0)$	$-\theta'(0)$	$-H'(0)$	$-G'(0)$	$f''(0)$	$-\theta'(0)$	$-H'(0)$	$-G'(0)$
0.01	3.1059	0.9457	-0.0994	0.0994	3.1059	0.9457	-0.0994	0.0994
0.02	3.1059	0.9465	-0.0994	0.0994	3.1059	0.9465	-0.0994	0.0994
0.03	3.1059	0.9472	-0.0994	0.0994	3.1059	0.9472	-0.0994	0.0994
0.04	3.1059	0.9480	-0.0994	0.0994	3.1059	0.9480	-0.0994	0.0994

TABLE 12: Computation for $f''(0)$, $-\theta'(0)$, $-H'(0)$, and $-G'(0)$ with $P_r = 0.5$, $S = -0.5$, $L = 0.01$, $\delta = 1$, $Q = 0.01$, $R = 0.1$, $Sc = 2.5$, $K1 = 0.3$, $K2 = 0.1$, $Ha = 0.2$, $\phi = 0.02$, $\phi_1 = \phi_2 = 0.01$, $\rho_1 = 5180$, $\rho_2 = 8900$, $\rho_3 = 1056$, $\sigma_1 = 0.74 \times 10^6$, $\sigma_2 = 1.602 \times 10^7$, and $\sigma_3 = 0.00509$ and varied values of R .

R	HAM results				Numerical results			
	$f''(0)$	$-\theta'(0)$	$-H'(0)$	$-G'(0)$	$f''(0)$	$-\theta'(0)$	$-H'(0)$	$-G'(0)$
0.1	3.1059	0.9457	-0.0994	0.0994	3.1059	0.9457	-0.0994	0.0994
0.2	3.1059	0.9515	-0.0994	0.0994	3.1059	0.9515	-0.0994	0.0994
0.3	3.1059	0.9562	-0.0994	0.0994	3.1059	0.9562	-0.0994	0.0994
0.4	3.1059	0.9601	-0.0994	0.0994	3.1059	0.9601	-0.0994	0.0994

velocity is increased for continued positive changes in Ha values while the same behavior is displayed as in the figure, for both situations. It is also found that the maximum velocity of HNF is greater than that of SNF. The impact on the temperature profile of the Prandtl number P_r is seen in Figure 4. It is examined to show $\theta(\eta)$ in the case of SNF and the inclining performance for high values of P_r in the case of HNF. Essentially, larger P_r values enhance the boundary layer thickness that stimulates the nanoparticle's cooling effect due to thermal diffusion ratio. As contrast to in the HNF nanoparticles are tightly packed SNF. The impact on the temperature profile of Q (heat generation parameter) is seen in Figure 4. For rising values of heat parameter Q , $T_u > T_l$ indicates a further transfer of heat from the surface into the fluid, thus raising the fluid temperature for both SNF and HNF. The growing temperature behavior in SNF and HNF for the larger value of R is shown in Figure 4. However, it is commonly recognized that the heat transfer phenomena of their radiation process emit the energy via fluid particles, so that more heat is created during flow. Thus, the thermal boundary layer with more R is defined as a development. Figure 5 indicates a rise in the Schmidt number Sc for SNF and HNF concentration profile of $H(\eta)$ and $G(\eta)$ and, as a result, reduction in the thickness of concentration boundary layer. The reactant concentration is observed to be increasing at a quicker rate when the diffusion

coefficient of species is reduced; i.e., higher Sc values lead to a more rapid increase of the flow field concentration. The impact of homogeneous parameter k_1 and a heterogeneous parameter k_2 on the concentration profile $H(\eta)$ can be seen in Figure 6. Increase in the concentration profiles $H(\eta)$ it is observed that due to increase in k_1 . According to this an increase in the homogeneous chemical reaction parameter which decreases viscosity. The concentration profile increases as the thickness of the boundary layer decreases for lower strength values of homogeneous reaction parameter. It is also proved that concentration profile is lower for the situation of HNF when compared with SNF. In both situations of SNF and HNF, the concentration boundary layer of the reactants decreases. However, they coincide for smaller values of η which physically means that the homogeneous and heterogeneous reactions have no effect on the concentration of the reactants. The strong conduct of heterogeneous reaction parameters K_2 on the distribution is studied in Figure 6. The distribution of the concentration is increasing towards the surface of the plate and decreasing away from the surface with smaller values of K_2 . When compared to HNF, the concentration distribution is smaller (SNF). It is noticed in Figure 6 that the behavior of concentration profile $G(\eta)$ and $H(\eta)$ is opposite. This shows the effects of the homogeneous chemical reaction parameter k_1 and the heterogeneous chemical reaction parameter k_2 on

FIGURE 3: Impact of S for $\text{Fe}_3\text{O}_4 - \text{C}_2\text{H}_6\text{O}_2 - \text{H}_2\text{O}$ and $\text{Fe}_3\text{O}_4 - \text{Co}/\text{C}_2\text{H}_6\text{O}_2 - \text{H}_2\text{O}$ on $f(\eta)$, $f'(\eta)$, $\theta(\eta)$, $H(\eta)$, $G(\eta)$ and impact of Ha on $f(\eta)$ with $L = 2$, $\delta = 1$, $Q = 4$, $R = 2$, $Sc = Pr = Ha = K1 = K2 = 0.5$, $\phi = 0.02$, $\phi_1 = \phi_2 = 0.01$, $\rho_1 = 5180$, $\rho_2 = 8900$, $\rho_3 = 1056$, $\sigma_1 = 0.74 \times 10^6$, and $\sigma_2 = 1.602 \times 10^7$, $\sigma_3 = 0.00509$.

FIGURE 4: Impact of Q for $\text{Fe}_3\text{O}_4 - \text{C}_2\text{H}_6\text{O}_2 - \text{H}_2\text{O}$ and $\text{Fe}_3\text{O}_4 - \text{Co}/\text{C}_2\text{H}_6\text{O}_2 - \text{H}_2\text{O}$ on $f(\eta)$ and $\theta(\eta)$ and impacts of Pr and R on $\theta(\eta)$ with $L = 2$, $\delta = 1$, $Q = 4$, $R = 2$, $\text{Sc} = \text{Pr} = \text{Ha} = K1 = K2 = 0.5$, $\phi = 0.02$, $\phi_1 = \phi_2 = 0.01$, $\rho_1 = 5180$, $\rho_2 = 8900$, $\rho_3 = 1056$, $\sigma_1 = 0.74 \times 10^6$, $\sigma_2 = 1.602 \times 10^7$, and $\sigma_3 = 0.00509$.

the concentration profiles $H(\eta)$ and $G(\eta)$. It has been observed that increasing k_1 causes the concentration profiles $H(\eta)$ and $G(\eta)$ to increase. This is due to the fact that as the homogeneous chemical reaction parameter rises, the viscosity declines. However, the heterogeneous parameter k_2 yields the opposite result, as shown in Figure 6. This is

because as k_2 increases, diffusion decreases, and the concentration of less diffused particles grows. The impacts of nanoparticles volume fraction ϕ on the velocity profiles $f(\eta)$, $\theta(\eta)$, $H(\eta)$, and $G(\eta)$ in case of SNF and HNF are shown in Figure 7. It can be clearly seen that the volume fraction parameter ϕ is increased with the increase in the

FIGURE 5: Impact of Sc for $\text{Fe}_3\text{O}_4 - \text{C}_2\text{H}_6\text{O}_2 - \text{H}_2\text{O}$ and $\text{Fe}_3\text{O}_4 - \text{Co}/\text{C}_2\text{H}_6\text{O}_2 - \text{H}_2\text{O}$ on $H(\eta)$ and $G(\eta)$ with $L = 2$, $\delta = 1$, $Q = 4$, $R = 2$, $S = P_r = Ha = K1 = K2 = 0.5$, $\phi = 0.02$, $\phi_1 = \phi_2 = 0.01$, $\rho_1 = 5180$, $\rho_2 = 8900$, $\rho_3 = 1056$, $\sigma_1 = 0.74 \times 10^6$, $\sigma_2 = 1.602 \times 10^7$, and $\sigma_3 = 0.00509$.

velocity for both SNF and HNF. In this physical problem the increase in velocity is because of the converse relationship that exists between the dynamic viscosity of nanofluid and the volume fraction. Consequently, the consistency of regular liquid is reduced against an increase in ϕ , and therefore the fluid flow is supported up. The quantities related to the local coefficient of skin friction, the local Nusselt number, and the Sherwood number (homogeneous-heterogeneous reactions), that is, $f(\eta)$, $\theta(\eta)$, $H(\eta)$, and $G(\eta)$, for various values of ϕ are depicted in Figure 7. The values of $f(\eta)$ increase with increasing ϕ , whereas the heat transfer rate $\theta(\eta)$ decreases. The values of homogeneous $H(\eta)$ increase with the increase in ϕ , whereas the values of heterogeneous $G(\eta)$ decrease. It is also seen from these figures that the values of $f(\eta)$, $\theta(\eta)$, $H(\eta)$, and $G(\eta)$ are always positive. The influence on concentration profiles $f(\eta)$, $\theta(\eta)$, $H(\eta)$, and $G(\eta)$ of the parameter S can be observed in Figure 8 in nanoparticles. All the concentration profiles are increased while $G(\eta)$ decreases, it is observed that due to increase in S . Figure 9 indicates that the $f(\eta)$ and $H(\eta)$ concentration profiles have increased with rising values of Schmidt number Sc , while $\theta(\eta)$ and $G(\eta)$ decrease. Figure 10 displays the effects of the homogeneous and heterogeneous chemical reaction parameters k_1 and k_2 on the concentration profiles $f(\eta)$, $H(\eta)$, and $G(\eta)$. It has been observed that k_1 increases and k_2 decreases on the concentration profile $f(\eta)$; both decrease on the concentration profile $H(\eta)$; and both increase on $G(\eta)$. The purpose of Tables 5–12 is to test the impact of various physical parameters numerically. As can be seen from the tables, all of the results are in good

settlement with the BVP4c and HAM results. It is observed that effects of skin friction coefficient, velocity, temperature, and Nusselt and Sherwood numbers, both homogeneous as well as the heterogeneous parameters cause increment in the mass transfer rate. A decrease in the skin friction coefficient, as well as the heat and mass transfer rate, is caused by an increment in the internal heat generation parameter. A similar set of results has been observed when the squeezing parameter S is increased. As the squeezing parameter S is enhanced, the friction factor reduces and the local Nusselt and Sherwood numbers increase. The skin friction coefficient showed a downward trend, showing that the fluid was being drawn by the floor. Tables 3–12, respectively, show the results of $f(\eta)$, $\theta(\eta)$, $H(\eta)$, $G(\eta)$, $f'(\eta)$, $-\theta'(\eta)$, $-H'(\eta)$, and $-G'(\eta)$.

It is acknowledged from Table 5 that perhaps the skin friction factor $f'(\eta)$ tends to increase the squeezing number S ; the disruptive effect can be seen for the Hartmann number Ha and the volume fraction ϕ of nanoparticles and hybrid nanoparticles. From Table 6, it has been noticed that the squeezing number S has declining influence on heat transfer efficiency, but Prandtl number P_r , Q (heat generation parameter), radiation R , and volume fraction ϕ of nanoparticles and hybrid nanoparticles are greatly influencing the heat transfer efficiency. Table 7 depicts the behavior of nanoparticles and hybrid nanoparticles on $-H'(\eta)$ and $-G'(\eta)$ when $\delta = 1$. It shows the decreasing values of $-H'(\eta)$ and increasing values of squeezing number S , Schmidt number Sc , and homogeneous reaction strength $K1$, but values of

FIGURE 6: Impact of K_1 and K_2 for $\text{Fe}_3\text{O}_4 - \text{C}_2\text{H}_6\text{O}_2 - \text{H}_2\text{O}$ and $\text{Fe}_3\text{O}_4 - \text{Co}/\text{C}_2\text{H}_6\text{O}_2 - \text{H}_2\text{O}$ on $H(\eta)$ and $G(\eta)$ with $L = 2$, $\delta = 1$, $Q = 4$, $R = 2$, $Sc = Pr = Ha = 0.5$, $\phi = 0.02$, $\phi_1 = \phi_2 = 0.01$, $\rho_1 = 5180$, $\rho_2 = 8900$, $\rho_3 = 1056$, $\sigma_1 = 0.74 \times 10^6$, $\sigma_2 = 1.602 \times 10^7$, and $\sigma_3 = 0.00509$.

FIGURE 7: Impact of ϕ for $\text{Fe}_3\text{O}_4 - \text{C}_2\text{H}_6\text{O}_2 - \text{H}_2\text{O}$ and $\text{Fe}_3\text{O}_4 - \text{Co}/\text{C}_2\text{H}_6\text{O}_2 - \text{H}_2\text{O}$ on $f(\eta)$, $\theta(\eta)$, $H(\eta)$, and $G(\eta)$ with $L = 2$, $\delta = 1$, $Q = 4$, $R = 2$, $Sc = Pr = Ha = K1 = K2 = 0.5$, $\phi = 0.02$, $\phi_1 = \phi_2 = 0.01$, $\rho_1 = 5180$, $\rho_2 = 8900$, $\rho_3 = 1056$, $\sigma_1 = 0.74 \times 10^6$, $\sigma_2 = 1.602 \times 10^7$, and $\sigma_3 = 0.00509$.

FIGURE 8: Impact of S on $f(\eta)$, $\theta(\eta)$, $H(\eta)$, and $G(\eta)$ with $P_r = 0.5$, $S = -0.5$, $L = 0.01$, $\delta = 1$, $Q = 0.01$, $R = 0.1$, $Sc = 2.5$, $K1 = 0.3$, $K2 = 0.1$, $Ha = 0.2$, $\phi = 0.02$, $\phi_1 = \phi_2 = 0.01$, $\rho_1 = 5180$, $\rho_2 = 8900$, $\rho_3 = 1056$, $\sigma_1 = 0.74 \times 10^6$, $\sigma_2 = 1.602 \times 10^7$, and $\sigma_3 = 0.00509$.

FIGURE 9: Impact of Sc on $f(\eta)$, $\theta(\eta)$, $H(\eta)$, and $G(\eta)$ with $P_r = 0.5$, $S = -0.5$, $L = 0.01$, $R = 1$, $Ha = 0.1$, $Sc = 2.5$, $K1 = 0.3$, $K2 = 0.1$, $\delta = 1$, $\phi = 0.02$, $\phi_1 = \phi_2 = 0.01$, $\rho_1 = 5180$, $\rho_2 = 8900$, $\rho_3 = 1056$, $\sigma_1 = 0.74 \times 10^6$, $\sigma_2 = 1.602 \times 10^7$, and $\sigma_3 = 0.00509$.

FIGURE 10: Impact of K_1 and K_2 on $f(\eta)$, $H(\eta)$, and $G(\eta)$ with $P_r = 1$, $S = -5$, $L = 0.5$, $Q = 5$, $R = 1$, $\delta = 1$, $Sc = 2.5$, $K_1 = 5$, $K_2 = 5$, $Ha = 0.5$, $\phi = 0.02$, $\phi_1 = \phi_2 = 0.01$, $\rho_1 = 5180$, $\rho_2 = 8900$, $\rho_3 = 1056$, $\sigma_1 = 0.74 \times 10^6$, $\sigma_2 = 1.602 \times 10^7$, and $\sigma_3 = 0.00509$.

TABLE 13: Computation for $f''(0)$, $-\theta'(0)$, $-H'(0)$, and $-G'(0)$ with $P_r = 0.5$, $S = -0.5$, $L = 0.01$, $\delta = 1$, $Q = 0.01$, $R = 0.1$, $Sc = 2.5$, $K1 = 0.3$, $K2 = 0.1$, $Ha = 0.2$, $\phi = 0.02$, $\phi_1 = \phi_2 = 0.01$, $\rho_1 = 5180$, $\rho_2 = 8900$, $\rho_3 = 1056$, $\sigma_1 = 0.74 \times 10^6$, $\sigma_2 = 1.602 \times 10^7$, and $\sigma_3 = 0.00509$ and varied values of Sc .

Sc	HAM results				Numerical results			
	$f''(0)$	$-\theta'(0)$	$-H'(0)$	$-G'(0)$	$f''(0)$	$-\theta'(0)$	$-H'(0)$	$-G'(0)$
2.5	3.1059	0.9457	-0.0994	0.0994	3.1059	0.9457	-0.0994	0.0994
3.5	3.1059	0.9457	-0.1044	0.1044	3.1059	0.9457	-0.1044	0.1044
4.5	3.1059	0.9457	-0.1106	0.1106	3.1059	0.9457	-0.1106	0.1106
5.5	3.1059	0.9457	-0.1200	0.1200	3.1059	0.9457	-0.1200	0.1200

TABLE 14: Computation for $f''(0)$, $-\theta'(0)$, $-H'(0)$, and $-G'(0)$ with $P_r = 0.5$, $S = -10$, $L = 0.01$, $\delta = 1$, $Q = 0.01$, $R = 0.1$, $Sc = 2.5$, $K2 = 0.1$, $Ha = 0.2$, $\phi = 0.02$, $\phi_1 = \phi_2 = 0.01$, $\rho_1 = 5180$, $\rho_2 = 8900$, $\rho_3 = 1056$, $\sigma_1 = 0.74 \times 10^6$, $\sigma_2 = 1.602 \times 10^7$, and $\sigma_3 = 0.00509$ and varied values of $K1$.

$K1$	HAM results				Numerical results			
	$f''(0)$	$-\theta'(0)$	$-H'(0)$	$-G'(0)$	$f''(0)$	$-\theta'(0)$	$-H'(0)$	$-G'(0)$
1.1	3.1059	0.9457	-0.0994	0.0994	3.1059	0.9457	-0.0994	0.0994
1.5	3.1059	0.9457	-0.0995	0.0995	3.1059	0.9457	-0.0995	0.0995
1.9	3.1059	0.9457	-0.0997	0.0997	3.1059	0.9457	-0.0997	0.0997
2.5	3.1059	0.9457	-0.0999	0.0999	3.1059	0.9457	-0.0999	0.0999

TABLE 15: Computation for $f''(0)$, $-\theta'(0)$, $-H'(0)$, and $-G'(0)$ with $P_r = 0.5$, $S = -10$, $L = 0.01$, $\delta = 1$, $Q = 0.01$, $R = 0.1$, $Sc = 2.5$, $K1 = 0.3$, $Ha = 0.2$, $\phi = 0.02$, $\phi_1 = \phi_2 = 0.01$, $\rho_1 = 5180$, $\rho_2 = 8900$, $\rho_3 = 1056$, $\sigma_1 = 0.74 \times 10^6$, $\sigma_2 = 1.602 \times 10^7$, and $\sigma_3 = 0.00509$ and varied values of $K2$.

$K2$	HAM results				Numerical results			
	$f''(0)$	$-\theta'(0)$	$-H'(0)$	$-G'(0)$	$f''(0)$	$-\theta'(0)$	$-H'(0)$	$-G'(0)$
0.01	3.1059	0.9457	-0.0994	0.0994	3.1059	0.9457	-0.0994	0.0994
0.02	3.1059	0.9457	-0.1758	0.1758	3.1059	0.9457	-0.1758	0.1758
0.03	3.1059	0.9457	-0.2362	0.2362	3.1059	0.9457	-0.2362	0.2362
0.04	3.1059	0.9457	-0.2850	0.2850	3.1059	0.9457	-0.2850	0.2850

heterogeneous reaction strength k_2 , for both $-H'(\eta)$ and $-G'(\eta)$, show incremental behavior. The volume fraction ϕ of nanoparticles and hybrid nanoparticles has the same values' behavior.

7. Conclusion

This investigation gives a mathematical answer for dissecting the impacts of flow between two squeezing plates with a homogeneous and heterogeneous reaction in the presence of hybrid nanoparticles. The impact of dimensional overseeing boundaries on velocity, temperature, profiles with skin friction, and local Nusselt and Sherwood numbers is examined with the assistance of graphs and tables. The effects of the current examination are listed below:

- The skin friction coefficient augmenting for growing values of solid volume fraction ϕ .
- The increasing values of the squeezing parameter S reduced the friction factor and local Nusselt numbers, but from Table 7 Sherwood numbers are decreasing and increasing on the $-H(0)$ and $-G(0)$.
- The Prandtl number, heat generation, and radiation parameters appear to increase in the local Nusselt numbers, as shown in Tables 9, 11, and 12.

- Homogeneous-heterogeneous parameters assist in observing the flow's utility profiles.
- The local Nusselt and friction factor in fluid viscosity are similar as Sc increases and the homogeneous parameter decreases while heterogeneous parameter increases, as shown in Table 13.
- Tables 14 and 15 show that homogeneous reaction strength and heterogeneous reaction strength are decreasing and increasing on the profile of $-H(0)$ and $-G(0)$.

Nomenclature

T :	Temperature
T_u :	Upper plate's temperature
T_l :	Lower plate's temperature
P :	Pressure
ρ_{mf} :	Effective density
$(\rho c_p)_{mf}$:	Effective heat capacity
σ_{mf} :	Electrical conductivity of nanofluid
u, v :	Nanofluid velocity
D_A, D_B :	Diffusion coefficients of the chemical species
δ :	Ratio of the diffusion coefficients
K^* :	Permeability
k_{mf} :	Nanofluid thermal conductivity

K_1 :	Homogeneous reaction strength
K_2 :	Heterogeneous reaction strength
S :	Squeeze number
P_r :	Prandtl number
Ha :	Hartmann number
R :	Radiation parameter
Q :	Heat generation parameter
L :	Length
C_f :	Skin friction coefficient
Nu :	Local Nusselt number
Sh :	Local Sherwood number
N_1, N_2 :	Chemical species.

Data Availability

No data were used in this study.

Conflicts of Interest

The authors declare that there are no conflicts of interest.

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