

Analysis of 3D Hybrid Base Liquid C₂H₆O₂–H₂O with AG–MoS₂ and Go–MoS₂ Hybrid Nano-Materials

G. Manish Reddy¹, M. Nagapavani², Prasad Mattipally³

¹*Bachelor student of Department of Computer Science, Hyderabad Institute of Technology and Management*

^{2,3}*Department of Mathematics, Hyderabad Institute of Technology and Management*

Abstract: Numeric simulations are performed for a comparative study of magneto hydrodynamic (MHD) rotational flow of hybrid nanofluids (MoS₂-Ag/ethylene glycol-water (50–50%) and MoS₂-Go/ethylene glycol-water (50–50%)) over a horizontally elongated plane sheet. The principal objective is concerned with the enhancement of thermal transportation. The three-dimensional formulation governing the conservation of mass, momentum, energy, and concentration is transmuted into two-dimensional partial differentiation by employing similarity transforms. The resulting set of equations (PDEs) is then solved by variation finite element procedure coded in MATLAB script. An intensive computational run is carried out for suitable ranges of the particular quantities of influence. The primary velocity component decreases monotonically and the magnitude of secondary velocity component diminishes significantly when magnetic parameter, rotational parameter, and unsteadiness parameter are incremented. Both the primary and secondary velocities are smaller in values for the hybrid phase Ag-MoS₂ than that of hybrid phase Go-MoS₂ but the nano particle concentration and temperature are higher for hybrid phase Ag-MoS₂. The increased values of parameters for thermophoresis, Brownian motion, shape factor, and volume fraction of ϕ_2 made significant improvement in the temperature of the two phases of nano liquids. Results are also computed for the coefficients of skin friction (x, y-directions), Nusselt number, and Sherwood number. The present findings manifest reasonable comparison to their existing counterparts. Some of the practical engineering applications of the present analysis may be found in high-temperature nanomaterial processing technology, crystal growing, extrusion processes, manufacturing and rolling of polymer sheets, academic research, lubrication processes, and polymer industry.

Key Words: magneto hydrodynamic; hybrid nano fluid; finite element method; shape factor; rotating frame.

I.INTRODUCTION

Global warming and environmental pollution are ultimately leading to energy shortages in the modern world. As a result, engineers and scientists are looking for new advances in energy for sustainable improvement. Based on current advances in nanotechnology, the improvement of nanomaterials is considered to be more effective in enhancing the thermal efficiency of base liquids.

Nanomaterials are mostly used as a coolant in industrial, mechanical, and chemical fields. Liquid cooling is currently a major problem because efficient heat and mass transfer fluids need to provide appropriate conditions for commercial applications. It can be obtained by immersing micro-sized nanomaterials in ordinary base liquids. These fluids are classified as nanofluids and can be commonly used in numerous manufacturing applications such as cooking processing, air condition, automobile radiators, waste heat recovery, refrigeration, etc Magneto hydro dynamics (MHD) engagement has valuable implementations in the area of medication, astronomy, advanced plane design, successfully deal with the heat transfer rates in cylinders, numerous machines, energy generators, and turbulent pumps. The MHD effect is discussed as a magnetic effect upon the electric conductor. It relates to the interaction between magnetic fields and electric conductor fluids. In recent years, the investigation of fluid and heat transport problems in the rotating frame is absolutely charming matter. It is a result of their colossal applications in the assembling of crystal development, computer stockpiling devices, thermal power stations, food handling, diffusive filtration process, rotating machinery, viscometer, and gas turbine rotors. This numeric investigation pertains to the two different

hybrid nano liquids rotational flow over a plane sheet that stretches horizontally. The novelties of the current study are (i) a comparative study of two hybrid nanofluids with hybrid base fluid and different shape factors, i.e., MoS₂-Ag/ethylene glycol-water (50–50%) and MoS₂-Go/ethylene glycol-water (50–50%), (ii) the Buongiorno nanofluid model is implemented together with Tiwari and Das nanofluid model, (iii) incorporate the chemical reaction and activation energy, and (iv) the finite element approach for this elaborated problem. It solves the boundary value problems adequately, rapidly, and precisely. Differentiated outcomes for temperature, Nusselt number, velocity components, skin friction coefficients, nanoparticle volume fraction, and Sherwood number are evaluated and presented. The numerical procedure (FEM) has established reliable results as verified through their comparison with those of existing formerly. Some of the practical engineering utilization of the present investigation might be found in crystal growing and glass, extrusion processes, paper industry, turbo-mechanics, thinning and drawing of copper wires, gas turbine rotors, polymer industry, lubrication processes, filtration process, and relevant to high-temperature nanomaterial processing technology.

II. LITERATURE SURVEY

Maxwell [1] proposes the innovative idea of adding solid particles to heat transfer fluids to rise their thermal conductivity thermodynamic parameter further discoveries that are put forth by Choi [2] and Kang et al. [3]. They experimented on an empirical model which develop a scope in heat exchange and give researchers a road map to develop new models for hybrid nanoparticles by the matter of fact that its thermal conductivity is more than that of the alone nanoparticle.

Another phenomenon that which is discussed here is natural convection which is independent of the motion of fluid over external source such as pump or suction devices, the parameter that is responsible for the motion of the fluid is generally natural fluid or we can pronounce it as buoyancy force. The followings are the practical usage of these parameters. Stagnation point

flow of Cu-TiO₂/H₂O hybrid Nanofluid under the effects of the magnetic field. Ghadikolai et al. [4] described their investigation on heat transfer and shape factors on stretching surfaces. The analysis of convective Poiseuille boundary layer flow of Al₂O₃/C₂H₆O₂ nanofluid over porous wavy channel has been presented by Zeeshan et al. [5]. Anwar and Rasheed [6] experimented on non-isothermal boundaries in MHD fractional inertial flow with the help of a finite-difference scheme and describe the numerical results on heat transfer. The shape factor and thermal influences on heat transfer and 3D squeezing flow of Ag-Fe₃O₄/Ethylene. Dinarvand S et al. [7] investigate the mathematical model's name for the Tiwari-Das nanofluid model based on three different water-based nanofluids (copper, alumina, titanium). This examination is interested in developed the homotopy analysis of the stagnation-point flow of MHD mixed convection with electrically conducted permeable vertical stretching/shrinking sheet.

Afterward, Mabood et al. [8] provide mathematical research on the properties of MHD stagnation point flow and heat transfer expending the Tiwari-Das nanofluid model. In 2017 the Pop et al. [9] also evaluate the free convective flow of hybrid nanofluid of copper water over the downward-pointing cone through the Tiwari-Das model. Subsequently, after a short cooling down in 2018 Aghamajidi et al. [10] make a similar work on the downward-pointing cone with the effect of rotation and natural convection of hybrid nanofluids.

III. 3D HYBRID BASE LIQUID C₂H₆O₂-H₂O WITH AG-MOS₂ AND Go-MoS₂ HYBRID NANO-MATERIALS

Unsteady transient three dimensional MHD viscous and an incompressible hybrid nanoparticles Ag-MoS₂ and Go-MoS₂ in hybrid base fluid C₂H₆O₂-H₂O (50–50%) flow over an extending sheet along with a rotating frame are considered as shown in Figure 1. The mathematical model is created through a species type that incorporates the chemical reactions and Arrhenius activation energy. The Buongiorno nanofluid model is implemented together with Tiwari and Das nanofluid model.

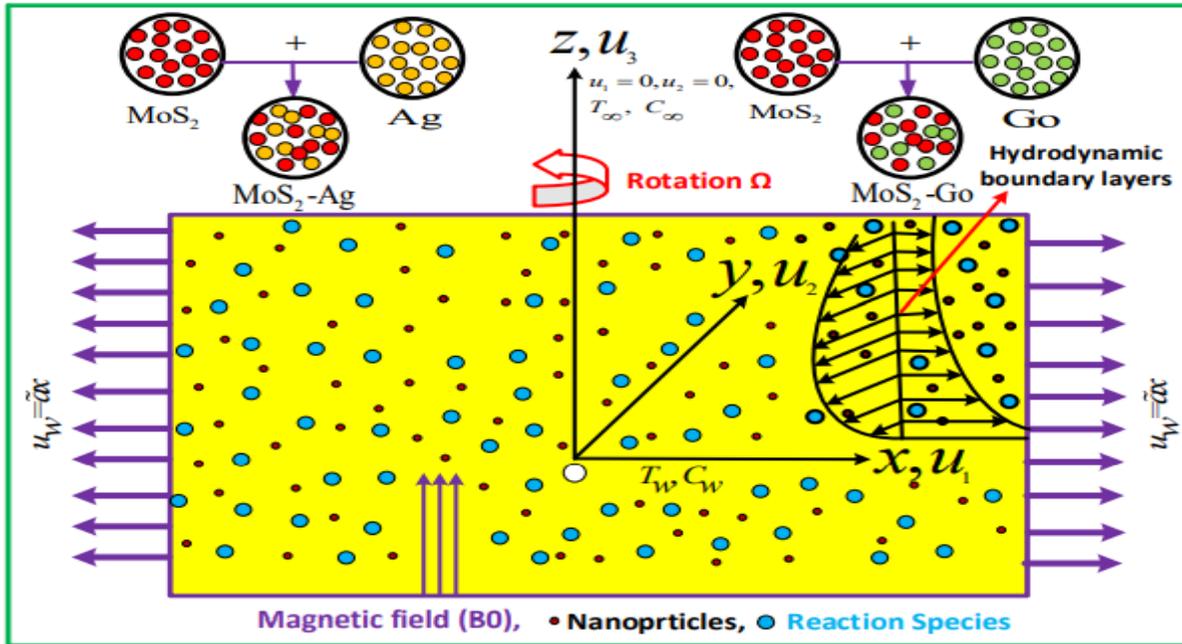


Fig.1: SCHEMATIC CONFIGURATION WITH COORDINATE SYSTEM

Physically, we assume that the whole framework is at rest in the time $t < 0$ however for $t = 0$, the sheet is stretched along x -direction at $z = 0$ with angular velocity (Ω). B_0 is uniform (magnetic field) and applied along with z -direction, the incited magnetic field is ignored due to a small magnetic Reynolds number, and moreover, Ohmic dissipation and Hall's current impacts are ignored since the field of magnetic is not too much strong. Moreover, the magnetic force acts normally to x and y -direction and no effect along z -direction as referred in schematic Figure 1.

Further, we assume that the thermo-physical properties of hybrid base, single and hybrid nanofluid along with shape factor are expressed in Table 1 and Table 2, the base fluid and nanoparticles are in thermal equilibrium and no slip occurs between them, and the agglomeration of nanoparticles is ignored because the hybrid nanofluid is synthesized as a stable compound. Furthermore, we assume that T_w, C_w are the surface temperature and concentration, respectively, and C_∞, T_∞ are the ambient concentration and temperature.

Considering the above suppositions, the consistent mass, momentum, energy, and conservation of concentration equations can be written as

$$\partial_x u_1 + \partial_y u_2 + \partial_z u_3 = 0, \tag{1}$$

$$\rho_{nf}(\partial_t u_1 + u_1 \partial_x u_1 + u_2 \partial_y u_1 + u_3 \partial_z u_1 - 2\Omega_1 u_2) = -\partial_x p + \mu_{nf} \partial_{zz} u_1 - \sigma_{nf} B_0^2 u_1, \tag{2}$$

$$\rho_{nf}(\partial_t u_2 + u_1 \partial_x u_2 + u_2 \partial_y u_2 + u_3 \partial_z u_2 - 2\Omega_1 u_1) = -\partial_y p + \mu_{nf} \partial_{zz} u_2 - \sigma_{nf} B_0^2 u_2, \tag{3}$$

$$\rho_{nf}(\partial_t u_3 + u_1 \partial_x u_3 + u_2 \partial_y u_3 + u_3 \partial_z u_3) = -\partial_z p + \mu_{nf} \partial_{zz} u_3, \tag{4}$$

$$\partial_t T + u_1 \partial_x T + u_2 \partial_y T + u_3 \partial_z T = \lambda_{nf} \partial_{zz} T + \tau^* \{ D_B \partial_z C \partial_z T + \frac{D_T}{T_\infty} (\partial_z T)^2 \}, \tag{5}$$

$$\partial_t C + u_1 \partial_x C + u_2 \partial_y C + u_3 \partial_z C = \tilde{D}_B \partial_{zz} C + \frac{\tilde{D}_T}{T_\infty} \partial_{zz} T - k_1^2 (C - C_\infty) \left(\frac{T}{T_\infty} \right)^m \exp \left(\frac{-E_a}{k_b T} \right). \tag{6}$$

The Equation (1) represents the mass conservation for incompressible flow. On L.H.S of each of Equations (2)–(6), the local rate of change is described in the first terms, the second, the third, and fourth terms represents convection rate of change. The fifth term in Equations (2) and (3) shows the rotation. The first term on R.H.S of each of the Equations (2)–(4) indicates pressure gradient, the second term corresponds to viscous effects and third term in Equations (2) and (3) signified the body force (magnetic effect). The right hand side of Equation (5), the first term is attributed with thermal diffusion and the second term exhibits the thermophoresis and Brownian motion phenomena. Similarly, on R.H.S of Equation (6), the first term stands for solutal diffusion, the second term for thermophoresis, and the last term in Equation (6).

Here, $u_1, u_2,$ and u_3 are velocity component in x, y, z directions, respectively, T and C are the fluid temperature and nanoparticle volume concentration, $D^* B$ and $D^* T$ are the Brownian diffusion and thermophoretic diffusion coefficient respectively, $\rho_n f, \alpha^* n f, \mu_n f,$ and $\sigma_n f$ are respectively the density, thermal diffusivity, dynamic viscosity, and electrical conductivity of the nanofluid. The current physical elaborated problem, characterized boundary conditions are

$$t < 0 : u_1 = 0, u_2 = 0, u_3 = 0, T = T_\infty, C = C_\infty, \quad (7)$$

$$t \geq 0 : u_1 = \bar{u}x, u_2 = 0, u_3 = 0, T = T_w, C = C_w, \text{ as } z = 0, \quad (8)$$

$$t \geq 0 : u_1 \rightarrow 0, u_2 \rightarrow 0, T \rightarrow T_\infty, C \rightarrow C_\infty, \text{ as } z \rightarrow \infty. \quad (9)$$

In this current investigation, the authors attempted to utilize another way to enhance the technique of heat transfer in liquids, which is presently being talked about among researchers and scientists. The utilization of hybrid nanoparticles instead of single nanoparticles alongside the utilization of various shapes of nanoparticle and hybrid base liquid is adopted technique by the writers of this paper. Since hybrid nanoparticles thermal conductivity is greater than single nanoparticles thermal conductivity ($k_{hnf} > k_n f$), it is an ideal strategy for improving heat transfer process in liquids

Table 2. Nanoparticles shape with shape factor

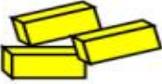
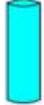
Nanoparticles Type	Shape	Shape Factor
Bricks		3.7
Cylinders		4.9
Platelets		5.7
Blades		8.9

Table 1. Thermo-physical properties of hybrid base fluid and nanoparticles [11,44].

Physical Properties	C ₂ H ₆ O ₂ -H ₂ O	MoS ₂	Ag	Go
$\rho(\text{kg} \cdot \text{m}^3)$	1063.80	5060.0	10,490.0	1800.0
$C_p(\text{J}(\text{kg} \cdot \text{°K}))$	3630.00	397.21	235.000	717.0
$\sigma(\Omega \cdot \text{m})$	9.75×10^{-4}	02.09×10^4	6.30×10^7	6.30×10^7
$\kappa(\text{W}(\text{m} \cdot \text{°K}))$	0.387	904.4	429	5000.0

Table 3. Thermo-physical properties of hybrid nanofluid [48,49].

Properties	Nanofluid	Hybrid Nanofluid
μ (viscosity)	$\mu_{nf} = \frac{\mu_f}{(1-\Phi)^{2.5}}$	$\mu_{hnf} = \frac{\mu_f}{(1-\Phi_1)^{2.5}(1-\Phi_2)^{2.5}}$
ρ (density)	$\rho_{nf} = \rho_f((1-\Phi) + \Phi \frac{\rho_s}{\rho_f})$	$\rho_{hnf} = \rho_f(1-\Phi_2)((1-\Phi_1) + \Phi_1 \frac{\rho_{s1}}{\rho_f}) + \Phi_2 \rho_{s2}$
ρC_p (Heat capacity)	$(\rho C_p)_{nf} = (\rho C_p)_f((1-\Phi) + \Phi \frac{(\rho C_p)_s}{(\rho C_p)_f})$	$(\rho C_p)_{hnf} = (\rho C_p)_f(1-\Phi_2)((1-\Phi_1) + \Phi_1 \frac{(\rho C_p)_{s1}}{(\rho C_p)_f}) + \Phi_2 (\rho C_p)_{s2}$
κ (Thermal conductivity)	$\frac{\kappa_{nf}}{\kappa_f} = \frac{\kappa_s + (s_f - 1)\kappa_f - (s_f - 1)\Phi(\kappa_f - \kappa_s)}{\kappa_s + (s_f - 1)\kappa_f + \Phi(\kappa_f - \kappa_s)}$	$\frac{\kappa_{hnf}}{\kappa_{bf}} = \frac{\kappa_{s2} + (s_f - 1)\kappa_{bf} - (s_f - 1)\Phi_2(\kappa_{bf} - \kappa_{s2})}{\kappa_{s2} + (s_f - 1)\kappa_{bf} + \Phi(\kappa_{bf} - \kappa_{s2})}$ where $\frac{\kappa_{bf}}{\kappa_f} = \frac{\kappa_{s1} + (s_f - 1)\kappa_f - (s_f - 1)\Phi_1(\kappa_f - \kappa_{s1})}{\kappa_{s1} + (s_f - 1)\kappa_f + \Phi_1(\kappa_f - \kappa_{s1})}$
σ (Electrical conductivity)	$\frac{\sigma_{nf}}{\sigma_f} = 1 + \frac{3(\sigma - 1)\Phi}{(\sigma + 2) - (\sigma - 1)\Phi}$	$\frac{\sigma_{hnf}}{\sigma_{bf}} = 1 + \frac{3\Phi(\sigma_1\Phi_1 + \sigma_2\Phi_2 - \sigma_{bf}(\Phi_1 + \Phi_2))}{(\sigma_1\Phi_1 + \sigma_2\Phi_2 + 2\Phi\sigma_{bf}) - \Phi\sigma_{bf}((\sigma_1\Phi_1 + \sigma_2\Phi_2) - \sigma_{bf}(\Phi_1 + \Phi_2))}$

IV.RESULTS AND DISCUSSION

S.No	Parameter	Nano Fluid	3D Hybrid Nano Fluid
1	velocity components,	low	High
2	temperature,	low	High
3	Nusselt number,		High
4	nano-particle volume fraction,	low	high
5	Sherwood number	low	High

V.CONCLUSION

Through this computational effort, we have successfully elucidated the parametric impacts on flow of hybrid and nano phases. The monotonic differences of the results for two phases are clearly observed. This study may be extended for two or more hybrid phases to point out the most effectual among them. Further, the boundary condition of zero heat flux at the surface could be taken into account and different hybrid base fluids. The finite element procedure is employed to examine the enhancement of thermal distribution for the magneto hydrodynamic rotational flow of hybrid nanofluids over a stretching plane. Numerical findings for velocity components, skin friction coefficients, temperature, Nusselt number, nano-particle volume fraction, and Sherwood number are computed for the hybrid phase and nanophase.

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