The Study Of Nanofluid Flow Over A Rotating ConeWith Suspension Offerrous Nanoparticles

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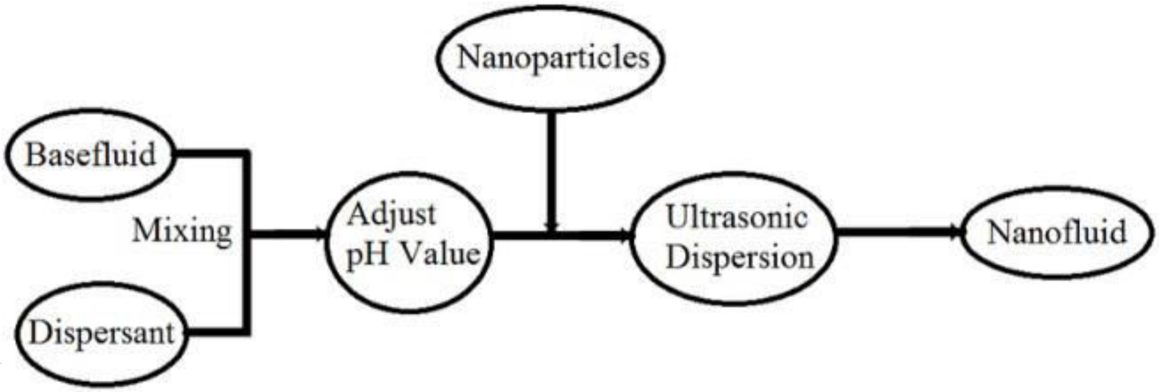
Abstract:

In this study, we used water-based nanoparticles as our medium of inquiry in order to evaluate the transfer of momentum and heat inside an unsteady flow of Casson $Mn - Zn\ Fe_2O_4$ nanofluid over a spinning cone. The relevance of heat flow situations and wall temperature conditions is well known in the engineering and industrial sectors. After that, a shooting approach based on the Runge-Kutta algorithm is used in order to numerically solve the ensuing set of governing equations. In the graphic representation of our results, we showed two potential outcomes for Wall temperature and Heat Flux. Even whether the wall is very hot or cold, this fact will not change. Tiny solid particles suspended in a colloidal media are a defining feature of nanofluids. Solid particles on the nanoscale range from metals and oxides to carbides and carbon nanotubes. This led Choi to realise that suspending nanoparticles in these common base fluids improves their thermal conductivity noticeably. The generated nanofluids outperform traditional base fluids in thermal conductivity. Solutions containing solid particles measuring on the nanoscale scale, such as metals, oxides, carbides, carbon nanotubes, and so on, are referred to as nanofluids or colloidal suspensions. Water, kerosene, and mineral oils, all of which have a poor thermal conductivity, are employed in the conventional mode of heat transfer. Choi realised that by suspending nanoparticles in these common base fluids, the thermal conductivity may be significantly improved. The generated nanofluids outperform traditional base fluids in thermal conductivity.

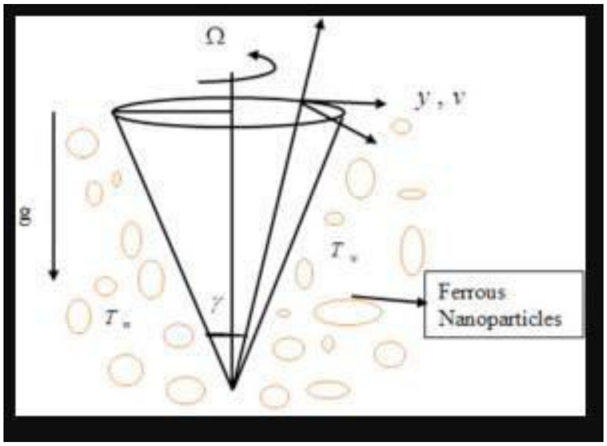
Keywords: Ferrous fluid, rotation, rotating cone casson fluid, non-uniform heat source/sink. MHD.

Introduction:

Electric motors, generators, transformers, phones, speakers, and even spinning X-ray machines all require ferromagnetic materials in some capacity. The magnetic properties of iron, cobalt, nickel, etc. are known as ferromagnetism. A large number of MHD-based fluid devices rely heavily on ferrous-based nanoparticles, including sensor systems (ultrasound, image), pressure transducers (gases, liquids), electro mechanical converters (loudspeaker, microphone), and so on. In a recent article, Paras Ram and Kushal Sharma[5] talked on Ferrofluid flow with a spinning disc and the influence of rotation on MHD viscosity. Referenced in Raju et al. Temperature and momentum transmission in a ferrofluid with a multi-scale, multi-dimensional (MHD) boundary layer. Using a spinning cone as an example, Hering et al. [11] spoke about Laminar mixed convection. Reference: K.Sarma et al. [12]. a cone-shaped source of laminar mixed convection. Conical convection with a mixture of hot and cold air. through M. Kumari [13]. Boundary layers that rotate on spherical, circular, and axisymmetric shapes. by means of Wang [14]. Nadeem and Saleem [16] theorised about the MHD movement of nanofluids across a rotating cone. C.L.Tien [17] A spinning cone creates a laminar flow that may carry heat and mass efficiently. M. Alamgir[18] shown that discs optimise heat convection in laminar free convection, when heat is transferred from a vertical cone. P. Cheng, et al. [19]. Natural convection is responsible for the movement of a darcian fluid around a cone. According to the well-known H.S.Takhar. [20]. a cone-shaped source of vertically-rotating, mixed convectional and magnetically-induced flow. a product of G.Nath's mind and hand. [21].



The conical source of laminar combined convection. W.A.Khan \s,Z.H.Khan [29] The movement and heat transmission of a ferrofluid across a flat plate subject to a constant heat flux. Furthermore, geometrical arrangement plays a vital part in modern manufacturing, engineering, and experimental design. Important research on normal fluids in cone geometries may be found in" . Industries as diverse as nuclear heat or cold treatment, spacecraft components preparation, rolling, engineering, etc. all rely on the magneto hydrodynamic flow to regulate production. With this goal in mind, the authors investigated the effects of different flow geometries and regulating parameters on the magnetohydrodynamic features of a suspension.



These analyses elucidated how the magnetohydrodynamic flow regulates the boundary layers of both fluid and thermal transfer. There is a comprehensive discussion of magnetic fields in the cited works [33–35]. Researchers have shown that using nanoparticles in a base liquid may speed up the operation of cooling and heating systems. In light of the fact that no theoretical work has been done to date on the topic of " Thermophoresis and Brownian motion in a solution of ferrous nanoparticles producing radiated magnetic flow," we conduct a study to learn more about the heat and mass transfer properties of magnetohydrodynamic (MHD) ferrofluid flow caused by a cone when Brownian motion and thermophoresis are present. In order to create nanoparticles, a combination of CoFe2O4 and water at 100c and CoFe2O4 and water at 500c was utilised. Solving the ODEs for the nonlinear flow using the shooting technique of Runge-Kutta (RKSM). Non-uniform heat sources and sinks, as well as thermal radiation, were also taken into account in this investigation to speed up the heat transfer process.What happens to a water-based fluid when its cone rotates depends on the presence of metallic particles and the fluid's buoyancy. The current study, “which discusses the heat transfer features of casson fluid flow around a spinning cone in a rotating frame containing Mn-ZnFe2o3 nan oparticles in water, is motivated by previous studies along these lines”. According to these findings, there are at least two potential explanations aimed at the partition temperature and heat transfer around a rotating

cone.

“Nomenclature:

F	Fluid	w	condition at the wall
∞	condition at the free stream	n_f	Nanofluid
q_w	Wall heat flux (W/m^2)	f, g	Dimensionless velocities
G_r	Grashof number	Re_L	Local Reynolds number
Nu_x	Local Nusselt number	Cf_x	Skin friction coefficient in x- direction
Cf_y	Skin friction coefficient in y- direction		
T	Temperature(k)	K^*	Mean absorption coefficient
α_{nf}	Diffusion coefficient (m^2/ s)	Pr	Prandtl number
β_T	Volumetric thermal expansion (K^{-1})	θ	Dimensionless temperature (K)
σ	Electical conductivity (s/m)		
$(\rho c_p)_p$	Effective heat capacity of the particle medium (Kg/m^3K)		
$(\rho c_p)_p$	Effective heat capacity (Kg/m^3K)	ϕ	Nano particle volume fraction
σ^*	Stefan-Boltzmann constant (Wm/K^4)	υ_{nf}	Kinematic viscosity (m^2/s)
η	Similarity variable	Ω	Composite angular velocity
K_{nf}	Thermal conductivity (W/mK)		
C_p	Specific heat capacity at constant pressure (J/Kgk)		
u, v, w	velocity components in x, y, z directions		

S	Unsteadiness parameter	x	Distance along the surface (m)
y	Distance normal to the surface (m)	α_1	Ration of angles
N_1, N_2	Heat generation	α^*	Semi vertical angle
μ_{nf}	Dynamic viscosity(Ns/m^2)	ρ_{nf}	Density (Kg/m^3)
υ	Kinematic viscosity (m^2/s)	g_e	Acceleration due to gravity (m/s^2)
υ_e	Free stream velocity		

Formulation of the problem:

In the study, we consider an unsteady ferrofluid flow on a rotating cone in rotating frame with non-uniform heat source/sink." Consideration is given to the fixed rectangular curved-linear coordinate system. The crucial geometric aspect of the problem is seen in Fig.1.

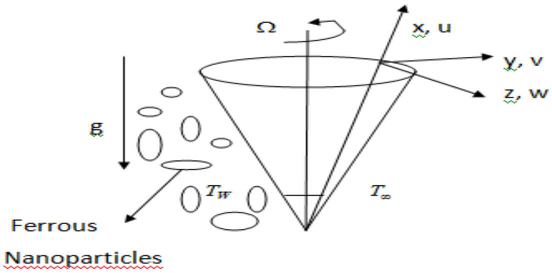


Fig 1. Physical model of the problem

Here, u, v, and w represent the x, y, and z components of velocity, respectively. The cone and the fluid both revolve steadily around the cone's axis, making them both stiff.Their rotation, which might be in the same or opposite direction as the fluid flow, causes the disruptions. The buoyant forces in the fluid flow are caused by the temperature gradient. The outside of the cone acts as an insulator for electricity. It is assumed that the flow isaxisymmetric. Given this, we estimate that the magnetic Reynolds number is low, suggesting that the produced magnetic field has a low impact. There is also no electric field present in the flow. One may write the wall's temperature as a function of x. For an incompressible, unsteady flow in the boundary layer, S. Raju presents the momentum and energy equations. [1]

Flow Analysis:

“

$$x\frac{\partial u}{\partial x}+u+\frac{\partial w}{\partial z}=0 \qquad \mathbf{1}$$

$$\rho_{nf}\left(\frac{\partial u}{\partial t}+u\frac{\partial u}{\partial x}+w\frac{\partial u}{\partial z}-\frac{v^2}{x}\right)=-\frac{v_e^2}{x}+\mu_{nf}\left(1+\frac{1}{\beta}\right)\frac{\partial^2 u}{\partial z^2}+g_e(\rho\beta)_{nf}\left(T-T_\infty\right)\cos\alpha^* \qquad \mathbf{2}$$

$$\rho_{nf}\left(\frac{\partial v}{\partial t}+u\frac{\partial v}{\partial x}+w\frac{\partial v}{\partial z}+\frac{uv}{x}\right)=\frac{\partial v_e}{\partial t}+\mu_{nf}\frac{\partial^2 v}{\partial z^2} \qquad \mathbf{3}$$

$$(\rho c_p)_{nf}\left(\frac{\partial T}{\partial t}+u\frac{\partial T}{\partial x}+w\frac{\partial T}{\partial z}\right)=K_{nf}\frac{\partial^2 T}{\partial z^2}+\frac{k_f U_W(x)}{x\,\nu_f}\left({}_1(T_w-T_\infty)f'+N_2(T-T_\infty)\right) \qquad \mathbf{4}$$

$(N$

The boundary conditions for the HF case are:

$$u = 0, v = x\Omega_1 \sin\alpha^* \left(1 - st\Omega\sin\alpha^*\right)^{-1}, w = 0, T = T_w \, at z = 0,$$
$$u = 0, v = v_e = x\Omega_2 \sin\alpha^* \left(1 - st\Omega\sin\alpha^*\right)^{-1}, T \to T_\infty as Z \to \infty \quad \mathbf{5}$$

The boundary conditions for the WT case are:

$$u = 0, v = x\Omega_1 \sin\alpha^* \left(1 - st\Omega\sin\alpha^*\right)^{-1}, w = 0, -K_f T = q_w \, at z = 0,$$
$$u = 0, v = v_e = x\Omega_2 \sin\alpha^* \left(1 - st\Omega\sin\alpha^*\right)^{-1}, T \to T_\infty asz \to \infty \quad \mathbf{6}$$

In the above equation $N_1 > 0, N_2 > 0$ corresponds to internal heat generation and $N_1 < 0, N_2 < 0$

Corresponds to heat absorption coefficients respectively and the nano fluid constants are given by

$$\rho_{nf} = (1-\phi)\rho_f + \phi\rho_s, (\rho c_p)_{nf} = (1-\phi)(\rho c_p)_f + \phi(\rho c_p)_s, \mu_{nf} = \frac{\mu_f}{(1-\phi)^{2.5}}, (\rho\beta)_{nf} = (1-\phi)(\rho\beta)_f + \phi(\rho\beta)_s$$

$$\frac{K_{nf}}{K_f} = \frac{K_s + 2K_f - 2\phi\left(K_f - K_s\right)}{K_S + 2k_f + \phi\left(K_f - K_s\right)} \quad \mathbf{7}$$

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Introducing non dimensional variables: $f^1(\eta)$

$$
\begin{aligned}
u &= -2^{-1} x\Omega\sin\alpha^*\left(1-st\Omega\sin\alpha^*\right)^{-1}\\
v &= x\Omega\sin\alpha^*\left(1-st\Omega\sin\alpha^*\right)^{-1} g(\eta)\\
w &= \left(\upsilon\Omega\sin\alpha^*\right)^{0.5}\left(1-st\Omega\sin\alpha^*\right)^{-o.5} f(\eta)\\
v_e &= x\Omega_2\sin\alpha^*\left(1-st\Omega\sin\alpha^*\right)^{-1}\\
\eta &= \left(\frac{\Omega\sin\alpha^*}{\upsilon}\right)^{0.5}\left(1-st\Omega\sin\alpha^*\right)^{-0.5} z\\
q_w &= q_0\left(\frac{x}{L}\right)\left(1-st\Omega\sin\alpha^*\right)^{-2.5}\\
T &= T_\infty + \left(\frac{\Omega\sin\alpha^*}{\upsilon}\right)^{-0.5}\left(1-st\Omega\sin\alpha^*\right)\left(\frac{q_w}{K_f}\right)\theta(\eta)\\
t^* &= \left(\Omega\sin\alpha^*\right)t''
\end{aligned}
\qquad \mathbf{8}
$$

“where s is the unsteady parameter, Ω_1 and Ω_2 are the angular velocities of the cone and free stream fluid respectively. $\Omega=\Omega_1+\Omega_2$ is the composite angular velocity, making use of eq,7,8 in Eqs (1)-(4) transformed boundary layer equations are given by

$$\left(1+\frac{1}{\beta}\right)\frac{1}{(1-\phi)^{2.5}}f''' - \left(1-\phi+\phi\left(\frac{\rho_s}{\rho_f}\right)\right)X\left(f f'' - 2^{-1}f'^2 - s\left(f' + 2^{-1}\eta f''\right) - 2\left(g^2-(1-\alpha_1)^2\right)\right) - \left(1-\phi+\phi\left(\frac{(\rho\beta)_s}{(\rho\beta)_f}\right)\right)\lambda\theta = 0 \qquad \mathbf{9}$$

$$\frac{1}{(1-\phi)^{2.5}}g'' + \left(1-\phi+\phi\left(\frac{\rho_s}{\rho_f}\right)\right)\left(f'g - g'f + s\left(1-\alpha_1 - g - 2^{-1}\eta g'\right)\right) = 0 \qquad \mathbf{10}$$

$$\frac{k_{nf}}{k_f}\theta'' - P_r\left(1-\phi+\phi\left(\frac{(\rho c_p)_s}{(\rho c_p)_f}\right)\right)\left(f\theta' - 2^{-1}f'\theta - s\left(2\theta + 2^{-1}\eta\theta'\right)\right) + \left(1-\phi+\phi\left(\frac{(\rho c_p)_s}{(\rho c_p)_f}\right)\right)\left(N_1 f' + N_2\theta\right) = 0 \qquad \mathbf{11}$$

The relevant boundary conditions for HF case are stated as

$$f(0) = 0,\ f'(0) = 0,\ g(0) = \alpha_1,\ \theta(0) = 1,\ f'(\infty) = 0,\ g(\infty) = 1 - \alpha_1,\ \theta(\infty) = 0 \qquad \mathbf{12}$$

The relative boundary conditions for WT case are stated as

$$F(0) = 0,\ F'(0) = 0,\ G(0) = \alpha_1,\ \Theta'(0) = -1,\ F'(\infty) = 0,\ G(\infty) = 1 - \alpha_1,\ \Theta(\infty) = 0. \qquad \mathbf{13}$$

The relevant boundary conditions

$$Gr = \frac{g\beta_T \cos\alpha^* \left(T_w - T_\infty\right) L^3}{\upsilon_f^2}, \mathrm{Re}_L = \frac{\Omega L^2 \sin\alpha^*}{\upsilon}, \alpha_1 = \frac{\Omega_1}{\Omega}, \Pr = \frac{\upsilon_f}{\alpha} \lambda = \frac{Gr}{\mathrm{Re}_L^2} \qquad \mathbf{14}$$

Where Gr is the Grashof number ,Re_L is the Reynolds number, λ is the buoyancy force parameter, and Pr is the prandtl number.

The coefficients of surface skin friction in tangential and azimuthal directions for the WT case

$$c_{fx} = \frac{\left[2\mu\left(\frac{\partial u}{\partial z}\right)\right]_{z=0}}{\rho\left[\Omega x \sin\alpha^*\left(1 - st\Omega\sin\alpha^*\right)\right]^2} = -\mathrm{Re}_x^{-0.5} f''(0),$$

$$c_{gy} = \frac{\left[2\mu\left(\frac{\partial v}{\partial z}\right)\right]_{z=0}}{\rho\left[\Omega x \sin\alpha^*\left(1 - st\Omega\sin\alpha^*\right)\right]^2} = \mathrm{Re}_x^{-0.5} g'(0) \qquad \mathbf{15}$$

Or

$$C_{fx}\mathrm{Re}_x^{o.5} = -f''(0), C_{fy} = \mathrm{Re}_x^{0.5} = -g'(0)$$

Where Re_x is the Reynolds number. The surface skin friction coefficient in tangential and azimuthal direction for HF case are

$$C_{fx}\mathrm{Re}_x^{o.5} = -F''(0), C_{fy} = \mathrm{Re}_x^{0.5} = -G'(0) \qquad \mathbf{16}$$

The Nusselt number for the WT and HF case are given by

$$Nu\,\mathrm{Re}_x^{-0.5} = \frac{K_{nf}}{K_f}\theta'(0), Nu\,\mathrm{Re}_x^{-0.5} = \frac{K_{nf}}{K_f}\frac{1}{\Theta(0)} \qquad \mathbf{17}$$

Method of solution:

The nonlinear differential Eqs. (9-11) with the boundary conditions (12-13) are solved numerically using Runge – Kutta based shooting method. Initially the set of nonlinear ordinary differential Eqs. (9- 1 1) converted to first order differential equations by using as following:

$$f = f(1),\ f' = f(2),\ f'' = f(3),\ g = f(4),\ g' = f(5),\ \theta = f(6),\ \theta' = f(7) \qquad 18$$

$$f''' = \left(\frac{\beta}{1+\beta}\right)(1-\phi)^{2.5}\left[\left(1-\phi+\phi\left(\frac{\rho_s}{\rho_f}\right)\right)\left(f''f - \frac{1}{2}f'^2 - s\left(f' + \frac{1}{2}\eta f''\right) - 2\left(g^2 - (1-\alpha_1)^2\right)\right) + \left(1-\phi+\phi\left(\frac{(\rho\beta)_s}{(\rho\beta)_f}\right)\right)\lambda\theta\right] \qquad 19$$

$$g'' = (1-\phi)^{2.5}\left[-\left(1-\phi+\phi\left(\frac{\rho_s}{\rho_f}\right)\right)\left(f'g-g'f+s\left(1-\alpha_1-g-\frac{1}{2}\eta g'\right)\right)\right] \qquad 20$$

$$\theta'' = \frac{k_f}{k_{nf}}\left[P_r\left(1-\phi+\phi\left(\frac{(\rho_{cp})_s}{(\rho_{cp})_f}\right)\right)\left(f\theta'-\frac{1}{2}f'\theta-s\left(2\theta+\frac{1}{2}\eta\theta'\right)\right)-\left(1-\phi+\phi\left(\frac{(\rho_{cp})_s}{(\rho_{cp})_f}\right)\right)\left(N_1 f'+N_2\theta\right)\right] \qquad 21$$

With the boundary conditions for HP case are

$$f(1)=0,\ f(2)=0,\ f(4)=\alpha_1,\ f(6)=1,\text{at}\ \eta\to 0,\ \ f(2)=0,\ f(4)=1-\alpha_1,\ f(6)=0,\text{at}\ \eta\to\infty \qquad 22$$

With the boundary conditions for WT case as

$$f(1)=0,\ f(2)=0,\ f(4)=\alpha_1,\ f(6)=-1,\ \text{at}\ \eta\to 0,\ f(2)=0,\ f(4)=1-\alpha_1,\ f(6)=0,\text{at}\ \eta\to\infty \qquad 23$$

To solve the Eqs. (19-21) with Eqs.(22-23) is an initial value of D(0) for HF and WT cases respectively. We guess the values of $y_3(0)$,$y_5(0)$, $y_7(0)$ which are not given at the initial conditions. Once all initial conditions are found then we solve the Eqs." Integrations (21-23) are performed using the Runge-Kutta fourth order technique with a 0.01-step iterative step length. To check the accuracy of the current solutions, we compare them to those found by S.Raju et al [1].

Consequences besides debate:

Using a Runge-Kutta based shooting method, we numerically solve the system of nonlinear coupled ordinary differential equations (9), (10), and (11) with boundary conditions (15), (16), and (17). (17). Wall temperature and heat flow examples demonstrate the influence of non-dimensional regulating components, such as the friction factor coefficient and the local nusselt number, on velocity and temperature profiles. The numerical calculations accounted for the values of the non-dimensional parameters.As $S = 5$, $\lambda = 1.0$, $\alpha_1=1.0$, $\phi=0.2$, $\beta=0.5$, $N_1=0.1$, $N=0.1$. All of these variables are held constant throughout the research, with the exception of minor adjustments made in the individual charts and tables.

The wall temperature scenario is shown in green on the graph, whereas the heat flow case is depicted in red.The thermophysical properties are given below Table 1.

Thermo physical properties of water and Mn-ZnFe2O4 are given by W.A. Khan et al[29]

"Physical properties	Base Fluids	Magnetic Nano Particles
	Water	Mn-ZnFe2O4
ρ(Kg/m^3	997	4900
Cp(j/Kg.k)	4179	800
K(W/m.k)	0.613	5 "

Figure: 1-3 as presented below the graphical depiction of temperature and velocity profiles for different values of the volume % of ferrous oxide nano practises. When the nanoparticle percentage in the air is raised, the tangential velocity field improves but the azimuthal velocity field and the wall temperature and heat flux temperature profiles deteriorate.

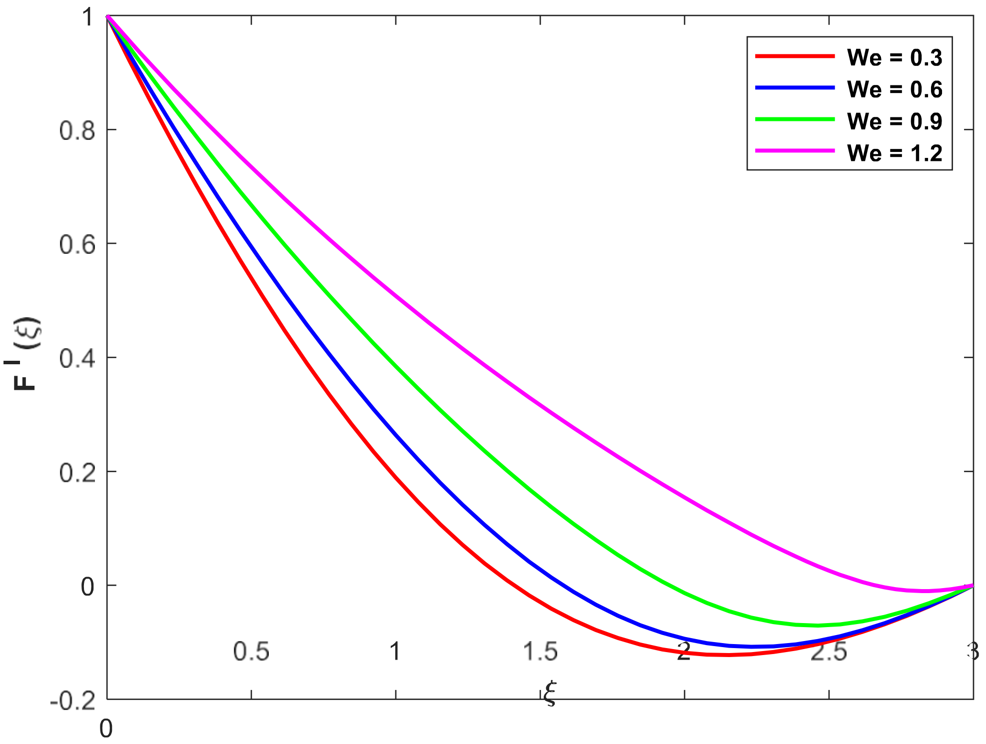

Figure 1: The tangential velocity field for a range of ferrous nanoparticle volume fractions.

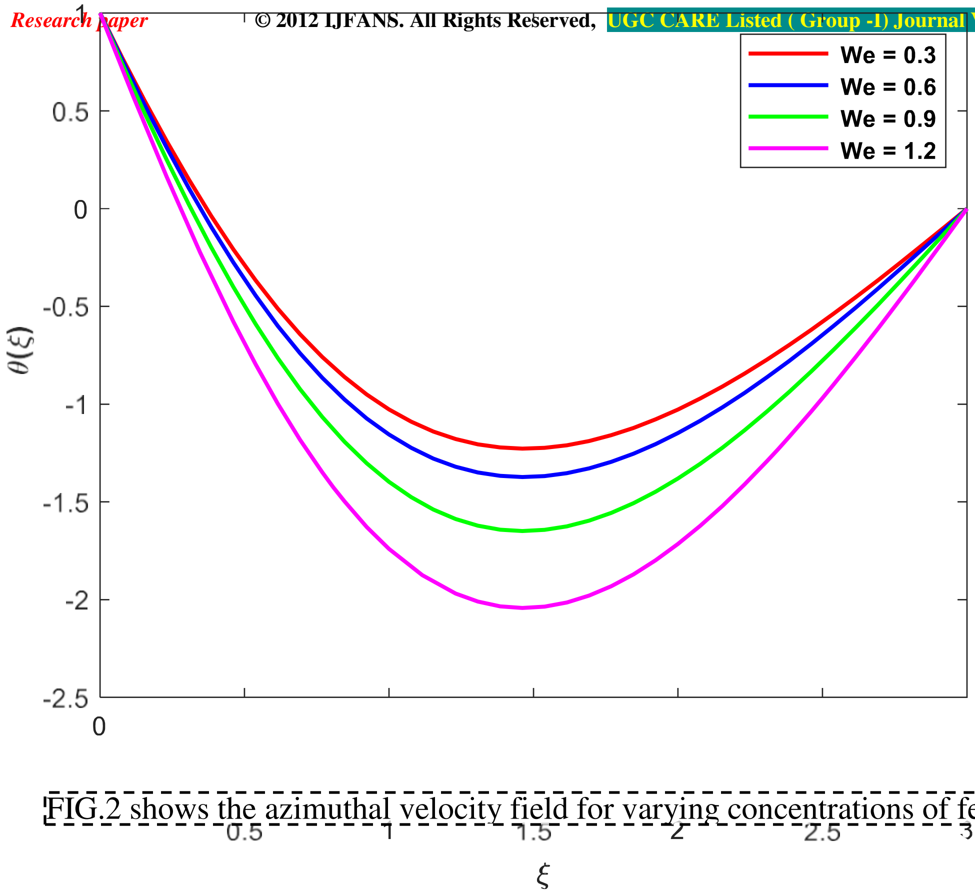

FIG.2 shows the azimuthal velocity field for varying concentrations of ferrous

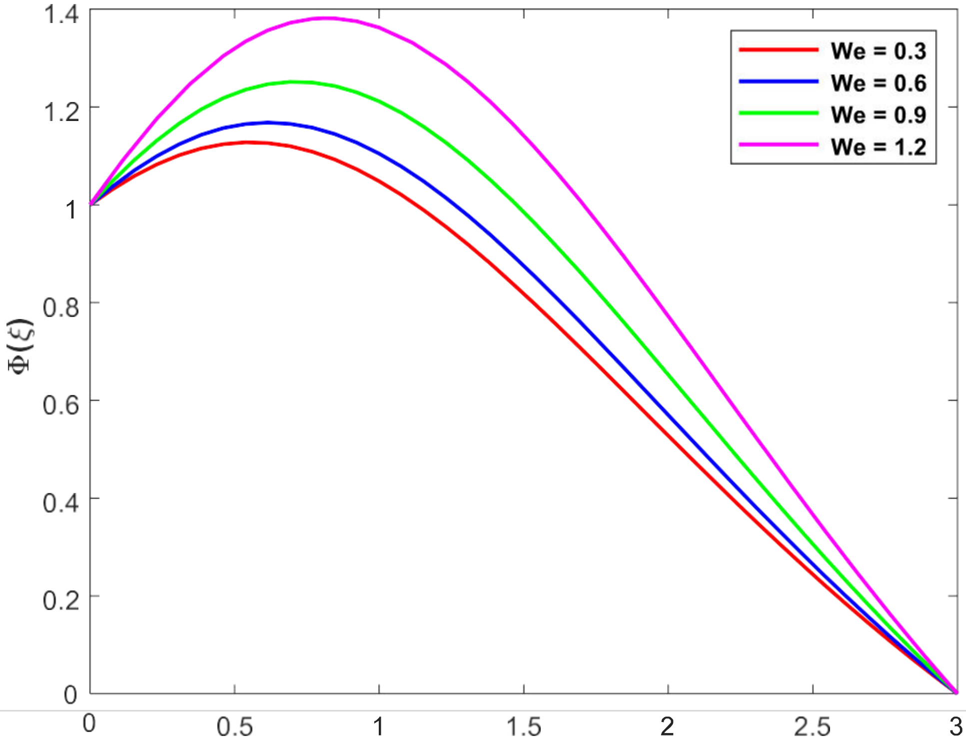

Figure 3: Temperature distribution for a range of ferrous nanoparticle volme

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Conclusions:

Since E rotation tends to control the flow, it finds most of its applications in industry and aviation. Casson fluid flow in a rotating frame containing Mn-Zn Fe2O3 nanoparticles in water is studied, along with its momentum and heat transmission features. The resultant connected non-linear governing equations may be numerically solved using a shooting strategy inspired by Runge-Kutta. The goal of this study was to address questions about the wall temperature and heat transfer across a rotating cone.

References:

[1]S.Raju, Chakravarthula s.k raju Unsteady casson nanofluid flow over a rotating cone in a rotating frame filled with ferrous nanoparticles,14PHD0072.

[2] D.B. Hathway, Use of ferrofluid in moving coil loud speakers, dB-sound Eng. Mag. 13 (1979) 42–44.

[3] M.D. Guptha, A.S. Guptha, Convective instability of a layer of a ferromagnetic fluid rotating about a vertical axis, Int. J. Eng. Sci. 17 (1979) 271–277.

[4] Paras Ram, Kushal Sharma, Effect of rotation and MHD viscosity on ferrofluid flow with rotating disk,Indian J. Pure Appl. Phys. 52 (2014) 87–92.

[5] M. Sheikholeslami, M.G. Bandpy, Free convection of ferrofluid in a cavity heated from below in the presence of an external magneticfield, Powder Technol. 256 (2014) 490–498.

[6] C.S.K. Raju, N. Sandeep, C. Sulochana, V. Sugunamma, Effects of aligned magneticfield and radiation on the flow of ferrofluids over a flat plate with nonuniform heat source/sink, Int. J. Sci. Eng. 8 (2) (2015) 151–158.

[7] M. Qasim, Z.H. Khan, W.A. Khan, I.A. Shah, MHD boundary layer slip flow and heat transfer of ferrofluidalong a stretching cylinder with prescribed heat flux, Plos One 9 (1) (2014) e83930.

[8] S. Nadeem, S. Saleem, Analytical treatment of unsteady mixed convection MHD flow on a rotating cone in a rotating frame, J. Taiwan Inst. Chem. Eng. 44 (2013) 596–604.

[9] Chakravarthula S.K. Raju, Naramgari Sandeep, Dual solutions for unsteady heat and mass transfer in Bio-convection flow towards a rotating cone/plate in a rotating fluid, Int. J. Eng. Res. Afr. 20 (2016) 161–176.

[10] C.S.K. Raju, N. Sandeep, Heat and mass transfer in MHD non-Newtonian bioconvection flow over a rotating cone/plate with cross diffusion, J. Mol. Liq. 215(2016)115-126.

[11] Hering, R. G., and Grosh, R. J., "Laminar Combined Convection from a Rotating Cone," Journal of Heat Transfer, Vol. 85, No. 1, 1963, pp. 29– 34. doi:10.1115/1.3686006.

[12] Himasekhar, K., Sarma, P. K., and Janardhan, K., "Laminar Mixed Convection from a Vertical Rotating Cone," International Communications in Heat and Mass Transfer, Vol. 16, No. 1, 1989, pp. 99–106.

[13] Kumari, M., Pop, I., and Nath, G., "Mixed Convection Along a Vertical Cone," International Communications in Heat and Mass Transfer, Vol. 16, No. 2, 1989, pp. 247–255. doi:10.1016/0735-1933(89)90026-2.

[14] Wang, C. Y., "Boundary Layers on Rotating Cones, Discs and Axisymmetric Surfaces with a Concentrated Heat Source," Acta Mechanica, Vol. 81, Nos. 3–4, 1990, pp. 245–251. doi:10.1007/BF01176992.

[15] Yih, K. A., "Mixed Convection about a Cone in a Porous Medium: The Entire Regime," International Communications in Heat and Mass Transfer, Vol. 26, No. 7, 1999, pp. 1041–1050. doi:10.1016/S0735- 1933(99)00093-7.

[16] Nadeem, S., and Saleem, S., "Theoretical Investigation of MHD Nanofluid Flow Over a Rotating Cone:An Optimal Solutions," Information Sciences Letters, Vol. 3, No. 2, 2014, pp. 55–62.

[17] C.L. Tien, Heat and mass transfer by laminar flow from a rotating cone, ASME J. Heat. Transf. 82 (1960) 252–253.

[18] M. Alamgir, Over-all heat transfer from vertical cone in laminar free convection: an approximate method, ASME J. Heat Transfer, 101 (1989) 174-176.

[19] P. Cheng, T.T. Le, I. Pop, Natural convection of a Darcian fluid about a cone, Int. Commun. Heat. MassTransf. 12 (1985) 705–717.

[20] I. Pop, H.S. Takhar, Compressibility effect in laminar free convection from a vertical cone, Appl. Sci. Res. 48 (1991) 78–82.

[21] H.S. Takhar, A.J. Chamkha, G. Nath, Unsteady mixed convection flow from a rotating vertical cone with magnetic field, Heat. Mass Transf. 39 (2003) 297–304.

[22] N. Sandeep, C. Sulochana, Dual solutions for unsteady mixed convection flow of MHD micropolar fluid over a stretching/shrinking sheet with non-uniform heat source/sink, Eng. Sci. Technol., Int. J. 18 (2015) 738–745.

[23] G. Palani, K.Y. Kim, influence of magnetic field and thermal radiation by natural convection past vertical cone subjected to variable heat flux, Appl. Math. Mech. Engl. 33 (2012) 605–620.

[24] A. Mahdy, A.J. Chamkha, Y. Baba, Double-diffusive convection with variable from a vertical truncated cone in porous media in the presence of magnetic field and radiation effects, Comput. Math. Appl. 59 (2010) 3867–3878.

[25] S. Nadeem, S. Saleem, Analytical study of rotating nonNewtonian nanofluid on a rotating cone, J. Thermophys. Heat. Transf. 28 (2) (2014) 295–302.

[26] B. Mallikarjuna, A.M. Rashad, A.J. Chamkha, Chemical reaction on MHD convective heat and mass transfer flow past a rotating vertical cone embedded in a variable porosity regime, Afr. Mat. (2015), http://dx.doi.org/10.1007/s13370-015-0372-1.

[27] C.Y. Cheng, Soret and Dufour effects on natural convection heat and mass transfer from a vertical cone in a porous medium, Int. Commun. Heat. Mass Transf. 36 (10) (2009) 1020–1024.

[28] R.G. Hering, R.J. Grosh, Laminar combined convection from a rotating cone, ASME J. Heat Transfer, 85 (1963) 29—34.

[29] W.A. Khan, Z.H. Khan, R.U. Haq, Flow and heat transfer of ferrofluids over a flat plate with uniform heat flux, Eur. Phys. J. 130 (2015) 86.

[30] S. Saleem, S. Nadeem, R.U.I. Haq, Buoyancy and metallic particle effects on an unsteady water-based fluid flow along a vertically rotating cone, Eur. Phys. J. 129 (2014) 213.

[31] C.J. Ali, A. Al-Mudhaf, Unsteady heat and mass transfer from a rotating vertical cone with a magnetic field and heat generation or absorption effects, Int. J. Therm. Sci. 44 (2005) 267–276.

[32] S. Saleem, S. Nadeem, Theoretical analysis of slip flow on a rotating cone with viscous dissipation effects, J. Hydrodyn. 27 (2015) 616–623.

[33] M.R. Gholami, O.A. Akbari, A. Marzban, D. Toghraie, G.A.S. Shabani, M. Zarringhalam, The effect of rib shape on the behavior of laminar flow of oil/MWCNT nanofluid in a rectangular microchannel, J. Therm. Anal. Calorim. 134 (3) (2018) 1611–1628.

[34] S. Amir Hussein, M. Akbari, D. Toghraie, An experimental study on rheological behavior of a nanofluid containing oXide nanoparticle and proposing a new correlation, Phys. E Low-dimens. Syst. Nanostruct. 99 (2018) 285–293.

[35] B. Pouya, D. Toghraie, R. Balali Dehkordi, Hossein Abed, MHD miXed convection and entropy generation in a lid-driven cavity with rotating cylinders filled by a nanofluid using two phase miXture model, J. Magn. Magn Mater. 483 (2019) 224–248.

[36] Z. Ali Deris, D. Toghraie, EXperimental investigation for developing a new model for the dynamic viscosity of silver/ethylene glycol nanofluid at different temperatures and solid volume fractions, J. Therm. Anal. Calorim. 131 (2) (2018) 1449–1461.

[37] N.A. Shah, T. Elnaqeeb, S. Wang, Effects of Dufour and fractional derivative on unsteady natural convection flow over an infinite vertical plate with constant heat and mass fluXes, Comput. Appl. Math. 37 (4) (2018) 4931–4943.

[38] G. Marjan, D. Toghraie, M. Reiszadeh, M. Afrand, EXperimental evaluation of dynamic viscosity of ZnO–MWCNTs/engine oil hybrid nanolubricant based on changes in temperature and concentration, J. Therm. Anal. Calorim. 136 (2) (2019) 513–525.

[39] N.A. Shah, T. Elnaqeeb, I.L. Animasaun, Y. Mahsud, Insight into the natural convection flow through a vertical cylinder using caputo time-fractional derivatives, Int. J. Algorithm. Comput. Math. 4 (3) (2018) 1–18.

[40] T. Elnaqeeb, N.A. Shah, I.A. Mirza, Natural convection flows of carbon nanotubes nanofluids with Prabhakar-like thermal transport, Mathematical Methods Appl. Sci. (2020), https://doi.org/10.1002/mma.6584.

[41] R. Behrooz, D. Toghraie, M. Hekmatifar, M. Hadian, Statistical investigation for developing a new model for rheological behavior of ZnO–Ag (50%–50%)/Water hybrid Newtonian nanofluid using experimental data, Phys. Stat. Mech. Appl. 525 (2019) 741–751.

[42] T. Elnaqeeb, N.A. Shah, D. Vieru, Heat transfer enhancement in natural convection flow of nanofluid with Cattaneo thermal transport, Phys. Scripta 95 (11) (2020) 115705.

[2] S.U. Mamatha, R.L. V Renuka Devi, C.S.K. Raju, H.M. Ali, Magnetohydrodynamic nonlinear thermal convection nanofluid flow over a radiated porous rotating disk with internal heating, J. Therm. Anal. Calorim. (2020) 1–12, https://doi.org/10.1007/s10973-020-09669-w.

[3] T. Elnaqeeb, I.L. Animasaun, Ternary-hybrid nanofluids: significance of suction and dual-stretching on three-dimensional flow of water conveying nanoparticles with various shapes and densities, Z. Naturforsch 76 (3) (2021) 231–243, https://doi.org/10.1515/zna-2020-0317.