ABSTRACT

Magnetohydrodynamics (MHD) is an area that discusses the coupled nature of fluid motion and magnetic field. The magnetic field induces a current on the moving conductive fluid that creates an induced magnetic field. Both the electric current and induced magnetic field generate a force namely Lorentz force on the moving fluid that can alter the velocity and magnetic effects of the fluid. Maxwell's equations for electromagnetism and Navier Stoke's equation for fluid mechanics are the basic equations that describe the governing equations of hydromagnetic fluid flows. MHD flows are widely used in metallurgy, polymer industry, plasma jet, electromagnetic pump, and aeronautics. Metal and metal oxides show higher thermal conductivity than fluids. Dispersion of these nanometer-sized (1 nm to 100 nm) particles in the conventionally used fluids like water, Ethylene glycol and oil, etc, revolutionised the area of fluid mechanics. These colloids are known as nanofluids. Hydromagnetic nanofluid flow past various geometries and its fascinating applications are discussed in this study.

CHAPTER-1: Introduction to nanofluids, classification, different types of fluid flow, and magnetohydrodynamics are addressed in this chapter. The chapter introduces various parametric effects on MHD nanofluid flow, solution methodology, and statistical tools. The chapter also examines prior studies on MHD convective flow that have been published. Further, the chapter discusses the fundamental equations and non-dimensional parameters used to describe fluid flow. Lastly the chapter elucidates the scope and objectives of the current research.

CHAPTER-2: The role of Hall current, heat source and Soret effects on MHD convective ferro-nanofluid (Fe_3O_4-water) flow through an inclined channel with porous medium has been theoretically and statistically examined. Velocity, thermal and concentration boundary layer in nanofluids are considered to be oscillatory. Heat due to radiation is induced by the huge disparity in temperature between the plates. Hall current is generated by the uniform application of a strong magnetic field perpendicular to the flow of fluid. Boundary layer equations are changed to non-dimensional type and then resolved using the perturbation approximation. The

outcomes are displayed in the form of tables and figures using MATLAB software. The outcome of pertinent parameters on concentration, temperature and velocity profiles are evaluated through graphs. Besides, wall heat, mass transfer rates and surface drag are investigated through statistical tools like regression and probable error.

CHAPTER-3: The response of MHD convective Carreau nanofluid flow over a bilateral nonlinear stretching sheet in the presence of heat source and zero mass flux condition has been analysed. The problem has been solved numerically using the MATLAB built in function bvp5c. The findings of velocity, temperature and concentration profiles based on various parameters are illustrated using graphs. Impact of various parameters on the heat transfer rate is scrutinized using statistical techniques like correlation coefficient, probable error and regression. The effect of various parameters on skin friction coefficients are studied via tables and slope of linear regression.

CHAPTER-4: The impact of multiple slip effects on the hydromagnetic Carreau nanofluid flow over an elongating cylinder considering linear heat source and exponential space based heat source has been studied. Suitable transformations are used in converting the highly nonlinear system of PDEs governing the flow into a system of ODEs and hence resolved using Runge Kutta method of order four coupled with shooting method. Parallel effect of parameters on Nusselt number is studied using surface plots and the corresponding effects are scrutinized using multiple linear regression. The consequence of different parameters on drag coefficient and mass transfer are quantified using slope of linear regression.

CHAPTER-5: The study focuses on the aggregation kinematics in the quadratic convective magneto-hydrodynamics of ethylene glycol (EG)-titania (TiO_2) nanofluid flowing through an inclined flat plate. The modified Krieger-Dougherty and Maxwell-Bruggeman models are used for the effective viscosity and thermal conductivity to account for the aggregation aspect. The effects of an exponential space-dependent heat source and thermal radiation are incorporated. The impact of pertinent parameters on the heat transfer coefficient is explored by using the Response Surface Methodology (RSM) and Sensitivity Analysis (SA). The various effects of several parameters on the skin friction and heat transfer coefficient at the plate are displayed via surface graphs. The velocity and thermal profiles are compared for two physical scenarios: flow over a vertical plate and flow over an inclined plate. The nonlinear problem is solved using the Runge-Kutta-based shooting technique.

CHAPTER-6: Injection and suction effects play a crucial role in astronomical disciplines, fuel injection, solar collector plate, thermal protection, and aerodynamics. Therefore, the dynamics of hydromagnetic Darcy-Forchheimer hybrid nanoliquid flow over an elongated permeable sheet in the presence of hydrodynamic slip and Newtonian boundary constraints is investigated. A realistic model considering the passive control of nanoparticles and the modified Buongiorno nanoliquid model has been utilized. The modeled partial differential equations are transmuted into a system of nonlinear ordinary differential equations with the aid of apposite similarity transformations which are then resolved numerically using the finite-difference based bvp5c routine. Further, regression analysis is employed to statistically scrutinize the relationship between the pertinent parameters and the drag coefficients and a commendable agreement is noted.

CHAPTER-7: The flow of Reiner-Rivlin hydromagnetic nanoliquid passing through a rotating disk in the presence of Joule heating and a non-uniform heat source is investigated. To control the volume fraction of nanoparticles on the surface of a disk, a realistic passive control strategy is used. Nonlinear governing differential equations are solved numerically using the Bulirsch-Stoer technique and a parametric analysis is performed using graphical representations. Using the Response Surface Methodology (RSM), the interaction effects of the influential parameters on the rate of heat transfer are visualised via three-dimensional surface graphs and contours. Further, the optimum rate of the heat transfer is estimated through RSM analysis.

CHAPTER-8: The nanofluid flow considering different nanoparticle shapes (namely sphere, platelet, cylinder, and brick) and the thermo-hydrodynamic slip constraints have been modeled utilizing the modified Buongiorno model. Von Kármán's similarity transformations are exercised in the transmutation of the mathematically modeled equations into a system of first-order ODEs and treated numerically using the generalized differential quadrature method. The consequence of effectual parameters on the physical quantities and the flow profiles is explained with the aid of graphs and tables.

Lastly **CHAPTER-9** presents an overall summary of the thesis followed by a few recommendations on the future scope of this work.

To My Family

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List of Symbols

r, φ, z	Cylindrical coordinates
x, y, z	Cartesian coordinates
A	Space-dependent heat source/sink parameter
a_v	Reference velocity (ms^{-1})
B	Temperature dependent heat source/sink parameter
Bi	Biot number
B_x	Strength of variable magnetic field
b_1	Velocity slip parameter
b_3	Concentration slip parameter
B_0	Strength of magnetic field
C^*	Fluid concentration in unsteady flow
$C^{'}$	Dimensionless fluid concentration in unsteady flow
C_0	Nanoparticle concentration at the origin
C_∞	Ambient nanoparticle concentration
C_d	Nanoparticle concentration at the distance d
C_p	Specific heat at constant pressure
C_w	Nanoparticle concentration at the wall
D_B	Brownian diffusion coefficient $(m^2 s^{-1})$
D_T	Thermophoretic diffusion coefficient $(m^2 s^{-1})$
D	Fractal index
Ec	Eckert number
$f'(\zeta), g'(\zeta)$	Non-dimensional velocity components in X and Y direction (ms^{-1})
$F(\zeta), F'(\zeta)$	Axial and radial velocity components

$G(\zeta)$	Azimuthal velocity component
G_m	Modified Grashof number
G_r	Grashof number
h_f	Convective heat transfer coefficient $(WK^{-1}m^{-2})$
H	Hall current parameter
j, o	Number of faces and factors
k^*	Rosseland mean absorption coefficient (m^{-1})
k_a	Thermal conductivity of aggregates $(Wm^{-1}\ K^{-1})$
k_f	Thermal conductivity of fluid $(Wm^{-1}\ K^{-1})$
K_1	Dimensionless porosity parameter
K_p	Permeability of the medium
K_r	Chemical reaction parameter
K	Reiner-Rivlin fluid parameter
κ	Curvature parameter
l	Characteristic length (m)
l'	Dimensionless velocity of unsteady flow
M	Hartmann number
m	Exponential index
Nu	Nusselt number
N_i	Slip factor ; $i = 1, 2, 3$
Nu_r	Reduced Nusselt number
Nb	Brownian motion parameter
Nt	Thermophoresis parameter
$\widetilde{n_s}$	Shape factor
n	Power law index

Pr_f	Prandtl number of the fluid
P	Pressure (Nm^{-2})
Q_1	Variable heat source parameter
Q_E	Exponential space based heat source (ESHS)
Q_T	Linear heat source (LHS)
q_R	Radiative heat flux (Wm^{-2})
$q_T, \quad q_E$	Heat source coefficients
q_w	Heat flux
Q	Volumetric rate of heat generation /absorption
R	Radiation parameter
$\mathbb{R}$	Radius of the cylinder (m)
Re	Reynolds number
Ra_x	Rayleigh number
Re_x	Local Reynolds number
$\mathcal{R}^2$	Coefficient of determination
r_a, r_p	Radii of aggregates and nanoparticles (m)
r_c	Correlation coefficient
S	Heat source/sink parameter
Sh	Sherwood number
Sc	Schmidt number
S'	Non-dimensional velocity
S_o	Soret number
T^*	Fluid temperature in unsteady flow (K)
T_0	Temperature of the fluid at the origin (K)
T_∞	Temperature of the ambient fluid (K)

T_d	Temperature of the fluid at the distance d (K)
T_w	Temperature of the fluid near the wall/disk (K)
u^*, v^*, w^*	Velocity components of unsteady flow (m/s)
$u, v, w,$	Velocity components (m/s)
U	Velocity of the palate (m/s)
U_0	Non zero constant mean velocity
We	Local Weissenberg number
w_0	Injection/suction velocity
	Greek symbols
$(\rho C_p)_f$	Fluid heat capacity $(Jm^{-3}K^{-1})$
$(\rho C_p)_p$	Nanoparticle effective heat capacity $(Jm^{-3}K^{-1})$
ϕ	Volume fraction of nanoparticles
ν	Kinematic viscosity (m^2s^{-1})
μ	Dynamic viscosity $(kgm^{-1}s^{-1})$
ζ	Similarity variable
σ	Electrical conductivity
$\theta(\zeta)$	Dimensionless temperature
θ'	Dimensionless temperature in unsteady flow
α_f	Thermal diffusivity (m^2s^{-1})
α_P	Absorption coefficient
Γ	Time material constant (s)
ρ	Density (kgm^{-3})
λ	Injection/suction parameter
β_T	Coefficient of volume expansion
β_C	Volumetric coefficient of expansion with concentration

ϕ_a	Volume fraction of nanoparticle aggregates
ϕ_m	Maximum volume fraction of nanoparticles
α	Angle of inclination
δ	Stretching ratio parameter
γ	Thermal slip parameter
τ	Effective heat capacity ratio
β^*	Viscosity ratio parameter
τ_w	Wall shear stress
μ_c	Cross-viscosity coefficient
α_1	Quadratic thermal convection parameter
β_0, β_1	First and second-order thermal expansion coefficients (K^{-1}, K^{-2})
σ^*	Stefan-Boltzmann constant $(Wm^{-2}\ K^{-4})$
ψ	Stream function
χ	Sphericity
$[\eta]$	Einstein coefficient
τ_{ij}	Stress tensors
τ_r, τ_φ	Radial and azimuthal wall stress
Ω	Angular velocity (s^{-1})
Ω^*	Rotation parameter
ω	Frequency parameter
δ_{ij}	Kronecker delta
	Subscripts
nf	Nanofluid
f	Base fluid
s	Nanoparticle

w	Quantities at wall
	Abbreviations
MHD	Magnetohydrodynamic
FPSC	Flat plate solar collector
EG	Ethylene glycol
RSM	Response surface methodology
DQM	Differential quadrature method
PE	Probable Error