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Micropolar nanofluid flow with MHD and viscous dissipation effects towards a stretching sheet with multimedia feature

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ABSTRACT

An applied thermal system for heat and mass transfer and energy management problem of hydromagnetic flow with magnetic and viscous dissipation effects micropolar nanofluids towards a stretching sheet has been studied. A system of partial differential equations for micropolar and nanofluid has been analyzed by a combination of the similarity transformation and accurate finite-difference method. Those solutions are used to obtain distributions of the local convective heat transfer coefficient and the stretching sheet temperature. The related importance dimensionless parameters are Prandtl number *Pr*, magnetic parameter M, material parameter K, Eckert number *Ec*, Brownian motion number *Nb*, thermophoresis parameter Nt and the Schmidt number *Sc*, respectively. The numerical results are indicated that an increasing in the magnetic parameter is given a decreasing in the values of the velocities and Nusselt number, or an increasing in the values of the shear stress, couple stress at the surface, temperature and concentration. The material parameter K has the opposite effect of magnetic field parameter on the values of the velocities, temperature, concentration, shear stress, Nusselt number and Schmidt number. The temperature is decreased as the Prandtl number increasing, or is increased as the Eckert number increasing. The concentration is decreased as Schmidt number increasing. At last, the study has been presented one multimedia video to show its main contain, it will be appeared at Elsevier AudioSlides website.

1. Introduction

The flow of an incompressible viscous magnetic fluid over a boundary layer is important in industrial applications. For instance, it occurs in the extrusion of a polymer sheet from a die or in the drawing of plastic films. In this study, film processing polymer melt has extruded through a slit die, stretched and cooled in micropolar fluid with magnetic effect. The heat and mass transfer problem of for hydromagnetic flow with magnetic effect micropolar fluids past through a stretching sheet has been studied, there are many applications for this problem, such as, porous rocks, foams and foamed solids, aerogels, alloys, polymer blends and microemulsions. In many industrial manufacturing processes, the problem of flow and heat transfer in two-dimensional boundary layers on a continuous stretching surface, moving in an otherwise quiescent fluid medium, have attracted considerable attention during the last few decades. Examples may be found in continuous casting, glass-fiber production, metal extrusion, hot rolling, wire drawing, paper production, drawing of plastic films, metal and polymer extrusion and metal spinning. Some of MHD related fluid flow studied by many aspects. Sheikholeslami et al. [1] studied MHD free convection of Al_2O_3–water nanofluid considering thermal radiation problem. Sajid and Hayat [2] investigated about MHD viscous flow due to a shrinking sheet problem, Hayat et al. [3] presented the analytic solution of magneto hydrodynamic flow of a second grade fluid over a shrinking sheet problem, Abbasbandy et al. [4] studied for Falkner-Skan flow of MHD Oldroyd-B fluid problem, and Hayat et al. [5] investigated for the unsteady three-dimensional MHD flow and mass transfer in a porous space problem. The non-Newtonian fluid flow related problems were studied by some works. Hsiao [6] discussed about combined electrical MHD heat transfer thermal extrusion system using Maxwell fluid with radiative and viscous dissipation effects, it was not the micropolar nanofluid flow. Hsiao [7] studied about nanofluid mixed convection with slip boundary on a stretching sheet, but not consider micropolar effect. Ghaffari et al. [8] investigated for heat transfer analysis of unsteady oblique stagnation point flow of elastico-viscous fluid, still was not included micropolar effect. Sakiadis [9] presented boundary layer flow over a continuous solid surface moving with constant speed. This problem was extended by Erickson et al. [10] and Fox et al. [11] to include the wall suction or blowing and investigated its effects on the heat and mass

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Nomenclature

b	constant: 1/s
B_0	magnetic field, T
C	concentration of the fluid inside the boundary layer, kg/m^3
C_f	skin friction coefficient
c_p	specific heat at a constant pressure, J/kg k
C_w	species concentration at the wall surface, kg/m^3
C_∞	concentration of the fluid outside the boundary layer, kg/m^3
D	coefficient of mass diffusivity, m^2/s
D_B	Brownian diffusion coefficient
D_T	thermophoresis diffusion coefficient
$Ec = u_w^2/(c_p(T_w - T_\infty))$	Eckert number
f	reduced stream function
i	=m/b reference length
j	microinertia per unit mass, m^2
j_w	local mass flux, kg/m^2 s
h_x	local surface heat flux transfer coefficient, W/m^2 k
k	vortex viscosity, kg/m s
k_f	thermal conductivity, W/m k
$K = k/\mu$	material parameter, J/kg k
$M = \sigma B_0^2/(\rho b)$	magnetic parameter
N	dimensionless components of microrotation or angular velocity
$N_b = \frac{(\rho c)_p D_B (C_w - C_\infty)}{(\rho c)_f \nu_f}$	Brownian motion parameter
$N_t = \frac{(\rho c)_p D_T (T_w - T_\infty)}{(\rho c)_f \nu_f T_\infty}$	thermophoresis parameter
$Nu_x = xh(x)/k_f$	Nusselt number
$P_r = (c_p \mu)/\kappa_\infty$	Prandtl number
q_w	heat transfer rate, W
$Re_w = bx^2/\nu$	local Reynolds number
$Sc = \nu/D$	Schmidt number
T	boundary layer fluid temperature, k
T_w	surface temperature, k
T_∞	temperature of the free stream fluid outside the boundary layer, k
u	fluid velocity component in the x directions, m/s
u_w	characteristic velocity, m/s
v	fluid velocity component in the y directions, m/s
x, y	coordinate directions, m
v_w	rate of stretching, m/s
$\theta(\eta) = \frac{T - T_\infty}{T_w - T_\infty}$	dimensionless temperature
$\phi(\eta) = \frac{C - C_\infty}{C_w - C_\infty}$	dimensionless concentration
ν	kinematic viscosity, $1/m^2$ s
μ	dynamic viscosity, kg/m s
ρ	fluid free stream density, kg/m^3
γ	spin gradient viscosity
η	dimensionless boundary layer thickness
$\tau = \frac{(\rho c_p)_p}{(\rho c_p)_f}$	shear stress
$(\rho c_p)_f$	heat capacity of the fluid
$(\rho c_p)_p$	heat capacity of the nanoparticle

transfer in the boundary layer. Crane [12] studied the flow caused by an elastic sheet whose velocity varies linearly with the distance from a fixed point on the sheet. Gupta and Gupta [13] analyzed the heat and mass transfer corresponding to the similarity solution for the boundary layer over a stretching sheet subject to suction or blowing. Chen and Char [14] investigated the effects of the variable surface temperature and variable surface heat flux on the heat transfer characteristics of a linearly stretching sheet subject to blowing or suction. Chakrabarti and Gupta [15] studied the hydromagnetic flow and heat transfer over a stretching sheet. All of the above investigators restricted their analysis to flows of a Newtonian fluid or not is the micropolar fluid. A new stage in the evaluation of fluid dynamic theory is in progress because of the increasing importance in the processing industries and elsewhere of materials whose flow shear behavior cannot be characterized by Newton relationships. Micropolar fluid theory was formulated by Eringen [16]. This theory included the effects of local rotary inertia and couple stresses and is able to describe the behavior of polymers, colloidal and suspension solutions, liquid crystals, animal bloods, etc. Flow motion of such fluids involves a spin vector and a microinertia tensor in addition to the velocity vector. The theory is expected to provide a mathematical model for the non-Newtonian fluid behavior observed in certain fluid such as exotic lubricants, polymeric fluid, colloidal fluids, liquid crystals, ferroliquid, etc., which is more realistic and important from a technological point of view. The theory of thermomicropolar fluids was developed by Eringen [17] by extending his theory of micropolar fluid. Boundary layer flow of a micropolar fluid presented by Takhar and Soundalgekar [18] and heat transfer of a thermomicropolar fluid past a porous stretching sheet analyzed by Chen and Hsu [19]. Hassanien [20] studied boundary layer flow and heat transfer on a continuous accelerated sheet extruded in an ambient micropolar fluid. Flow and heat transfer in a micropolar fluid past a stretching surface investigated by Abo-Eldahab and El Aziz [21]. Hsiao [22] studied numerical solution for Ohmic Soret-Dufour heat and mass mixed convection of viscoelastic fluid over a stretching sheet. Hsiao [23] investigated about the MHD non-Newtonian fluid flow past a wedge. Above studies [17–23] are not consider the nanofluid effects.

At high operating temperatures, magnetic effect can be quite significant. The entire system involving the polymer extrusion process is placed in thermally controlled environment, then magnetic could become important. Some magnetic effects for similar field studies have been provided. MHD flow of a micropolar fluid over a stretching surface with variable thermal conductivity was studied by Mahmoud [24]. Magnetic effects presented by Abo-Eldahab and Ghonaim [25], they studied the convective heat transfer in an electrically conducting micropolar fluid at a stretching surface with uniform free stream. The heat and mass transfer in a hydromagnetic flow of a micropolar fluid past a stretching surface with Ohmic heating and viscous dissipation were studied by Eldabe et al. [26]. Recently, the micropolar fluid flow considered by Mahmood et al. [27] for fluid over a nonlinearly stretching/shrinking sheet: Dual solutions by using Chebyshev Spectral Newton Iterative Scheme. Turkyilmazoglu [28] analyzed about flow of a micropolar fluid due to a porous stretching sheet and heat transfer problem. Waqas et al. [29] presented magnetohydrodynamic (MHD) mixed convection flow of micropolar liquid due to nonlinear stretched sheet with convective condition. Mabood et al. [30] employed non-uniform heat source/sink and Soret effects on MHD non-Darcian convective flow past a stretching sheet in a micropolar fluid with radiation effect. Ramzan et al. [31] examined radiative and Joule heating effects in the MHD flow of a micropolar fluid with partial slip and convective boundary condition problem. From above studies, they have been studied for micropolar fluid flow, but not consider the nanofluid flow.

For nanofluid flow aspect, Pal and Mandal [32] observed about mixed convection and radiation on stagnation-point flow of