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Nanofluid flow with multimedia physical features for conjugate mixed convection and radiation

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ABSTRACT

In this study, energy conversion problems of conjugate conduction, convection and radiation heat and mass transfer with viscous dissipation and magnetic effects have been investigated. Governing equations including continuity equation, momentum equation, energy equation and heat conduction equation for nanofluid flow have been analyzed by a combination of similarity transformation and finite-difference method. For heat convection energy conversion aspect, some importance parameters applied to the system, such as buoyancy parameters G_t and G_c, radiative energy parameter k_0, boundary proportional parameter A_b and Prandtl number Pr which can be produced positive effects for larger values of those parameters. For mass transfer energy conversion aspect, it has been obtained a larger effect with a larger value of Sc. For heat conduction aspect, it depends on the conduction–convection parameter N_{cc}, a larger N_{cc} number can be produced a larger heat conduction effect. The study work considers multimedia effects, so that it is also one kind of multimedia physical features study.

1. Introduction

Energy conversion problems for nanofluid flow past an extrusion stretching sheet with magnetic and radiative effects are importance in industrial applications. For instance, it occurs in the extrusion of a polymer sheet with very high temperature radiative phenomena and combines with magnetic fluid from a die. In this study, film processing polymer melt has been extruded through a slit die and which is cooled by nanofluid with magnetic and radiation effects. The temperature distribution along the draw direction is a function of flow rate. If the surface under observation is that of a thin forming film, the emissivity is strongly dependent upon both wavelength of the radiation and thickness of the film, since it is a polymer, semi-transparent to radiation. Magnetic liquid rotary seals operate with no maintenance and extremely low leakage in a very wide range of applications, and it utilizing the property magnetic properties of the magnetic nanoparticles in liquid. Present study is a combination of the radiative and magnetic nanofluids which can be applied to the extrusion manufacturing processing or other related fields.

Nanofluid is a fluid containing nanometer particles typically made of metals (Al, Cu), oxides (Al_2O_3), etc. The base fluid is usually a conductive fluid, such as water or ethylene glycol. Other base fluids are oil and other lubricants, biofluids and polymer solutions, etc. Nanofluids commonly contain up to 5% volume fraction of nanoparticles to ensure effective heat transfer enhancements. A comprehensive survey of convective transport in nanofluids was made by Buongiorno [1]. Some works on nanofluids are now discussed. Vajravelu et al. [2] investigated convective heat transfer in the flow of viscous Ag–water and Cu–water nanofluids over a stretching surface. Hamad and Ferdows [3] presented a similarity solution for boundary layer stagnation-point flow toward a heated porous stretching sheet which saturated with a nanofluid. Makinde et al. [4] studied buoyancy effects on MHD stagnation point flow and heat transfer of a nanofluid past a convectively heated stretching/shrinking sheet. Ibrahim and Shankar [5] investigated MHD boundary layer flow and heat transfer of a nanofluid past a permeable stretching sheet. Ibrahim et al. [6] studied MHD stagnation point flow and heat transfer due to nanofluid toward a stretching sheet. Rana and Bhargava [7] investigated flow and heat transfer of a nanofluid over a nonlinearly stretching sheet. Hamad [8] developed an analytical solution of natural convection flow of a nanofluid over a linearly stretching sheet in the presence of magnetic field. Khan and Pop [9] studied boundary-layer flow of a nanofluid past a stretching sheet. Makinde and Aziz [10] investigated boundary layer flow of a nanofluid past a stretching sheet with a convective boundary condition. Hassani et al. [11] investigated an analytical solution for boundary layer flow of a nanofluid past a stretching sheet. Bachok et al. [12] studied unsteady

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boundary-layer flow and heat transfer of a nanofluid over a permeable stretching/shrinking sheet. Mustafa et al. [13] investigated stagnation-point flow of a nanofluid toward a stretching sheet. Kandasamy et al. [14] studied a scaling group transformation for MHD boundary-layer flow of a nanofluid past a vertical stretching surface. Aziz and Khan [15] studied natural convective boundary layer flow of a nanofluid past a convectively heated vertical plate. Rashad et al. [16] investigated natural convection boundary layer of a non-Newtonian fluid about a permeable vertical cone which embedded in a porous medium with nanofluid. All of above studies are about the flow field for convection energy conversion problems.

For energy conversion conjugate heat conduction, convection and radiation problems were processed by following studies. Hsiao and Hsu [17] studied mixed convection and non-Newtonian fluid flow pass a plate fin heat transfer problem. Hsiao [18] studied energy conversion conjugate conduction–convection and radiation over non-linearly extrusion stretching sheet with physical multimedia effects problem. Lee et al. [19] studied pin fins heat transfer problems. Hsiao [20] studied conjugate heat transfer for mixed convection and maxwell fluid on a stagnation point problem, which was mainly for mixed convection with magnetic and viscous dissipation effects.

Another related study about radiation phenomenon was presented by Mahantesh et al. [21]. Tzirtzilakis and Kafoussias [22] had studied three-dimensional magnetic fluid boundary layer flow over a linearly stretching sheet. The heat transfer problems had been investigated by Hayat et al. [23,24]. There are some important studies about related energy management application to heat mass transfer works, Pal and Mondal [25] studied a complex chemical reaction and thermal radiation on mixed convection heat and mass transfer over a stretching sheet problem. Malekzadeh et al. [26] investigated the radiation and variable viscosity effects on electrically conducting fluid over a vertically moving plate problem and Ezzat et al. [27] combined heat and mass transfer for unsteady MHD flow of perfect conducting micropolar fluid. Most recently, nanofluid flow have been developed to homogeneous–heterogeneous reactions by Kameswaran et al. [28]. Zheng et al. [29] investigated flow and radiation heat transfer problem. Xu et al. [30] studied flow and heat transfer in a nano-liquid film over an unsteady stretching surface. Recently, Ibrahim and Shankar [31] studied MHD boundary layer flow and heat transfer of a nanofluid past a permeable stretching sheet with velocity, thermal and slip boundary conditions. Rosmila and Kandasamy [32] investigated scaling group transformation for boundary-layer flow of a nanofluid past a porous vertical stretching surface in the presence of chemical reaction with heat radiation. Das [33] solved slip flow and convective heat transfer of nanofluids over a permeable stretching surface problem.

From above, provide the motivation for the present analysis. The present analysis of energy conversion for conjugate conduction, convection and magnetic-radiative heat and mass transfer problem is a novel study. The paper deals with the energy conversion problem for flow and heat transfer in an incompressible nanofluid which has been caused by a stretching sheet energy conversion system. With a view to examine the effects of viscous force on flow and heat transfer characteristics of mixed convection phenomena. The thermal forming process, see as Fig. 1 which is an extrusion processing system, the extrusion process is one kind of thermal forming process. There are many different kinds of extrusion materials, such as plastic, metal. The motivation of the work is provided the thermal analysis about the cooling processing for the extrusion parts. Because the extrusion parts are at a very high temperature, it is need to slow down the temperature with a suitable fluid field. The best way is choice a non-Newtonian fluid as the cooling matter. The physical about the process, it is a stagnation point flow field

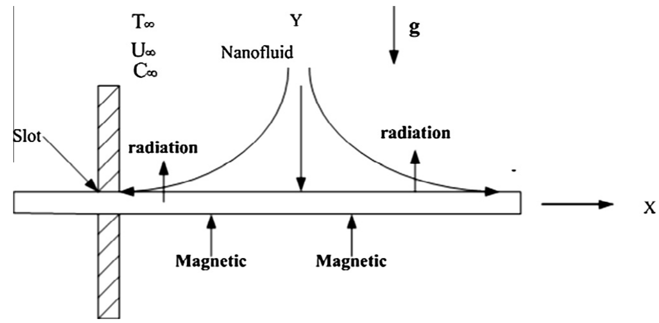

Fig. 1. A sketch of the physical model for nanofluid toward an extrusion stretching sheet with magnetic and radiation energy conversion conjugate heat and mass transfer system.

phenomenon, couple with the magnetic and electric force applied to the process, to obtain a well done product. For some application in industry, plastic stretch forming services including sheet plastic stretch forming. Products include aerospace, automobile, window frames, structural and trim plastic components for recreational vehicles and trucks, etc. Sheet plastic stretch formed parts hold their shapes and remain wrinkle free. Markets served include food processing, automotive, aerospace, appliance, architecture and industrial, etc.

2. Theory and analysis

2.1. Flow field analysis

Consider the steady boundary layer MHD flow with radiation effect past a convectively heated stretching sheet embedded in a medium filled with a water-based nanofluid containing gyrotactic microorganism. We consider a Cartesian coordinate system (x, y) in which the x-axis is along the sheet direction and the y-axis is normal to the sheet surface, respectively. An incompressible, homogeneous, magnetic-radiative heat and mass transfer nanofluid fluid has a constitutive equation. The steady two-dimensional boundary-layer equations for this flow and heat transfer, in usual notations, are

$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}=0 \tag{1}$$

$$u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}=U_\infty\frac{\partial U_\infty}{\partial x}+\nu\frac{\partial^2 u}{\partial y^2}+\frac{\sigma B_0^2}{\rho}(U_\infty-u)+g\beta_t(T-T_\infty)+g\beta_c(C-C_\infty) \tag{2}$$

$$u\frac{\partial T}{\partial x}+v\frac{\partial T}{\partial y}=\alpha\frac{\partial^2 T}{\partial y^2}+\tau\frac{\partial u}{\partial y}+\tau\left[D_B\left(\frac{\partial C}{\partial y}\frac{\partial T}{\partial y}\right)+\frac{D_T}{T_\infty}\left(\frac{\partial T}{\partial y}\right)^2\right]-\frac{1}{\rho c_p}\frac{\partial q_r}{\partial y} \tag{3}$$

$$u\frac{\partial C}{\partial x}+v\frac{\partial C}{\partial y}=D_B\frac{\partial^2 T}{\partial y^2}+\frac{D_T}{T_\infty}\left(\frac{\partial^2 T}{\partial y^2}\right) \tag{4}$$

There is an important term $\tau\frac{\partial u}{\partial y}$ at Eq. (3), it is importance for Nanofluid flow using, and it is standard the viscous dissipation phenomena. Viscous dissipation of fluid means the Nanofluid is relatively thick in consistency. It's the difference between the rates of flow of fluids such as Nanofluid and Nano motor oil or honey. The greater the viscosity is, the slower the flow speed is. Greater viscosity will cause the fluid flow at such a slow rate that the fluid