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Energy conversion conjugate conduction–convection and radiation over non-linearly extrusion stretching sheet with physical multimedia effects

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ABSTRACT

Energy conversion for conjugate conduction, convection and radiation analysis have been performed for free convection heat transfer with radiation effect of a steady laminar boundary-layer flow that pass a non-linearly flow field over extrusion stretching sheet by two kinds of boundary-layer conditions. The well-known Boussinesq approximation has been used to represent the buoyancy term adding to the governing equation. All of the important parameters m, Nr, Pr, G, Bi are represented the dominance of the non-linearly effect, radiation effect, free convection effect and conduction–convection effect which have been presented in governing equations, respectively. The similarity transformation and the finite-difference method have been used to analyze the present problem. The results were shown that the free convection effect will be produced a larger heat transfer effect better than the forced convection. On heat conduction processing, the convection–conduction number Ncc or free convection parameter G will be provided a good effect with a larger value. The results are shown by graphics, so that it is a physical multimedia technique features study also.

1. Introduction

The study energy conversion problem about viscous fluids passing a non-linearly extrusion stretching sheet have been become of increasing importance in the past few years. Qualitative analyses of these studies had significant bearing on several industrial applications, such as polymer sheet extrusion from a dye, drawing of plastic films, etc. When the manufacturing process at high temperature and need cooling the extrusion stretching sheet. The flows need viscous fluids to produce a good effect to reduce the temperature from the sheet. And also, the fluids have been processed many types of effects (i.e. magnetic force, buoyancy and mass diffusion) for the problem, and have been become a conjugate energy conversion system which need to analysis by many different ways. It is a well-known fact in the studies of non-Newtonian fluid flows by Hartnett [1]. Rajagopal et al. [2] considered a Falkner–Skan flow field of a second-grade visco-elastic fluid. Aman and Ishak [3] had solved the problem of mixed convection boundary-layer flow adjacent to a stretching vertical sheet in an incompressible electrically conducting fluid. An excellent review of boundary layers in non-linear fluids was written by Rajagopal [4]. Vajravelu and Soewono [5] had solved the fourth order non-linear systems arising in combined free and forced convection flow of a second-order fluid over a stretching sheet. The stretching sheet flow of a non-Newtonian fluid is also one of important flow fields in real world. Afify [6] studied heat and mass transfer of a viscous, incompressible and electrically conducting fluid over a stretching surface with a constant transverse magnetic field. On the other hand, researches in connection with visco-elastic fluid or second-grade non-Newtonian fluids, but there were not the mixed convection flow by Khan [7]. Recently, the thermal boundary layer over a non-linearly stretching sheet has been become importance for many studies toward the related problems. Rafael Cortell [8] studied effects of radiation on the thermal boundary layer over a non-linearly stretching sheet. Kechil and Hashim [9] studied series solution of flow over non-linearly stretching sheet with chemical reaction and magnetic field. Cortell [10] analytically studied similarity solutions for flow and heat transfer of a quiescent fluid over a non-linearly stretching surface. Cortell [11] also studied viscous flow and heat transfer over a non-linearly stretching sheet. Vajravelu [12] studied viscous flow over a non-linearly stretching sheet. Sanjayanand and Khan

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[13], Cortell [14] and Seddeek [15] had solved the heat and mass transfer problems about the visco-elastic boundary-layer flow over a stretching sheet with magnetic effect, but not consider the heat and mass convection with dissipation effect. Lately Liu et al. [16,17] studied the related thermal boundary-layer flow problems. Hsiao [18,19] had studied heat and mass transfer for micropolar flow with radiation effect past a non-linearly stretching sheet and had obtained many important effects about the heat and mass transfer phenomena. Flow and heat transfer characteristics in a viscous fluid over a non-linearly stretching sheet had recently analyzed by Akyildiz and Siginer [20]. Furthermore, Afzal [21] examined flow and heat transfer arising from non-linear power-law stretching velocity. Realize that, heat transfer in the MHD (Magneto-Hydrodynamic) flow of a power-law fluid over a non-isothermal stretching sheet was studied by Prasad and Vajravelu [22]. For energy conversion related problems were provided by some studies. Elshafei [23] studied natural convection heat transfer from a heat sink with hollow/perforated circular pin fins. Sertkaya et al. [24] studied pin-finned surfaces in natural convection. Kundu and Barman [25] investigated about an annular fin assembly. Bouaziz and Aziz [26] studied convective–radiative fin with temperature dependent thermal conductivity using double optimal linearization. Jang et al [27] studied 3-D turbulent flow of venting flue gas using thermoelectric generator modules and plate fin heat sink. Torabi et al. [28] studied longitudinal fins of rectangular, trapezoidal and concave parabolic profiles with multiple nonlinearities. Present study is an extension work and application to an extrusion stretching sheet energy conversion problem. Nandeppanavar et al. [29, 30] investigated the related problems for heat transfer in a liquid film over an unsteady stretching sheet, and for heat transfer in MHD visco-elastic boundary-layer flow over a stretching sheet with thermal radiation phenomena problem.

In the present investigation, different from above studies, a novel energy conversion study for conjugate conduction and free convection heat transfer with two kinds of boundary conditions that passing a non-linearly stretching surface has been processed. From the results, find a better heat transfer effect which was made by free convection. On the other hand, the paper has been made a comparison with previous study, to prove the results are corrected. For well done purpose, adding the conduction analysis and obtaining a good application to a real world purpose. All of the important results are shown by figures, so that it is also one kind of physical multimedia technique application.

2. Theory and analysis

2.1. Flow field analysis

In this study, consider the energy conversion problem for multimedia physical feature flow of an incompressible viscous fluid past a extrusion stretching sheet coinciding with the plane $y=0$, the flow being confined to $y>0$. Two equal and opposite forces are applied along the x-axis so that the wall is stretched keeping the origin fixed. The well-known Boussinesq approximation is used to represent the buoyancy term. The steady two-dimensional boundary-layer equations for this fluid, in the usual notation, are

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

$$u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}=\upsilon\frac{\partial^2 u}{\partial y^2}+g_x\beta(T-T_\infty), \tag{2}$$

where (x, y) denotes the Cartesian coordinates along the sheet and normal to it, u and v are the velocity components of the fluid in the x and y directions, respectively, g_x is the magnitude of the gravity, β is the coefficient of thermal expansion and υ is the kinematic viscosity. The boundary conditions to the problem are

$$u_W(x)=\frac{\nu}{L^{4/3}}x^{1/3},\quad v=v_W \quad \text{at} \quad y=0, \tag{3}$$

$$u\to 0 \quad \text{as} \quad y\to\infty.$$

Defining new similarity variables as

$$\eta=y\frac{x^{-1/3}}{L^{2/3}},\quad u=\frac{\nu}{L^{4/3}}x^{1/3}f'(\eta),\quad v=-\frac{\nu}{L^{2/3}}x^{-1/3}\frac{2f-\eta f'}{3}. \tag{4}$$

Defining the non-dimensional temperature

$$\theta(\eta)=\frac{T-T_\infty}{T_W-T_\infty}\quad \text{and} \quad T_W=T_\infty+A\left(\frac{x}{L}\right)^m, \tag{5}$$

substituting into Eqs. (1) and (2) gives

$$(f')^2-2ff''-3f'''-G\theta=0. \tag{6}$$

$G=g_x\beta A(u_W^3L^3/\nu^3)^m$ is the free convection parameter. The boundary conditions (3) becomes

$$f=-b,\quad f'=1 \quad \text{at} \quad \eta=0, \tag{7}$$

$$f'\to 0 \quad \text{as} \quad \eta\to\infty.$$

The shear stress at the stretched surface is defined as

$$\tau_W=\mu\left(\frac{\partial u}{\partial y}\right)_W, \tag{8}$$

and we obtain from Eqs. (4) and (8)

$$\tau_W=\mu\frac{\nu}{L^2}f''(0), \tag{9}$$

where μ is the viscosity of the fluid.

2.2. Heat transfer analyses

By using usual boundary-layer approximations, the equation of the energy for temperature T in the presence of radiation and viscous dissipation, is given by:

$$u\frac{\partial T}{\partial x}+v\frac{\partial T}{\partial y}=\frac{k}{\rho c_p}\frac{\partial^2 T}{\partial y^2}-\frac{1}{\rho c_p}\frac{\partial q_r}{\partial y}, \tag{10}$$

where k is the thermal conductivity, ρ is the density, c_p is the specific heat of a fluid at constant pressure and q_r is the radiative heat flux. Using the Rosseland approximation for radiation by Brewster [31], the radiative heat flux is simplified as

$$q_r=-\frac{4\sigma^*}{3k^*}\frac{\partial T^4}{\partial y}, \tag{11}$$

where σ^* and k^* are the Stefan–Boltzmann constant and the mean absorption coefficient, respectively. We assume that the temperature differences within the flow such as that the term T^4 may be expressed as a linear function of temperature. Hence, expanding T^4 in a Taylor series about T_∞ and neglecting higher-order terms we get