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ORIGINAL ARTICLE

Magnetohydrodynamic Cattaneo-Christov flow past a cone and a wedge with variable heat source/sink

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Abstract In the present article, the problem of boundary layer flow of MHD electrically conducting fluid past a cone and a wedge with non-uniform heat source/sink along with Cattaneo-Christov heat flux is investigated numerically. At first, the flow equations are converted into ODE via appropriate self similarity transforms and the resulting equations are solved with the assistance of R.-K. and Newton's methods. The influence of several dimensionless parameters on velocity and temperature fields in addition to the friction factor and reduced heat transfer coefficient has been examined with the support of graphs and numerical values. The heat transfer phenomenon in the flow caused by the cone is excessive when compared to the wedge flow. Also, the thermal and momentum boundary layers are not the same for the flow over a cone and wedge.

1. Introduction

The boundary layer flow of a viscous electrically conducting fluid over a wedge in the presence of Lorentz force has magnetized the attention of many authors owing to its significance in technology and science such as oil exploration, nuclear reactors, plasma studies, MHD generators and boundary layer control in aerofoil. By keeping a view into these, Stewart and Prober [1], and Lin and Lin [2] described the impact of heat transfer on the boundary layer flow caused by a wedge. Vajravelu and Nayfeh [3] numerically investigated the influence of heat generation on the MHD flow along the surface of a cone. In continuation of this, Chamkha [4] analysed the flow past a cone and wedge through porous medium. He found that a rise in Darcy number enhances the friction factor. The impact of thermal radiation on the boundary layer flow of a non-Newtonian liquid along a wedge was reported by Hsu et al. [5]. Yih [6] presented a mathematical model to examine the impact of suction/blowing on laminar flow through a wedge. Then after, Kumari [7] investigated the effects of adequate blowing rates and induced magnetic field on the wedge flow. The influence of applied magnetic field on mixed convective flow past a wedge under the influence of viscous dissipation was studied by Kumari et al. [8]. Massoudi [9] has found a new mathematical model to discuss the heat transfer of the power-law fluid past a wedge considering heat genera-

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Nomenclature

A^*	non-uniform heat source or sink parameter
a	constant
B^*	non-uniform heat source or sink parameter
B_0	applied magnetic field strength
C_f^*	dimensional wall shear stress
C_f	friction factor
c_p	specific heat at constant pressure
Gr	Grashof number
g	acceleration due to gravity
h	heat transfer coefficient
k	thermal conductivity
l	characteristic length
M	magnetic field parameter
Nu	Nusselt number
Pr	Prandtl number
r	radius of the cone
s	wall temperature parameter
T	temperature of the fluid
T_w	temperature near the surface
T_∞	ambient temperature
u, v	velocity components along x and y directions respectively
u_w	velocity near the flow surface

Greek letters

β	thermal relaxation parameter
β_T	volumetric thermal expansion coefficient
δ	relaxation time of heat flux
Ω	wedge full angle
γ	cone/wedge half angle
ξ	stream function
μ	dynamic viscosity
υ	kinematic viscosity
ρ	density of the fluid
σ	electrical conductivity of the fluid
ζ	similarity variable

tion. By making use of Runge-Kutta Gill method, the impact of chemical reaction and Joule's dissipation on the wedge flow was discussed by Devi and Kandasamy [10]. Cheng and Lin [11] investigated the Falkner-Skan wedge flow by taking into consideration heat flux and wall temperature.

Kim [12] presented an analytical solution to study the time dependent convective transport of a micropolar fluid. The effects of heat transfer on the flow caused by a wedge with first order chemical reaction were numerically analysed by Kandasamy et al. [13]. An analytical solution to investigate the asymmetric flow over a stretched surface using Kummer's function was presented by Ouaf [14] and concluded that increasing values of wall temperature parameter suppress the fluid temperature. The heat transfer of unsteady mixed convective flow past a symmetric wedge was deliberated by Hossain et al. [15]. The influences of heat source/sink and chemical reaction on the flow of viscous micropolar fluid past a cone with magnetic field were studied by El-Kabeir et al. [16] and stated that increasing values of magnetic field parameter suppress the fluid motion. Yao [17] has given a strange mathematical model to analyse the flow past a wedge using Falkner-Skan model. On the other hand a mathematical model was constructed by Hayat et al. [18] and Postelnicu and Pop [19] to discuss the flow properties of non-Newtonian fluids along a wedge. In continuation of this, Seddeek et al. [20] discussed the influence of varying thermal conductivity on the wedge flow by using Keller box technique. Similar type of study on nanofluids was presented by Yacob et al. [21]. The influence of heat flux and the magnetic field on the convective flow past a wedge was investigated by Rashad and Bakier [22]. Atalik and Sonmezler [23] studied the significance of electric field on the flow induced by a wedge.

Hsiao [24] has considered the study of second grade fluid flow over a porous wedge. Rahman et al. [25] analysed the effects of heat source/sink on MHD nanofluid flow over a wedge with convective surface. Through this study, they found that velocity of the nanofluid enhances with elevating values of wedge angle. The impact of linear radiation on a chemically reacting flow with nanoparticles along a moving wedge was examined by Khan et al. [26]. Kandasamy et al. [27] worked on unsteady motion of a nano liquid along a wedge by taking solar radiation and viscous dissipation. An investigation on the problem of mixed convective flow past a wedge with porous medium was done by Rashidi et al. [28]. Kasmani et al. [29] explored the effects of thermophoresis and Brownian motion on the wedge flow. The effects of Lorentz force and non-uniform heat on the flow caused by a slendering sheet were inquired by Ramana Reddy et al. [30]. Mathili et al. [31] studied the impact of higher order chemical reaction on Casson fluid flow caused by a cone with heat absorption. In this study, they found that the heat generation helps to elevate the fluid velocity. Babu et al. [32] considered the study of Eyring-Powell fluid flow caused by a cone with heat transfer. Raju and Sandeep [33] presented the dual solutions to analyse the bio-convective flow of Williamson fluid past two different geometries namely cone and plate. A numerical analysis on the flow over a wedge and a cone with thermal radiation was performed by Harbi [34] by employing finite difference method.

The heat conduction law suggested by Fourier [35] was utilized by many authors to picture the heat transfer phenomenon. Further, this model was amended by Cattaneo [36] by including relaxation time. In continuation of this, Christov [37] proposed a derivative model of Cattaneo's law and that became popular as Cattaneo-Christov heat flux model. This mechanism plays a pivotal role in medical and bio-engineering processes such as reducing heat in nuclear reactors, hybrid power generators, electronic devices and pasteurization of milk. Owing to these numerous applications in heat transfer mechanism, many researchers are using this model in their studies. Among them Han et al. [38] and Hayat et al. [39] addressed the heat transfer behaviour of Maxwell fluid past a stretched sheet using Cattaneo-Christov heat flux model. Further, this model was extensively used by many researchers [40–42] to construct the energy equation and discussed the flow and heat transfer behaviour of various kinds of non-Newtonian fluids. In addition to these, the authors [43–46] have been giving importance in their research to illustrate the MHD flow of different types of non-Newtonian fluid

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