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Entropy generation analysis for viscoelastic MHD flow over a stretching sheet embedded in a porous medium

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Abstract In this paper it is intended to analyse entropy generation by applying second law of thermodynamics to magnetohydrodynamic flow, heat and mass transfer of an electrically conducting viscoelastic liquid (Walters B') past on a stretching surface, taking into account the effects of Joule dissipation, viscous dissipation and Darcy dissipation, and internal heat generation. The boundary layer equations are solved analytically by using Kummer's function. The entropy generation has been computed considering Darcy dissipation besides viscous and Joule dissipation. Results for some special cases of the present analysis are in good agreement with the existing literature. Increase in viscoelastic and magnetic parameter reduces the velocity. Increase in elastic parameter causes a greater retardation in the velocity. Presence of porous matrix enhances temperature whereas increase in Prandtl number decreases the temperature. One striking result of the present study is that Darcy dissipation favours higher level entropy generation in all the cases except the flow of liquid with low thermal diffusivity assuming the process to be irreversible.

1. Introduction

The fluid flow over a stretching sheet is important in many practical applications such as extrusion of plastic sheets, paper production, glass blowing, metal spinning, polymers in metal spring processes, the continuous casting of metals, drawing plastic films and spinning of fibres, all involve some aspects of flow over a stretching sheet or cylindrical fibre (Paullet and Weidman [1]). The quality of the final product depends on the rate of heat transfer at the stretching surface.

Literature survey indicates that interest in the flows over a stretched surface has grown during the past decades. The problem of stretching surface with constant surface temperature was analysed by Crane [2]. Later, the stretching sheet flow has been studied by several researchers for the sole effects of rotation, velocity and thermal slip conditions, heat and mass

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Nomenclature

A	constant	B	constant
B_0	uniform magnetic field strength	B_r	Brinkman number
C_p	specific heat of the solid	D	molecular diffusivity
D_a	Darcy number	d	characteristic length
f	dimensionless function	H_a	Hartmann number
K'	permeability of the medium	K_P	porosity parameter
K	thermal conductivity of the fluid	M	Kummer's function
Mn	magnetic parameter	P_r	Prandtl number
Q	heat source/sink parameter	q_r	radiative heat flux
q_w	wall heat flux	R_c	elastic parameter
R	radiation parameter	S_c	Schmidt number
T	non-dimensional temperature	t'	time
t	non-dimensional time	T_∞	temperature far from sheet
T'	temperature of the field	T_w	wall temperature
ρ	density of the fluid	υ	kinematic coefficient of viscosity
k_1	absorption coefficient	σ^*	Stefan–Boltzmann constant
σ	electrical conductivity	τ_w	wall shear stress
k_0	dimensionless elastic parameter	m_w	rate of mass flux
q	heat generation coefficient	r	plate temperature parameter
s	plate concentration parameter		

transfer, chemical reaction, MHD, suction/injection, different non-Newtonian fluids or possible combinations of these effects ([3–8]).

Chamkha [9] studied the MHD flow of uniformly stretched vertical permeable surface in the presence of heat generation/absorption and a chemical reaction. Ishak et al. [10] investigated theoretically the unsteady mixed convection boundary-layer flow and heat transfer due to a stretching vertical surface in a quiescent viscous and incompressible fluid. Sammer [11] investigated the heat and mass transfer over an accelerating surface with heat source in the presence of magnetic field. Wang [12] studied the stagnation flow towards a shrinking sheet. Akbar et al. [13] investigated the dual solutions in MHD stagnation-point flow of a Prandtl fluid impinging on a shrinking sheet. Akbar et al. [14] have also studied MHD stagnation point flow of Carreau fluid towards a permeable shrinking sheet. Partial slip effect on non-aligned stagnation point nanofluid over a stretching convective surface has been investigated by Nadeem et al. [15].

Naseem and Khan [16] investigated boundary-layer flow past a stretching plate with suction, heat and mass transfer and with variable conductivity. Cortell [17] also reported the flow and heat transfer of a fluid through porous medium over a stretching surface with internal heat generation. Combined effects of magnetic field and partial slip on obliquely striking rheological fluid over a stretching surface have been investigated by Nadeem et al. [18]. Akbar et al. [19] have studied the numerical analysis of magnetic field effects on Eyring–Powell fluid flow towards a stretching sheet. Free convective heat and mass transfer for MHD fluid flow over a permeable vertical stretching sheet in the presence of the radiation and buoyancy effects has been investigated by Rashidi et al. [20,21].

The main concern in the present study is to account for the entropy generation/minimization on the heat transfer process. One of the most important characteristics of the medium in thermodynamics is the entropy. In an adiabatic process, the entropy either increases or remains unchanged (second law of thermodynamics). Entropy generation is closely associated with the thermodynamic irreversibility. Irreversibility analysis in a couple stress film flow along an inclined heated plate with adiabatic free surface has been studied by Adesanya and Makinde [22]. Recently, inherent irreversibility in Sakiadis flow of nanofluids has been investigated by Makinde et al. [23]. Mahamud and Fraser [24–26] applied the second law of thermodynamics to convective heat transfer in non-Newtonian fluid flow through a channel. Akbar [27] has studied entropy generation analysis for a CNT Suspension Nanofluid in Plumb Ducts with Peristalsis. He has also investigated Peristaltic flow with thermal conductivity of H_2O + Cu nanofluid and entropy generation [28]. Entropy generation and energy conversion rate for the peristaltic flow in a tube with magnetic field has also been investigated by Akbar [29]. Makinde [30] has investigated entropy analysis for MHD boundary layer flow and heat transfer over a flat plate with a convective surface boundary condition. Entropy analysis for an unsteady MHD flow past a stretching permeable surface in nano-fluid has been studied by Abolbashari et al. [31]. Chemical reaction effect on MHD free convective surface over a moving vertical plane through porous medium has been studied by Tripathy et al. [32].

Moreover, Aiboud et al. [33] studied the second law analysis of laminar fluid flow in a heated channel with hydromagnetic and viscous dissipation effect. They made an entropy analysis for viscoelastic MHD flow over a stretching surface [34].

The growing need for chemical reaction and hydrometallurgical industries requires the study of heat and mass transfer with chemical reaction. There are many transport processes that are governed by the combined action of buoyancy forces

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