MHD flow and heat transfer in a non-Newtonian liquid film over an unsteady stretching sheet with variable fluid properties

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Abstract: The present paper is concerned with the study of variable viscosity and variable thermal conductivity on the flow and heat transfer of an electrically conducting non-Newtonian power-law fluid within a thin liquid film over an unsteady stretching sheet in the presence of a transverse magnetic field. The transformed system of nonlinear ordinary differential equations describing the problem is solved numerically. The effects of various parameters on the velocity and temperature profiles are shown through graphs and discussed. The values of the local skin-friction coefficient and the local Nusselt number for different values of physical parameters are presented through tables.

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Résumé : Nous étudions ici les effets d'une viscosité et d'une conductivité thermique variables sur l'écoulement et le transfert de chaleur d'un fluide non Newtonien conducteur à l'intérieur d'un mince film liquide sur une surface instable élastique en présence d'un champ magnétique transverse. Le système transformé d'équations différentielles ordinaires non linéaires est alors solutionné numériquement. Nous présentons de façon graphique et analysons les résultats illustrant les effets des différents paramètres sur les profils de vitesse et de température. Nous présentons sous forme de tables les valeurs du coefficient local de friction de peau et du nombre local de Nusselt pour différentes valeurs des paramètres physiques.

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1. Introduction

The study of fluid flow and heat transfer in a thin liquid film over an unsteady stretching surface has gained considerable attention due to its many theoretical and technical applications in the engineering and technology fields. The knowledge of heat transfer within a thin liquid film is crucial in understanding the coating process and design of various heat exchangers and chemical-processing equipment. Some applications include reactor fluidization, wire and fiber coating, polymer processing, food-stuff processing, transpiration cooling; etc. Many metallurgical processes, such as drawing, annealing, and tinning of copper wires involve cooling of continuous strips or filaments by drawing them through a quiescent fluid. The quality of the final product depends on the rate of heat transfer at the stretching surface. Wang [1] was the first who studied the flow of a Newtonian fluid in a thin liquid film over an unsteady stretching sheet. Later Andersson et al. [2] extended Wang's problem to the case of heat transfer. Dandapat et al. [3] investigated the effect of the thermocapillarity on the flow and heat transfer in a thin liquid film over an unsteady stretching sheet. Liu and Andersson [4] generalized the analysis by Andersson et al. [2] by considering a more general form of the prescribed temperature variation of the stretching sheet that is considered in ref. 2. The combined effect of viscous dissipation and magnetic field on the flow and heat transfer in a liquid film over an unsteady stretching surface was studied by Subhas Abel et al. [5]. In the studies mentioned above [1–5], the fluid was assumed to be Newtonian. Many materials such as polymer solutions or melts, drilling mud, certain oils, greases, pulps, fossil fuels; etc. are classified as a non-Newtonian fluids due to the nonlinearity in the relationship between the stress and the rate of the strain of these fluids. Many of the non-Newtonian fluids used in the chemical engineering follow the Ostwald-de Waele power-law model for the shear stress. Andersson et al. [6] examined, numerically, the problem of hydrodynamic power-law fluid flow within a liquid thin film over a stretching sheet. Chen [7] studied the heat transfer occurring in a thin liquid film of a power-law fluid over an unsteady stretching sheet. Wang and Pop [8] analytically studied the flow of a power-law fluid film on an unsteady stretching surface by means of the homotopy analysis method. Hayat et al. [9] investigated magneto-hydrodynamic (MHD) flow and heat transfer of a second-grade fluid film over an unsteady stretching sheet. Siddiqui et al. [10] studied the thin film flow of two non-Newtonian fluids, namely, a Sisko fluid and an Oldroyd 6-constant fluid on a vertical moving belt. The effect of viscous dissipation on heat transfer in a non-Newtonian power-law liquid in a thin film over an unsteady stretching surface has been studied by Chen [11]. The above studies are discussed in the case of constant fluid properties. Particularly, the physical properties change significantly with temperature. Therefore, it is necessary to take the variation of viscosity and thermal conductivity into consideration. Dandapat et al. [12] discussed the ef-

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