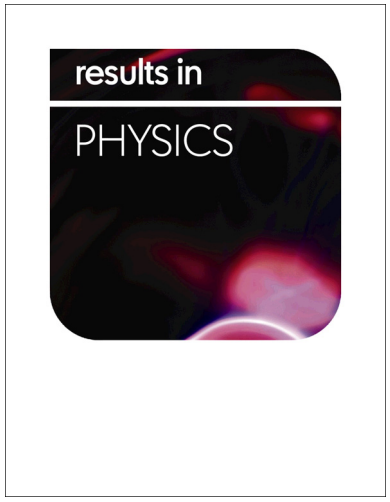

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A similarity solution of time dependent MHD liquid film flow over stretching sheet with variable physical properties

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Abstract

An analysis is performed for the fluid dynamics incorporating the variation of viscosity and thermal conductivity on an unsteady two-dimensional free surface flow of a viscous incompressible conducting fluid taking into account the effect of a magnetic field. Surface tension quadratically vary with temperature while fluid viscosity and thermal conductivity are assumed to vary as a linear function of temperature. The boundary layer partial differential equations in cartesian coordinates are transformed into a system of nonlinear ordinary differential equations (ODEs) by similarity transformation. The developed nonlinear equations are solved analytically by Homotopy Analysis Method (HAM) while numerically by using the shooting method. The Effects of natural parameters such as the variable viscosity parameter A, variable thermal conductivity parameter N, Hartmann number Ma, film Thickness, unsteadiness parameter S, Thermocapillary number M and Prandtl number Pr on the velocity and temperature profiles are investigated. The results for the surface skin friction coefficient $f''(0)$, Nusselt number (heat flux) $-\theta'(0)$ and free surface temperature $\theta(1)$ are presented graphically and in tabular form.

Keywords: Variable viscosity and thermal conductivity, Thermocapillary number, Magnetic field, Thin film, Unsteady stretching surface.

1 Introduction

In several engineering processes boundary layer flow and heat transfer phenomena of an unsteady free surface flow have promising applications such as continuous casting, wire coating, metal and polymer extrusion, foodstuff processing, drawing of plastic sheets, daily life uses equipments, etc. Crane [1] in 1970 is the first who studied the hydrodynamics of a steady stretching of a flat elastic sheet in a two-dimensional boundary layer flow by reducing the steady Navier-Stokes equations to a nonlinear ordinary differential equations by means of similarity transformation. Wang [2] in 1990 first studied the hydrodynamics of an unsteady stretching surface in a thin liquid film of a flow by converting the unsteady Navier-Stokes equations to a nonlinear ordinary differential equations by means of similarity transformation. But Lai and Kulacki [3] in 1991, assumed that viscosity and thermal conductivity are vary as an inverse functions of temperature and then solved numerically by using Runge-Kutta shooting method. Anderson et al. [4] in 2000, extend the work of Wang [2] by studying heat transfer and analysis has been performed by shooting method. Wang [5] in 2006, give analytical solution by using HAM [17] to the work of Anderson et al. [4] and found good agreement with multiple shooting method. Furthermore Seddeek and Faiza [6] in 2006, considered variable viscosity, variable thermal conductivity and variable suction with in Magneto Hydrodynamic (MHD) unsteady convective heat transfer along with semi-infinite vertical porous moving plate. Temperature variation phenomena in more general form introduced by Liu et al. [7] in 2008, in the work of Anderson et al [4]. Mean while, Abel et al. [8] in 2008, introduce the magnetic field effect to the flow of an unsteady stretching surface in a thin liquid film and subsequent heat transfer from the stretching surface is investigated with the aid of similarity transformation, which is the extension of the work of Wang [2]. Moreover, unsteady stretching phenomena has been discussed with the effects of the thermocapillary number in the references $[9-11]$. More realistic approach was used by Yasir et al. [12] in 2011, by studying flow over stretching sheet by taking variable physical properties. For solution purpose they used HPM. Hazarika and Jadav Konch [13] in 2014, investigate the effects of varying thermal conductivity

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