ISSN PRINT 2319 1775 Online 2320 7876

Research paper UGC CARE Listed (Group -I) Journal Volume 10, Spl Iss 2, 2021

Computational Methods for Solving Time-Dependent Magnetohydrodynamic Flow and Heat Transfer over a Surface that Extends, Considering Suction or Injection.

T tarun teja, Dept of mechanical, Koneru Lakshmaiah Education Foundation, India-522302,

Abstract

The aim of this study is to examine the unsteady two-dimensional flow of an electrically conducting, viscous, and incompressible fluid over a stretching surface in the presence of a constant transverse magnetic field. Through the use of a similarity transformation, the original boundary layer equations governing the problem are transformed into nonlinear ordinary differential equations. These equations are then numerically solved using the fourth-order Runge-Kutta method coupled with a shooting technique. The study explores the influence of various parameters on both the velocity and temperature distributions, along with the skin-friction coefficient and Nusselt number.

Introduction

Boundary layer flow over a continuously moving surface is a significant fluid behavior encountered in various engineering processes. Practical instances include the aerodynamic extrusion of plastic sheets, the cooling of metallic sheets within an electrolytic cooling bath, crystal growth, the boundary layer formed along a liquid film during condensation, and the continuous extrusion of polymer sheets from a die. Furthermore, materials produced through extrusion processes and those subjected to heat treatment, while moving between feed and wind-up rolls or along a conveyor belt, exhibit traits akin to continuous moving surfaces [1]. In recent decades, the study of hydromagnetic flow involving electrically conductive fluids impinging on a stretching surface has garnered substantial attention from researchers [2]. This attention is driven by the widespread applicability of these phenomena across industrial manufacturing, modern metallurgy, and metalworking processes. Examples encompass hot rolling, glass shaping, paper production, wire and plastic film drawing, metal spinning, as well as metal and polymer extrusion within liquid composite molding [3]. Noteworthy contributions to this field include Crane's pioneering work (Crane, 1970) on boundary layer flow past a solid surface moving at a constant speed. Elbashbeshy (1998) delved into heat transfer over a stretching surface characterized by a variable surface heat flux. Additionally, Magyari and Keller (2000) provided exact solutions for self-similar boundary layer flows induced by permeable stretching walls. The optimal fluid characteristics crucial to various manufacturing processes primarily encompass the rate of stretching and the cooling properties of the liquid. Achieving a favorable outcome hinge on these factors [4-6]. The stretching rate assumes paramount significance, as swift stretching can lead to abrupt solidification, undermining the anticipated attributes of the final product. The utilization of electrically conductive fluids coupled with the application of a magnetic field emerges as a means to regulate cooling rates and tailor the desired properties of the end product [7]. Magnetic fields find application in diverse processes, including the purification of molten metal by removing non-metallic inclusions. The study of hydromagnetic flow in electrically conductive fluids over heated sheets has garnered substantial attention due to its multifaceted relevance in technological domains such as plasma research, food processing, liquid crystal solidification, nuclear reactor cooling, novel lubricants and suspension

ISSN PRINT 2319 1775 Online 2320 7876

Research paper © 2012 IJFANS. All Rights Reserved, UGC CARE Listed (Group -I) Journal Volume 10, Spl Iss 2, 2021

solutions, boundary layer manipulation in aerodynamics, MHD power generation, and planetary magnetospheric studies [8-10].

Andersson (1992) provided an exact analytical solution for the MHD flow of Walters liquid B past a stretching sheet. Subsequently, several researchers, including Chaudhary and Kumar (2015) as well as Singh and Singh (2012), have directed their efforts towards various facets of the heat transfer and hydromagnetic flow challenges related to stretching surfaces [11].

Mathematical formulation

Under the boundary layer approximation, the unsteady two-dimensional boundary layer equations can be written as:

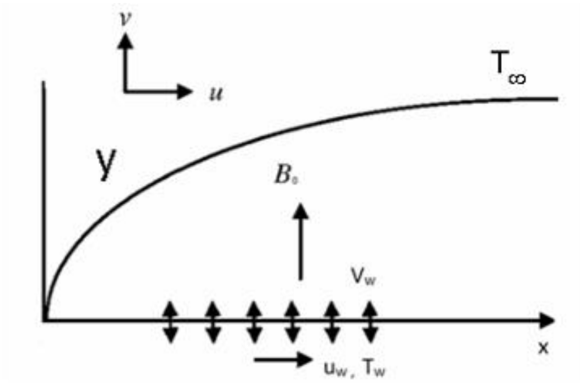

Figure 1: Geometry of the problem

$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}=0 \qquad (1)$$

$$\frac{\partial u}{\partial t}+u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}=\nu\frac{\partial^2 u}{\partial y^2}-\frac{\sigma_e\mu_e B_0^2}{\rho}u \qquad (2)$$

$$\xi(x,y,t)=\sqrt{\nu x u_w}\, f(\eta),\eta=\sqrt{\frac{u_w}{\nu x}}y \text{ and } T=T_\infty+\frac{b}{a}u_w\theta(\eta)$$

Using the above equations, the boundary layer governing equations are

$$f'''+ff''-A\left(\frac{1}{2}\eta f''+f'\right)-f'^2-Mf'=0$$

$$\theta''+\Pr f\theta'-A\left(\frac{1}{2}\eta\theta'+\theta\right)-f'\theta+Ecf''^2=0$$

Subject to the corresponding boundary conditions are

$$f=f_0,\ f'=1,\ \theta=1 \text{ at } \eta=0$$
$$f'\to 0,\ \theta\to 0 \quad \text{as} \quad \eta\to\infty$$

ISSN PRINT 2319 1775 Online 2320 7876

Research paper © 2012 IJFANS. All Rights Reserved, UGC CARE Listed (Group -I) Journal Volume 10, Spl Iss 2, 2021

Results

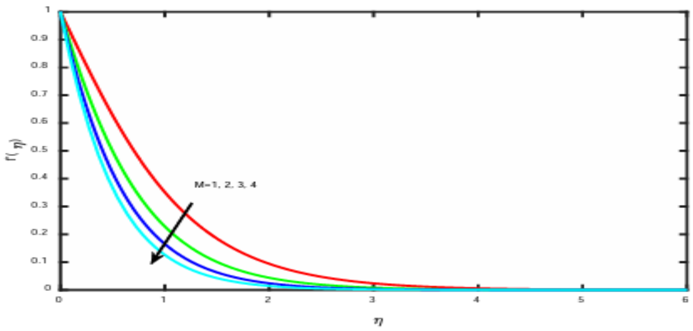

Figure 2: Effect of velocity profiles for different values of the magnetic parameter (M)

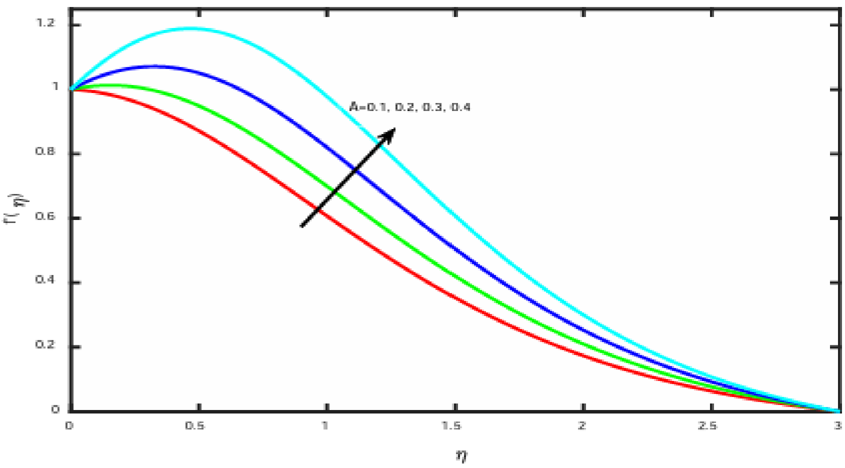

Figure 3: Effect of velocity profiles for different values of unsteadiness parameter (A)

Conclusion

The impacts of various parameters on velocity, temperature, skin friction coefficient, and Nusselt number are visually presented and thoroughly deliberated upon. Observations lead to the conclusion that, as the suction or injection parameter and the unsteadiness parameter escalate, the velocity boundary layer thickness, thermal boundary layer thickness, surface gradient, and heat transfer rate all decline. However, a contrasting trend emerges after the turning point for both velocity and thermal boundary layer thickness concerning the unsteadiness parameter. Furthermore, when the magnetic parameter increases, the velocity and surface gradient diminish, while the inverse holds true for the thermal boundary layer thickness and heat transfer rate. Additionally, an augmentation in the Prandtl number corresponds to a reduction in the thermal boundary layer thickness and heat transfer rate, whereas the Eckert number produces an opposite effect, yielding divergent outcomes.

References

[1] Andersson, H. I. (1992): MHD flow of a viscoelastic fluid past a stretching surface. Acta Mechanica, vol. 95, pp. 227-230.

[2] Chaudhary, S.; Kumar, P. (2014): MHD forced convection boundary layer flow with a flat plate and porous substrate. Meccanica, vol. 49, pp. 69-77.

ISSN PRINT 2319 1775 Online 2320 7876

Research paper © 2012 IJFANS. All Rights Reserved, UGC CARE Listed (Group -I) Journal Volume 10, Spl Iss 2, 2021

[3] Chaudhary, S.; Choudhary M. K.; Sharma, R. (2015): Effects of thermal radiation on hydromagnetic flow over an unsteady stretching sheet embedded in a porous medium in the presence of heat source or sink. Meccanica, vol. 50, pp. 1977-1987.

[4] Crane, L. J. (1970): Flow past a stretching plate. Zeitschrift für angewandte Mathematik und Physik ZAMP, vol. 21, pp. 645-647.

[5] Elbashbeshy, E. M. A. (1998): Heat transfer over a stretching surface with variable surface heat flux. Journal of Physics D: Applied Physics, vol. 31, pp. 1951-1954.

[6] Ganesh Kumar, K.; Gireesha, B. J.; Krishanamurthy, M. R; Rudraswamy, N. G. (2017): An unsteady squeezed flow of a tangent hyperbolic fluid over a sensor surface in the presence of variable thermal conductivity. Result in Physics, vol. 7, pp. 3031-3036.

[7] Ganesh Kumar, K.; Gireesha, B. J.; Manjunatha, S; Rudraswamy, N. G. (2017): Effect of nonlinear thermal radiation on double-diffusive mixed convection boundary layer flow of viscoelastic nanofluid over a stretching sheet. International Journal of Mechanical and Materials Engineering, pp. 12-18.

[8] Ganesh Kumar, K.; Gireesha, B. J; Rudraswamy, N. G.; Manjunatha, S. (2017): Radiative heat transfers of Carreau fluid flow over a stretching sheet with fluid particle suspension and temperature jump. Result in Physics, vol. 7, pp. 3976-3983.

[9] Ishak, K.; Naza, R.; Pop, I. (2009): Heat transfer over an unsteady stretching permeable surface with prescribed wall temperature. Nonlinear Analysis Real World Applications, vol. 10, pp. 2909-2913.

[10] Khader, M. M. (2014): Laguerre collocation method for the flow and heat transfer due to a permeable stretching surface embedded in a porous medium with a second order slip and viscous dissipation. Applied Mathematics Computation, vol. 243, pp. 503-513.

[11] Magyari, E.; Keller, B. (2000): Exact solutions for self-similar boundary-layer flows induced by permeable stretching walls. European Journal of Mechanics B-Fluids, vol. 19, pp. 109-122.