Malaysian Technical Universities Conference
on Engineering & Technology (MUCET) 2013

Effect of Radiation on Magnetohydrodynamic Free Convection Boundary Layer Flow on a Solid Sphere with Newtonian Heating

Hamzeh Taha Alkasasbeh[a *], Mohd Zuki Salleh[a], Razman Mat Tahar[b], and Roslinda Nazar[c]
[a]Faculty of Industrial Science and Technology, Universiti Malaysia Pahang, 26300 UMP Kuantan, Pahang, Malaysia
*E-mail: hamzahtahak@yahoo.com
[b]Faculty of Technology, Universiti Malaysia Pahang, 26300 UMP Kuantan, Pahang, Malaysia
[c]School of Mathematical Sciences, UniversitiKebangsaan Malaysia, 43600 UKM Bangi, Selangor, Malaysia

Key words: Free Convection, Magnetohydrodynamic (MHD), Newtonian Heating, Radiation Effects, Solid Sphere.

Abstract

In this paper, the effect of radiation on magnetohydrodynamic free convection boundary layer flow on a solid sphere with Newtonian heating, in which the heat transfer from the surface is proportional to the local surface temperature, is considered. The transformed boundary layer equations in the form of partial differential equations are solved numerically using an implicit finite difference scheme known as the Keller-box method. Numerical solutions are obtained for the local wall temperature, the heat transfer, and the local skin friction coefficient, as well as the velocity, and temperature profiles. The features of the flow and heat transfer characteristics for various values of the Prandtl number Pr, magnetic parameter *M*, radiation parameter N_R, the conjugate parameter γ and the coordinate running along the surface of the sphere, *x* are analyzed and discussed.

Introduction

The effect of radiation on magnetohydrodynamic flow, heat and mass transfer problems has become industrially more important. Many engineering processes occur at high temperatures, the knowledge of radiation heat transfer leads significant role in the design of equipment. Nuclear power plants, gas turbines and various propulsion devices for aircraft, missiles, satellites and space vehicles are examples of such engineering processes. At high operating temperature, the radiation effect can be quite significant, see [Sivaiah et al. 2010]. [Molla et al. 2010] studied the radiation effect on free convection flow from an isothermal sphere with constant wall temperature. The viscous dissipation and magnetohydrodynamic effect on a natural convection flow over a sphere in the presence of heat generation have been presented by [Ganesan and Palani 2004]. [Alam et al 2007] and [Molla et al 2005], respectively.

For the condition Newtonian heating, many of the research were written with this condition It seems that [Merkin1994] was the first to use the term Newtonian heating for the problem of free convection over a vertical flat plate. Recently [Salleh, et al. 2010] and [Salleh, et al. 2012] studied the free convection boundary layer flows on a sphere with Newtonian heating in a viscous and micropolar fluid, respectively.

Results and Discussion

The Equations were solved numerically using an efficient, implicit finite-difference method known as the Keller-box scheme for Newtonian heating (NH) with several parameters considered, namely, magnetic parameter *M*, radiation parameter N_R, the Prandtl number Pr, the conjugate parameter γ and the coordinate running along the surface of the sphere, *x*.

Table 1 shown the values of the wall temperature $\theta(0)$ and the skin friction coefficient $f''(0)$ at the lower stagnation point of the sphere, $(x \approx 0)$, for various values of N_R when Pr = 0.7, $\gamma = 1$ and M = 0, 5, 10. It is observed that, when the magnetic parameter *M* is fixed an increasing of the radiation parameter N_R, results the values of $\theta(0)$ and $f''(0)$ decreases, and also when N_R is fixed, an increasing of *M* results the values of $\theta(0)$ and $f''(0)$ increases.

Figure 1 illustrates the variation of the wall temperature $\theta(x,0)$,with radiation parameter N_R when Pr =0.7, M = 5 and $\gamma = 1$. It is found that, if the radiation parameter N_R increasing and with fixed parameter γ causes to the decreasing $\theta(x,0)$.

Table 2: Values of the wall temperature $\theta(0)$ and the skin friction coefficient $f''(0)$ at the lower stagnation point of the sphere, $x \approx 0$, for various values of N_R when Pr= 0.7, M = 0, 5, 10 and $\gamma = 1$

	M = 0 Present		M = 5 Present		M = 5 Present	
N_R	$\theta(0)$	$f''(0)$	$\theta(0)$	$f''(0)$	$\theta(0)$	$f''(0)$
1	84.6126	24.2288	112.7021	26.5229	140.1570	28.63586
3	42.6999	13.5465	61.28889	15.2316	79.03272	16.71782
5	35.8107	11.6383	52.39761	13.1705	68.11037	14.50669
7	33.0155	10.8461	48.73030	12.3084	63.56162	13.57723
10	30.9817	10.2623	46.03631	11.6703	60.20188	12.88732
100	26.8867	9.0660	40.53631	10.3544	53.29070	11.45869
1000	26.4904	8.9487	39.99804	10.2246	52.61029	11.31734
∞	26.4595	8.9626	39.93837	10.2102	52.53481	11.30165

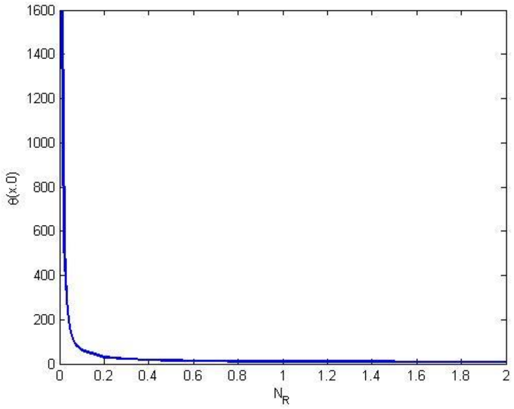

Figure 1: Variation of the wall temperature $\theta(x,0)$, with N_R when Pr = 7, M = 5 and $\gamma = 1$

Acknowledgement: The authors thank University Malaysia Pahang for the Graduate Research Scheme GRS 110357 and the Ministry of Higher Education for MTUN-COE Grant RDU121216.

References

Alam, M. M., M. Alim & M. M. Chowdhury (2007) Viscous dissipation effects on MHD natural convection flow over a sphere in the presence of heat generation. Nonlinear Analysis: Modell. and Cont, 12, 447-459.

Ganesan, P. & G. Palani (2004) Finite difference analysis of unsteady natural convection MHD flow past an inclined plate with variable surface heat and mass flux. International Journal of Heat and Mass Transfer, 47, 4449-4457.

Merkin, J. (1994) Natural-convection boundary-layer flow on a vertical surface with Newtonian heating. International journal of heat and fluid flow, 15, 392-398.

Molla, M. M., M. A. Hossain & S. Siddiqa (2011) Radiation Effect on Free Convection Laminar Flow from an Isothermal Sphere. Chemical Engineering Communications, 198, 1483-1496.

Molla, M. M., M. Taher, M. M. Chowdhury & M. A. Hossain (2005) Magnetohydrodynamic natural convection flow on a sphere in presence of heat generation. Nonlinear Analysis: Modelling and Control, 10, 349-363.

Salleh M, Nazar R, Pop I. 2010, "Modeling of free convection boundary layer flow on a solid sphere with Newtonian heating". Acta Applicandae Mathematicae,112:263-274.

Salleh M, Nazar R, Pop I. 2012, "Numerical Solutions of Free Convection Boundary Layer Flow on a Solid Sphere With Newtonian Heating in a Micropolar Fluid". Meccanica 47 1261-1269.

Sivaiah, M., A. Nagarajan & P. S. Reddy (2010) Radiation effects on MHD free convection flow over a vertical plate with heat and mass flux. Emirates Journal for Engg. Research, 15, 35-40.