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Effects of parabolic motion on an isothermal vertical plate with constant mass flux

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KEYWORDS

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Abstract An analytical study of free convection flow near a parabolic started infinite vertical plate with isothermal in the presence of uniform mass flux was considered. The mathematical model is reduced to a system of linear partial differential equations for the velocity, the concentration and the temperature; the closed form exact solutions were obtained by the Laplace transform technique. The velocity, temperature and concentration profiles for the different parameters as thermal Grashof number Gr, mass Grashof number Gc, Prandtl number Pr, Schmidt number Sc and time t were graphed and the numerical values for the skin friction were as tabulated. It is observed that the velocity is enhanced as the time increased and the velocity is decreased as the Prandtl number increased.

1. Introduction

Heat transfer problem on a continuous moving surface is very important in many practical applications occurring in a number of engineering processes. Examples of processes include continuous casting, extrusion of plastics and other polymeric materials, bonding, annealing and tempering, cooling and/or drying of paper and textiles, chemical catalytic reactors, nuclear waste repositories, petroleum reservoirs, composite materials manufacturing and many others, as reviewed in Refs. [1–3]. The process of heat and mass transfer is encountered in aeronautics, fluid fuel nuclear reactor and many engineering applications in which the fluid is the working medium as Ref. [4].

There are many applications for the parabolic motion such as solar cookers, solar concentrators and parabolic trough solar collector. A parabolic concentrator type solar cooker has a wide range of applications like baking, roasting and distillation due to its unique property of producing a practically higher temperature of nearly 250 °C and hence it provides inconvenience to the user due to high amount of glare. Solar concentrators have their applications in increasing the rate of evaporation of waste water, in food processing, for making drinking water from brackish and sea water. It produces a high temperature around 250 °C and the food gets cooked in less time [5]. A parabolic trough solar collector system will provide

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Nomenclature

C'	species concentration in the fluid	u	velocity of the fluid in the x-direction
C	dimensionless concentration	u_0	velocity of the plate
C_w	wall concentration	U	dimensionless velocity
C_∞	concentration far away from the plate	X	spatial coordinate along the plate
C_p	specific heat at constant pressure	y'	coordinate axis normal to the plate
D	mass diffusion coefficient	Y	dimensionless coordinate axis normal to the plate
Gc	mass Grashof number	β	volumetric coefficient of thermal expansion
Gr	thermal Grashof number	β^*	volumetric coefficient of expansion with concentration
g	accelerated due to gravity		
k	thermal conductivity	μ	coefficient of viscosity
Pr	Prandtl number	υ	kinematic viscosity
Sc	Schmidt number	ρ	density of the fluid
T	temperature of the fluid near the plate	τ	dimensionless skin friction
T_W	temperature of the plate	θ	dimensionless temperature
T_∞	temperature of the fluid far away from the plate	η	similarity parameter
t'	time	erfc	complementary error function
t	dimensionless time		

within next decade a significant contribution to efficient, economical, sustainable renewable and clean energy supply with positive effect on environmental activities and it is designed to concentrate sun rays via parabolic curved solar reflectors onto a heat absorber element – a receiver- located in the optical focal line of the collector [6].

Natural convection flows are frequently encountered in science and technological problems such as chemical catalytic reactors, nuclear waste repositories, petroleum reservoirs, fiber and granular.

Insulation, geothermal systems. Natural convection induced by the simultaneous action of buoyancy forces from thermal and mass diffusion is of considerable interest in many industrial applications such as geophysics, oceanography, drying processes and solidification of binary alloy. Free convection flows occur not only due to concentration difference or the combination of these two. The study of combined heat and mass transfer plays an important role in the design of chemical processing equipment, nuclear reactors formation, dispersion of fog, etc.

Pioneering work on heat and mass transfer was discussed by Eckert and Drake [7]. Gebhart et al. [8] studied the natural convection boundary layer flow due to simultaneous heat and mass transfer with various geometries. Mathematical modeling of mass transfer and free convection current effects on unsteady viscous flow with ramped wall temperature was discussed by Marneri Narahari et al. [9]. Free convection flow past on a vertical plate has been studied extensively by Ostrach [10]. Siegel [11] investigated the transient free convection from a vertical plate. Bejan and Khair [12] have investigated the vertical free convective boundary layer flow embedded in a porous medium resulting from the combined heat and mass transfer. Mass transfer effects on free convection flow of an incompressible viscous dissipative fluid have been studied by Manohar and Nagarajan [13]. Sivaiah et al. [14] have been discussed on heat and mass transfer effects on MHD free convection flow past vertical porous plate. Free convective about a vertical plate embedded in a porous medium with application to heat transfer was discussed by Cheng et al. [15]. Abdus Sattar and Hamid kalim [16] investigated the unsteady free convection interaction with thermal radiation in a boundary layer flow past a vertical porous plate. Radiation effects on an unsteady MHD vertical porous plate in the presence of homogeneous chemical reaction were discussed by Anand Rao et al. [17]. Free convection flow past an impulsively started infinite vertical plate with Newtonian heating in the presence of thermal radiation and mass diffusion was studied by Marneni Narahari and Yunus Nayan [18]. Callahan and Marner [19] gave a numerical solution for the problem of transient free convection with mass transfer on an isothermal vertical plate. Takhar et al. [20] considered the unsteady free convective flow over a semi-infinite vertical plate. Shanker and Kishan [21] discussed the effects of mass transfer on the MHD flow past an impulsively started vertical plate with variable temperature or constant heat flux. Michiyochi et al. [22] have considered natural convection heat transfer from a horizontal cylinder to the mercury under a magnetic field. Ganesan and Rani [23] studied the unsteady free convection on vertical cylinder with variable heat and mass flux. Gokhale and Samman [24] studied the effects of mass transfer on the transient free convection flow of a dissipative fluid along a semi-infinite vertical plate with constant heat flux. Recently Vijaya et al. [25] had discussed MHD free convective flow past an exponentially accelerated vertical plate with variable temperature and variable mass diffusion. The effect of a incompressible viscous fluid flow past on a parabolic started isothermal vertical plate in the presence of uniform mass flux has not been studied in the literature.

In the present work, it is proposed to study under the presence of uniform mass flux on the parabolic started isothermal vertical plate in the incompressible viscous fluid is considered. The dimensionless governing equations are solved using the Laplace transform technique. The solutions are obtained in terms of exponential and complementary error functions.

2. Mathematical analysis

The unsteady flow of a viscous incompressible fluid past an impulsively started isothermal vertical plate with constant heat