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Effects of volumetric heat source and temperature dependent viscosity on natural convection flow along a wavy surface

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Abstract

The conjugate effects of volumetric heat source and temperature dependent viscosity on natural convection flow along a wavy surface have been investigated. The governing boundary layer equations of the present physical problem are first transformed into non-dimensional form using suitable set of dimensionless variables. The resulting nonlinear system of partial differential equations are mapped into the domain of a vertical flat plate and then solved numerically employing the implicit finite difference method, known as Keller-box scheme. The numerical results of the surface shear stress in terms of skin friction coefficient as well as the rate of heat transfer in terms of local Nusselt number are shown in tabular form and the stream lines as well as the isotherms are shown graphically for a selection of parameters set consisting of viscosity variation parameter ε, internal heat generation parameter Q of volumetric heat source and Prandtl number Pr.

Keywords: Natural convection; volumetric heat source; internal heat generation; wavy surface; variable viscosity; finite difference method.

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1. Introduction

In this study, the effects of temperature dependent viscosity on natural convection flow along a wavy surface with internal heat generation due to volumetric heat source have been focused. The sinusoidal wavy surface can be viewed as an approximation to match practical geometries like cooling fin or roughened surface in heat transfer. Roughened surfaces are better heat transfer devices than a plain surface and are encountered in several heat transfer devices such as flat plate solar collectors, condensers in refrigerators etc. The effects of such non-uniformities on the vertical convective boundary layer flow of a Newtonian fluid are first studied by Yao [1] and using an extended Prantdl's transposition theorem and a finite-difference scheme. Alam et al. [2] have studied the problem of free convection from a wavy vertical surface in presence of a transverse magnetic field. Combined effects of thermal and mass diffusion on the natural convection flow of a viscous incompressible fluid along a vertical wavy surface have been investigated by Hossain and Rees [3]. Hossain et al. [4] have studied the problem of natural convection of fluid with temperature dependent viscosity along a heated vertical wavy surface. Natural convection heat and mass transfer along a vertical wavy surface have been investigated by Jang et al. [5]. Molla et al. [6] have studied natural convection flow along a vertical wavy surface with uniform surface temperature in presence of heat generation/absorption. Tashtoush and Al-Odat [7] investigated magnetic field effect on heat and fluid flow over a wavy surface with a variable heat flux. Yao [8] studied natural convection along a vertical complex wavy surface. Molla and Gorla [9] studied natural convection laminar flow with temperature dependent viscosity and thermal conductivity along a vertical wavy surface. Parveen and Alim [10] investigated Joule heating effect on Magnetohydrodynamic natural convection flow along a vertical wavy surface with viscosity dependent on temperature. Hossain et al. [11] investigated the natural convection flow past a permeable wedge for the fluid having temperature dependent viscosity and thermal conductivity. The present study is to incorporate the idea of the effects of volumetric heat source and temperature dependent viscosity on natural convection flow along a uniformly heated vertical wavy surface.

2. Formulation of the problem

Steady, two dimensional natural convection flow of a viscous and incompressible fluid with variable viscosity along a vertical wavy surface is considered. The surface temperature of the vertical wavy surface T_w is uniform, where $T_w>T_\infty$. The boundary layer analysis outlined below allows $\bar{\sigma}(\bar{x})$ being arbitrary, but detailed numerical work assumed that the surface exhibits sinusoidal deformations. The wavy surface may be described by

$$\bar{y}_w = \bar{\sigma}(\bar{x}) = \alpha \sin\left(n\pi\bar{x}/L\right) \tag{1}$$

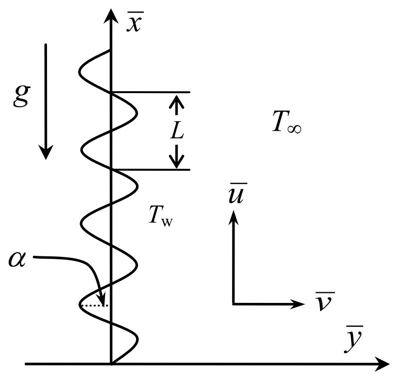

Fig. 1. Physical model and coordinate system

The geometry of the wavy surface and the two-dimensional Cartesian coordinate system are shown in Fig. 1. The conservation equations on the flow field, the continuity, momentum and energy equations can be written as:

$$\frac{\partial \bar{u}}{\partial \bar{x}} + \frac{\partial \bar{v}}{\partial \bar{y}} = 0 \tag{2}$$