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Double diffusion from a vertical wavy surface in a porous medium saturated with a non-Newtonian fluid ☆

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Abstract

This paper reports a study on the phenomenon of double diffusion near a vertical sinusoidal wavy surface in a porous medium saturated with a non-Newtonian power-law fluid with constant wall temperature and concentration. A coordinate transformation is employed to transform the complex wavy surface to a smooth surface, and the obtained boundary layer equations are then solved by the cubic spline collocation method. Effects of Lewis number, buoyancy ratio, power-law index, and wavy geometry on the Nusselt and Sherwood numbers are studied. The mean Nusselt and Sherwood numbers for a wavy surface are found to be smaller than those for the corresponding smooth surface. An increase in the power-law index leads to a smaller fluctuation of the local Nusselt and Sherwood numbers. Moreover, increasing the power-law index tends to increase both the thermal boundary layer thickness and the concentration boundary layer thickness, thus decreasing the mean Nusselt and Sherwood numbers.

Keywords: Non-Newtonian fluid; Vertical wavy surface; Porous medium; Cubic spline collocation method; Natural convection; Double diffusion

1. Introduction

The non-linear behavior of non-Newtonian fluids in porous matrix is quite different from that of Newtonian fluids in porous media. The prediction of heat or mass transfer characteristics about natural convection of non-Newtonian fluids in porous media is very important due to its practical engineering applications, such as oil recovery and food processing. Chen and Chen [1] obtained similarity solutions for free convection of a non-Newtonian fluid over spheres and cylinders in porous media. Nakayama and Koyama [2] studied the natural convection of a non-Newtonian fluid over non-isothermal body of arbitrary shape embedded in a porous medium. Rastogi and Poulikakos [3] examined the problem of double diffusion from a plate in a porous medium saturated with a non-Newtonian power law fluid. Getachew et al. [4] performed a numerical and theoretical study of double-diffusive natural convection in a rectangular porous cavity saturated with a non-Newtonian power law fluid. Kim and Hyun [5] studied the natural convection heat transfer of power law fluid in an enclosure filled with heat-generating porous media.

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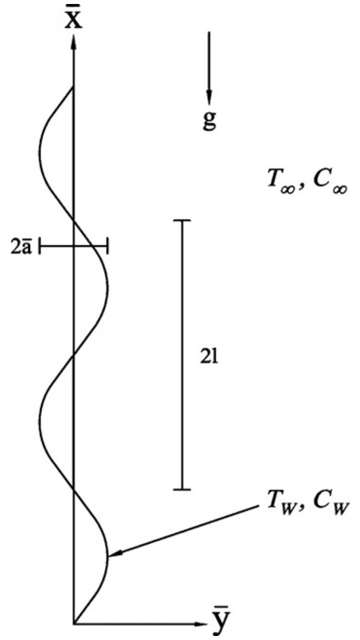

Fig. 1. Flow model and coordinate system.

The study of heat or mass transfer near irregular surfaces is of fundamental importance; that is because it is often met in many practical applications. Yao [6] studied the natural convection heat transfer from isothermal vertical wavy surfaces, such as sinusoidal surfaces, in Newtonian fluids. Rees and Pop [7] examined the natural convection flow over a vertical wavy surface with constant wall temperature in porous media saturated with Newtonian fluids. Hossain and Rees [8] studied the heat and mass transfer in natural convection flow along a vertical wavy surface with constant wall temperature and concentration in Newtonian fluids. Cheng [9] presented the solutions of the heat and mass transfer in natural convection flow along a vertical wavy surface in a porous medium saturated with Newtonian fluids. Wang [10] focused on the effect of thermophoresis on particle deposition rate from a natural convection flow onto a vertical wavy plate.

From the literature survey, it seems that the problem of natural convection heat and mass transfer from vertical wavy surfaces in porous media saturated with non-Newtonian power law fluids has not been investigated so far. Thus this work aims to study the double diffusion near a vertical wavy surface in a power-law fluid embedded in a porous medium with constant wall temperature and concentration. This work use a coordinate transformation to transform a wavy surface to a smooth surface, and the obtained boundary layer equations are then solved by the cubic spline collocation method [11,12]. The effects of Lewis number, buoyancy ratio, power-law index, and amplitude–wavelength ratio on the

Table 1
Comparison of the values of $Nu_{\bar{x}}(Ra^{1/n}\xi)^{-0.5}$ for $a=0$ and $N=0$

n	$Nu_{\bar{x}}(Ra^{1/n}\xi)^{-0.5}$	
	Results of Chen and Chen [1]	Present results
0.4	0.3533	0.3533
0.5	0.3769	0.3772
0.8	0.4238	0.4243
1.0	0.4437	0.4441
1.2	0.4588	0.4590
1.5	0.4753	0.4755
2.0	0.4937	0.4939