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# Effects of non-Darcian on forced convection heat transfer over a flat plate in a porous medium-with temperature dependent viscosity☆

M.A. Seddeek*

*Kingdom of Saudi Arabia, King Saud University, Al-Qasseem Branch, College of Science, Mathematics Department, P.O. Box 237, Buriedah, 81999, KSA*

**Abstract**

The non-Darcian effect on forced convection heat transfer over a flat plate in a porous medium is examined. The fluid viscosity is assumed to vary as an inverse linear function of temperature. The effects of inertia forces and the distance from the leading edge of the plate on the velocity and temperature fields as well as on the skin friction and heat transfer coefficients in the boundary layer over a semi-infinite plate are studied. The nonlinear boundary layer equations, governing the problem under consideration, are solved numerically by applying an efficient numerical technique based on the Keller box method. The velocity profiles, temperature profiles and the skin friction components on the plate are computed and discussed in detail numerically for various values of the variable viscosity parameter, the modified Reynolds number, the stream wise coordinate and the Prandtl number.


*Keywords:* Non-Darcian; Forced convection; Heat transfer; Porous medium

## 1. Introduction

Due to the increasing importance in the processing industries and elsewhere where materials whose flow behavior in shearing cannot be characterized by Newtonian relationships, a new stage in the evolution of

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* Permanent address: Department of Mathematics, Faculty of Science, Helwan University, Ain Helwan, P.O.Box 11795 Cairo, Egypt.

*E-mail address:* seddeek_m@hotmail.com.

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fluid dynamic theory is in progress. An intensive research effort, both theoretical and experimental, has been devoted in the last decade to problems of free and forced convection heat transfer in porous media. Comprehensive references in this area may be found in recent review articles by Cheng [1], Nield [2] and Bejan [3]. However, most of the work refers to the Darcy's flow model and only a few papers have studied the inertia effects in problems of free and forced convection in porous media. Kumari et al. [4] have discussed the non-Darcian effects on forced convection heat transfer over a flat plate in a highly porous medium. They have shown that the non-Darcian effects play a significant role in a highly porous medium.

Most of the existing analytical studies for this problem are based on the constant physical properties of the ambient fluid. However, it is known (see Herwig and Gersten [5]) that these properties may change with temperature, especially for fluid viscosity. To accurately predict the flow and heat transfer rates, it is necessary to take into account this variation of viscosity. Seddeek [6] studied the effect of variable viscosity on hydromagnetic flow and heat transfer past a continuously moving porous boundary with radiation. Also, Seddeek [7] studied the effect of thermal radiation and buoyancy effects on MHD free convective heat generating flow over an accelerating permeable surface with temperature dependent viscosity. Recently, Seddeek [8] studied the effects of magnetic field, variable viscosity and non-Darcy on forced convection flow about a flat plate with variable wall temperature in porous media in the presence of suction and blowing.

It is worth mentioning that non-Darcian forced flow boundary layers form a very important group of flows, the solution of which is of great importance in many practical applications such as in biomechanical problems, in filtration transpiration cooling and geothermal.

Hence, the purpose of the present work is to study the effects of non-Darcian on forced convection heat transfer over a flat plate in a porous medium with temperature dependent viscosity. The governing non-linear partial differential equations are first transformed into a dimensionless form and the resulting non-similar set of equations is solved by a finite-difference method. The boundary condition of variable surface heat flux is treated in this paper.

## 2. Basic equations

The fluid properties are assumed to be isotropic and constant, except for the fluid viscosity which is assumed to be an inverse linear function of temperature (see Lai and Kulacki [9]).

$$\frac{1}{\mu} = \frac{1}{\mu_\infty}[1 + \gamma(T - T_\infty)] \tag{1}$$

or

$$\frac{1}{\mu} = a(T - T_r) \tag{2}$$

where

$$a = \frac{\gamma}{\mu_\infty} \text{ and } T_r = T_\infty - \frac{1}{\gamma} \tag{3}$$

Both $a$ and $T_r$ are constant and their values depend on the reference state and the thermal property of the fluid, i.e., $\gamma$. In general $a>0$ for liquids and $a<0$ for gases.