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Mathematical modelling on convective boundary layer of non-Newtonian micropolar viscoelastic fluid

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ABSTRACT – This article presents the mixed convection boundary layer flow over a circular cylinder placed in a viscoelastic micropolar fluid with surface heat flux. The governing boundary layer equations are transformed into non-dimensional form by using appropriate dimensionless variables. Then, the resulting equations are transformed into similarity equations and solved using an implicit finite difference scheme known as the Keller box method. For validation purpose, the current results are compared to previous study. With congruent results from both study, authors are convinced that the proposed model is reliable.

1. INTRODUCTION

Viscoelastic is a renowned type of fluid in industrial-manufacturing processes and engineering field with practicality in petroleum drilling, manufacturing of foods and paper, as well as reducing frictional drag on the hulls of ships and submarines. The study of the flow of viscoelastic fluid has sparked interests in many researchers due to its special ability to deform semi-permanently. However, in the existing models of viscoelastic fluids (refer [1-3]), the presence of rigid, randomly oriented suspended particles are neglected. Considering that the presence of the particles in the fluid might affect the behavior of the flow and heat transfer, therefore, this article will propose a new model of viscoelastic micropolar fluid.

According to the model proposed by Eringen in [4], micropolar fluids is a type of fluid consisting of rigid, randomly oriented (or spherical) particles suspended in a viscous medium which is particularly useful to model fluids with presence of dust and smoke, especially in gas. Hence, viscoelastic micropolar fluid can be defined as fluid with suspended particles that displays viscous and elastic characteristics.

In this study, the outcomes of the numerical solutions of the fluid flow of viscoelastic micropolar model on the outer of a circular cylinder will be presented.

2. METHODOLOGY

2.1 *Mathematical formulation*

Figure 1 illustrates the physical geometry of the problem and the corresponding coordinate system.

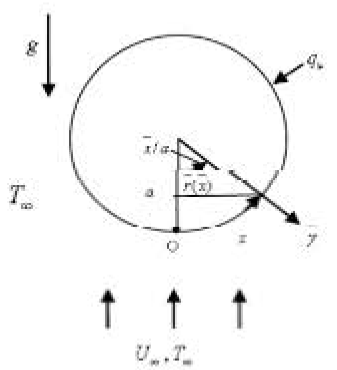

Figure 1 Physical model and coordinate system.

Under the assumptions that the Boussinesq and boundary layer approximations are valid, the dimensional equations governing the mixed convection boundary layer flow are

Continuity equation:

$$\frac{\partial \bar{u}}{\partial \bar{x}} + \frac{\partial \bar{v}}{\partial \bar{y}} = 0 \qquad (1)$$

Momentum equation:

$$\bar{u}\frac{\partial \bar{u}}{\partial \bar{x}} + \bar{v}\frac{\partial \bar{u}}{\partial \bar{y}} = \bar{u}_e\frac{\partial \bar{u}_e}{\partial \bar{x}} + \left(\frac{\mu+\kappa}{\rho}\right)\frac{\partial^2 \bar{u}}{\partial \bar{y}^2} + K_0\left(\frac{\partial}{\partial \bar{x}}\left(\bar{u}\frac{\partial^2 \bar{u}}{\partial \bar{y}^2}\right) + \bar{v}\frac{\partial^3 \bar{u}}{\partial \bar{y}^3} - \frac{\partial \bar{u}}{\partial \bar{y}}\frac{\partial^2 \bar{u}}{\partial \bar{x}\partial \bar{y}}\right)$$
$$- g\beta(T - T_\infty)\sin\left(\frac{\bar{x}}{a}\right) + \frac{\kappa}{\rho}\frac{\partial \bar{H}}{\partial \bar{y}} \qquad (2)$$

Energy equation:

$$\bar{u}\frac{\partial T}{\partial \bar{x}} + \bar{v}\frac{\partial T}{\partial \bar{y}} = \alpha\frac{\partial^2 T}{\partial \bar{y}^2} \qquad (3)$$