FLUCTUATING FLOW OF A VISCOELASTIC FLUID PAST AN INFINITE FLAT PLATE WITH UNIFORM SUCTION

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The problem of a two-dimensional incompressible viscoelastic fluid flow along an infinite flat plate is discussed when the suction velocity normal to the plate is uniform and the external flow velocity varies periodically with time. Expressions for the velocity and skin-friction are obtained in dimensionless forms and the effect of the fluid's elastic parameter on their behaviour is sought.

1. Introduction

The effect of unsteady fluctuations in the external flow velocity on the boundary layer flow was first studied by Lighthill [1]. Stuart [2] found some interesting features for an oscillatory flow over an infinite plate with uniform suction. Recently Rath and Mishra [3] have discussed the exponential boundary layer flow of a second order fluid along a porous infinite flat plate with uniform suction. They have shown that the steady components of the velocity and skin-friction coefficient are influenced by the elastic parameter of the fluid, but their unsteady parts are not affected by this parameter, and therefore, the nature of unsteadiness is not different from the Newtonian behaviour.

In the present paper an attempt has been made to study the fluctuating flow of a viscoelastic fluid past an infinite flat plate with uniform suction. The effect of the fluid's elastic parameter on the skin-friction amplitude and the velocity field is also discussed.

In the present work the viscoelastic fluid is of the Kuvshinski type (Michael and Bird [4]). The external flow velocity has been taken as $U_0[1 + \varepsilon e^{int}]$, and $v_0$ is a non-zero negative constant suction velocity.

2. Equations of motion

The equations governing the viscoelastic fluid model considered here consist of stress-strain rate law

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\[ D \frac{D}{Dt} (p_{ij}) = \frac{\partial p_{ij}}{\partial t} + v_m \frac{\partial p_{ij}}{\partial x_m} , \]  

(2.2)

\[ e_{ij} = \frac{1}{2} \left[ \left( \frac{\partial v_i}{\partial x_j} \right) + \left( \frac{\partial v_j}{\partial x_i} \right) \right] . \]  

(2.3)

The physical significance of \( \lambda_0 \) (relaxation time) lies in the fact that, if the motion suddenly stops, the shear stress will cease as \( \exp (-t/\lambda_0) \).

Here, the stress tensor is given by

\[ S_{ij} = -pg_{ij} + p_{ij} , \]  

(2.4)

where \( p \) is the static pressure, \( g_{ij} \) is the associated metric tensor and \( p_{ij} \) is a tensor usually related to the rate of strain, \( e_{ij} \), by “the equation of state” (2.1).

We consider the problem of a two-dimensional incompressible viscoelastic fluid flow along an infinite plane porous wall. The flow is independent of the distance parallel to the wall and the suction velocity \( v \), normal to the wall, is directed towards it and is constant. The \( x \)-axis is taken along the wall and \( y \)-axis normal to the wall. Then the equations governing the flow are

\[ \rho \left( \frac{\partial u}{\partial t} + v \frac{\partial u}{\partial y} \right) = -\frac{\partial p}{\partial x} + \frac{\partial p_{xy}}{\partial y} , \]  

(2.5)

\[ 0 = -\frac{\partial p}{\partial y} + \frac{\partial p_{yy}}{\partial y} , \]  

(2.6)

\[ \frac{\partial v}{\partial y} = 0 . \]  

(2.7)

Although \( \partial v/\partial y = 0 \) in (2.7) shows that \( v \) is only a function of time, we now further restrict consideration to the case of \( v \) equal to a negative constant \( (-v_0) \). Eq. (2.1) then gives

\[ p_{xx} + \lambda_0 \left( \frac{\partial p_{xx}}{\partial t} - v_0 \frac{\partial p_{xx}}{\partial y} \right) = 0 , \]  

(2.8)

\[ p_{xy} + \lambda_0 \left( \frac{\partial p_{xy}}{\partial t} - v_0 \frac{\partial p_{xy}}{\partial y} \right) = \mu \frac{\partial u}{\partial y} , \]  

(2.9)

\[ p_{yy} + \lambda_0 \left( \frac{\partial p_{yy}}{\partial t} - v_0 \frac{\partial p_{yy}}{\partial y} \right) = 0 . \]  

(2.10)