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Flow of a power-law fluid with memory past an infinite plate

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Abstract

We examined the flow of a power law fluid with a non-constant relaxation λt^b past an infinite plate. When λ is zero the fluid is pseudoplastic and when the power law exponent is 1, the fluid is a Maxwell fluid. It is shown that the problem has a solution when $0 < n \le 1$. Moreover, we show that momentum penetration decreases with λ.

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1.0 Introduction

The flow of a fluid past a moving plate has been of much interest since stokes introduced the problem in 1851. The problem is important because of its practical applications. In 1959 Bird [1] extended the problem by considering a pseudo plastic fluid. Recently Olajuwon [3] investigated the flow of a power law fluid, which is in contact with a Newtonian fluid. Also Vajraveln and Rivera [4] examined the hydro-magnetic flow at oscillating plate for large and small suction Reynolds numbers.

In this paper we extend the works of Bird [1] and Fetecau [2] who introduced a new exact solution for the flow of a Maxwell fluid past an infinite plate. In particular we examine the flow of a power law fluid with a non-constant relaxation time, that is, a flow with memory.

2.0 Mathematical formulation

Based on [1] and [2] the appropriate equations are

$$\frac{\partial u}{\partial t} + \lambda t^b \frac{\partial^2 u}{\partial t^2} = -\upsilon \frac{\partial}{\partial y}\left(-\frac{\partial u}{\partial y}\right)^n \qquad (2.1)$$

$$u(0, t) = V,\ u(\infty, t) = 0,\ t > 0; \qquad (2.2)$$

where υ is the kinematics' viscosity, λ is the relaxation time at $t = 1$, u is x-component velocity, n is the power law exponent

3.0 Method of solution

We seek a similarity transformation of the form $U = V^{-1} f(\eta)$, (3.1)

Such that the dimensionless variable $\eta = \dfrac{Ay}{t^a}$, (3.2)

Using equation (3.1) and (3.2) in equation (2.1), we have

$$a\eta \frac{df}{d\eta}(\lambda(a+1)-1) + \lambda a^2 \eta^2 \frac{d^2 f}{d\eta^2} = \upsilon n A^{n+1} \frac{d^2 f}{d\eta^2}\left(-\frac{df}{d\eta}\right)^{n-1}, \qquad (3.3)$$

$$f(0) = 1,\ f(\infty) = 0 \qquad (3.4)$$

Remark

Analytical similarity solution exist for a = $\dfrac{1}{n+1}$ and b = 1

Solving equation (3.3) using shooting method. Let;

$$\begin{pmatrix} x_1 \\ x_2 \\ x_3 \end{pmatrix} = \begin{pmatrix} \eta \\ f \\ f' \end{pmatrix} \tag{3.5}$$

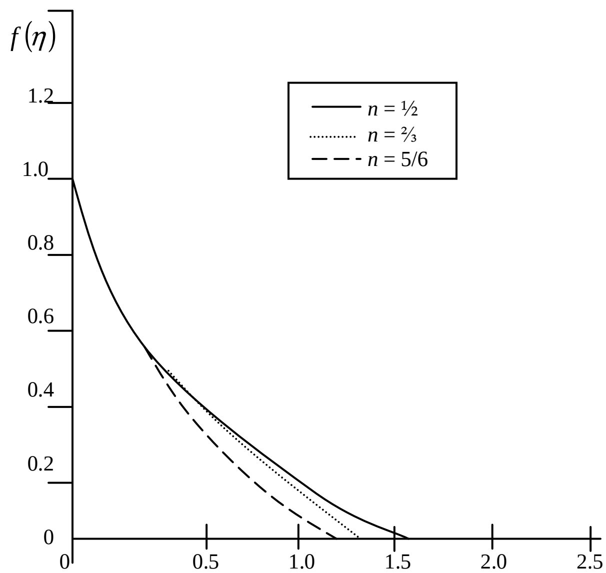
We solve the system of equations

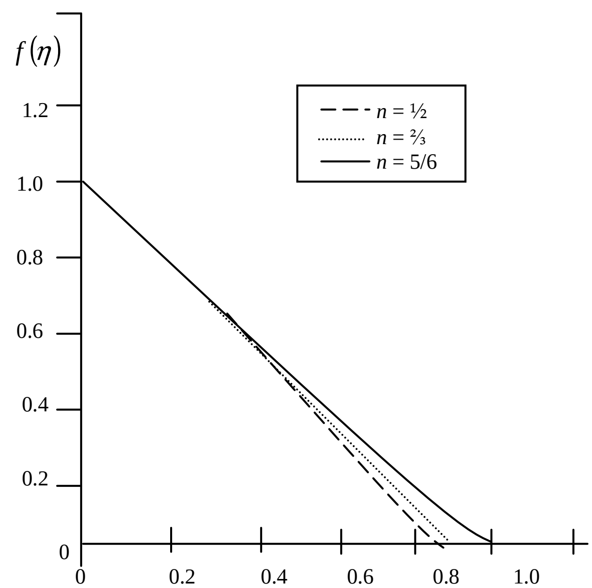
$$\begin{pmatrix} x_1' \\ x_2' \\ x_3' \end{pmatrix} = \begin{pmatrix} 1 \\ x_3 \\ \dfrac{ax_1\, x_3\, [\,\lambda\, [\,a + 1] - 1]}{\upsilon n\, (-x_3\,)^{\,n-1} - \lambda a^2 x_1^2} \end{pmatrix} \tag{3.6}$$

Together with conditions;

$$\begin{pmatrix} x_1\ (0) \\ x_2\ (0) \\ x_3\ (0) \end{pmatrix} = \begin{pmatrix} 0 \\ 1 \\ -\alpha \end{pmatrix} \tag{3.7}$$

Note: The value of α is guessed such that the boundary condition (3.4) is satisfied. The Numerical results is presented as the momentum distribution, Figures 1 and 2, for various values of the power law exponents n = $\frac{1}{2}, \frac{2}{3}$ and $\frac{5}{6}$. And for the values of λ = 0.3 and 0.8 respectively.





1.2

η

η

Figure 1: Momentum distribution for $\lambda = 0\cdot 3$

Figure 2: Momentum distribution for $\lambda = 0\cdot 8$

4.0 **Discussion of result**

Figure 1 and 2 show the momentum distribution for λ = 0.3 and λ = 0.8 respectively. Tables 1 and 2 below show the momentum penetration η.

Table 1

n	$1/2$	$2/3$	$5/6$
η	1.56	1.27	1.17

Table 2

n	$1/2$	$2/3$	$5/6$
η	0.85	0.97	0.99

The above tables clearly show that momentum penetration decreases as λ increases.

References

[1] **R.B. Bird (1959) Unsteady pseudoplastic flow near a moving wall A.I. Ch. E Journal, 5, pp 565, 6D.**

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