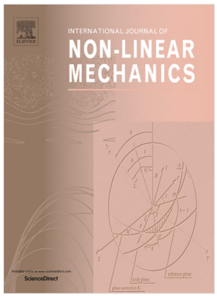

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REVERSAL OF FLOW OF A NON-NEWTONIAN FLUID IN AN EXPANDING CHANNEL

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Abstract

The flow of an incompressible power-law fluid through convergent-divergent channels is considered where the choice of the viscosity is such that the stress tensor is not degenerate in the sense that the zero shear rate viscosity is neither zero nor infinity for any finite value of the power-law exponent in contrast to the earlier study by Mansutti and Rajagopal [1] wherein the viscosity could be zero or infinity for certain values of the power-law exponent. We observe the appearance of boundary layers for the non-Newtonian fluid, even in the case of divergent flow. Sharp and pronounced boundary layers develop adjacent to the boundaries, even at zero Reynolds number. Furthermore, for values of the angle beyond a critical value, we detect regions of flow reversal; i.e. different flow regimes are observed wherein there is inflow and outflow. We are also able to assess the consequences of introducing a traction boundary condition at the boundaries of the channel on the behaviour of the fluid. In this case we find the possibility of asymmetric solutions. We also find a new solution in the case of the Navier-Stokes fluid, albeit numerical, by setting the power-law exponent to zero.

Keywords: incompressible fluid, Jeffery-Hamel flow, implicit constitutive relation, boundary layer, flow reversal

1. INTRODUCTION

Flow through convergent-divergent channels has been investigated extensively due to their relevance to many technological applications in: aerospace, chemical, industrial and bio-mechanical engineering. A prime example relates to an understanding of the flow of rivers and canals. This class of flows, first identified by Jeffery [2] in 1915 and independently by Hamel [3] in 1916, is known as the Jeffery-Hamel flow. These types of flows describe the outflow and inflow of a viscous incompressible fluid in a linearly expanding channel (wedge) with a given angle between the walls. The angle between the walls of the wedge is given by 2α as per convention. Thus we are considering two dimensional source or sink flow which displays self-similar behaviour with no-slip boundary conditions at the walls.

Many authors have worked on special aspects of this problem after the first studies by Jeffery and Hamel; classical studies include: Harrison [4], Kármán [5], Tollmien [6], Noether [7] and Dean [8]. The general solution to the

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