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Full Length Research Paper

Oscillatory channel flow for non-Newtonian fluid

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This paper deals with an analytical solution of oscillatory flow of an incompressible second grade fluid in a channel. The flow in the channel is driven by suction at the permeable walls, whereas small amplitude time harmonic pressure waves are responsible for oscillations in the velocity field. The time independent axial velocity and the time dependent oscillatory axial velocity are calculated analytically. The important physical quantities like the velocity profile, amplitude of the oscillation and penetration depth of the wave are given special emphasis. The effects of second grade parameter and suction parameter on these quantities are particularly examined. A comparative study of the oscillatory flow for second grade with viscous fluid is also made.

Key words: Oscillatory channel flow, second grade fluid, shear stress, perturbation solution, Wentzel-Kramers-Brillouin (WKB) approximation.

INTRODUCTION

The history of channel flows goes back to the celebrated paper by Berman (1953) who initiated the study of two-dimensional laminar flow of incompressible viscous fluid in a rectangular channel with permeable walls. Several attempts were later made under the assumptions of small and large cross flow Reynolds number. Majdalani (1998) introduced the oscillatory viscous flow between two parallel porous plates subject to sidewall injection for the first time. Later on, some studies extended their work of oscillatory channel flows to different flow configurations (Jankowski and Majdalani, 2000, 2002; Majdalani and Roh, 2000, 2001; Majdalani, 2001). We witness that these studies of oscillatory channel flows have been undertaken in viscous fluid.

The oscillatory flows have special relevance in vibrating media with applications in oil-drilling, control of blood flow during surgical operations, manufacturing and processing of foods and paper, oil exploration and paper industry. In biology, it has applications in modeling of respiratory functions in lungs, modeling of chemical/blood dispensing in biochemistry/clinical labs, etc. Some other applications of value are: to detect the intensity of underground explosions, chemicals and material processing, isotope separation, irrigation systems, rocket propulsion, filtration mechanism, sweat cooling, cooling of electronic device, heat exchanger and many others.

It is now well established that the non-Newtonian fluids are more appropriate than viscous fluids in many practical applications. Examples of such fluids include certain oils, lubricants, mud, shampoo, ketchup, blood at low shear rate, cosmetic products, polymers and many others. Unlike the viscous fluids, all the non-Newtonian fluids (in terms of their diverse characteristics) cannot be described by a single constitutive relationship. Hence, several models of non-Newtonian fluids are proposed in the literature. Although, in general, the classification of non-Newtonian fluids is presented into three categories, namely, the differential, rate and integral types, but the differential type of fluids has been properly studied by the researchers in the field. In particular, there is a simplest subclass of differential type of fluids known as second grade which has attracted much attention in recent studies (Wenchang and Takashi, 2005; Yigit et al. 2007; Fetecau et al., 2008; Chunhong, 2009; Nazar et al., 2010; Naeem et al., 2010; Yuedong and Yanhua, 2010; Erdogan and Imrak, 2011; Norfifah et al., 2011).

The purpose of the present paper is to investigate the

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