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UNSTEADY BOUNDARY LAYER FLOW OF FRACTIONAL OLDROYD-B VISCOELASTIC FLUID PAST A MOVING PLATE IN A POROUS MEDIUM*†

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Abstract

This paper considers the unsteady boundary layer flow over a moving flat plate embedded in a porous medium with fractional Oldroyd-B viscoelastic fluid. The governing equations with mixed time-space fractional derivatives are solved numerically by using the finite difference method combined with an L1-algorithm. The effect of various physical parameters on the velocity and average skin friction are discussed and graphically illustrated in detail. Results show that the porosity ϵ and fractional derivative α enhance the flow of Oldroyd-B viscoelastic fluid within porous medium, but fractional derivative β weakens the flow. Moreover, it is found that the average skin friction coefficient rises with the increase of fractional derivative β.

Keywords fractional derivative; Oldroyd-B viscoelastic fluid; porous medium; moving plate

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1 Introduction

The viscoelastic fluid is a kind of non-Newtonian fluid, which possesses viscidity and elasticity, such as pitch and napalm. In the studies of the viscoelastic fluid, the Maxwell fluid model is an important classic model used in studying the flow and heat transfer. In the past few decades, a large number of research achievements regarding Maxwell fluid model have been published. Choi et al. [1] studied the steady and incompressible suction flow of the Maxwell fluid in a porous surface channel. Pandey and Tripathi [2] analytically investigated the unsteady peristaltic transport of the

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Maxwell fluid in a finite contractive tube. Qadri and Krishna [3] considered the flow of an incompressible viscous Maxwell fluid between two parallel plates, initially induced by a constant pressure gradient. Besides, the Oldroyd-B fluid is also a class of usual viscoelastic fluids. Tan and Masuoka [4] analyzed the stokes' first problem for an Oldroyd-B fluid in a porous half space. Hayat et al. [5] investigated the steady flow of an Oldroyd-B fluid through an exponentially stretched surface.

The porous medium is a common physical model used for discussing the flow and heat transfer of viscoelastic fluid. Due to its wide application in different flieds of engineering and industry, numerous studies have focused on the flow of viscoelastic fluid in the porous medium. Chouwdhury and Islam [6] considered the MHD free convection flow of viscoelastic fluid past an infinite vertical porous plate with the help of the Laplace transform technique. Malashetty et al. [7] investigated the linear stability of a viscoelastic fluid saturated porous medium heated from below and cooled from above with the Oldroyd-B type fluid.

As one of the viscoelastic properties, the impact of the long-term memory is ignored in the classical studies. The integer order models restrict the developments of the theory of viscoelastic fluid. In the past few decades, many scholars have found that the fractional derivatives can be a valuable tool in describing the complex dynamics. By replacing integer order with the fractional calculus operators, the governing equations of well-known viscoelastic fluids are modified. Using the Riemann-Liouville definition, Friedrich [8] formulated a four-parameter Maxwell model with fractional derivatives of different orders of the stress and strain. A five-parameter Jeffreys model in terms of fractional derivatives was documented by Song and Jiang [9]. Recently, for the sake of better solving the complex fractional derivatives equations, numerical methods have been focused widely. Liu et. al [10] proved that the implicit different method is unconditionally stable and convergent for the space-time fractional advection diffusion equation, but the explicit difference method is conditionally stable and convergent. Based on this theory, [11-13] provided a newly developed finite difference method combined with an L1-argorith to solve the nonlinear fractional boundary layer governing equations with mixed time-space derivative in the convection terms.

The aim of this work is to explore the flow characteristics of fractional Oldroyd-B fluid through a porous medium over a moving plate with the effects of porosity and permeability. Unlike the classic studies, the fractional derivatives and the Darcian velocity depending on porosity are taken into consideration in this paper. It is more accurate to characterize the flow complexity of porous medium. Meanwhile, by applying the fractional derivative to the momentum equation, the thickness of velocity boundary layer is investigated in unsteady condition. The effects of various