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Lin Liu, Fawang Liu

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Boundary layer flow of fractional Maxwell fluid over a stretching sheet with variable thickness

Lin Liu [a,*], Fawang Liu [b]

[a] School of Mathematics and Physics, University of Science and Technology Beijing, Beijing 100083, China

[b] School of Mathematical Sciences, Queensland University of Technology, GPO Box 2434, Brisbane, Queensland 4001, Australia

Abstract: A novel investigation about the boundary layer flow of fractional Maxwell fluid over a stretching sheet with variable thickness is presented. By introducing new variables, the irregular boundary changes as a regular one. Solutions of the governing equations are obtained numerically where the L1-scheme is applied. Dynamic characteristics with the effects of different parameters are shown by graphical illustrations. Three kinds of distributions versus power law parameter are presented, including monotonically increasing in nearly linear form at y=1, increasing at first and then decreasing at y=1.4 and monotonically decreasing in nearly linear form at y=2.

Keywords: Fractional derivative; Maxwell fluid; Constitutive equation; Boundary layer

1. Introduction

Boundary layer flow has attracted much attention due to its ever growing physical and industrial applications [1-3], such as glass blowing, metal extrusion and cooling, glass fiber production, plastic extrusion processes and paper production. In view of its great importance, many attempts [4-6] thus have been committed for its study.

The previous papers mainly discuss the boundary layer flow with flat stretching sheet. Due to the acceleration or deceleration of the sheet, the thickness of the stretched sheet may decrease or increase with distance from the slot [7], which is dependent on the value of the velocity power index. Motivated by this discussion, a stretching sheet with variable thickness can be more close to the situation in practical engineering applications. And it has attracted a large number of scholars' attention. Among the researchers, Fang et al. [8] were the first scholars to study the boundary layers over a continuously stretching sheet with a power law surface velocity revisited for a sheet with variable thickness. The key references about the stretching sheet with variable thickness are given in Refs. [9-11].

The classical constitutive equation to describe the boundary layer flow is deduced from the integer order constitutive relationship in linear form. With the progress of the scientific research, fractional calculus achieves great development due to its vast application foregrounds. As is well known, the integral order operator possesses the local nature while the time fractional operator is a nonlocal one which possesses the memory characteristic [12-13].

The effectiveness and importance of fractional derivative on the engineering applications have been verified through experiments by many researchers. Song and Jiang [14] studied the viscoelastic fluids with fractional Jeffreys model, verifying that the modified Jeffreys model was appropriate to describe the behaviors for xanthan gum and Sesbania gel. Bagley and Torvik [15] indicated that the fractional calculus models of viscoelastic material behavior were consistent with the predictions of the molecular theory of polymer solids, and provided a link between accepted microscopic theories and macroscopic observations. The fractional kinetics proved to be valuable by Zaslavsky [16] to describe some important physical phenomena, such as cooling of particles and signals, particle and wave traps, Maxwell's Demon, etc. Meral et al. [17] verified that the fractional order Voigt model can be better simulate the surface wave response of soft tissue-like material phantoms by experiment. Jiang

*Corresponding author.

Email addresses: liulin1020@126.com