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Numerical Investigation of the Pulsatile Flow of Viscous Fluid in Constricted Wall Channel with Thermal Radiation

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Abstract. The main theme of the current article is to investigate the heat transfer in the pulsatile flow of an electrically conducting viscous fluid in a constricted channel under the effect of the magnetic field and thermal radiation. The unsteady governing equations simplified for low conducting fluids are solved numerically by finite difference method using stream-vorticity function formulation. The influence of the flow parameters such as the Hartmann number (magnetic parameter), Strouhal number (flow pulsation parameter), Prandtl number, and radiation parameter is studied on the relevant flow profiles. The influence of different emerging parameters on the skin friction coefficient and Nusselt number are examined, as well. In general, the profiles are observed to exhibit a relatively more regular pattern upstream of the construction than that downstream of the constriction.

AMS subject classifications: 76D05

Key words: Constricted channel, pulsatile flow, thermal radiation, magnetic field, Strouhal number, Prandtl number.

1 Introduction

The pulsatile fluid flows have received much consideration in the last few years due to its applications in various industrial applications and physiological systems, particularly in the cardiovascular system. The study of Newtonian and Non-Newtonian fluids' pulsating motion is useful in understanding blood flow, especially in stenotic arteries. Wall pressure and shear stress play significant roles in arterial hemodynamics. In literature,

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numerous contributions are available regarding the analysis of pulsatile flows. Initially, researchers modeled the blood flow as steady flow and later discussed, more realistically, as pulsatile flow in channels or vessels with some irregularity on the walls. Pal et al. [1] and Midya et al. [2] discussed the steady flow of an electrically conducting flow in a channel subject to magnetic field. Makinde and Alagoa [3] investigated the blood flow through an artery with stenosis. Prakash et al. [4] proposed a non-Newtonian incompressible model for steady blood flow via blood vessels with a uniform cross-section in stenosed arteries. Isler et al. [5] performed such an analysis with equilibrium states. Chakravarty et al. [6] discussed unsteady pulsatile flow in an artery with an abnormal surface. Analysis of pulsatile flow in a constricted channel was presented by Bandyopadhyay and Layek [7]. Later, Bandyopadhyay and Layek [8] extended the study [7] to examine the effect of the magnetic field. In a constricted tube, Khair et al. [9] examined the transformation of a pulsatile flow from the laminar to the turbulent one. The pulsatile flow of a dusty liquid through a constricted channel in the existence of a magnetic field was inspected by Kiran et al. [10]. Clark [11] examined both pulsatile and non-pulsatile flows through a vessel with nozzle-like stenosis and discussed highly disturbed flow patterns, especially for velocity fluctuations. Zhang et al. [12] examined the electro-MHD behavior of a third-grade non-Newtonian fluid, flowing among a pair of parallel plates using a semi-analytical/numerical method. They studied the impact of viscous dissipation and Joule heating. Makinde et al. [13] used a compliant walled channel to investigate the cumulative influence of a magnetic field, thermal radiation, heat source, velocity slip, and thermal jump on peristaltic Walters-B fluid. They reported that the magnetic field enhances the temperature profile and retards the velocity profile.

Several authors have studied heat transfer through a constricted channel or tube because of its usages in various heat transfer systems in the industry ranging from simple heat exchangers to most complicated nuclear reactors. Moschandreu and Zamir [14] investigated heat transfer in pipe flow with varying pulsating frequency. Kim et al. [15] investigated the heat transfer problem in a thermally developing pulsatile flow. Zohir et al. [16] and Baffigi and Bartoli [17] experimentally studied the heat transfer in pulsating airflow with varying amplitudes. Elshafei et al. [18] investigated heat transfer in pulsatile turbulent pipe flow. Cho and Hyun [19] found a numerical solution of boundary layer equations with heat transfer in the pipe coupled with a resultant form of the energy equation for pulsatile flow. Shit and Majee [20] examined the MHD pulsatile blood flow and heat transfer in the arteries with permeability. Farooq et al. [21] numerically investigated the heat transfer in a magneto-bio-fluid flow. They considered the geometry vertical ciliated channel.

Makinde et al. [22] investigated MHD laminar flow of a conducting incompressible viscous nanofluid via various channels of slowly varying width by employing Buongiorno's model. They reported opposite behavior of the thermal number for skin friction, heat, and mass transfer. Shahid et al. [23] investigated the incompressible steady flow of MHD nanofluid over a vertically stretched porous sheet with temperature-dependent viscosity. The mathematical modeling was done using the Reynolds exponential model.