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Joule heating effects on electromagnetohydrodynamic flow through a peristaltically induced micro-channel with different zeta potential and wall slip

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Abstract

This paper aims to develop a mathematical model for magnetohydrodynamic flow of biofluids through a hydrophobic micro-channel with periodically contracting and expanding walls under the influence of an axially applied electric field. The velocity slip effects have been taken into account at the channel walls by employing different slip lengths due to hydrophobic gating. Different temperature jump factors have also been used to investigate the thermomechanical interactions at the fluid-solid interface. The electromagnetohydrodynamic flow in a microchannel is simplified under the framework of Debye-Hückel linearization approximation. We have derived the closed-form solutions for the linearized dimensionless boundary value problem under the assumptions of long wave length and low Reynolds number. The axial velocity, temperature, pressure distribution, stream function, wall shear stress and the Nusselt number have been appraised for diverse values of the parameters approaching into the problem. Our main focus is to determine the effects of different zeta potential on the axial velocity and temperature distribution under electromagnetic environment. This study puts forward an important observation that the different zeta potential plays an important role in controlling fluid velocity. The study further reveals that the temperature increases significantly with the Joule heating parameter and the Brinkman number (arises due to the dissipation of energy).

Keywords: Electro-osmosis, Peristaltic pumping, Joule heating, MHD, Zeta potential, Slip velocity

1. Introduction

In the recent past, more attention has been paid towards a new area of research called "microfluidics" with the new microfabrication technologies made available because of the development of microelectronics. Microfluidic or lab-on-a-chip (LOC) devices have grown explosively due to their inherent advantages associated with miniaturization, integration, parallelization and automation, including low consumption of reagents and samples, rapid analysis, cost-effectiveness, separation and analysis of chemical and biological agents, micro-electro-mechanical systems (MEMS), high efficiency and less human interference during operation [1]-[3]. The effect of surface potential on liquid transport across ultrafine capillary slits under an imposed electric field was studied by Burgreen and Nakache [4]. The electroosmotic flow is driven by Coulomb force due to the application of electric potential along the length of the micro-channel. The electro-osmotic flow is one of the most important factors in the optimization of electrophoretic separations [5].

Peristaltic pumping refers to the mechanism that involves mixing and propelling materials through diminution or expansion of the waves propagating along the channel walls. Such mechanism is observed in several physiological scenarios such as swallowing of food bolus through the esophagus, the movement of chyme in the gastrointestinal tract, conveyance of spermatozoa in ductus efferentes of the male reproductive tracts, transport of lymph in the lymphatic tracheas and in the vasomotion of the arteries, venules and capillaries. Weinberg et al. [6] studied hypothetically the nature of peristaltic transport and have led the way for several theoretical and analytical predictions. Akbar et al. [7] investigated the combined effects of thermal and velocity slip on the peristaltic flow of a Johnson-Segalman liquid in an inclined asymmetric channel. Recently, the attention has been made to the study of heat and mass transfer in peristaltic pumps by several researchers. In this direction, Srinivas and Kothandapani [8] examined the heat transfer effect on the peristaltic transport in an asymmetric channel. Hayat et al. [9] investigated the slip effect on MHD peristaltic