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Electrokinetically driven fluidic transport of power-law fluids in rectangular microchannels

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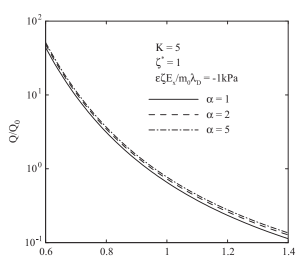
HIGHLIGHTS

- ► Electroosmotic flow of power-law fluids in rectangular microchannels is analyzed.
- ► The governing equations are numerically solved using a finite difference procedure.
- ► The flow rate of shear-thinning fluids is much higher than that of shear-thickenings.
- ► The mean velocity is an increasing function of the channel aspect ratio.

GRAPHICAL ABSTRACT

The flow rate of shear-thinning fluids is substantially higher than that of shear-thickenings, irrespective of the channel aspect ratio. This indicates that for driving shear-thinning biofluids such as blood much lower power is needed than what is computed using a Newtonian behavior.



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ABSTRACT

Electroosmosis is the predominant mechanism for flow generation in lab-on-chip devices. Since most biofluids encountered in these devices are considered to be non-Newtonian, it is vital to study the flow characteristics of common non-Newtonian models under electroosmotic body force. In this paper, the hydrodynamically fully developed electroosmotic flow of power-law fluids in rectangular microchannels is analyzed. The electrical potential and momentum equations are numerically solved through a finite difference procedure for a non-uniform grid. A thoroughgoing parametric study reveals that the Poiseuille number is an increasing function of the channel aspect ratio, the zeta potential, the flow behavior index, and the dimensionless Debye–Hückel parameter. It is also found that the validity range of the Debye–Hückel approximation for shear-thickening fluids is much wider than that of shear-thinnings. Furthermore, while the dimensionless mean velocity is an increasing function of the channel aspect ratio and the dimensionless Debye–Hückel parameter, it is a decreasing function of the flow behavior index. Moreover, to increase the zeta potential is to increase the dimensionless mean velocity for shear-thinnings, nevertheless, its effect is not significant for shear-thickenings.

1. Introduction

When a surface is brought into contact with an electrolyte solution, its chemical state may be significantly altered. As an example, the surface groups may be ionized leaving a net surface charge. Due to the electroneutrality principle, the liquid takes on an opposite charge in the electric double layer (EDL) near the surface. The electric double layer, shown schematically in Fig. 1, contains an immobile inner layer and an outer diffuse layer [1]. If an electric field is applied tangentially along the surface, a force will be exerted on the ions within

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