ABSTRACT

Rheologically complex fluids are important in many applications concerning narrow confinements and small channels. These applications range from uses in bearings to lab-on-a-CD based medical diagnostic platforms. Based on such applications, problems have been proposed to study the dynamics of the complex fluids in environments close to what would be observed in the said applications through numerical techniques. Fluid actuation in narrow confinements may be done by many methods. Apart from physically pumping, there are methods such as electrical actuation, magnetic actuation, etc. The method of fluid actuation could be a combination of one or more such methods as well. Some of the most important applications such as melting, pressurization, mixing, bearings, etc. use complex fluids. In pharmaceutical industries, where the manufacturing processes are primarily in the domain of squeezing and extrusion, very often use biological fluids. Accordingly numerical analysis is conducted to study the dynamic evolution of a non-Newtonian fluid modelled by the power-law model as well as viscoelastic model under the simultaneous action of squeezing and extrusion. In particular, the main aim is to bring out the rheology driven alteration in the extensional flow dynamics, as modulated by the complex growth of the fluid stresses under simultaneous effects of squeezing and extrusion. Recent advances in microfluidic applications, especially in Lab-on-chip devices, have triggered interests in exploring the electroosmotic method of flow activation. Lab-on-chip devices can be used for the analysis of chemical and biological samples which find many applications, especially important in clinical and pathological practices. Implications of studying electrosmotically actuated flows of complex fluids may therefore be far-reaching, ranging from the development of medical devices with artificial flow actuation to portable diagnostic kits. It is well known that the lack of moving parts makes it easier for fabrication and pumping of a fluid in microchannels by this method. Electroosmosis of viscoelastic fluid is not well explored in rectangular microchannels, therefore a numerical analysis is conducted on the electroosmotically driven transport of viscoelastic fluids characterized by the Oldroyd-B model in a rectangular microfluidic channel with focus on both symmetry and asymmetry in the wall zeta potentials. The physics involved with the microflows in a rotationally actuated platform is, indeed, complex largely attributed to the interference of rotation induced forces on the underlying flow dynamics.

Motivated by this challenging proposition, a numerical analysis is conducted here for the electroosmotically driven transport of a power-law fluid and viscoelastic fluid in a rotating rectangular microchannel. Our results captured that the growth of the velocities in the flow field owing to simultaneous action of squeezing and extrusion forces and its interactions with the rheological behaviour of the fluid. The results from this study are also useful in enhancing the understanding of the behaviour of a viscoelastic fluid within microchannels actuated by eletroosmosis, with far-reaching implications in various applications including microfluidics based medical diagnostics. Vortex structures in the secondary flow field, mainly originating from the interactive effects of the rotation induced Coriolis acceleration and the electrical force driven uniform velocity profile in the channel gives rise to some interesting physics, which is discussed in detail. The results obtained from the analysis may bear a significant impact in designing the lab-on-chip based microsystems/devices, which are typically used for the transportation of bio-fluids.

Keywords: Rheology; complex fluids; squeeze flow; extrusion; electroosmosis; Oldrodyd-B; viscoelastic; power-law; rotational microfluidics; Coriolis force; zeta potential.