Hydrodynamic interactions of flexible membranes in shear flows: A DPD study

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ABSTRACT

There is a large scale need to develop simple, efficient and optimal technological solutions for diagnostics, such as lab on a chip. Infact, most of the biofluid mechanics applications also require fundamental understanding of flow through microchannel and their interaction with flexible surfaces. There is often a two-way coupling between the hydrodynamic forces and the flexible material. Moreover, in these small scale flows it is important to account for the Brownian effects to enable any meaningful insights. To this end, a number of attempts have been made in the literature to model the membranes more realistically and be able to predict their behavior to achieve the desired functionality.

To investigate the flow through microchannels, mesoscopic modeling techniques such as, dissipative particle dynamics (DPD) [1] are gaining popularity, as they can suitably account for the random Brownian effects. The authors have extensively validated a DPD model (see Ref. [2]) for a number of benchmark problems by introducing a novel wall boundary model. This algorithm was further utilized in the analysis of flow through patterned microchannels with a splitter plate for an efficient handling of bioassays (see Ref. [3]). However, such plates are often flexible and their interaction with the flowing fluid needs to be fully understood. To this end, the present study analyzes the effect of a flexible membrane in a 2-D mircrochannel and its associated hydrodynamics.

In the present work, flow through a microchannel of size $300r_c \times 20r_c$ with asymmetrically placed flexible membrane is analyzed. This membrane is located at a distance of $100r_c$ from the inlet and has a length of $100r_c$. This is modelled as a bead-spring system, which incorporates both extensional and flexural rigidity through the parameters k_e and k_b respectively. The membrane possess visco-elastic behavior by virtue of damping coefficient (c). By performing detailed DPD calculations, it was observed that for a fixed Reynolds number, the membrane attains different steady state configurations. This deflection is observed to be dependent on extensional and bending stiffness of the membrane. These membrane deflections are found to be maximum for low stiffnesses and almost rigid for high stiffness parameters. Thus, the membrane dynamics is effectively modeled by analyzing the hydrodynamics of microchannel flows and its associated fluid-structure interaction effects.

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