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ANALYTICAL STUDY OF VESICLE DYNAMICS AND RHEOLOGY

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ABSTRACT

Vesicles, which consist of a closed fluid membrane surrounding a Newtonian liquid, have been studied extensively in recent years due to their importance as biomimetic models for real cells. Suspensions of vesicles can, for example, give insights into challenging problems like blood rheology.

Recent experiments [1] and theoretical studies [2,3] demonstrate that vesicles in a shear flow display different dynamical behaviour, depending on the viscosity contrast between inner and outer fluid and depending on the capillary number. For small viscosity contrast one observes a time-independent vesicle shape with fixed orientation in the flow while the fluid membrane undergoes a tank-treading motion. For sufficiently large viscosity ratio, however, a tumbling motion of the long vesicle axis in the shear plane is observed. For certain intermediate values an oscillatory motion of the vesicle around the flow direction (vacillating-breathing) has been predicted theoretically [2] and observed experimentally [1]. We address the problem of vesicle dynamics in shear flow by performing an asymptotic expansion in the small excess area limit. A consistent solution of the free-boundary problem to higher order in the excess area yields a dynamical phase diagram, which predicts a direct transition from tank-treading to tumbling at a critical viscosity contrast for low capillary number, while for higher capillary number there is first a transition from tank-treading to vacillating-breathing and then a second transition from vacillating-breathing to tumbling. In comparison to other approaches [3], we present a closed analytical solution that consistently takes the hydrodynamical response into account.

We apply the same strategy to nonlinear flow, such as Poiseuille flow, in order to investigate the question of lateral migration. Finally we make a link between the dynamics of the single vesicle and the rheological properties of a sufficiently dilute suspension [4].

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