Vesicle dynamics in flows

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1. INTRODUCTION

The dynamical behavior of vesicles in flows is an important subject not only of fundamental research but also in medical applications. For example, in microcirculation, the deformation of red blood cells reduces the flow resistance of microvessels. In diseases such as diabetes mellitus, red blood cells have reduced deformability and often block microvascular flow. We studied the dynamics of vesicles in shear flow and in cylindrical capillary using a particle-based hydrodynamics simulation technique, multi-particle collision (MPC) dynamics.

2. SIMPLE SHEAR FLOW

In simple shear flow, a fluid vesicle transits from steady tank-treading to unsteady tumbling motion with increasing membrane viscosity [1, 2]. The shear induces a transformation from discocyte to prolate ellipsoid at low membrane viscosity. On the other hand, at high membrane viscosity, the shear induces a transformation from prolate to discocyte, or tumbling motion accompanied with oscillations between these two morphologies. We found that between the tank-treading and tumbling states, a new oscillatory "swinging" state can appear [3]. Our results agree well with recent experiments [4]. These dynamical behaviors can be understood from a simplified model.

3. CAPILLARY FLOW

In capillary flow, an elastic vesicle (red-blood-cell model) transits from a discocyte to parachute-like shape, while the fluid vesicle transits into prolate with increasing flow rate [5]. In both cases, the shape transitions reduce the flow resistance.

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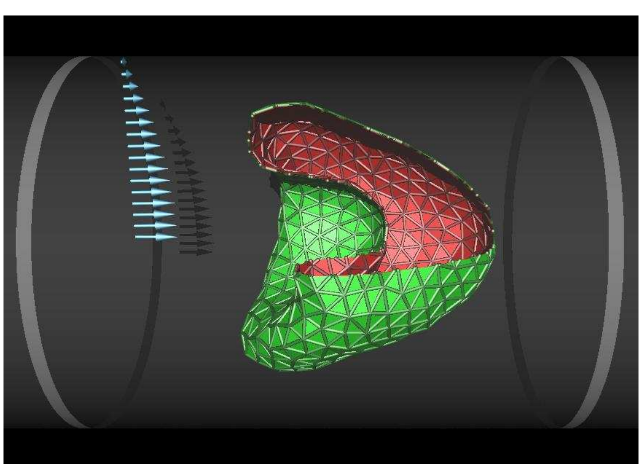

Figure 1: Snapshot of an elastic vesicle with a parachute shape in capillary flow. The upper quarter of vesicle is removed to show the inside. Arrows represent velocity field of solvent.