

A REDUCED-ORDER MODEL OF A SPHERICAL CAPSULE FLOWING IN A MICROFLUIDIC CHANNEL

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Drug targeting is one of the high potential applications of microcapsules, which are liquid droplets enclosed by a thin elastic membrane. But scientific challenges remain to synthesize them with the optimal payload and mechanical properties that allow the rupture of the membrane under certain flow conditions. When subjected to an external flow, capsule membrane may undergo large deformation and wrinkles and damage can appear. The determination of the membrane mechanical properties is thus crucial to control the release. It can be done by flowing the capsules through a microchannel. In order to apply inverse analysis techniques to the observed deformed profiles [1], numerical simulations solving the complex fluid-structure interactions are needed [2][3]. However, their computational cost is high. Our objective is thus to develop a non-intrusive kinematics-consistent data-driven reduced-order model (ROM) of an initially spherical capsule flowing in a microfluidic channel in order to open the way to real-time simulations.

The high-fidelity problem is simulated using a full order model (FOM) coupling the finite element and boundary integral methods [3] by varying the capsule-to-tube confinement ratio a/ℓ and the capillary number Ca , ratio of the viscous to elastic forces. For a given $(Ca, a/\ell)$ couple, the displacement and velocity of each membrane nodes at each discrete time step are stored in snapshots matrices. A singular value decomposition is applied to these matrices to determine the reduced variables of the displacement and velocity. A Dynamic Mode Decomposition (DMD) is then constructed assuming that kinematics and membrane equilibrium equations are verified. The DMD algorithm is applied using the reduced variables. The relative error on the capsule shape estimated by the ROM is less than 0.2% compared to that simulated by the FOM for 142 $(Ca, a/\ell)$ couples and the computational time can be divided by up to 52000. The developed ROM thus allows to reproduce in real time the dynamics of a capsule flowing in a microfluidic channel with great precision while preserving the physics of the problem.

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