Modelling membranes in a flow with a stream function formulation

Andreu F. Gallen[1], Joan Muñoz[1], Mario Castro[2], and Aurora Hernandez-Machado[1,3].
[1] Universitat de Barcelona
[2] Instituto de Investigación Tecnológica (IIT), Universidad Pontificia Comillas, Madrid
[3] Institute of Nanoscience and Nanotechnology, Barcelona

Some existing numerical methods have successfully simulated the coupling between a fluid and membranes, with special interest in red blood cells. We introduce an alternative phase-field model formulation that solves the flow using the vorticity and stream function, which simplifies the numerical implementation. The biggest strength of this modelling is its adaptability as we can adapt it to time-dependent flows, inertial flows, and even expand the stream function formulation to a 3D system.

To prove this model we integrate red blood cell dynamics immersed in a Poiseuille flow and reproduce previously reported morphologies (slippers and parachutes). However after that we explore the morphology in different confinements.

For cells in a very wide channel, we discover a new meta-stable shape referred to as anti-parachute. This sort of meta-stable morphology may contribute to the dynamical response of the blood. We also study red blood cells in a Couette flow, where we observe cells experiencing a displacement perpendicular to the flow direction that can be modulated with the viscosity contrast.

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[1] Gallen, A. F., Castro, M., & Hernandez-Machado, A. (2021). Red blood cells in low Reynolds number flow: A vorticity-based characterization of shapes in two dimensions. Soft Matter, 17(42), 9587-9594.