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NUMERICAL MODELLING OF THE DYNAMICS OF ISOLATED RED BLOOD CELLS FLOWING IN A CYTOMETER

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Research in numerical simulations of red blood cells (RBCs) under flow has been a very active field for the last decade. Numerous studies have focused on *in vivo* micro-circulation, but additional questions are raised in non-physiological flows. In biomedical devices, for instance, flows of RBCs interact with complex manufactured geometries. Moreover, high Reynolds number flows can be encountered, where inertial effects are non negligible even at the cellular scale. This is notably the case in industrial cytometers. The goal of this study is to investigate the dynamics of RBCs within a Horiba cytometer.

The YALES2BIO flow solver (*http://www.math.univ-montp2.fr/~yales2bio/*) is used to perform numerical simulations of RBCs flowing in a cytometer. The numerical method is based on a front-tracking immersed boundary method (FT-IBM). Internal and external fluids are represented by a unique incompressible fluid of variable properties, where the membrane is represented by a Lagrangian mesh while the flow equation are resolved over an Eulerian fixed mesh. The membrane is supposed to be an infinitely thin hyperelastic surface, accounting for shear, area dilatation and bending resistance. The displacement of the membrane vertices is computed by solving the fluid-structure interaction problem. The membrane presence is taken into account by adding a source term (a volumetric force) to the Navier-Stokes equations, solved using an unstructured finite-volume flow solver. Regularization of the membrane force and interpolation of the fluid velocity is done by extending the FT-IBM to unstructured grids [1]. YALES2BIO has been validated in numerous 2D and 3D configurations, including linear shear [2], optical tweezers [3], pressurization or spontaneous curvature test cases.

Based on the Coulter effect, the Horiba cytometer involves the passage of isolated RBCs in a small orifice of diameter 50 μm. Within a transit time of approximately 10 μs, RBCs

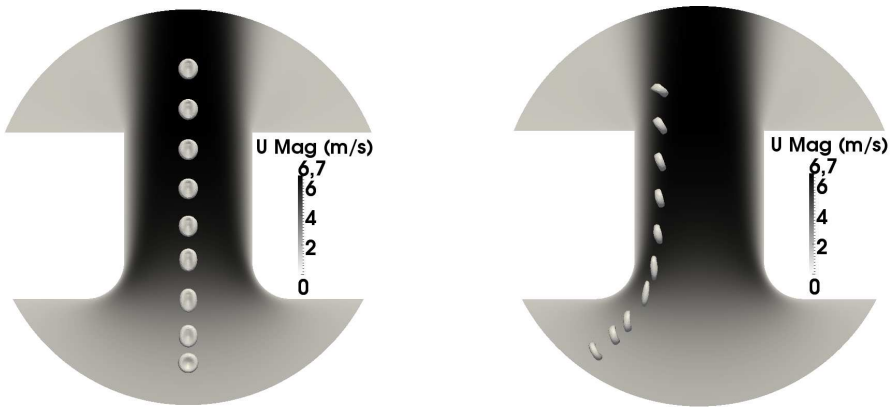

Figure 1: Successive positions of a RBC flowing from bottom to top, through an actual cytometer micro-orifice. Initial position of the cell is either centred *(left)* or shifted *(right)*.

are counted and their volume is obtained by means of an electrical measurement [4].
An important feature of the flow inside this device is the high values for the Reynolds number reached inside the micro-orifice (approx. 300). The Reynolds number associated to the particle is found to be higher than unity, thus much larger than in classical microfluidic applications or micro circulation. Figure 1 shows examples of how the initial position and orientation of the RBC modifies its deformation and trajectory [5]. Flow simulations are post-processed in YALES2BIO to reproduce the electrical measurement.
A parametric study will be presented, with two main objectives : 1) To determine the complexity of the RBC model necessary to obtain accurate predictions of the RBC dynamics. We will notably investigate the effect of bending stiffness, membrane viscosity or density differences, often neglected in the literature; 2) To get an insight into the relation between the RBC dynamics and trajectory, and the electrical measurement.

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