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Simulation of interacting drops with multilevel adaptive local refinement

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SEVENTH FRAMEWORK PROGRAMME

Introduction

Simulation of interacting drops can be challenging since the distance between interfaces of the drops can get up to three to four decades smaller than the original radius of the drops. To achieve this, a locally refined mesh which can adapt with deformation and movement of the drops is required.

Objective

Predict accurately the flow between interfaces of the drops while they approach each other under shear flow.

Mathematical model

As depicted in Fig. 1, an initially circular liquid drop is suspended in a fluid. In general each of the domains could consist of a different type of fluid but for now only the case of a Newtonian fluid is studied. For all phases it is assumed that inertia can be neglected and that the volume is constant. Therefore, the mass and momentum balance reduce to

$$\nabla \cdot \boldsymbol{u} = 0$$
$$\nabla \cdot \boldsymbol{\sigma} = 0$$

and for the case of Newtonian fluid $\boldsymbol{\sigma}$ can be expressed as

$$\boldsymbol{\sigma} = -p\boldsymbol{I} + 2\eta\boldsymbol{D}$$

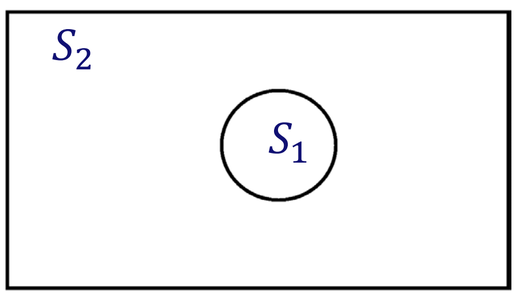

Fig 1. Geometry of a circular drop suspended in a fluid.

where the viscosity η can be different for each domain.

For the boundary condition on the drop-matrix interface there is a traction jump

$$(\boldsymbol{\sigma} \cdot \boldsymbol{n})_2 - (\boldsymbol{\sigma} \cdot \boldsymbol{n})_1 = \Gamma\kappa\boldsymbol{n}$$

and no slip on the interface, i.e. the velocity is continuous

$$\boldsymbol{u}_2 = \boldsymbol{u}_1$$

Numerical description

The fluid is discretized using the finite element method employing a mesh of quadratic triangles and for the time discretization second order backwards differencing is used. The interface mesh consist of quadratic lines while maintaining conforming geometry. Quadratic interpolation is used for the velocity and linear interpolation for the pressure.

Multilevel adaptive local refinement

The interface mesh is refined by splitting elements into two as shown in Fig. 2. The rest of the volume is refined by locally defining the element size in Gmsh. For each element level the parent and the child element is stored. In this way it is possible to move back and forth through element levels easily.

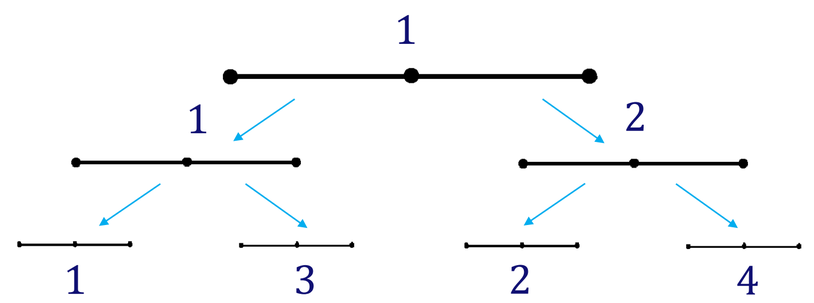

Fig 2. For each new level of refinement the element splits into two new while storing the number of the parent and the child element.

Results

Fig. 3B shows the effect of shear flow on the drops of Fig. 3A. In this example the maximum element level reached is 9 which means the final element size is approximately 500 times smaller than the starting size.

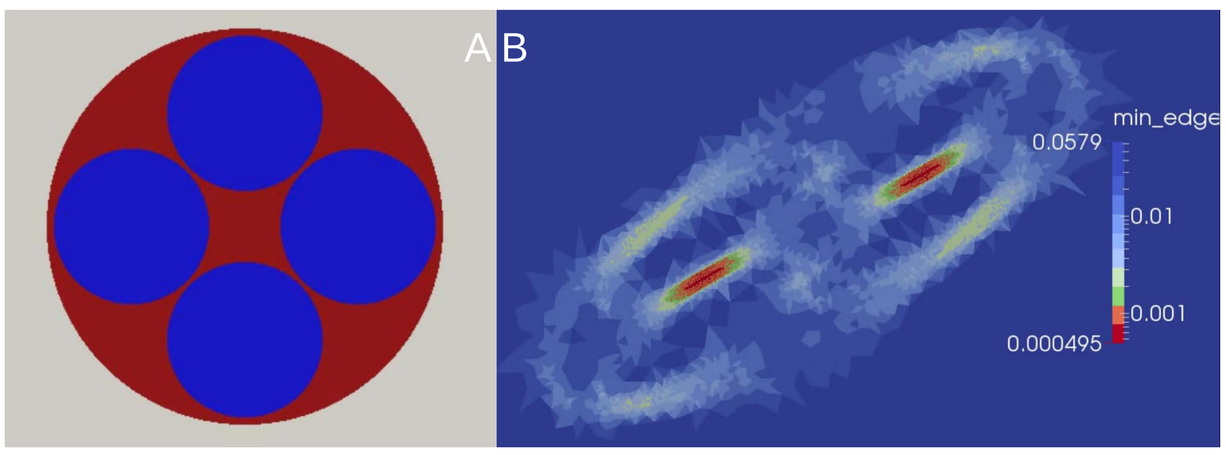

Fig 3. A) Initial configuration of circular drops, all of which consist of Newtonian fluid. **B)** Plot of the minimum edge size of each element in a $\log_2$ scale after applying shear flow.

Conclusions

Using an adaptive multilevel local refinement technique the mesh is refined where and when it is needed. It is possible to deal with a large range of scales. Multiple domains can be used with the finite element method to simulate fluids having different properties.