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# The Extended Finite Element Method for Fluid Solid Interaction

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## Introduction

Many daily processes depend on the intricate interaction of a fluid with a solid. Examples are the flight of birds and insects, hartvalves, flapping flags and on smaller length-scales, the motion of lung cilia, sperm and red blood cells, see Fig. 1. Recently the eXtended Finite Element Method (XFEM) has been successfully applied to fluid solid interaction (fsi) problems[1].

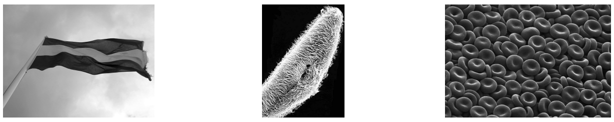

**Fig. 1** *Left: A flag flapping in the wind. Center: Paramecium, an organism covered with cilia. Right: Red blood cells.*

## Objective

Model the interaction between a solid and a fluid with the eXtended Finite Element Method.

## Numerical Model

In fixed mesh FSI the fluid mesh is intersected by the solid mesh. Since the fluid and solid stresses are different, a discontinuity exists within these elements. In the XFEM extra degrees of freedom are added to these elements, whilst elements fully underneath the solid are deprived of them. The equations of motion are applied only on the fluid part of the intersected elements, see Fig. 2 for the domain and the triangular subdomains used for integration.

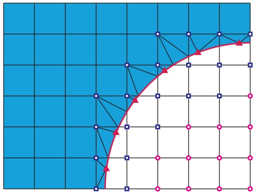

**Fig. 2** The fluid mesh intersected by the solid (line), with ▲ the nodes coupling the fluid and solid together, ◻ the enriched nodes and ○ the nodes which are underneath the solid.

## Model problem

The flow in a lid-driven cavity containing an immersed elastic cylinder is modelled, see Fig. 3. The fluid is assumed inertialess, incompressible and Newtonian, the solid inertialess, incompressible and Neo-Hookean.

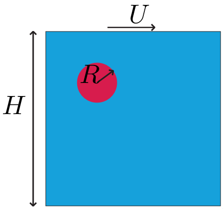

**Fig. 3** The problem domain, with height $H$, lid velocity $U$ and particle radius $R = 0.1H$.

## Results

The governing dimensionless group in the equations of motion is R $= GH/\eta U$, where $G$ is the modulus of the solid and $\eta$ the viscosity of the fluid. This number is the ratio of the elastic and viscous forces on the interface. Simulations are peformed for R $= 0.01$ and R $= 0.1$. Particle paths and the shape of the solid are shown in Fig. 4.

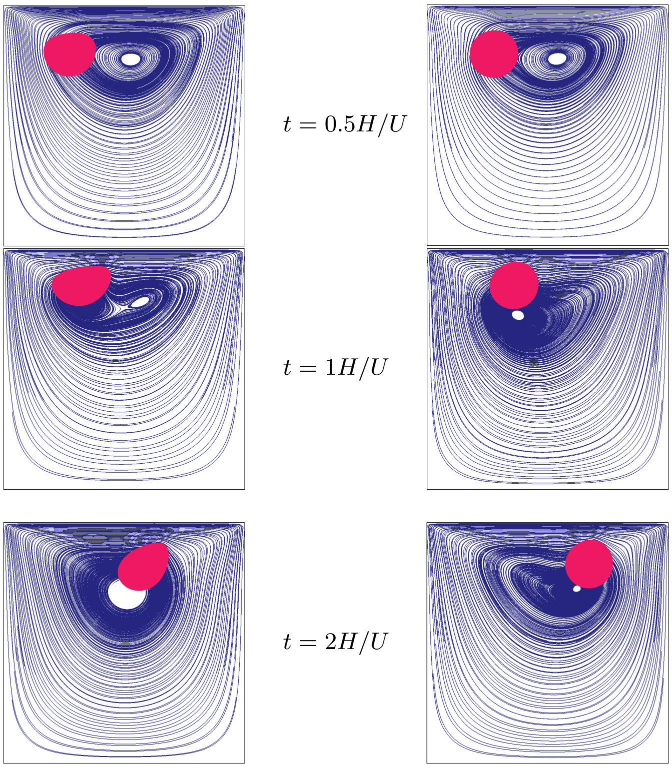

**Fig. 4** *Particle paths and the position of the solid for R $= 0.01$ (left) and R $= 0.1$ (right) at different times.*

The compliant particle (left) deforms much more than the stiff particle (right). This results in more complex flow patterns, although the general motion of the solid is similar.

## Conclusion

Fluid solid interaction has been modelled within a XFEM framework and the motion of particles with different properties in a driven cavity flow have been simulated. More compliant particles deform more and hence create more complex flow patterns.

### References

[1] GERSTENBERGER A. , WALL, W. A. : *An eXtended Finite Element Method/Lagrange multiplier based approach for fluid-structure interaction* (Comput. Methods Appl. Mech. Engrg. 2008)

### Acknowledgements

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