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Developing a new FSI method to compute transitional blood flow

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Introduction

The aim of my PhD-project is:

to compute the transitional blood flow through artificial heart valves and its fluid-structure interaction in order to investigate coagulation related problems.

When blood is pumped through the heart valves into the aorta, it has a relatively high speed, with Reynolds numbers between 1500 and 3000. This is called transitional flow, as it is a transition between laminar flow and turbulence.

Figure 1: Transitional blood flow through artificial heart valves [1]. Transitional flow contains small scale fluctuations, see Figure 1 and may result in local high deformation rates. This can activate platelets and eventually lead to blood coagulation. Therefore, it is important to develop a fluid-structure interaction (FSI) algorithm to compute accurately the:

• spatial and temporal scales of transitional flow
• fluid stress near the deforming solid
• stress history.

Monolithic fat boundary method

In TFEM [2] a fixed grid with spectral elements is implemented to compute transitional flow, as they have a higher accuracy than finite elements (Figure 2). The immersed elastic (Neo-Hookean) solid consists of finite elements, which are non-conform with the spectral elements.

Figure 2: The schematic representation of the FSI method proposed.

To obtain a correct stress description on the fluid-structure interface, a fat finite element fluid layer is added. Now a standard FSI method can be used and only the fluid-fluid boundary needs a special coupling, some characteristics are:

• The fluid-fluid interface is coupled by forcing a kinematic constraint, based on Baumann & Oden [3].

Flow around a cylinder

To test the coupling of the fluid-fluid interface, the flow around a cylinder benchmark [4] is used, see Figure 3 for the mesh.

Results

In Figure 4 the velocity and vorticity is shown for Re=100, the solution is smooth and there are no oscillations visible at the fluid-fluid interface. The obtained hydrodynamic forces on the cylinder and the frequency of the fluctuations are similar to the results of [4].

Conclusion

The fluid-fluid coupling algorithm proposed computes accurately the velocity, pressure and vorticity, without introducing errors. Now the proposed FSI-method needs to be tested for a FSI benchmark.

References