Fluid structure interaction

Andreas Strøm Slyngstad

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Chapter 1

Numerical Results

In this chapter the main calculations of the proposed theories and will be presented.

1.1 Verification

1.2 Validation

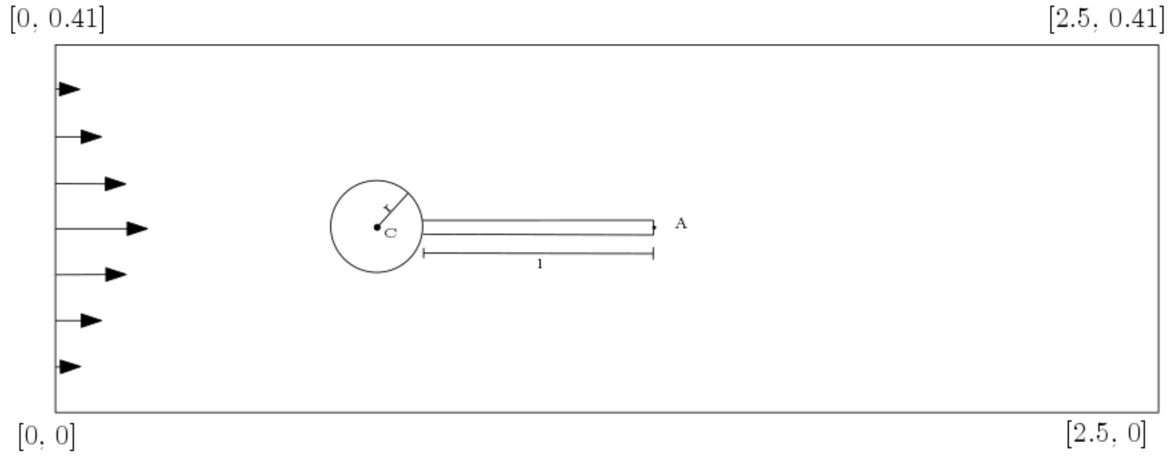
For verification purposes the numerical benchmark presented in [1] has been chosen for this thesis. This benchmark as been widely accepted throughout the fluid-structure interaction community as a rigidly validation benchmark. This is mainly due to its diversity of tests included, challenging all the main components of a FSI solver.
The benchmark is divided into three main testenvironments. In the first environment the purely fluid solver is tested for a range of different inflow parameters.
The second environment regards the purely structure implementation, regarding bending of the elastic flag. We will in this thesis consider the final environment, testing the total system in terms of a fluid-structure interaction problem. The others have been tested and proved to be an essential part of the development of the solver, but will for brevity not be reported.

The fluid-structure interaction validation benchmark is divided into three different problems with increasing difficulty, posing different challenges to the implementation. Each problem alters the fluid and solid parameters to provoke different behavior of the system.
Several quantites for comparion is presented in [1] for validation purposes. We will report

- The position of point A(t) as the strucutre undergoes deformation.
- Drag and lift forces exerted on of the whole interior geometry in contact with the fluid, consisting of the rigid circle and the elastic beam.

$$(F_D, F_L) = \int_{\Gamma} \sigma \cdot \mathbf{n} dS$$

Figure 1.1: Domain configuration



Where **n** is the unit normal vector, pointing into the fluid domain.

The amplitude and mean values for the time dependent properties are calculated from the last period of oscillations, together with the period.

Table 1.1: Benchmark environment

Solid parameters			
parameter	FSI1	FSI2	FSI3
$\rho^s[10^3\frac{kg}{m^3}]$	1	10	1
ν^s	0.4	0.4	0.4
$\mu^s[10^6\frac{kg}{ms^2}]$	0.5	0.5	2.0
Fluid parameters			
$\rho^f[10^3\frac{kg}{m^3}]$	1	1	1
$\nu^f[10^{-3}\frac{m^2}{s}]$	1	1	1
U	0.2	1	2
parameter	FSI1	FSI2	FSI3
Re	20	100	200

1.2.1 FSI1

The first environment yields a steady state solution for the system. It is meant as a basic implementation test as it applies small deformations to the system. Therefore is provides a test for the solving procedure, but doesn't excess large constrain of choice of mesh extrapolation operator.

1.2.2 FSI2

The second environment results in a periodic solution. It proved to be one of the most demanding tests due to its large deformation, leading to the risk of entangled mesh cells. As such this raised the need for a high quality extrapolation of the solid deformation.

1.2.3 FSI3

The final environment does not induce deformation to the extent of the FSI2 benchmark. However a critical phase in the transition to the periodic solution was discovered, where the pressure oscillation induces a large deformation to the system.

Table 1.2: FSI 3 - Laplace

$\Delta t = 0.01 \theta = 0.51$					
nel	ndof	ux of A [x 10^3]	uy of A [x 10^3]	Drag	Lift
1	1	-1.79 +/- 1.80	0.7740	14.17280	0.7614
1	1	-2.48 +/- 2.48	0.7740	14.17280	0.7614
1	1	-2.47 +/- 2.45	0.7740	14.17280	0.7614
$\Delta t = 0.001 \theta = 0.501$					
nel	ndof	ux of A [x 10^3]	uy of A [x 10^3]	Drag	Lift
1	1	–2.17+/- 2.08	0.7740	14.17280	0.7614
1	1	-3.04 +/- 2.88	0.7740	14.17280	0.7614
1	1	-3.03+/- 2.85	0.7740	14.17280	0.7614
$\Delta t = 0.001 \theta = 0.5$					
nel	ndof	ux of A [x 10^3]	uy of A [x 10^3]	Drag	Lift

Table 1.3: FSI 3 - Biharmonic BC1

$\Delta t = 0.01 \theta = 0.51$					
nel	ndof	ux of A [x 10^3]	uy of A [x 10^3]	Drag	Lift
1	1	-1.77 +/- 1.79	0.7740	14.17280	0.7614
1	1	-2.43,+/ 2.44	0.7740	14.17280	0.7614
$\Delta t = 0.001 \theta = 0.501$					
nel	ndof	ux of A [x 10^3]	uy of A [x 10^3]	Drag	Lift
1	1	-3.39+/- 3.38	0.7740	14.17280	0.7614
$\Delta t = 0.001 \theta = 0.5$					
nel	ndof	ux of A [x 10^3]	uy of A [x 10^3]	Drag	Lift
1	1	–2.18 +/- 2.10	0.7740	14.17280	0.7614

Table 1.4: FSI 3 - Biharmonic BC2

$\Delta t = 0.01 \theta = 0.51$					
nel	ndof	ux of A [x 10^3]	uy of A [x 10^3]	Drag	Lift
1	1	-1.74 +/- 1.76	0.7740	14.17280	0.7614
1	1	-2.39 +/- 2.40	0.7740	14.17280	0.7614
$\Delta t = 0.001 \theta = 0.501$					
nel	ndof	ux of A [x 10^3]	uy of A [x 10^3]	Drag	Lift
1	1	-3.39 +/- 3.38	0.7740	14.17280	0.7614
1	1	-4.70 +/- 4.71	0.7740	14.17280	0.7614
$\Delta t = 0.001 \theta = 0.5$					
nel	ndof	ux of A [x 10^3]	uy of A [x 10^3]	Drag	Lift
1	1	-2.17+/-2.09	0.7740	14.17280	0.7614

1.3 Mesh movement

The final enviroment

Bibliography

[1] Jaroslav Hron and Stefan Turek. Proposal for numerical benchmarking of fluid-structure interaction between an elastic object and laminar incompressible flow. *Fluid-Structure Interaction*, 53:371–385, 2006.