Field:
Mathematics/Informatics/Engineering

Session Topic:
Fluid-Structure-Interaction in Math and Engineering

Introductory Speaker:
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Fluid-Structure-Interaction
From classical divide to challenging reunion

Historically the sister disciplines of structural and fluid dynamics have split very early in the development of their respective mathematical modelling. The reasons for this divide are many - mathematical/physical as well as more personal. The most compelling reason is that the underlying equations, which are - in a special formation - mathematically identical, show linear or non-linear behaviour, depending on which field they describe.

The methods to solve the respective problems have therefore also developed in a divergent fashion.

Recently the trend to treat problems where flow forces cause structural deformation or structural deformation causes flow have been treated separately without taking into account the other discipline has been broken. More and more researchers and engineers alike are interested in multi-physics problems, i.e. problems that involve more than just one classical discipline.

Fluid-Structure-Interaction is only one combination. Others include Flow-Thermodynamics, Thermo-Structure, Flow-Structure-Acoustics, etc.

We will look at the problem of Fluid-Structure-Interaction exemplary to show the challenges that are arise.

1. Continuum Mechanics

While both Fluid and Structural Mechanics are parts of Continuum Mechanics and the derivation of the equations is similar the properties of solid matter vs. those of a fluid demand different approaches. While in structural mechanics the Lagrangian description of movement is useful in fluid mechanics the Eulerian approach has proven to be more suited. This gives rise to distinct differences and even a hybrid formulation (Arbitrary Lagrangian Eulerian, ALE) only gives formal coincidence – the characteristics remain different.

2. Interaction Schemes

The mathematical schemes to solve the two fields and their interaction can be split into monolithic and partitioned schemes – the partitioned into hard and soft coupling schemes. Each of these has its specific characteristics. Which scheme is applicable depends not on the scheme alone, but on the problem at hand.

3. Applications of Fluid Structure Interaction

The possible field of applications is wide indeed. From the deformation of aerodynamic structures, flutter in turbines, oscillation in buildings and bridges to the deformation of biological structures under internal and external pressure and the movement of solid particles and droplets in clouds.

The properties of the solid and fluid materials as well as the nature of the movement that occurs demand for a specific strategy as to which of the possible schemes and algorithm will be applied.

We will see examples for Fluid-Structure-Interaction-Models that range from very simple to extremely complex, with modelling and computational efforts that differ by many orders of magnitude.

4. Conclusion and Outlook

While some simple cases involve little more than an additional differential equation others challenge the state of the art of mathematical modelling and numerics to the brink. A (very subjective) outline of the challenges ahead will be given.

Introductory Literature:

Bungartz, H.-J. and Schäfer, M.; Fluid-Structure Interaction (Modelling, Simulation, Optimization); Springer-Verlag; 2006

Paidussis, M.P., Price, S.J. and de Langre, E.; Fluid-Structure Interactions: Cross-Flow-Induced Instabilities, Cambr. Univ. Press, 2010