11th World Congress on Computational Mechanics (WCCM XI)
5th European Conference on Computational Mechanics (ECCM V)
6th European Conference on Computational Fluid Dynamics (ECFD VI)
July 20–25, 2014, Barcelona, Spain

EFFICIENT FLUID-STRUCTURE INTERACTION BASED ON MODALLY REDUCED MULTIBODY SYSTEMS AND SMOOTHED PARTICLE HYDRODYNAMICS

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Key words: *flexible multibody dynamics, fluid-structure interaction, generalized component mode synthesis, smoothed particle hydrodynamics, simulator coupling*

Fluid-structure interaction (FSI) is a well-known challenging subject in the field of multiphysics problems, with applications in many different areas in science and industry.

A lot of effort has been expended on the development of efficient approaches to cope with the ever-increasing complexity of state-of-the-art applications (see, for example, [1]). The current challenges in computational FSI are diverse, and especially include problems involving large rigid-body motion (with small superimposed flexible deformation) or even large deformation of the mechanical components in contact with the fluid.

As sketched in Fig. 1, our approach is based on the coupling of flexible multibody systems with particle-based fluid dynamics (c.f. [3, 4]), by means of an explicit co-simulation between two open-source simulators (see `www.hotint.org` and `www.liggghts.com`). The framework of flexible multibody dynamics allows for versatile modeling and simulation of complex mechanical or mechatronical systems, including rigid and deformable bodies, loads, constraints, contact, and control. As to the fluid, the meshfree particle method SPH (smoothed particle hydrodynamics) is well suited for handling fluid dynamics in complex moving or changing domains.

Real-world problems in multibody dynamics often require a model-order reduction in order to make a transient analysis feasible in the first place. To this end, the floating frame of reference formulation (FFRF) can be combined with component mode synthesis (CMS) to describe small flexible displacements superimposed to a large rigid body motion. The generalized component mode synthesis (GCMS) is an alternative approach abandoning a relative description of the flexible deformation which has recently been proposed by Pechstein et al. [2]. Using absolute coordinates only, typical drawbacks of the FFRF-based

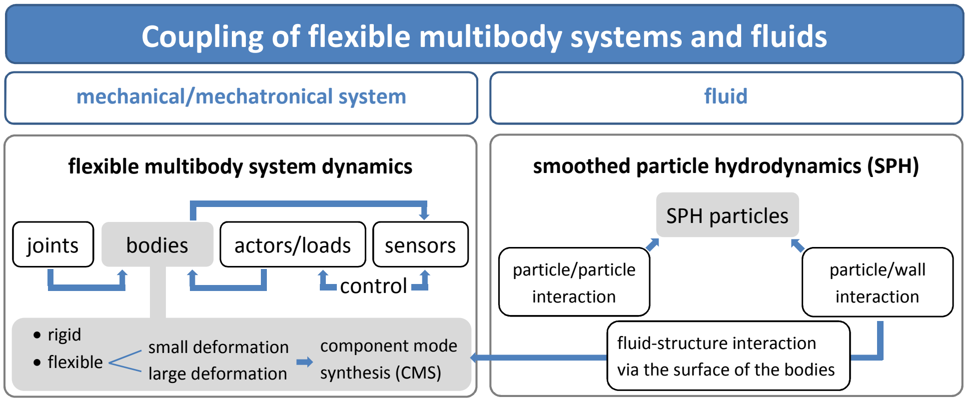

Figure 1: Coupling of flexible multibody dynamics and particle-based fluid dynamics.

CMS such as a non-constant mass matrix, gyroscopic terms and complicated constraint conditions are avoided elegantly.

As particular feature of our co-simulation approach, benefitting from the linear relationship between the generalized coordinates and the total displacement of the described structure in GCMS, the transformation between the reduced and the full (actual) set of coordinates, as well as the computation of the fluid-structure contact, are performed fully MPI-parallel within the particle simulation environment. Therefore, also large mechanical problems with fluid interaction can be treated efficiently by serial computation of the mechanical system in terms of the reduced set of generalized coordinates and forces, while the possible bottleneck of the coupling with a (massively) parallelized particle-based fluid simulation is eliminated.

This work includes details on the coupling scheme and the fluid-structure contact formalism, especially with respect to GCMS, and provides numerical examples and validation.

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