Coupling Fluid-Structure Interaction with an Ultrasonic Wave Propagation

Bhuiyan S. M. Ebna Hai[†,*] **and Markus Bause**[†]

[†] Helmut Schmidt University, Holstenhofweg 85, 22043 Hamburg, Germany.
[*] e-mail: ebnahaib@hsu-hh.de

ABSTRACT

In this contribution, a concept of coupling fluid-structure interaction (FSI) with an ultrasonic wave propagation is proposed, which is referred to as extended Fluid-Structure Interaction (eXFSI) problem. The eXFSI is a one-directional coupling of typical FSI problem with an ultrasonic wave propagation in fluid-solid and their interaction (WpFSI). The WpFSI is a strongly coupled problem of acoustic and elastic wave equations and automatically adopts the boundary and initial condition from previous time step. To the best of our knowledge, such a model is new in the literature. The FSI is modelled in terms of the arbitrary Lagrangian Eulerian (ALE) technique and couples the isothermal, incompressible Navier-Stokes equations with nonlinear elastodynamics using the Saint-Venant Kirchhoff solid model. The WpFSI problems are solved on the moving mesh which is automatically adopted from the FSI problem at each time step. The ALE approach provides a simple, but powerful procedure to couple solid deformations with fluid flows by a monolithic solution algorithm. In such a setting, the fluid equations are transformed to a fixed reference configuration via the ALE mapping. However, combining fluid dynamics with structural analysis traditionally poses a formidable challenge for even the most advanced numerical techniques due to the disconnected, domain-specific nature of analysis tools. The principal aim of this research is the exploration and development of concepts for the efficient numerical solution of the eXFSI problem. The finite element method is used for the spatial discretization. Temporal discretization is based on finite differences and is formulated as a one step-θ scheme, from which we can consider shifted Crank-Nicolson and the fractional-step-θ schemes. The nonlinear problem is solved by a Newton-like method. Our application of the eXFSI and WpFSI models is the design of on-live and off-live Structural Health Monitoring (SHM) systems for composite material and lightweight structure, respectively. Further applications of the models can be found in biomechanics and biomedicine, e.g. hemodynamics, vibro-mechanics, poroelasticity as well as subsurface and porous media flow. The implementation is accomplished via the software library package DOpElib.
Keywords: *Multiphysics, fluid-structure interaction, wave propagation, interaction between waves fluid flow and structures, Galerkin finite element method, finite elements based SHM, guided waves.*

REFERENCES

[1] Ebna Hai, B.S.M., Bause, M. and Kuberry, P. *Finite Element Approximation of the eXtended Fluid-Structure Interaction (eXFSI) Problem.* In proceedings of: the ASME 2016 Fluids Engineering Division Summer Meeting, Washington, D.C., USA, July 10–14, 2016.

[2] Ebna Hai, B.S.M. and Bause, M. *Adaptive Multigrid Methods for eXtended Fluid-Structure Interaction (eXFSI) Problem: Part I - Mathematical Modelling.* In proceedings of: the ASME 2015 International Mechanical Engineering Congress & Exposition, Vol. **7B**: Fluids Engineering Systems and Technologies, Houston, Texas, USA, Nov 13–19, 2015. ISBN: 978-0-7918-5747-2. doi:10.1115/IMECE2015-53265.

[3] Ebna Hai, B.S.M. and Bause, M. *Finite Element Approximation of Wave Propagation in Composite Material With Asymptotic Homogenization.* In proceedings of: the ASME Turbo Expo 2014: Turbine Technical Conference and Exposition, Vol. **7A**: Structures and Dynamics, Dsseldorf, Germany, June 16–20, 2014. ISBN: 978-0-7918-4576-9. doi:10.1115/GT2014-26314.