A temporal consistent monolithic approach to fluid-structure interaction enabling single field predictors

Matthias Mayr\textsuperscript{1}, Thomas Klöppel\textsuperscript{2}, Wolfgang A. Wall\textsuperscript{2} and Michael W. Gee\textsuperscript{1}
\textsuperscript{1}Mechanics & High Performance Computing Group, Technische Universität München, Germany - \textsuperscript{2}Institute for Computational Mechanics, Technische Universität München, Germany - www.mhpc.mw.tum.de

Introduction

Motivation and goals
- Possibility to choose time integration scheme in structure and fluid field differently and tailored to the needs of the respective field
- Interpolation of interface traction in presence of different temporal discretizations in structure and fluid field in order to avoid possible stability problems \cite{1}
- Enable field specific predictors in order to reduce computational costs

Problem Definition

Domain of interest
- Structural domain $Ω^S$ (governed by elastodynamics)
- Fluid-ALE domain $Ω^F$ (governed by Navier-Stokes equations)

Coupling conditions at fluid-structure interface
- Weak enforcement of kinematic coupling condition by Lagrange multiplier field $\lambda = H^F_{FS} - H^S_{FS}$
- Identify Lagrange multiplier field as interface traction $\lambda$

Discretization

Spatial discretization of structure and fluid field
- Mixed/hybrid finite elements for fluid field
- Stabilized finite elements for fluid field

Spatial discretization of Lagrange multiplier field
- Dual Mortar method for Lagrange multiplier field \cite{2}

Temporal discretization
- Temporal convergence study with different time integrators in structure and fluid field (Fig. 4)
- Overall order of accuracy depends on single field accuracy \cite{2} - second order accuracy only if all time integrators are second order accurate

Monolithic System of Equations

Linear System of Equations
- We exemplarily choose the structure field as master field $→$ structure-governed interface motion $→$ Mortar coupling operators: $\mathbf{F}_{FS} = \mathbf{M}_{FS} \mathbf{c}_{FS} + \mathbf{D}_{FS} \mathbf{d}_{FS}$

Condensation of Lagrange multipliers
- Use balance of linear momentum of slave interface DOFs for condensation
- Dual Mortar method leads to diagonal form of Mortar matrix $\mathbf{D}$ \text{-} Computationally cheap condensation of Lagrange multipliers and slave interface DOFs

Numerical Examples

Pseudo 1D FSI example with analytical solution
- Temporal convergence study with different time integrators in structure and fluid field (Fig. 4)
- Overall order of accuracy depends on single field accuracy \cite{2} - second order accuracy only if all time integrators are second order accurate

2D leaky driven cavity with flexible bottom
- Number of linear iterations reflects computational costs
- Reference solution without predictor (ConstDis)
- Reduction of number of linear iterations by 10% on average by employing simple predictors, \cite{1}

References

\cite{3} Mayr N, Klöppel T, Wall WA, Gee MW. A temporal consistent monolithic fluid-structure interaction approach enabling single field predictors, in preparation.