CO-SIMULATION METHOD OF FLUID STRUCTURE COUPLINGS IN HOPSAN AND LS-DYNA

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Introduction

- **Background**
  - Product development of hydraulic hammer and the need for virtual prototypes
  - Decoupled methods used today do not capture failure mechanisms experienced at tests
  - End-product performance highly affected by fluid-structure interaction

- **Ultimate vision**
  - Simulate the hydraulic hammer under real working conditions where the interaction to the excavator and the working material is included

- **New simulation method**
  - System level simulation model
  - Simplified method for fluid system simulation, FSI-methods are not feasible for system level simulations
  - Stress, fatigue, wear and noise requires 3D structure simulation model
  - Efficient method to simulate fluid-structure couplings
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Research Project

- To develop a new simulation tool that is able to capture the main fluid and structural mechanisms of a hydraulic hammer
- Co-simulation of fluid power and structural mechanics -models
- Simulate the running condition for the hydraulic hammer at the in-house test rig and ultimately in its real working environment

Partners
- Atlas Copco Construction Tools – Project owner, Industrial Ph.D.
- Solid Mechanics, Linköping University – Academic
- Fluid and Mechatronic Systems, Linköping University – Hopsan
- Dynamore Nordic – Software, ass. academic advisor
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New simulation method

- 1D system simulation model incl. fluid power system
- 3D structural mechanics simulation model
- Co-simulation interface
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New simulation method

- Implementation
  - Hopsan: 1D system simulation model
  - LS-DYNA: 3D structural mechanics simulation model
  - Development of co-simulation interface according to the FMI-standard
  - Co-simulation communication
    - FMU on the Hopsan side
    - UDF on the LS-DYNA side
    - TCP/IP
  - Native LS-DYNA Keyword format FMU-configuration file
  - Automatic FMU-generator
    - Python
  - Time step, timing and synchronization
    - Hopsan simulation master and administering the simulation
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Simulation Tools

- System level simulation of multi domain fluid power models, hydraulic/mechanic
- Hopsan
  - Hopsan is a 1D free multi-domain system simulation tool developed at the division of Fluid and mechatronic systems at Linköping university
  - Bi-directional delay lines or transmission line elements, Transmission Line Modelling (TLM)
  - Explicit time integration technique
  - Fluid, mechatronic, electric power, flight dynamics etc.
  - Co-simulation using FMI-standard
  - TLM element happens to be very efficient for co-simulation couplings
  - Efficient and accurate technique for simulation of pressure waves in the fluid system
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Simulation Tools

- Structural mechanic simulation tool, LS-DYNA
  - Well known software suit for 3D structural mechanic simulations
    - Stress
    - Fatigue
    - Noise
  - Explicit time integration technique
  - No co-simulation interface according to FMI-standard
  - Communication through the user defined function (UDF)
  - Efficient and accurate technique for simulation of stress waves in the structure
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Demonstration and validation

- Simple fluid power test model in Hopsan
- 3D FE-model of hydraulic cylinder in LS-DYNA
- Co-simulation interface for one hydraulic cylinder
- Typical mechanisms from a hydraulic percussion unit
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Demonstration and validation

- Case 1: Hydraulically controlled piston, comparison pure Hopsan vs. co-simulation
  - Rigid body piston model in Hopsan and LS-DYNA

- Case 2: Hydraulically controlled piston with external force, comparison pure Hopsan vs. co-simulation
  - Rigid body piston model in Hopsan and LS-DYNA

- Case 3: Co-simulation of elastic bodies with impact
  - No reference model in Hopsan
  - Elastic material in LS-DYNA
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Demonstration and validation

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Summary

- A co-simulation method for a fluid–structure coupling has been developed
- The implemented co-simulation interface is based on the FMI-standard and TLM
- Flexible engineering-friendly automatic generation of the interface FMU module
- Computationally inexpensive 1D-system fluid simulation
- Extended simulated time period facilitated due to an efficient fluid simulation
- Short duration dynamics in both the fluid and the structural system are resolved
- Full 3D results and time history data from the structural FE-simulation are available for, e.g. stress analysis, fatigue assessment or calculation of acoustical radiation
- The first published paper in this project
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