



Experimental validation of a co-simulation method for hydraulic percussion units

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A Co-Simulation Method for Hydraulic Percussion Units

Introduction

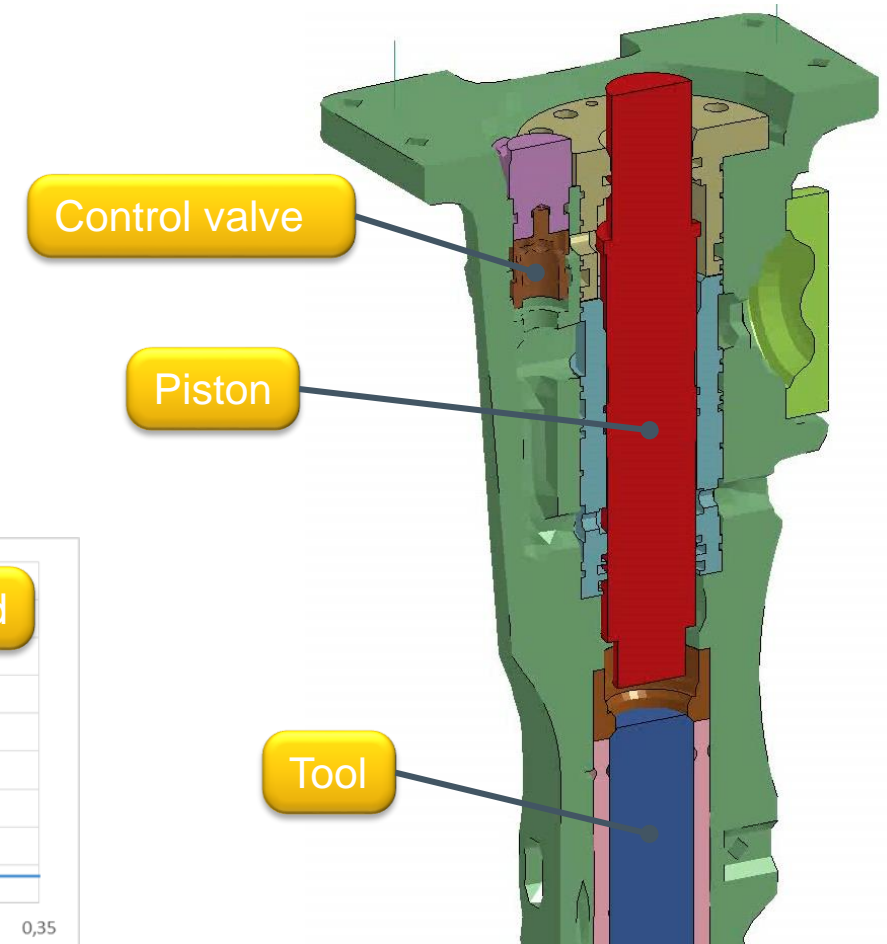
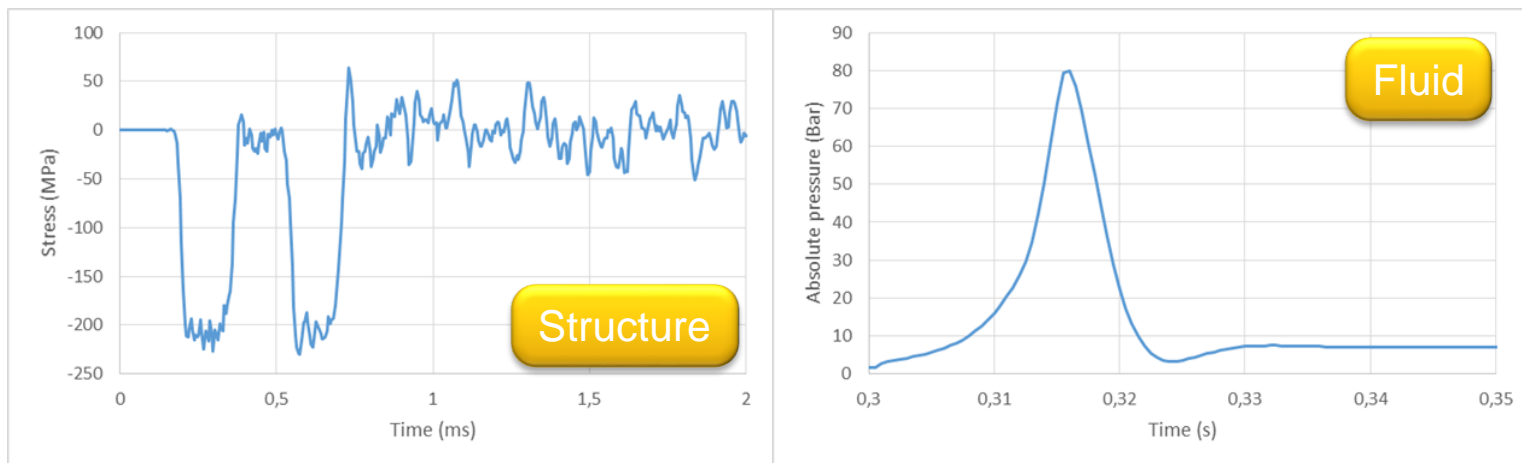
- Improved simulation methods are required
 - Demands from legislation on noise radiation
 - Robustness
 - Sustainability
 - Minimise the need for prototypes
 - Optimise product performance
- Complex coupled mechanisms
 - Fluid-structure interaction
 - Wave propagation in fluid and structure
- Aim
 - Simulation method to handle coupled mechanisms
 - Computationally inexpensive



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Hydraulic percussion units

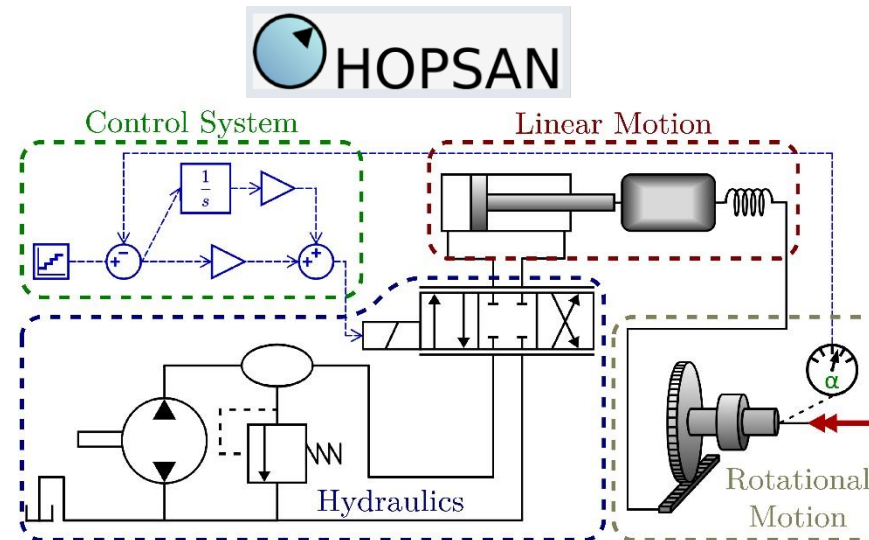
- Main mechanism of the hydraulic hammer
 - Reciprocating piston movement due to alternating pressure
- Critical mechanisms
 - Structural stress waves generated by impacts
 - Fluid pressure waves generated by opening and closing valves



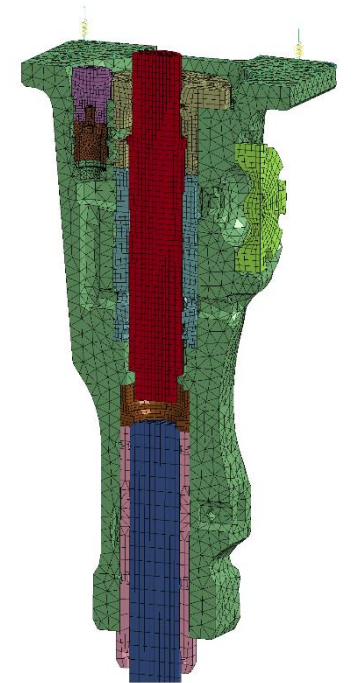
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Method

- The Hopsan simulation tool
 - 1D system simulation
 - Fluid power and mechatronic systems
 - Transmission line modelling, TLM
 - Co-simulation by FMI-standard
 - Widely used within Epiroc
 - Fast and represents pressure waves very well
- LS-DYNA finite element software
 - Highly non-linear and transient problems
 - Simulation of stress waves and complex contacts
 - Explicit time integration
 - No co-simulation functionality



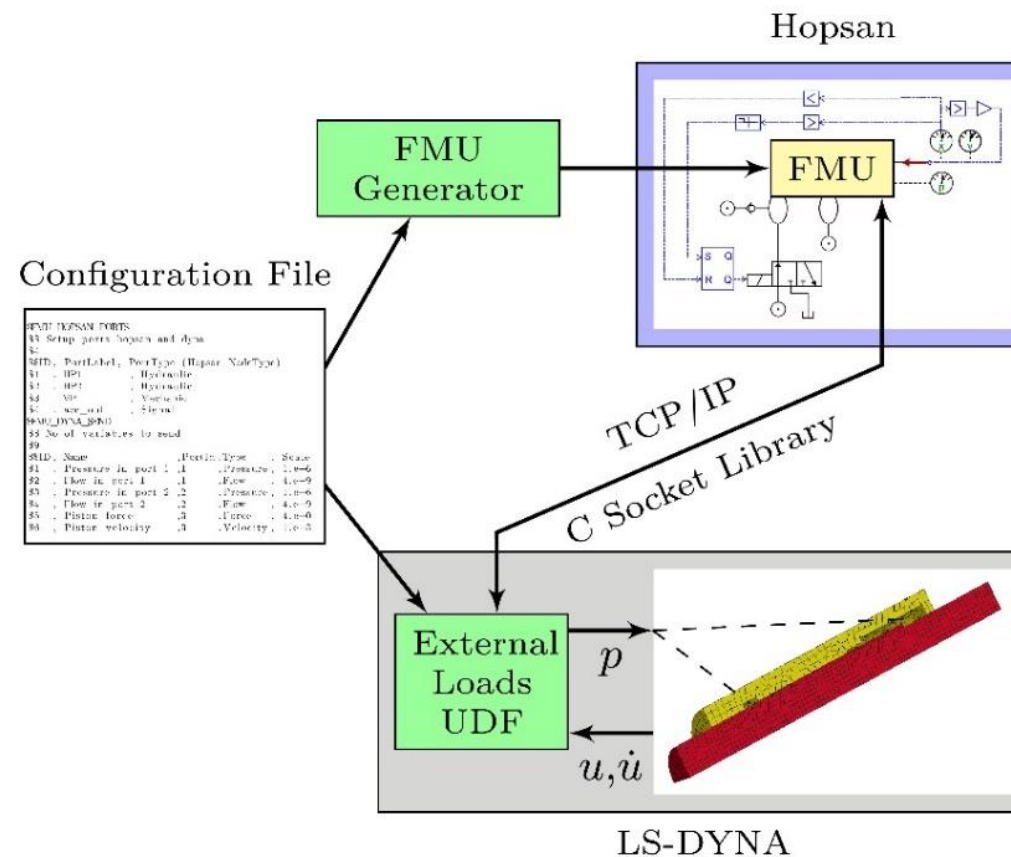
LS-DYNA



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Method

- Co-simulation interface
 - Based on FMI-standard for Hopsan
 - LS-DYNA User Load Interface
 - FMU-generator
 - Configuration file
- Co-simulation sequence
 - Hopsan simulation master
 - Trigger each time step
 - Fixed time step
 - Data exchange at the Send-Receive points
 - Effective synchronization by blocking socket receive calls



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Experiments

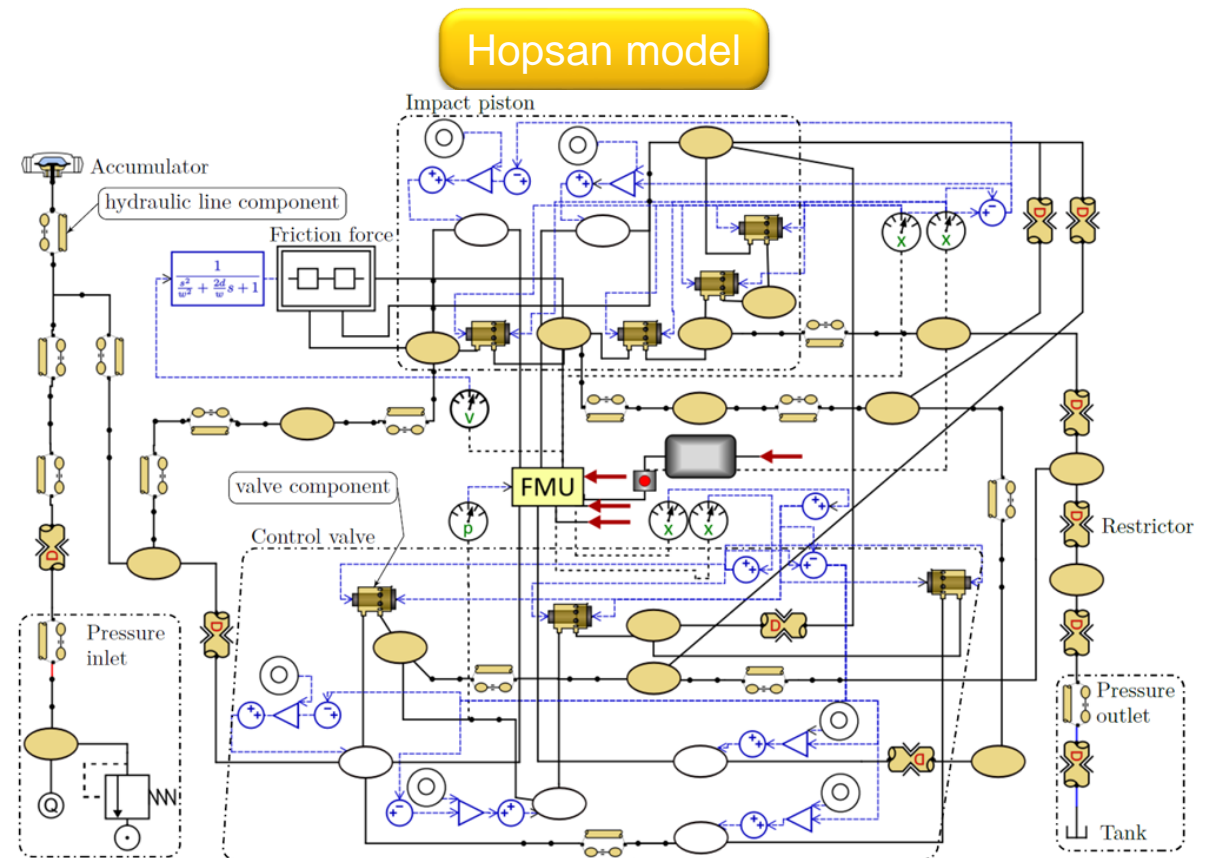
- Experimental validation of a simulation model representing a real hydraulic hammer
- Main goals
 - Evaluate functionality
 - Evaluate both global and local responses
 - Collect data for parameter study
- Four different running conditions
 - Pressure: 150 & 100 bar
 - Flow restrictor: Ø5.4 & Ø6.0 mm
- Registered signals
 - Position: Piston, Control valve, Hammer body
 - Acceleration: Hammer body
 - Stress (strain): Hammer body, Measurement tool
 - Pressure: Inlet, Outlet, Piston top side, Piston lower side, Control line



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Simulations

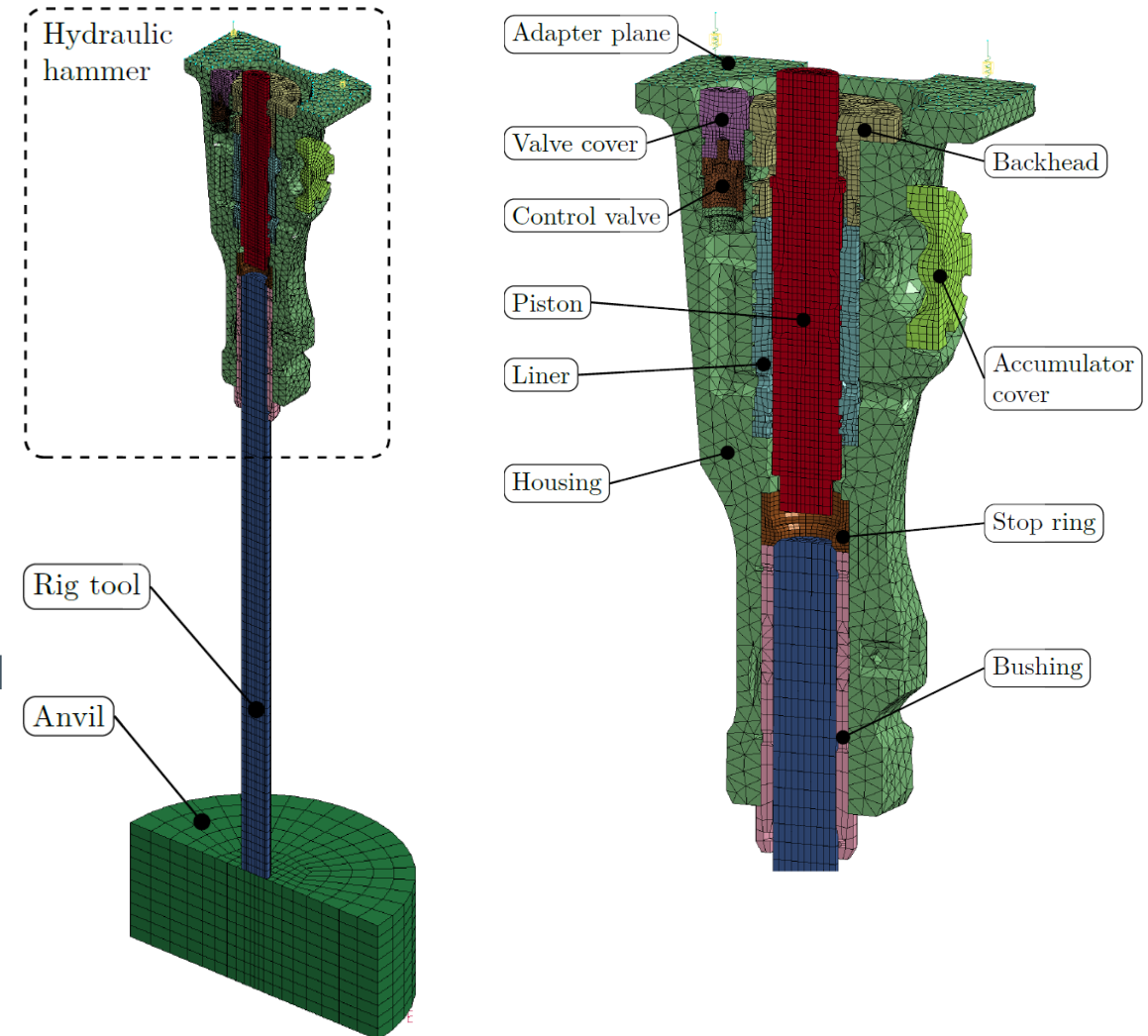
- System Simulation Model
 - Complex network of 114 sub-models
 - Co-simulation of
 - Piston
 - Control valve
 - Oil leakage simulated in Hopsan
 - Real measures of main components
 - Friction force from piston sealings simulated in Hopsan and transferred and applied in LS-DYNA
 - Corresponding running conditions as in measurement



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Simulations

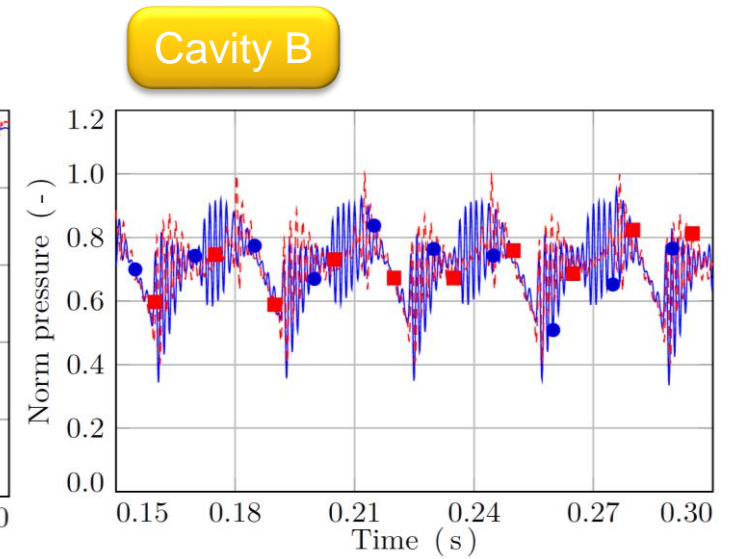
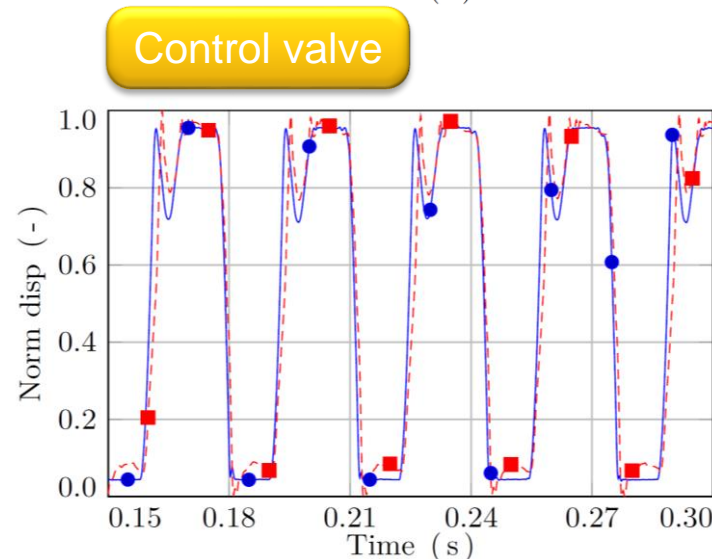
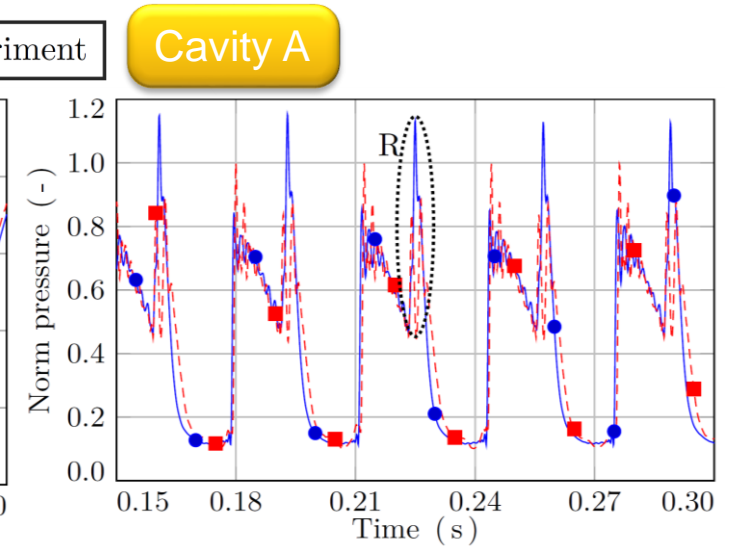
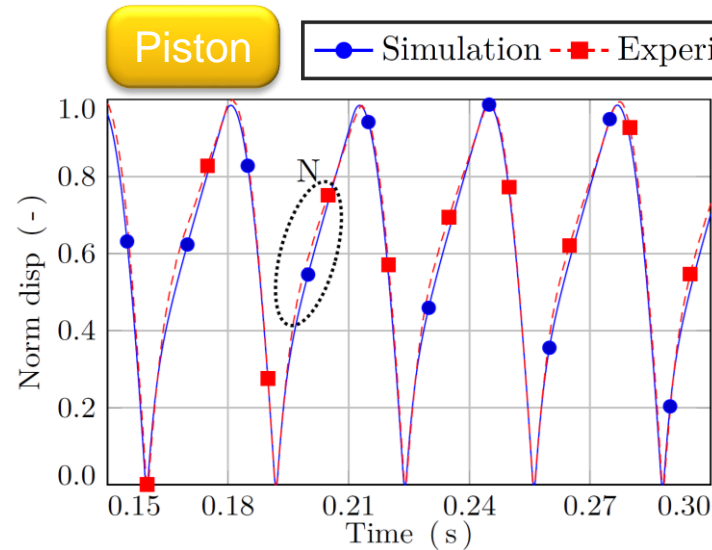
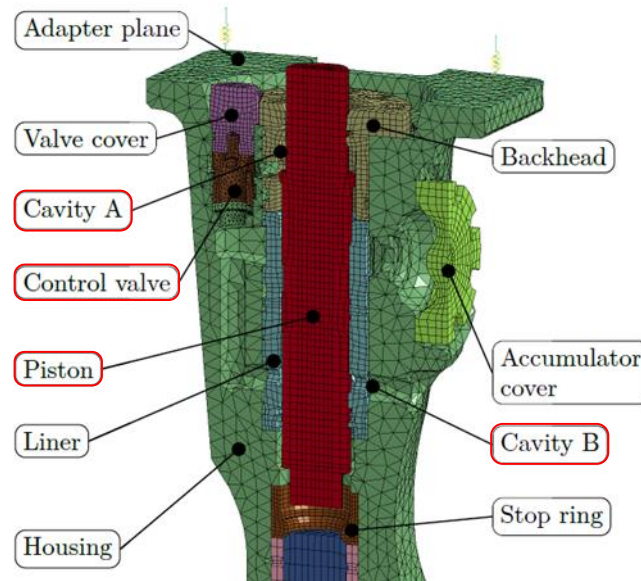
- Simulation model
 - FE-model, $\frac{1}{2}$ -model, ~111000 DOF
 - Elastic material of steel and ductile iron
 - Contact
 - Working material: Steel plate, anvil
 - Hammer and Anvil connected by spring- damper elements to ground
 - Structural damping
 - Pre-tension by Dynamic Relaxation of prescribed displacement of the spring elements
 - Clock time: 7.5h for 0.3s, SMP 8 core



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Results

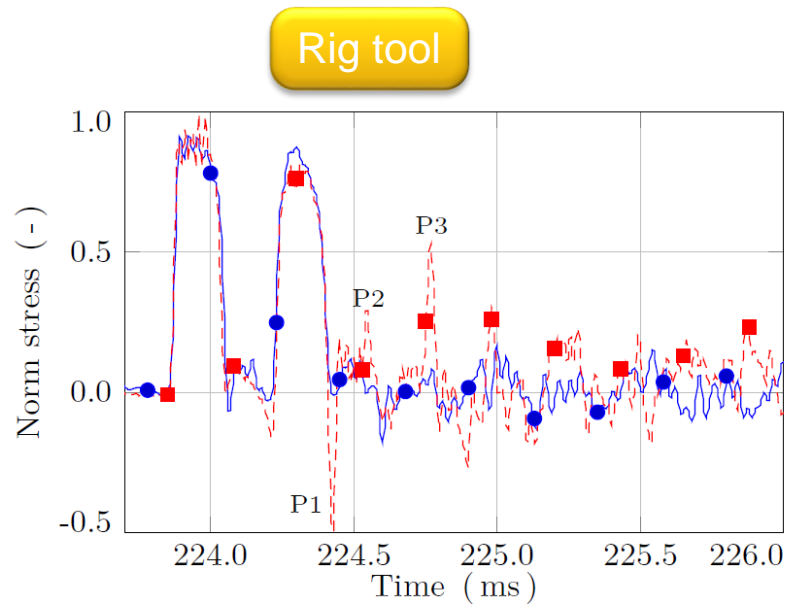
- Results
 - Standard running condition
 - Tuned impact frequency
 - Very good agreement



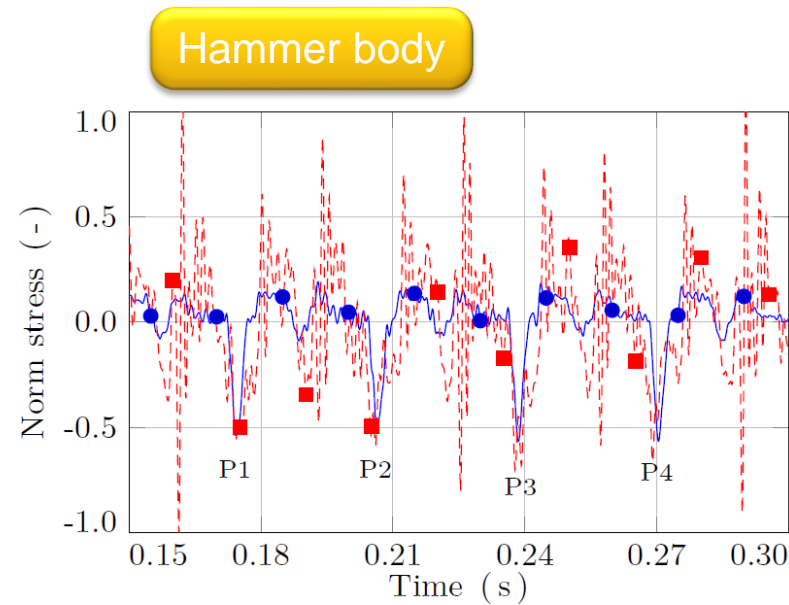
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Results

- Results
 - Time dependent stress → Fatigue assessment
 - Vibration on surfaces → Acoustic radiation

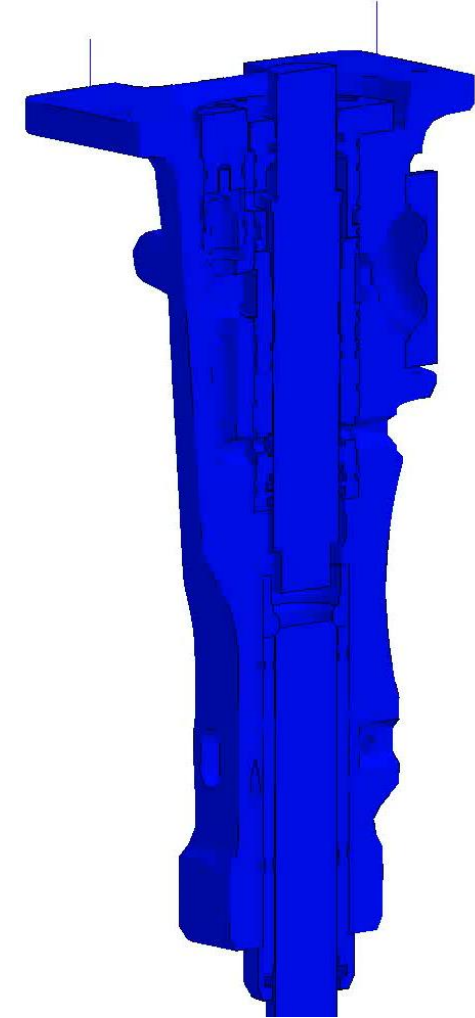


(a) Rig tool



(b) Housing

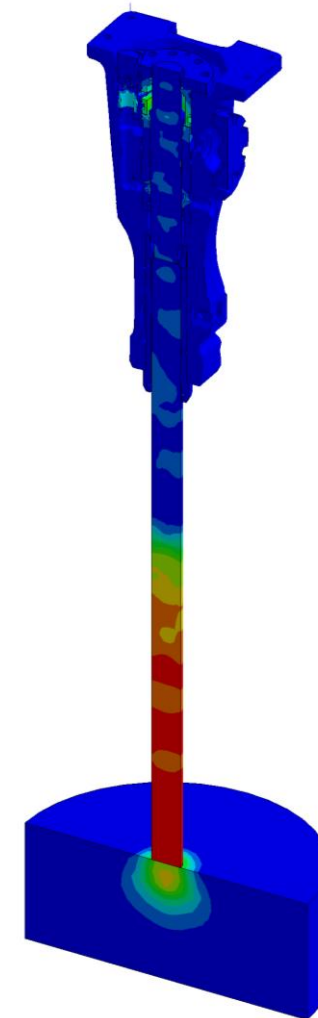
—●— Simulation —■— Experiment



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Conclusion

- Co-simulation approach handling both essential and critical fluid-structure couplings
- Computational inexpensive
- Full 3D results facilitating analyses of
 - Fatigue assessment
 - Noise radiation
 - Wear
- Validation confirms a correct representation of the real mechanisms
- Parameter study confirms a correct response from a parameter change
- Promising as an efficient tool for other applications where short duration mechanisms need to be studied



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