DAIMLERCHRYSLER

Co-Simulation-Interface for User-Force-Elements

Ideas, Properties and Results

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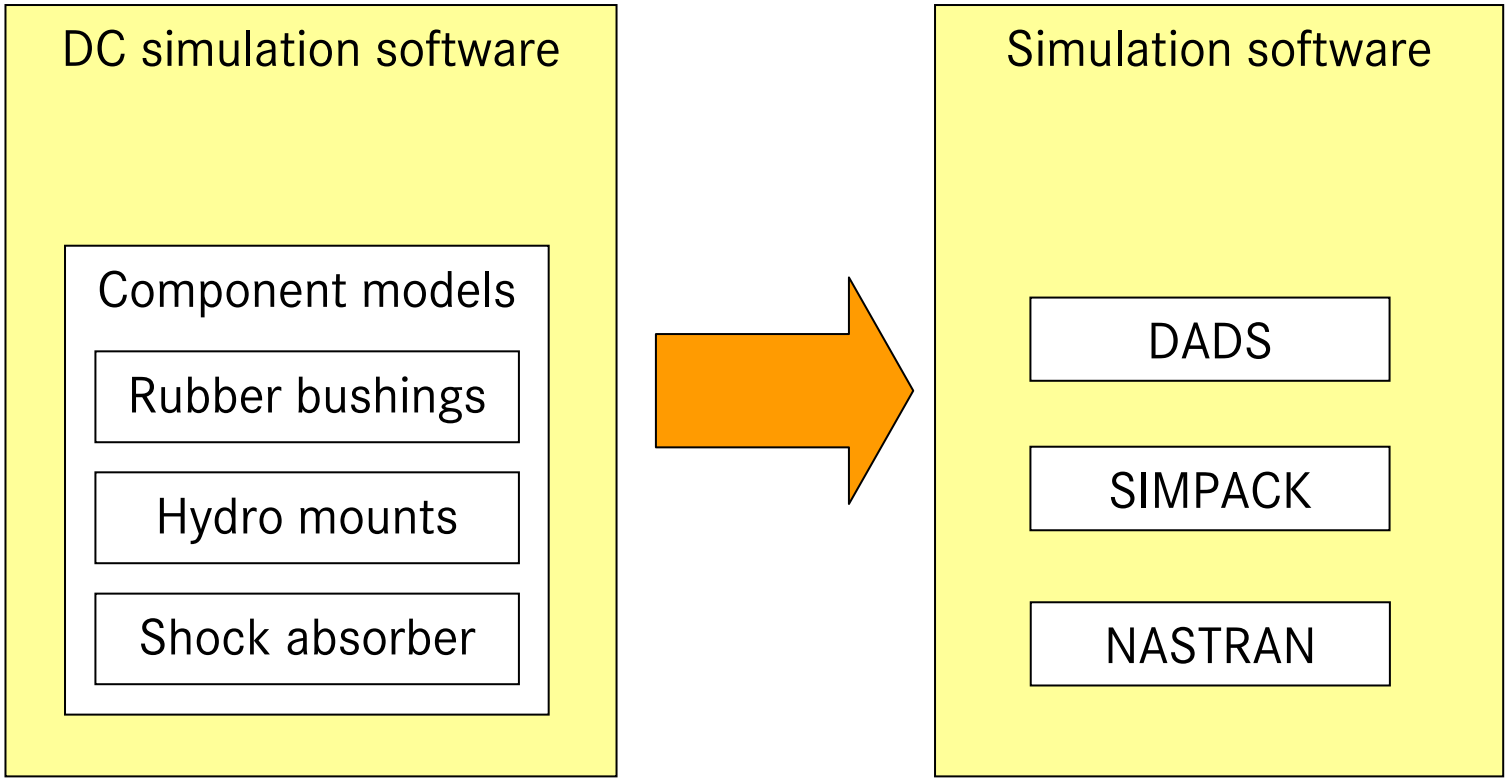
Research and Technology

Overview

- Objective
- Review of the existing approaches
- Idea of Extrapolated Interpolation
- Implementation
- Test example: check of interface influence
- Summary
- Literature references

Objective



Development of a general interface for the integration of self-integrating subsystems into other simulation environments

Situation and Requirements

- Situation
  - Include rubber bushing model based on fractional derivatives into the SIMPACK software
    - Calculation like a discrete filter → Model needs fixed step size
    - Only one call per time step is allowed
- Include with interface which
  - avoids unnecessary calculations and
  - does not disturb the step size control algorithm of the SIMPACK integrator.

Existing approaches

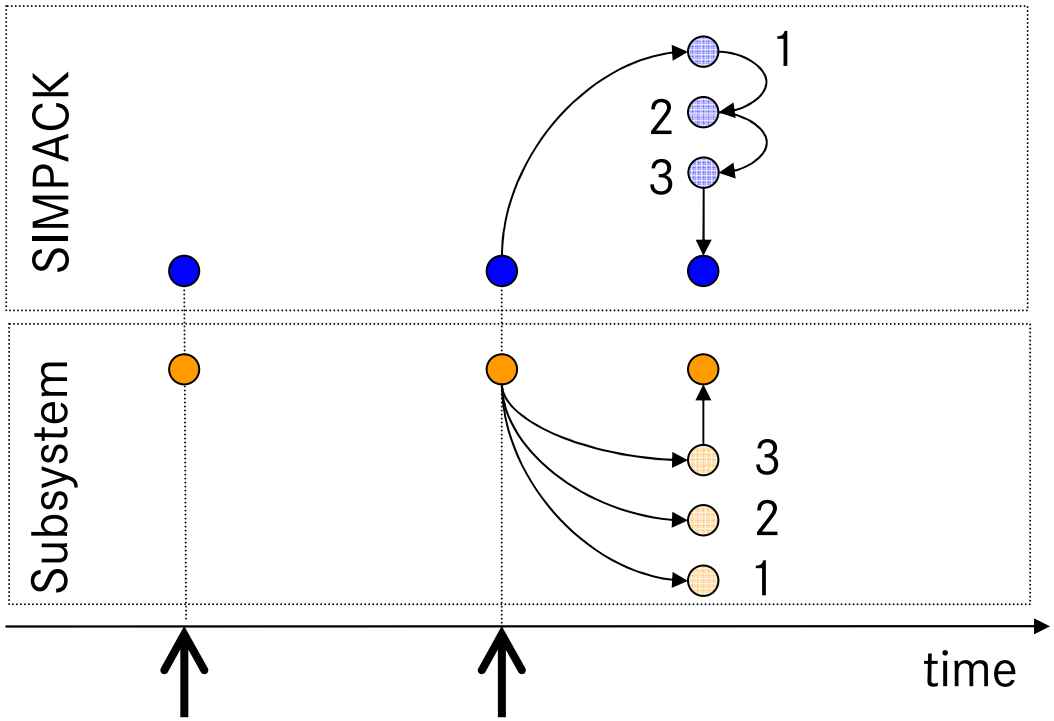
- Assumption: an implicit integration algorithm with variable step size is used in SIMPACK (e.g. SODART)
  - Step size control yields:
    - Iterations (repeated calls of the subsystem at the same point in time)
    - Step size change (enlargement / reduction)
- 2 existing approaches to include subsystems
  - Interface for subsystems which behave like continuous systems

    → Subsystem can be called for each point in time
  - Interface for subsystems which behave like discrete systems

    → Subsystem can be called only in fixed time periods

Existing approaches:
Include time continuous subsystems

Example: iteration

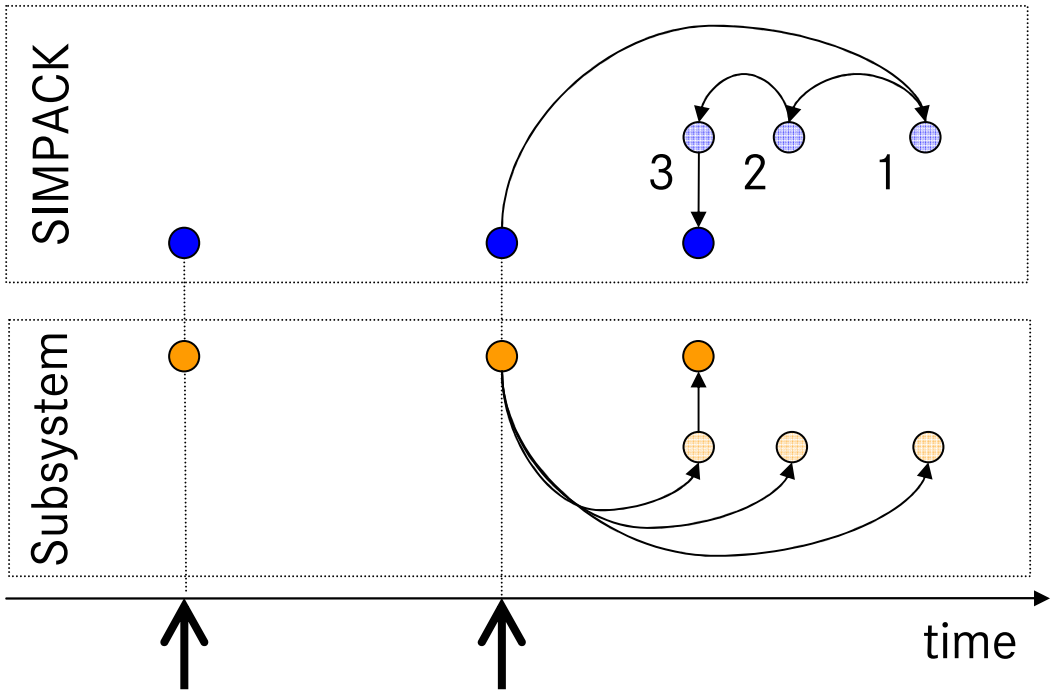


- Test steps of the SIMPACK integrator
- Accepted steps of the SIMPACK integrator
- valid subsystem steps (with save of state variables)
- Temporary subsystem steps (without save of state variab.)

Saved states at accepted time steps

Existing approaches:
Include time continuous subsystems

Example: step size reduction



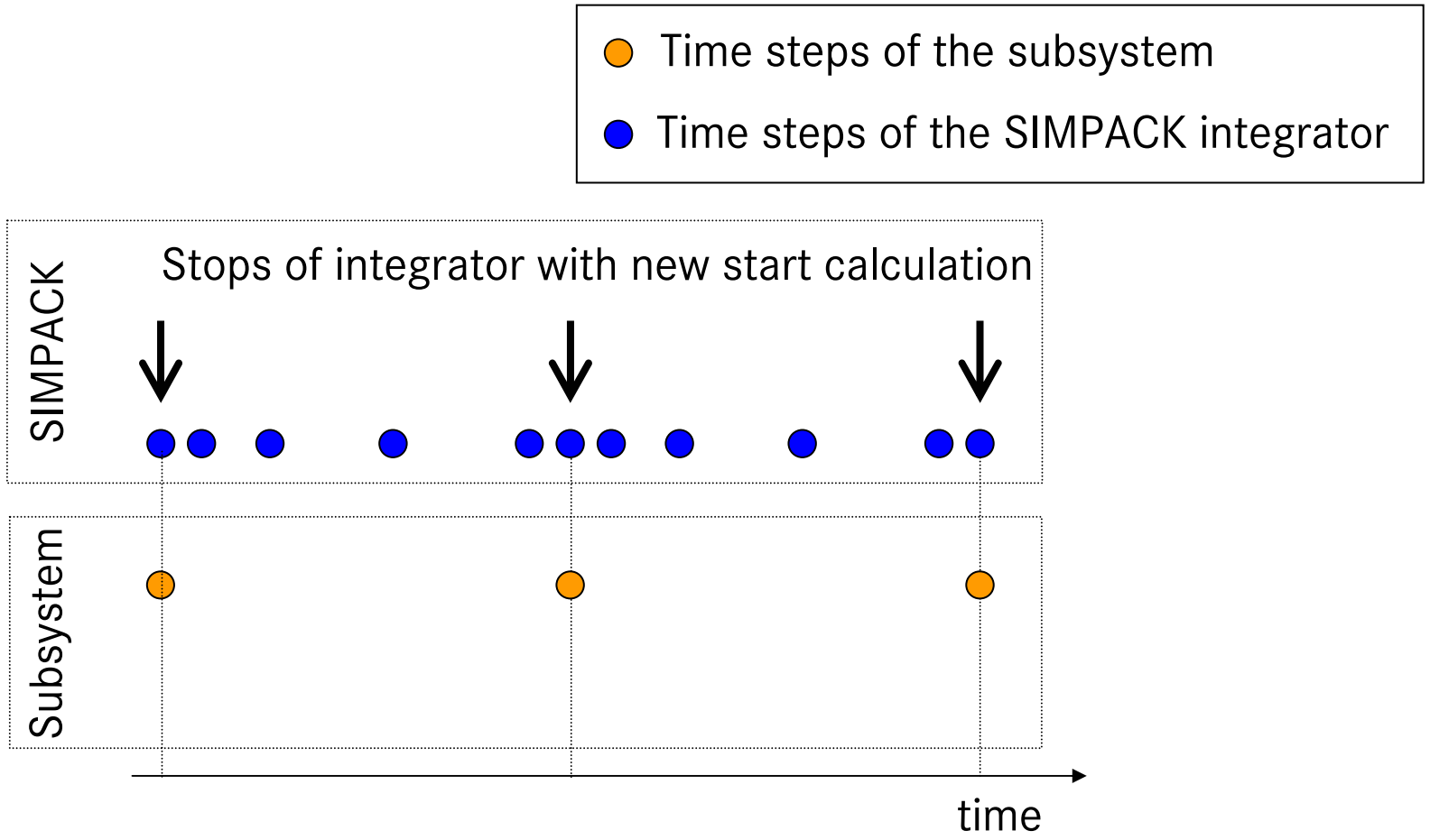
- Test steps of the SIMPACK integrator
- Accepted steps of the SIMPACK integrator
- valid subsystem steps (with save of state variables)
- Temporary subsystem steps (without save of state variab.)

Saved states at accepted time steps

Existing approaches:
Include time continuous subsystems

- Subsystem does the same time steps as the SIMPACK integrator
  - ➔ Adaptation of the subsystem step size to the SIMPACK integrators step size
  - ➔ Variable step sizes must be possible for the subsystem
  - ➔ Reset of the subsystem to a given (saved) state must be possible
- Repeated calculation of the subsystem for the same space of time
  - ☹ Effects calculation power/time

Existing approaches:
Include time discrete subsystems

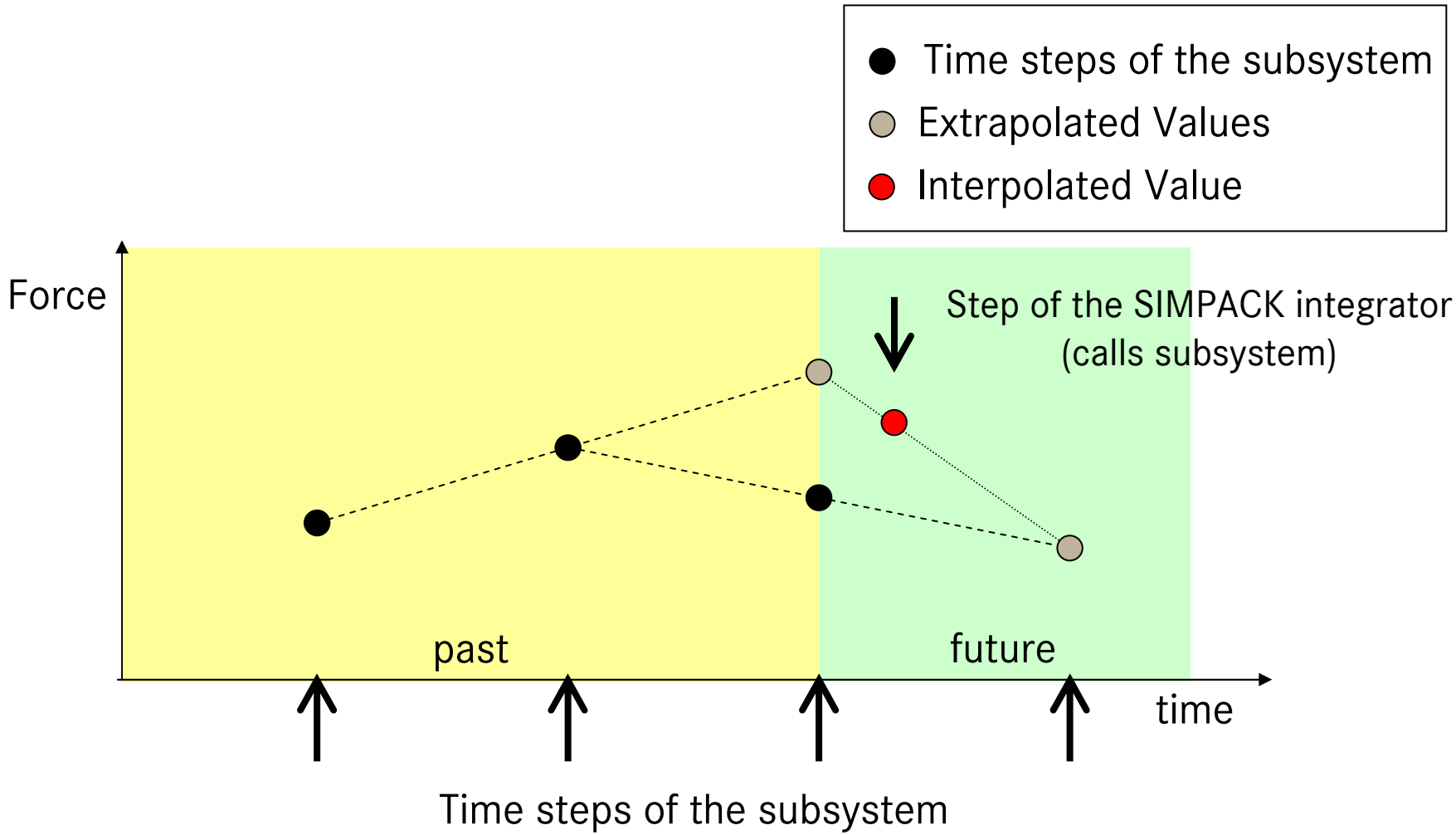


Existing approaches:
Include time discrete subsystems

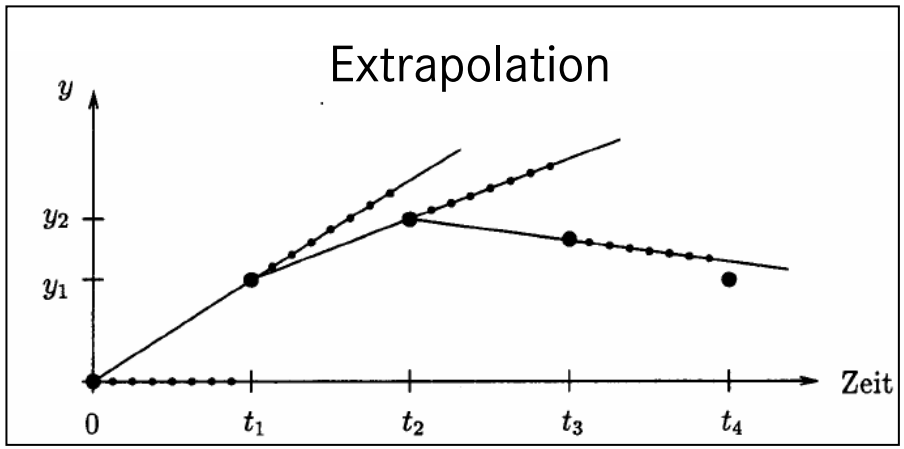
- SIMPACK integrator has to stop every time when the subsystem must be called
  - ➔ Adaptation of the SIMPACK integrators step size control to the subsystem step size
  - ➔ influence on the step size control algorithm of the SIMPACK integrator
- After each stop of the SIMPACK integrator a new start calculation is necessary

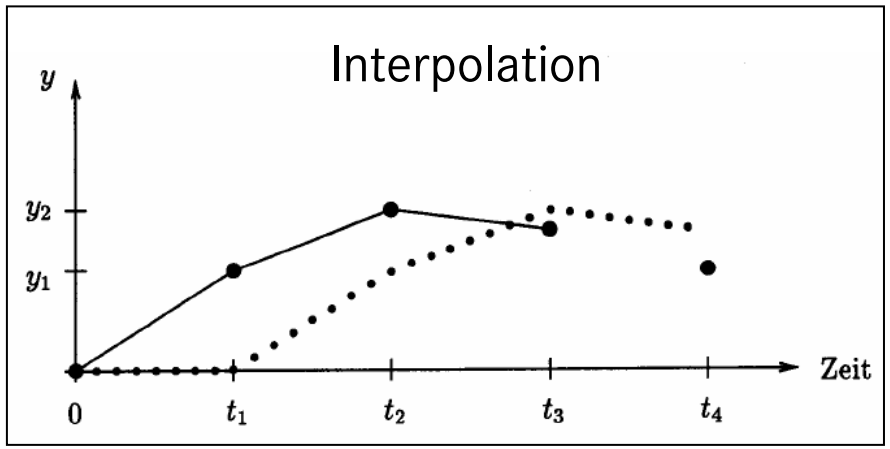
  ☹ Effects calculation power/time

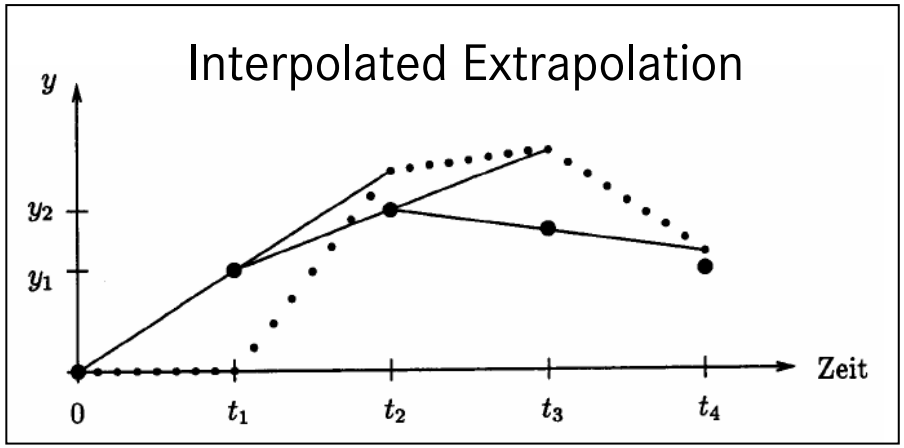
Idea of the Extrapolated Interpolation



Data exchange methods for parallel simulation



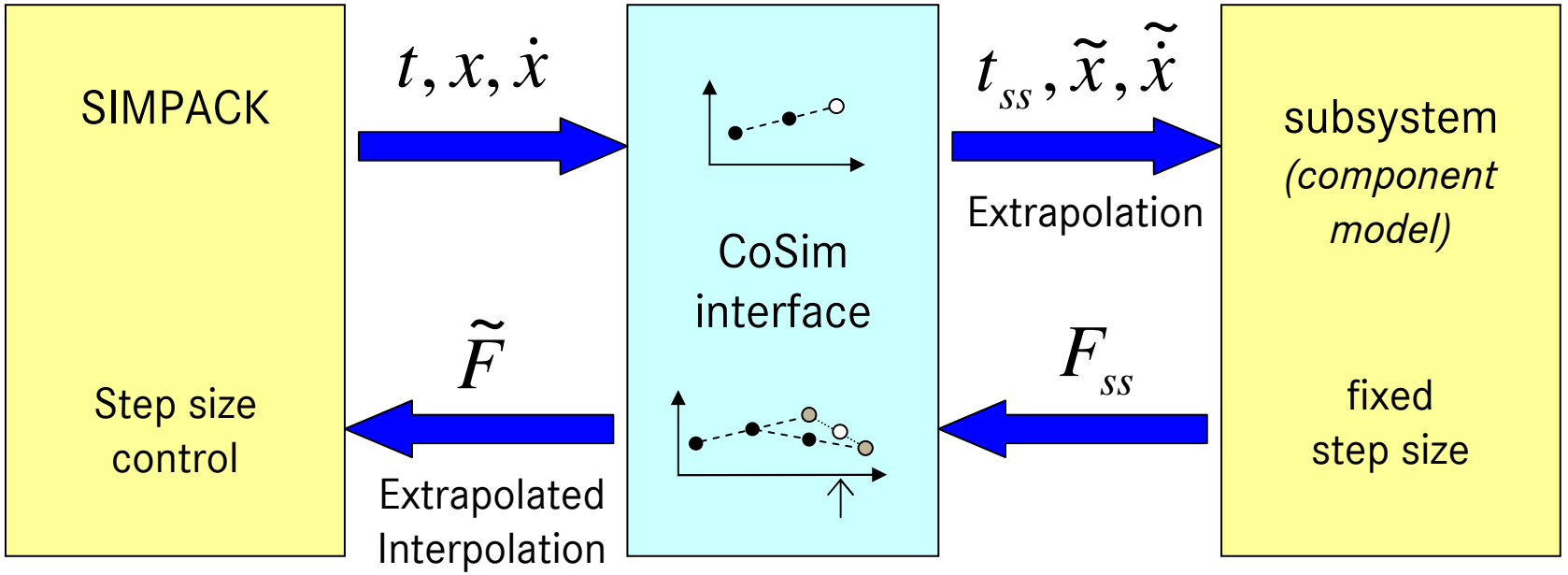




Data exchange methods for parallel simulation

- For coupling of parallel working integrators data exchange is needed
- Possibilities for data exchange
  - Interpolation
    - results in phase shift
  - Extrapolation
    - results in roughness and discontinuity
  - Interpolated Extrapolation
    - lower phase shift than interpolation
    - property of continuity of interpolation

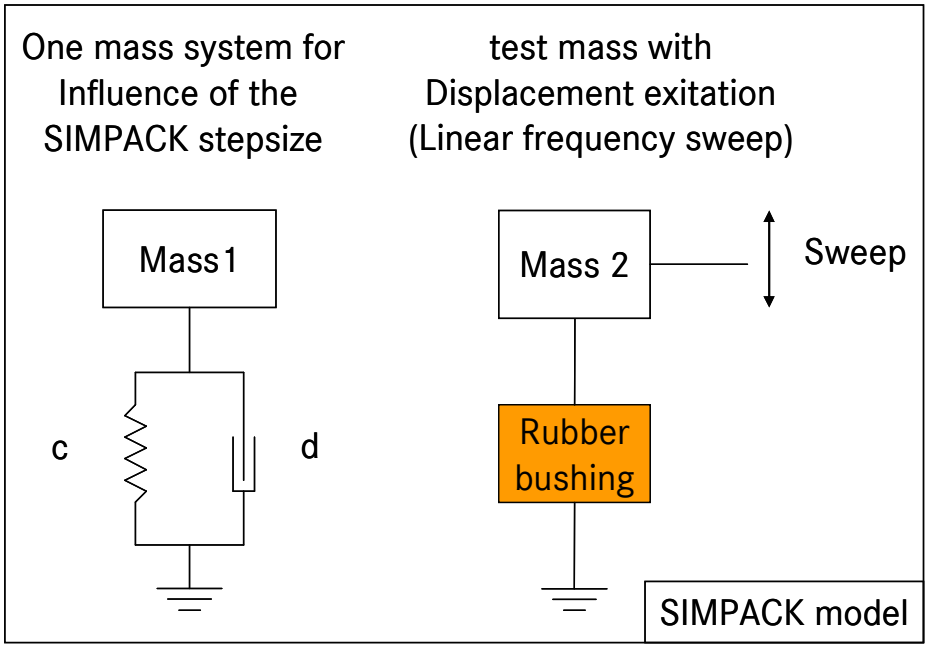
Implementation of the CoSim interface



State machine
+
algorithm

Test example

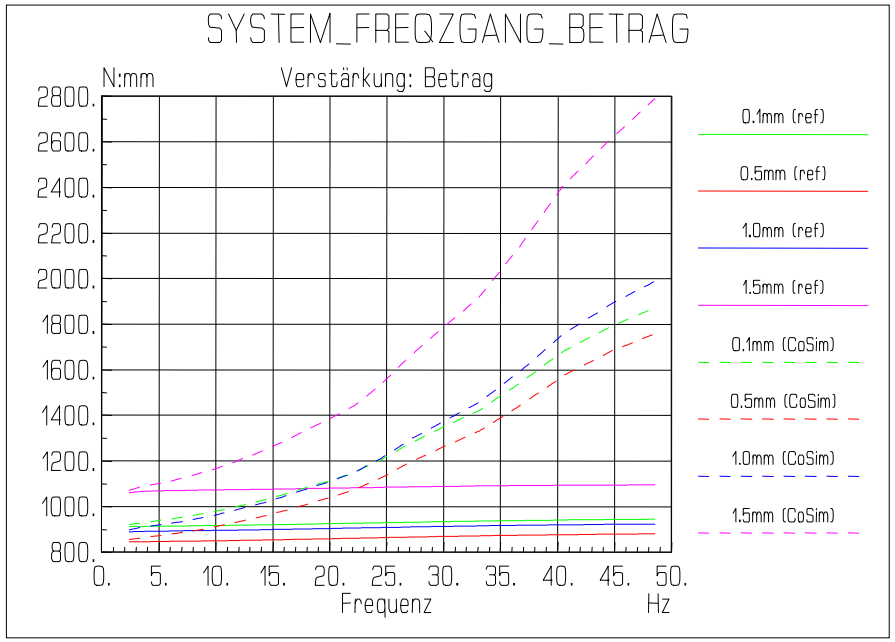
calculations of the rubber bushing model in the **DC simulation program** (reference *without* influence of interface)	**?** **=**	calculations of the rubber bushing model in the **SIMPACK simulation program** (*with* influence of the new interface)



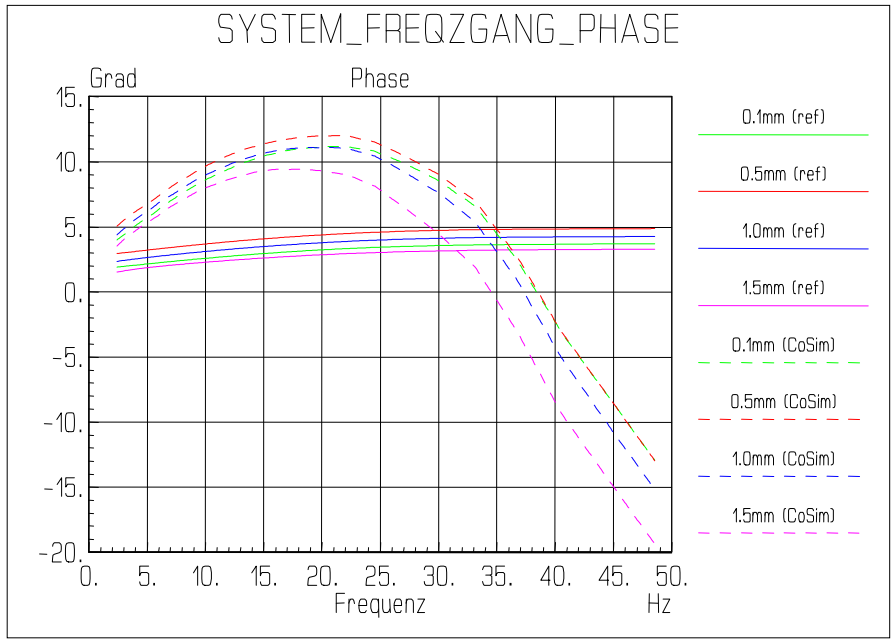
Test case: $h_{sub} < h_{int}$

h_{sub} = 1 ms, h_{int} = 10^{-2} .. 10^{-3} s

magnitude



phase angle



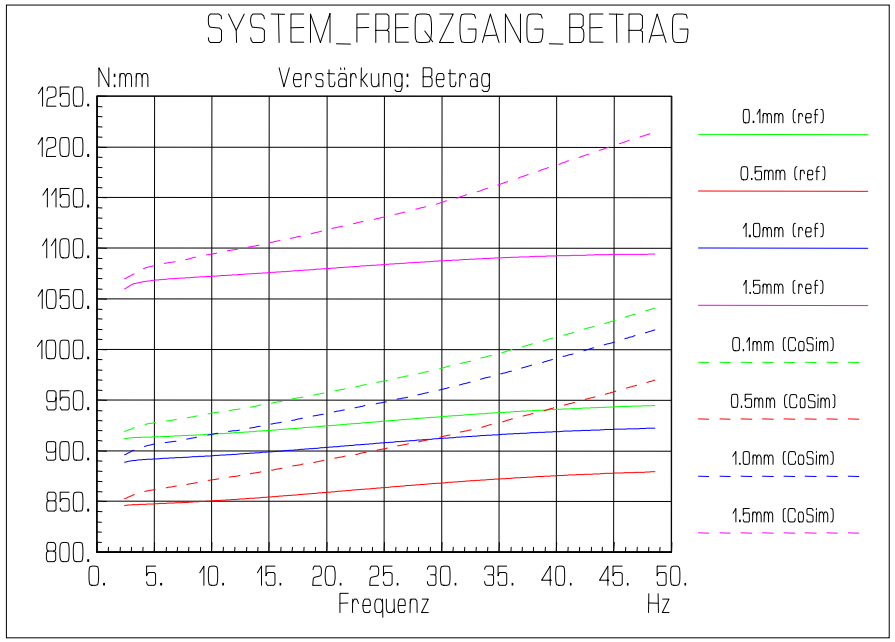
Solid line – Reference Simulation

Dashed line – Simulation in SIMPACK (CoSim)

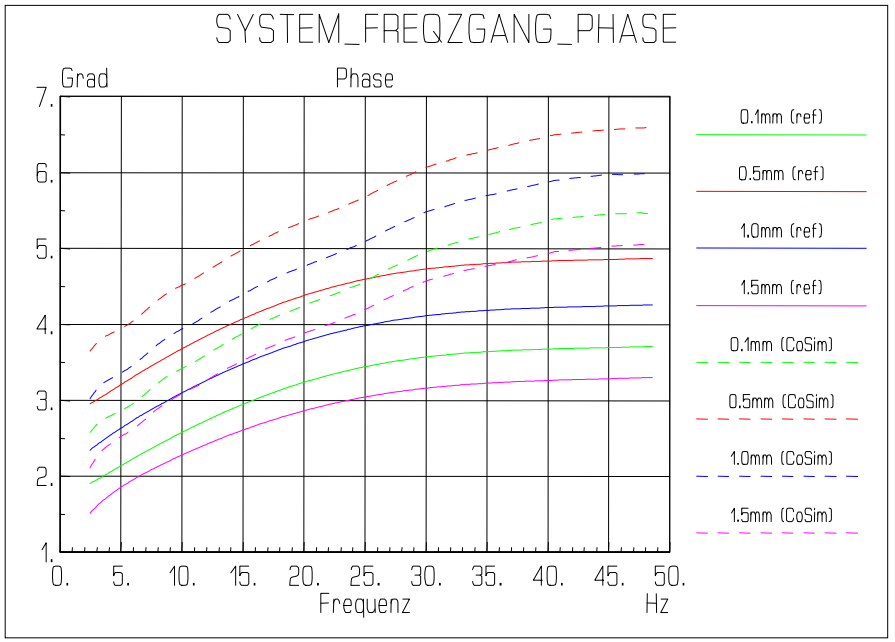
Test case: $h_{sub} > h_{int}$

h_{sub} = 1 ms, h_{int} = 10^{-3} .. 10^{-4}

magnitude



phase angle



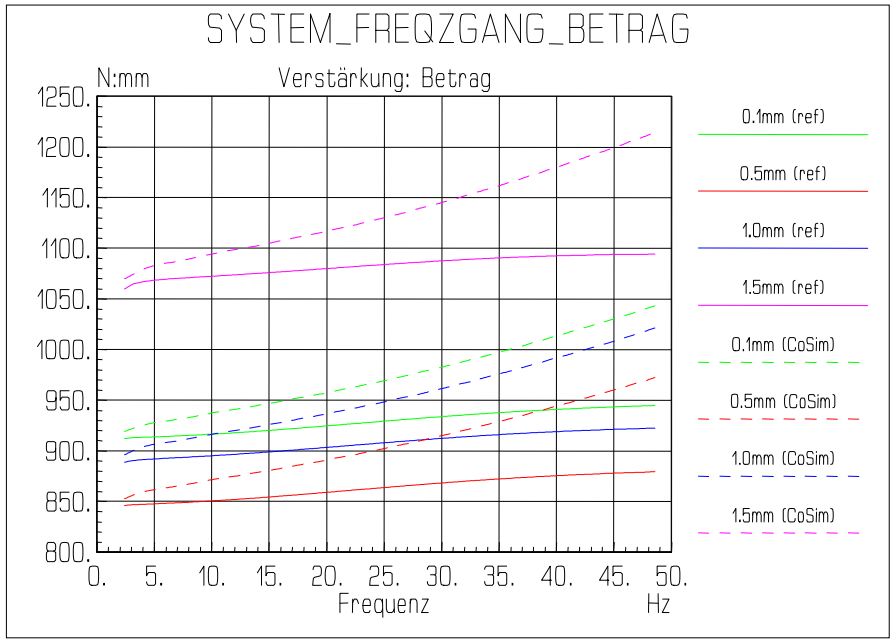
Solid line – Reference Simulation

Dashed line – Simulation in SIMPACK (CoSim)

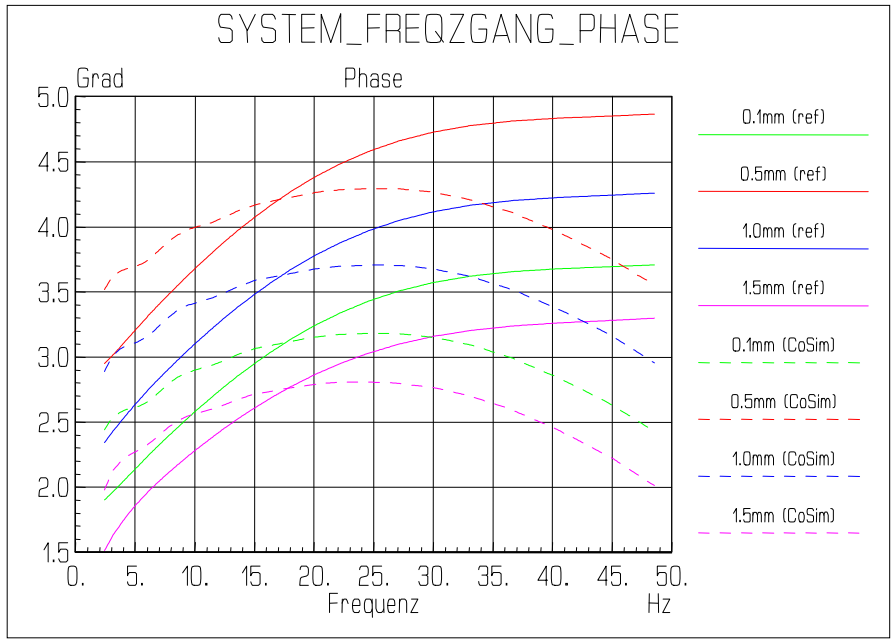
Test case: h_{sub} >>> h_{int}

h_{sub} = 1 ms, h_{int} = 10^{-4} .. 10^{-5}

magnitude



phase angle



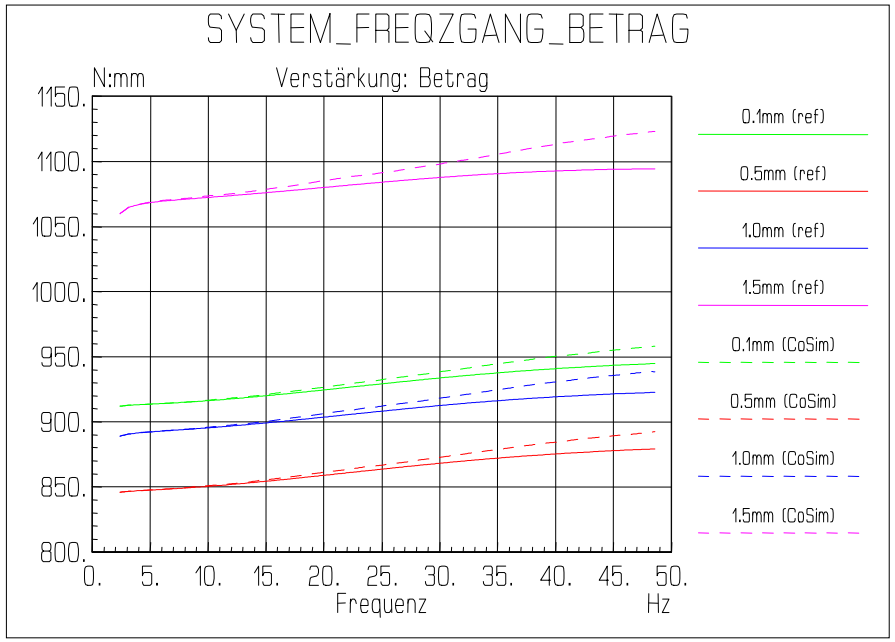
Solid line – Reference Simulation

Dashed line – Simulation in SIMPACK (CoSim)

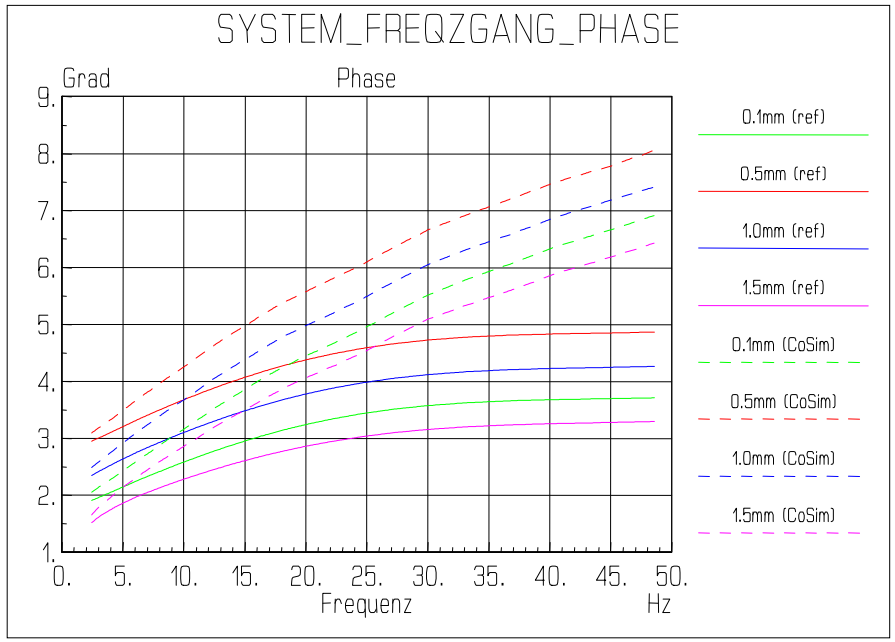
Test case: $h_{sub} < h_{int}$

h_{sub} = 0,1 ms, h_{int} = 10^{-3} .. 10^{-4} s

magnitude



phase angle



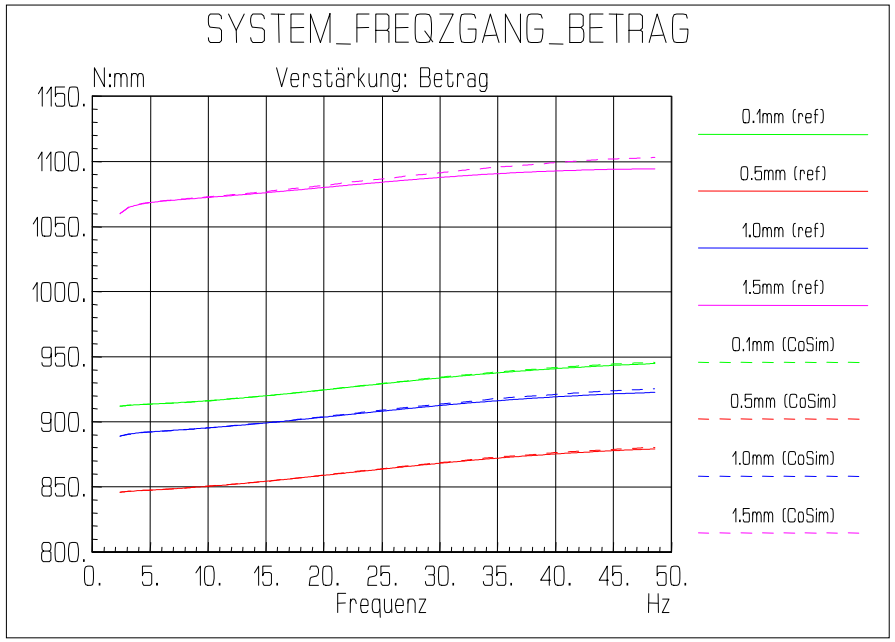
Solid line – Reference Simulation

Dashed line – Simulation in SIMPACK (CoSim)

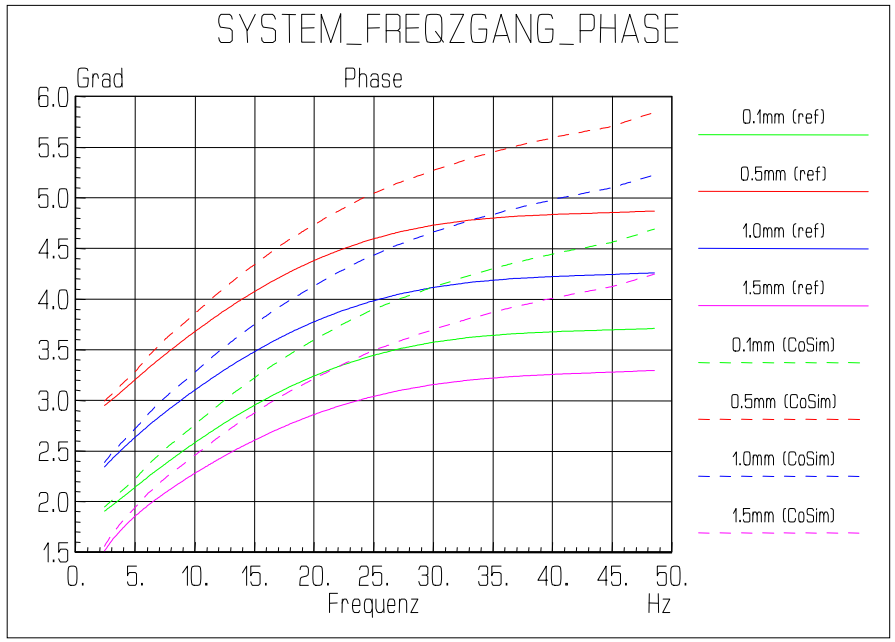
Test case: $h_{sub} \sim h_{int}$

h_{sub} = 0,1 ms, $h_{int} \sim 10^{-4}$ s

magnitude



phase angle



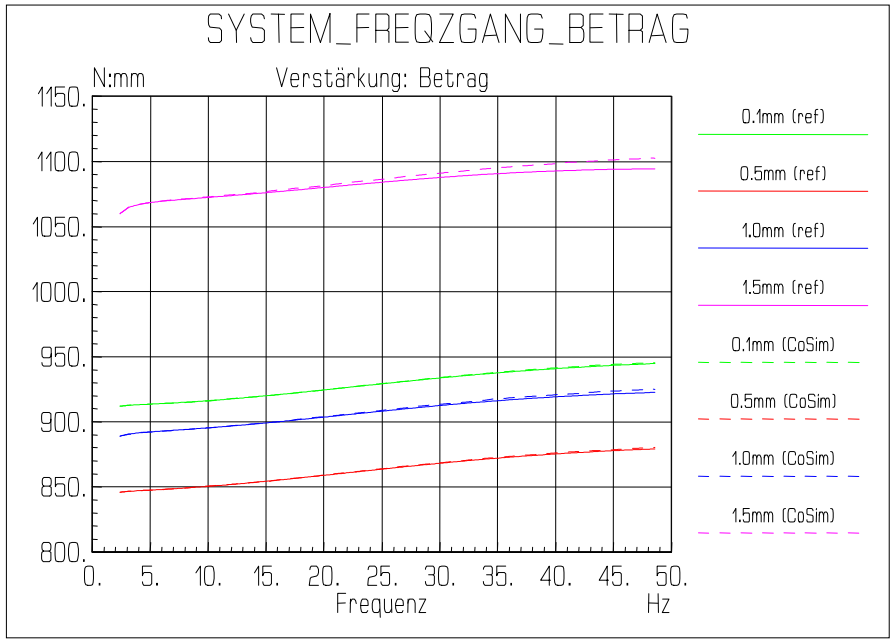
Solid line – Reference Simulation

Dashed line – Simulation in SIMPACK (CoSim)

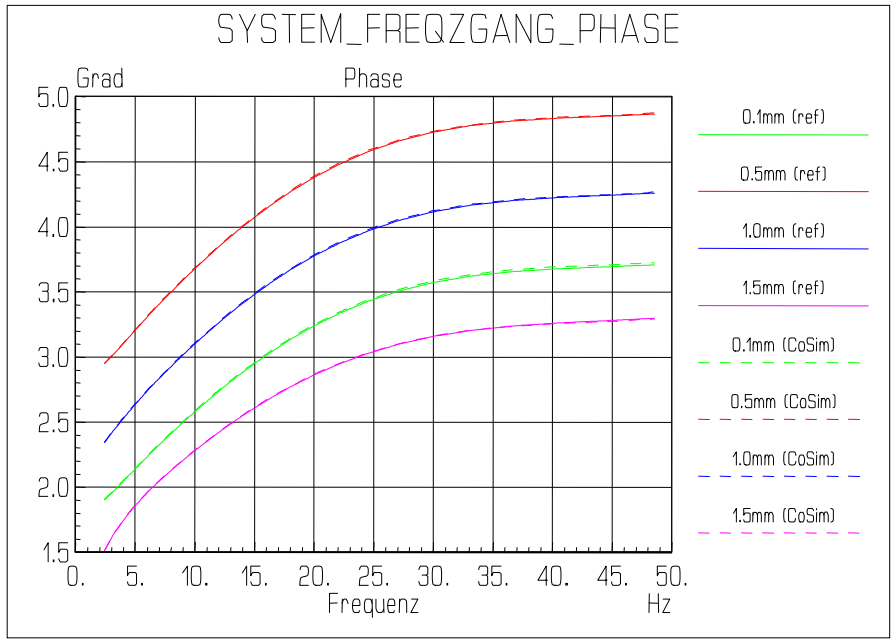
Test case: h_{sub} >>> h_{int}

h_{sub} = 0,1 ms, h_{int} = 10^{-5} .. 10^{-6} s

magnitude



phase angle



Solid line – Reference Simulation

Dashed line – Simulation in SIMPACK (CoSim)

Summary / Results

- Include the component model using the new CoSim interface with the following properties:
  - Subsystem is only called once per time step
  - Step size control of the SIMPACK integrator is not influenced
  - A potentially large number of SIMPACK integrator calls is answered from the interface without a call of the subsystem.
- Test example calculations with different combinations of step sizes for SIMPACK and the subsystem
  - algorithm suitable, if step size of the SIMPACK integrator is lower or close to the step size of the subsystem
  - Interface may influence the results considerably
  - Step sizes $h_{int} > 10 * h_{sub}$ should be avoided
  - Step size of the subsystem must be suitable (not too large)

References

- F. Lieschke, S. Knorr, J. Rauh: Co-Simulation eines Fahrzeugs mit aktiver Federung. In: Frontiers in Simulation, Band 12 (2002) p. 476-485, Delft: Society for Computer Simulation International (SCS). (ASIM 2002, Simulationstechnik, 16. Symp., Tagungsband, Rostock, D., 13. Sep, 2001)
- Diploma thesis: S. Knorr: „Multirate-Verfahren in der Co-Simulation gekoppelter dynamischer Systeme mit Anwendung in der Fahrzeugdynamik“, DaimlerChrysler AG, 2001
  - explored the idea of „extrapolated interpolation“
- Diploma thesis: A. Pichlkostner: „Interfaces und Multi-Rate Co-Simulation für Reifensimulationsmodelle in der Fahrzeugsimulation“, DaimlerChrysler AG, 2004
  - implemented a discrete time link between the BRIT (brush and ring tire) simulation model and DADS