DYNAMIC ANALYSIS OF POWERTRAIM SYSTEMS – STATE OF THE ART AND FUTURE DEVELOPMENTS

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Overview

Powertrain Simulation – State of the Art

Powertrain Simulation – Challenge: ‚Local Non-Linearities'

- General Considerations
- Demonstrative Example: Bolted Joint

Powertrain Simulation – Tabular Summary

Future Strategies – MAGNA Powertrain Developments

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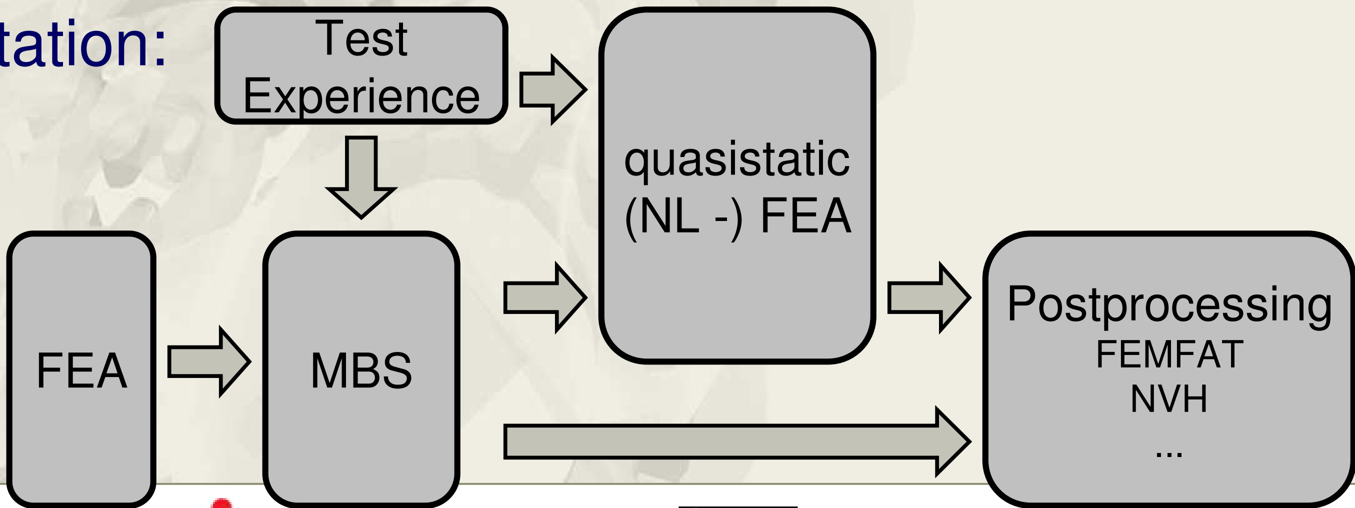
Powertrain Simulation: State of the Art

Dominating simulation techniques

(NL) Finite Element Analysis	Multi Body Simulation
✔ Non-linear static problems	✔ Dynamics of rigid bodies and monolithic linear elastic FE-Structures (modal representation).
✘ Dynamic simulation (time integration)	? Dynamics of FE-Structures with (local) non-linear characteristic.

Typical computation:



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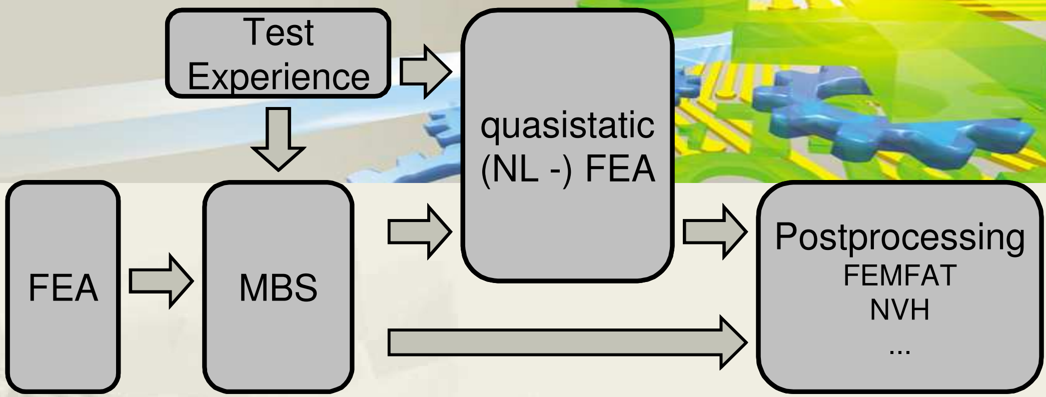
Powertrain Simulation:
State of the Art



Good efficiency:

- Full dynamic of monolithic linear elastic FE-Structures (like crankshaft)

Possibly acceptable efficiency:

- Transient computation of non-linear FE Structures
  - Not too much time steps (Which time steps?)
  - Linearized MBS has to deliver meaningful 'Internal forces' or 'global displacements'

} Significant limitation in terms of accuracy and process-automation

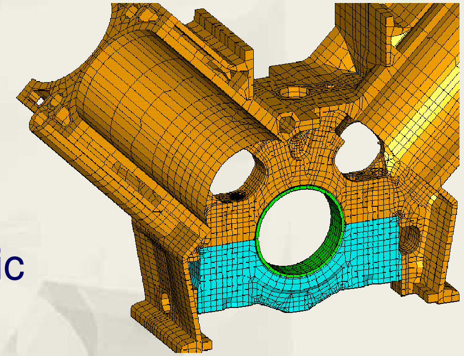
Unsatisfying efficiency:

- Full dynamic of non-linear FE Structures and long time series
  - Economically not possible

Powertrain Simulation:
Challenge: ‚Local Non-Linearities‘

General considerations

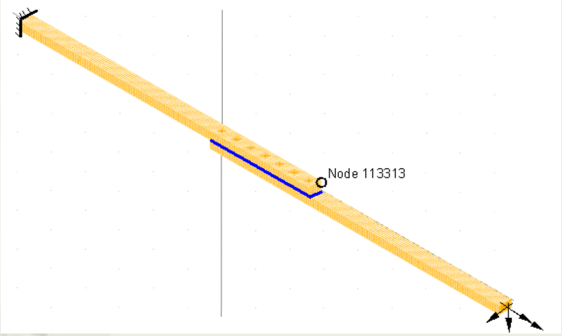
Local non-linear characteristic significant ***local*** effects



I.g.: Local non-linearities dominate the mechanical strength of a bearing chair.

- Preload
- Local non-elastic material characteristic
- Pressed-in bearing shell

Local non-linear characteristic significant ***global*** effects



I.g.: Bolted Joints: Preload will influence

- Global stiffness
- Global damping

Powertrain Simulation: Challenge: ‚Local Non-Linearities‘

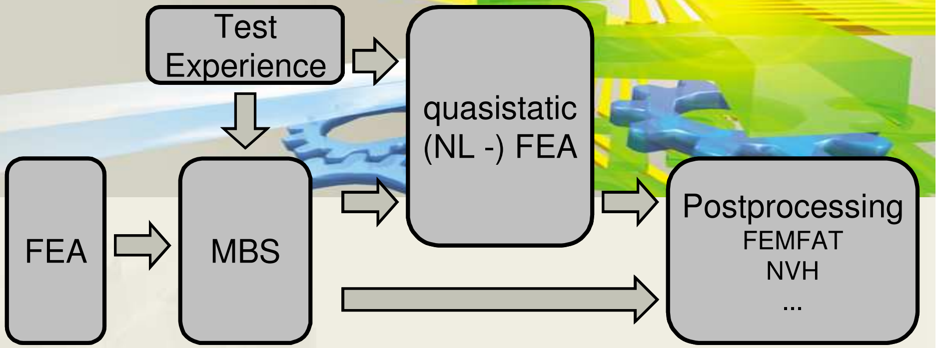
Detailed example: Bolted Joints (Contact Problem) in MBS

E.g.: Surface velocities of engine-transmission-unit. Joints main source of damping

Reality	MBS – modelling: State of the Art	Remarks
Stiffness non-linear function of preload and system state	Stiffness linearized	Change of parameters Computation with updated FE model
Damping non-linear function of system state and some parameters	Damping linearized	
Local effect	Global, modal damping	• Damping values? • Results accuracy?
Damping is almost frequency independent	modal damping is freqency depended	High frequencies overdamped

What would be nice? : A physically meaningful, nonlinear consideration of the joints contact without loosing the typical efficiency of MBS

Powertrain Simulation: Tabular Summary



State of the Art

	Computational effort (long time series)	Dynamic effects	Parameters physical relevance	Accuracy of Results	Typical field of application
Linear Structures	√	√	√	√	Crankshaft
Non-linear Structures – Linearized	√	√	?	?	Acoustics
Non-linear Structures – Internal Forces (NL-FEA)	X	X	√	?	
Non-linear Structures – Substructure Analysis (NL-FEA)	X	?	√	?	

What would be nice?

Non-linear Structures	√	√	√	√	

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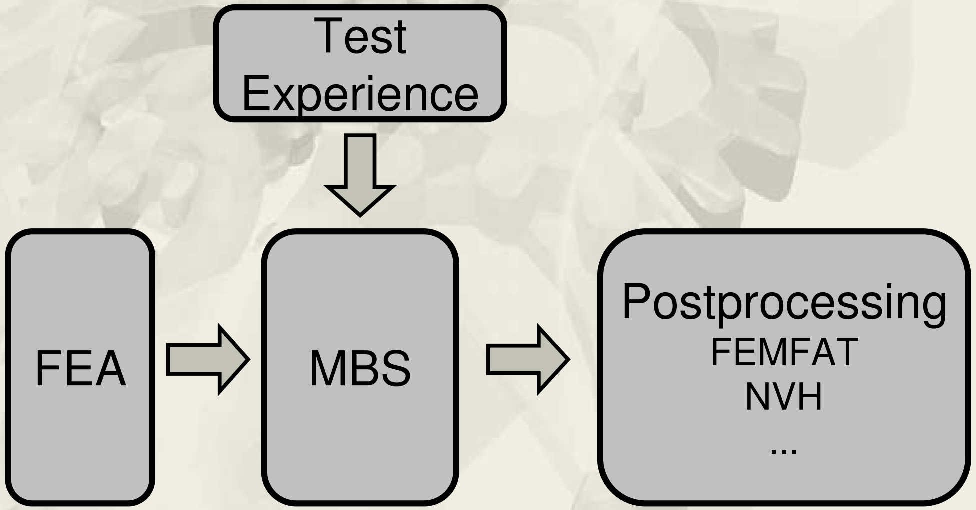
Powertrain Simulation - Future Strategies:

Consideration of local non-linearities inside the MBS for acoustics (first step) and stress computation for lifetime prediction (second step)

Significant boundary condition is to provide the typical efficiency of MBS

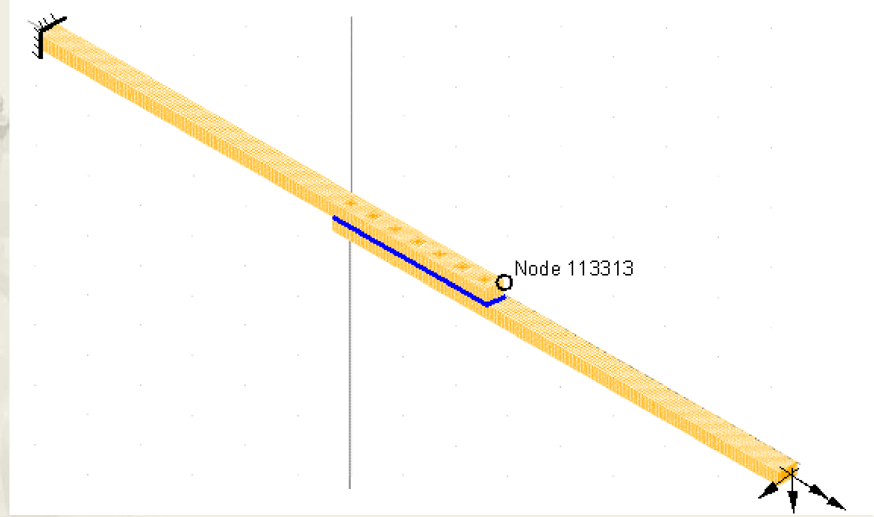


Powertrain Simulation - Future Strategies:

Development of MBS – ‚Plug-In‘ to regard non-linearities in MBS:

Demonstration example: Cantilever beam

- Two jointed substructures
- Both ends fixed
- Impulsive displacement excitation of one end
- Particular Node for evaluation



Goal:

- Full dynamic analysis inside a MBS software
- Consideration of contact
- Sufficient accuracy by significant save of computational time with respect to non linear FE computations (like ABAQUS)

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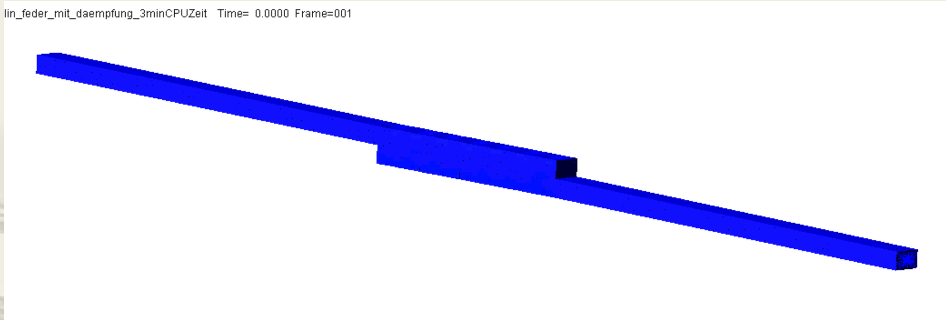
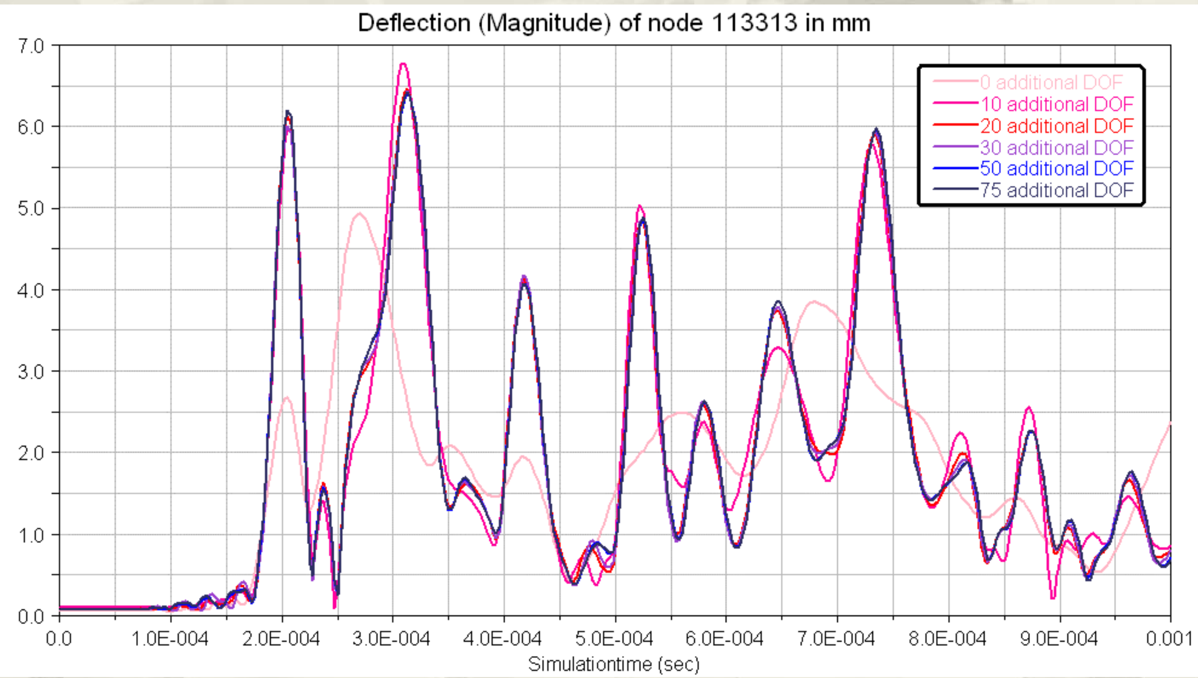
Powertrain Simulation - Future Strategies:

Results:





- Unacceptable results in case of no additional DOF‘s for the MBS
- Excellent Results with 10, 20 or more additional DOF‘s for the MBS
- Entire Number of DOF‘s is 134 + ‚additional DOF‘s‘ instead of several thousands which are necessary for a non-linear FE computation

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Powertrain Simulation - Future Strategies:

Eye-Catcher: Local Damping

Powertrain Simulation - Future Strategies
Summary

Application engineers challenge: Non-linearities

State of the Art:

- Linearization (Acoustics)
- MBS Non-linear FEA (Stress)

MAGNA Powertrain Development of MBS – ‚Plug In' in order to regard the non-linearities in the MBS

- Theoretical foundation elaborated
- First examples promise a big potential
- Vision: Software package and parameters for solving contact problems inside the MBS