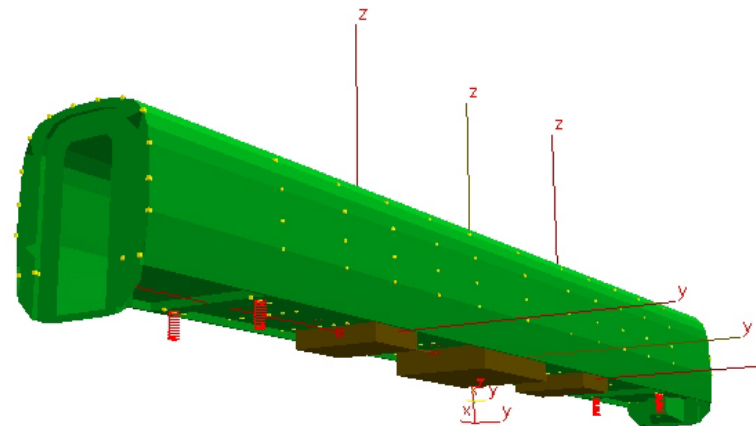


The New, Powerful Linear Subsystem Solver for Flexible Bodies



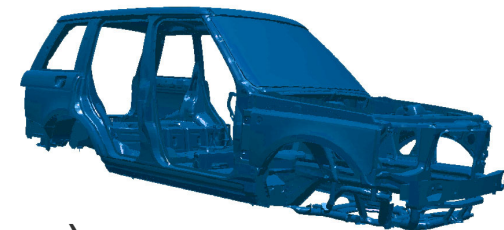
problems associated with the integration of FE models into MBS

finite element analyses

-use frequently more than $1e+6$ degrees of freedom

-need a reduction of the number of load cases

-are applied to a component of a system (deformation, stresses, ...)



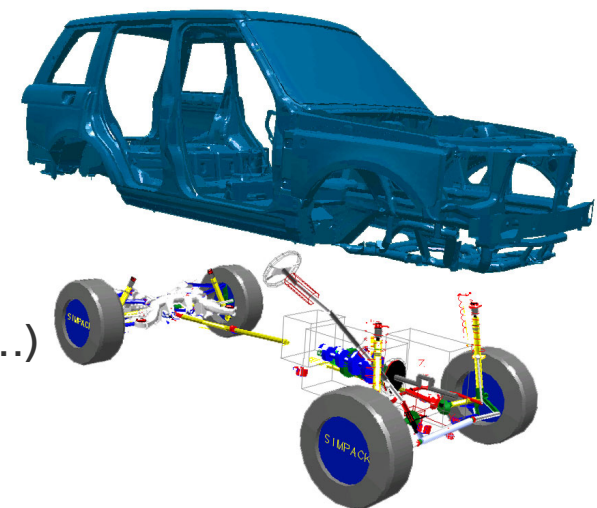
problems associated with the integration of FE models into MBS

multi-body dynamic analyses

-use app. 500 degrees of freedom

-allow less than 100 degrees of freedom for flexible bodies

-are applied to complete (vehicle) systems (motion, forces, ...)



► **reduction of FE models required**

integration of FE models into MBS – further development – 1st approach

rigid body motion

3 translations 3 rotations

deformation

$$\mathbf{u}(\mathbf{c}, t) = \mathbf{u}_1 z_{e1}(t) + \dots + \mathbf{u}_n z_{en}(t)$$

modes

\mathbf{u}_i



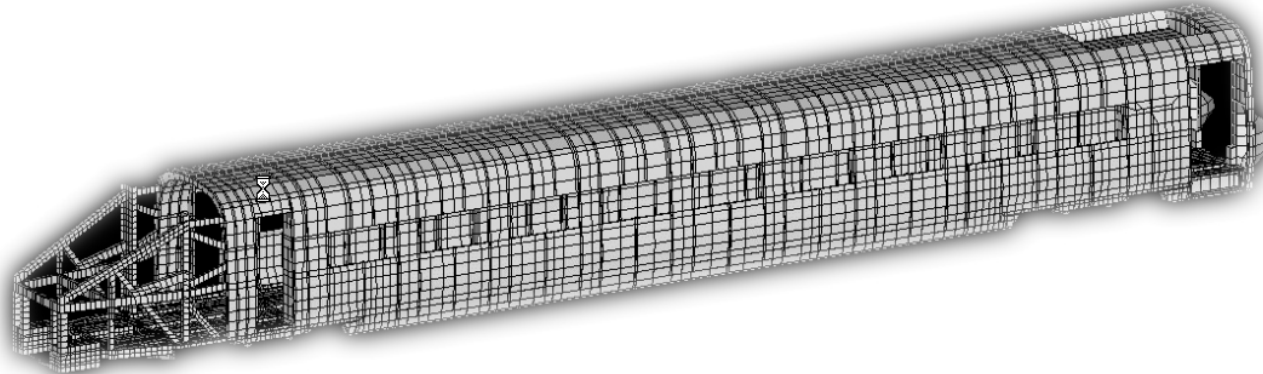
modal co-ordinates

$z_{ei}(t)$

-decrease the number of modes and modal co-ordinates

► **automatic selection of modes**

integration of FE models into MBS – further development – 2nd approach



-large number of attachment points requires a large number of stiff correction modes

-large number of local normal modes

▶ **automatic mode selection sometimes yields a large number of modes**

▶ **increased solver power is also required**

current solver technology

rigid body motion

3 translations 3 rotations

deformation

n modal co-ordinates (e.g. $n=100$)



numeric time
integration



- ▶ **numeric time integration is optimised for non-linear behaviour**
- ▶ **... is mainly applied to linear behaviour**

The New, Powerful Linear Subsystem Solver ...



SIMPACK User Meeting 04, New Solver for Flexible Bodies, 9th Nov. 2004, Stefan Dietz

SIMPACK User Meeting 2004



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new solver technology – basic idea

subsystem 1 (non-linear):

rigid body motion

3 translations 3 rotations

numeric time integration



subsystem 2 (linear):

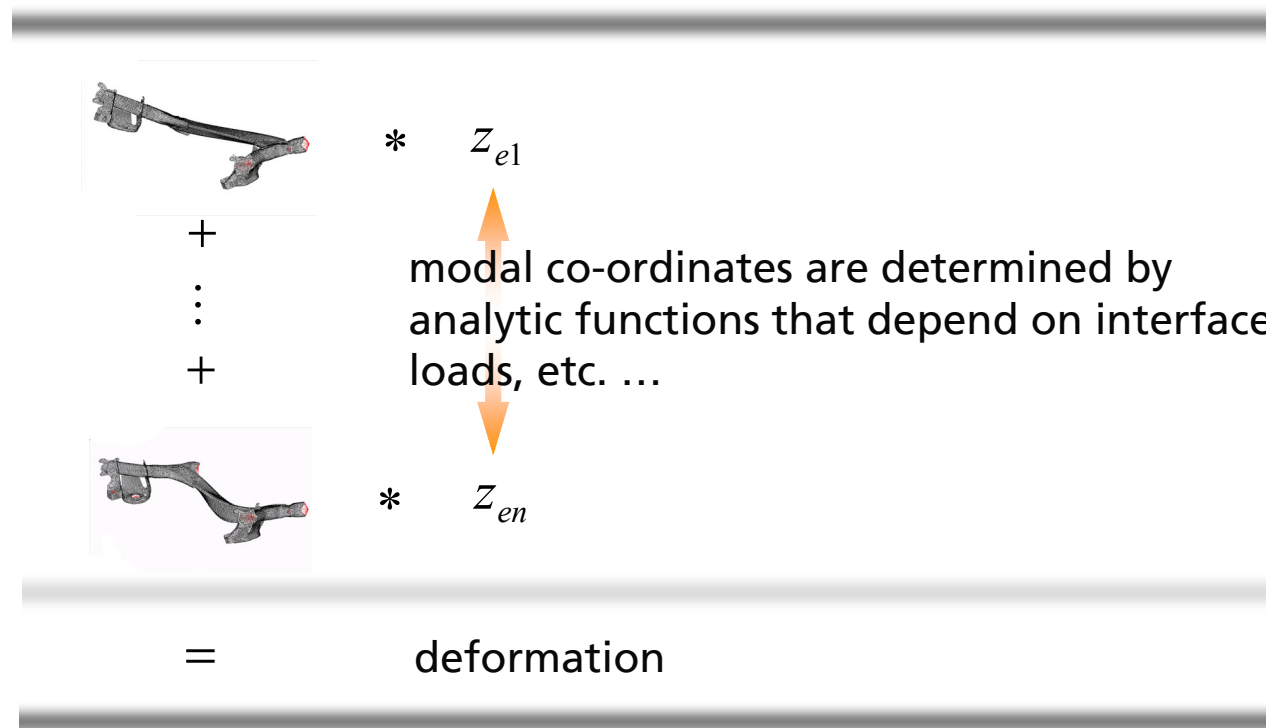
deformation

n modal co-ordinates (e.g. $n=100$)

linear subsystem solver

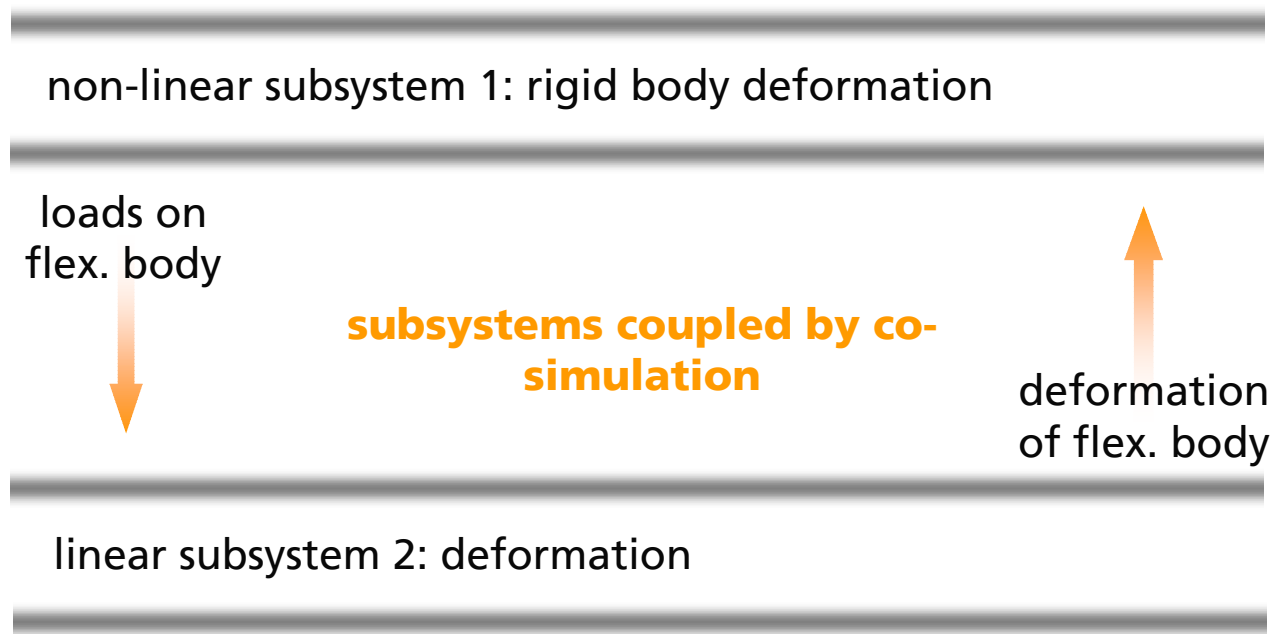


new solver technology – the linear subsystem solver – efficient calculation of flexible body deformation



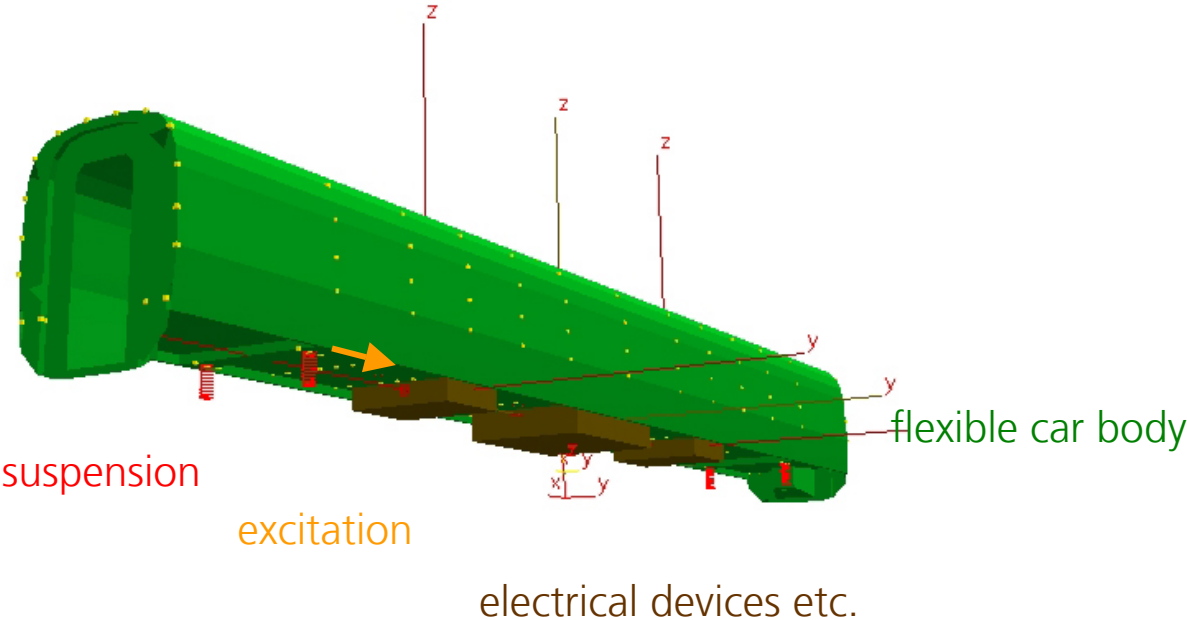
► this representation is always available in the case of linear structural behaviour

new solver technology – the linear subsystem solver – co-simulation

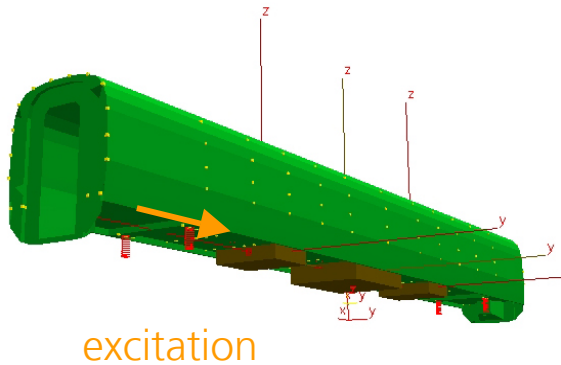


- ▶ **stiff modes have no longer an influence on the numeric time integration**
- ▶ **cpu time depends linearly on the number of modes**

example

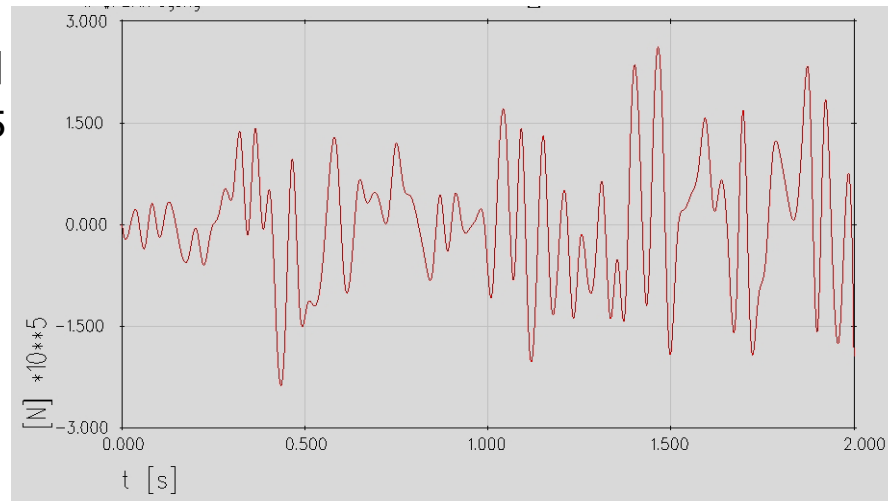


example – the excitation



- maximum forces app. $2e+5$ N
- frequencies up to 30 Hz

force [N]
 $1.5e+5$
0.0



0.0

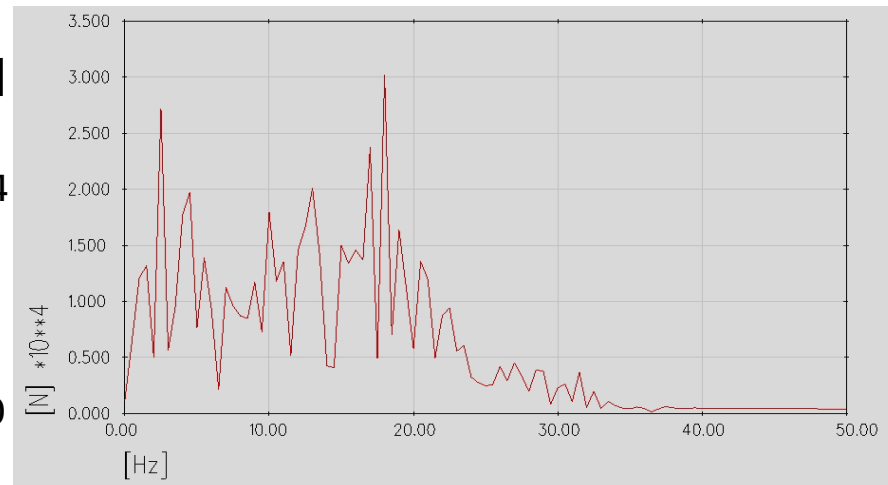
time [s]

2.0

PSD [N]

$2.0e+4$

0.0



0.0

frequency [Hz]

50.0

example – the influence of deformation

lateral displacement [m]

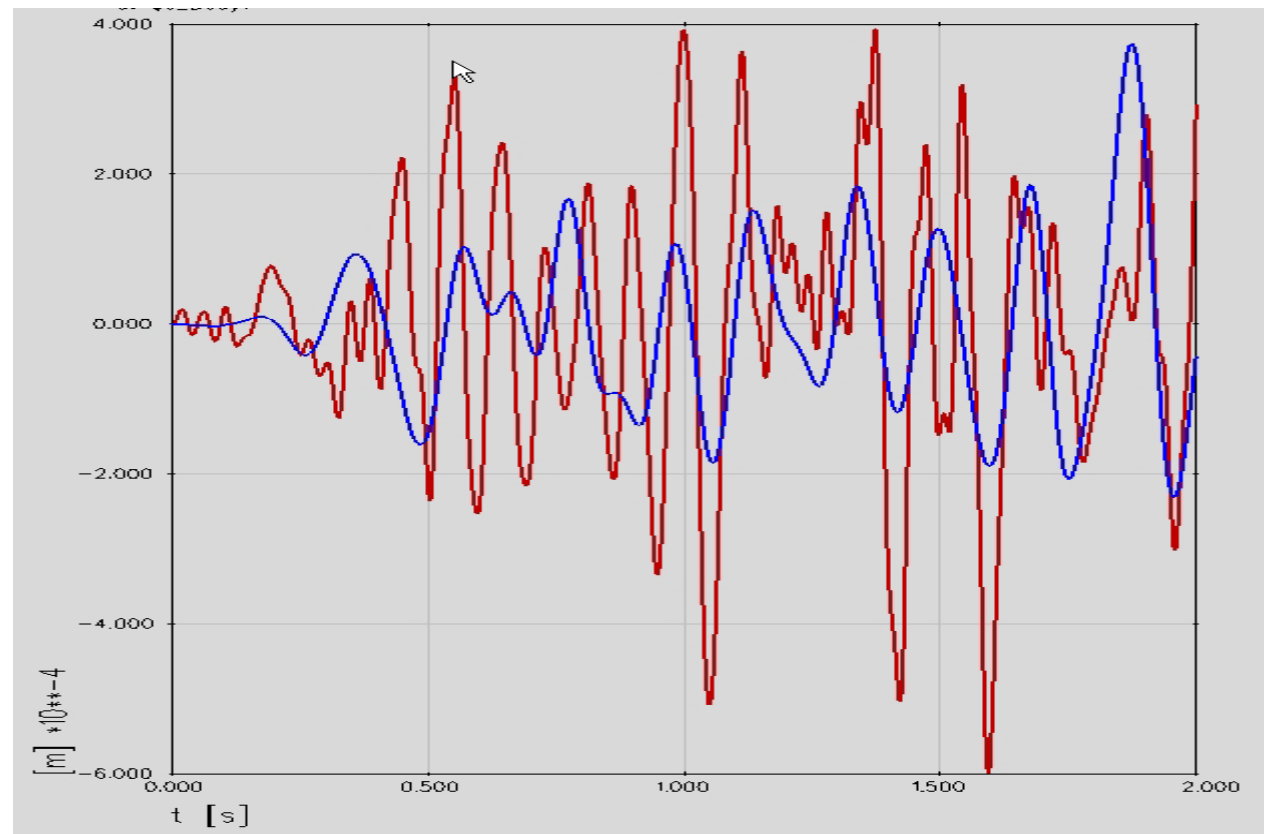
2.0e-4

0.0

-2.0e-4

rigid body motion

total motion



0.0

time [s]

2.0

example – comparison of the approaches

lateral displacement [m]

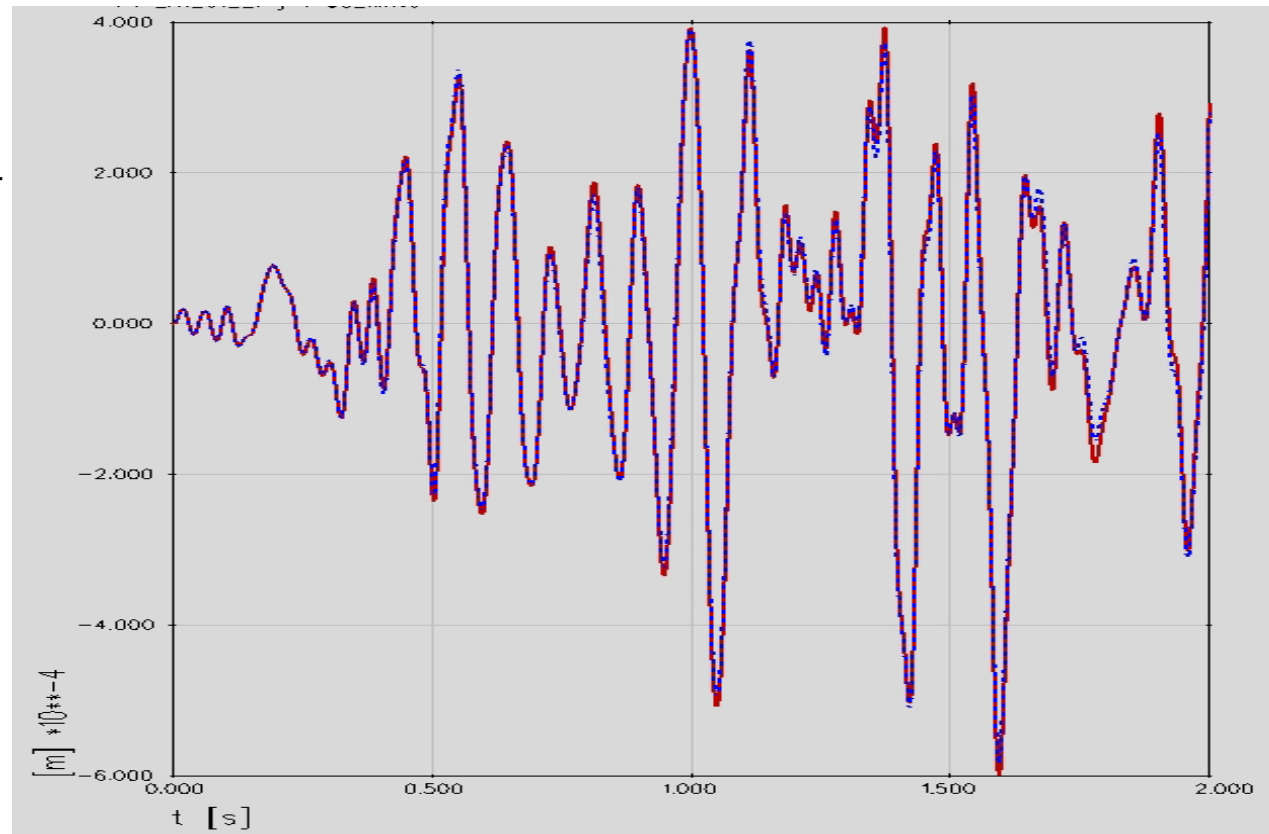
2.0e-4

0.0

-2.0e-4

standard solver

linear subsystem solver



0.0

time [s]

2.0



example – comparison of the cpu times

| number of modes | cpu time standard solver [s] | cpu time linear subsystem solver [s] |
|-----------------|------------------------------|--------------------------------------|
| 29 | 11.4 | 8.9 |
| 51 | 29.6 | 16.8 |
| 81 | 269.1 | 26.9 |


| number of modes | frequency range of normal modes [Hz] | frequency range of correction modes [Hz] |
|-----------------|--------------------------------------|--|
| 29 | 9.56 - 40.55 | - |
| 51 | 9.56 - 40.55 | 55.24 - 198.87 |
| 81 | 9.56 - 40.55 | 55.24 - 1151.50 |

The New, Powerful Linear Subsystem Solver ...



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summary

- simplified mode selection
- improved solver accuracy
- increased solver speed

test version is available