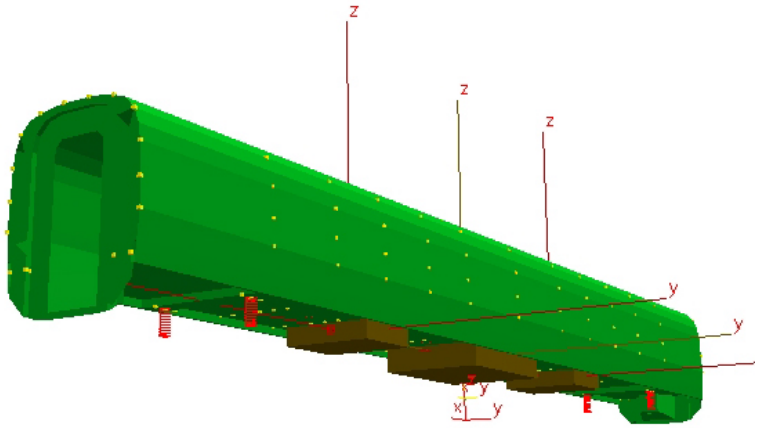
The New, Powerful Linear Subsystem Solver for Flexible Bodies



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, …)

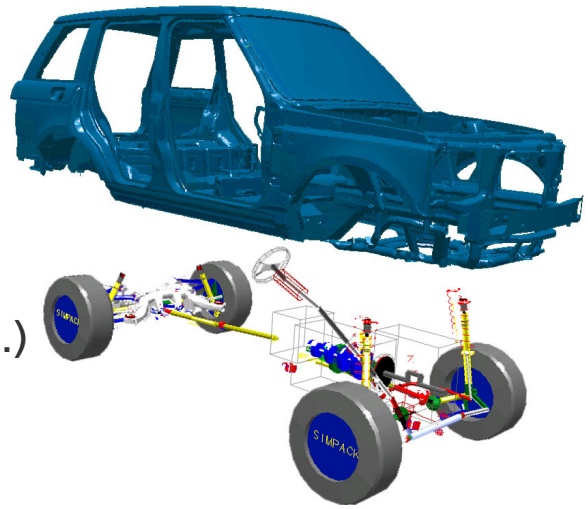
problems associated with the integration of FE models into MBS

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

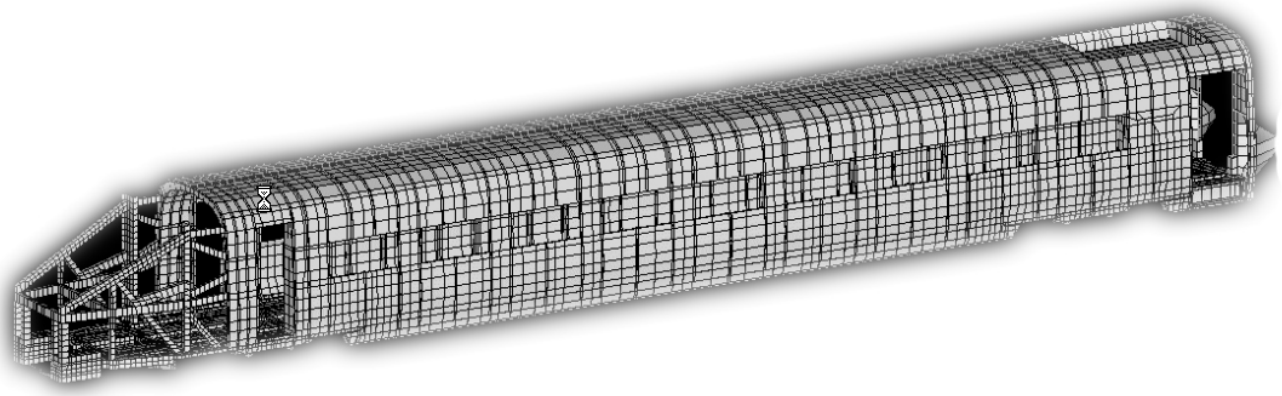
integration of FE models into MBS – further development – 1st approach

rigid body motion	3 translations 3 rotations
deformation	$\mathbf{u}(\mathbf{c},t) = \mathbf{u}_1 z_{e1}(t) + \cdots + \mathbf{u}_n z_{en}(t)$
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	← numeric time integration
deformation	*n* modal co-ordinates (e.g. *n*=100)	←

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

new solver technology – basic idea

subsystem 1 (non-linear):

rigid body motion 3 translations

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

$* \quad Z_{e1}$

\+

⋮

\+

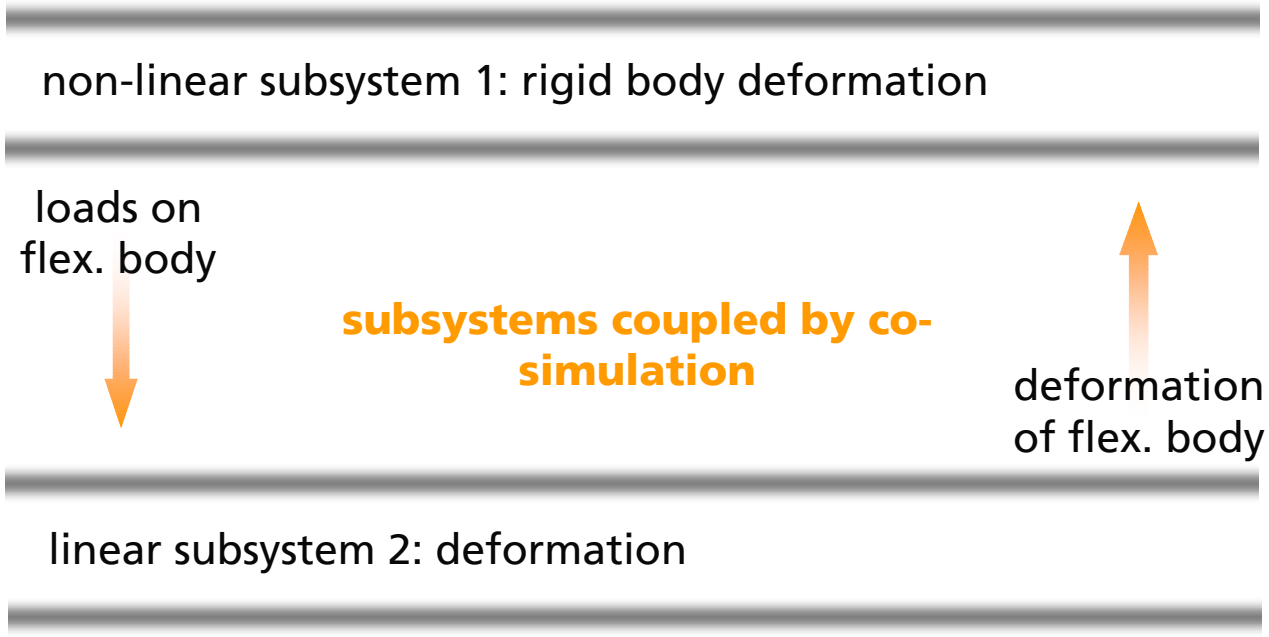
modal co-ordinates are determined by analytic functions that depend on interface loads, etc. …

$* \quad Z_{en}$

$=$ deformation

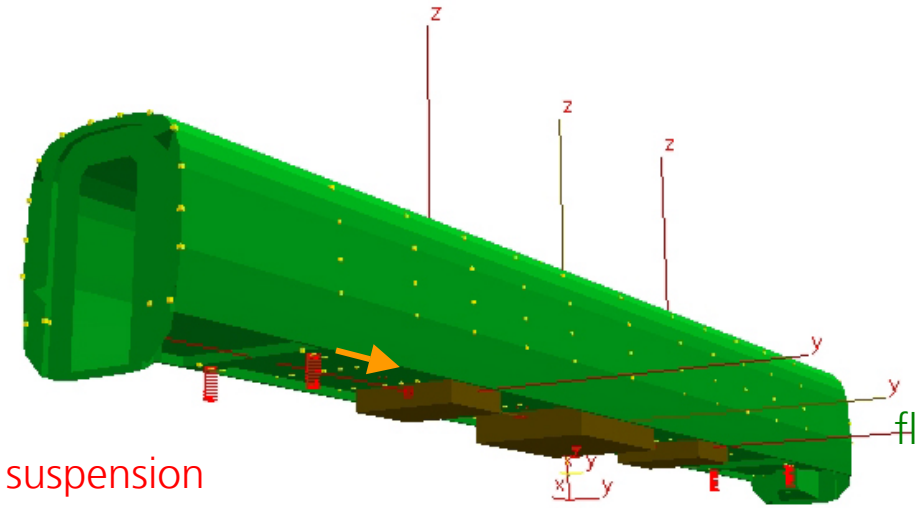
▶this representation is always available in the case of linear structural behaviour

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

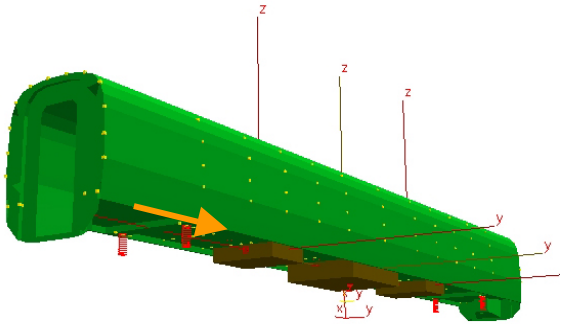


- **stiff modes have no longer an influence on the numeric time integration**
- **cpu time depends linearly on the number of modes**

example

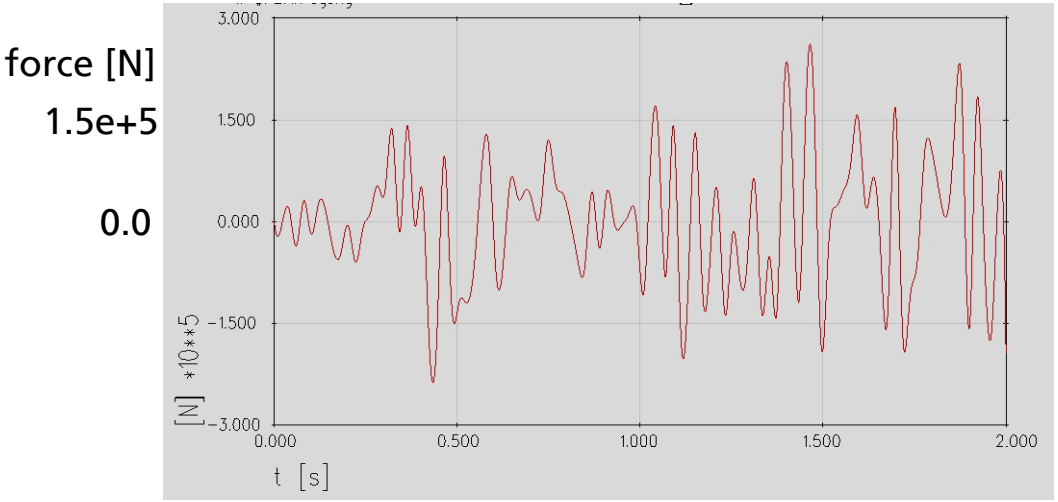

z
z
z
y
y
flexible car body
suspension
excitation
electrical devices etc.

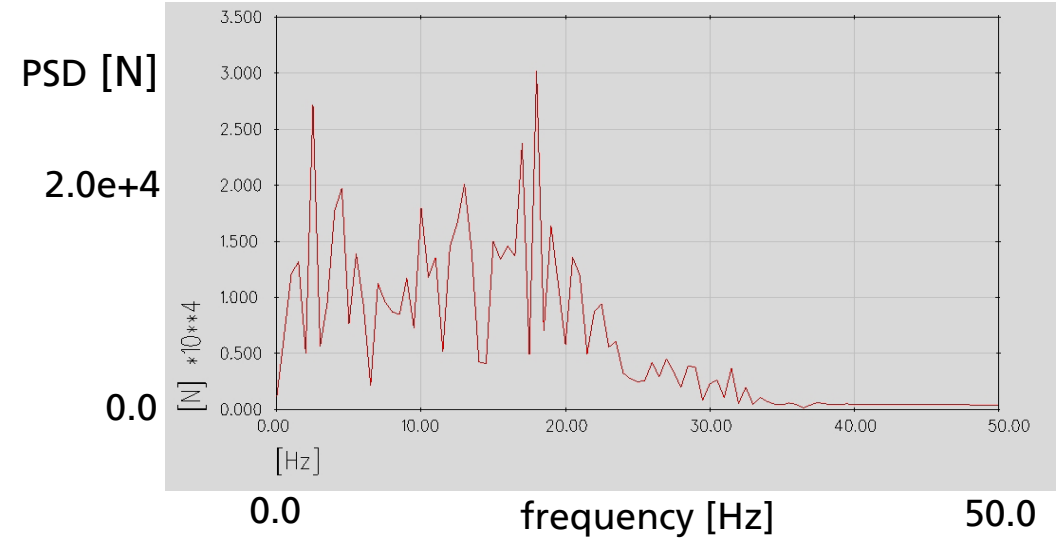
example – the excitation



excitation

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





example – the influence of deformation

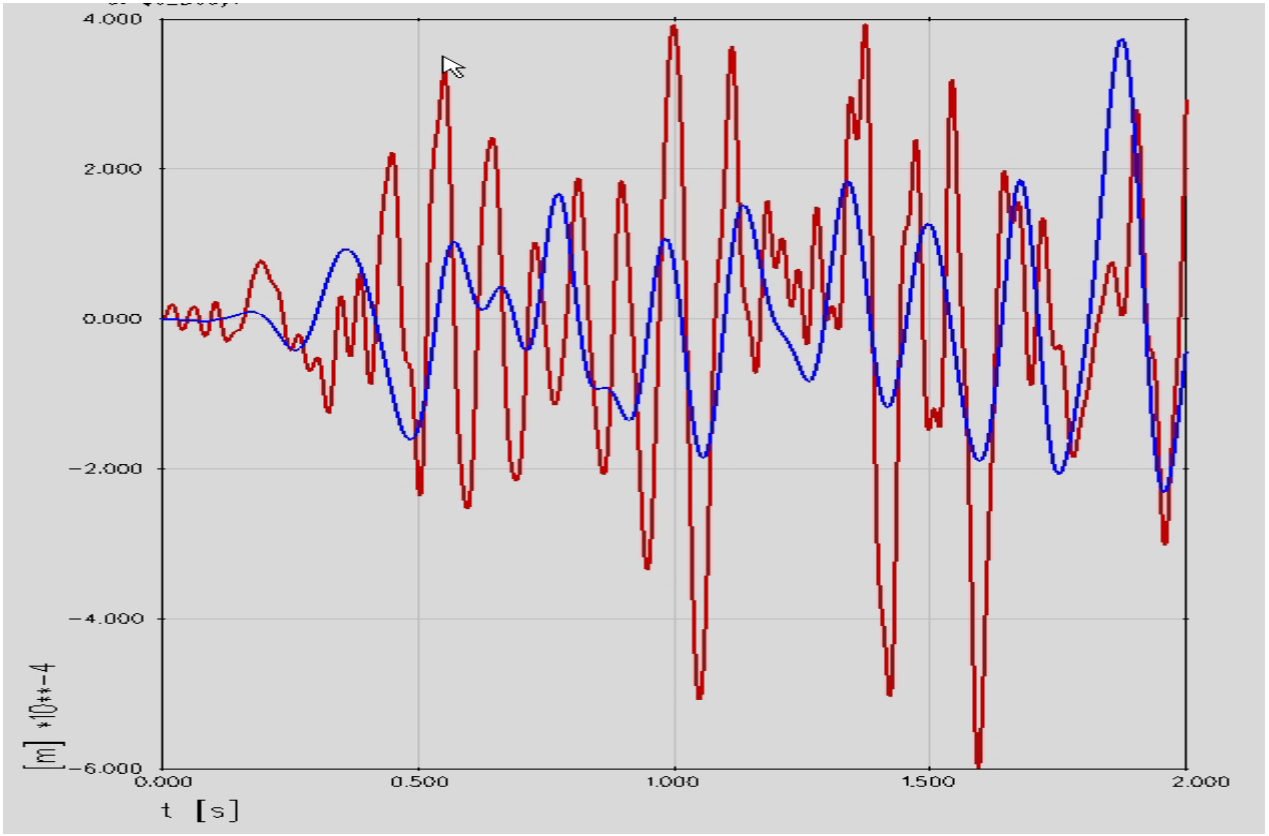
lateral displacement [m]

2.0e-4

0.0

-2.0e-4

rigid body motion
total motion



0.0 time [s] 2.0

example – comparison of the approaches

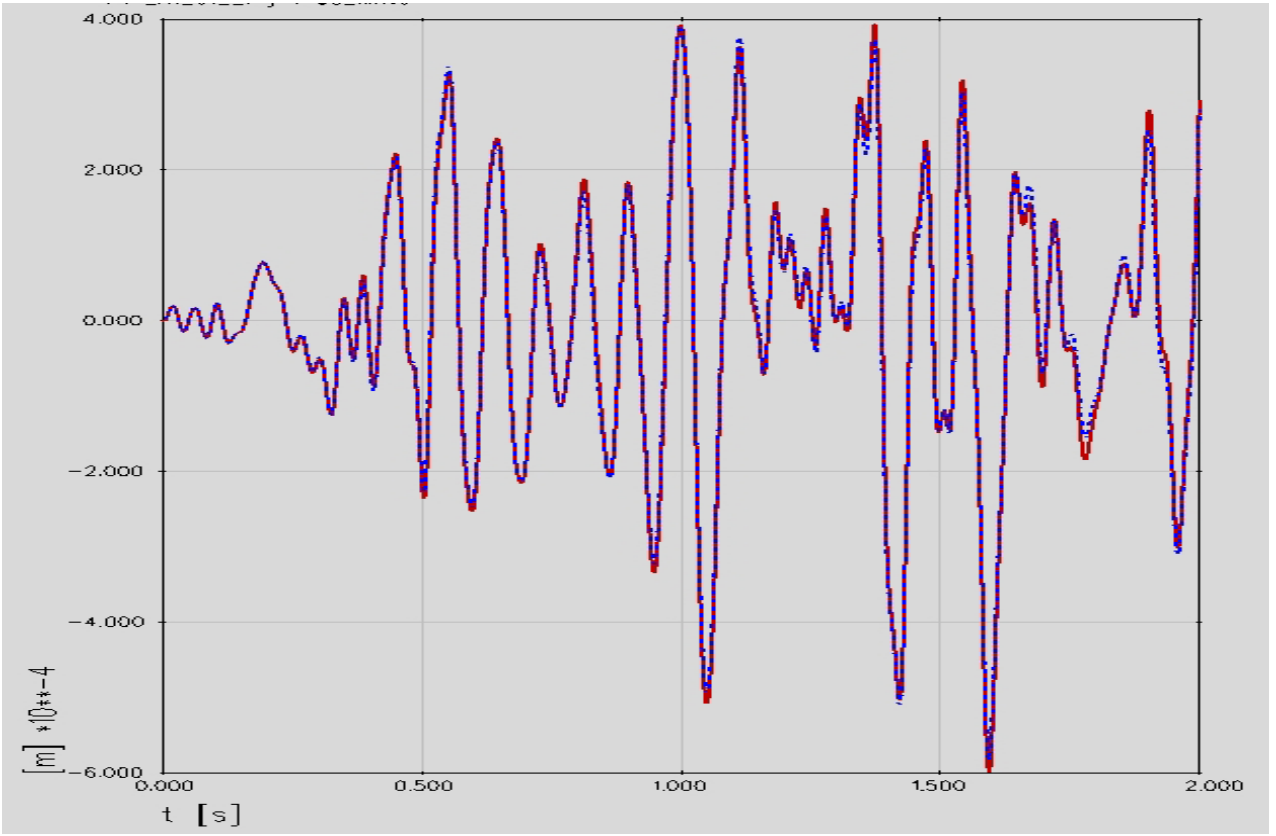
lateral displacement [m]

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

summary

-simplified mode selection

-improved solver accuracy

-increased solver speed

test version is available