Leaf Spring Modeling in SIMPACK:
A New Approach to Model-Diversity

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- Motivation
- Component-modeling – leaf spring
  - Functionality
  - Model-diversity
    - „Massless“-model
    - SIMBEAM-model
- Validation by test rig results
- Leaf-Spring-Generator (LSG)
- Summary

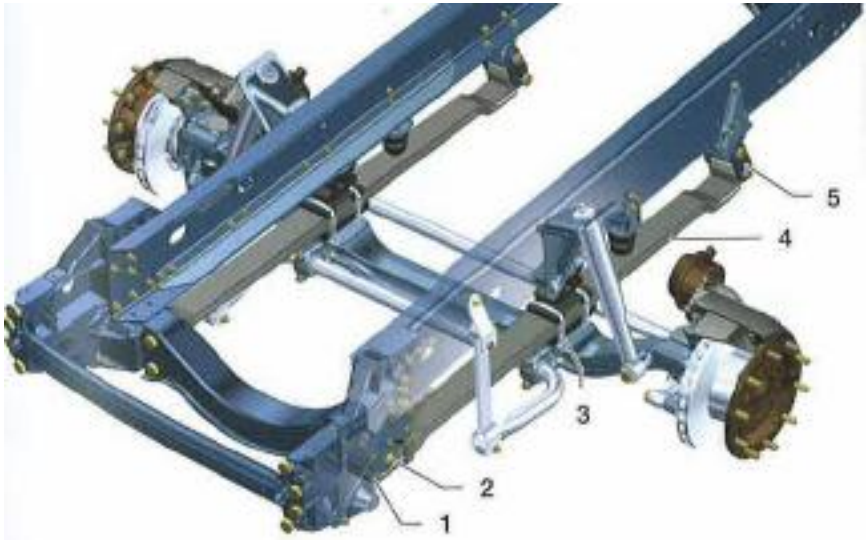


image courtesy of MAN Truck & Bus AG

State of the Art

- No standards in component-modeling (air-, leaf-spring, etc.)
  - Uncertain and fault-prone modeling process
  - Hard-to-compare simulation results

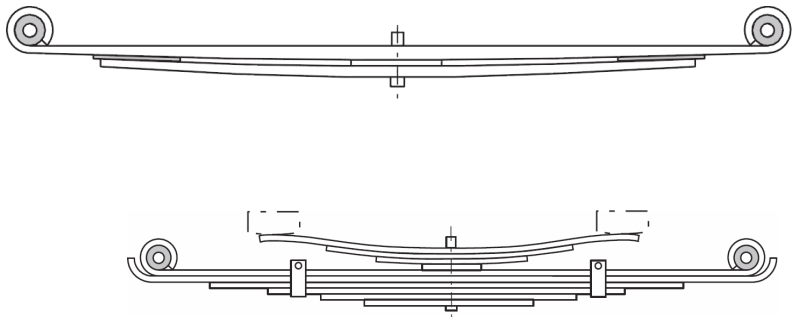
- The quality of the model depends on the
  - Experience of the user
  - Methodology
  - Availability of measurement data

Main goal of this Project

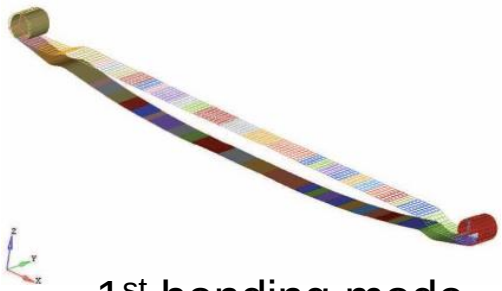
- Knowledge-based and standardized component modeling
- Model-generator and data input process

Leaf springs

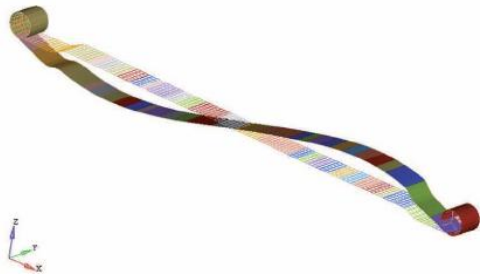
- Widely used in heavy vehicles
- Robust component
- Low cost



- Main tasks
  - Spring function (z)
  - Control of the axle (y, x)
- Main deformations
  - 1st bending – deflection
  - 2nd bending (S-shape) – braking

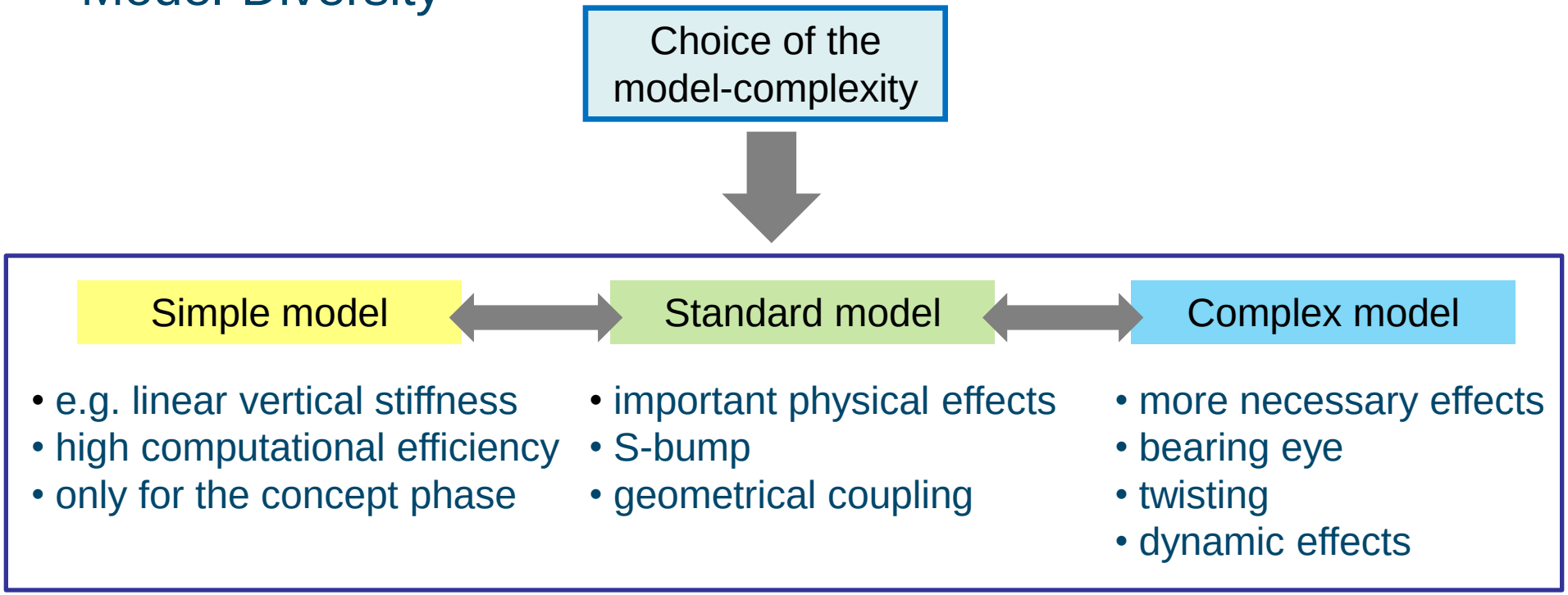


1st bending mode



2nd bending mode

Model-Diversity



- Higher model-complexity → more modeling demand and CPU time
- Switching between model-types → no flexibility, in most of the cases new model necessary

→ Leaf-Spring-Generator: automatized process

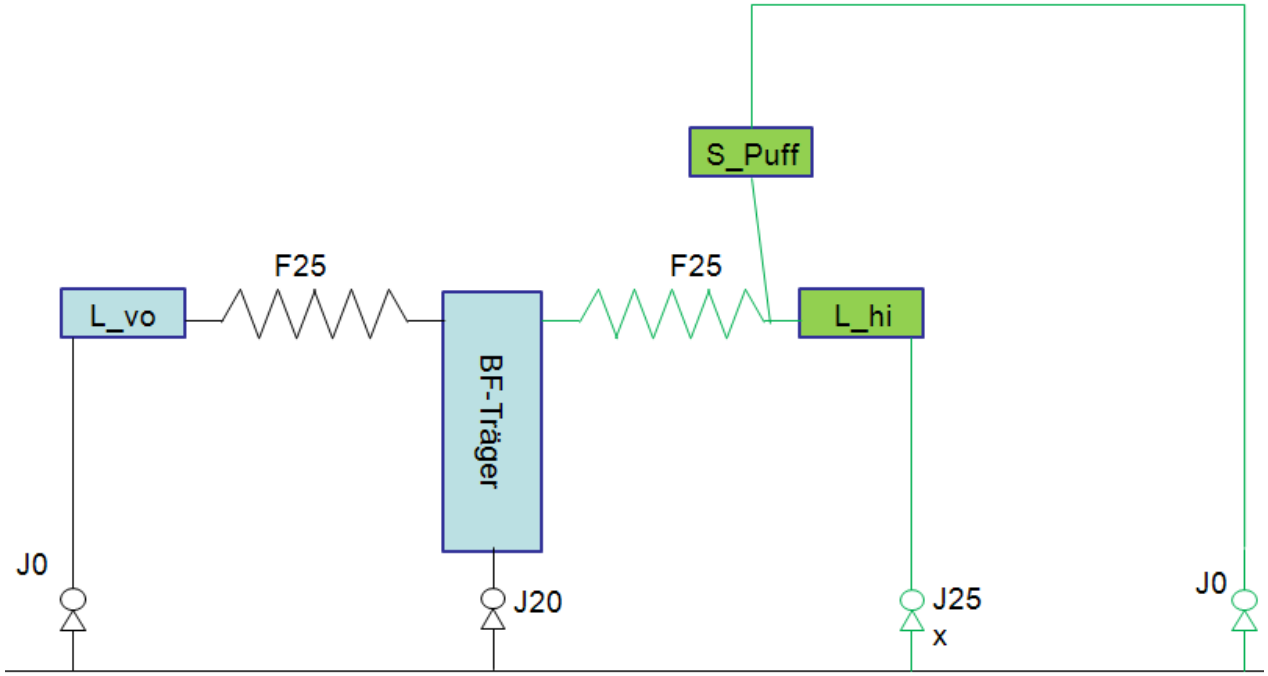
„Massless“-model

- User Routine - force element (UForce – massless beam)
- Neglects the mass influence – static model

- Concept
  - 2..10 3D beam elements
  - Deformed shape → linear beam static
  - Nonlinear coupling between displacement and rotation
  - Data-input modes
    1. Geometry-based: discretized sections $\{x_i, h_i, b_i\}$
    2. Vertical stiffness-based: requested stiffness with deviation (C_z, ΔC_z)

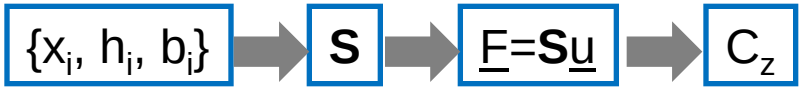
„Massless“-model

- One force element for the half of a leaf spring
- Model approach: cantilever beam
- Generalized coordinates only at the end nodes → Guyan-reduction → efficient time integration
- S-bump internally handled

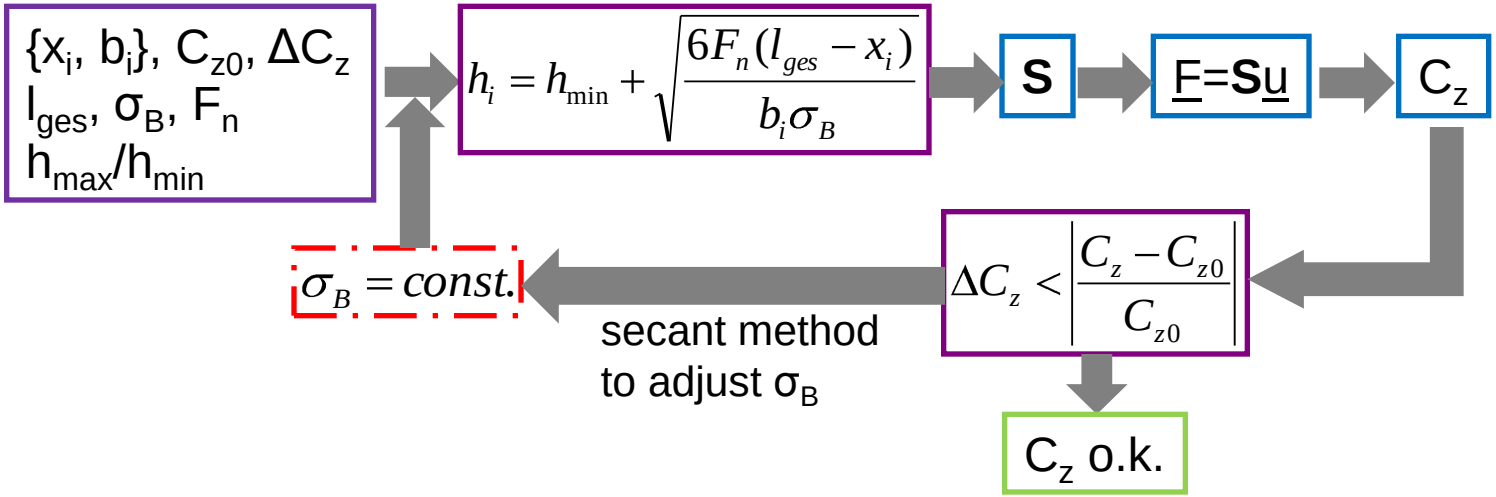


„Massless“-model

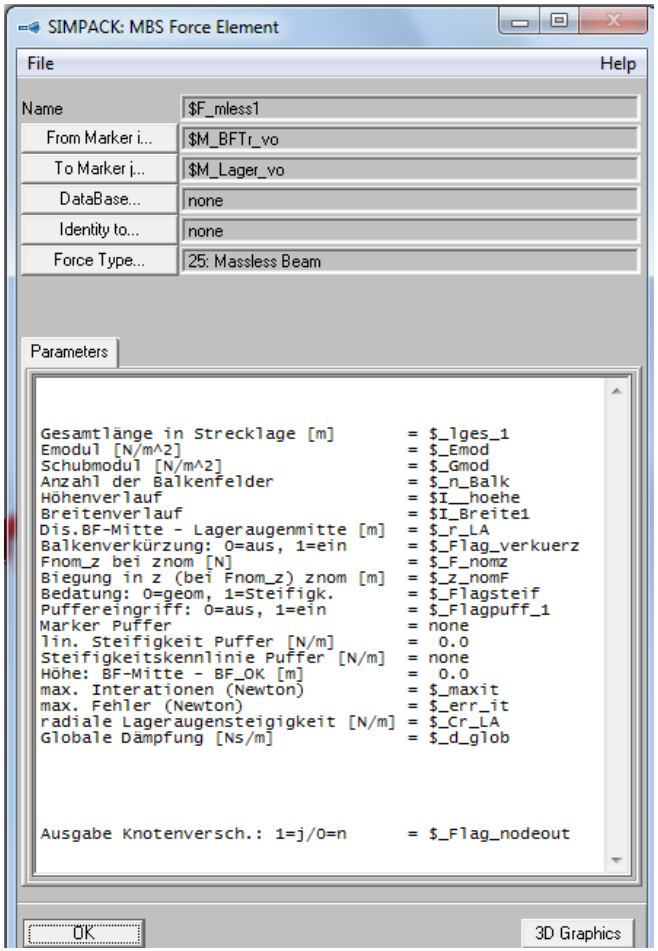
- Data-input process
  - Geometry-based



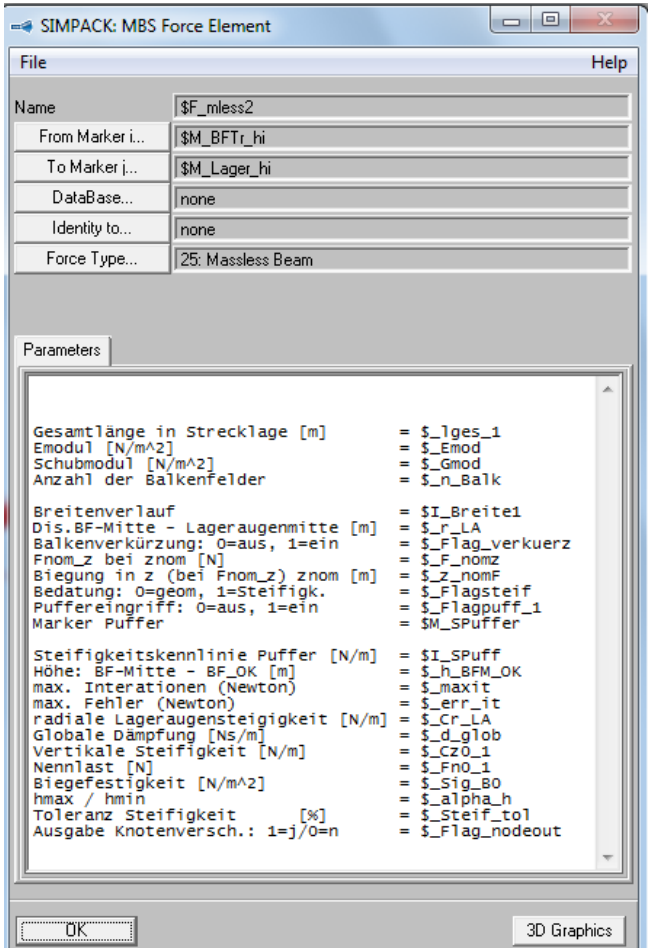
  - Stiffness-based
    - Iterative process
    - Assumption: bending stress (σ_B) is constant over the cantilever beam



„Massless“-model in SIMPACK



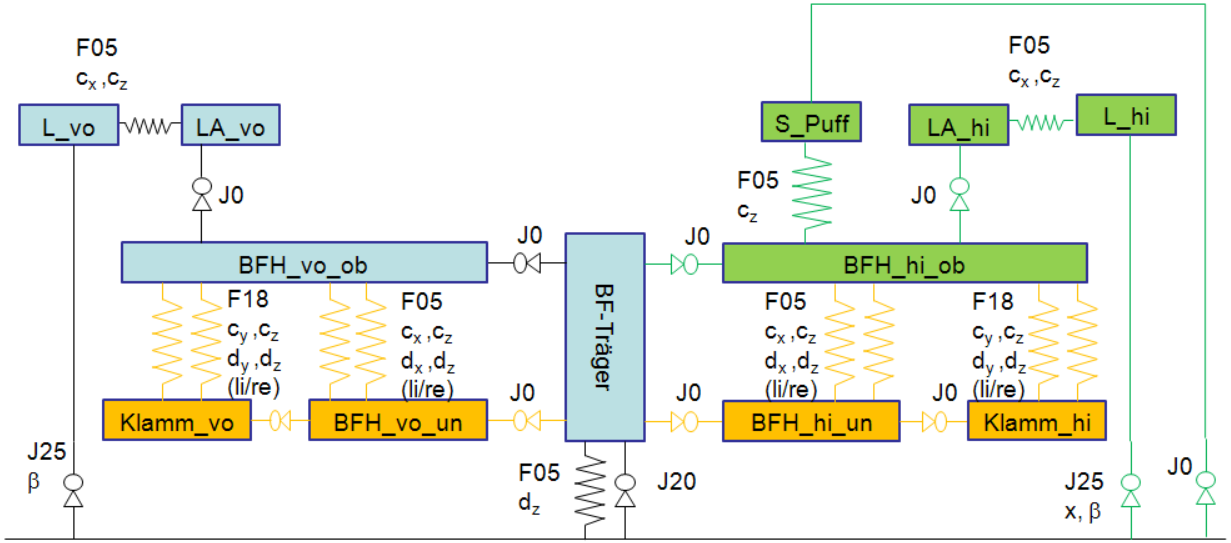
Input data based on geometry, without S-bump



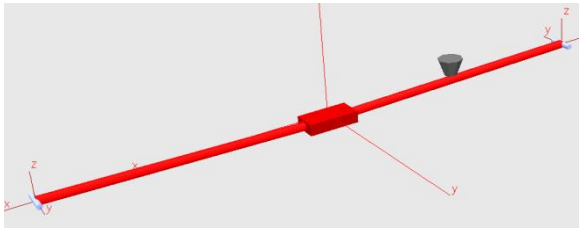
Input data based on stiffness, with S-bump

SIMBEAM-model

- A cantilever beam for each leaf spring halves
- Considered modes:
  - First 2 bending modes in vertical direction
  - First bending mode in lateral direction
  - First torsional mode
- Geometric stiffness (coupling x-z)
- More leaf spring layers can also be modelled

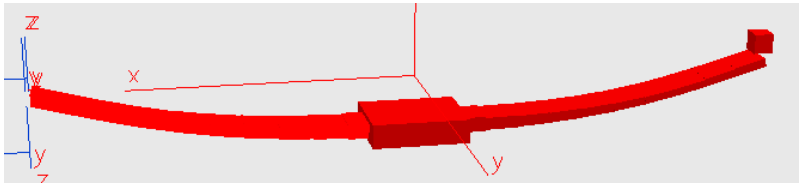


„Massless“-model vs. SIMBEAM-model



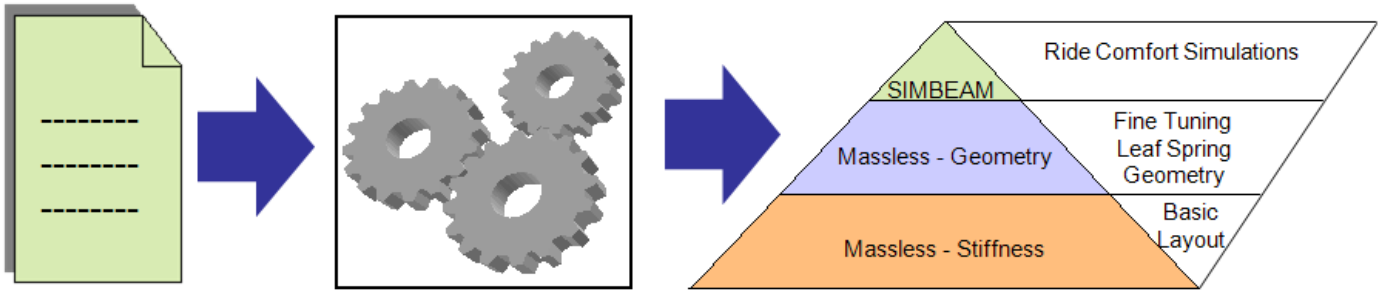
- Only one layer is considered
- Input:
  1. Geometry
  2. Stiffness
- Force element
- No structural dynamics

Masless-Model

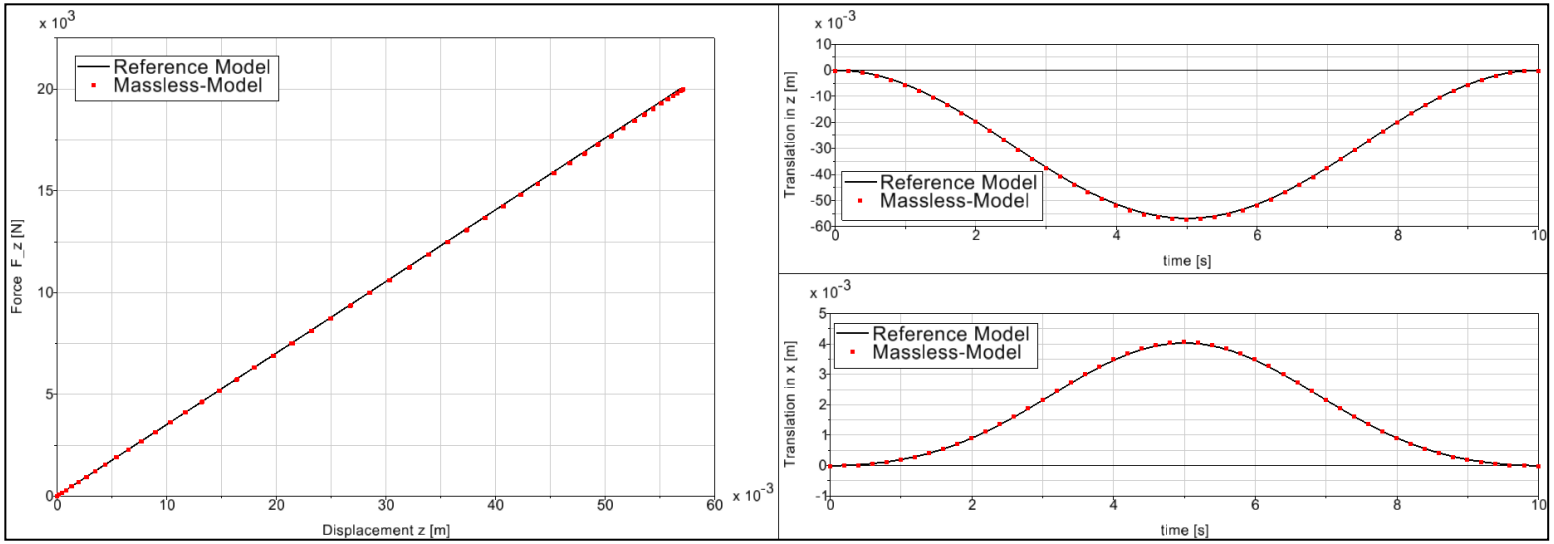


SIMBEAM-Model

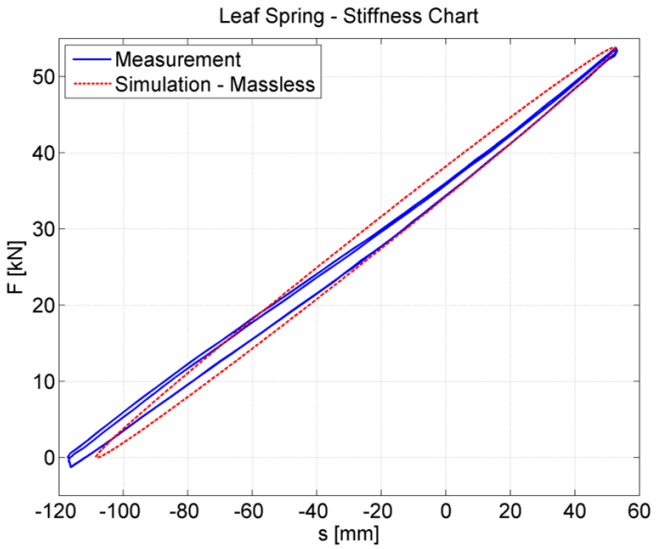
- One or more layers can be considered
- Input:
  1. Geometry
- Elastic body
- Structural dynamics



Comparison „Massless“- SIMBEAM-Modell



Validation with test-rig measurements at MAN



More about validation:

Müller et al: *„A New Massless Leaf Spring Model and Its Application in The Simulation of Heavy Commercial Vehicles“*, IAVSD 2011

Modeling concept

General data

material properties
E,G

position markers
-from, to
-S-Bump

mass, inertia
- bearing eye
- axle beam

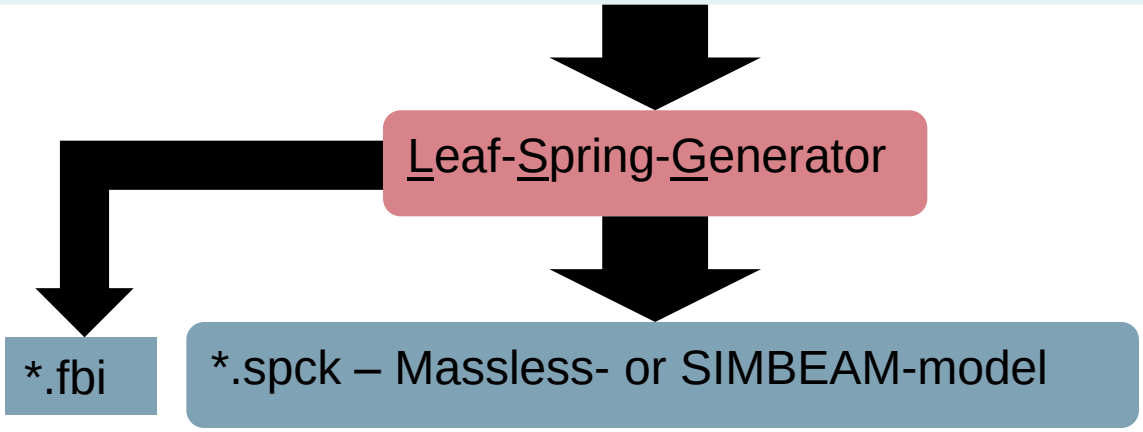
stiffness-chart
- S-bump

Data – leaf-spring generation

geometry
$\{x_i, h_i, b_i\}$

vertical stiffness
$C_z, \Delta C_z$

Input-data steering file

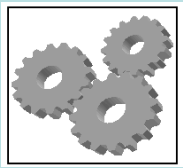


Functionality

ASCII Steering File

```
Datei  Bearbeiten  Format  Ansicht  ?
! Flags

Flag_SID                = 0             ! 0=Massless, 1=SIMBEAM
Flag_Steif              = 1             ! Bedatung nach 0=Geometrie, 1=Steifigkeit
Flag_SPuffer            = 1             ! S-Schlagpuffer 1=existiert, 0=nicht existiert

!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
! Federlagen und Federhaelften

n_FLage                 = 1             ! Anzahl der Federlagen
n_FHaelfte/Lage         = 2             ! Anzahl der Federhaelften pro Federlage

!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
! Daten - Geom
! mk_to - lges
mk_to_vo_1_x            = 1.0           ! to Marker x-Koord., vorne, BFL #1
mk_to_vo_1_y            = 0.0           ! to Marker y-Koord., vorne, BFL #1
mk_to_vo_1_z            = 0.0           ! to Marker z-Koord., vorne, BFL #1
l_ges_vo                = 0.91          ! Gesamtlaenge der BFH, vorne, BFL #1

mk_to_hi_1_x            = -1.0          ! to Marker x-Koord., hinten, BFL #1
mk_to_hi_1_y            = 0.0           ! to Marker y-Koord., hinten, BFL #1
mk_to_hi_1_z            = 0.0           ! to Marker z-Koord., hinten, BFL #1
l_ges_hi                = 0.91          ! Gesamtlaenge der BFH, hinten, BFL #1

! Global Geom
w_BFTrh                 = 0.09          ! Halbe Breite des BF-Traegers
r_LA_vo                 = 0.02          ! Lageraugenradius - vorne
r_LA_hi                 = 0.02          ! Lageraugenradius - hinten

! S-Puffer
mk_SPuff_x              = -0.5          ! x-Koordinate S-Schlagpuffer
mk_SPuff_y              = 0.0           ! y-Koordinate S-Schlagpuffer
mk_SPuff_z              = 0.01          ! z-Koordinate S-Schlagpuffer

! END
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
! Daten - Masse
! Blattfeder-Gesamtmasse
m_BF                    = 30.0          ! Masse des Gesamtmodells
! Lager
m_L_vo                  = 1.0e-6        ! Masse Lager vorne
Ix_L_vo                 = 1.0e-6        ! I_x Lager vorne
Iy_L_vo                 = 1.0e-6        ! I_y Lager vorne
Iz_L_vo                 = 1.0e-6        ! I_z Lager vorne

m_L_hi                  = 1.0e-6        ! Masse Lager hinten
Ix_L_hi                 = 1.0e-6        ! I_x Lager hinten
Iy_L_hi                 = 1.0e-6        ! I_y Lager hinten
```

LSG

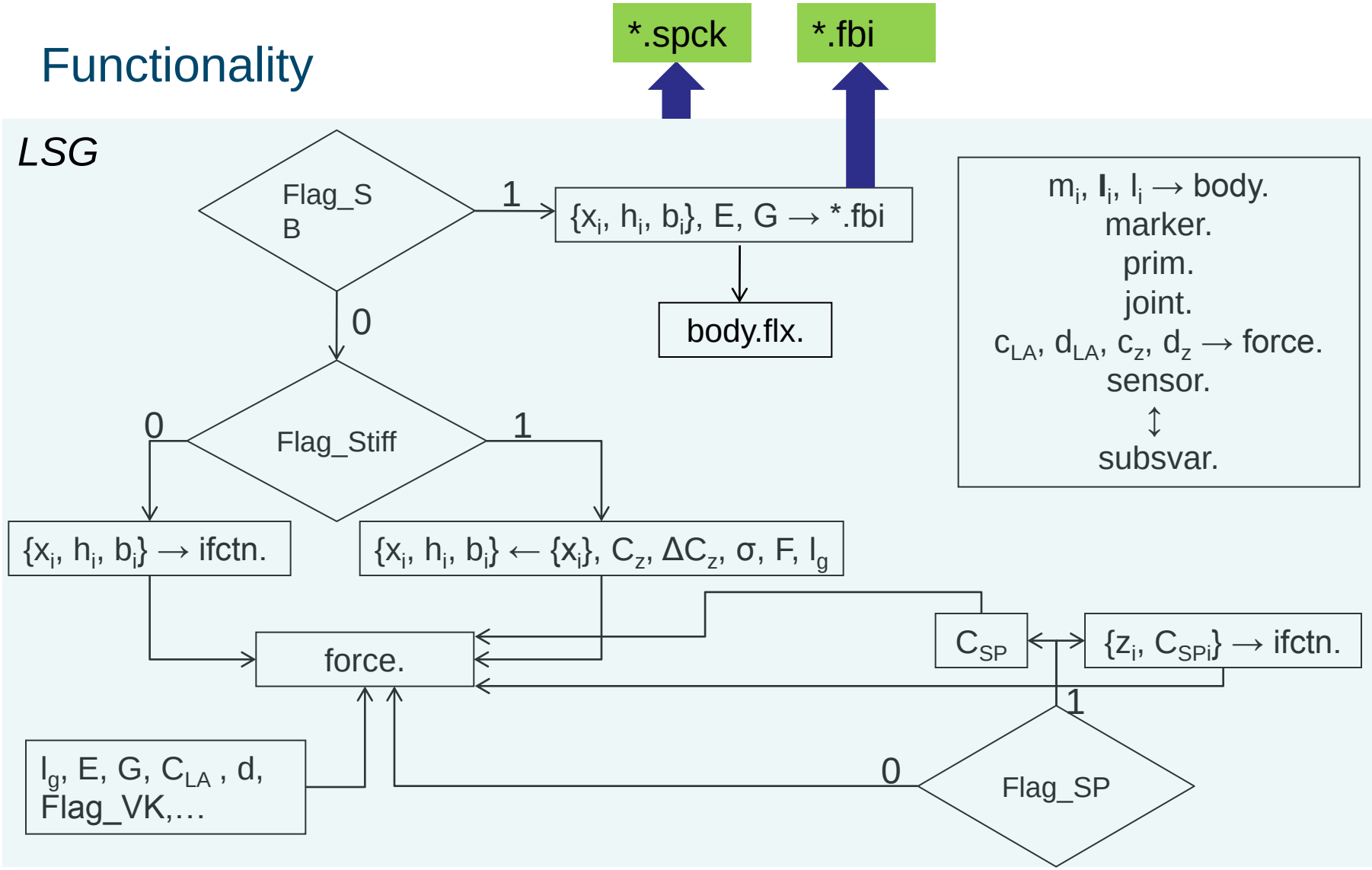


*.spck

```
Datei  Bearbeiten  Format  Ansicht  ?
prop2d.grid.vert.step                                   = 1.0000000000000000E+001 ! Vertical step
prop2d.line.width                                       = 0                       ! Line width
prop2d.proj.dir                                         = 1                       ! Projection directio
!********************************************************************
! Substructures
!********************************************************************
!********************************************************************
! Input Function Sets
!********************************************************************

!********************************************************************
! Reference systems
!********************************************************************
refsys.type (                   $B_Isys                 ) = 1                     ! Type

marker.type (                   $M_Isys                 ) = 1                     ! Type
marker.parent (                 $M_Isys                 ) = $B_Isys               ! Reference system

marker.type (                   $M_Isys_Lager_vo        ) = 1                     ! Type
marker.parent (                 $M_Isys_Lager_vo        ) = $B_Isys               ! Reference system
marker.pos (            1 ,     $M_Isys_Lager_vo        ) = $_rx_Lager_vo         ! Position
marker.pos (            2 ,     $M_Isys_Lager_vo        ) = $_ry_Lager_vo         ! Position
marker.pos (            3 ,     $M_Isys_Lager_vo        ) = $_rz_Lager_vo         ! Position

marker.type (                   $M_Isys_BFTr            ) = 1                     ! Type
marker.parent (                 $M_Isys_BFTr            ) = $B_Isys               ! Reference system
marker.pos (            1 ,     $M_Isys_BFTr            ) = $_rx_BFTr             ! Position
marker.pos (            2 ,     $M_Isys_BFTr            ) = $_ry_BFTr             ! Position
marker.pos (            3 ,     $M_Isys_BFTr            ) = $_rz_BFTr             ! Position

marker.type (                   $M_Isys_Lager_hi        ) = 2                     ! Type
marker.parent (                 $M_Isys_Lager_hi        ) = $B_Isys               ! Reference system
marker.pos (            1 ,     $M_Isys_Lager_hi        ) = $_rx_Lager_hi         ! Position
marker.pos (            2 ,     $M_Isys_Lager_hi        ) = $_ry_Lager_hi         ! Position
marker.pos (            3 ,     $M_Isys_Lager_hi        ) = $_rz_Lager_hi         ! Position
marker.ang (            1 ,     $M_Isys_Lager_hi        ) = { 0 deg }             ! Angles
marker.ang (            2 ,     $M_Isys_Lager_hi        ) = { 0 deg }             ! Angles
marker.ang (            3 ,     $M_Isys_Lager_hi        ) = { 180 deg }           ! Angles

marker.type (                   $M_Isys_SPuffer         ) = 1                     ! Type
marker.parent (                 $M_Isys_SPuffer         ) = $B_Isys               ! Reference system
marker.pos (            1 ,     $M_Isys_SPuffer         ) = $_rx_SPuffer          ! Position
marker.pos (            2 ,     $M_Isys_SPuffer         ) = $_ry_SPuffer          ! Position
marker.pos (            3 ,     $M_Isys_SPuffer         ) = $_rz_SPuffer          ! Position

marker.type (                   $M_BFTr_PtP             ) = -80                   ! Type
marker.parent (                 $M_BFTr_PtP             ) = $B_Isys               ! Reference system
marker.par (            2 ,     $M_BFTr_PtP             ) = 2.0000000000000000E+000 ! [-] Point-to-point
marker.par (            3 ,     $M_BFTr_PtP             ) = $M_BFTr_vo            ! [-] From-Marker
```

*.fbi

Functionality



- Standardized and unique leaf spring modelling for the different simulation phases
  - „Massless“-model – stiffness-based → basic layout
  - „Massless“-model – geometry-based → fine tuning leaf spring geometry
  - SIMBEAM-model → ride comfort simulation
  - Good correlation with test-rig measurements
- Leaf-Spring-Generator
  - Flexible parameterization for all model levels
  - Steering-file in ASCII-format
  - Automatized model generation

Have a good time at SIMPACK Usermeeting 2011

Questions?

virtual vehicle

…bringing the parts together.

The authors would like to acknowledge the financial support of the "COMET K2 - Competence Centres for Excellent Technologies Programme" of the Austrian Federal Ministry for Transport, Innovation and Technology (BMVIT), the Austrian Federal Ministry of Economy, Family and Youth (BMWFJ), the Austrian Research Promotion Agency (FFG), the Province of Styria and the Styrian Business Promotion Agency (SFG) .

We would furthermore like to express our thanks to our supporting industrial and scientific project partners, namely MAN Truck & Bus AG, SIMPACK AG, Bundeswehr University of Munich and to the Graz University of Technology.

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