Validation and Verification of a Beam Model during the Development of an Aircraft Landing Gear

ACUM 2015

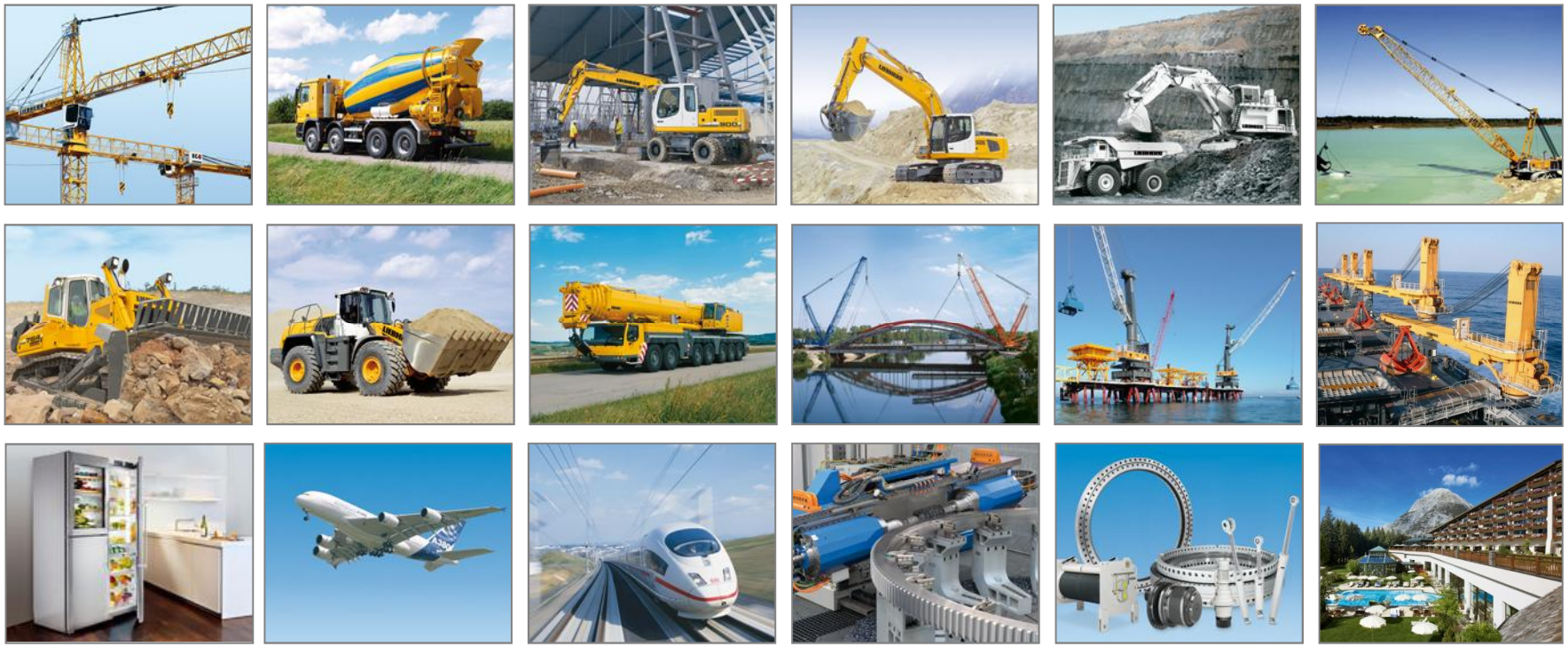
Björn Sudeck, Liebherr-Aerospace Lindenberg GmbH

Table of Contents

LIEBHERR

Liebherr Group

Multifaceted Product Range

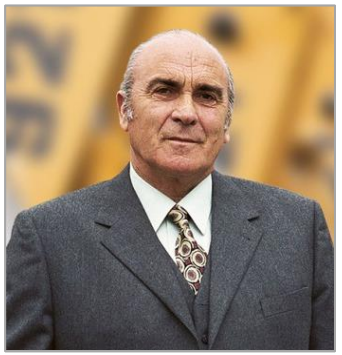


LIEBHERR

Liebherr Group

Liebherr Group

- Company founded in 1949 by Dr.-Ing. E.h. Hans Liebherr
- Over 130 companies worldwide
- More than 41,000 employees
- About € 9 billion turnover (2014)



Liebherr-Aerospace Lindenberg GmbH

- Site: Lindenberg im Allgäu
- More than 2,700 employees
- About € 600 million turnover
- Products:
  - Flight Control and Actuation Systems
  - Landing Gear Systems

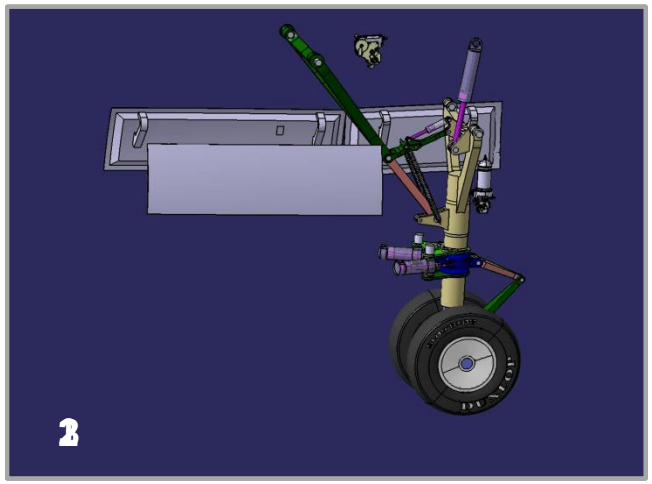
Liebherr-Aerospace site in Lindenberg

LIEBHERR

Landing Gears

Landing Gear System Requirements

- Manoeuvrability and stability during ground operation
- Actuation system to retract the shock struts during cruise
- Small installation space und low weight
- Energy absorption during landing impact
- High reliability in service and safety in Operation



Function of a Landing Gear

Bombardier Cseries during landing

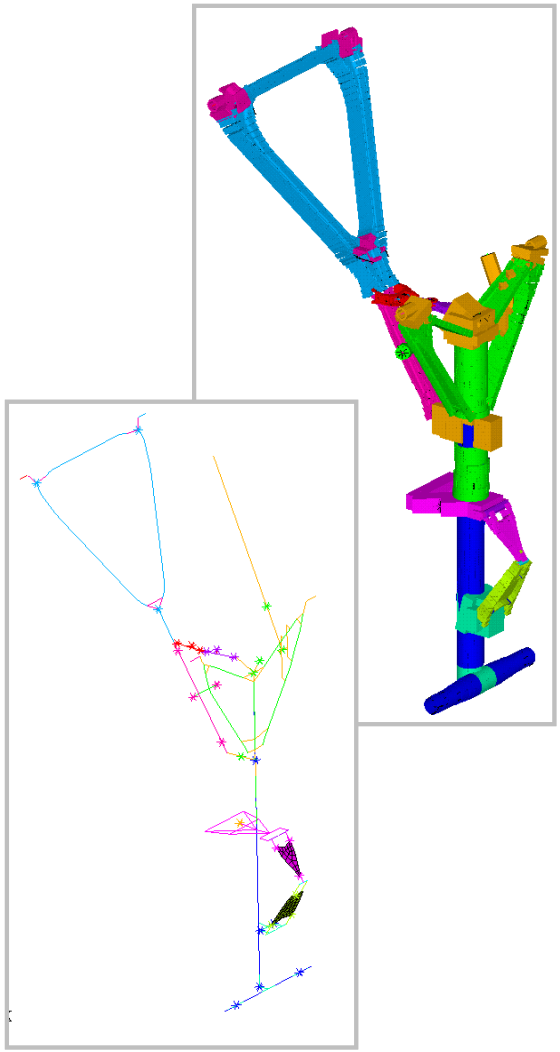
LIEBHERR

Beam Model: Introduction

- Beam Model is a very quick, stable and reliable tool with sufficient accuracy for section load calculation and dynamic analyses
- Established tool in aeronautics
- Delivered to aircraft manufacturer for Landing Gear integration

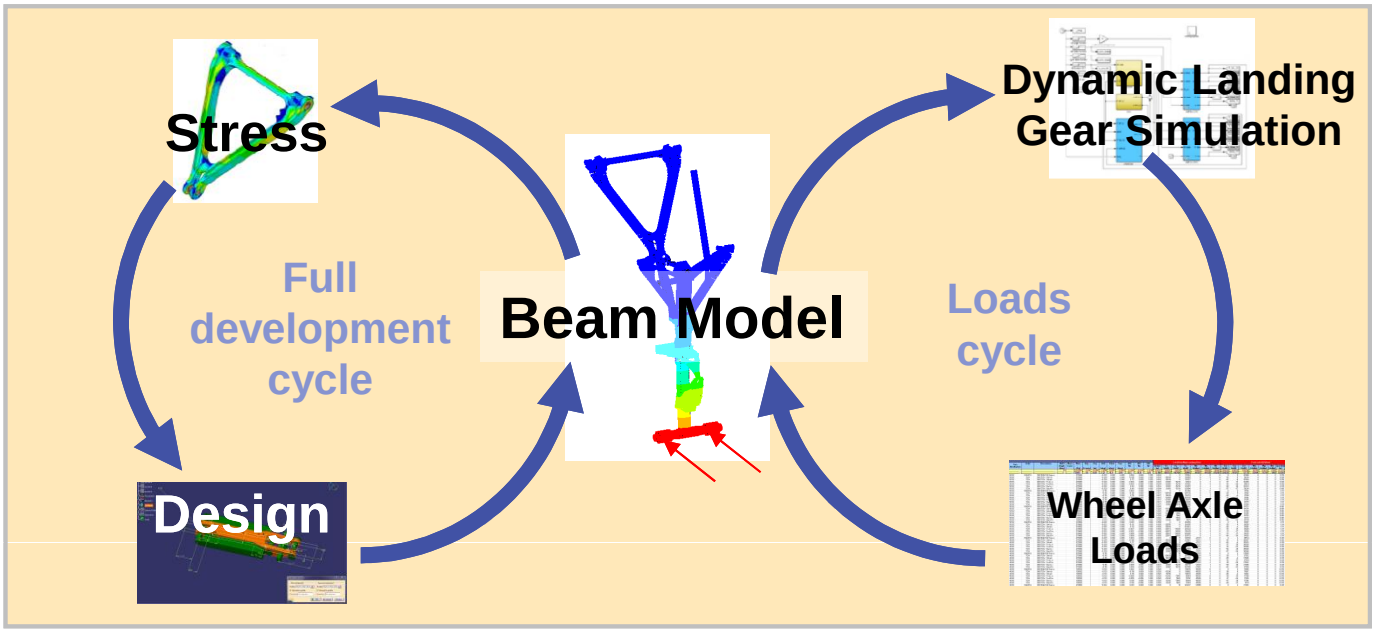
- Less than 10^3 elements
- Intuitive handling due to visualization of 3D beam cross sections
  - Ø One of the major reasons why ANSYS Mechanical APDL is the tool of choice

- Beam model matches the real Landing Gear mechanical behavior
  - Ø Stiffness
  - Ø Mass
  - Ø Modal behavior
  - Ø Load path distribution



LIEBHERR

Beam Model: Utilization

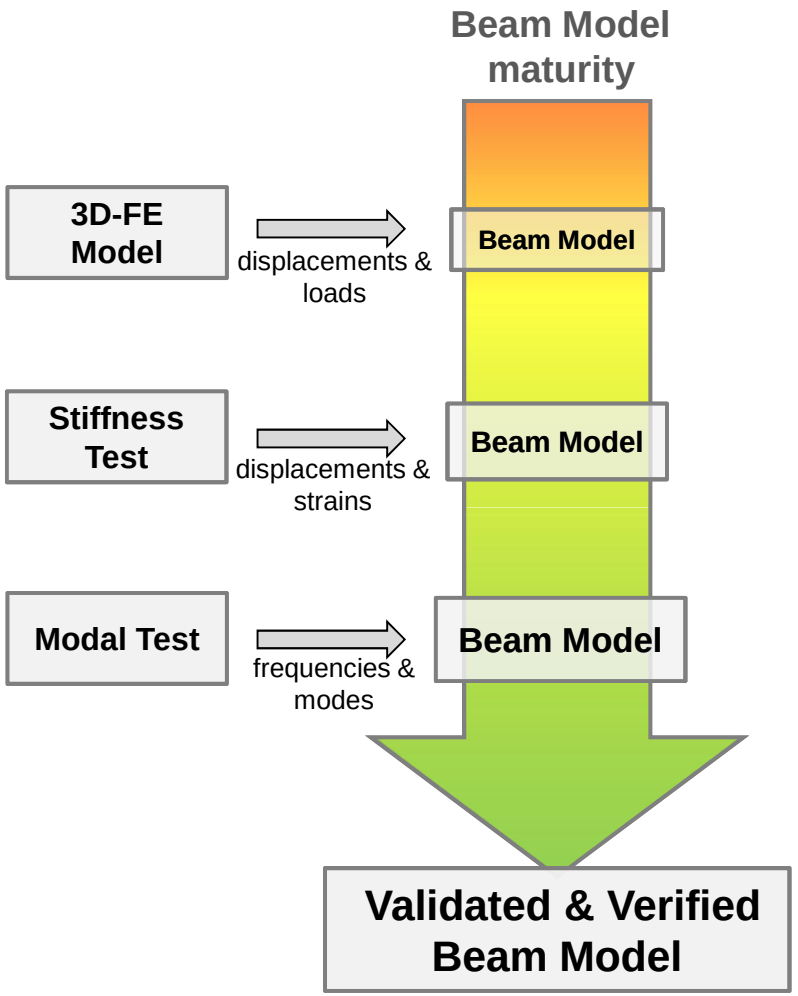


- Beam Model used for calculation of static and fatigue load cases
- Loads extraction (section forces and moments) at defined locations for analytical or component stress calculation
- Basis for dynamic analysis (vibration, shimmy etc.)
- Highly automated in spite of the high number of interface points

LIEBHERR

Validation & Verification (V&V): Overview

- Due to the prominent role of the beam model, a comprehensive validation and verification is essential
- Alignment of Beam Model and 3D-FE results is a proven and mature process
  - Ø Can be performed at every step in development process
  - Ø Stiffness and modal test are for validation purposes but prevalently do not lead to modifications
- The beam model can only be as precise as the data basis from test or simulation

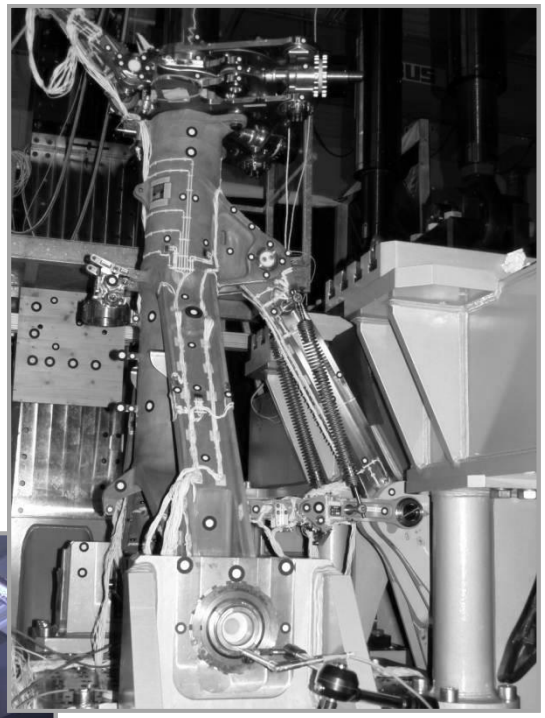


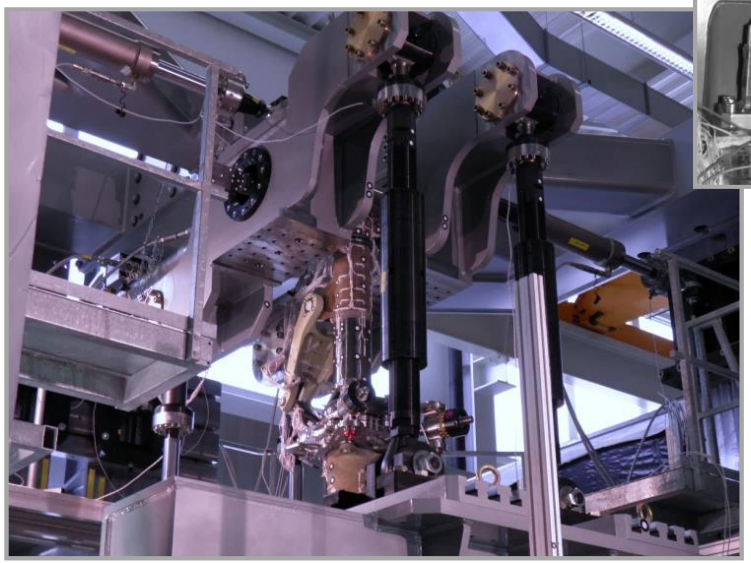
LIEBHERR

V&V: Stiffness Test

- Different shock absorber strokes
- Different unit load cases: fore/aft, lateral, torsional

- Displacements recorded at about 200 locations
- Strains recorded at hundreds positions

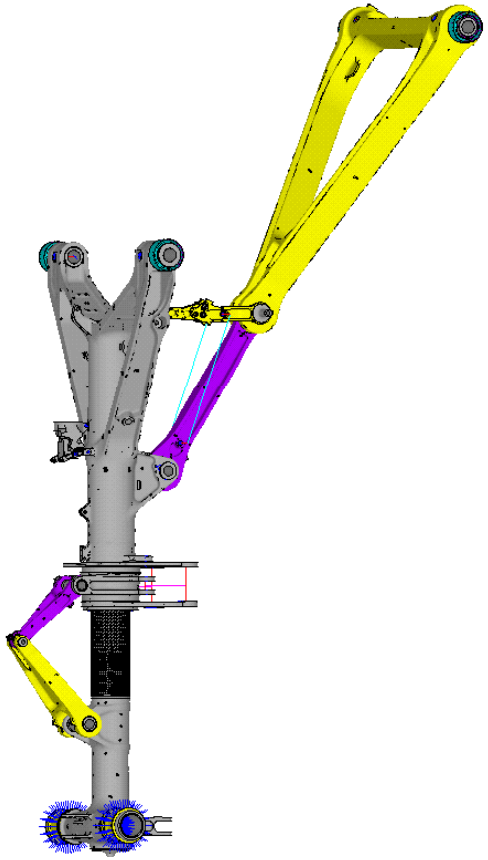




Strength test rig including landing gear from two perspectives

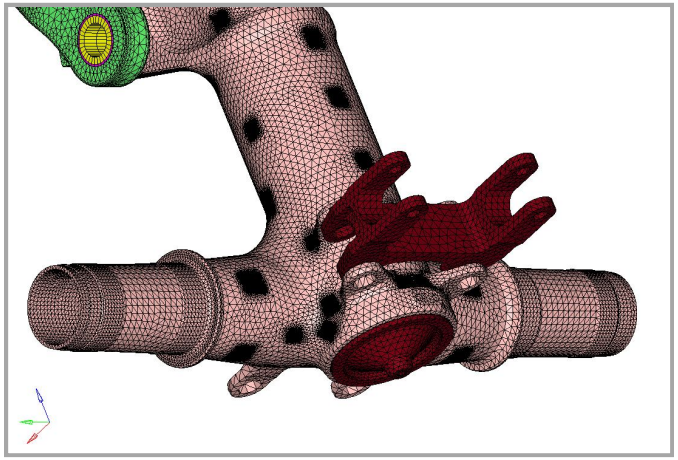
LIEBHERR

V&V: Validation with 3D-FE Model



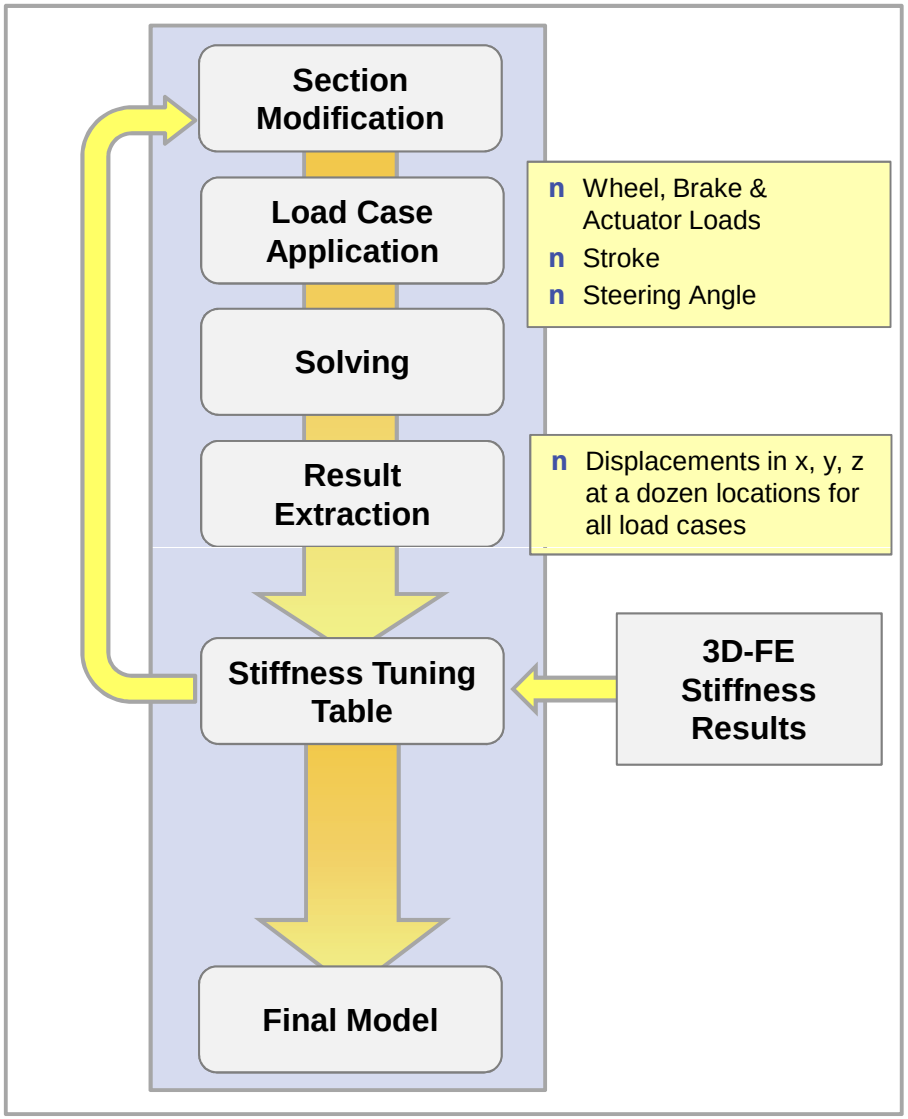
3D-FE Model

- Nonlinear 3D-FE model with
  - $12 \cdot 10^6$ DOF
  - All important structural parts included
  - Contact elements between components
  - Strain Gauges simulated in model
- Load extraction at defined cross sections
- Displacement measurement at positions defined by beam model nodes



LIEBHERR

V&V: Stiffness Tuning

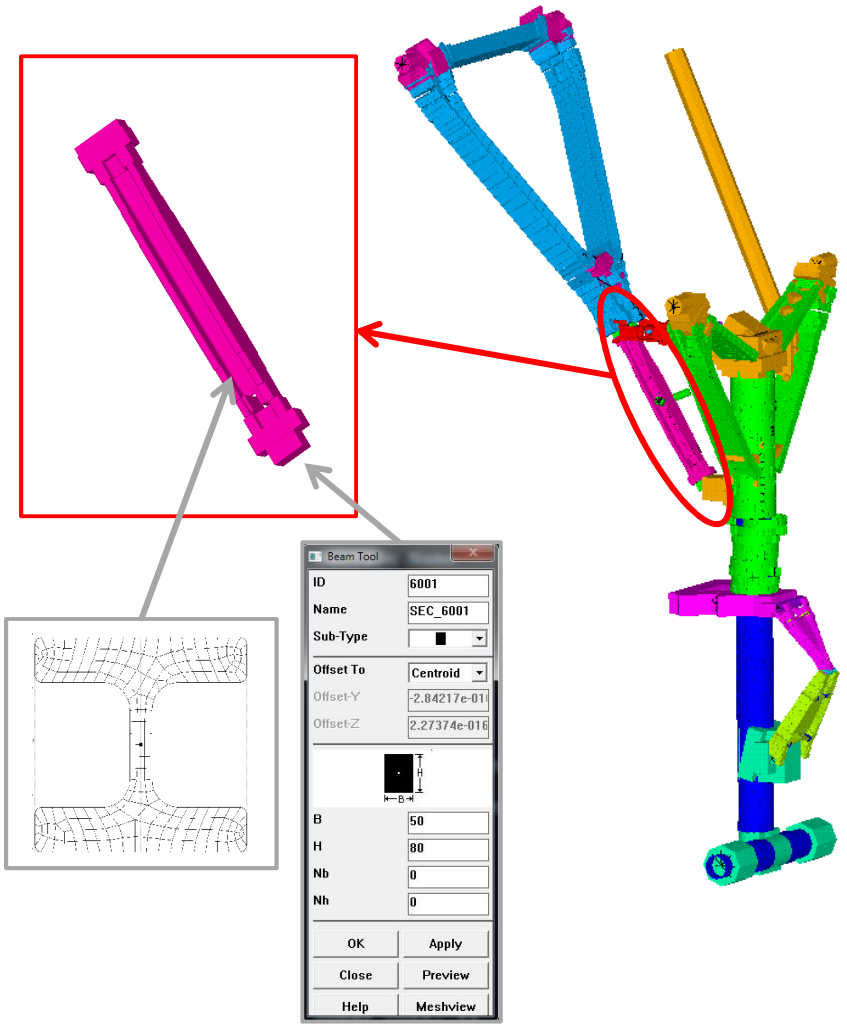


Stiffness Tuning

- 3D-FE or test as data basis
  - Ø Commonly validation by 3D-FE and verification through test
- Modification of the beam model's stiffness in order to match the stiffness behavior of the real landing gear
- Without tuning stiffness deviations may be unreasonable high
- A proper stiffness basis is required: Either from a test or a 3D-FE model

LIEBHERR

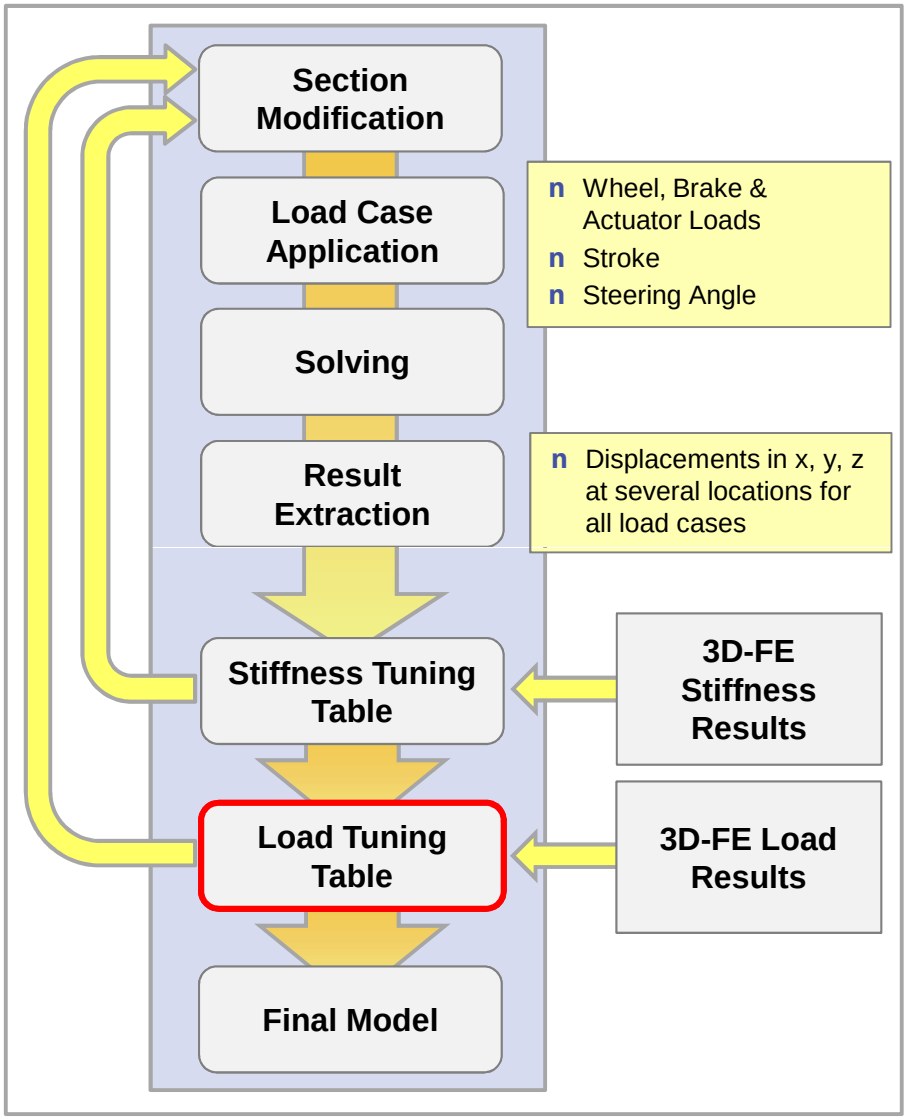
V&V: Stiffness Tuning (2)



- Stiffness Tuning process
  - Modify section dimensions until a specific target displacement value is reached
  - Check influence on displacements of different strokes and load cases
- APDL scripts available und utilized for Preprocessing, Solving and Postprocessing
- Fully automated optimization has been established

LIEBHERR

V&V: Load Tuning



Load Tuning

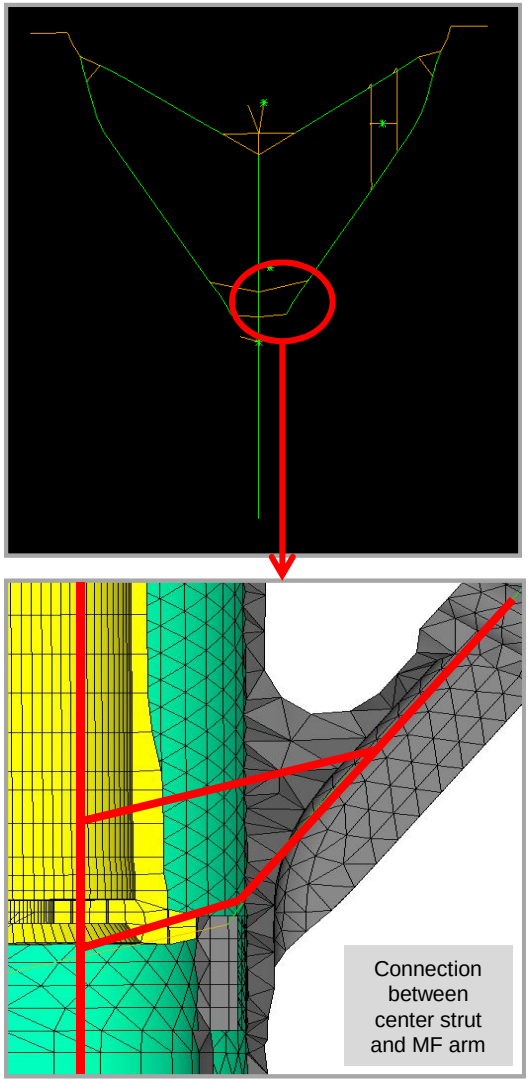
- Modification of the beam model's stiffness in order to match the load distribution of the real landing gear
- Load tuning is optional because the stiffness tuning provides an adequate accuracy
- Load tuning improves the accuracy of load path distribution which is the main purpose of the beam model
- A load basis for a load tuning can only be delivered by 3D-FE model

LIEBHERR

V&V: Load Tuning (2)

- Load tuning performed by modifying connections between substructures
- Individual section modification at each connection essential for load distribution
- However, the overall stiffness shall not be changed.

- Criteria for load comparison and assessment developed:
  - Only loads of considerable magnitude compared
  - $\frac{F_i}{F_{res}} > 60\% \; ; \; \frac{M_i}{M_{res}} > 60\%$
  - …

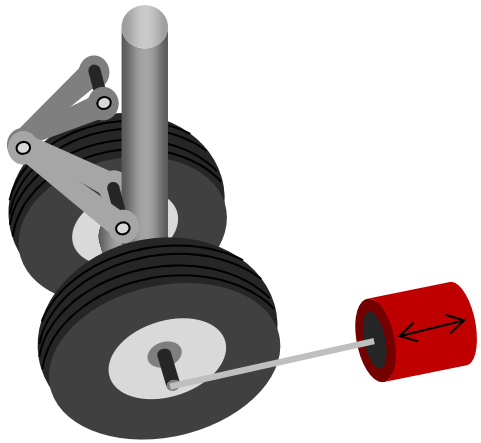


LIEBHERR

V&V: Modal Test & Tuning

Modal Test

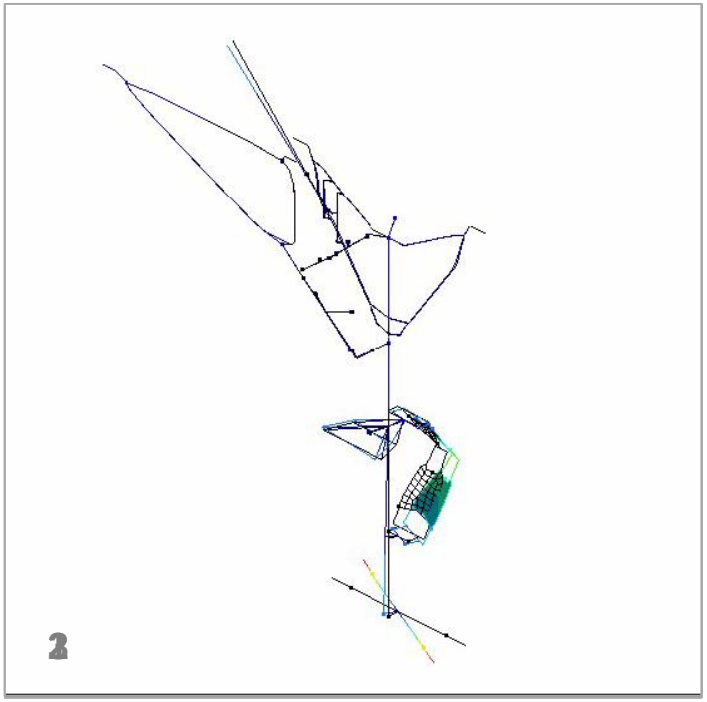
- Landing gear attached to aircraft prototype structure (aircraft on jacks)
- Landing gear fully equipped (wheels, hydraulic equipment and supply…)
- Load introduction at wheel axle in different directions
- Mode, frequency and damping is measured



Setup of modal test

Modal Analysis

- Beam Model attached to aircraft stiffness matrix (superelement)
- Hydraulic steering stiffness considered

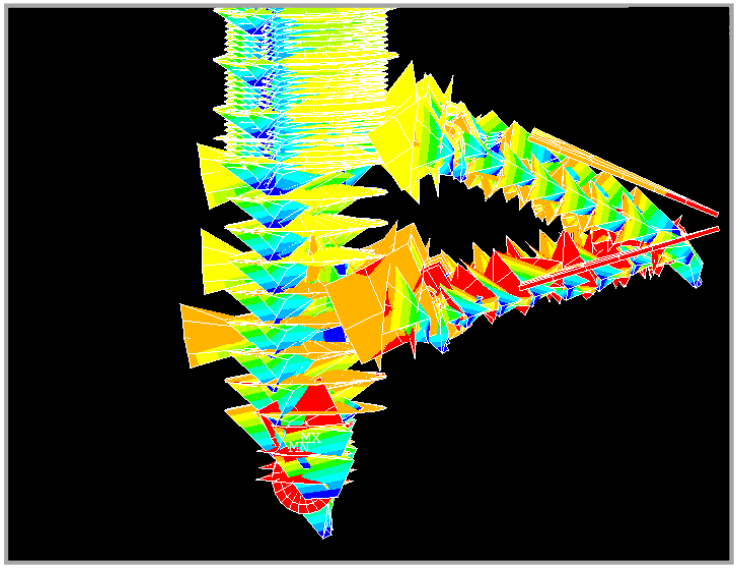


Typical Landing Gear mode shapes

LIEBHERR

Summary

- Beam Model is central tool in load calculation process during landing gear development
- Efficient due to small size, but resembles mass, stiffness and load distribution
- Beam Model is adapted to 3D-FE model in order to reach sufficient accuracy
  - Adaption process inevitable in order to reach sufficient accuracy
  - Stiffness Tuning
  - Load Tuning
- Several tests performed in order to verify the Beam Model



Miscarried Beam Model result displacement plot

LIEBHERR

Thank you for your attention

LIEBHERR

Copyright