FE-Application in Aircraft Structure Analysis

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Slides

FE-Applications in Aircraft Structure Analysis

Dr.-Ing. Matthias Hörmann, CADFEM GmbH
Intl. LS-DYNA Users Conference, Dearborn, June 9.-10. 2008
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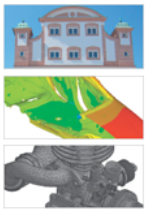

LSTC Livermore Software Technology Corp.

10th International LS-DYNA Users Conference

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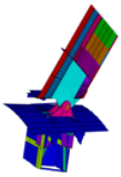
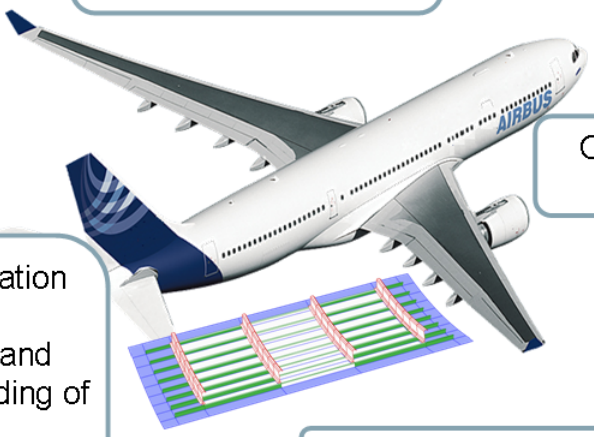
Selected Projects / Airbus

Accident Investigation
A300
2001 New York, AA587

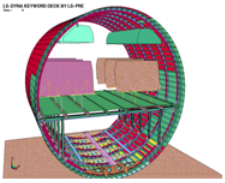
ANSYS

LS-DYNA





Crashworthiness
EU CRAHVI



Test-Rig Simulation
ViTAI
Compressive and shear stress loading of panels
Stability problems (buckling)

Delamination/Debonding

Tire Debris Impact

CADFEM

Selected Projects / Airbus

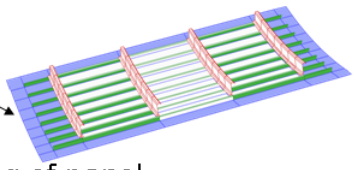
Structure Analysis

Software Tool ViTAL

Test-Rig Simulation

- Loads from
- Weight
- Manouvres
- Oscillations
- Inner pressure

Stiffened fuselage panel



- result in
- Compressive, shear stress and membrane loading of panel
- Stability problems (buckling)
- System collapse (load to be determined)

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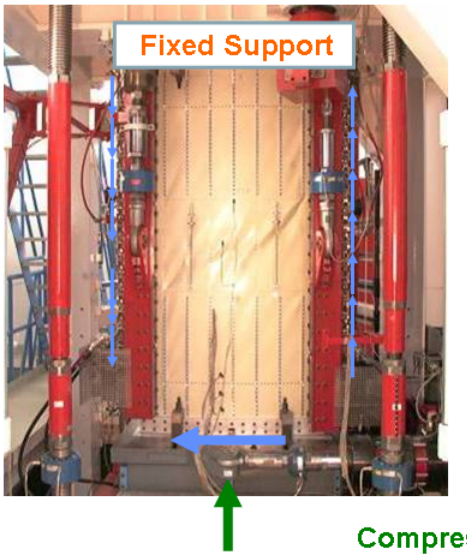
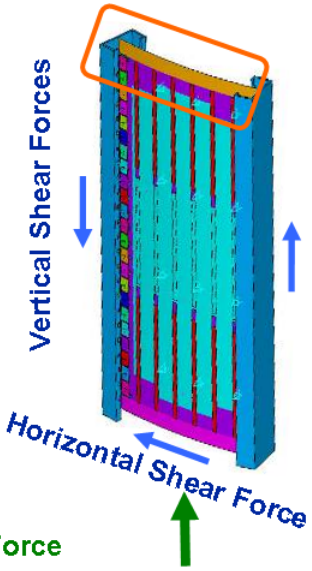
ViTAI

Shear - Compression Test-Rig Simulation

Airbus Deutschland Test Facility



FE Simulation of Panel in Test Rig



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ViTAI

ViTAI - Virtual Structural Test Analysis System

- ViTAI is a software tool created by CADFEM on behalf of AIRBUS
- Goal: ultimate load (maximum load carrying capacity)
  - Test rig set ups for Shear-compression test, frame bending test
  - Force controlled / displacement controlled
- Fully nonlinear analysis of thin-walled aircraft fuselage panels
- Parametric, automatic generation of models
  - User macros for geometry and material data / laminates
- Elaborate modeling and meshing options
- Open to customisation (new test rig set ups, geometries, bonding techniques, …)
- Graphical user interface for pre- and postprocessing
- ANSYS and LS-DYNA
- 2006 Airbus internal price awarded!

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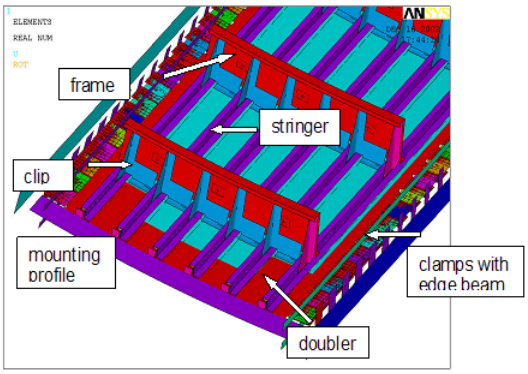
ViTAI

Panel Analysis with ViTAI

- Main components
  - Skin
  - Stringers (riveted, welded or bonded)
  - Frames
  - Clips connecting all parts (riveted)
- Construction principles like
  - Integrated frames
  - Cut outs
  - Pocketing
  - Doublers
- Materials
  - Aluminum
  - Layered Aluminum
  - Metal-fiber laminate (Glare®)
  - Composites (CRFP)



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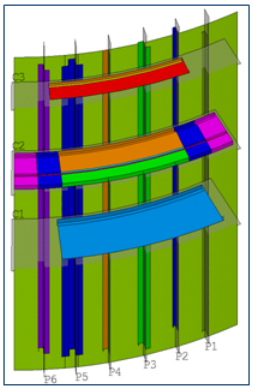
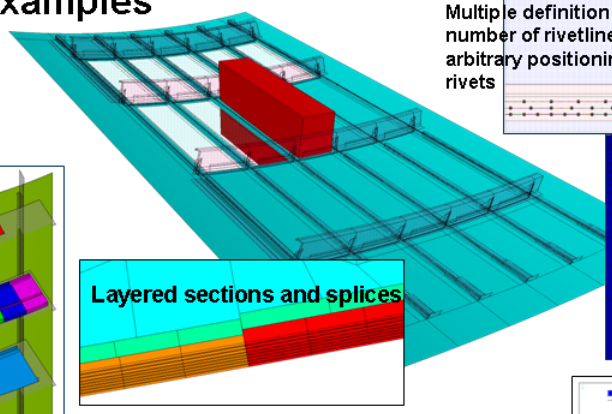
ViTAI

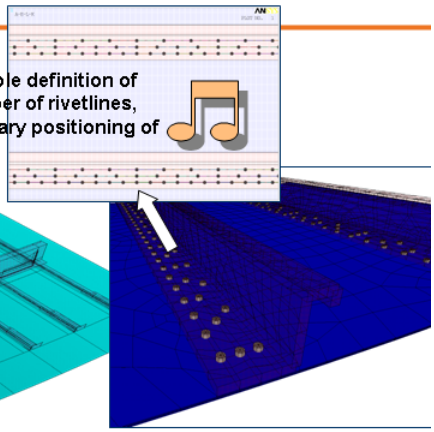
ViTAI – Examples

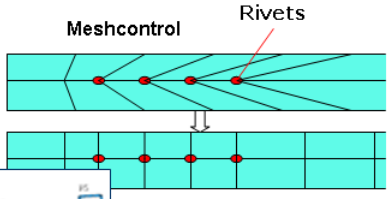
Variability of geometries and combinations (examples)

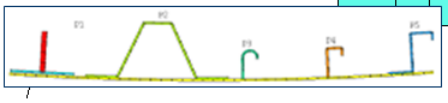


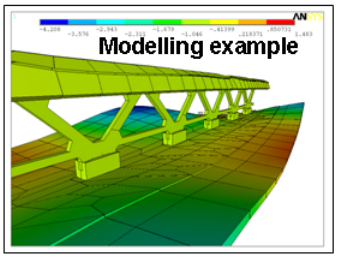


Multiple definition of number of rivetlines, arbitrary positioning of rivets









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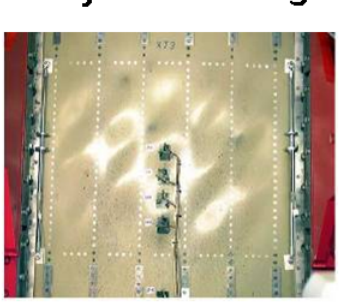
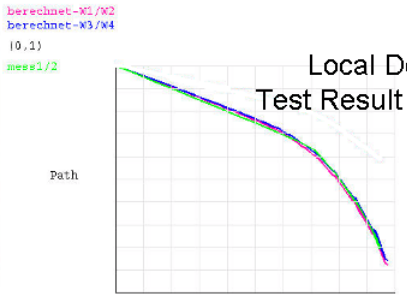
ViTAI

Panel Analysis / Test Rig Results

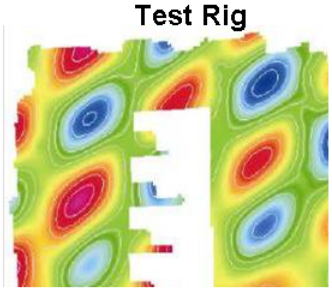


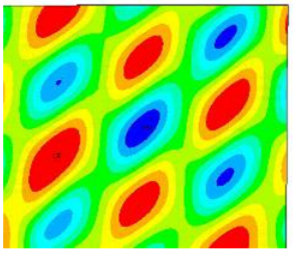


Local Deformations
Test Result vs. FE-Solution

Test Rig

ANSYS





Radial skin deformation

Radial skin deformation

CADFEM

ViTAI

ViTAI – Quasi Static Solution with Explicit Code LS-DYNA

Explicit means no iteration for equilibrium → no convergence problem

Quasi Static Solution

→ Increase of load in time has to ensure small inertia forces related to reaction forces

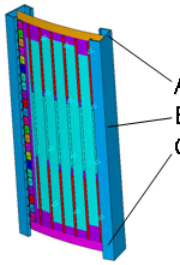
Simulation time range can be adjusted to reduce CPU time

→ check of kinetic energy necessary

reaches **post-buckling region → ultimate load** sure

Test Rig Simul. Results

Cross sections for resultant force output



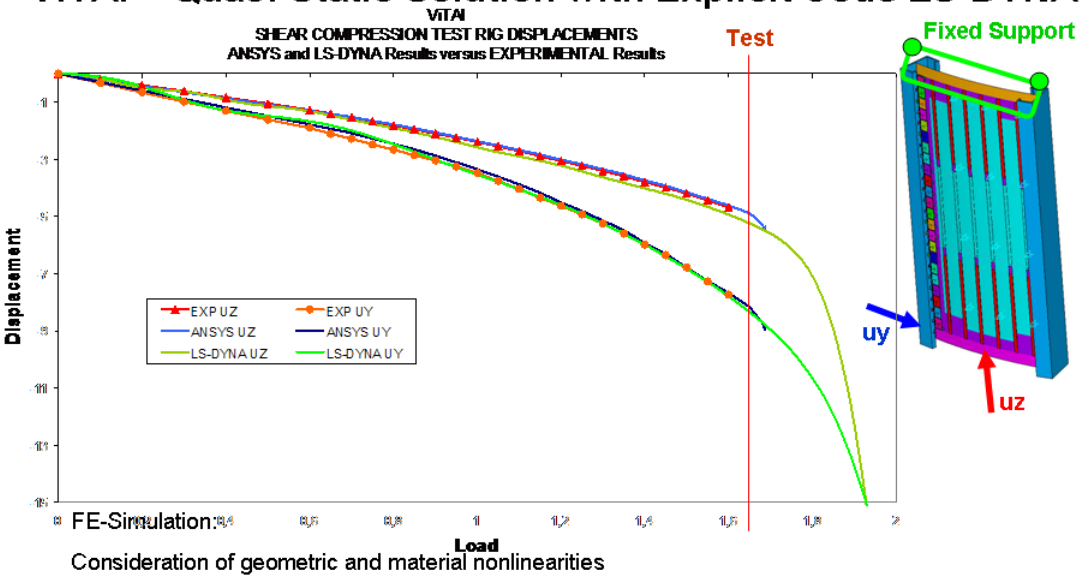
A load application
B mid cross section
C Clamped edge

Results are synchronous until limit-point

CADFEM

ViTAI

ViTAI – Quasi Static Solution with Explicit Code LS-DYNA



FE-Simulation:

Consideration of geometric and material nonlinearities

No failure criteria defined for joints (welds, rivets, …) ⟹ **implementation possible**, but dependend on availability of suitable experimental data

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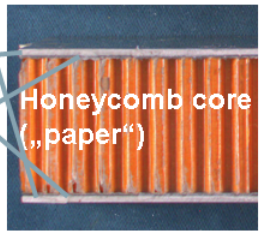
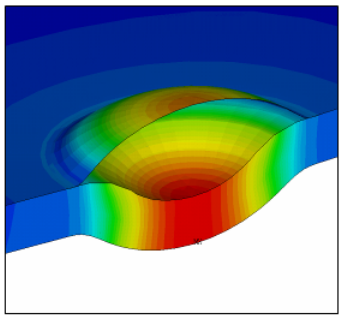
Delamination/Debonding

Sandwich Structure & Circular Face Sheet Delamination

Face sheet (CFRP)

Adhesive sealing





Which is the load level for face sheet delamination progress ?

Special Load Case:
Pressure Difference between Ground Level and Cruising Altitude

Increase of volume
→ decrease of pressure

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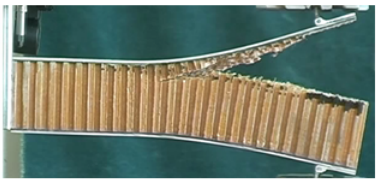
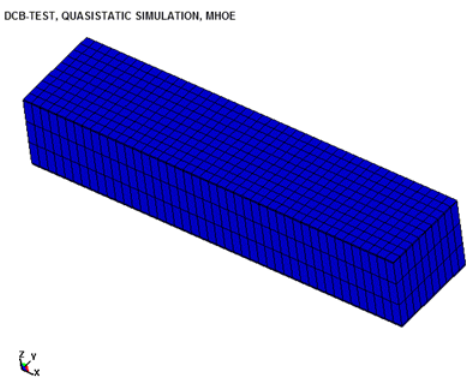
CADFEM

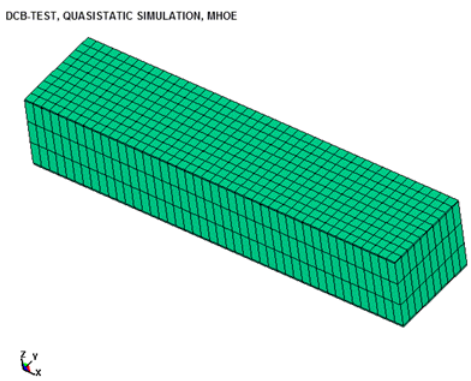
Delamination/Debonding



Resultant M_x-Moment



Resultant N_x-Force



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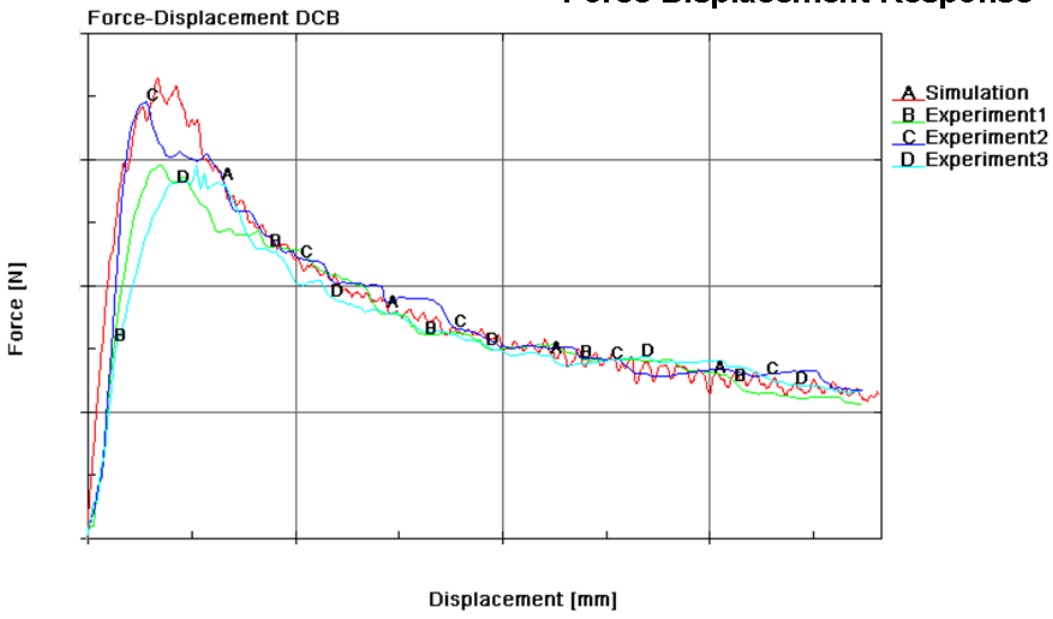
Delamination/Debonding

Force-Displacement-Response



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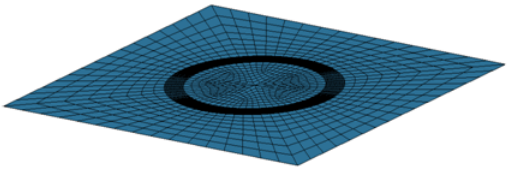
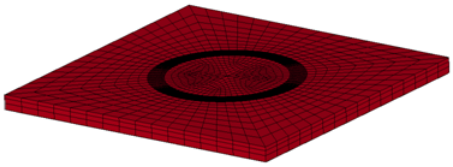
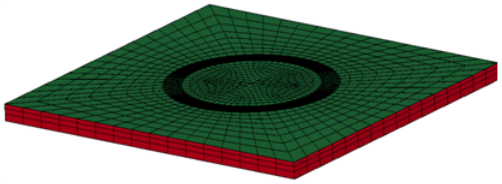
Delamination/Debonding



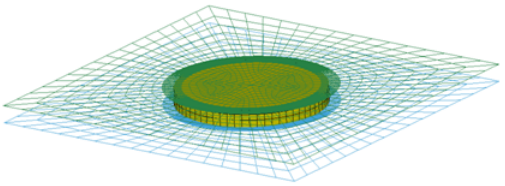
Bottom face layer (intact bonding)



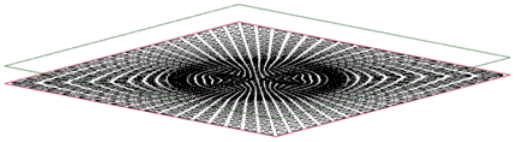
Core



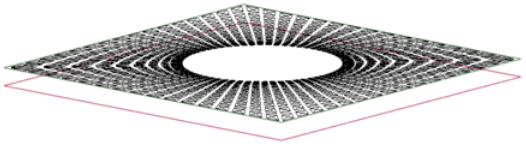
Top face layer with initially debonded zone



Inside airbag resp. control volume



Bonding of bottom face layer



Bonding of top face layer with initially debonded zone

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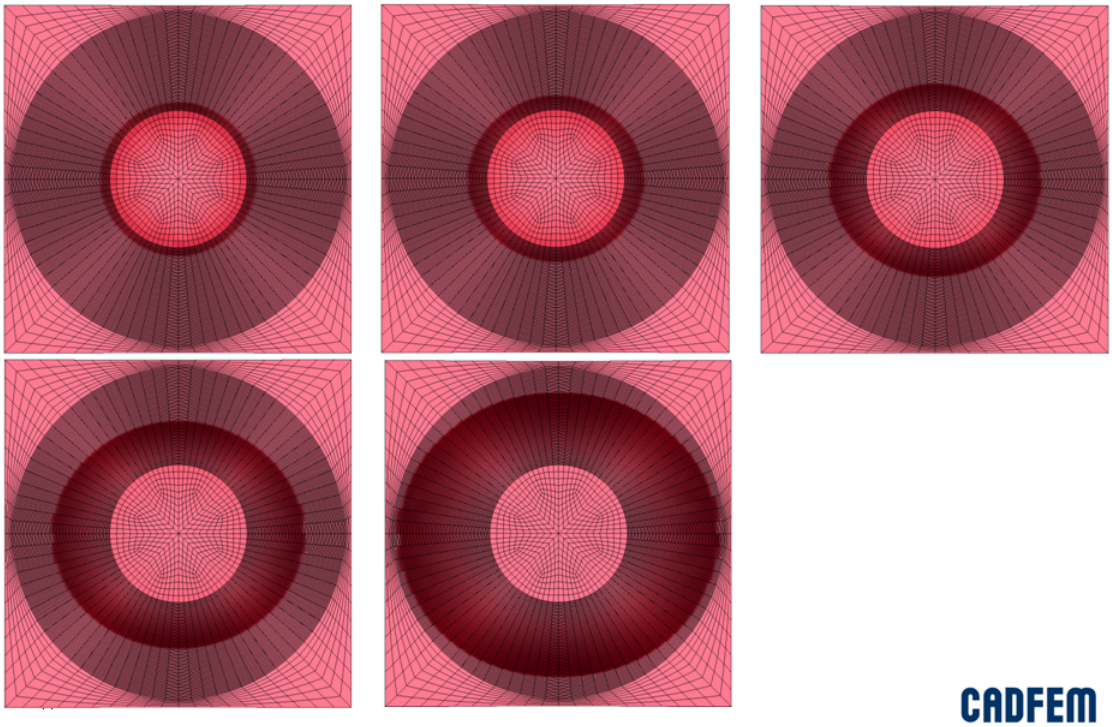
Delamination/Debonding



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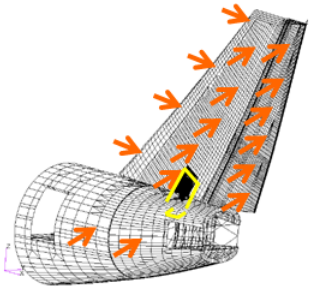
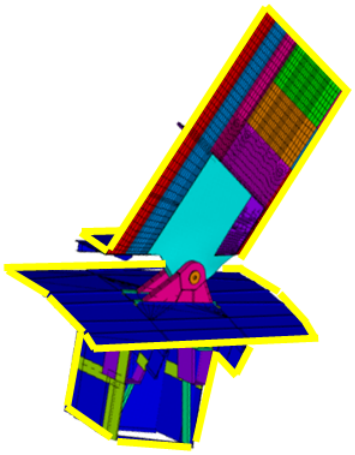
Vertical Tail Plane

Dimensioning and Implementation of Rupture Tests of
AIRBUS Vertical Tail Plane (VTP) Fittings



"2D linear global" model

Essential: Contact Modeling
→ Non-linear Analysis



Transfer NASTRAN results
to
ANSYS Submodel

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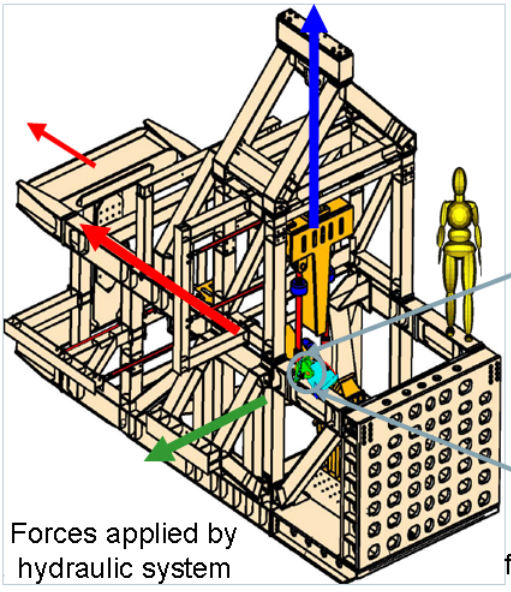
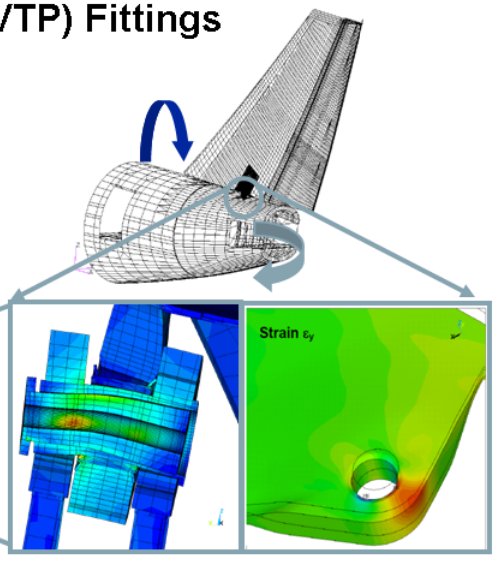
CADFEM

Vertical Tail Plane

Dimensioning and Implementation of Rupture Tests of
AIRBUS Vertical Tail Plane (VTP) Fittings



Forces applied by
hydraulic system



Generate deformation & strain distribution of
flight load case at test specimen around the lug

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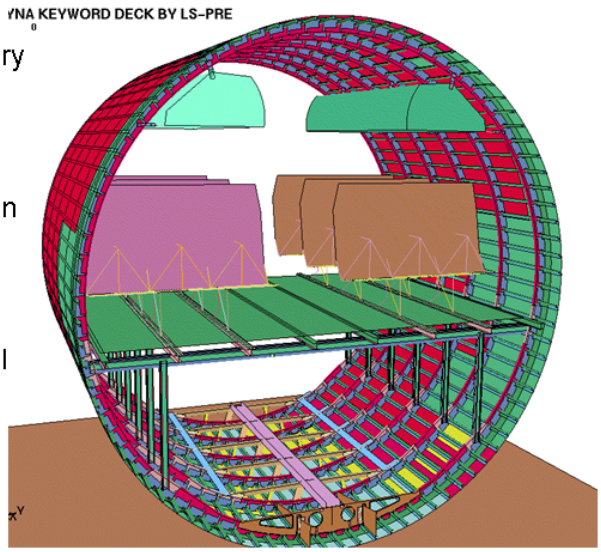
Crashworthiness Cross Section

Crashworthiness Simulation

- Purpose
  - Load interaction between primary structure and interiors
  - Load curves to be imposed on detailed hat rack models
  - Hat rack models and suspension concepts may be implemented
  - Model based on parametric model (DLR)
  - Comparison to composite barrel



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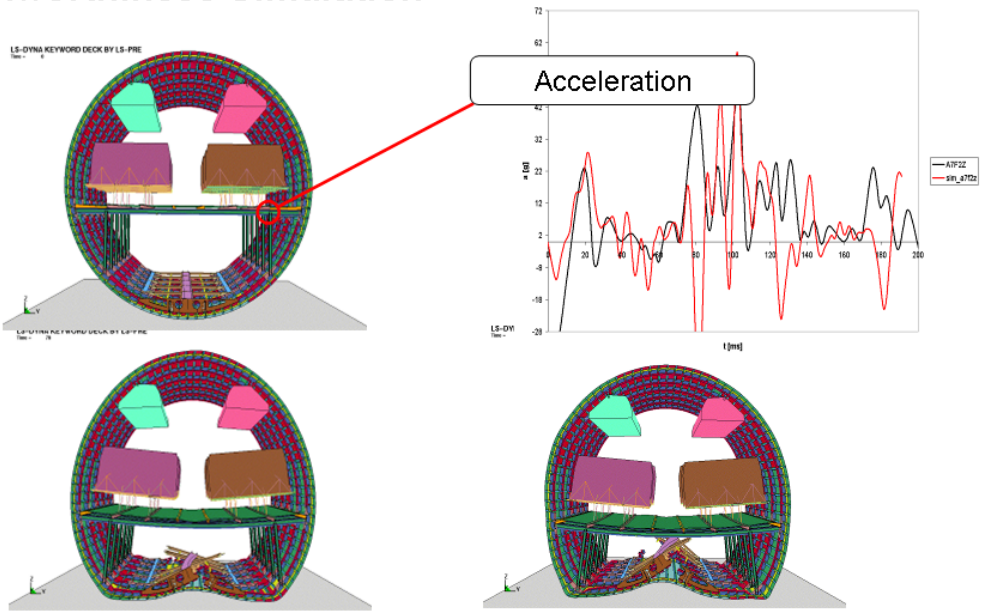
Crashworthiness Cross Section

Crashworthiness Simulation



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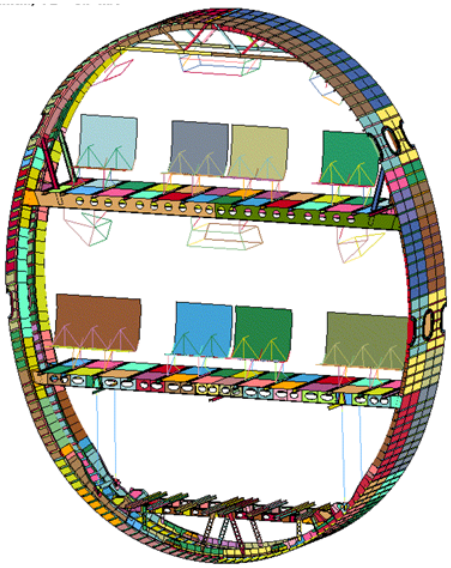
CADFEM

Crashworthiness Cross Section

Crashworthiness Simulation

- Modeling Aspects
  - Simplified passenger and seat model – validated by detailed model
  - Breakable rivets modeled with *MAT_SPOTWELD and *CONTACT_SPOTWELD
  - Discrete mass points represent hat rack mass – attached to fittings by joint definitions
  - …



Simplified modeling of aircraft interiors – focus on primary structure

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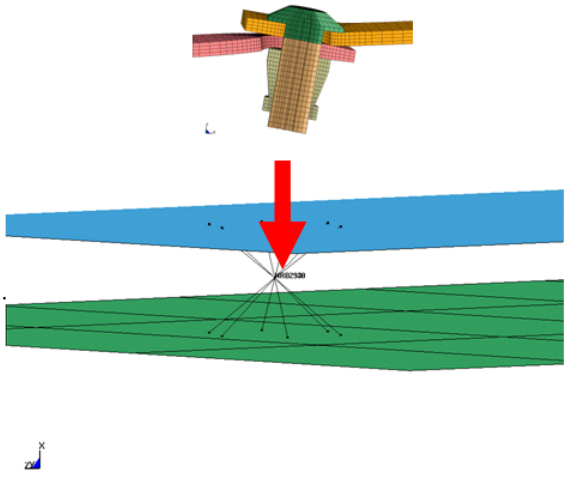
Crashworthiness Cross Section

Crashworthiness Simulation / Rivet Modeling

- Simplified model
  - Zero length discrete beams between sheets (mat68)
  - Constrained interpolation between discrete beam nodes and nodes tied to each shell midface -> introduction of moment
  - 3 translational and 3 rotational stiffness values and plasticity load vs. deflection curves in local coordinate system, tied to shells
  - Prestress possible – additional nonlinear elastic beam (mat67)
  - Rate dependency possible – define curve function
  - Axial and shear load interaction may be calibrated (curve_function)



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Rigid Pole Impact

Rigid Pole on Composite HTP

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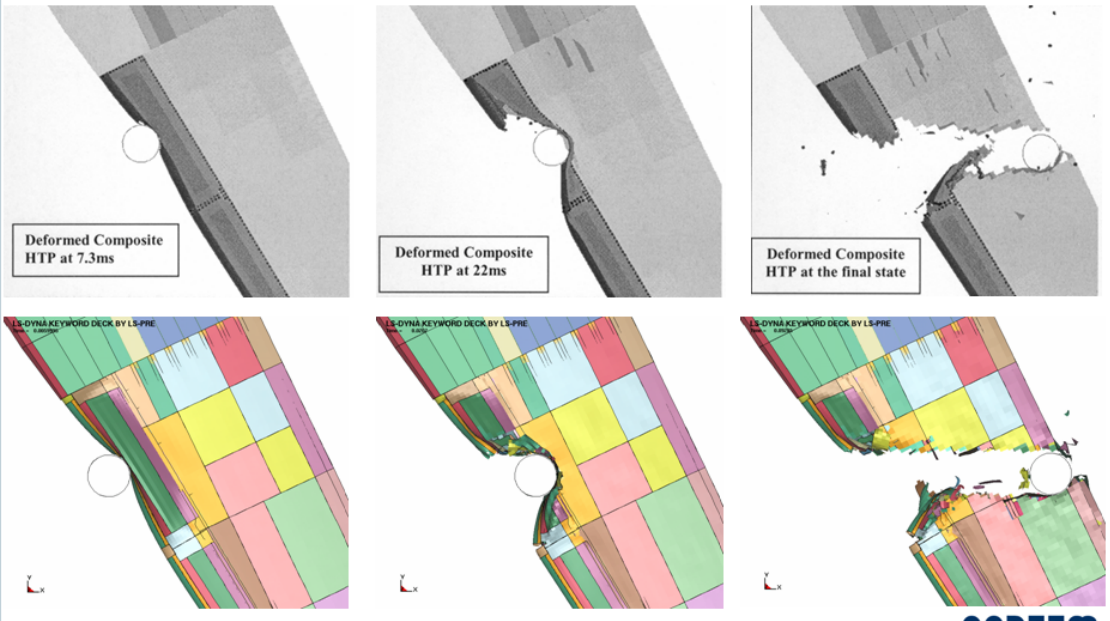
Rigid Pole Impact

Comparsion with other explicit FE-code



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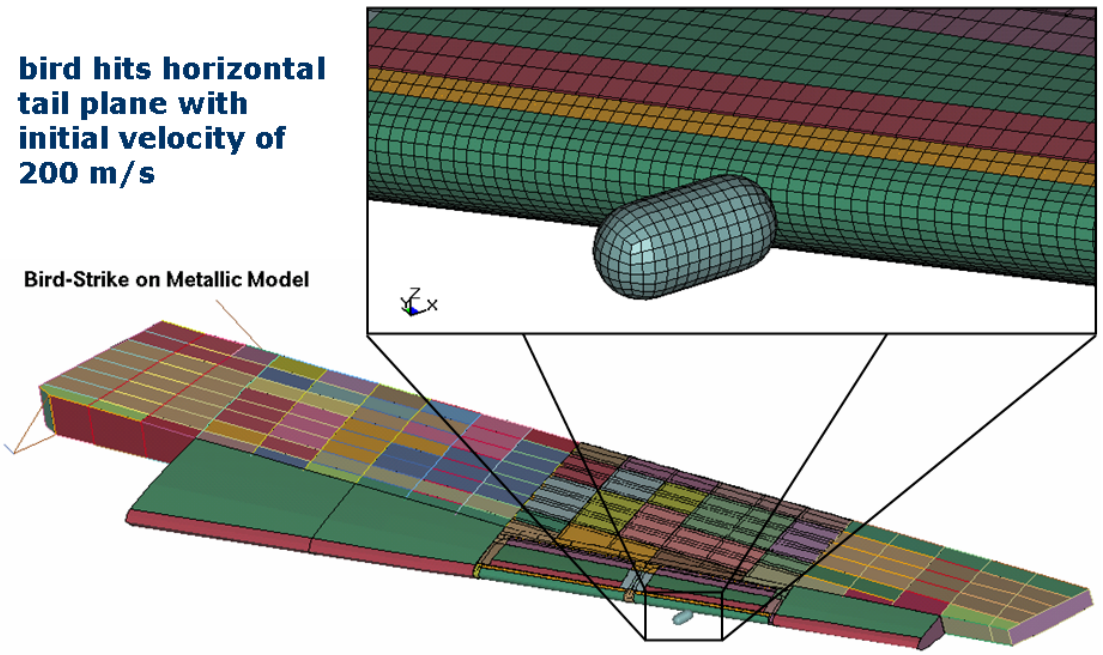
CADFEM

Bird Strike Impact

bird hits horizontal tail plane with initial velocity of 200 m/s



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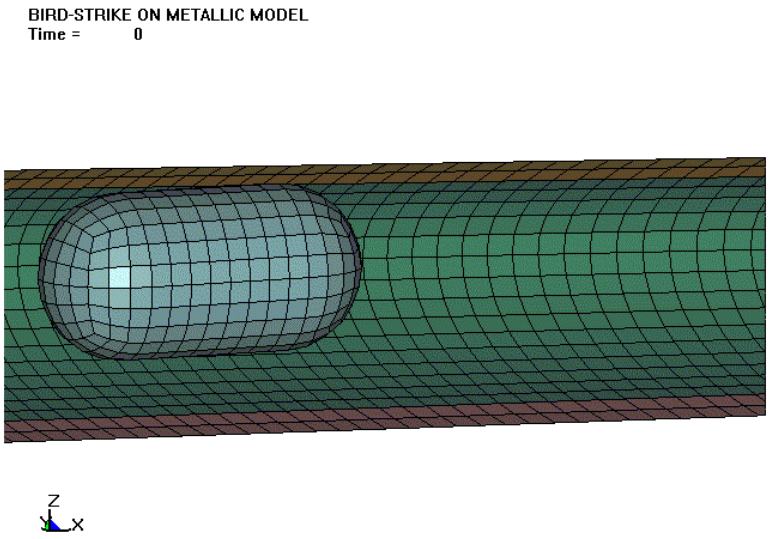
CADFEM

Bird Strike Impact

Lagrangian Bird Strike



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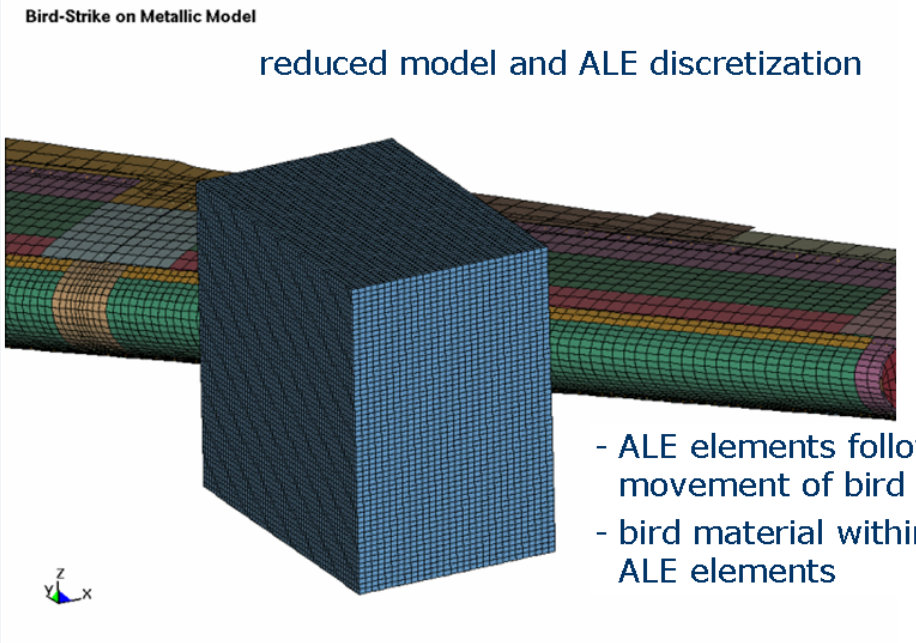
CADFEM

Bird Strike Impact



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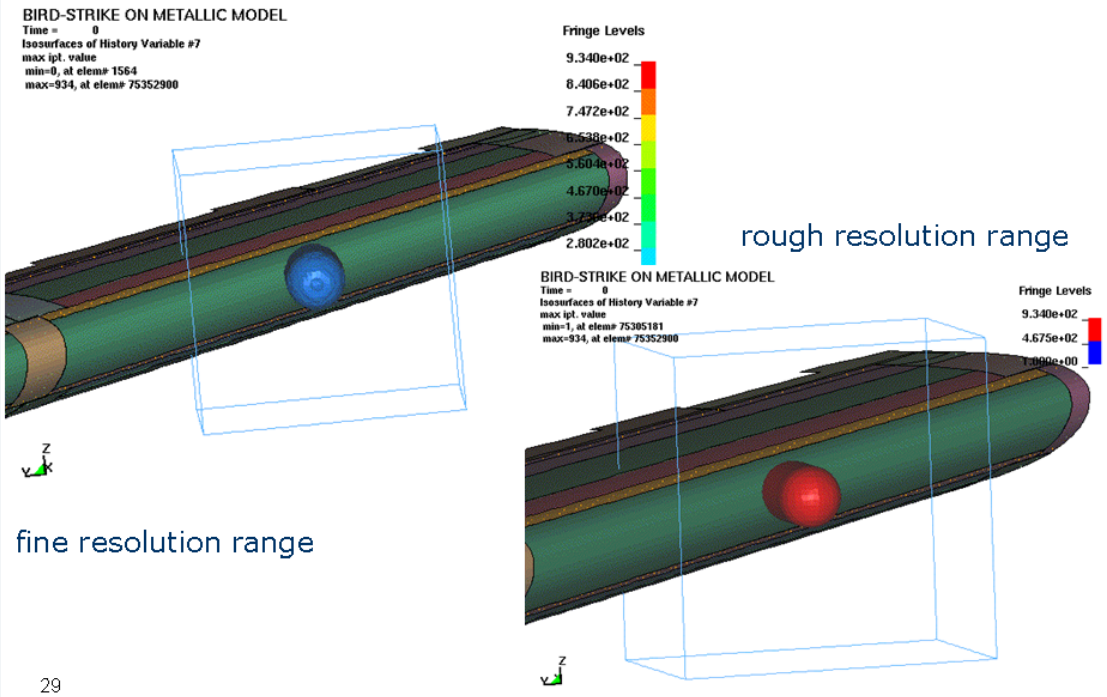
CADFEM

Bird Strike Impact



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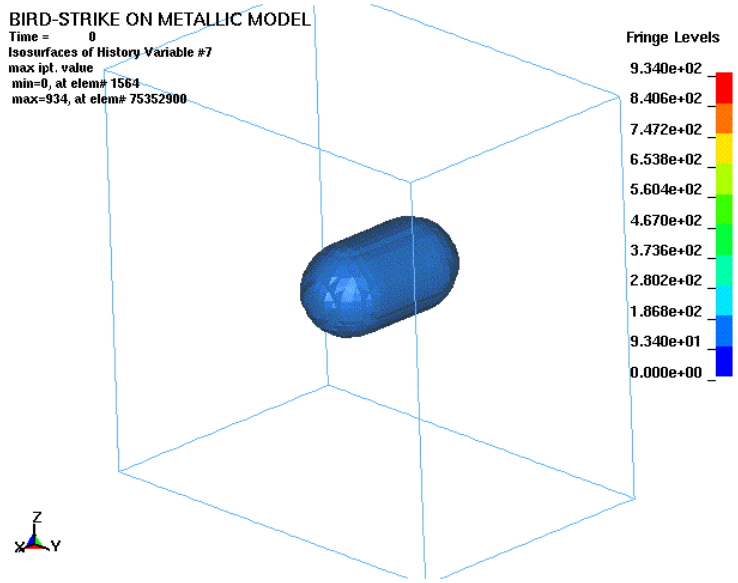
Bird Strike Impact



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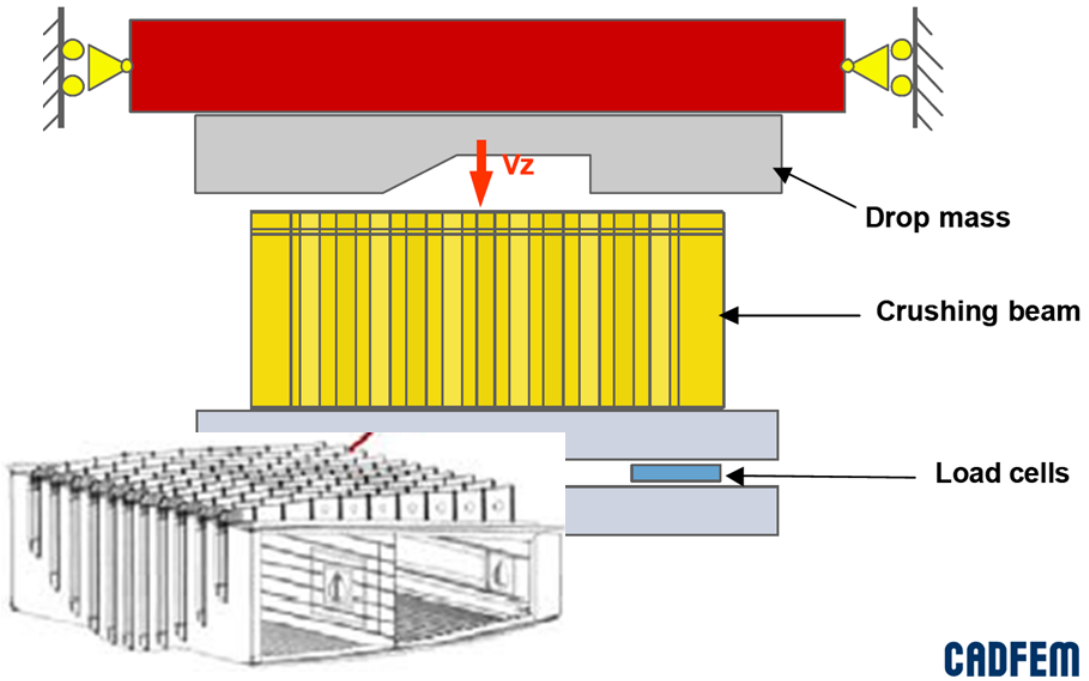
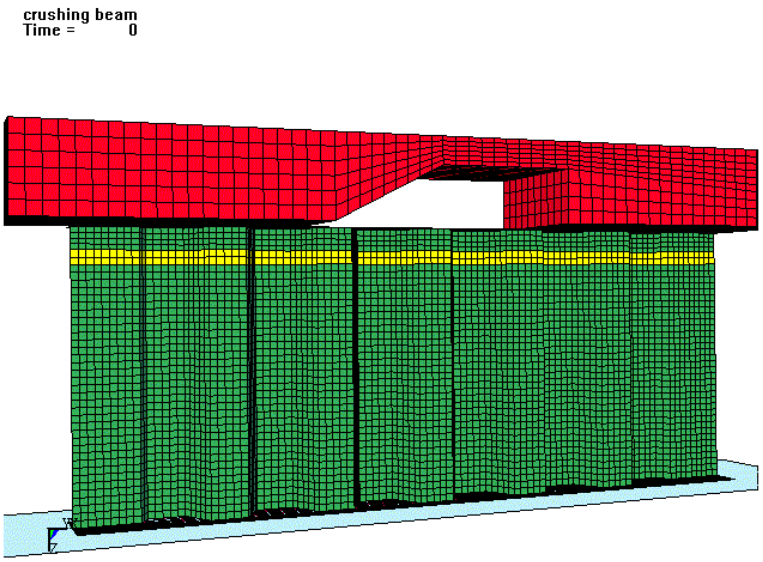
Crushing of Trapezoidal Beam

Ramp - step



CADFEM

Crushing of Trapezoidal Beam



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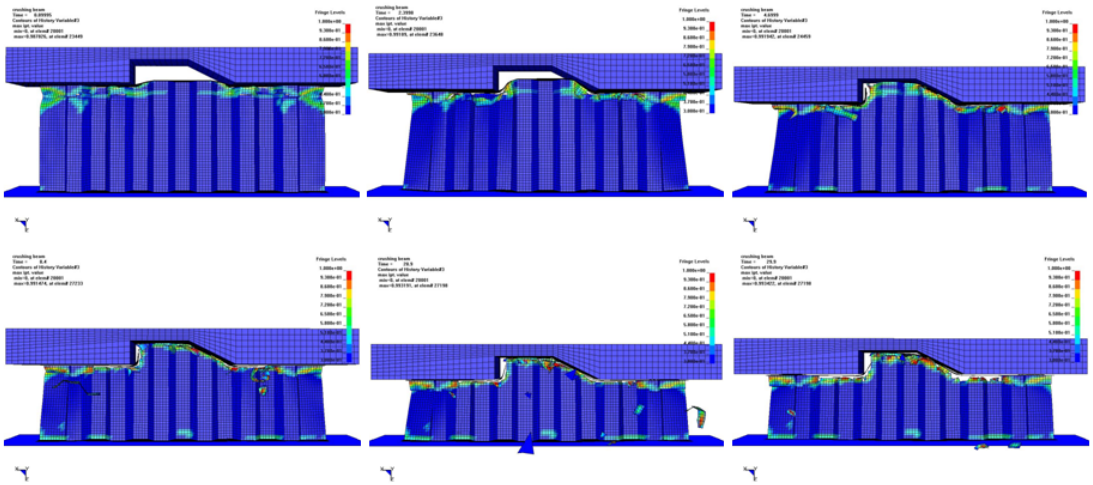
CADFEM

Crushing of Trapezoidal Beam



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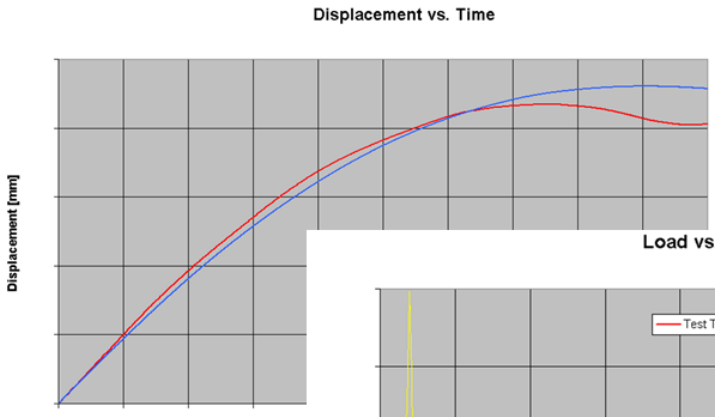
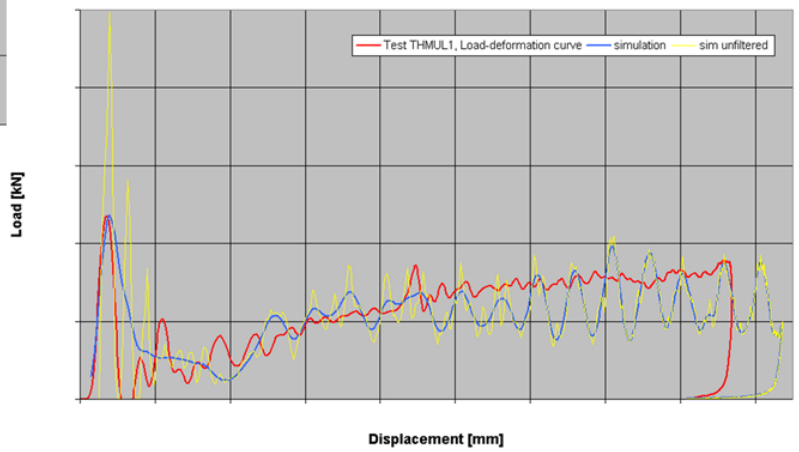
CADFEM

Crushing of Trapezoidal Beam





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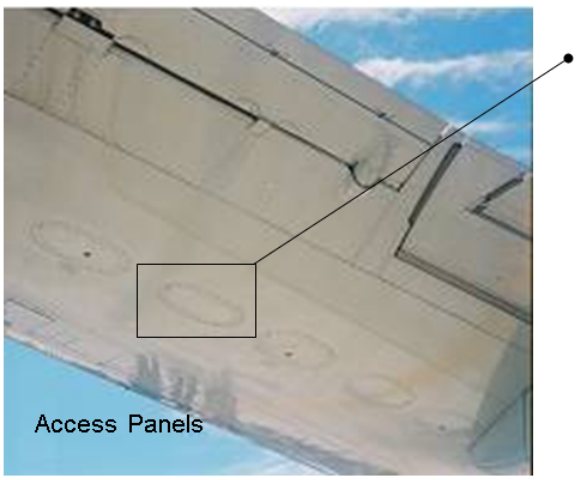
Tire Debris Impact

Tire Debris Impact Simulation



Part of European Research Program, in cooperation with CEAT (experiments) and University of Liverpool (tire material modeling)

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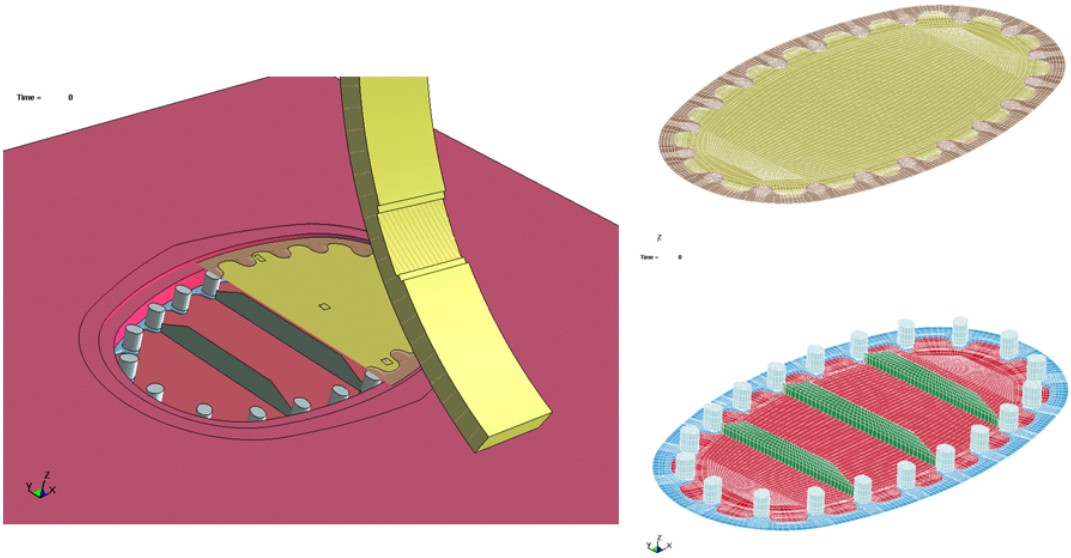
Tire Debris Impact

Tire Debris Impact Simulation / FE Model



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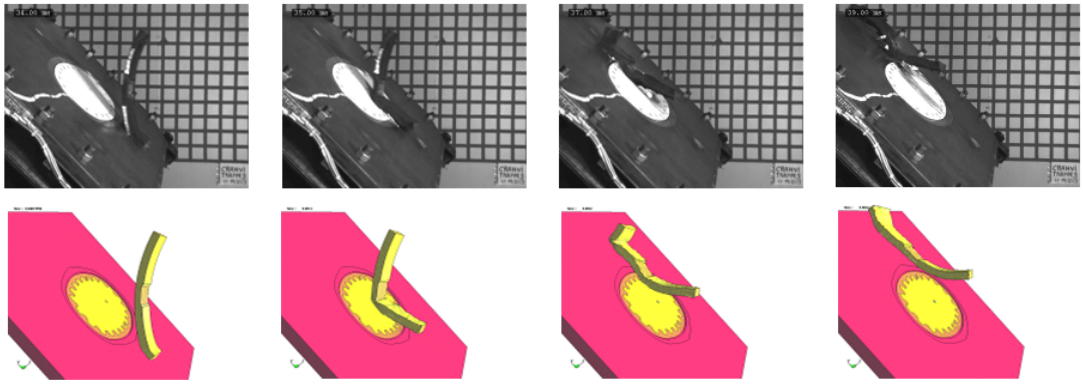
Tire Debris Impact

Tire Debris Impact Simulation / Test&Simulation Sequence



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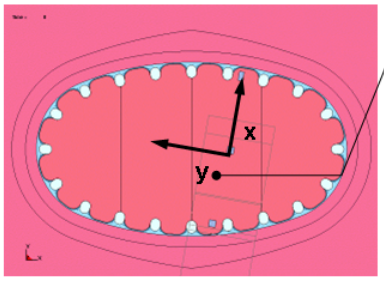
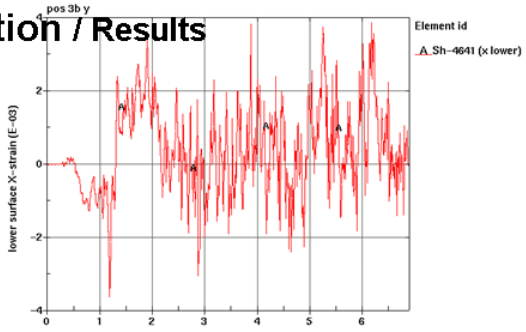
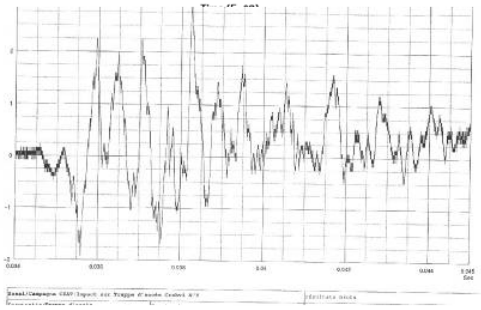
Tire Debris Impact

Tire Debris Impact Simulation / Results

Strain calculation, inner panel, y-dir. Position B







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