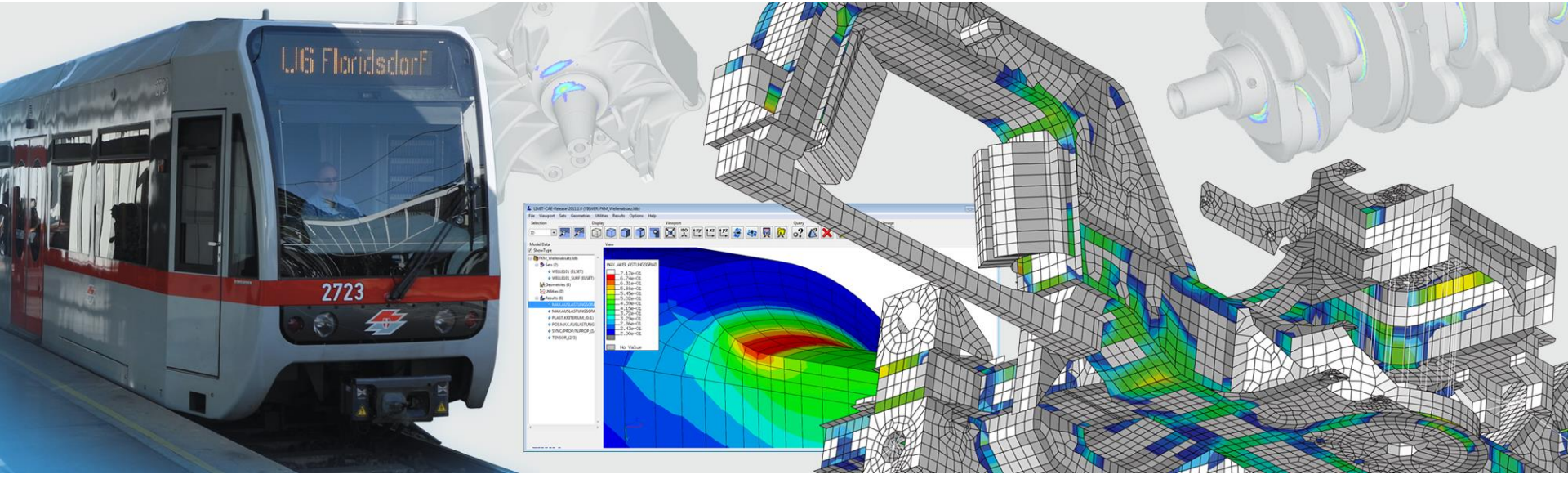
LIMIT
stress evaluation

Railway Applications



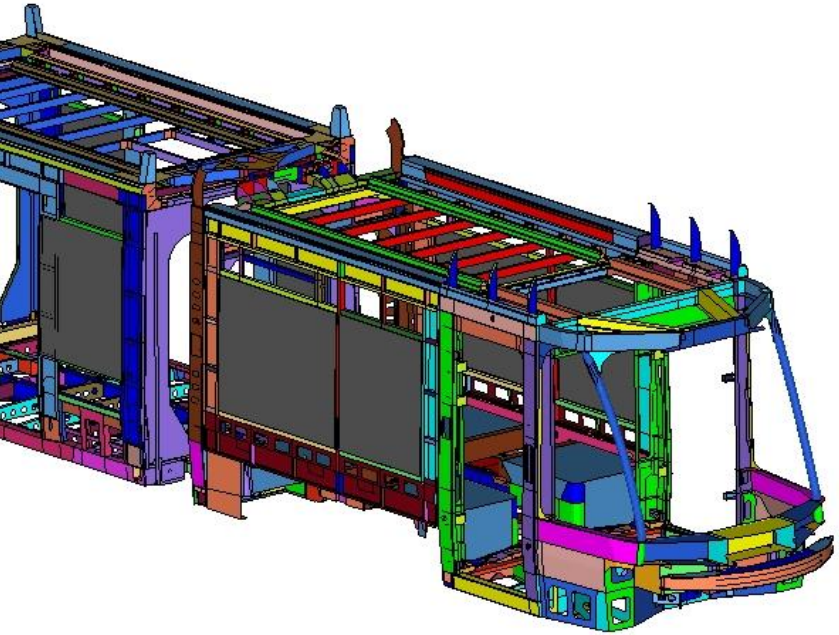
Easy certification according to EN12663 and DVS using FEM and LIMIT

Motivation for LIMIT

A way to certification of railway vehicles according to DVS

- Overview of the strength assessment
- Challenges for the assessment of welded structures
- Types of railway structures: shells vs. volume
- Applying the design codes
- Interfaces FEM to LIMIT
- Generating Reports as part of the documentation for Notified Body, the complete procedure with LIMIT

Certification according to EN12663 and DVS

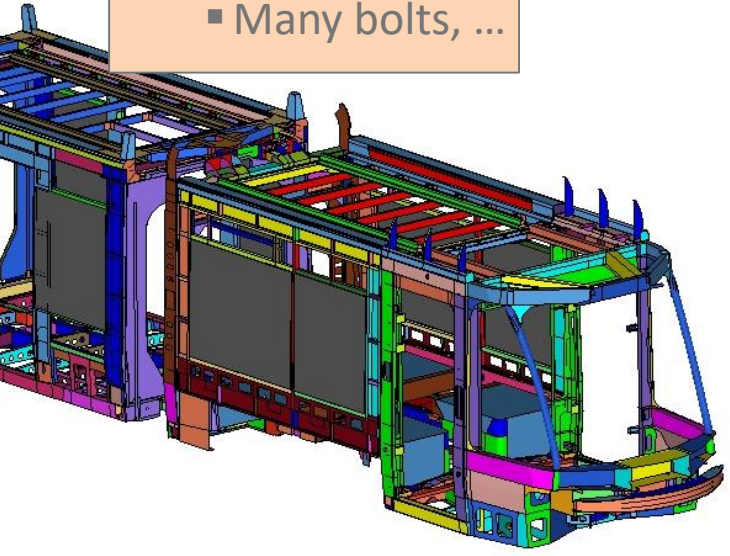


Final strength report for certification by Notified Body

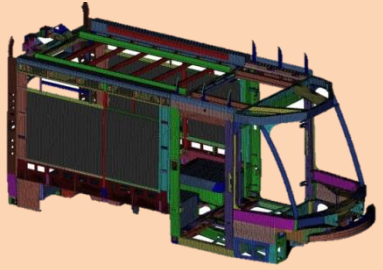
Certification according to EN12663 and DVS

Train design

- **3D geometry**
- **Materials**
- **Joints:**
  - Many welds
  - Many bolts, …



Finite Element Analysis

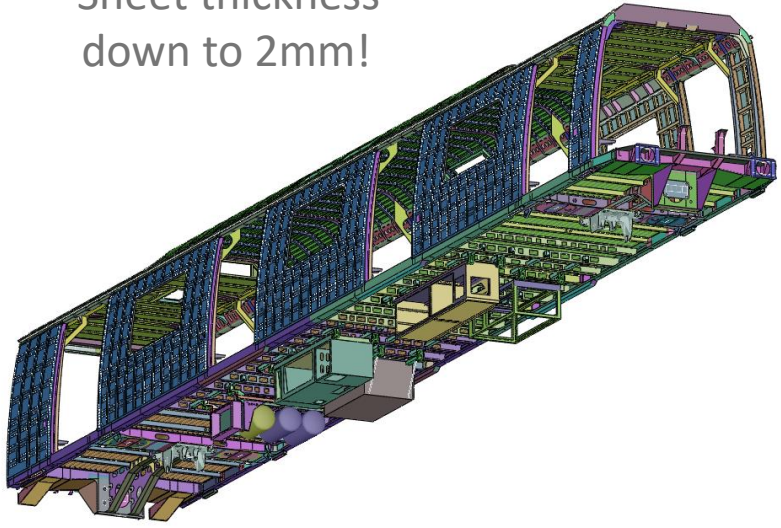


Final report for certification

Typical railway structures

Thin walled large structure

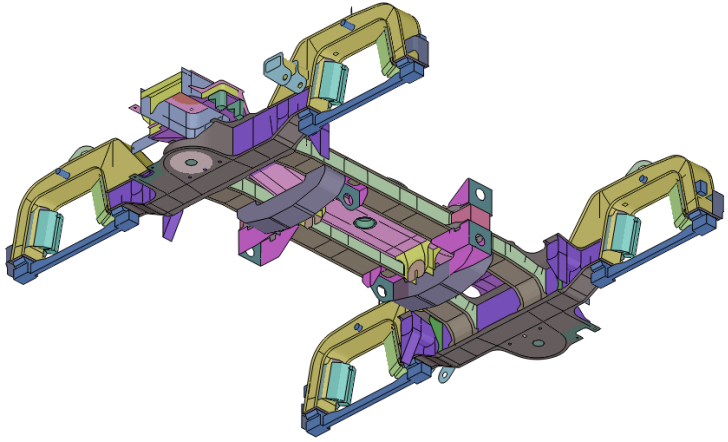
- Vehicle body
- Sheet thickness down to 2mm!



Source: Siemens, Austria

Medium sized structures

- Bogies
- Sheet thickness starting from 5mm

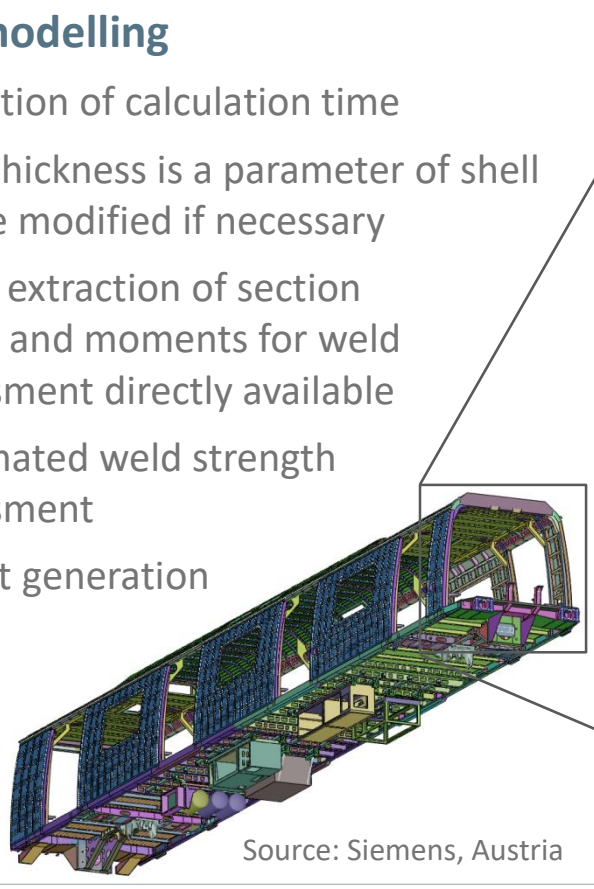


Source: Bombardier, Vienna

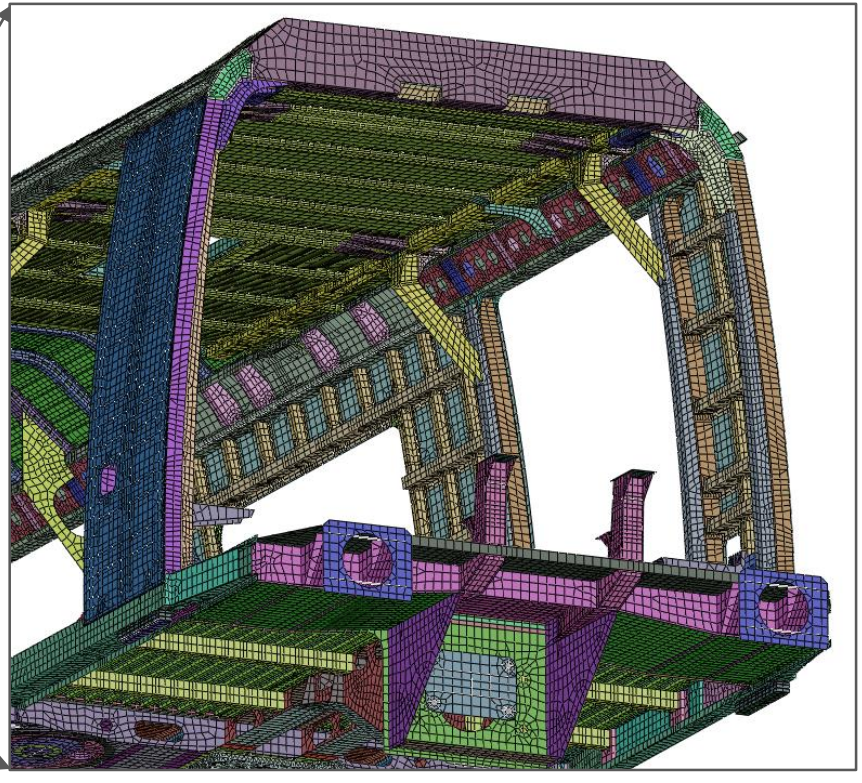
Modelling strategies

Shell modelling

- Reduction of calculation time
- Shell thickness is a parameter of shell can be modified if necessary
- Easier extraction of section forces and moments for weld assessment directly available
- Automated weld strength assessment
- Report generation



Source: Siemens, Austria

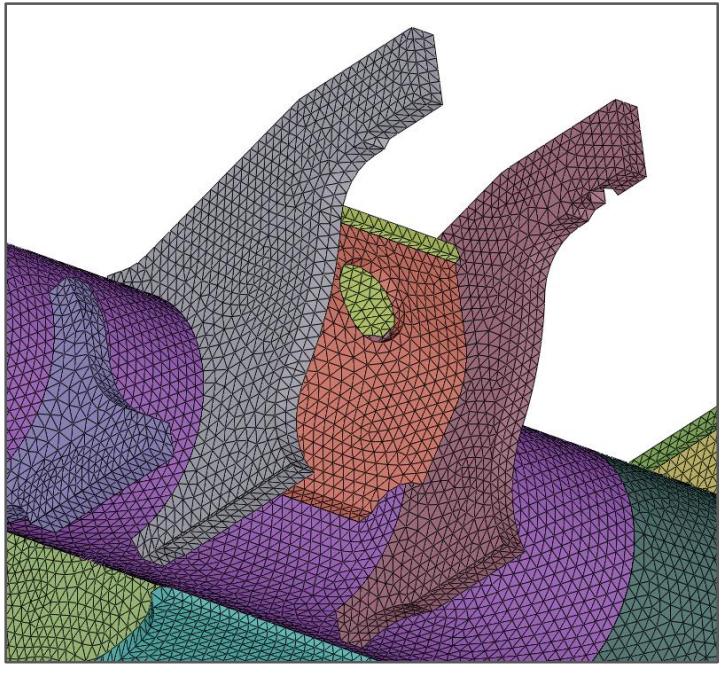


Shell model

Typical railway structures

Solid modelling

- No mid surface modelling (faster)
- Large thickness of plates can be captured more accurate
- More flexibility with different variants
- Less singularities and therefore less conservative



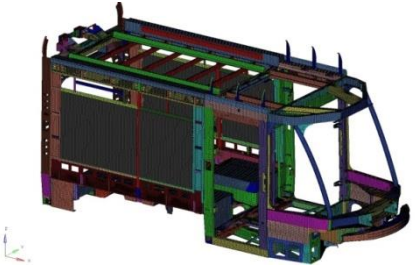
Source: Logomotive, Germany

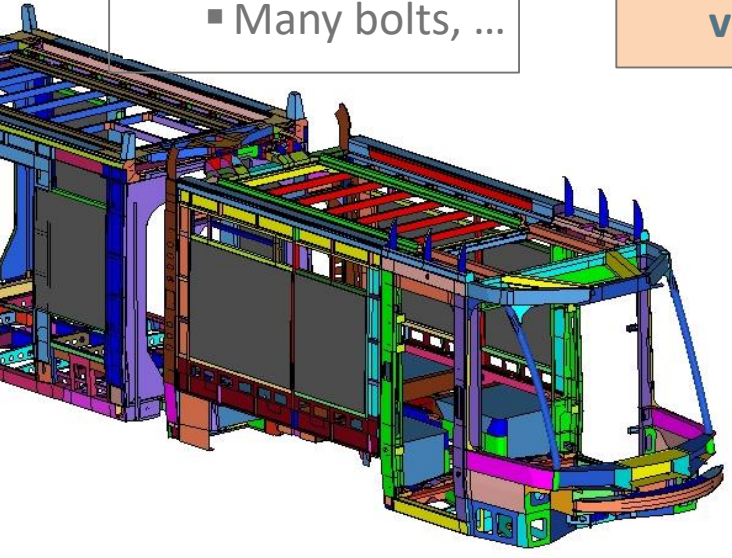
Certification according to EN12663 and DVS

Train design
- 3D geometry
- Materials
- Joints:
  - Many welds
  - Many bolts, …

Strength Requirements according to EN12663
- Loads depending on vehicle category

Finite Element Analysis





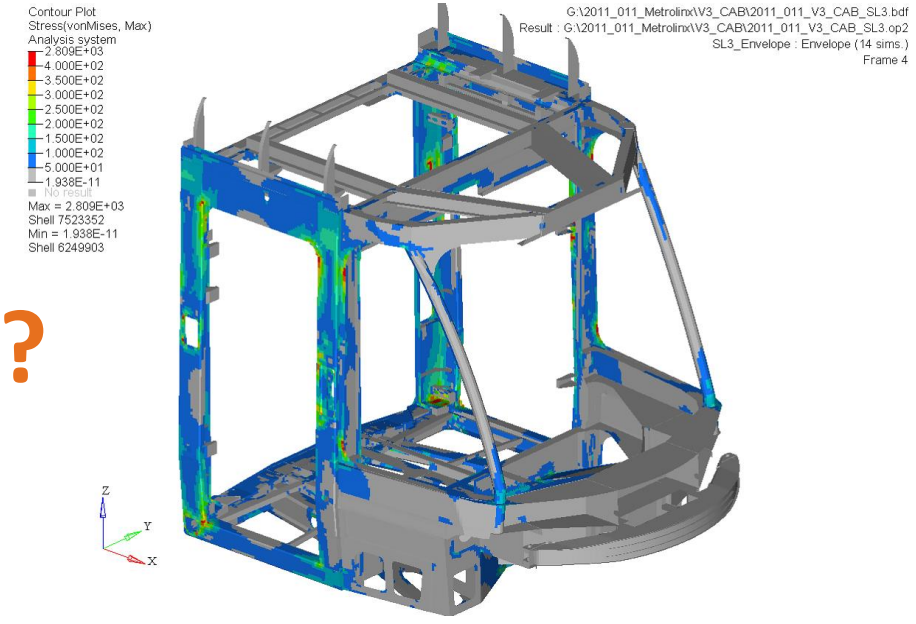
Final report for certification

Challenges with certification of railway structures

- **Finding critical loads and load cycle numbers**
  - According to EN12663: minimum of approximately 25 LCs necessary
- **Assessing large numbers of welds**
  - 500 to 1000 welds in a typical carbody
- **Applying the design code**

EN 12663
Strength requirements
Static and Fatigue

o.k.?



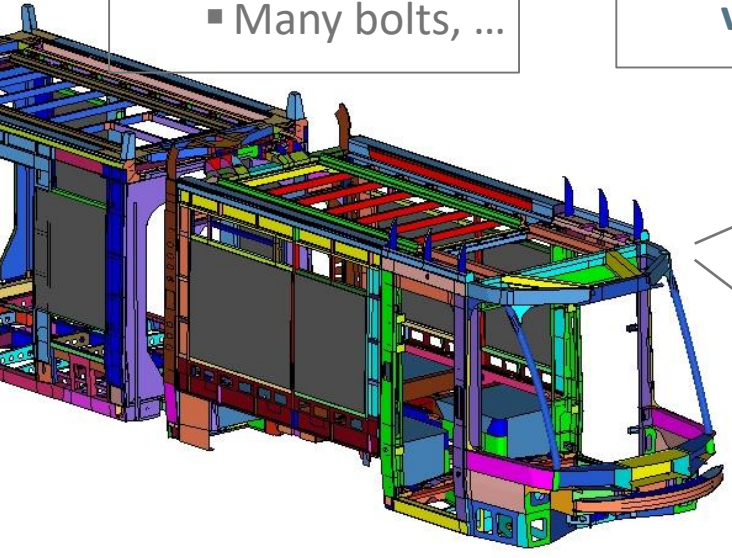
Complex structure

Certification according to EN12663 and DVS

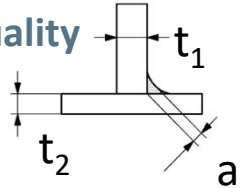
Train design
- 3D geometry
- Materials
- Joints:
  - Many welds
  - Many bolts, …

Strength Requirements according to EN12663
- Loads depending on vehicle category

Finite Element Analysis



Weld quality



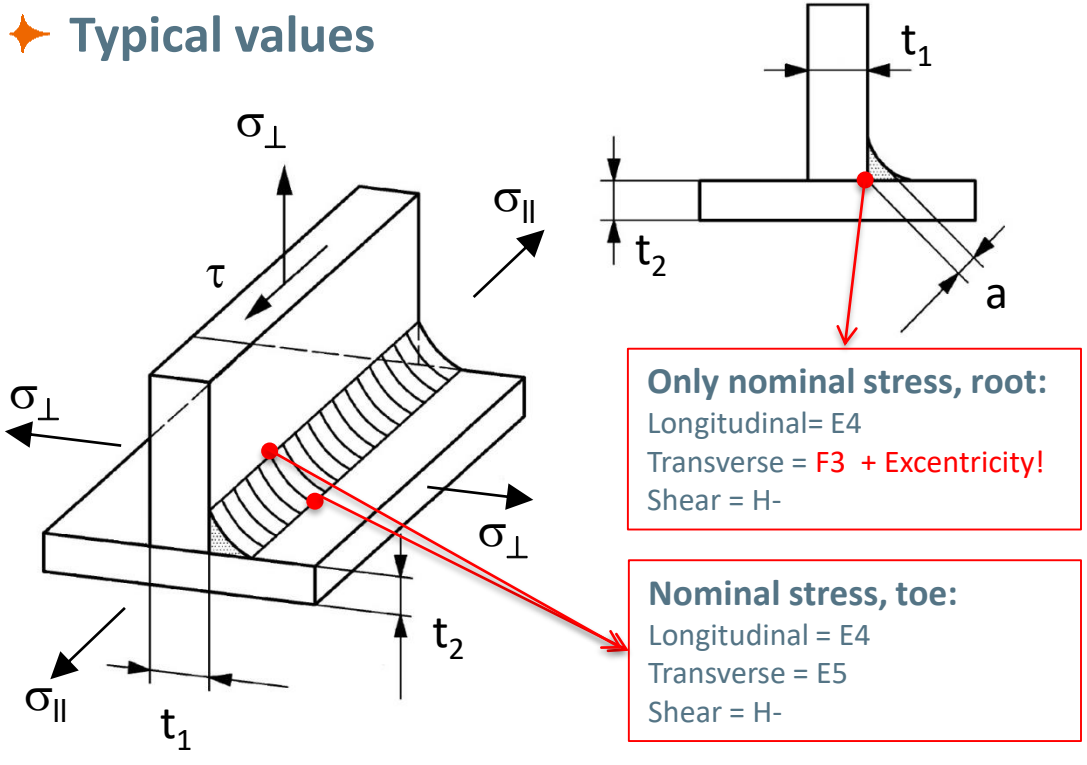
- Static assessment
- Fatigue assessment
  - DVS 1612 (steel)
  - DVS 1608 (alu)

LIMIT

Final report for certification

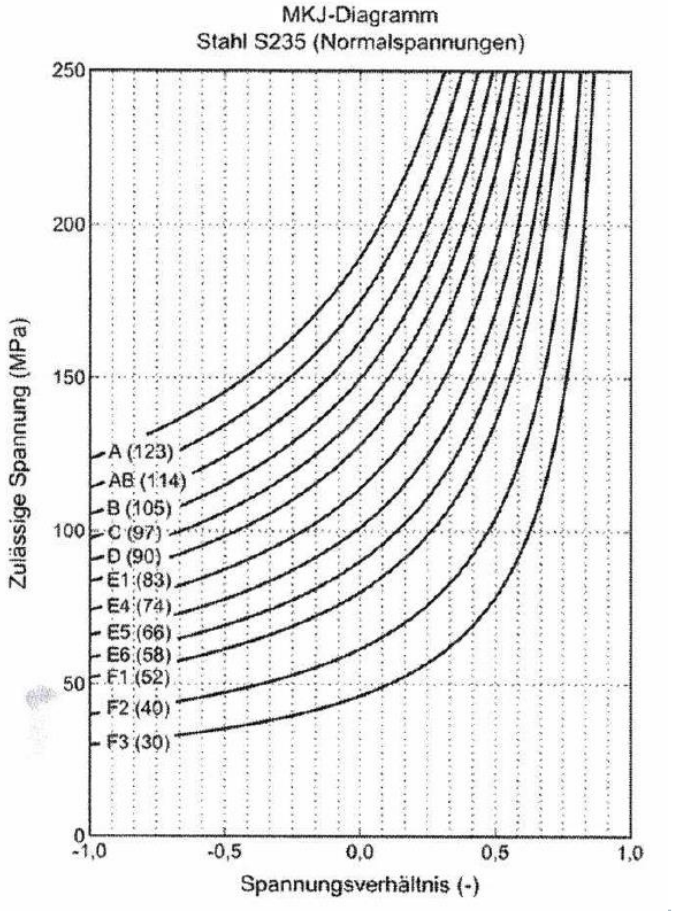
Notch cases, one sided fillet weld:

Typical values



Only nominal stress, root:
Longitudinal= E4
Transverse = F3 + Excentricity!
Shear = H-

Nominal stress, toe:
Longitudinal = E4
Transverse = E5
Shear = H-



Weld Analysis according to DVS1612

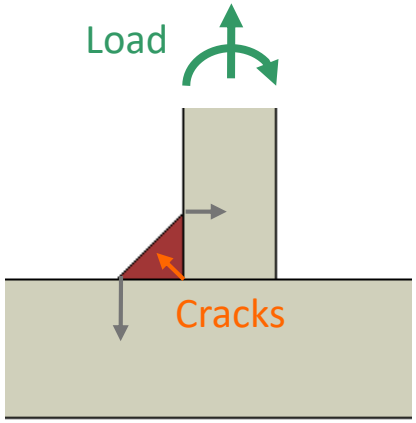
E.g.: Single sided fillet weld

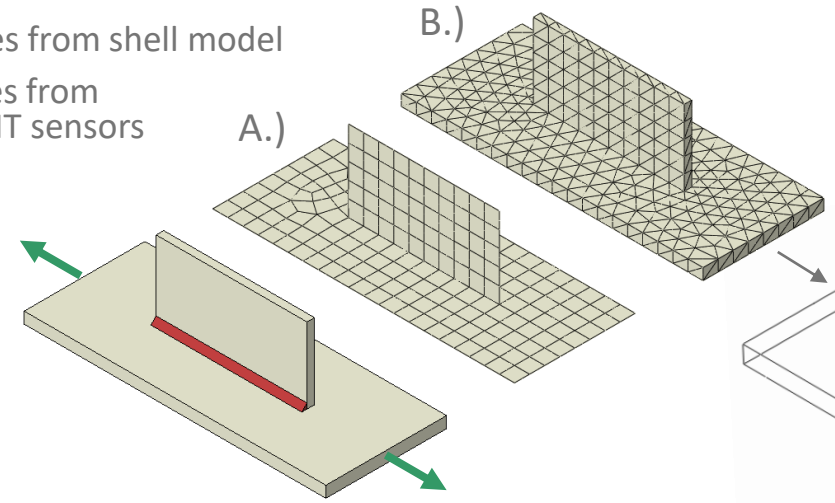
- Fillet throat critical => stresses in throat needed!

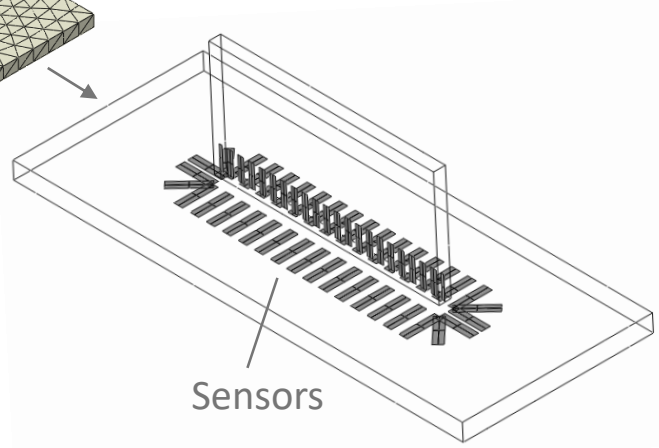
A.) Using section forces from shell model

B.) Using section forces from solid model & LIMIT sensors

C.) R1-effective notch



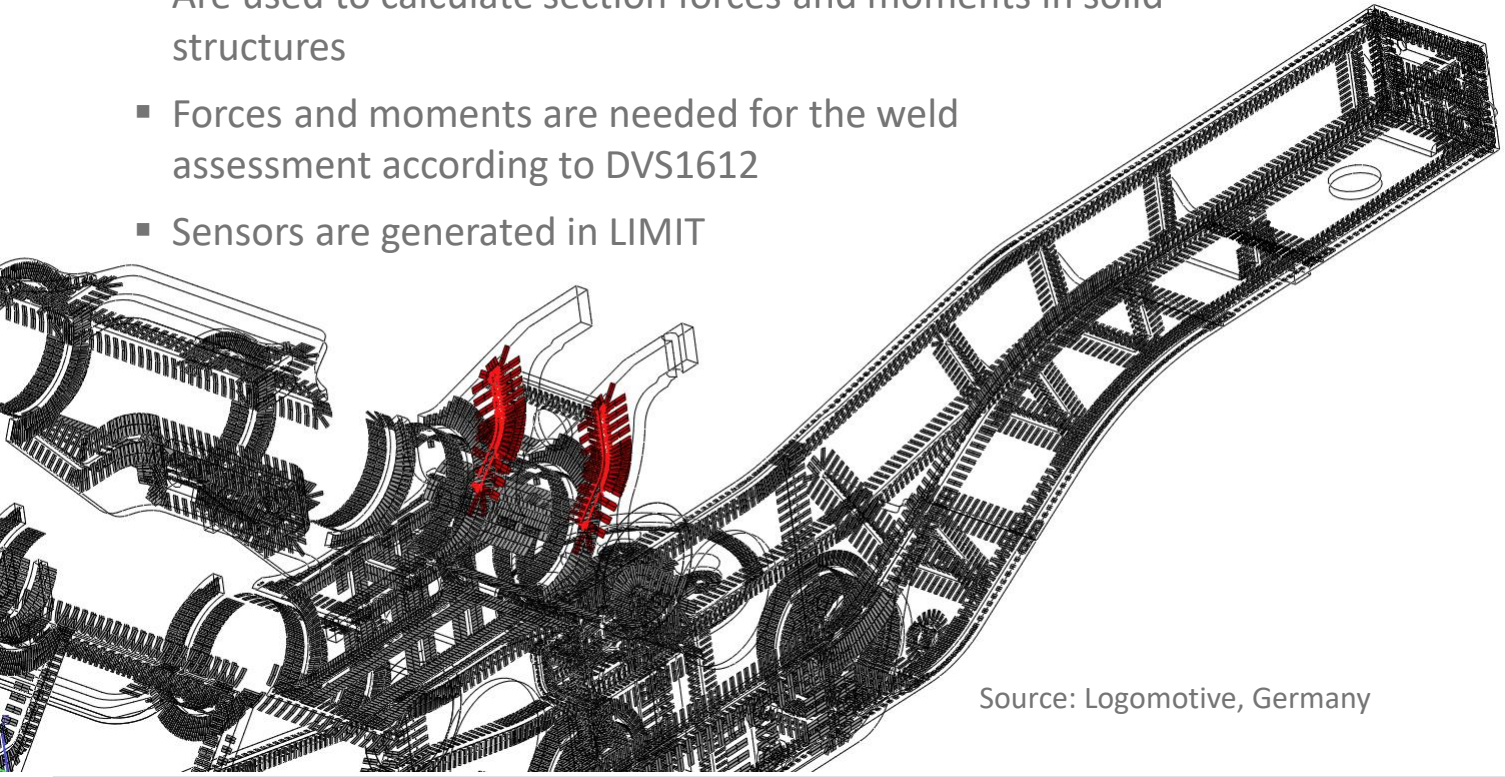




Typical railway structures

Sensor technology

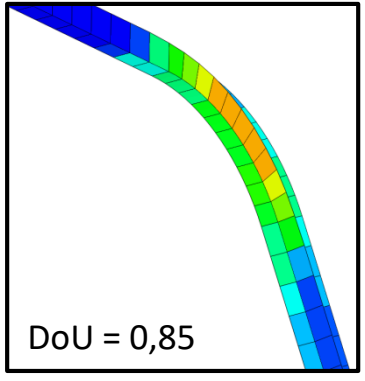
- Are used to calculate section forces and moments in solid structures
- Forces and moments are needed for the weld assessment according to DVS1612
- Sensors are generated in LIMIT

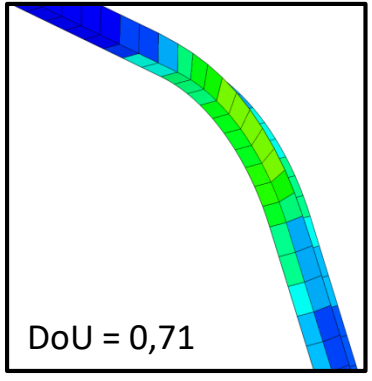


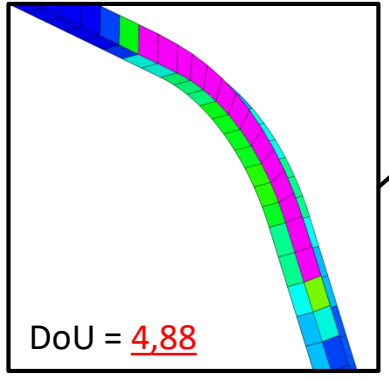
Source: Logomotive, Germany

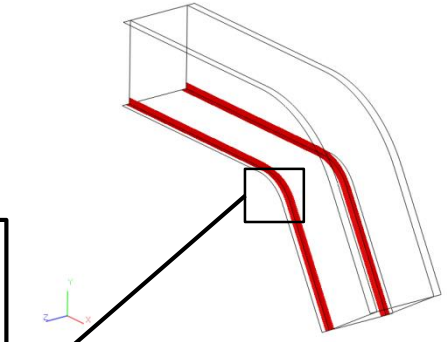
Comparison for different geometries

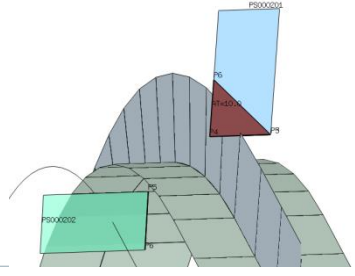
Degree of Utilization (DoU)

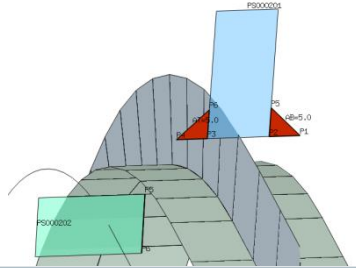


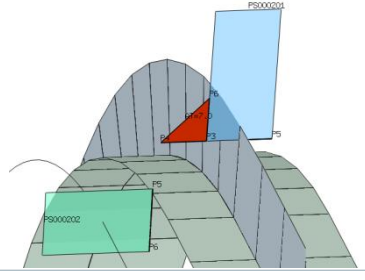












Easy certification with LIMIT

Design: 3D-CAD

FE model
Patran, Hypermesh, Abaqus/CAE, ANSYS, NX

Finite Element Input
.bdf, .out, .dat, .inp

FE Solver
Nastran, Abaqus, ANSYS

FE Results
.fil, .odb, .op2, .rst

LIMIT-CAE
Definition of assessments in the GUI

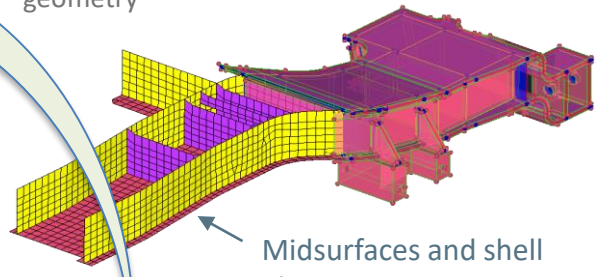
LIMIT-SOLVER
Analysis

LIMIT-VIEWER
Post processing

Global iteration loop, changing geometry

Local loop, e.g. changing weld quality

3D-CAD



Midsurfaces and shell elements

Setup	Degree of Utility
WELD_006_001-	10.9400
WELD_009_001-	8.0510
WELD_005_010-	7.3200
WELD_007_010-	7.2680
WELD_007_009-	7.2110
WELD_005_009-	7.0150
WELD_005_001-	4.6920
WELD_009_002-	3.9230
WELD_010_002-	3.9230
WELD_007_001-	2.8060
WELD_008_010-	2.4190
WELD_008_009-	2.3930
WELD_004_010-	0.8570
WELD_004_009-	0.8543
WELD_006_009-	0.7398
WELD_006_010-	0.7357
WELD_008_001-	0.6323
WELD_003_010-	0.5490
WELD_003_009-	0.5478
WELD_010_001-	0.3452
WELD_004_001-	0.1621
WELD_003_001-	0.0851

Not o.k.!

Easy certification with LIMIT

Design: 3D-CAD

FE model
Patran, Hypermesh,
Abaqus/CAE, ANSYS, NX

Finite Element Input
.bdf, .out, .dat, .inp

FE Solver
Nastran, Abaqus, ANSYS

FE Results
.fil, .odb, .op2, .rst

LIMIT-CAE
Definition of assessments
in the GUI

LIMIT-SOLVER
Analysis

LIMIT-VIEWER
Post processing

Automated Report
Generation:

Setup	Degree of Utility
PS0007	0.9480
PS0022	0.9428
PS0020	0.5556
PS0005	0.5525
PS0003	0.4951
PS0018	0.4935
PS0013	0.4749
PS0002	0.3172
PS0017	0.3165
PS0011	0.2922
PS0006	0.2897
PS0021	0.2897
PS0014	0.2657
PS0001	0.2656
PS0012	0.2637
PS0019	0.2402
PS0004	0.2401
PS0016	0.2250
PS0015	0.2249
PS0010	0.2171
PS0009	0.1218
PS0008	0.0637

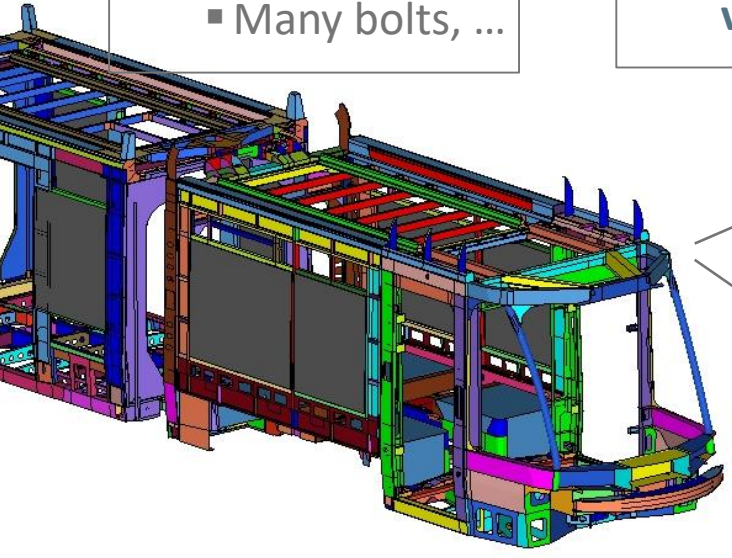
All welds o.k.!

Certification according to EN12663 and DVS

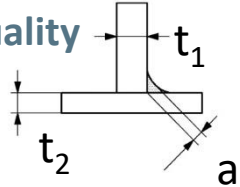
Train design
- 3D geometry
- Materials
- Joints:
  - Many welds
  - Many bolts, …

Strength Requirements according to EN12663
- Loads depending on vehicle category

Finite Element Analysis



Weld quality



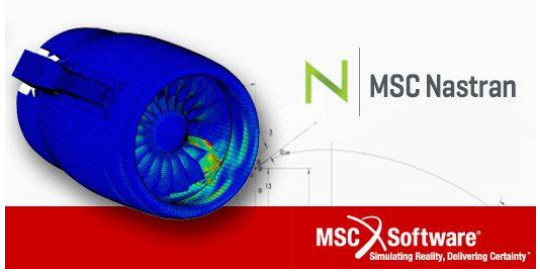
- Static assessment
- Fatigue assessment
  - DVS 1612 (steel)
  - DVS 1608 (alu)

LIMIT

Final report for certification

LIMIT Interfaces to MSC Products

- *MSC-MARC (t16)*
- *MSC-NASTRAN (op2)*



- *HDF5 format will be available in the beginning of 2018 for:*

  - MSC-Apex

  - MSC-Nastran

  - Patran

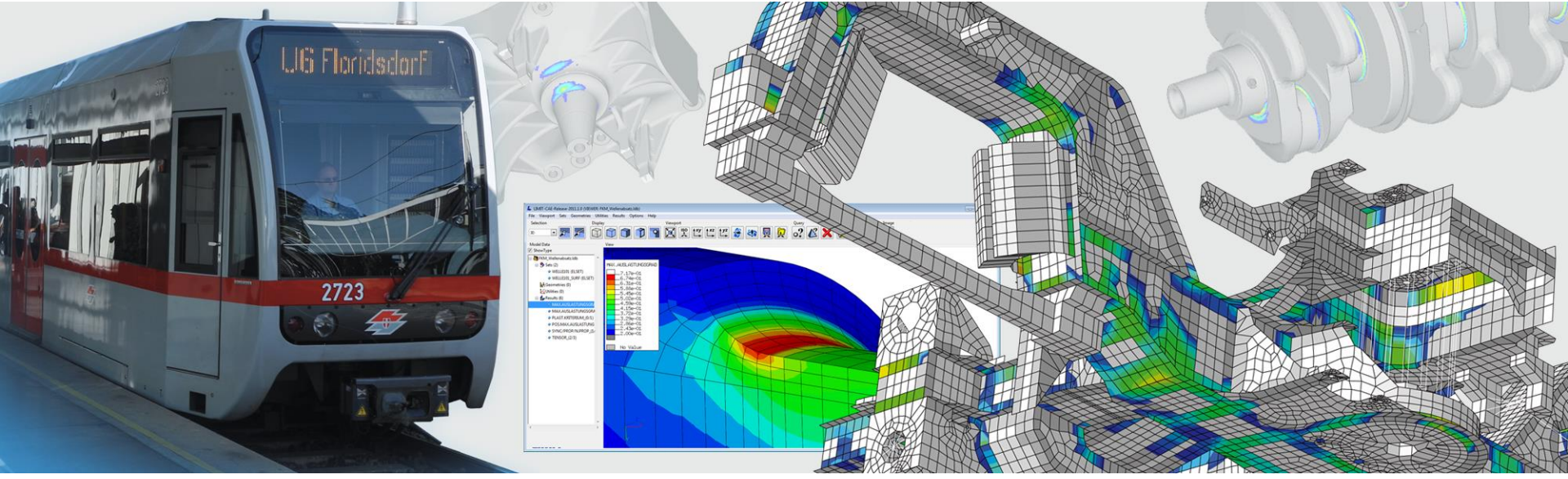
Further LIMIT Interfaces

in alphabetic order:

- *ABAQUS*
- *ANSYS*
- *ANSYS LS DYNA*
- *CATIA FE*
- *NX NASTRAN*
- *RADIOSS/OPTISTRUCT*
- *SOLIDWORKS Simulation*
- *LIMIT Universal Interface*

References

- AMST-Systemtechnik GmbH
- AUDI, Werkzeugkonstruktion, Germany
- Bühler AG, Switzerland
- China Energine International Ltd.
- FEMCOS-Ingenieurbüro mbH, Germany
- Gardner Denver Schopfheim GmbH, Germany
- Hydromek, Turkey
- IBV-Engineering, Germany
- IFF Engineering & Consulting GmbH, Germany
- Istanbul Technical University, Turkey
- K + V Ingenieurgesellschaft mbH, Germany
- Ludwig Engel KG, Austria
- Liebherr-Transportation Systems GmbH & Co KG
- LogoMotive GmbH, Germany
- MAV-START, Hungary
- NEWAG, Poland
- PESA Bydgoszcz SA, Poland
- Plasser & Theurer, Austria
- Prisma Engineering, Austria
- RUAG Schweiz AG, Switzerland
- Stadler Valencia, Spain
- STREICHER Maschinenbau GmbH & Co. KG, Germany
- Taiwan Rolling Stock Company, Taiwan
- TUV Rheinland Rail Sciences, Inc., Nebraska, USA
- Vossloh Locomotives, Kiel



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Please contact:

Dr. Nikolaus Friedl
friedl@cae-sim-sol.at
+43 1 974 89 91-12