European Commission

Horizon 2020
European Union funding
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AffordabLe LIghtweight Automobiles AlliaNCE

Future of Automotive Lightweighting Day

September 19, 2019

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Material development – Steel

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thyssenkrupp Steel

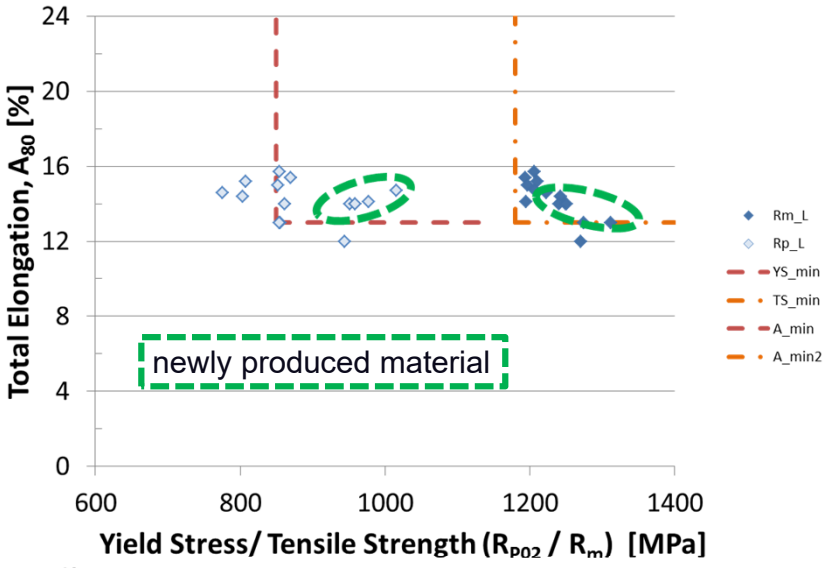
Introduction & Objectives

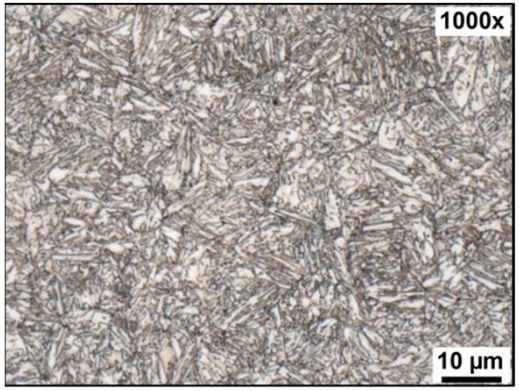
- **Motivation:**
  - **increased need for higher strength materials with good global and excellent local ductility**
- **Objectives & Targets:**
  - **further development of 3rd generation AHSS from TRL (**Technology Readiness Level**) 3 to 5**

Material development

- 3rd generation of AHSS based on a Quench and Partitioning concept
- Production trials are undergoing:
- Initial industrial heats of material have been processed with extensive characterization of the mechanical properties and microstructure
- New series of mill (annealing) trials have been carried out with various degrees of characterization with focus on:
  - mechanical (tensile) properties:

    YS > 850MPa ☑, UTS > 1180MPa ☑, A80 > 13% ☑ , improved hole-exp. ☑ .
  - surface quality: surface satisfies non-exposed criteria ☑, good Zn-adhesion ☑
- Mechanical & forming properties optimized via annealing temperatures
- Surface quality influenced by furnace atmosphere
- Welding properties also influenced by a combination of process parameters
- Production and sampling of material in other thicknesses in progress





Microstructure: tempered Martensite, 16% Retained Austenite

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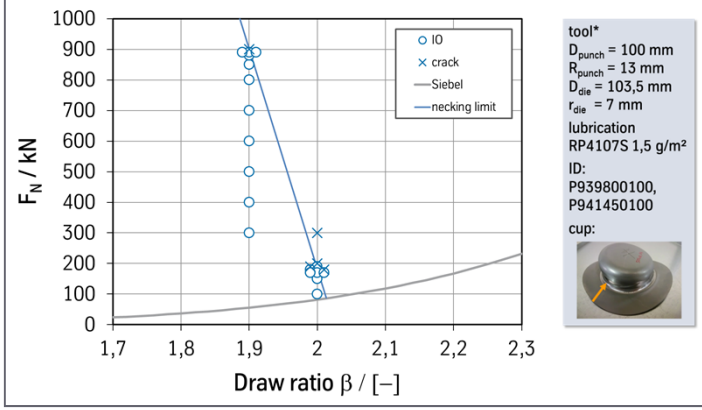
Material characterization

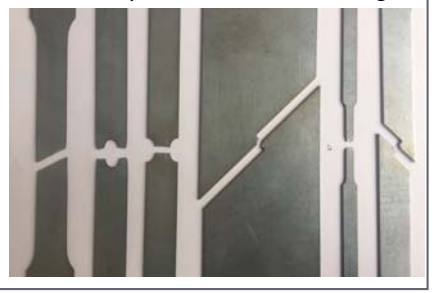
Deep-Drawing-Test



→ Good deep drawing proterties for the AHSS class

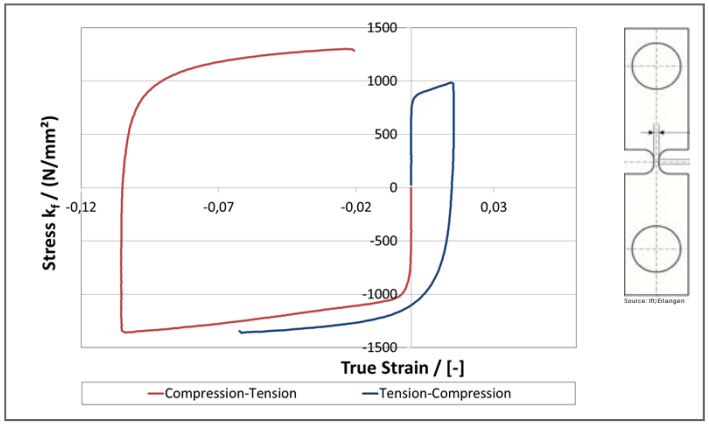
Fracture Strain

Fracture Specimen after Testing



→ Tests performed
→ tkse and Daimler samples are used

Tensile Compression Test



→ Tensile compression test for better springback prediction

Forming Behavior

- ✓ Deep Drawing Test
- ✓ Experiment for fracture strains
- ✓ Tensile Compression Tests
- ✓ DIC of fracture strain
- ✓ Microscopic measurement
- ✓ Fracture Curves

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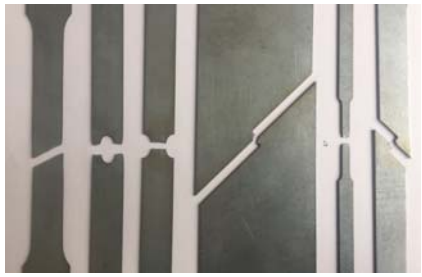
Material characterization

Testing Machine/Fracture Geometry

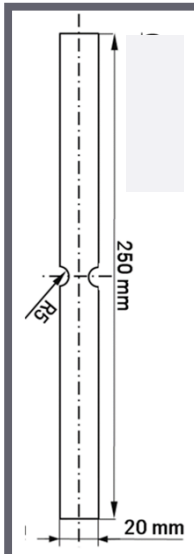
Testing machine

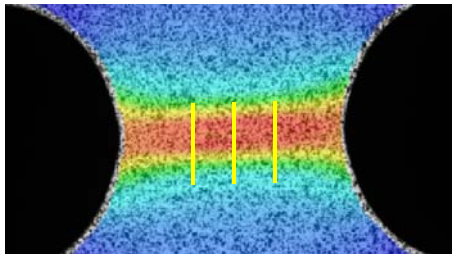
Fracture Specimen after Testing

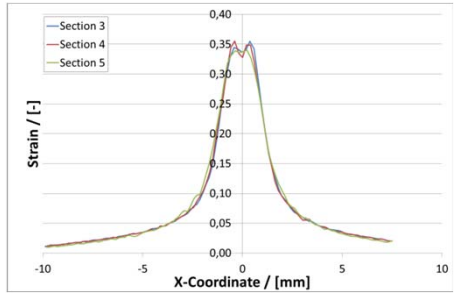


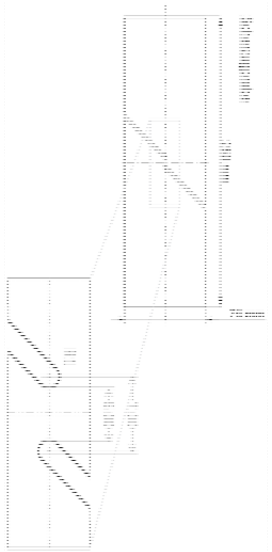
→ Tests performed
→ tkse and Daimler samples are used

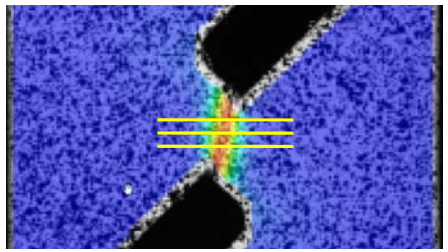
Local Fracture Strain Measurement with DIC and Microscope

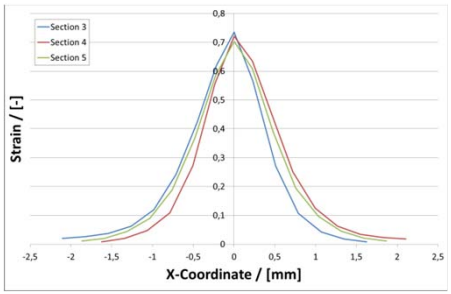




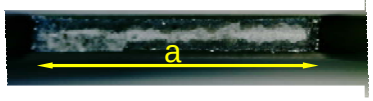


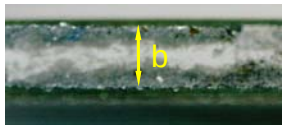




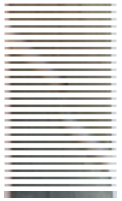


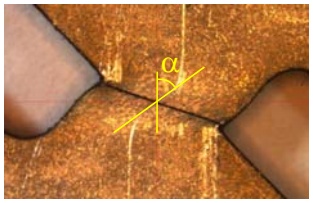
Thickness
Width





Angle





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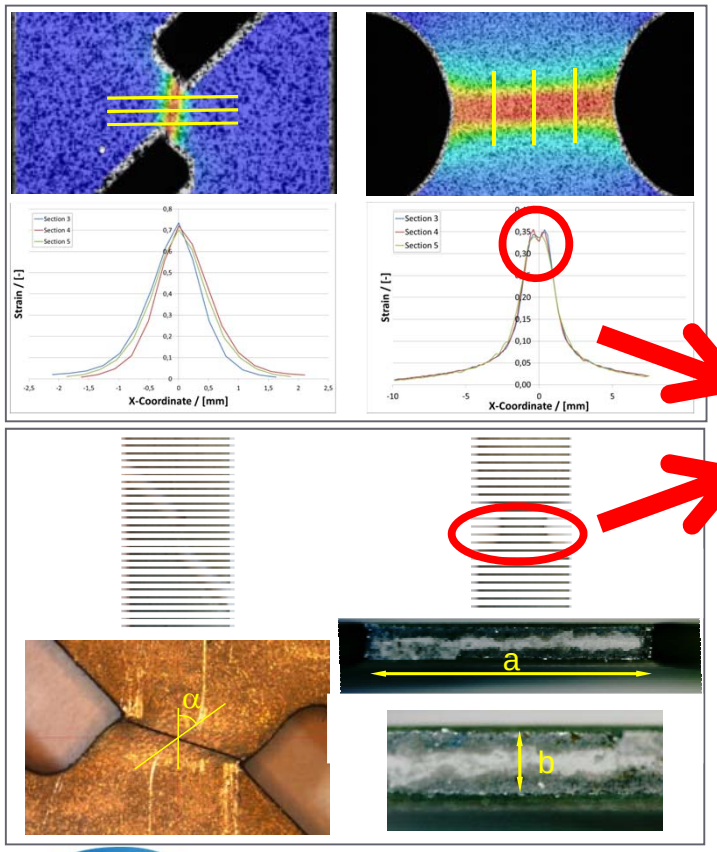
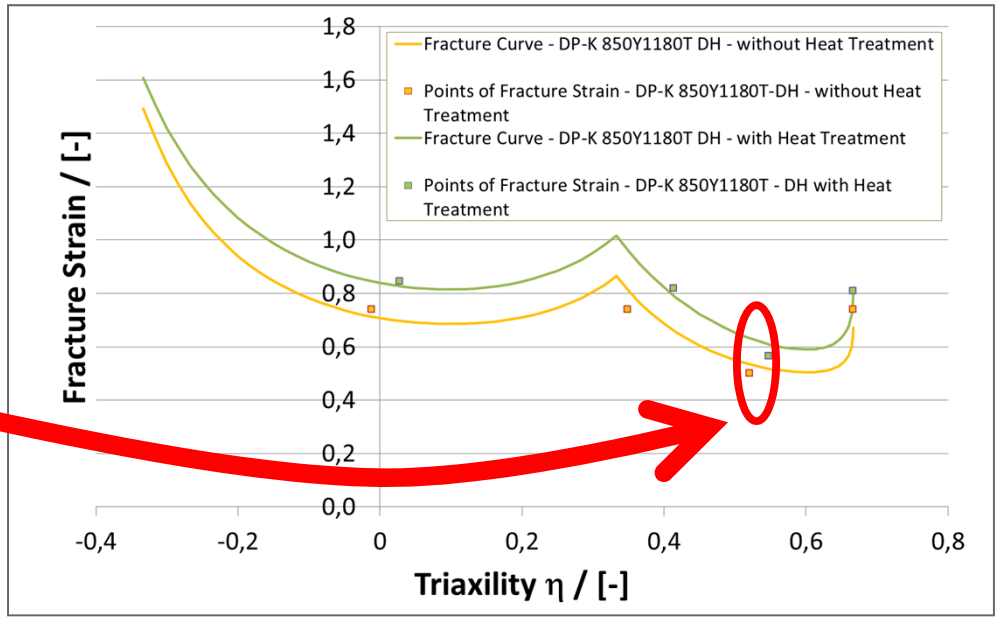
Material characterization



Mixed Fracture Strain:
DIC
+
Microscope



→ Fracture curves depending on heat treatment

→ Good material specific forming potential

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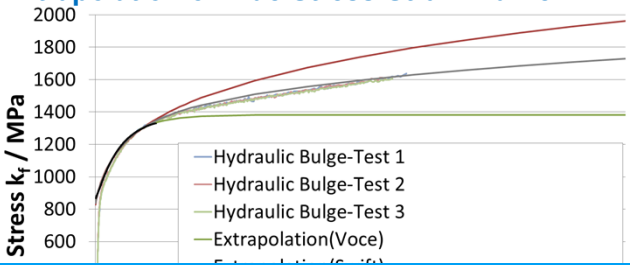
Material characterization

Format of a GISSMO-Material-Card

```
$---+----1----+----2----+----3----+----4----+----5----+----6----+----7----+----8
*MAT_PIECEWISE_LINEAR_PLASTICITY
$MATERIAL NAME:BLANKMAT
$      MID        RO         E        PR      SIGY      ETAN      FAIL      TDEL
    101300  7.83E-09  2.07E+05      0.34                           0.0       0.0
$        C         P      LCSS     LCSR
       0.0       0.0    777777
$     EPS1      EPS2      EPS3     EPS4      EPS5      EPS6      EPS7      EPS8
       0.0       0.0       0.0      0.0       0.0       0.0       0.0       0.0
$      ES1       ES2       ES3      ES4       ES5       ES6       ES7       ES8
       0.0       0.0       0.0      0.0       0.0       0.0       0.0       0.0
$---+----1----+----2----+----3----+----4----+----5----+----6----+----7----+----8
*MAT_ADD_EROSION
$      MID      EXCL    MXPRES    MNEPS    EFFEPS    VOLEPS    NUMFIP      NCS
    101300                                                        -65
$   MNPRES     SIGP1     SIGVM    MXEPS     EPSSH     SIGTH   IMPULSE   FAILTM
$     IDAM     DMGTYP    LCSDG    ECRIT     DMGEXP    DCRIT     FADEXP    LCREGD
       1.          1
$   SIZFLG     REFSZ     NAHSV    LCSRS     REGSHR    REGBIAX   LCINST
$---+----1----+----2----+----3----+----4----+----5----+----6----+----7----+----8
```

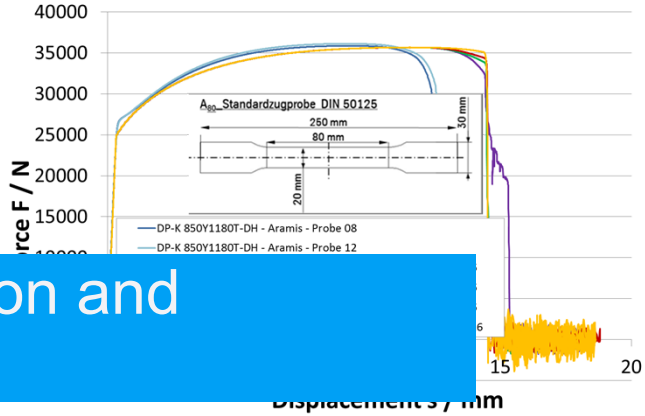
Description of Plasticity

Extrapolation of True Stress-Strain Curve

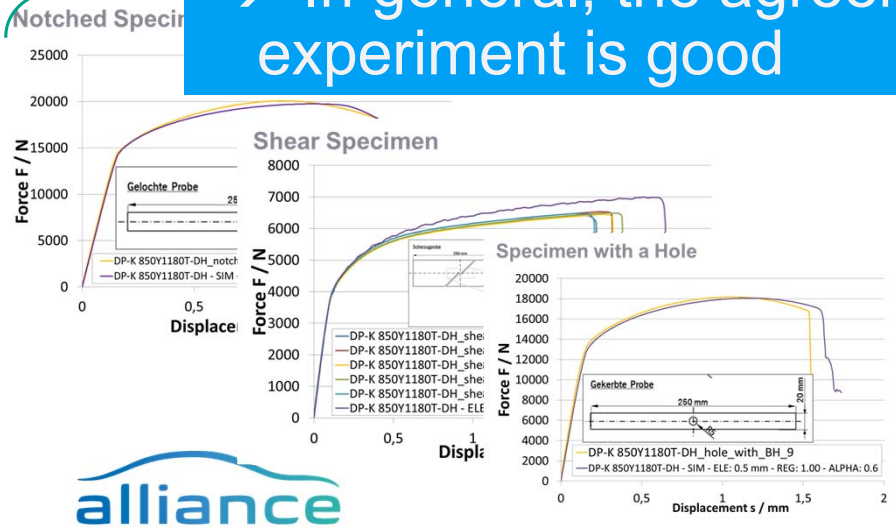


Adjustment of Regularisation Curve

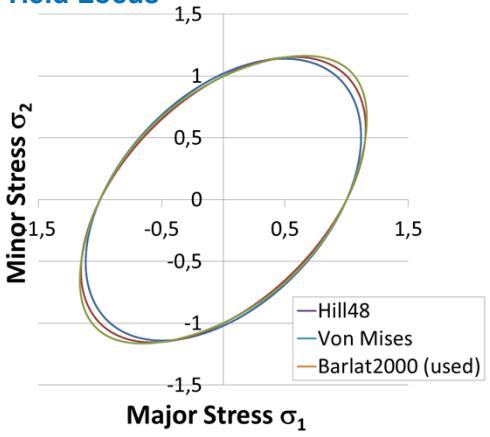
Regularisation Curve by simulation of A_{80}-Tensile Test



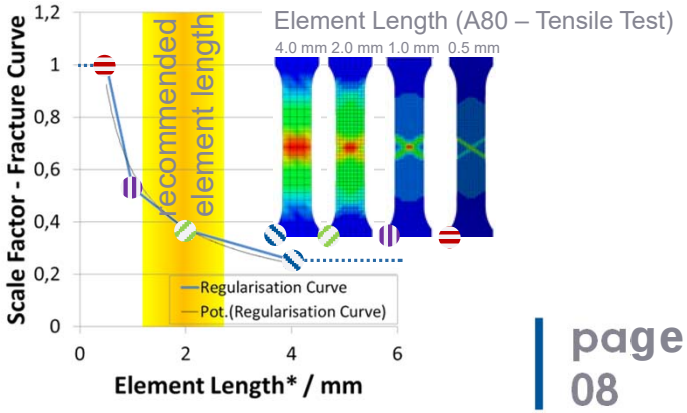
→ In general, the agreement between simulation and experiment is good



Yield Locus



Regularisation Curve



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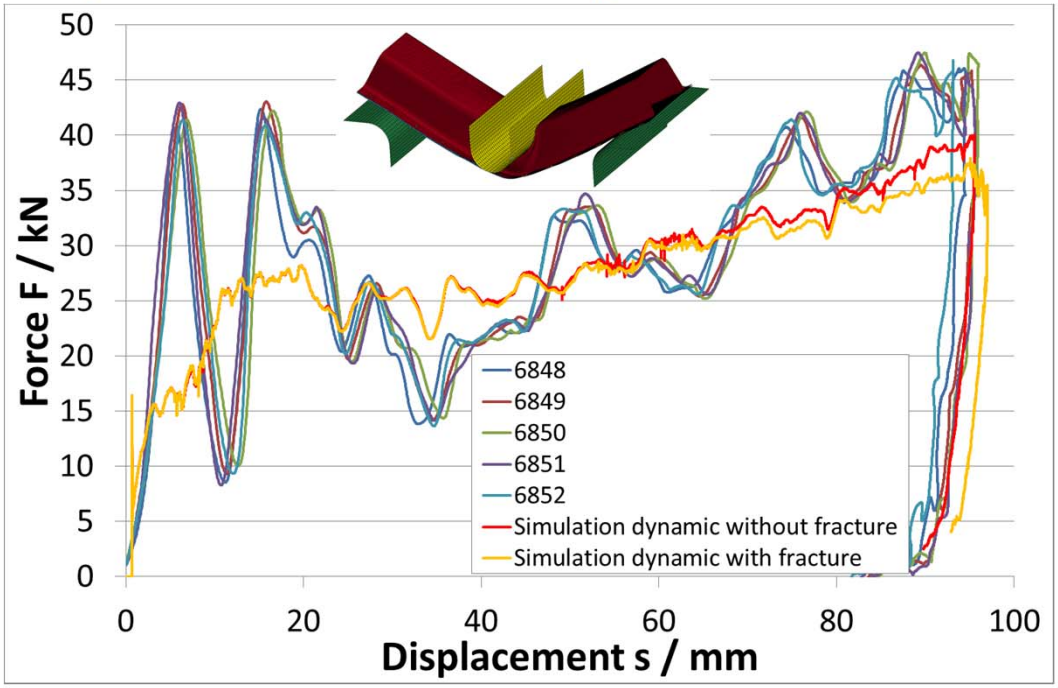
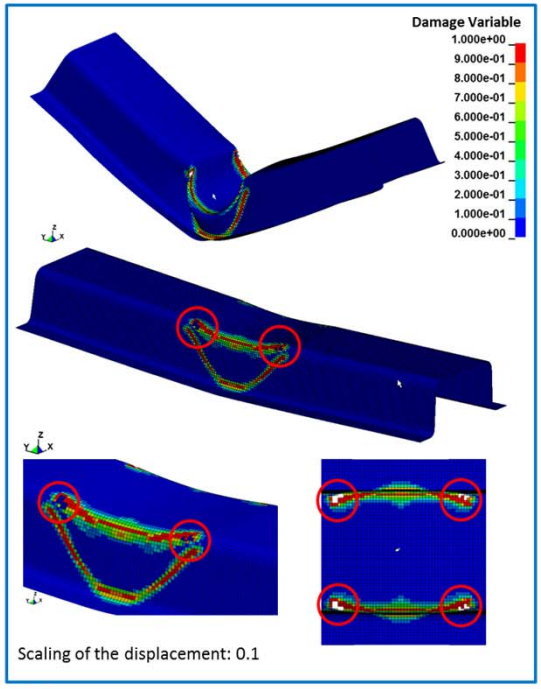
Material characterization

Comparison of Simulation and Experiment



Simulation



Experiment

Fracture

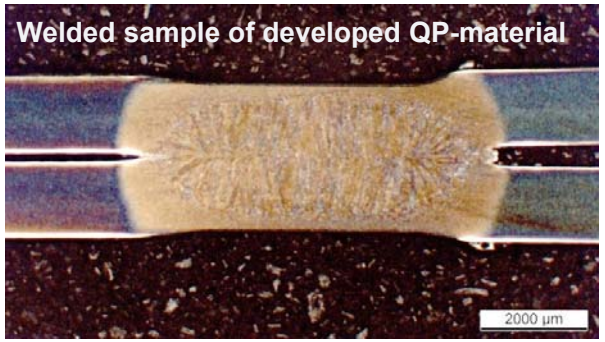
→ accuracy of the prediciton of fracture in the simulation is good

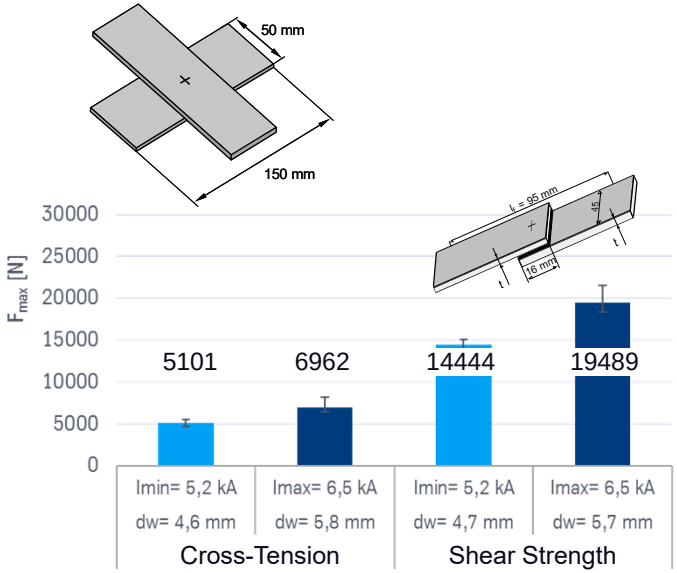
Material characterization

- ☑ The welding range for spot welding has been brought to an acceptable level (>1kA).
- ☑ The cross-tension (CT) and tensile-shear (TS) strength as well as sensitivity to LME are comparable or even better than conventional grades in the 1200 MPa strength class.

Open Issues:

- Further investigations and development of test procedures towards LME require continued effort.





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Material final properties / Summary

- **Brief description of the final material properties**

	Property	Threshold
☑	TS	≥ 1180 MPa
☑	YS	≥ 850 MPa
☑	A80	≥ 13%
☑	Hole Expansion (ISO)	≥ 30%
☑	Welding Range (SEP 1220)	> 1 kA

☑ **▪ Optimization of Yield Strength, Tensile Strength and Weldability**

☑ **▪ The taken experimental results filled the GISSMO Card and a comparison even with structural component simulation and experimental results are in good accordance**

☑ **▪ The welding range for spot welding as well as the cross-tension and shear strength satisfy initial requirements.**

→ Within the ALLIANCE project, a new 3rd generation steel has been developed fulfilling the mechanical requirements as well as initial tests for applications