GREAT DESIGNS IN STEEL

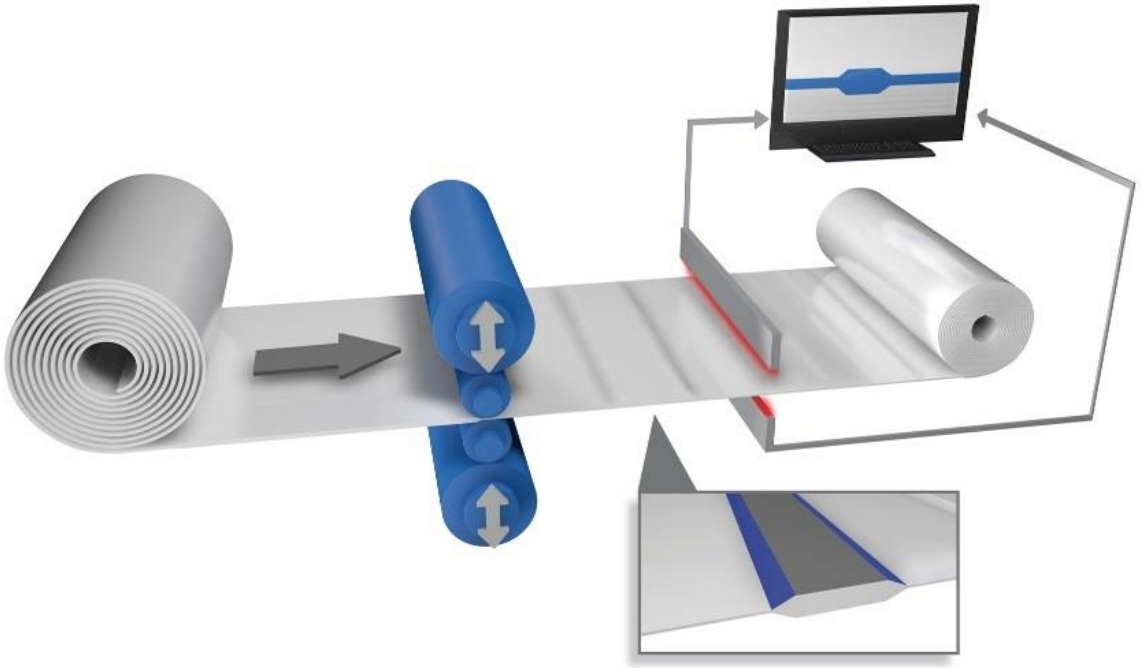
CAE MATERIAL MODELING AND TEST CORRELATION OF COST-EFFECTIVE TRB COLD STAMPINGS

Guido Borgna – Head of Engineering

Parveen Panchal – CAE Engineering Manager

Mubea Tailor Rolled Blanks

TRB FLEXIBLE ROLLING PROCESS

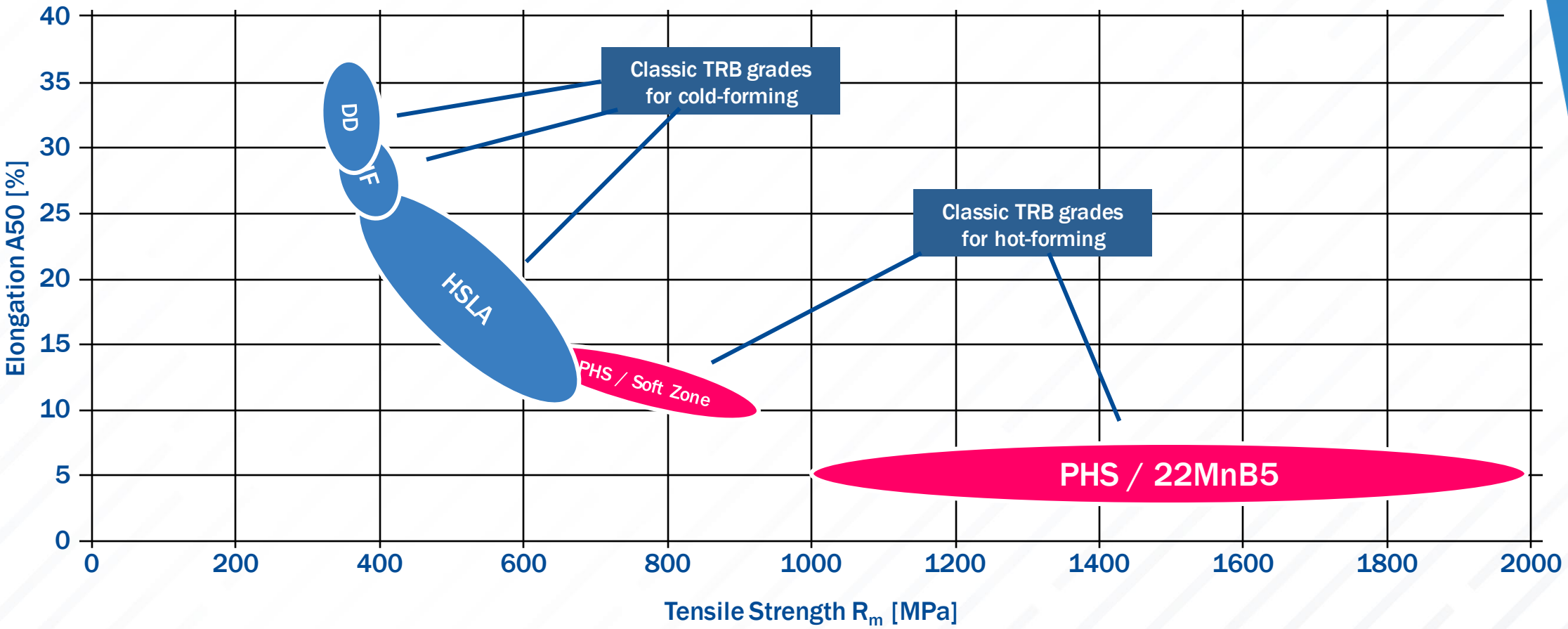


Benefits of Tailor Rolled Blanks (TRB)

- Cost reduction
- Weight reduction
- Part integration
- Joining reduction
- Functional improvement (crash, NVH, etc.)
- Compared to tailor welded blanks:
  - No Heat Affected Zone
  - No notch effect

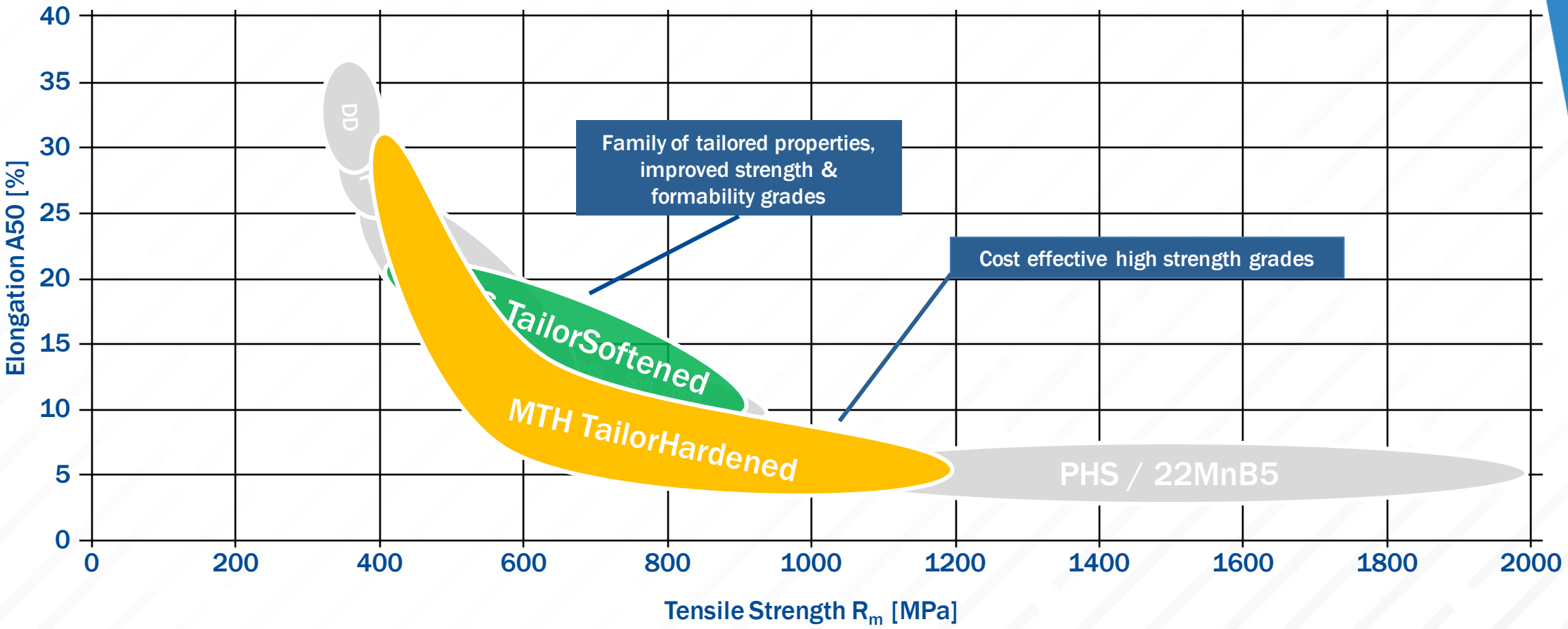
MUBEA INNOVATIVE MATERIALS

GDIS



MUBEA INNOVATIVE MATERIALS

GDIS

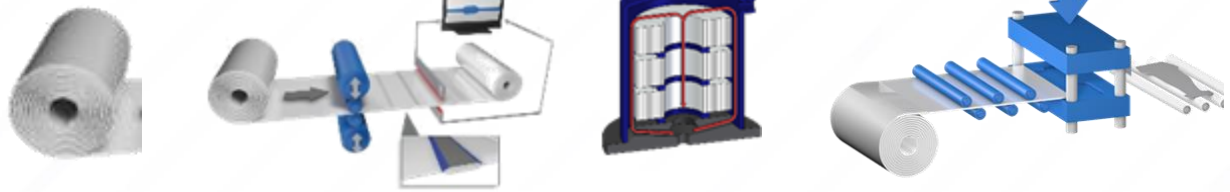


Mubea has developed innovative grades to meet current demands of US market (high strength, low cost)

MUBEA MTS: CONCEPT AND APPLICATION

GDIS

Process Flow



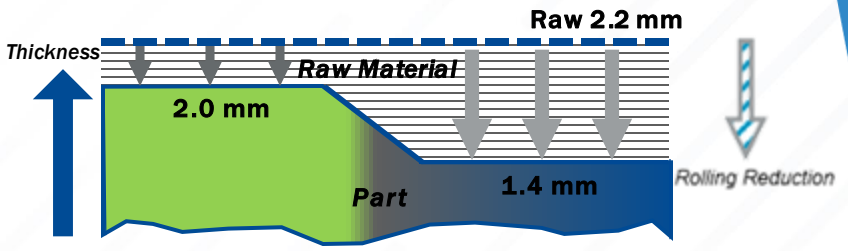
Raw Material
HR HSLA x 2.2 mm

Flex Rolling

Batch Annealing

Blanking/Forming

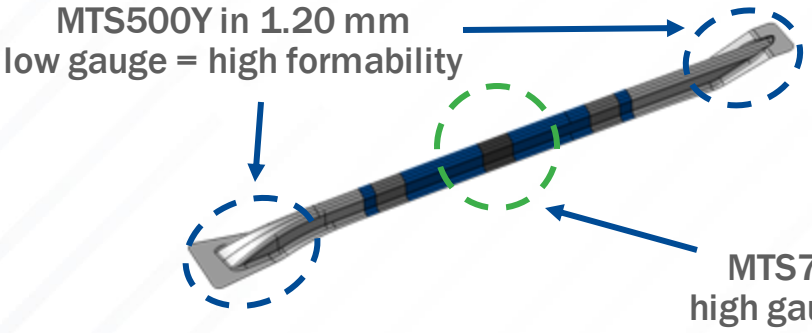
Mubea TailorSoftened
MTS 700Y/500Y TRB

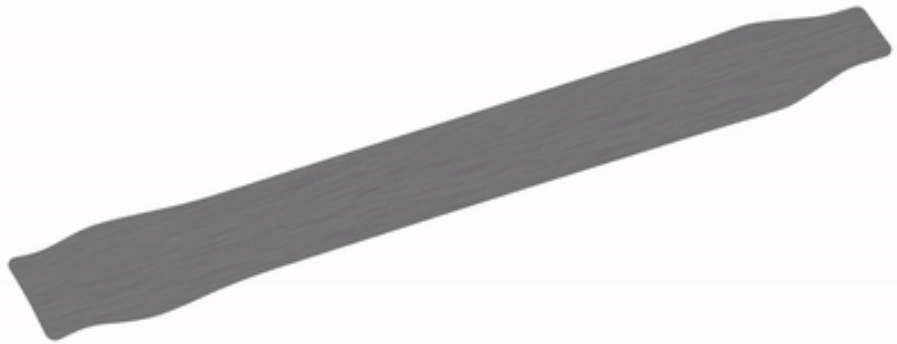


Recovered ➡ 700 MPa Min Yield Strength

Full recrystallization ➡ 500 MPa Min Yield Strength

Example of application: door intrusion beam





Mubea MTS delivers tailored properties and variable gauges: high formability and high strength where needed

MUBEA MTH: CONCEPT AND APPLICATION

GDIS

Process Flow

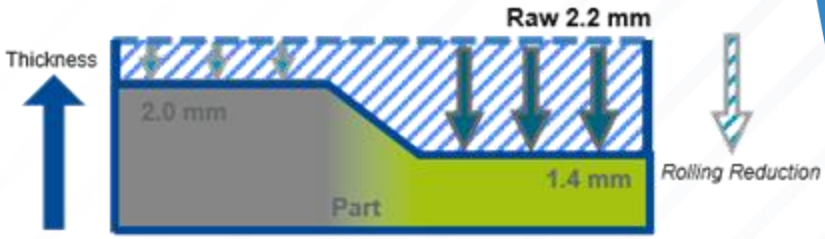
Raw Material
HR HSLA x 2.2 mm

Flex Rolling

Batch Annealing

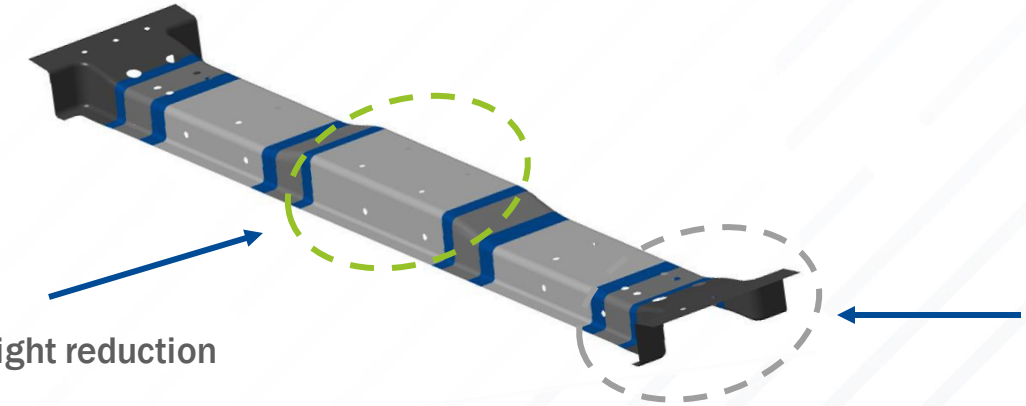
Blanking/Forming

Mubea TailorHardened
MTH 300-800Y/500-1100Y TRB



Low Rolling red% ➡ High elongation
High Rolling red % ➡ High strength

Example of application: floor cross-member

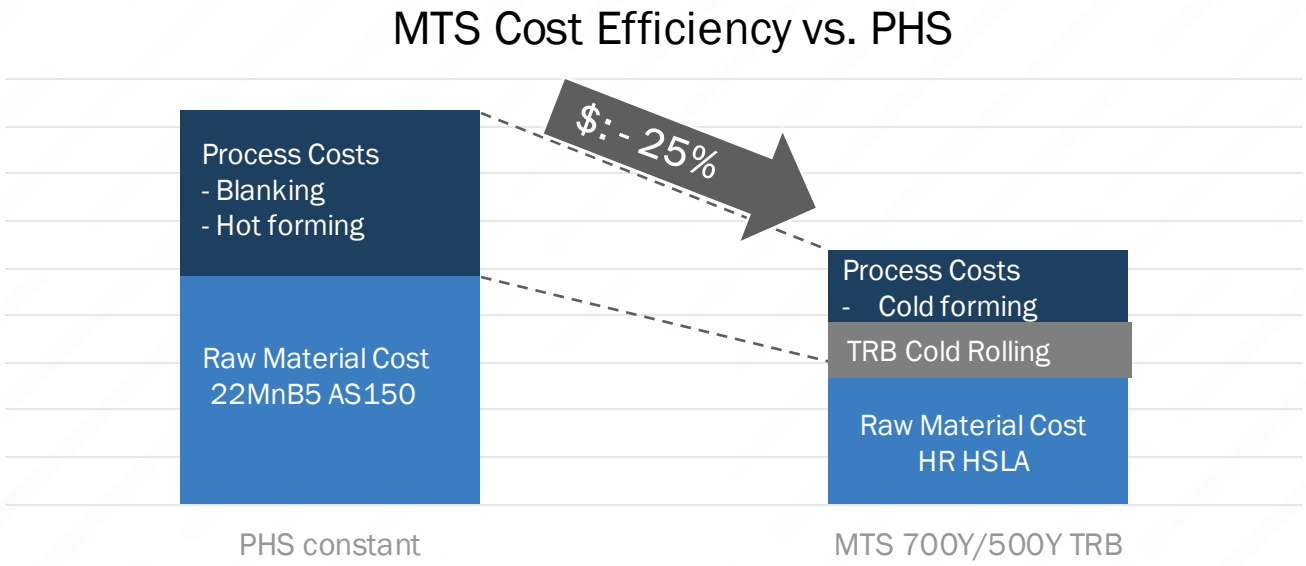


MTH750Y / 6% E
Low gauge / high strength / weight reduction

MTH550Y / 15% E
High gauge / high formability / energy absorprion

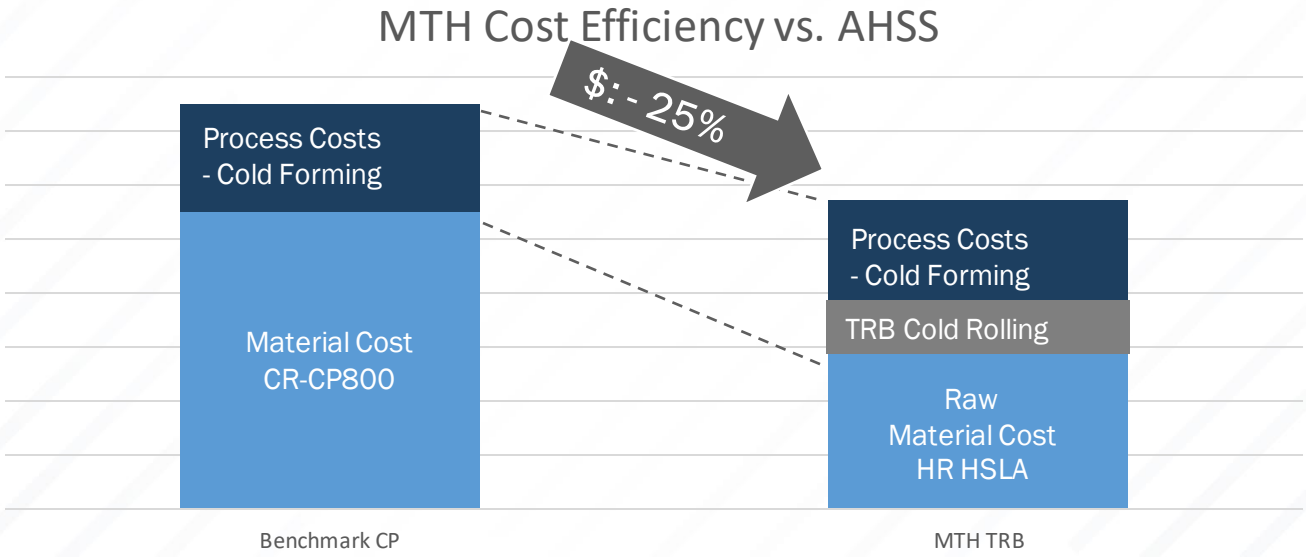
MTH delivers cost-efficient lightweight high-strength solution, with higher formability in thick regions

MUBEA MTS & MTH: COST BENEFITS



MTS Cost Efficiency

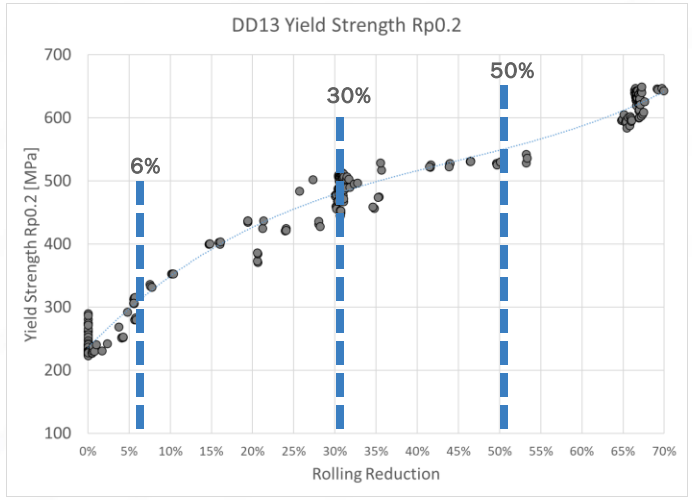
- MTS TRB achieves same performance as PHS
- MTS TRB offers cost reduction with comparable weight

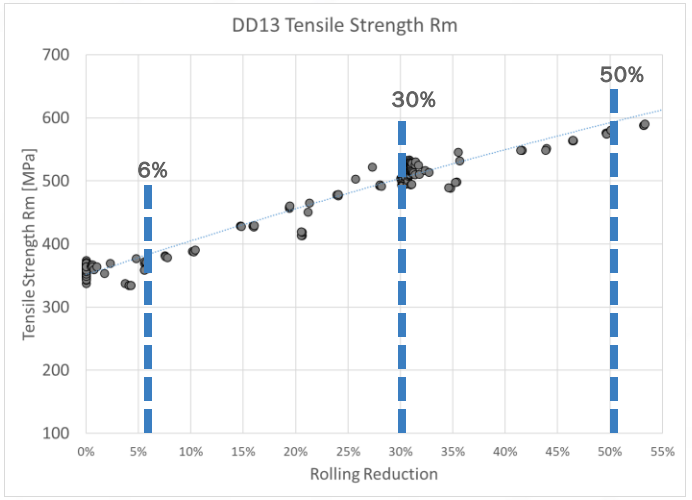


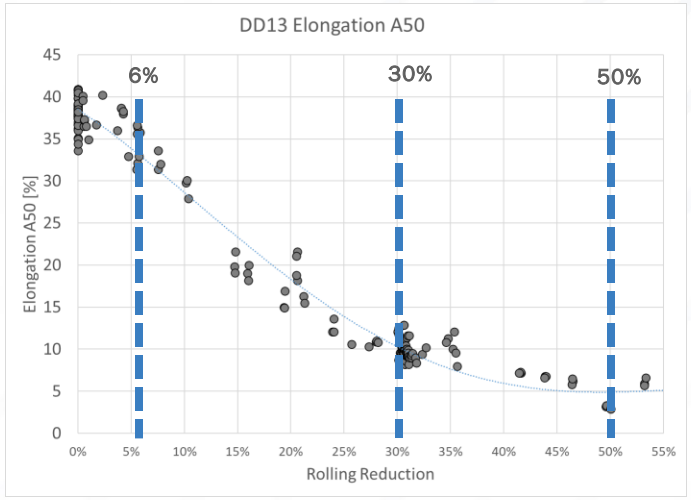
MTH Cost Efficiency

- MTH achieves same performance as AHSS
- MTH TRB reduces material cost using less expensive raw material

MTS & MTH MATERIAL CARD DEVELOPMENT







- Fully characterized (crash & formability) hot-rolled material grades: DD13, HR420, HR700, CP800
- Features of CAE cards:
  - Quasi static & dynamic (LS-DYNA)
  - Formability curves (AUTOFORM)
  - Failure models (Gissmo and CrachFEM)
  - Durability curves (stress-life, strain-life) for HR700 (at Fraunhofer Institute)
- Ongoing development: HR550 (crash & formability) with MatFEM

TRB THICKNESS & MATERIAL MODELING IN CAE

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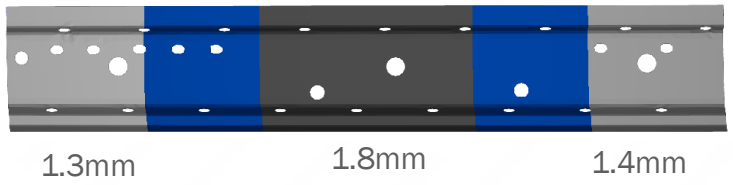
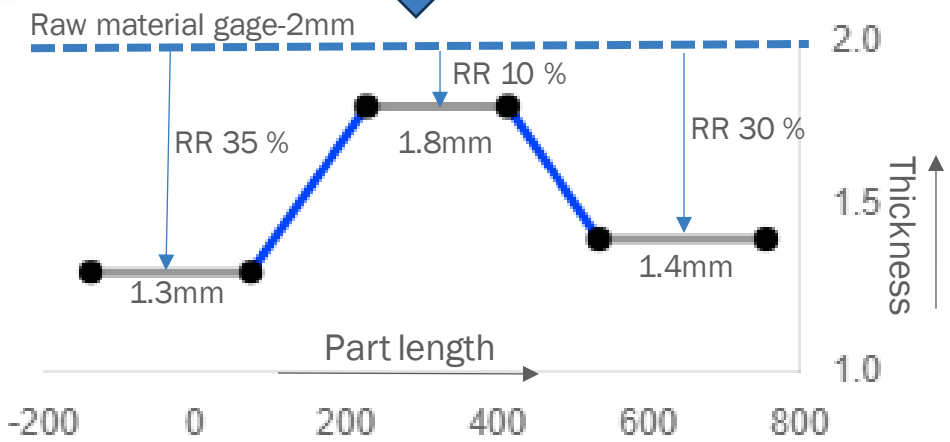
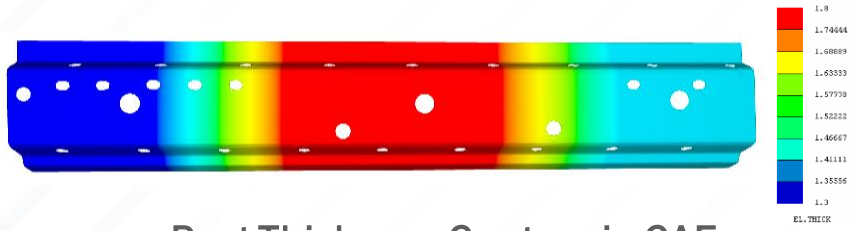
Side Member TRB Part



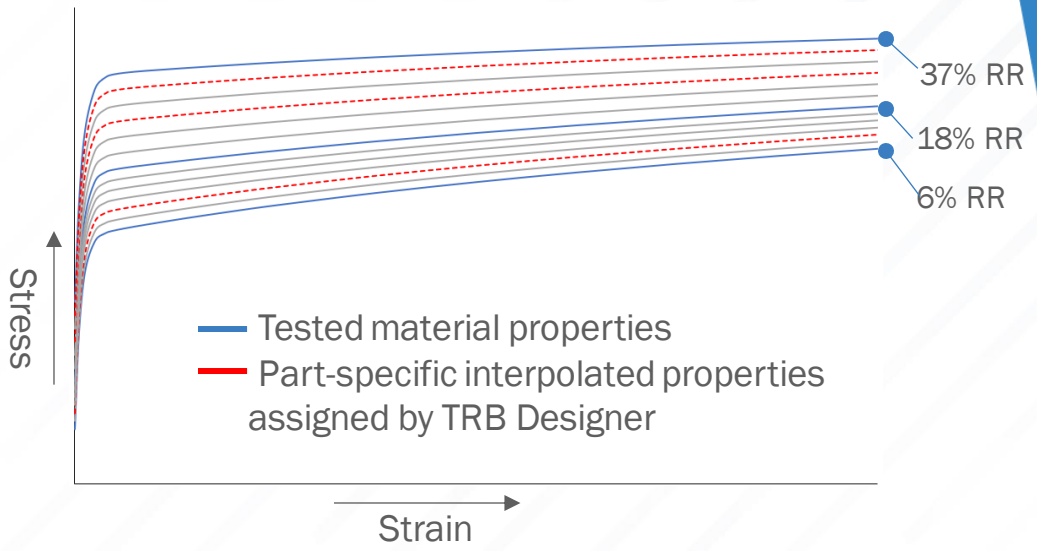


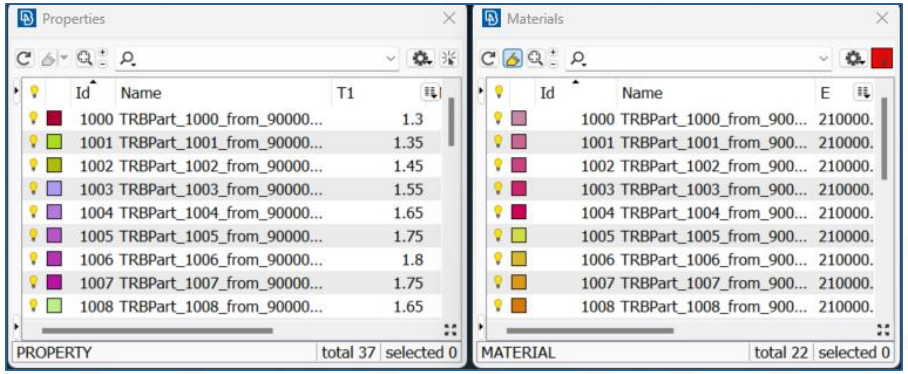
Thickness Profile Chart



Part Thickness Contour in CAE

MTH Material Properties





PIDs and MIDs in CAE Pre-processor

TRB thickness and material modeling can be done automatically using TRB Designer

TRB DESIGNER

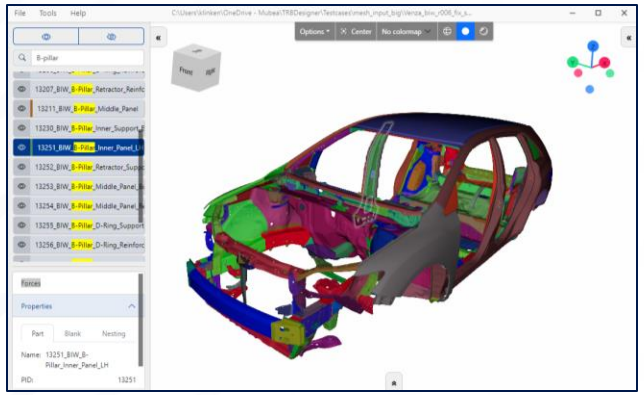
GDIS

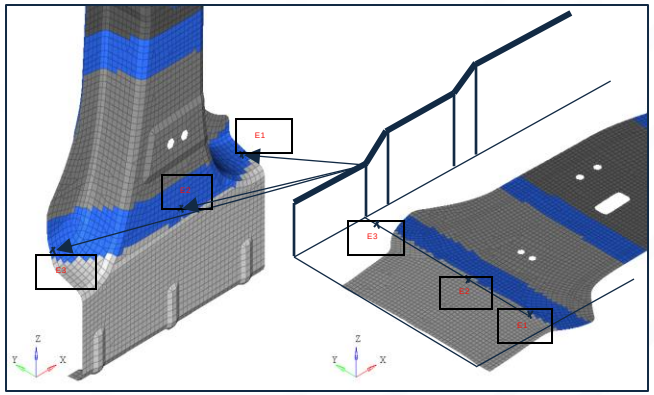
The concept

- Modern, UI driven application for TRB thicknesses application, respecting manufacturing constraints
- Possibility to generate & visualize FEM models with various thickness profiles, for fast CAE assessment and decision making

Features

- Operating systems: Windows, and Linux Systems
- Supported CAD formats: step, igs, JT and CATPart (surface and solid models), NX
- Supported CAE formats: NASTRAN, OPTISTRUCT, LS-DYNA, ABAQUS, RADIOSS, PAMCRASH
- Stand-alone software: Mubea can provide complimentary licenses to customers
- Nesting analysis requires Altair HyperWorks license





Tools for CAD Designers

- Blanking & Nesting
- Material utilization calculation
- Mapping of transition zones from blank to part & export to Catia

Tools for CAE Engineers

- Automatic meshing
- Application of TRB thickness profile
- Applicaiton of TRB material cards

TRB DESIGNER FOR CAE

GDIS

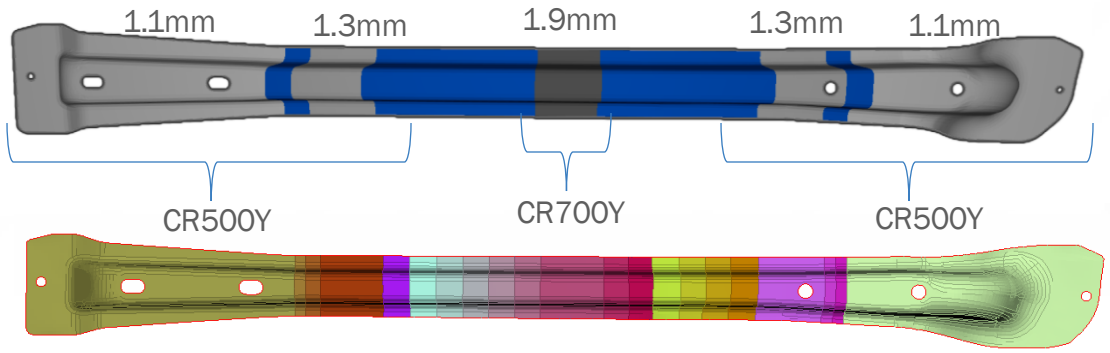
TRB DESIGNER FOR CAD

GDIS

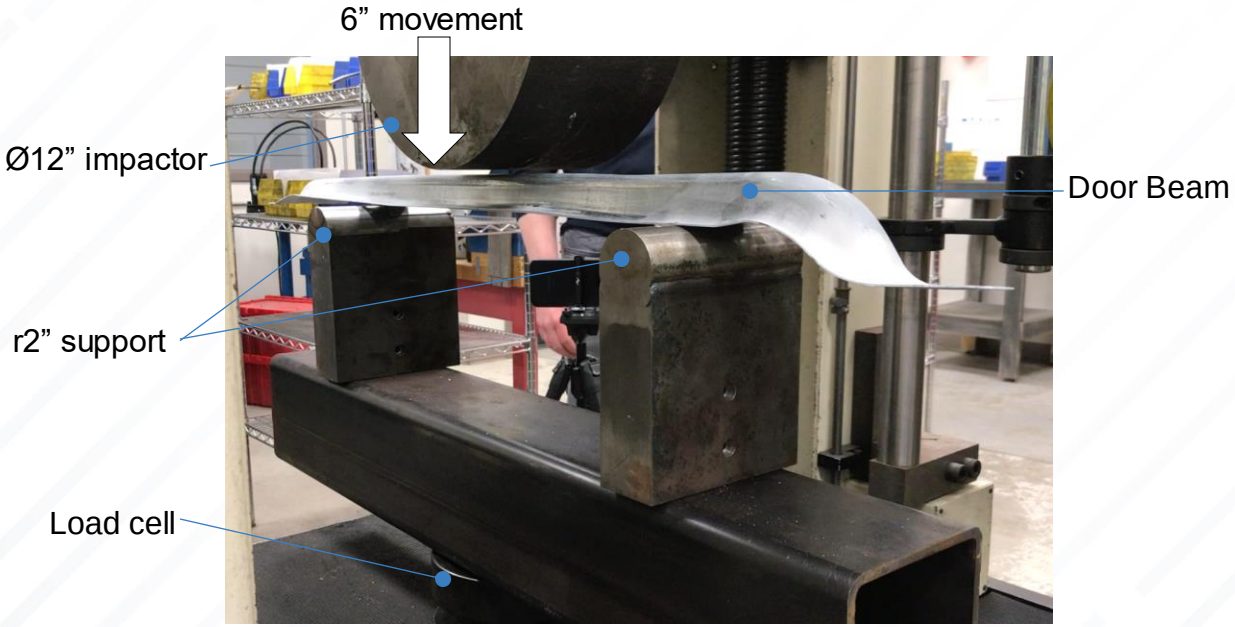
MTS PART: TEST vs. CAE CORRELATION

GDIS

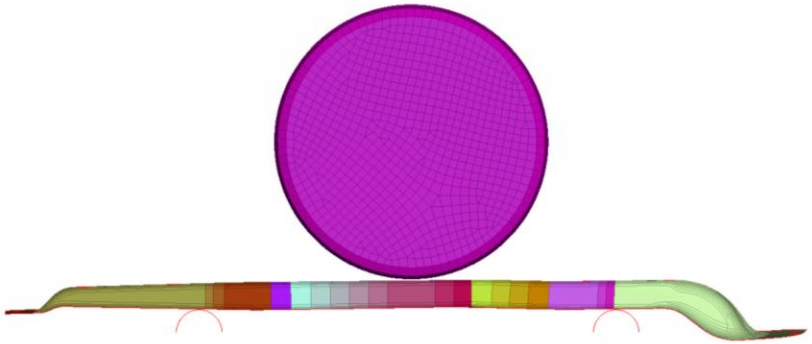
Door Intrusion Beam



3 Point Bending Test Setup



3 Point Bending CAE Setup



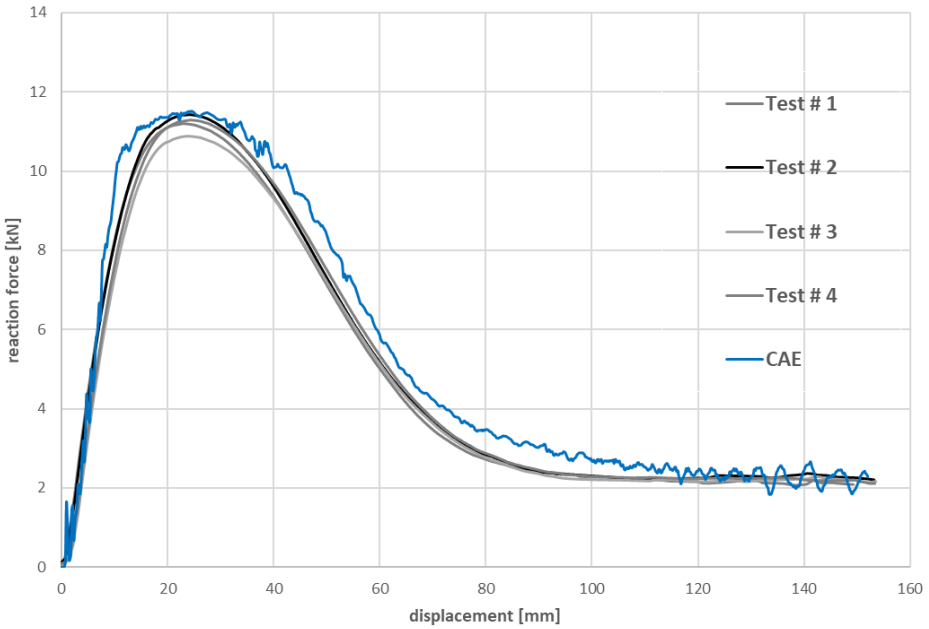
Correlation Criteria:

- Beam deformation mode
- Force vs displacement chart

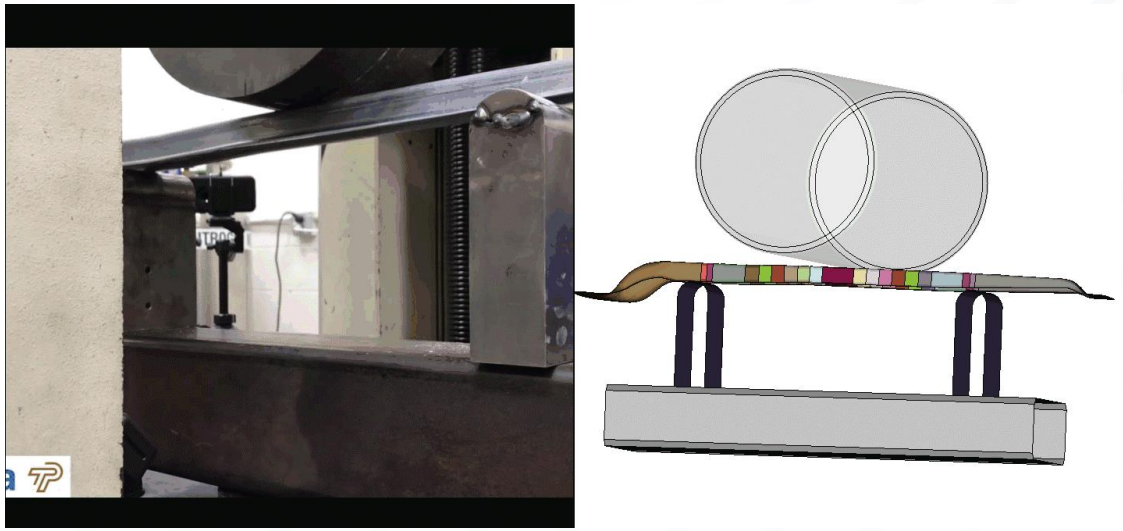
MTS PART: TEST vs. CAE CORRELATION

GDIS

Force vs. Displacement Chart



Deformation Mode



	Peak force	Location of peak force
Test	11.20 kN (average)	24.06 mm (average)
CAE	11.53 kN (+2.95%)	24.60 mm (+2.24%)

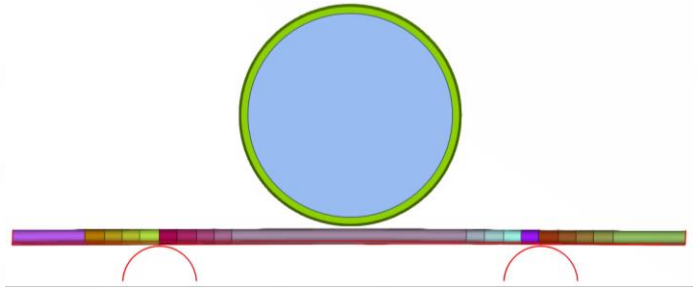
Test vs CAE Correlation Summary:

- Similar deformation mode observed
- The FD chart from CAE showed a 3% higher peak force
- The peak force location was within 0.5 mm
- Overall good correlation was achieved

MTH HR700 PART: TEST vs. CAE CORRELATION

GDIS

3 Point bending test setup CAE



U Channel with central bead

2.52mm
RR:37%
1109 MPa

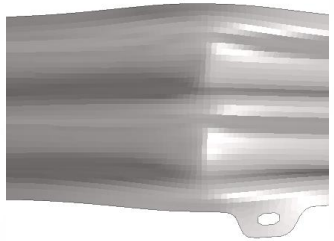
3.29mm
RR:17.75%
1007 MPa

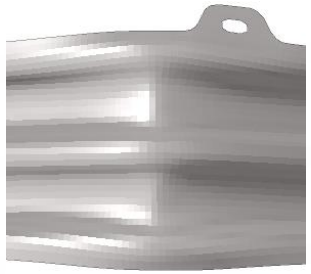
2.52mm
RR:37%
1109 MPa

Deformation Mode

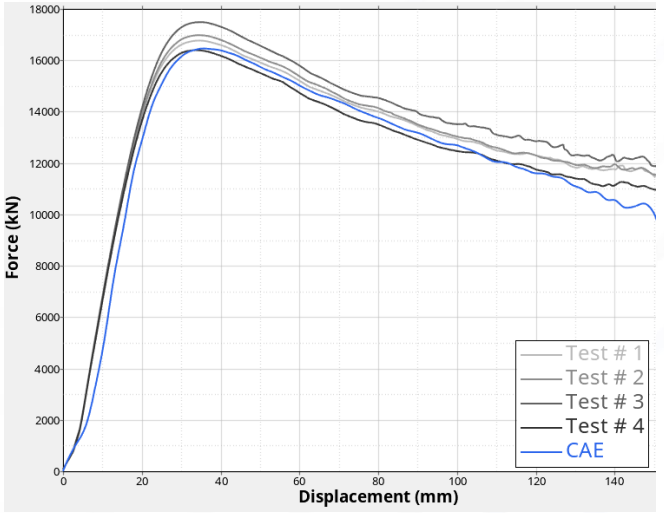
Test

CAE





Force vs. Displacement Chart



	Peak force	Location of peak force
Test	16.91 kN (average)	34.6 mm (average)
CAE	16.46 kN (-2.7%)	35.6 mm (+2.9%)

Test vs CAE Correlation Summary:

- Similar overall deformation mode was observed.
- The FD chart from CAE indicated a 3% lower peak force vs avg.
- The location of the peak force remained within 1 mm range.
- Overall, good correlation was achieved.

MTH HR550: MATERIAL CARD DEVELOPMENT

GDIS

Phase 1 - Completed

- Creation of preliminary material cards based on tensile tests
- Preliminary correlation of 3-point bending test on Roof Bow application

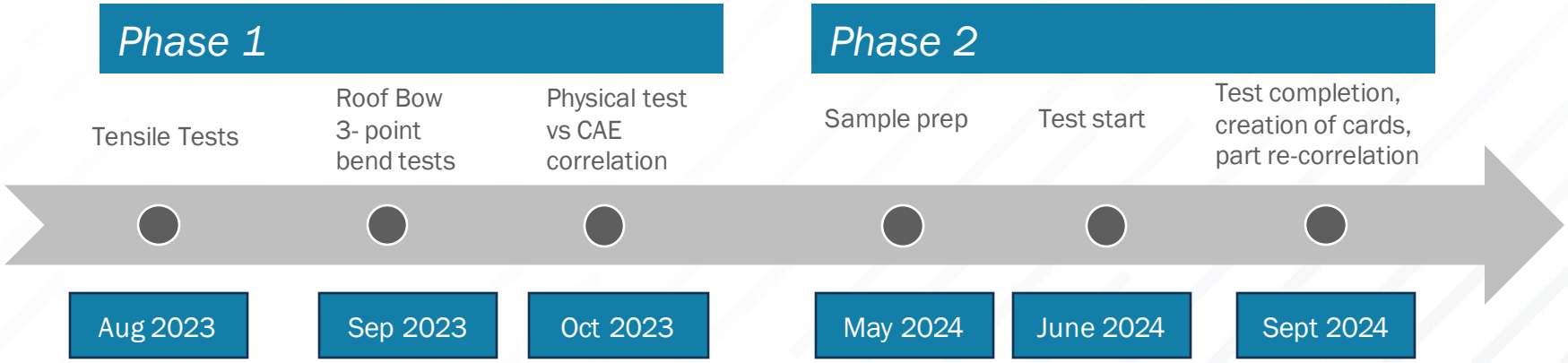
Phase 2 - Started

Creation of material cards for forming and crash (Partner: MatFem)

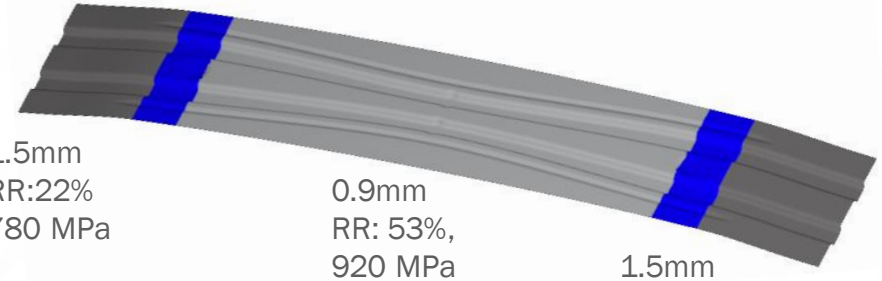
- Static and dynamic characterization of material
- Static and dynamic correlation (physical test vs simulation)
- Release of material cards:

  Crash: LS Dyna + Gissmo/CrachFem

  Forming: AutoForm



MTH HR550 ROOF BOW: PRELIMINARY TEST vs. CAE CORRELATION

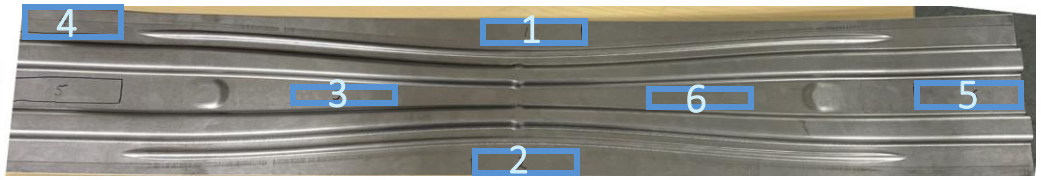


1.5mm
RR:22%
780 MPa

0.9mm
RR: 53%,
920 MPa

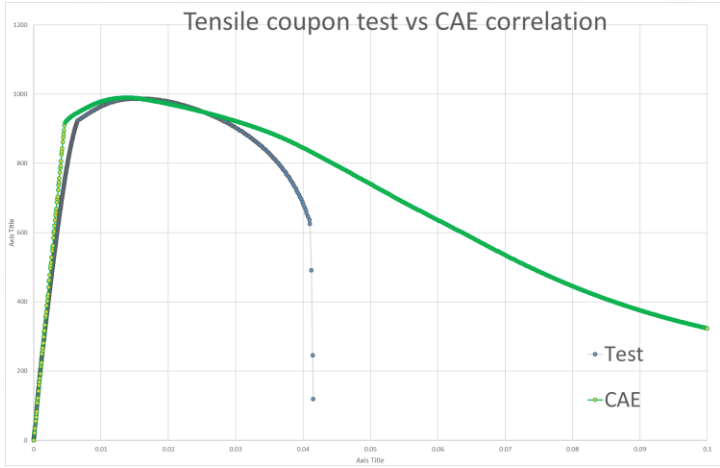
1.5mm
RR:22%
780 MPa

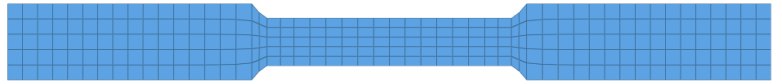
Raw material: 1.7 mm



(6) Tensile Test Samples(sub-size) taken from former Roof Bow project

Stress-Strain Curve





TEST RESULTS:

Sample	Thickness (mm)	YS (MPa) 0.2% Offset	UTS (MPa)	EL (%) 25.4 mm GL
#1	0.92	990	1000	5.5
#2	Not OK test			
#3	0.93	920	990	4.5
#4	1.5	780	840	8.9
#5	1.48	800	860	8.9
#6	0.93	970	980	4.6

YS = Yield Strength; UTS = Ultimate Tensile Strength; EL = Elongation; GL = Gage Length

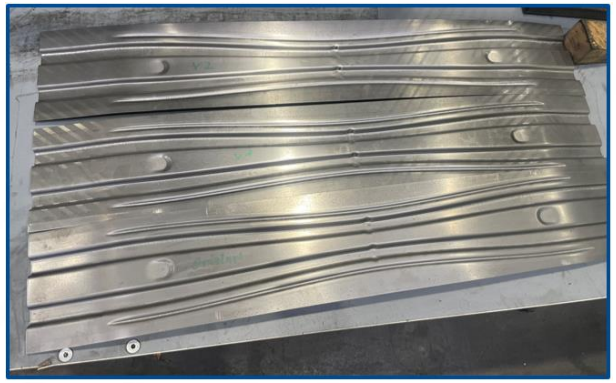
Correlation Summary:

- In both test and CAE analysis, initial slope of the stress-strain curve and yield strength are correlated
- Ultimate tensile strength and onset of necking are also matched between test and CAE
- Due to unavailability of failure curves in CAE, necking to fracture behavior is not captured

MTH HR550 ROOF BOW: PRELIMINARY TEST vs. CAE CORRELATION

GDIS

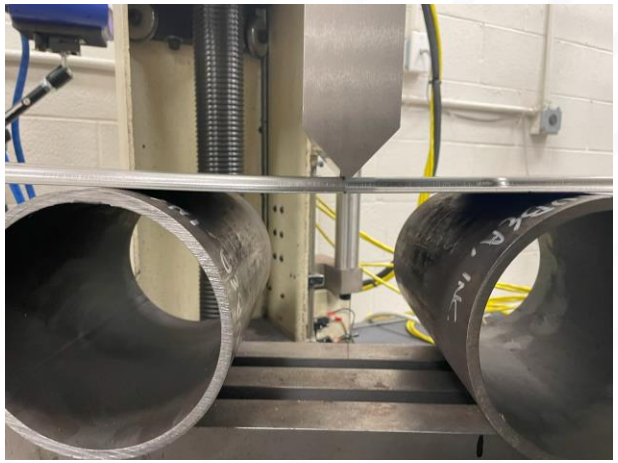
Roof Bow Samples



Physical Test Setup:

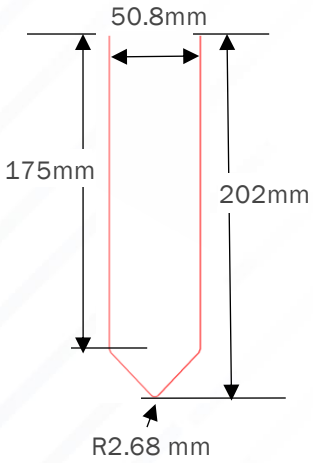
- 3-point bending test was performed with conical plunger to induce high local deformation
- 3 samples tested
- Correlation Criteria: Deformation mode and force-displacement chart

3-Point Bending Test Setup

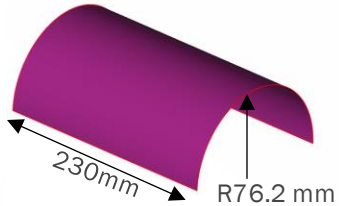


CAE Setup

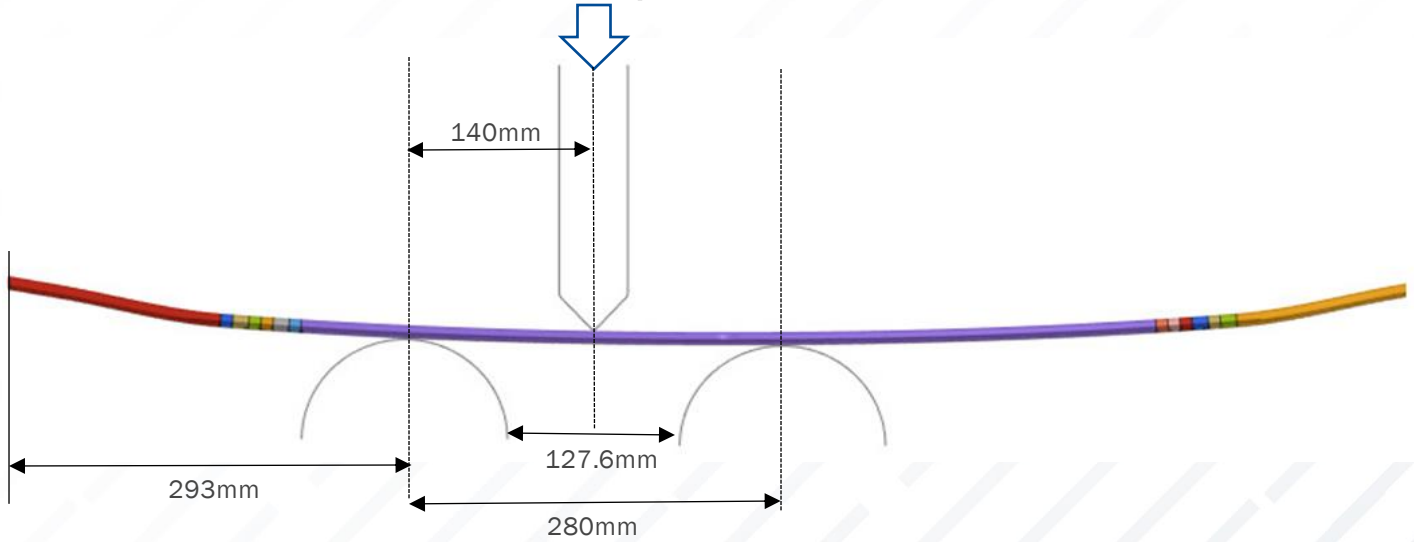
Plunger



Spacer



6 inches Displacement

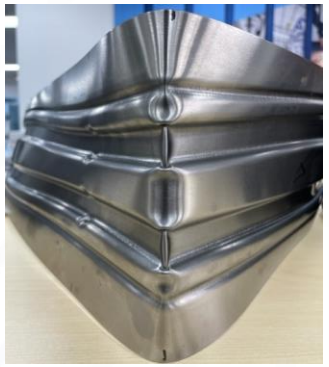


MTH HR550 ROOF BOW: PRELIMINARY TEST vs. CAE CORRELATION

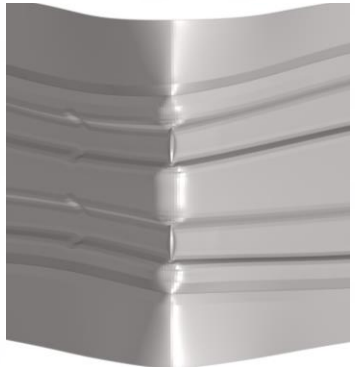
GDIS

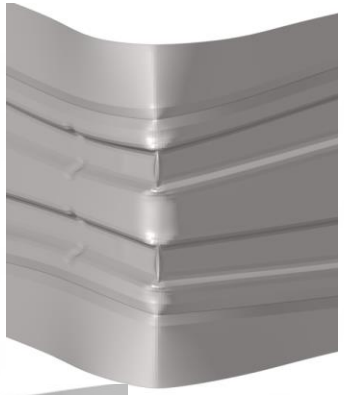
Deformation Mode

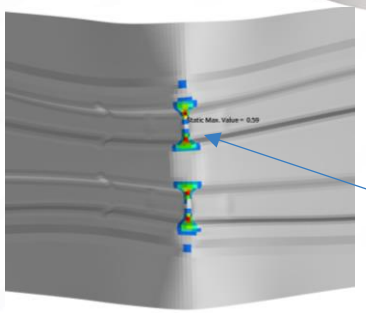
Test



CAE

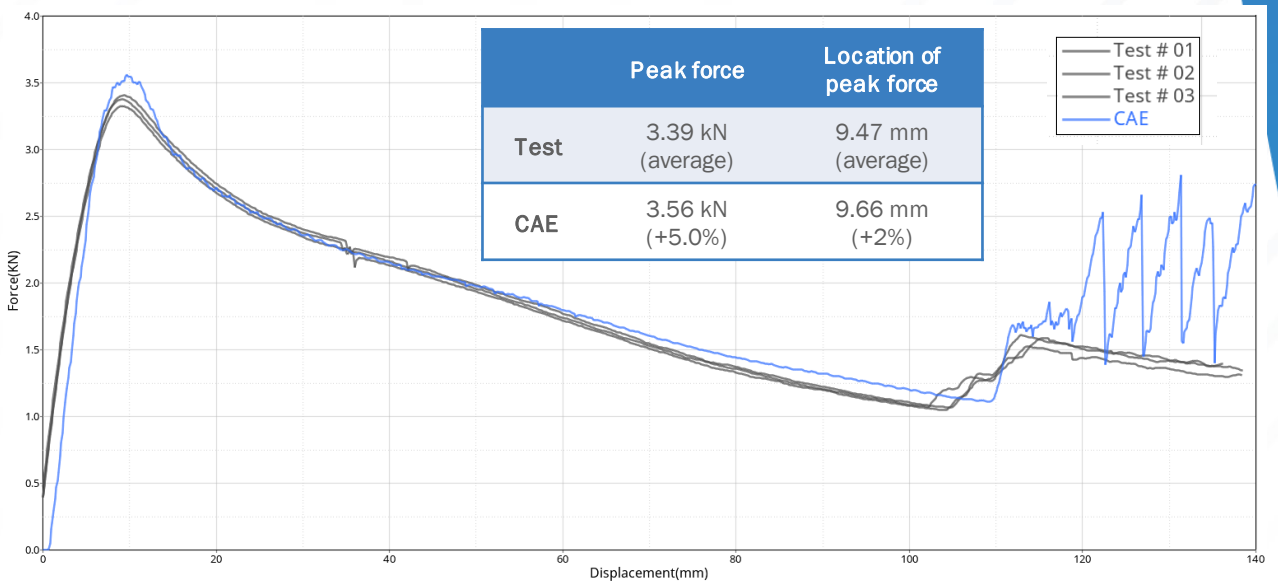






Plastic strain: 59%

Force vs. Displacement Chart



	Peak force	Location of peak force
Test	3.39 kN (average)	9.47 mm (average)
CAE	3.56 kN (+5.0%)	9.66 mm (+2%)

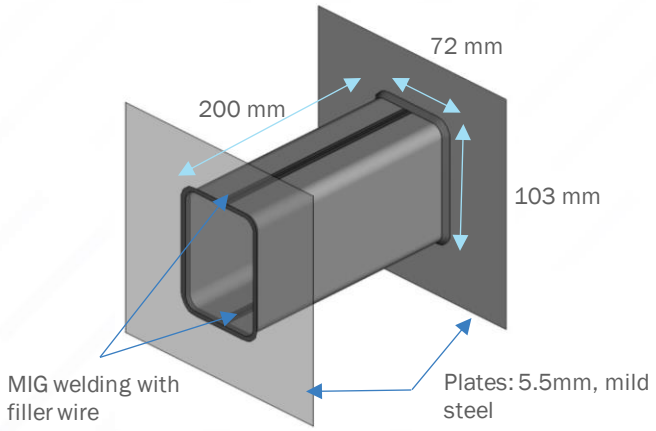
Correlation Summary:

- Similar deformation modes observed
- The FD chart from CAE indicated 5% higher peak force than experimental data. Better correlation is expected using final material card from phase 2 development.
- The peak force location was within 0.2 mm
- Despite high local deformation (CAE: 59% EPS), no Roof Bows showed cracks in the physical test.

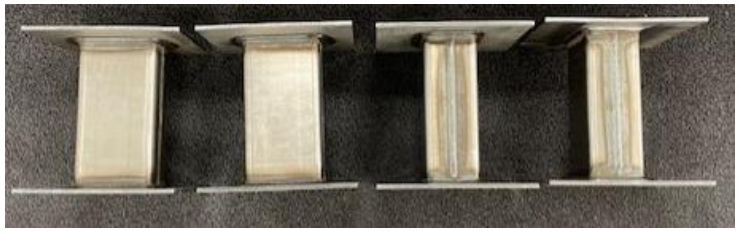
MTH HR420 CRUSH BOX: TEST vs. CAE CORRELATION

GDIS

Crush Box



Crush Box Prototypes Parts

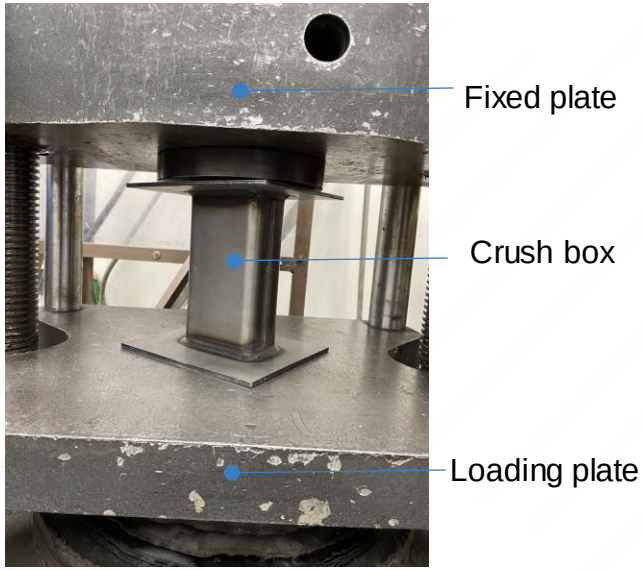


5 prototype parts were built for each of the 3 gages (1.79mm, 1.55mm, 1.2mm), with same geometry.

Gage	Rolling Reduction	Yield strength (Mpa)	Tensile strength (Mpa)	A50 % Elongation	No. of sampled tested
1.79 mm	6%	530	562	18.5	5
1.55 mm	18%	638	658	7.0	5
1.2 mm	37%	720	741	4.2	5

(Raw material gage: 1.9mm)

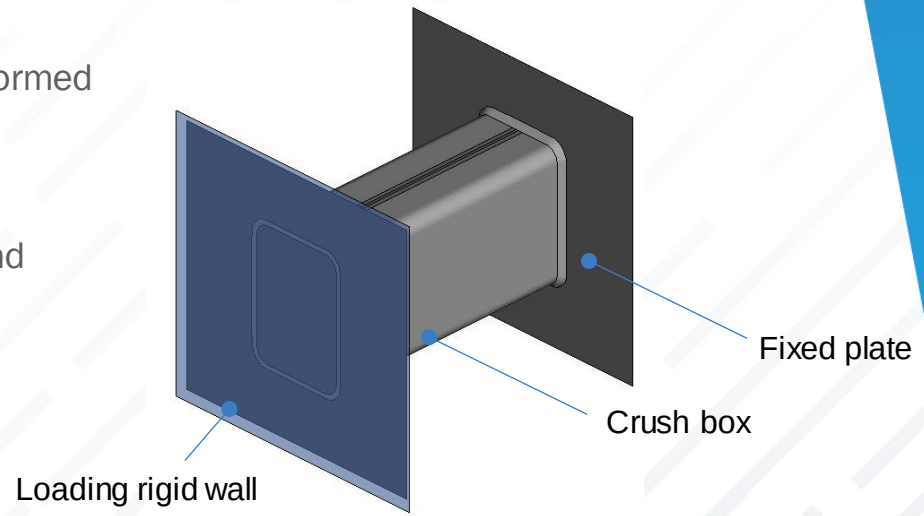
Quasi-static axial crush Test setup



Physical Test Setup:

- An axial crush compression test was performed to induce high deformation
- Total crush: 100mm
- 5 samples of each gages tested
- Correlation Criteria: Deformation mode and force-displacement chart

CAE Test setup



MTH HR420 CRUSH BOX: TEST vs. CAE CORRELATION

GDIS

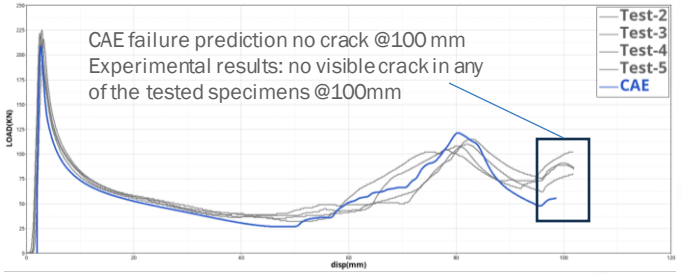
Deformation Mode

Test

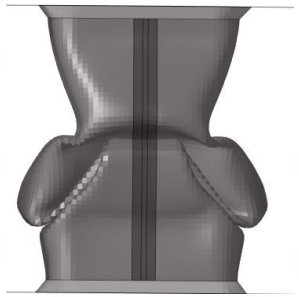
CAE

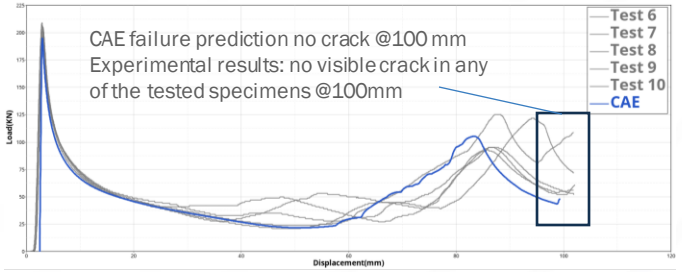
Force vs. Displacement Chart

1.79 mm, 6% RR

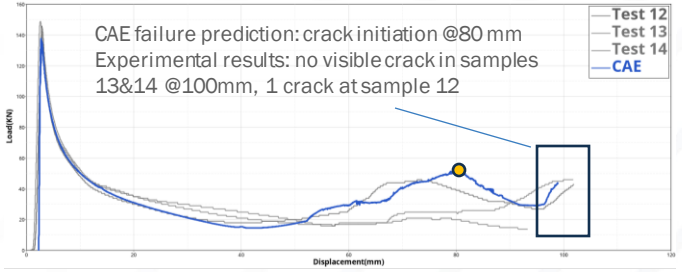


1.55 mm, 18% RR





1.2 mm, 37% RR



Gage (mm)	Rolling Reduction (Raw material gage: 1.9mm)	Test Peak force (KN) (average)	CAE Peak force (KN)	% Change Peak force
1.79	6%	221	209	-5.4%
1.55	18%	204	195	-4.9%
1.2	37%	145	138	-4.8%

Correlation Summary:

- Good correlation achieved between Test vs CAE:
  - Deformation mode
  - F-D curve: less than 6% difference between test vs CAE
  - Damage model (crack occurrence)
- Due to weld imperfections and heat affected zone, test deformation mode is offset marginally compared to CAE

FOR MORE INFORMATION

THANK YOU!

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