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SPOT WELD MODELING WITH IMPLEMENTED RUPTURE CRITERIA

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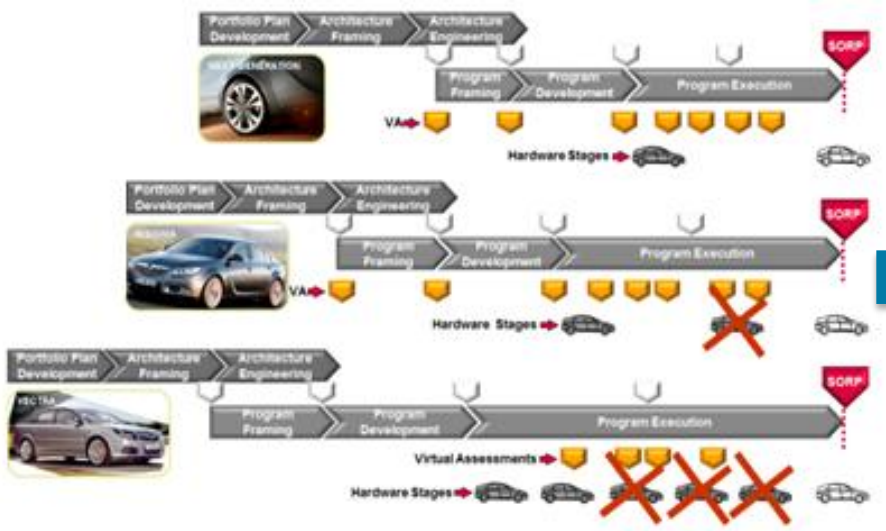
Motivation

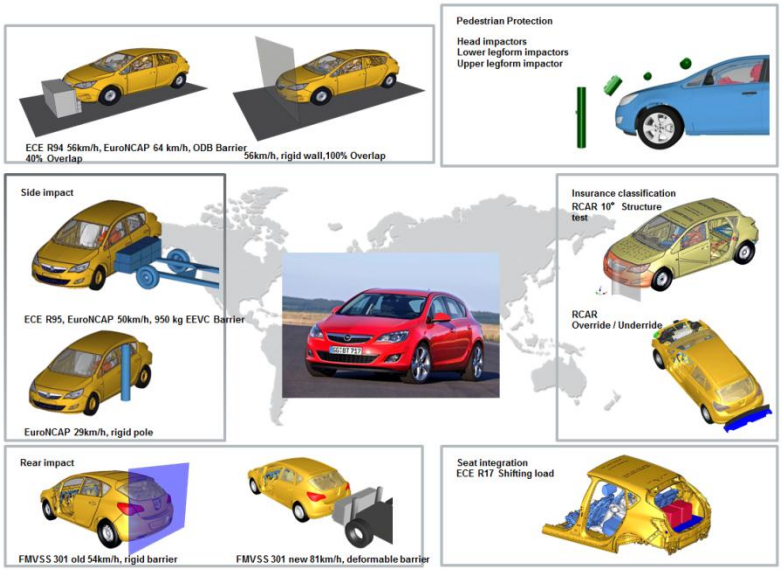
Requirements

- Faster to market
- Reduced prototypes
- Reduced weight
- Reduced carbon dioxide emission
- legal and customer requirements

Crashworthiness Simulation

- More appropriate weld rupture behavior required to meet the advanced requirements and to increase the accuracy of structural response assessment





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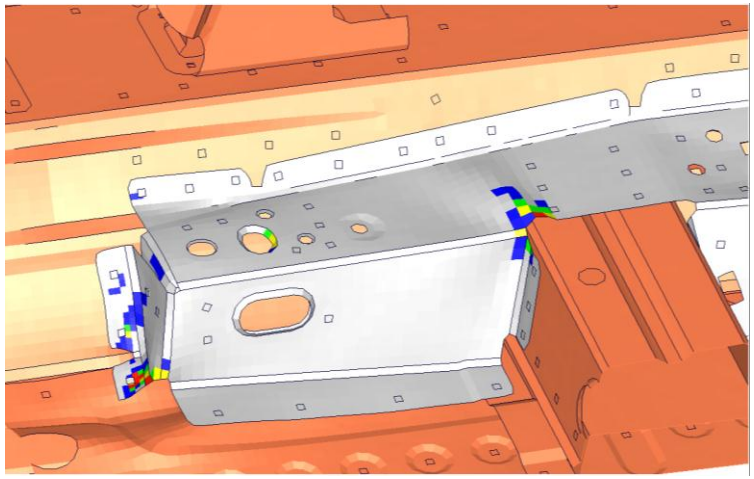
Motivation

- appropriate weld rupture behavior required to
  - meet the advanced requirements (fewer prototypes, faster development process)
  - to increase the accuracy of structural response assessment
- vehicle typically contains a few thousand spot welds joining a large number of materials and gage combinations
- consideration of their specific mechanical properties and fracture behavior is a key to accurately predict the response of vehicle structures
- an automated tool is prerequisite to implement specific weld data for each spot weld joint for full simulation model

Motivation

Simulation w/o weld rupture compared to principle hard ware test

Simulation w/o weld rupture



Hard ware test

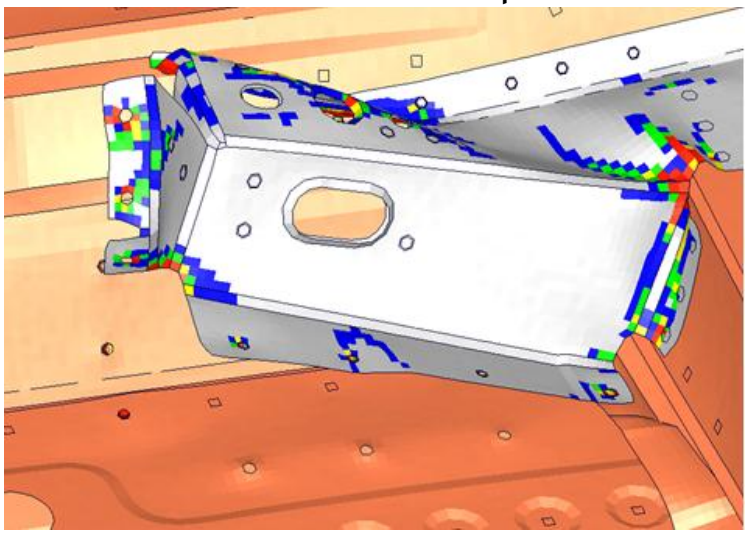
- obviously high loaded weld joint connecting seat console and floor panel
- no indicator for a high risk of integrity loss
- expectation of only one weld joint rupture

- structure integrity loss due to extensive spot weld rupture before reaching load maximum
- behavior was strongly influenced by nugget pull out

Motivation

Simulation w/ weld rupture compared to principle hard ware test

Simulation w/ weld rupture



- rupture mode and carried loads are comparable to hard ware test
- suitable to represent the hard ware test behaviour

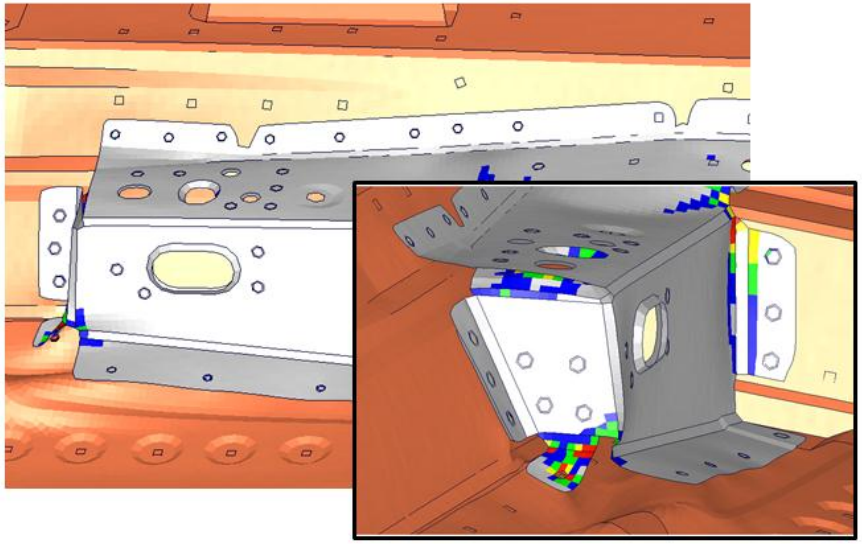
Hard ware test

- structure integrity loss due to extensive spot weld rupture before reaching load maximum
- behavior was strongly influenced by nugget pull out

Motivation

Optimized design - Simulation w/ weld rupture compared to principle hard ware test

Simulation w/ weld rupture



- an optimized design was developed by using the validated simulation model
- local weld rupture is expected but no risk for loosing seat integrity is assessed

Hard ware test

- Hard ware test behavior shows that simulation prediction was very good

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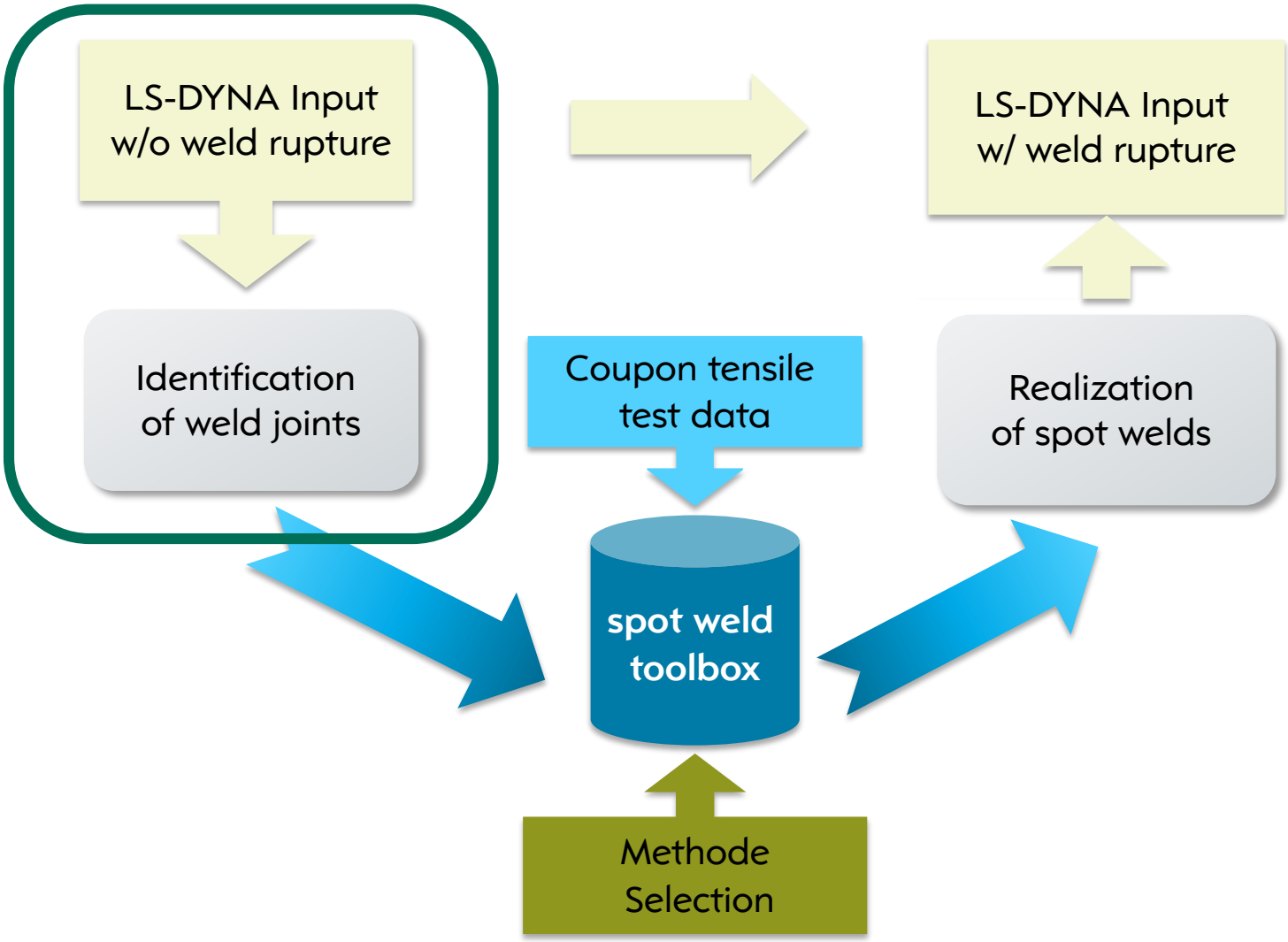
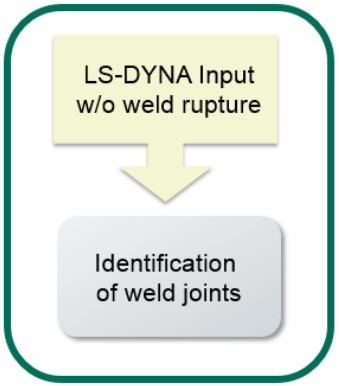
Automated spot weld realization procedure

Overview



Automated spot weld realization procedure

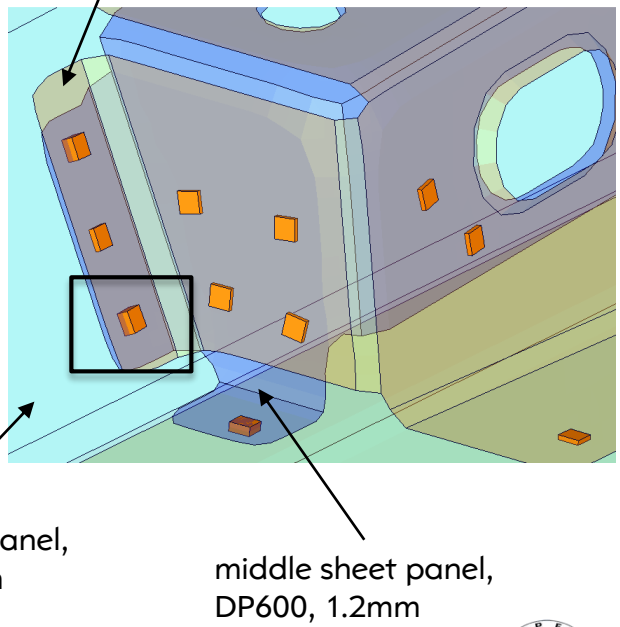
Spot weld joint identification



Identification of each spot weld joint

- number of weld partners
- panel stack up (top/middle/bottom)
- material grade
- sheet gauges

3 layered weld



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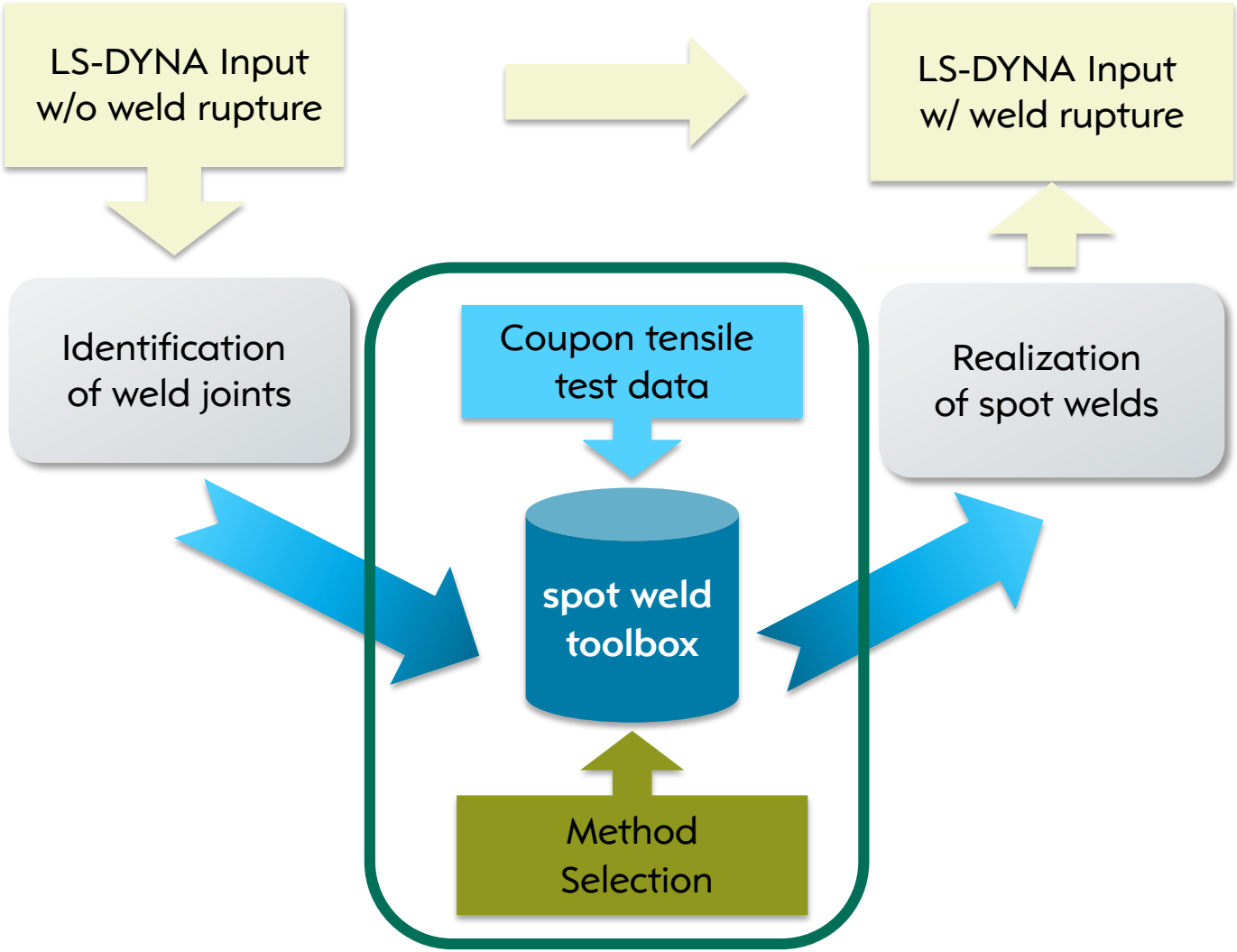
Automated spot weld realization procedure



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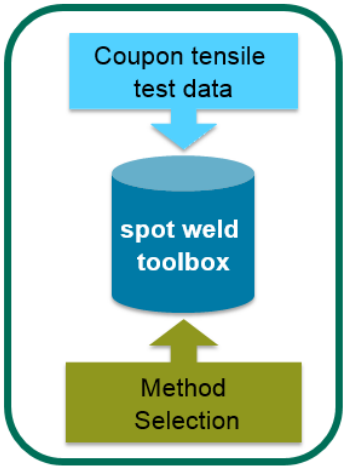
Automated spot weld realization procedure

Spot weld tool box: Data Input

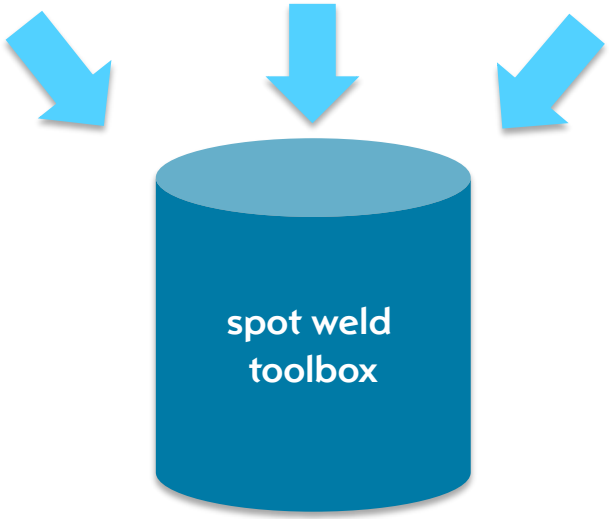


Test data weld joint A
nugget diameter,
Yield, ETAN,
rupture criteria

Test data weld joint B
nugget diameter,
Yield, ETAN,
rupture criteria

...

Test data weld joint X
nugget diameter,
Yield, ETAN,
rupture criteria



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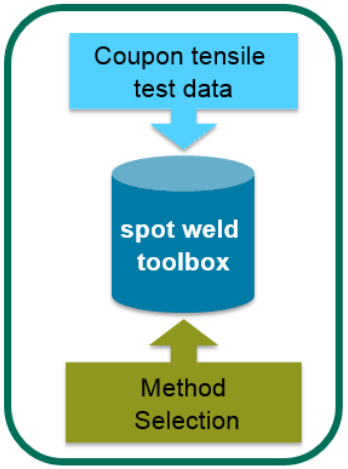
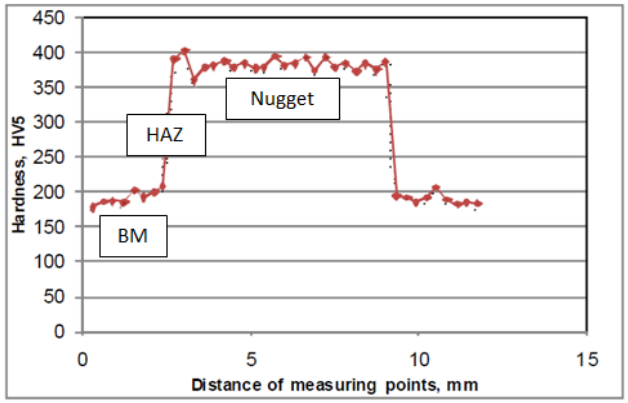
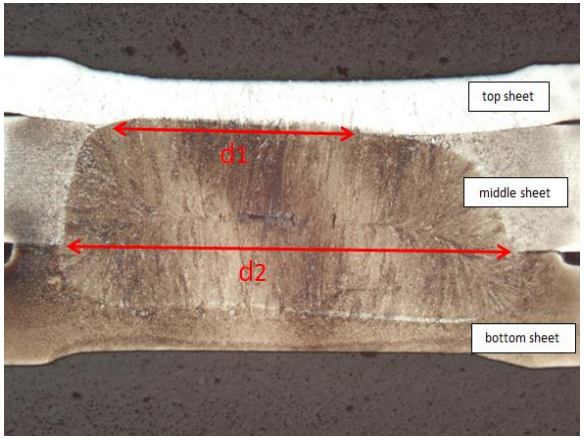
Automated spot weld realization procedure

Spot weld tool box: Metallurgical tests



- Identification of three different subzones in the micro structure sheet basis material (BM), heat affected zone (HAZ) and nugget
- Determination of nugget and HAZ diameter





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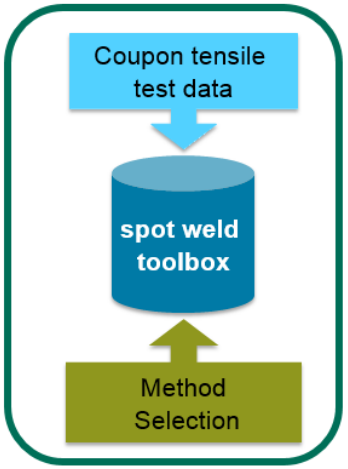
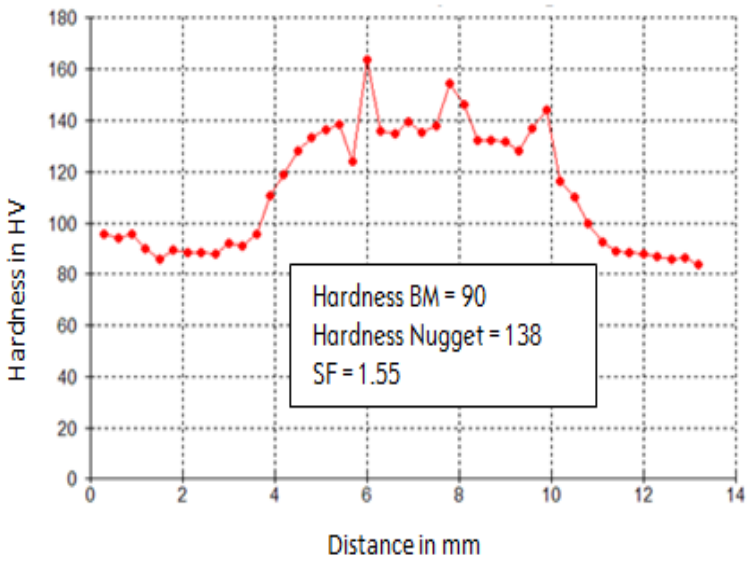
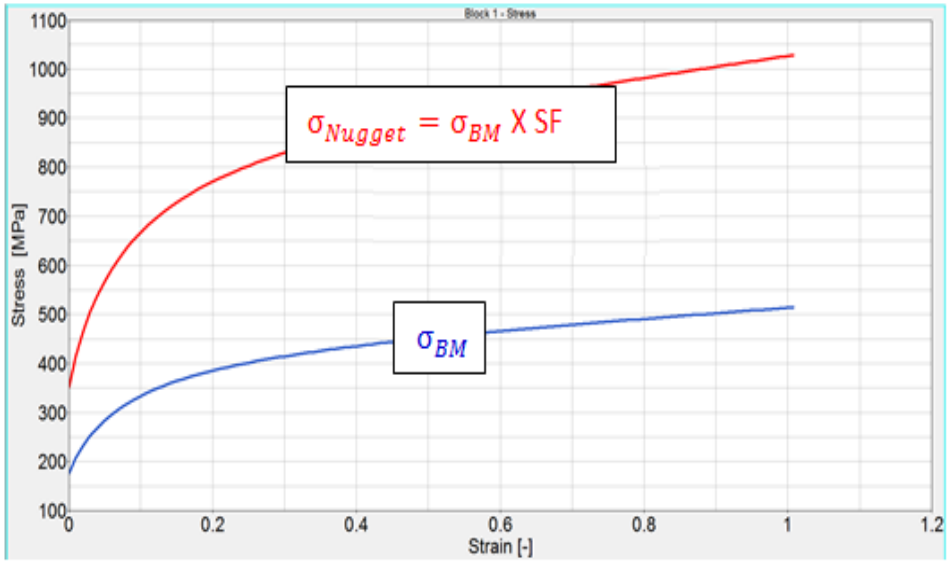
Automated spot weld realization procedure

Spot weld tool box: Metallurgical tests



- Extraction of hardness distribution enables the calculation of nugget and HAZ material properties (base yield curve scaled by hardness ratio)





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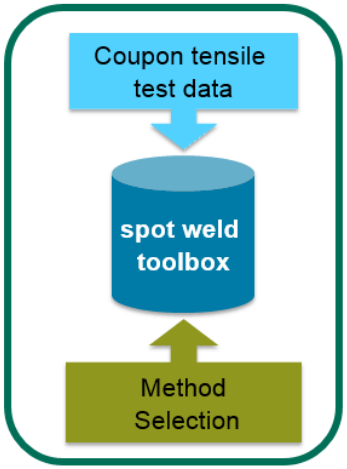
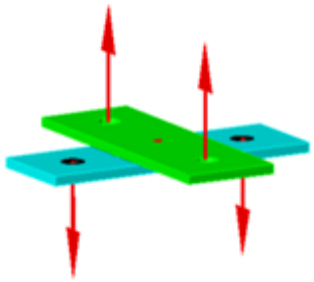
Automated spot weld realization procedure

Spot weld tool box: Coupon tensile test data



Coupon Tensile Tests for Different Load Conditions

cross-tension specimen

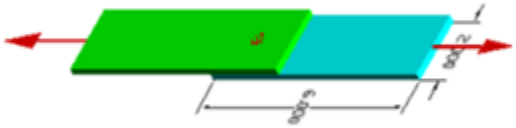


Pure Axial weld loading

coach-peel specimen

Axial & bending weld loading

tensile-shear specimen



Axial, bending & shear weld loading

Property Identification (stiffness & rupture)

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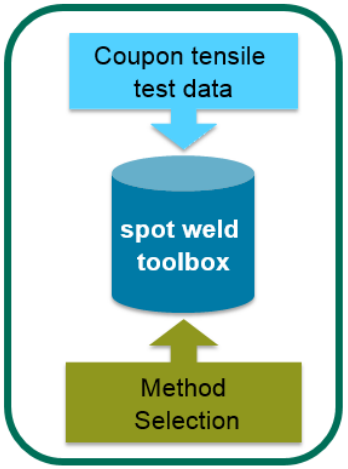
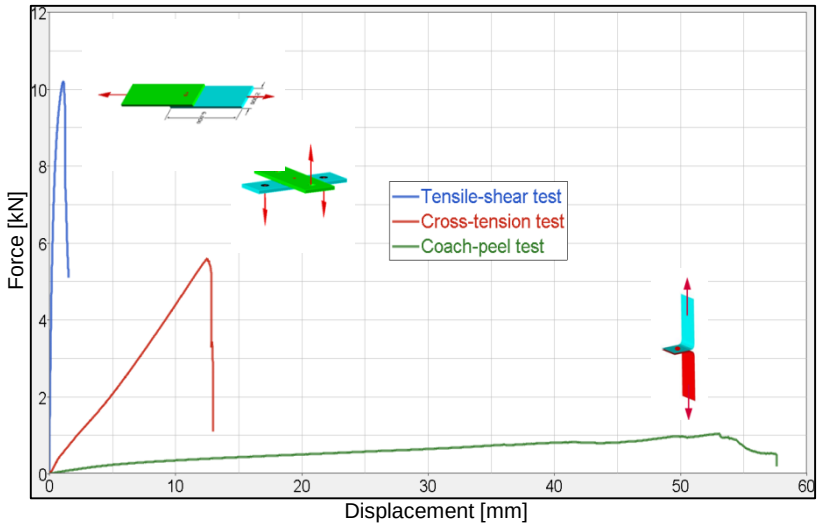
Automated spot weld realization procedure

Spot weld tool box: Coupon tensile test data

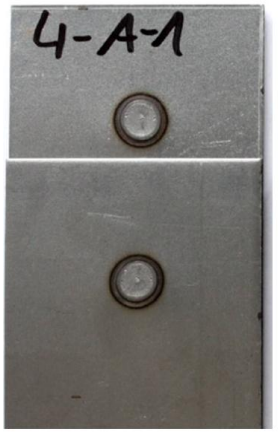


- Measurement of force-displacement characteristic
- Capturing resultant peak force
- Determination of fracture mode
- Determination of spot weld strength values



tensile-shear, cross-tension and coach-peel test results (DP600, 1.00mm)

nugget pullout fracture mode



interfacial fracture mode

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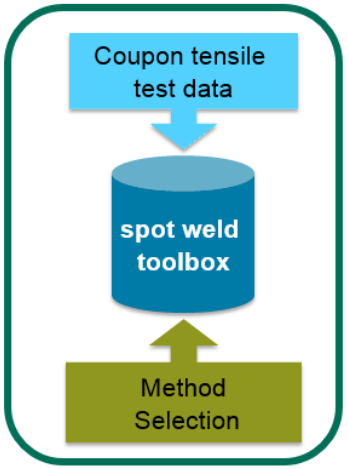
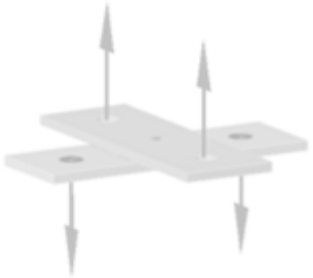
Automated spot weld realization procedure

Spot weld tool box: Coupon tensile test data



cross-tension specimen

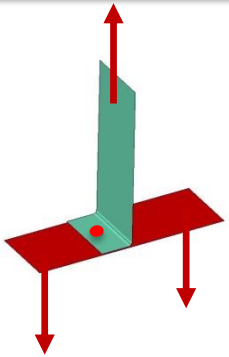


coach-peel specimen

tensile-shear specimen

Property Identification

Asymmetrical coach-peel specimen



Property Validation

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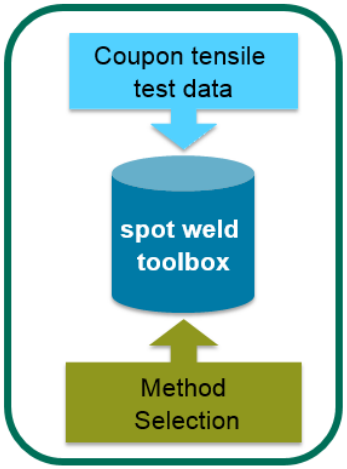
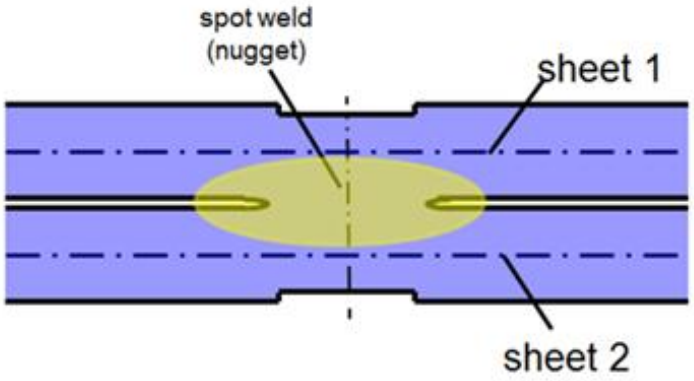
Automated spot weld realization procedure

Spot weld tool box: FE Modeling / Background

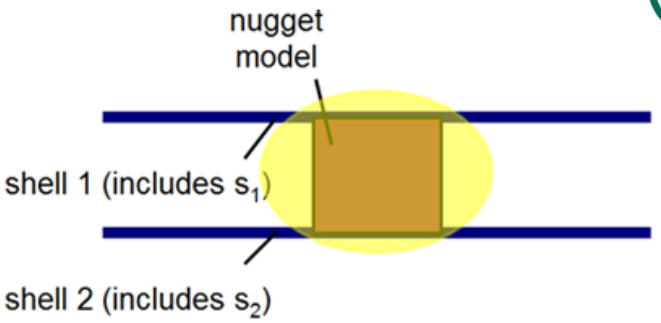


Spot weld joint

Real spot weld joint



FE spot weld joint



- Solid weld element is tied to sheet shells
- Weld has artificial thickness which leads to excessive artificial bending moments

FE solver can correct bending moment

- calculation with real thickness of the spot weld

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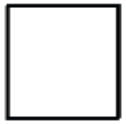
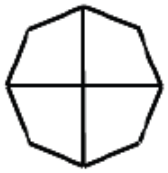
Automated spot weld realization procedure

Spot weld tool box: FE Modeling / Background

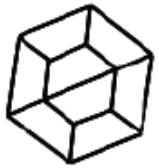
FE solid nugget discretization



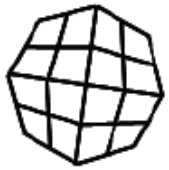
single hexahedron



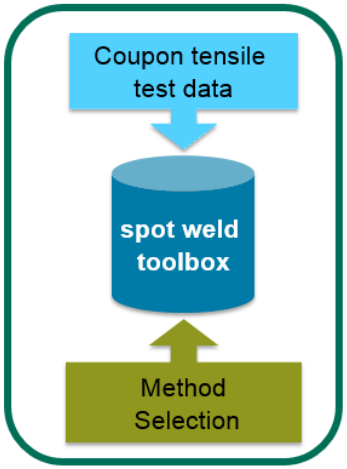
cluster4



cluster8



cluster16



spot weld assembly (cluster) is preferred modeling variant

- the tied contact is more robust
- more mesh independent
- allows a better representation of the complex mechanism of spot weld rupture

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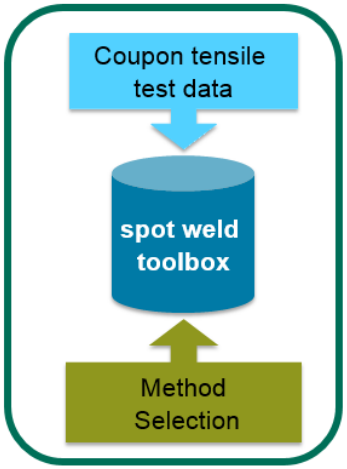
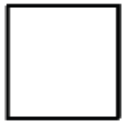
Automated spot weld realization procedure

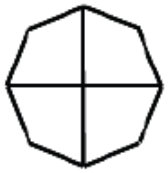
Spot weld tool box: FE Modeling / Background



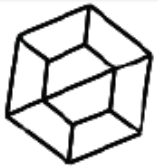
FE solid nugget discretization



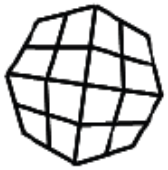
single hexahedron



cluster4



cluster8



cluster16

Full vehicle crash models:

- typical sheet mesh size is 3mm to 4mm in load path area
- Cluster of 8 solids is fine enough to represent weld and time step is not violated

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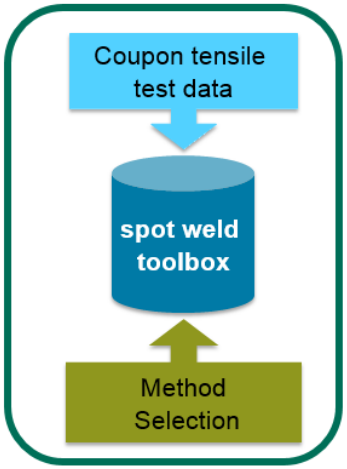
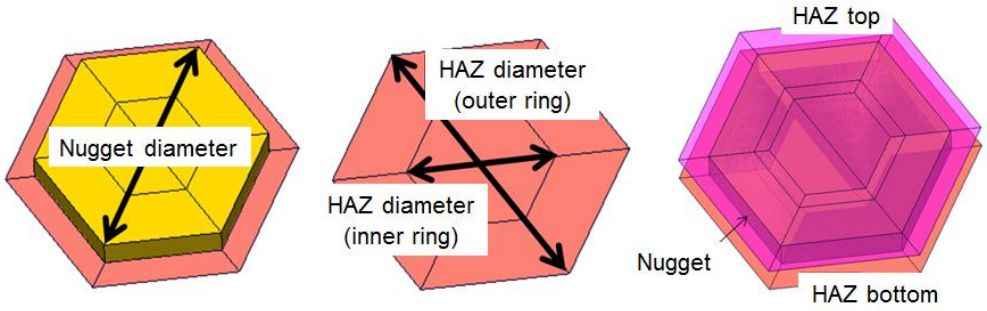
Automated spot weld realization procedure



Spot weld tool box: FE Modeling / Background

FE HAZ discretization

- HAZ mesh is required to apply different material stiffness and rupture properties compared to base sheet material
- Representation of HAZ is depending on the discretization of the nugget



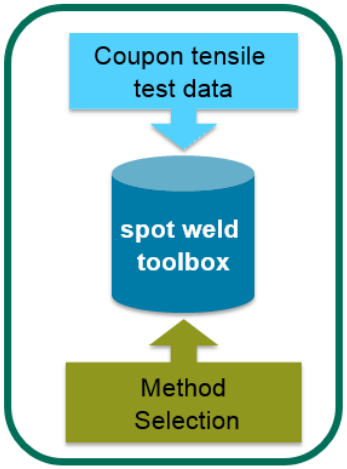
Full vehicle crash models:

- HAZ as one homocentric annulus around the nugget with the HAZ diameter
- HAZ diameter can be approximated based on the hardness distribution by scaling the spot weld diameter according to the thickness combination of the joint
- HAZ with eight shell elements (elements alignment equal to the weld cluster), inner element ring is half of the outer element ring

Automated spot weld realization procedure

Spot weld tool box: FE Modeling / Background

FE material modeling



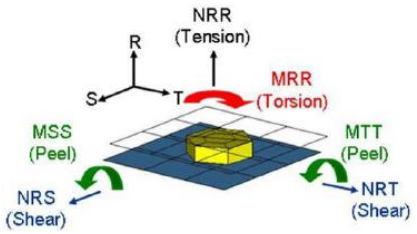
An appropriate material modeling approach is required to Characterize the spot weld separation and the fracture mode.

interfacial fracture mode

A simple material model with force-based or stress-based rupture criteria

- describes the spot weld separation, which is equivalent to the rupture of the spot weld solid elements

*MAT_SPOTWELD_DAMAGE_FAILURE
OPT=0



Axial Force | Shear Force | Torsional Moment | Bending Moment

$$\left(\frac{\max(N_{rr},0)}{N_{rr_F}}\right)^2+\left(\frac{N_{rs}}{N_{rs_F}}\right)^2+\left(\frac{N_{rt}}{N_{rt_F}}\right)^2+\left(\frac{M_{rr}}{M_{rr_F}}\right)^2+\left(\frac{M_{ss}}{M_{ss_F}}\right)^2+\left(\frac{M_{tt}}{M_{tt_F}}\right)^2-1>0$$

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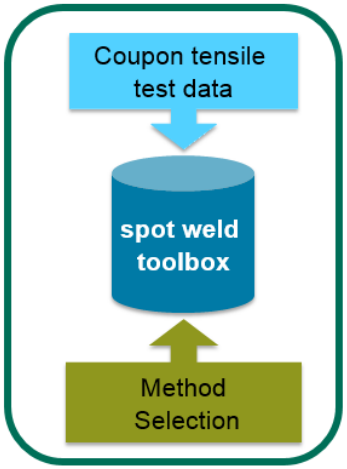
Automated spot weld realization procedure

Spot weld tool box: FE Modeling / Background

FE material modeling

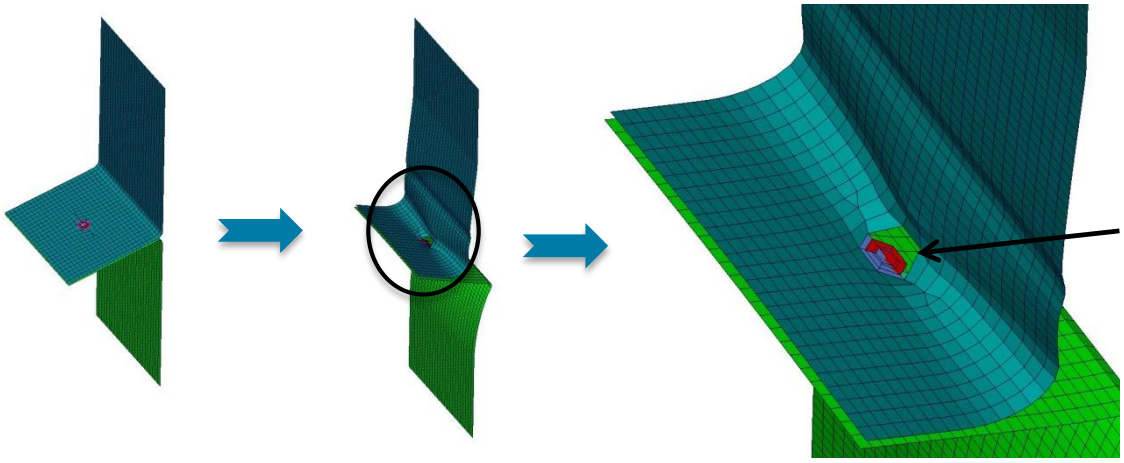


An appropriate material modeling approach is required to characterize the spot weld separation and the fracture mode.

nugget pullout fracture mode

nugget pullout rupture mode:

A more sophisticated material model is required to model the rupture in or adjacent to the HAZ.



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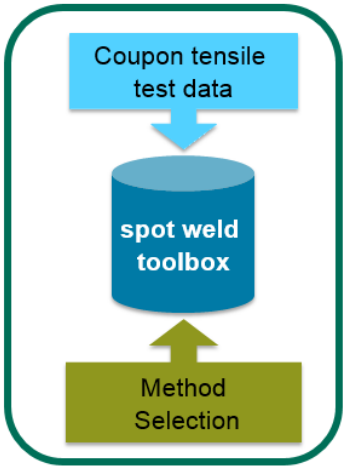
Automated spot weld realization procedure

Spot weld tool box: Data Input

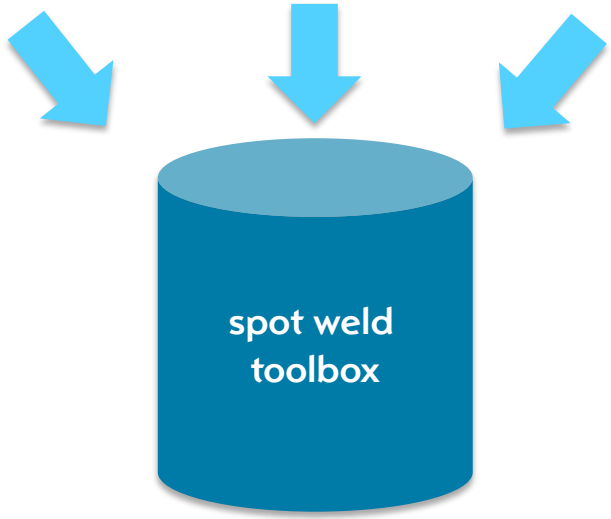


Test data weld joint A
nugget diameter,
Yield, ETAN,
rupture criteria

Test data weld joint B
nugget diameter,
Yield, ETAN,
rupture criteria

...

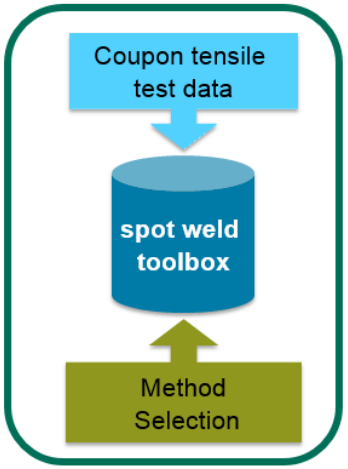
Test data weld joint X
nugget diameter,
Yield, ETAN,
rupture criteria



- All determined rupture criteria were stored in tool box with specific test parameter.

Automated spot weld realization procedure

Spot weld tool box: Method Selection



Test data weld joint A
nugget diameter,
Yield, ETAN,
rupture criteria

Test data weld joint B
nugget diameter,
Yield, ETAN,
rupture criteria

...

Test data weld joint X
nugget diameter,
Yield, ETAN,
rupture criteria

Properties of weld joints in simulation model

Computation

Required data for weld joints in simulation model with respective material properties and rupture criteria:

- nugget diameter
- material properties(Yield, ETAN)
- rupture criteria

Weld nugget diameter dependency?
HAZ consideration?
Method of HAZ discretization?
...

➢ Depending on user method selection the rupture criteria and material properties were calculated for simulation weld joint.

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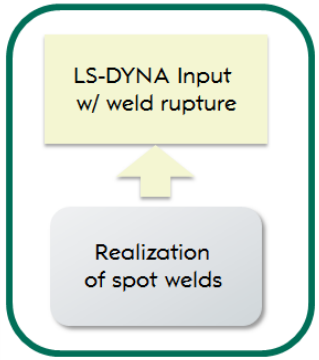
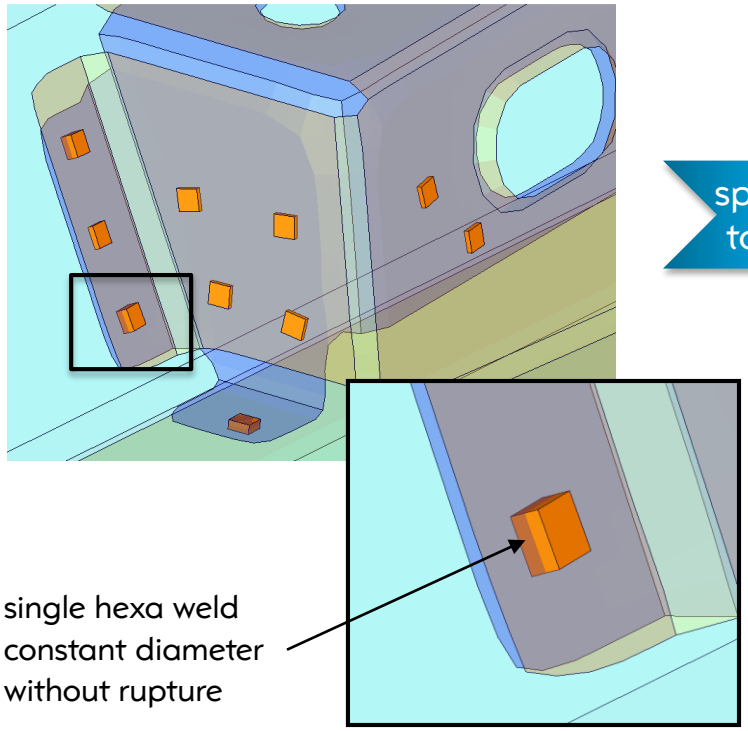
Automated spot weld realization procedure

Spot weld tool box: Realization

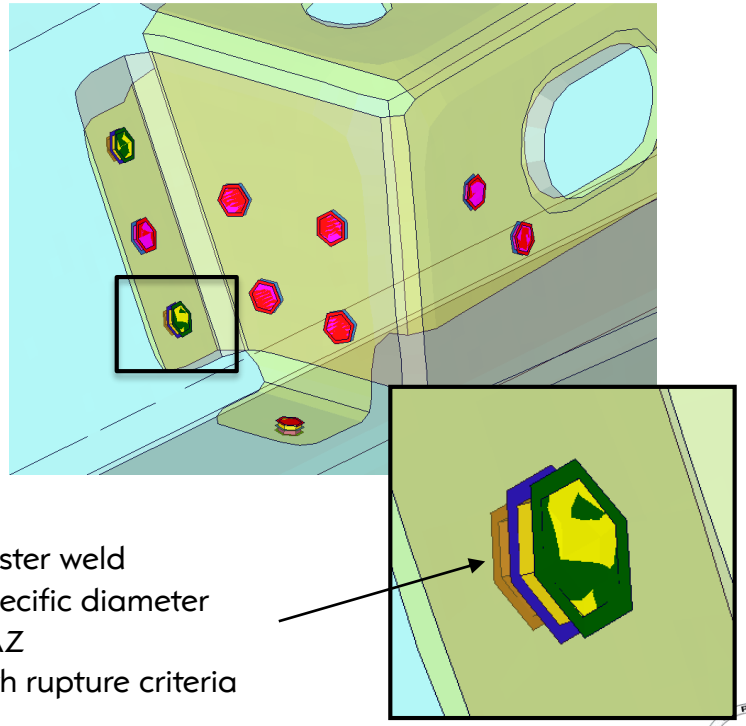


LS-DYNA Input
w/o weld rupture

LS-DYNA Input
w/ weld rupture



spot weld
tool box



- single hexa weld
- constant diameter
- without rupture

- cluster weld
- specific diameter
- HAZ
- with rupture criteria

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Conclusion

Spot weld tool box

- A general procedure was developed to apply spot weld rupture criteria to full vehicle simulation model in a very efficient way.
- Data from coupon tests are used to determine rupture criteria for weld joints in simulation.
- Tool box needs to be filled with coupon test data to improve predictability of weld rupture behavior.
- The definition of a sophisticated material model for the HAZ is under development.


GG FN 304
Thank you
Wir leben Autos.