13. LS-DYNA Forum

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Influences of manufacturing, process parameters and their tolerances on the crash-behavior of adhesive bonds - experimental and numerical investigation

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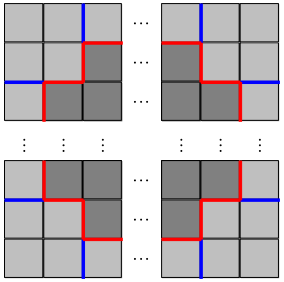
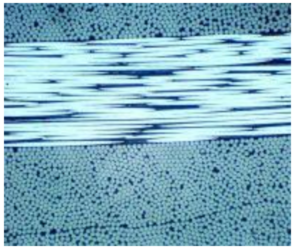
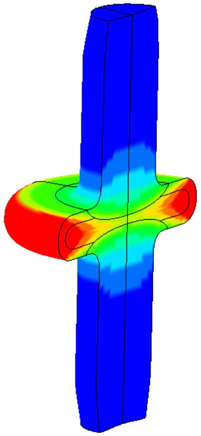
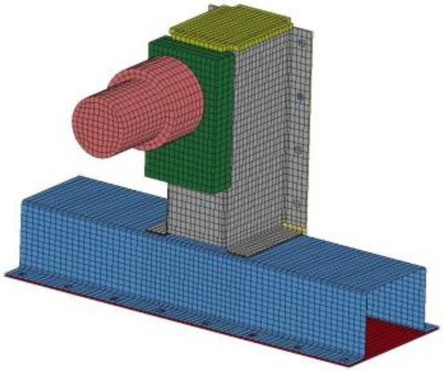








Outline

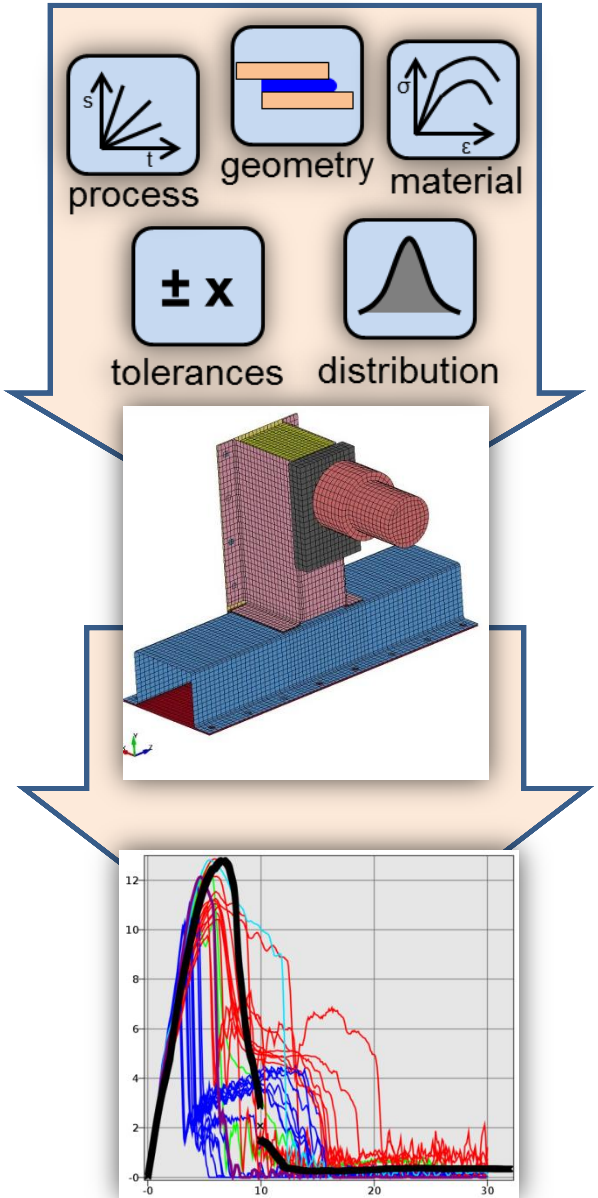
Introduction

Problem:

- Manufacturing and process influences emerge in automotive mass production during adhesive bonding
- Geometrical discrepancies such as different adhesive layer thicknesses and gap-fillings appear
- Significant influence on the mechanical behavior of the joints is possible
- Methods are needed to predict these effects for car crash situations

Solution:

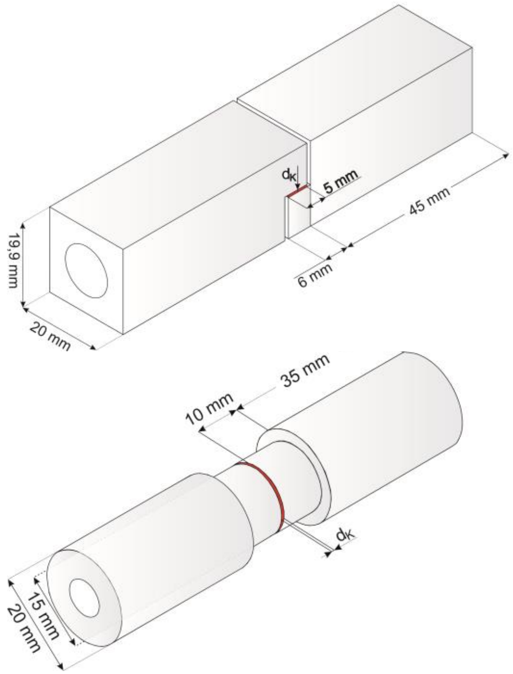
- Extensive experimental investigation of parameters and their influences on mechanical behavior of adhesive joints
- Parameter identification and material modelling for different parameter combination on basic tests
- Validation on technological speciments
- Sensitivity analysis of parameters on components for validation of the computation method



Outline

Basic Tests

Specimen Geometry:



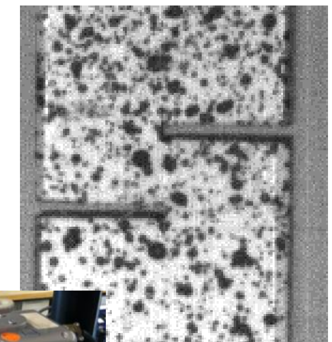
Measurement and Control technique:

Quasi-static

- Local controlled/ measured
- Local extensometer

Crash

- Global machine speed controlled
- Local measurement
- High speed cam



Testing Parameter:

Adhesive layer thicknesses: 0.15 mm, 0.30 mm, 0.60 mm and 1.00 mm

Testing rates: 0.002 1/s, 0.02 1/s, 50 1/s, 1000 1/s

Normal/ shear strain: $\varepsilon = \ln(1+\frac{u}{d_k}); \gamma = \arctan(\frac{v}{d_k})$

Testing rate: $\dot{\varepsilon}_t = \frac{\dot{u}}{d_k}; \dot{\gamma}_t = \frac{\dot{v}}{d_k}$

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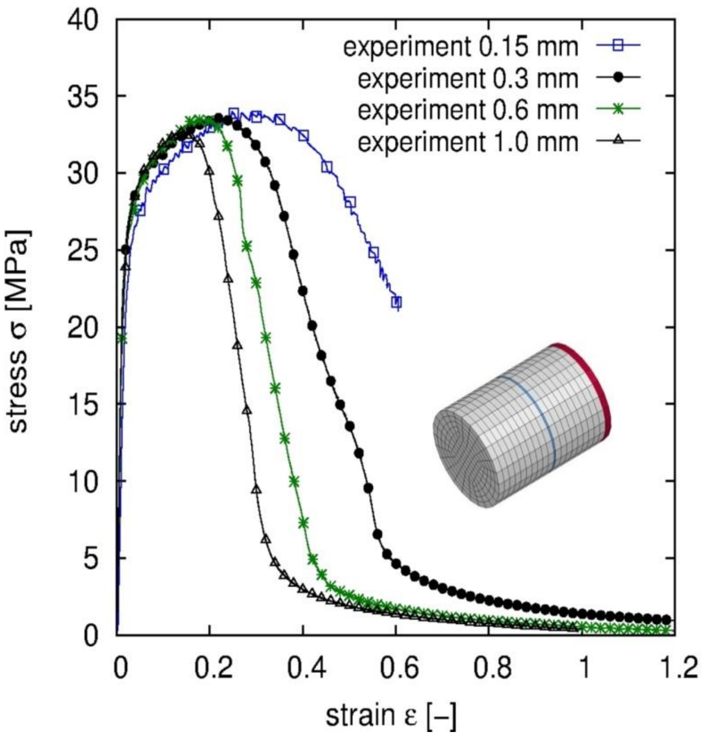
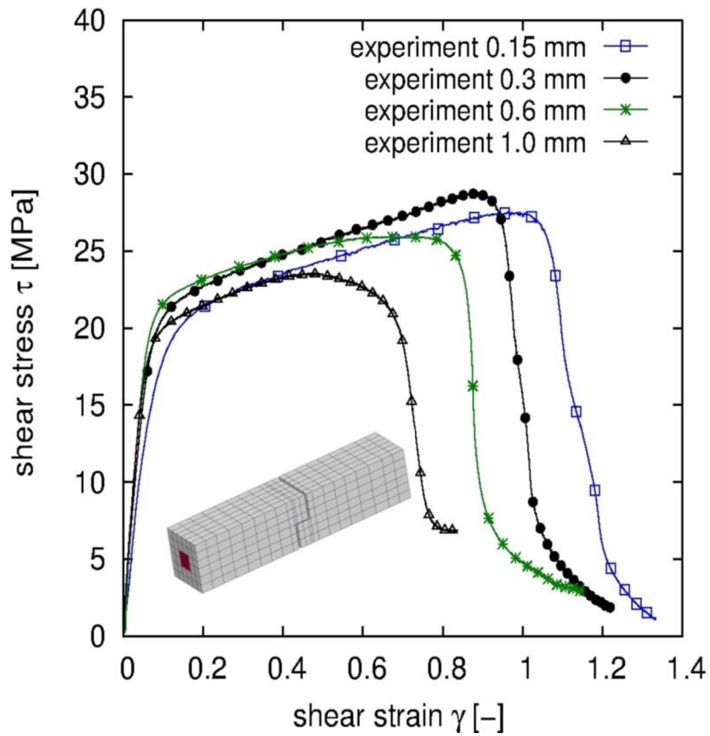
Basic Tests

Butt Joint Specimen (BJS) and Thick Adhered Shear Specimen (TASS)

Effect of the layer thickness on the mechanical behavior under normal and shear loading at quasi static testing rate





Adherent Material
S235 JRG2+C
Adhesive
BM 1496 V
Specimen Type
BJS/ TASS
Surface Treatment
SACO-PLUS
Layer Thickness
See Diagram
Specimen Diameter/Overlap
15mm/ 5mm
Testing
Testing rate: 0.002 1/s
Temperature: T = RT

Different layer thickness have different mechanical behavior
Mainly damage initiation and failure are depended on layer thickness

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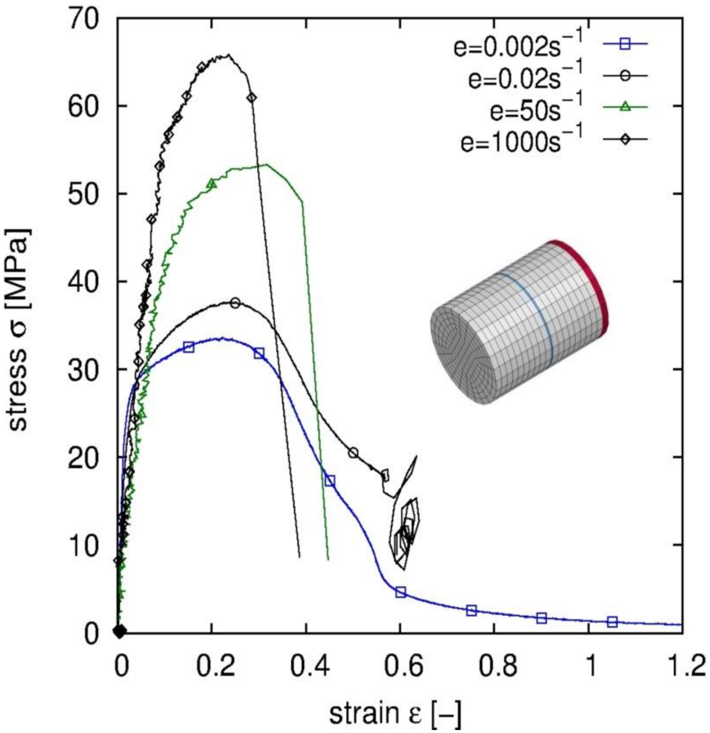
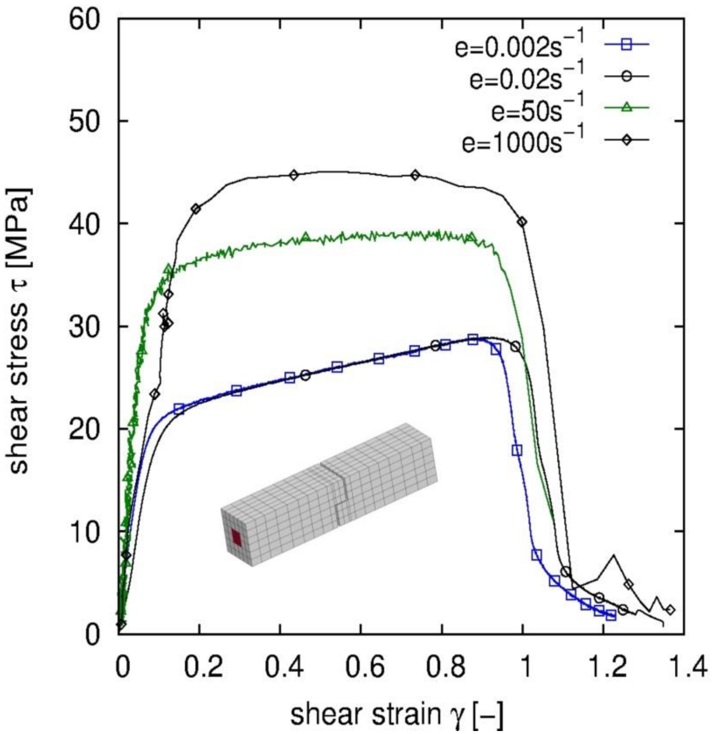
Butt Joint Specimen (BJS) and Thick Adhered Shear Specimen (TASS)

Effect of the testing rate on the mechanical behavior under normal and shear loading at quasi static testing rate





Adherent Material
S235 JRG2+C
Adhesive
BM 1496 V
Specimen Type
BJS/ TASS
Surface Treatment
SACO-PLUS
Layer Thickness
0.3mm
Specimen Diameter/Overlap
15mm/ 5mm
Testing
Testing rate: see diagram
Temperature: T = RT

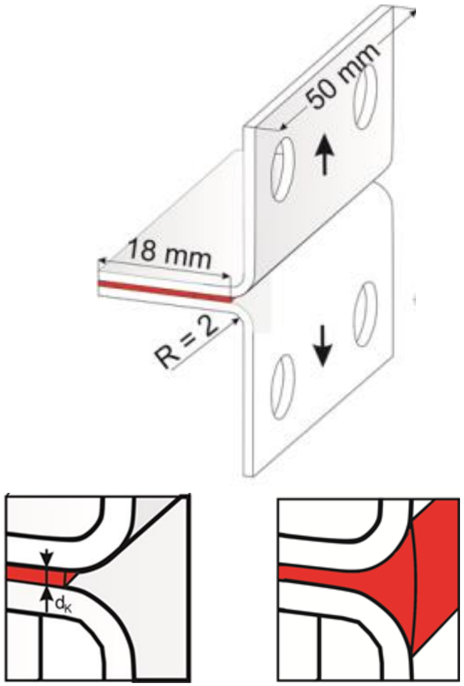
➡ higher testing rate increase a maximum force

Outline

1. Introduction
2. Basic Tests
3. **Technological Tests**
4. Parameter Identification and validation
5. Component Tests and Conclusions

Technological Tests

Specimen Geometry:



Measurement and Control technique:

Quasi-static

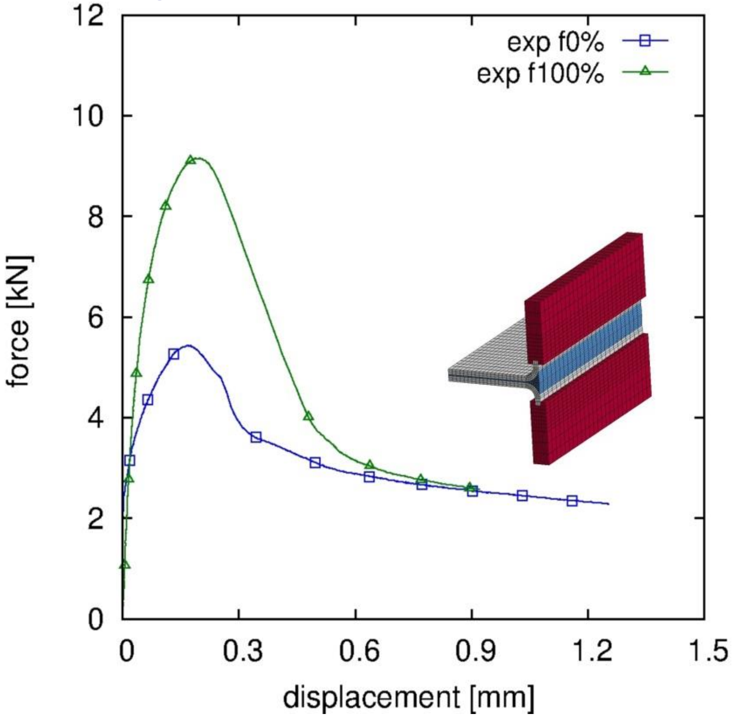
- Global machine speed controlled
- Local measurement with optical system

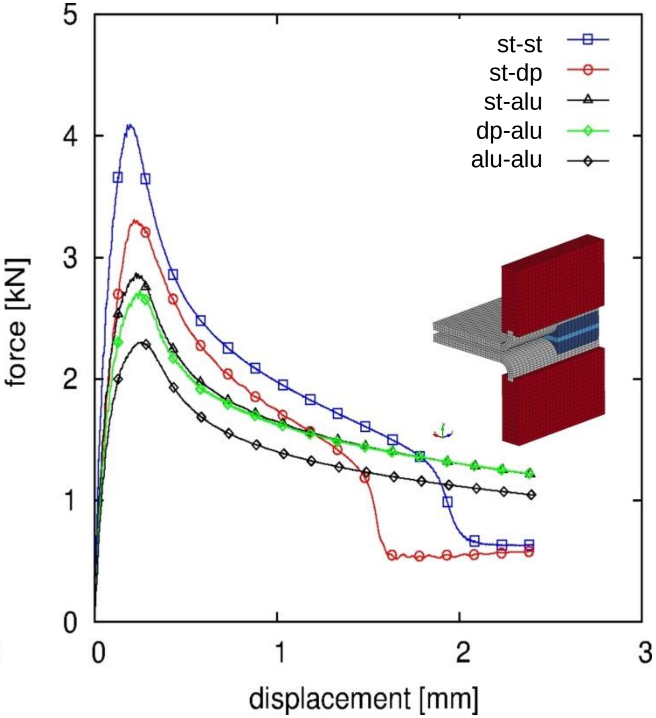
Testing Parameter:

Adhesive layer thicknesses:	0.15 mm, 0.30 mm, 0.60 mm and 1.00 mm
Testing rates:	0.002 1/s, 0.02 1/s, 50 1/s, 1000 1/s
Testing rate:	$\dot{\varepsilon}_t = \frac{\dot{u}}{d_k}; \dot{\gamma}_t = \frac{\dot{v}}{d_k}$
Substrates:	H 340 LAD (1.5mm); DP 1000 (1.2mm); EN AW 5182 (1.5mm)

Peel Specimen

Effect of gapgilling and substrate on the mechanical behavior under peel loading at quasi static testing rate





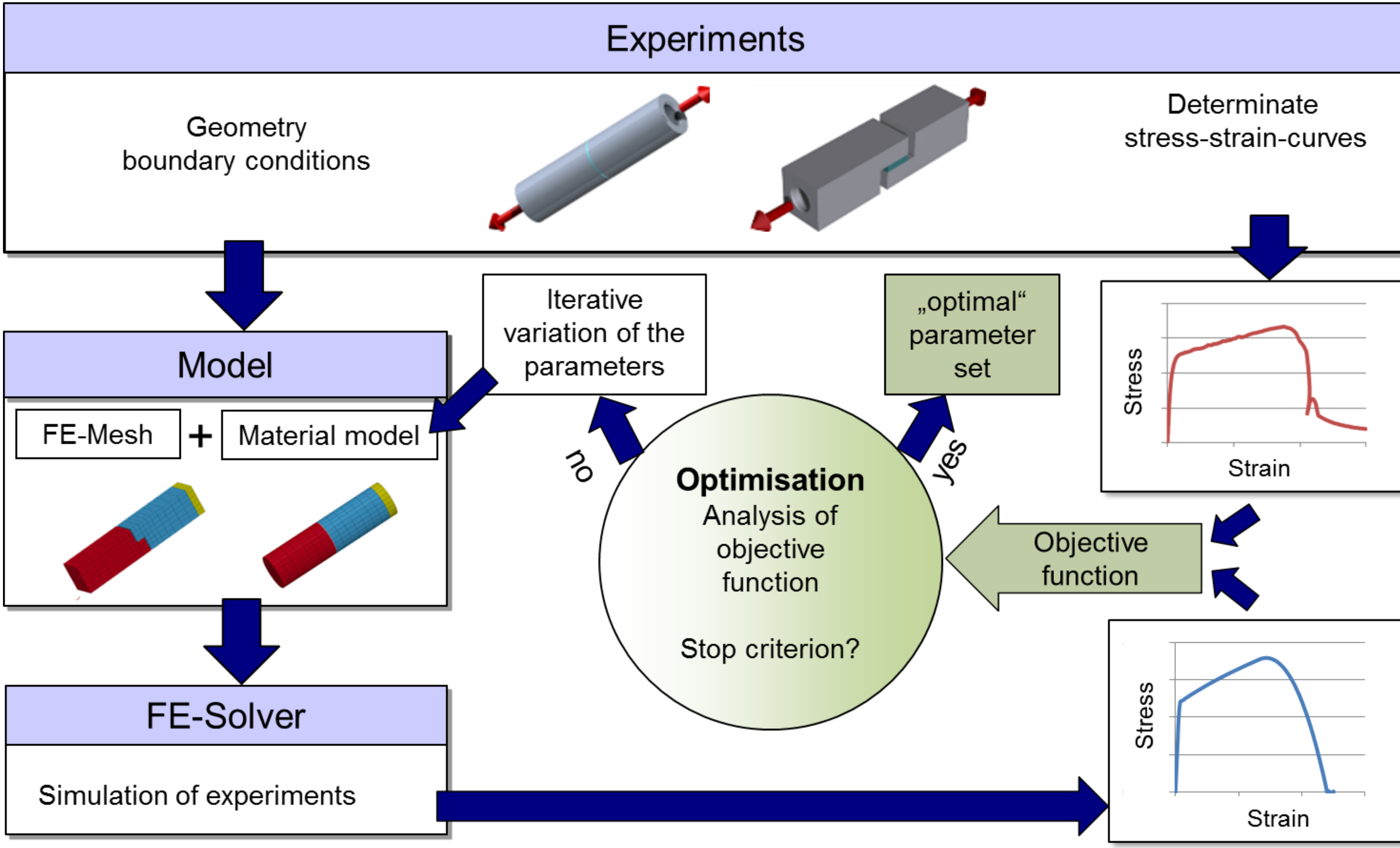
Adherend Material
See Diagram*
Adhesive
BM 1496 V
Specimen Type
Peel specimen
Surface Trearment
degreased
Layer Thickness
0.3mm
Gap Filling
See Diagram
Testing
Testing rate: 0.002 1/s
Temperature: T = RT

Gapfilling and substrate have substantially influence on the force maximum

* st – H 340 LAD (1.5mm); dp – DP 1000 (1.2mm); alu – EN AW 5182 (1.5mm)

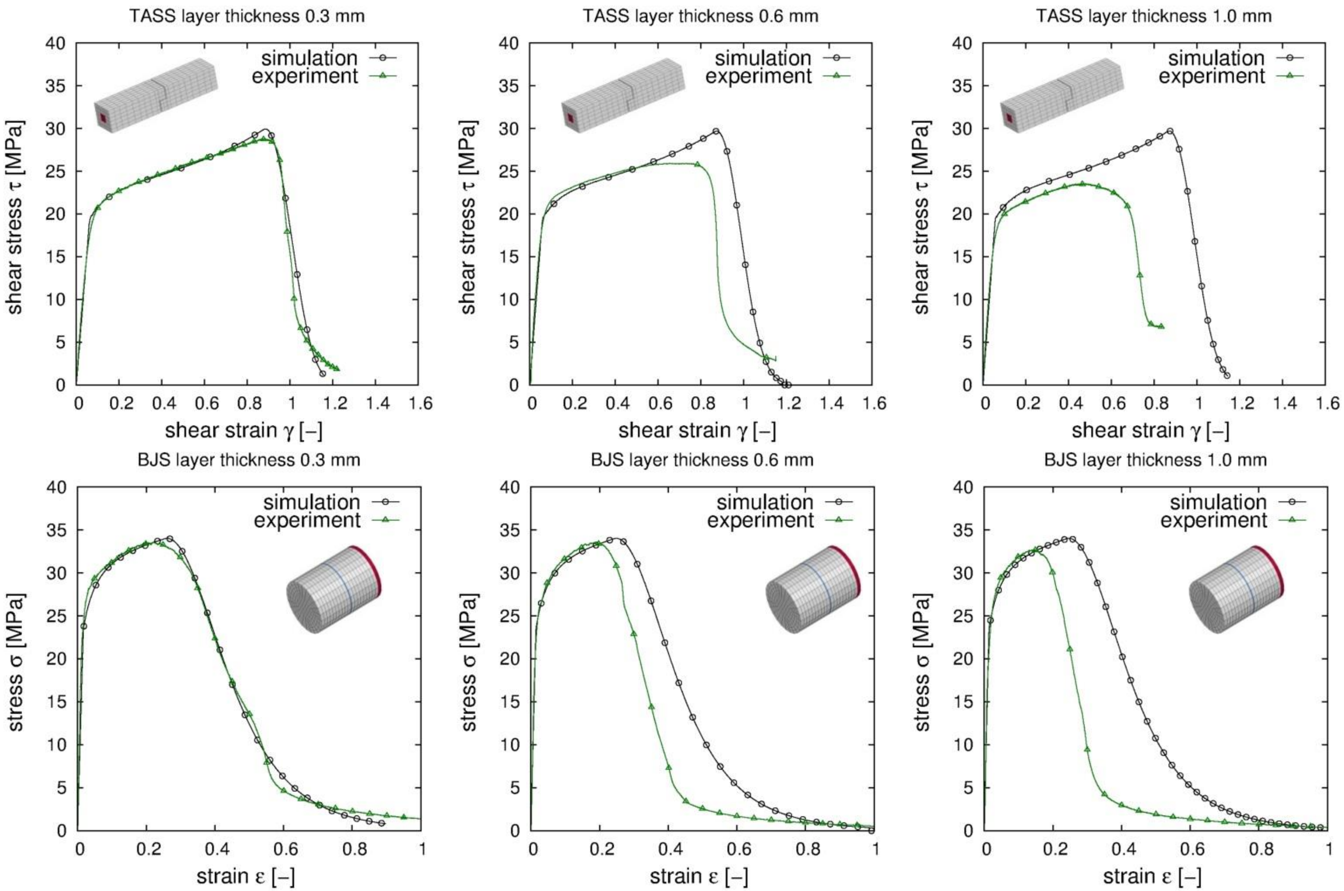
Outline

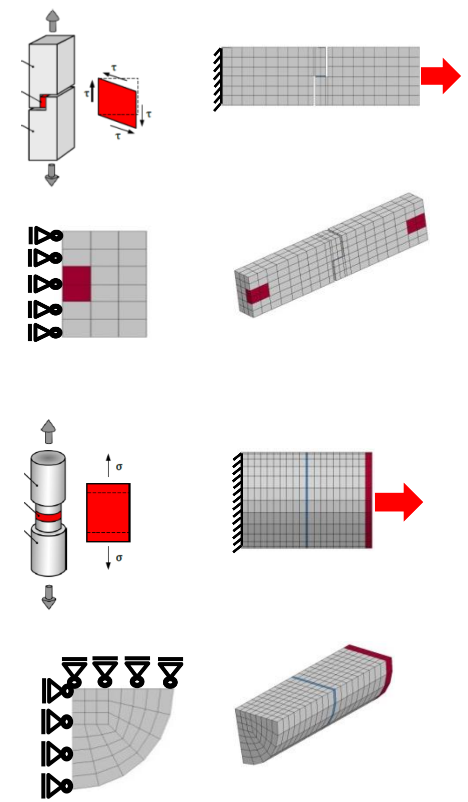
Parameter Identification



Parameter Identification

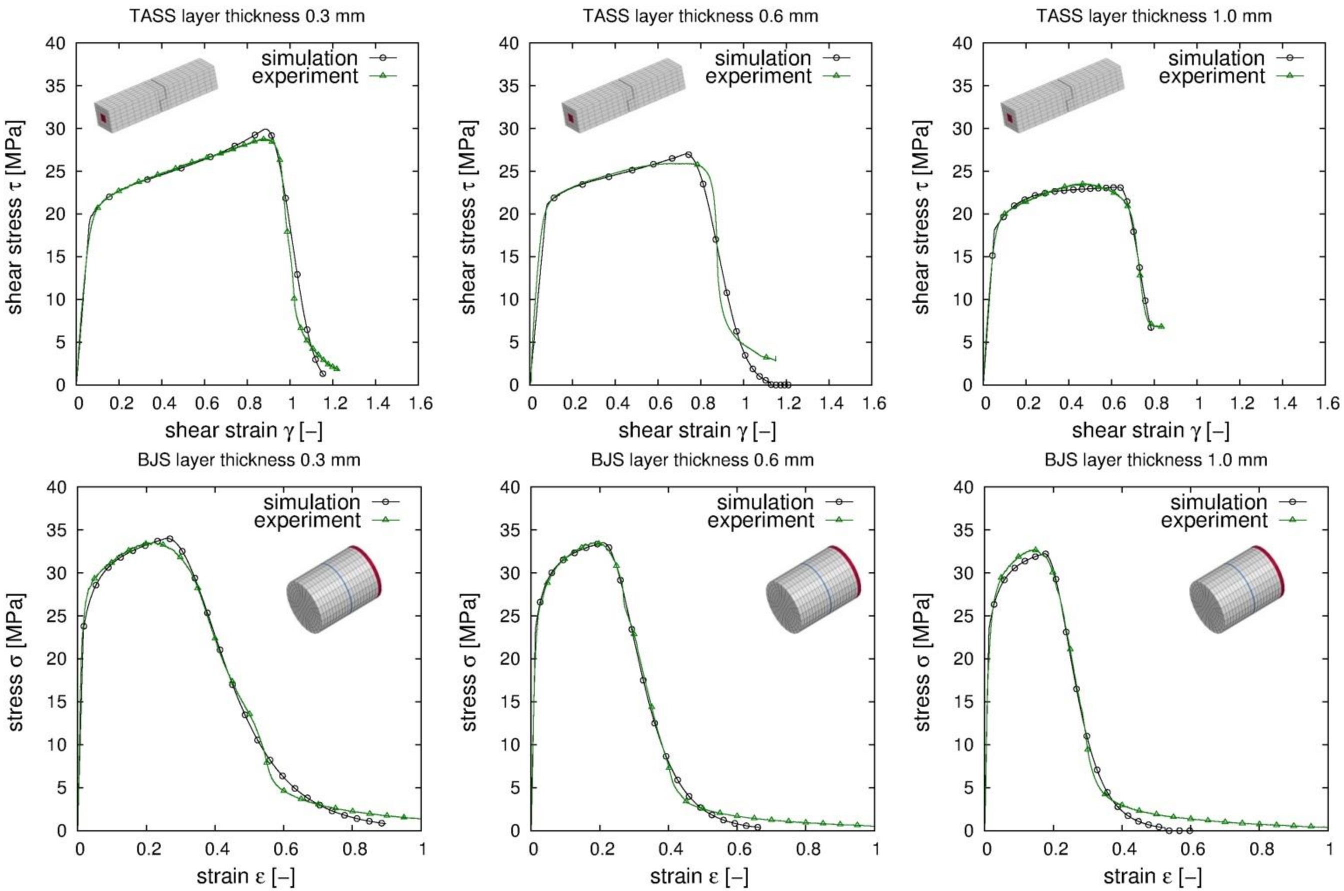
- Identification of a set of parameter at a layer thickness of 0.3 mm (TASS and BJS)
- Calculation for other layer thicknesses (TASS and BJS)
- Good prediction for 0.3 mm, overvalue of the strain with increasing layer thickness

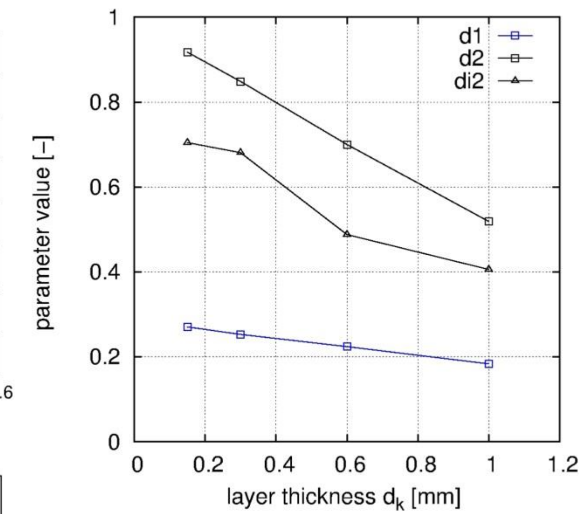




Parameter Identification

- Identification of a set of parameter at a layer thickness of 0.3 mm (TASS and BJS)
- Identification of new damage parameters for each layer thickness
- Good prediction for 0.3 mm, 0.6 mm and 1.00 mm

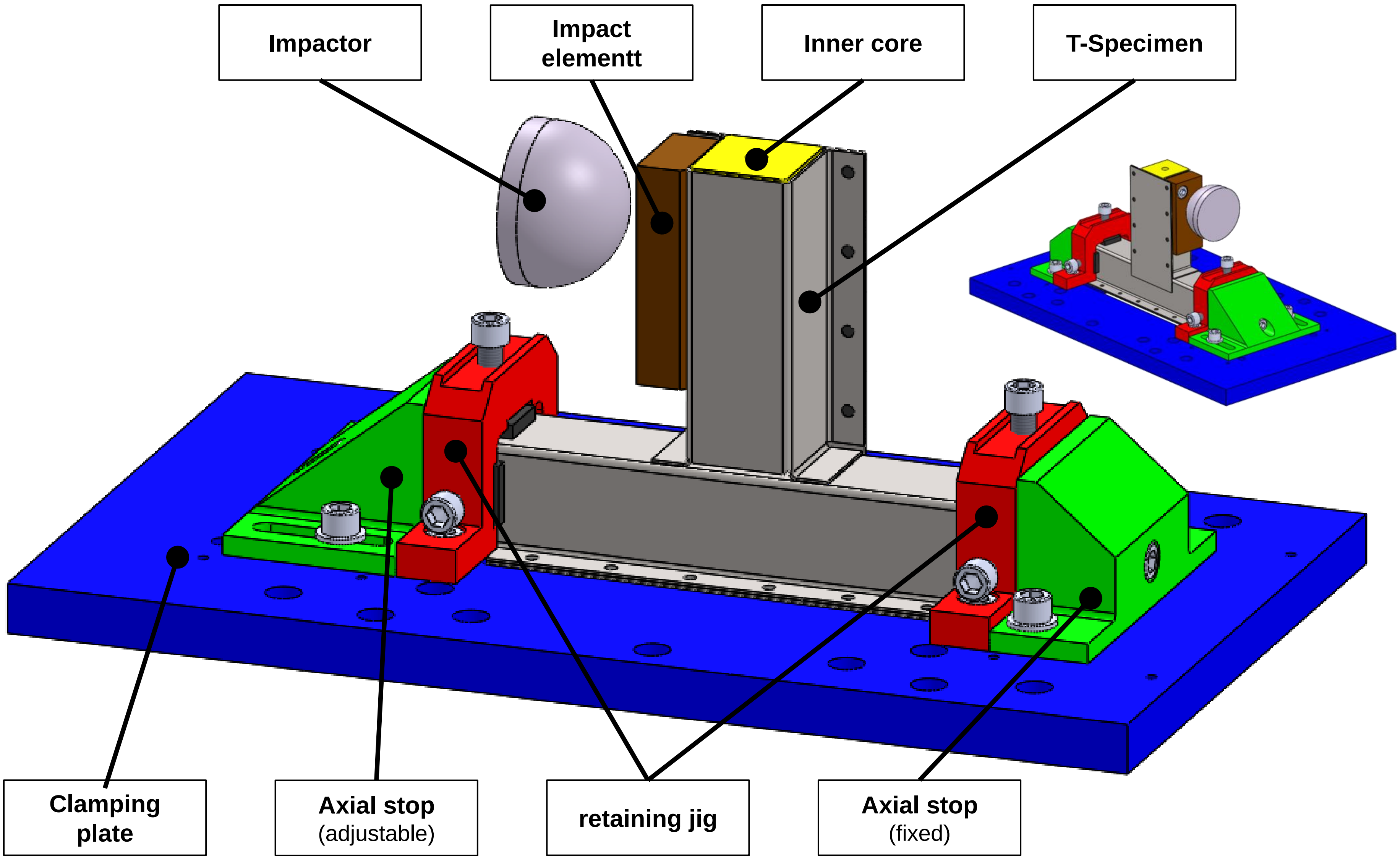




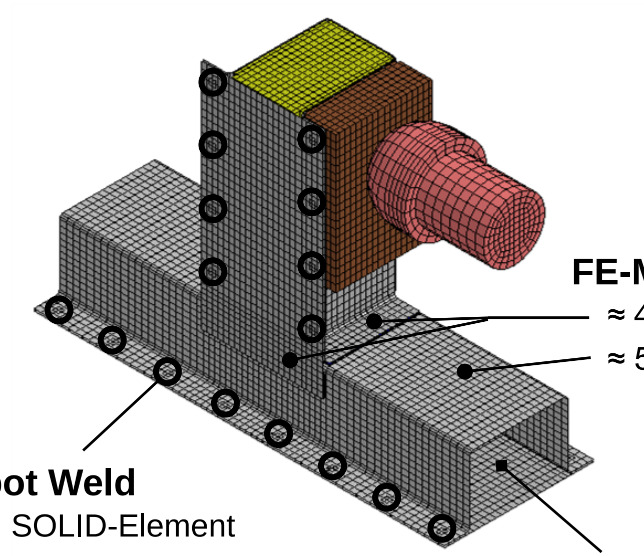
In the first approximately: Linear depency of damage Parameters from layer thickness

Outline

Structure of Component Specimen

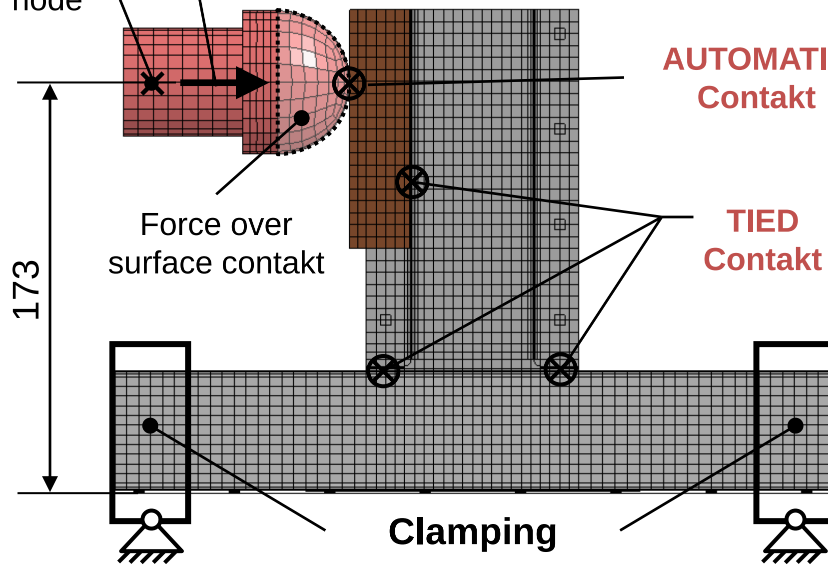


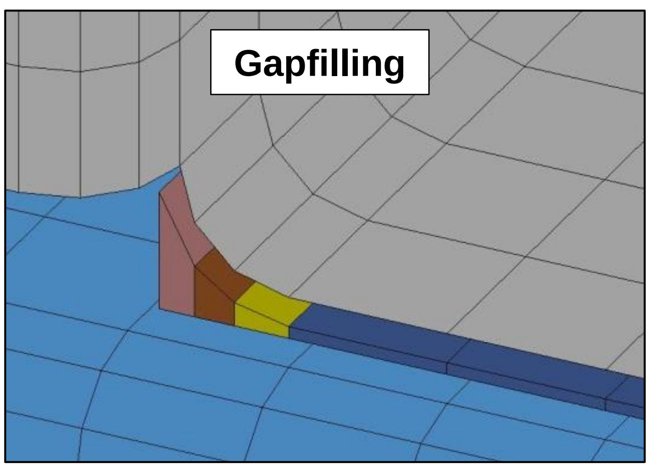
longitudinal load

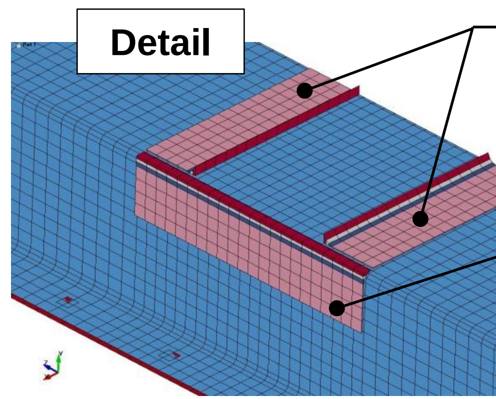


Spot Weld

- SOLID-Element
- SPOTWELD-Contakt







Adhesive Layer

- d_k = 0.3 mm
- B x L = 16 x 66 mm
- eB x eL ≈ 4 x 4 mm

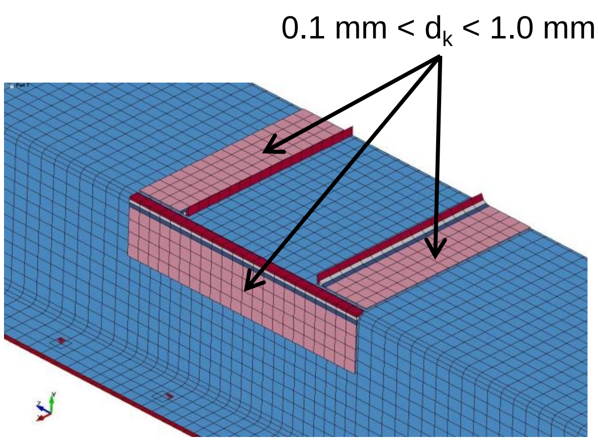
Adhesive Layer

- d_k = 0.3 mm
- B x L = 16 x 89 mm
- eB x eL ≈ 4 x 4 mm

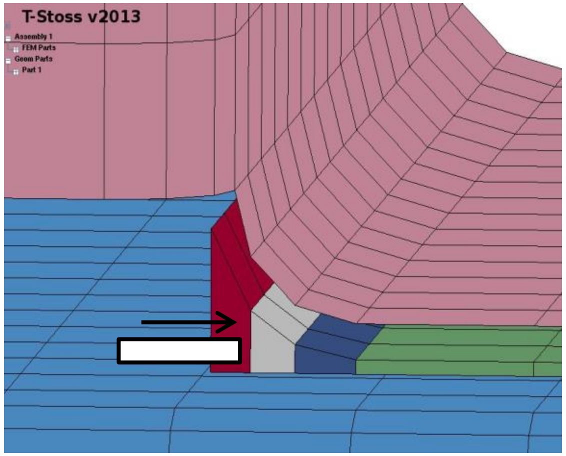
Sensitivity Analysis

Parameters	Start value	Variation range and distribution	setting	remark
Adherent Thickness	0.3 mm	0,1 – 1,0 mm each 0,1 mm	PreProcessor	The adherent thickness of two upper overlaps is varied simultaneously
Gap filling	100 %	0% – 100% four steps	PreProcessor	Delete of elements in the gap
Yield stress of steel	$R_{p0,2}$=380 Mpa	±20 MPa each 10 MPa	Define as variable	Yield stress of steel is varied
Position of spot welds	Accordingly to experiment	±5 mm	Node position define as variable	The position of two upper and two lower spot welds is varied

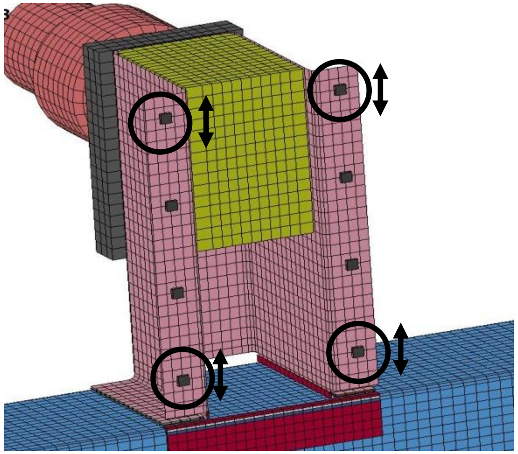
Setting of adherent thickness



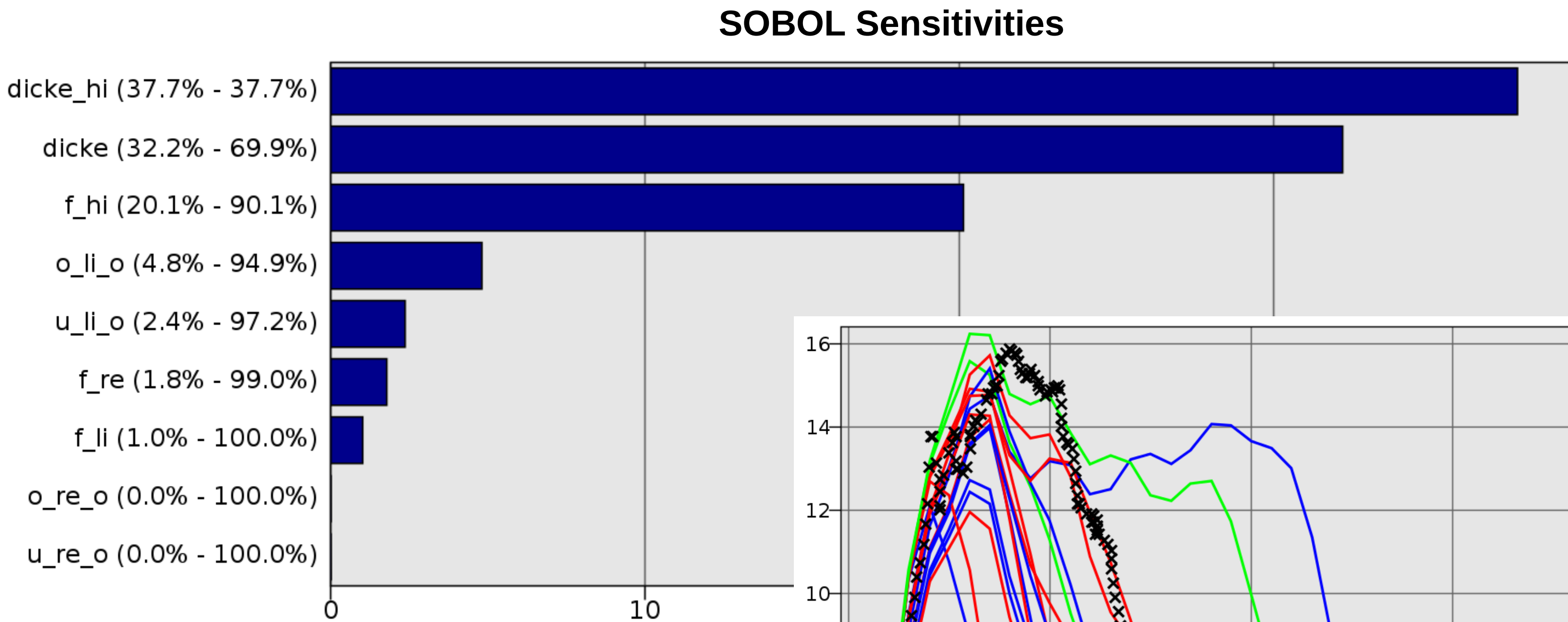
Settign of gapfilling

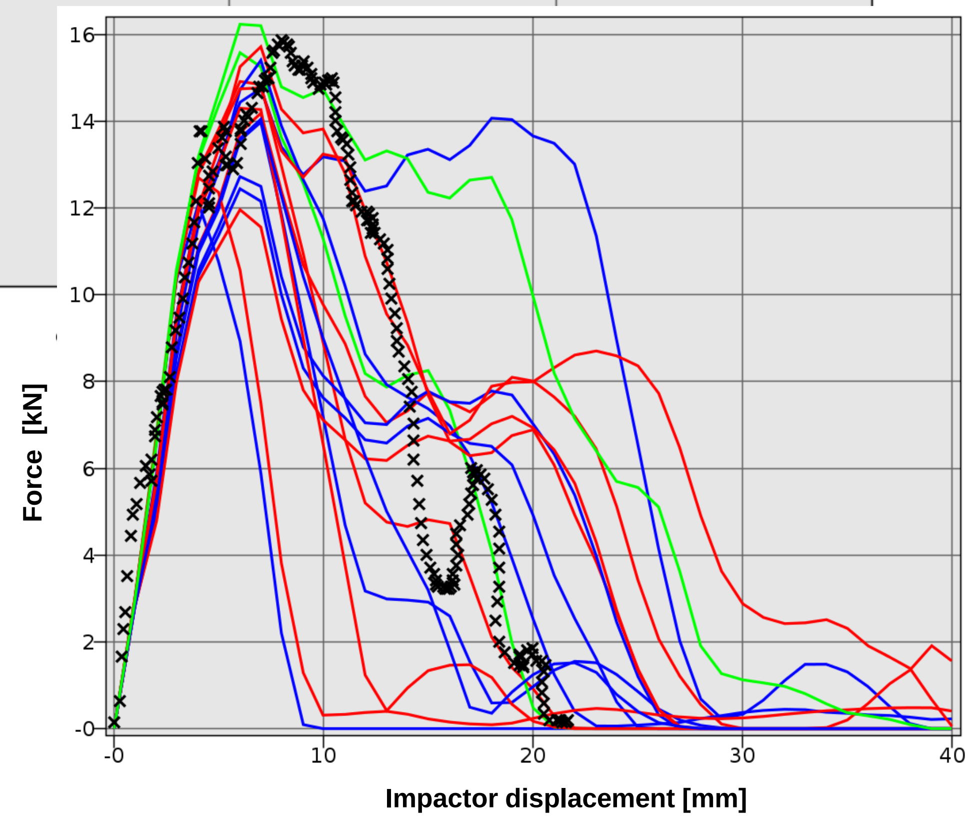


Settign of welding points position



Sensitivity Analysis





dicke_hi	Adhesive layer thickness rear
dicke	Adhesive layer thickness above
f_hi	Gapfilling rear
f_li / f_re	Gapfilling above
o_re_o/ o_li_o	Upper spot welds
u_re_o/ u_li_o	Lower spot welds

Conclusions

- The influence of the layer thickness on the mechanical behavior of the adhesive layer can be determined by basic specimen types like TASS or BJS
- The influence of parameters gap filling, strain rate and substrate material are shown
- The results of the basic tests can be used to identify a set of parameters in dependence of the layer thickness
- Sensitivity and stochastic analysis with more complex specimen types are possible
- Adhesive layer geometry (thickness + gap filling) has large effect on mechanical behavior of adhesive bonded joints