MSE 2020

TRR285 – TP A01 Method development for the joinability prognosis

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Development of a numerical method for analyzing the robustness of clinching in versatile process chains

In many areas of product manufacturing individual components are usually joined together to form complex structures with numerous joints. Using mechanical joining technologies offers the possibility of joining structures with a wide range of material-geometry combinations. In order to realize the increasing number of varying products using different materials and designs within a process chain, they need to be versatile.

Due to changing properties of the materials to be joined, tool geometries and process variables in mechanical joining processes, especially clinching, must be continuously adapted which results in a limited versatility of the process. Out of this reason, it is necessary to examine the robustness of the clinching process in versatile process chains. Therefore, a method is developed which describes the joint characteristics based on the material properties in order to enable the investigation of the clinching process regarding the robustness concerning continuously changing process and material conditions.

The predictive accuracy of numerical simulations for mechanical joining processes depends on the implemented material model, especially the plasticity of the joining parts. Therefore, experimental material characterization processes are used to determine material properties. Furthermore, clinched joints in different material combinations are experimentally generated and examined. Based on these investigations a simulation model of the joining process is developed as 2D-Clinching FEM model in LS-Dyna. The Validation of the developed simulation model is ensured by comparing the geometric formation of the joint and force-displacement curves of the joining process with experimental generated joints. By combining the simulation model with an optimization tool (LS-OPT) the influence of different parameters on the joint characteristics is determined and the robustness of the joining process in versatile process chains is investigated.

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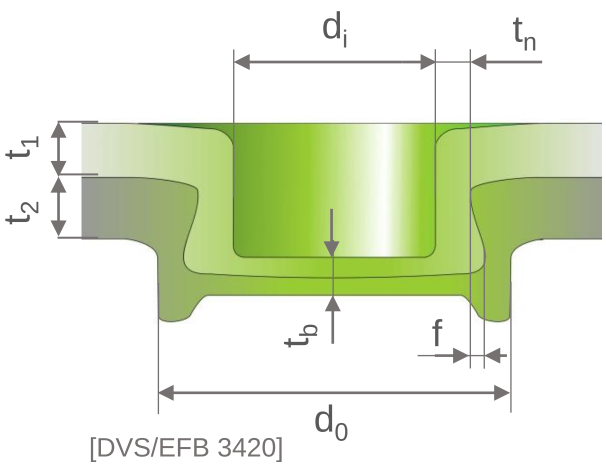
Agenda

1. Clinching process
2. Material characterization
3. Simulation model and method
4. Results and discussion
5. Conclusion

Clinching process

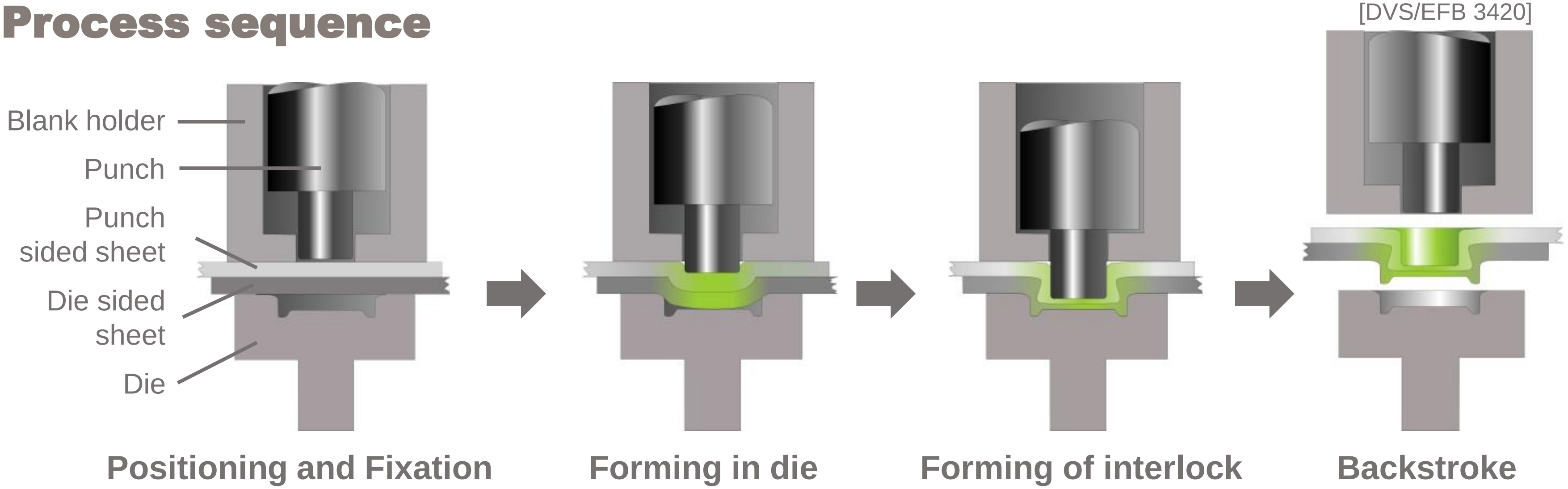
Fundamentals

- Mechanical joining without auxiliary element by cold forming the material
- Form fit and force fit joint
- Joining of different materials possible
- High quasistatic and dynamic load capacities
- Both sides accessibility required



$d_{i,0}$	Joint diameters
$t_{1,2}$	Sheet thicknesses
t_b	Bottom thickness
f	Interlock
t_n	Neck thickness

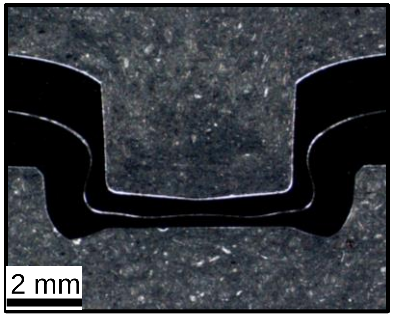
Process sequence



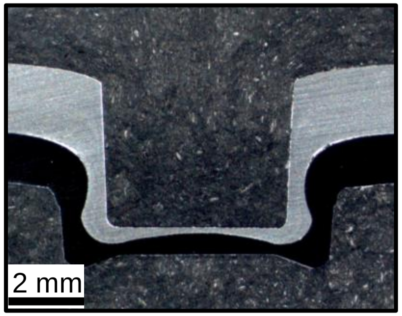
Clinching process

Experimental

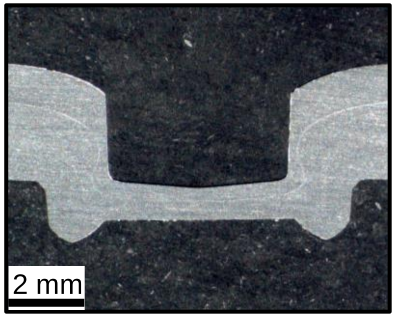
- Experimental investigation of different material combinations
- Determination of process parameters due to optimized geometric characteristics



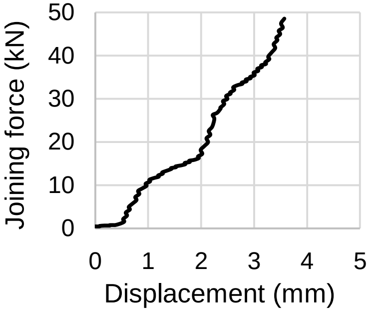
HCT590X – 1.5 mm
HCT590X – 1.5 mm

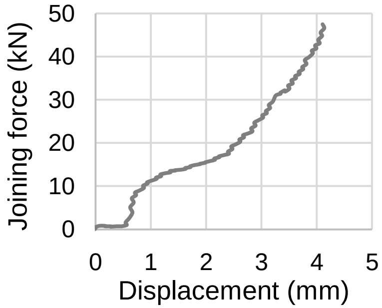


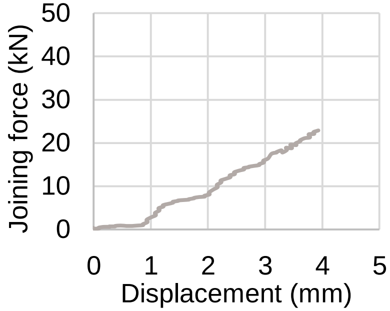
EN AW-6014 T4 – 2.0 mm
HCT590X – 1.5 mm



EN AW-6014 T4 – 1.0 mm
EN AW-6014 T4 – 2.0 mm



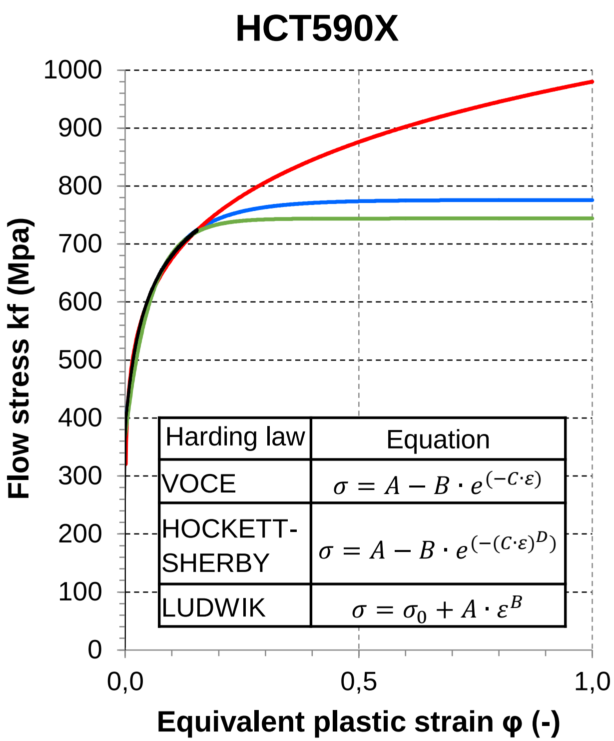




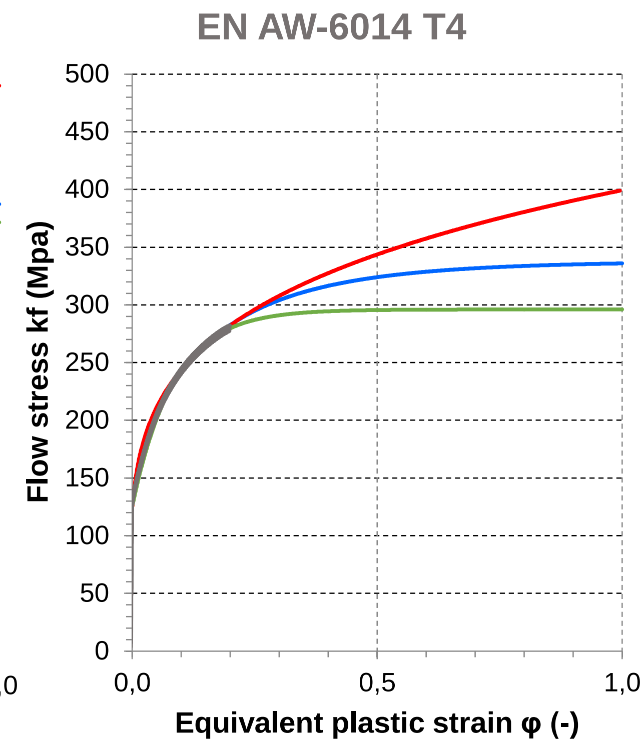
Materials
HCT590X, t = 0.8/1.5 mm EN AW-6014 T4, t = 1.0/2.0 mm
Joining technology
Clinching with rigid die
Joining speed
2 mm/s
Blank holder force
785 N
Type: TOX® TZ-VSN Engine: EPMR 100.113 Max. joining force: 90 kN Stroke: 190 mm

Tensile tests and extrapolation

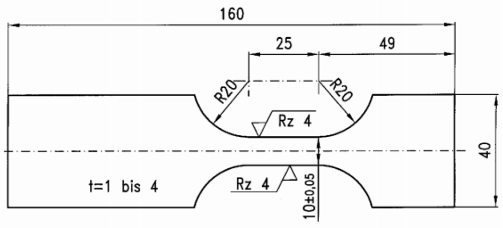
- Quasistatic tensile tests according to SEP1230 standard
- Flow curves generated by accordingly extrapolation with different hardening laws



Harding law	Equation
VOCE	$\sigma = A - B \cdot e^{(-C \cdot \varepsilon)}$
HOCKETT-SHERBY	$\sigma = A - B \cdot e^{(-(C \cdot \varepsilon)^{D})}$
LUDWIK	$\sigma = \sigma_0 + A \cdot \varepsilon^{B}$



Testing method
Quasistatic tensile test
Strainrate
0,01 s^{-1}
Material
HCT590X, t =1.5 mm, 0°
EN AW-6014 T4, t = 2.0 mm, 0°
Testing standard
SEP 1230
Strain measurement
GOM ARAMIS
Specimen geometry

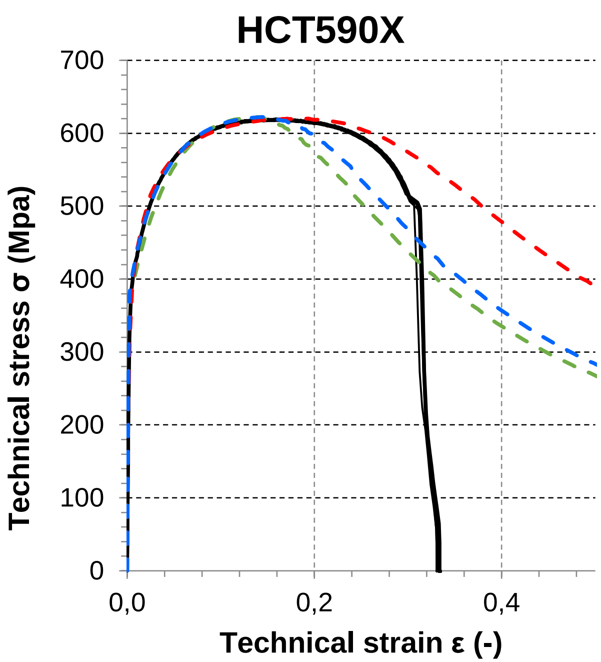


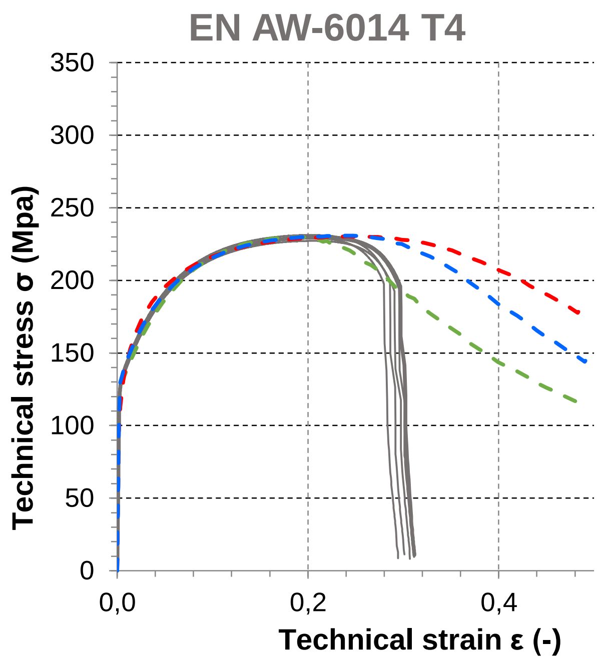
Legend

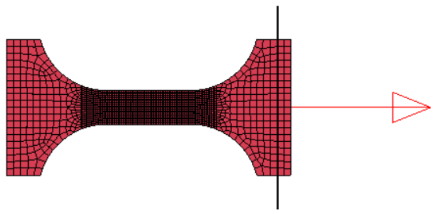
- Experimental (black)
- VOCE (green)
- LUDWIK (red)
- HOCKETT-SHERBY (blue)

Simulated tensile tests

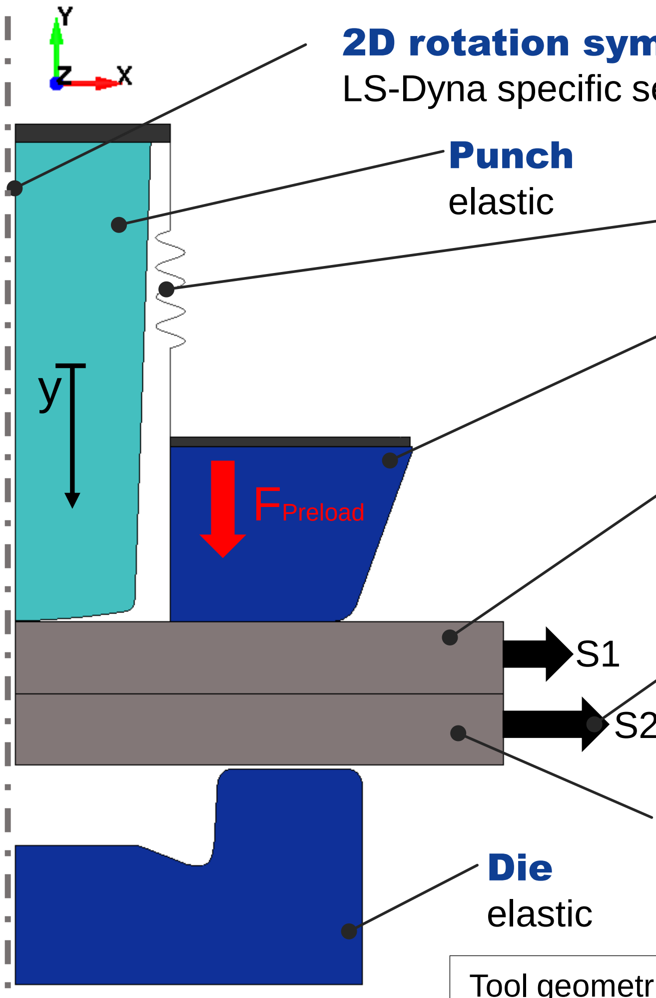
- Flow curves implemented in numerical model for simulating tensile test
- Determining flow curves for further investigation by best fitting of the experimental data
  - HCT590X → LUDWIK
  - EN AW-6014 → HOCKETT-SHERBY





Simulation object
Quasistatic tensile test
Strainrate
0,01 s^{-1}
Material
HCT590X, t =1.5 mm, 0° EN AW-6014 T4, t = 2.0 mm, 0°
Simulation software
LS Dyna
Material model
MAT 224
Specimen geometry

Legend
Experimental; VOCE; LUDWIK; HOCKKET-SHERBY

Simulation model and method



2D rotation symmetry
LS-Dyna specific setting

Punch
elastic

Blank holder spring
linear elastic stiffness

Blank holder
elastic
preload

Contact setting
static friction coefficients

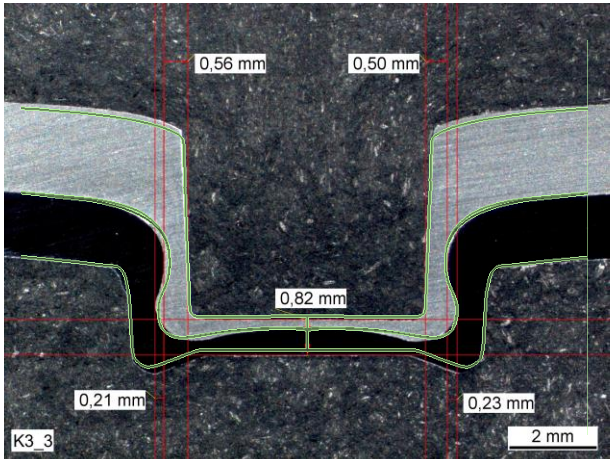
Pre-forming
S1: top-sheet
S2: bottom-sheet

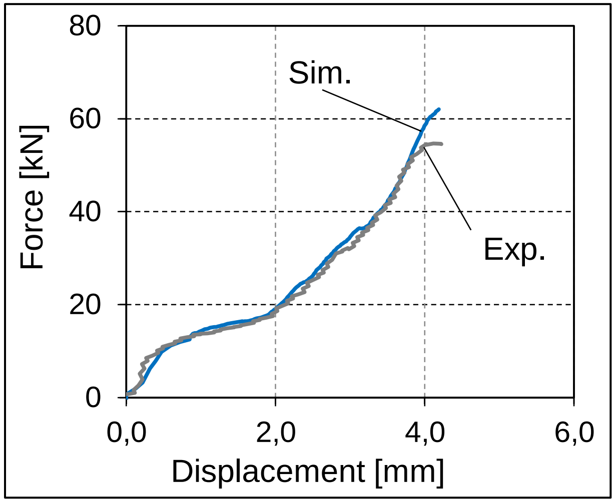
Materials
HCT590x
EN AW6014-T4

Die
elastic

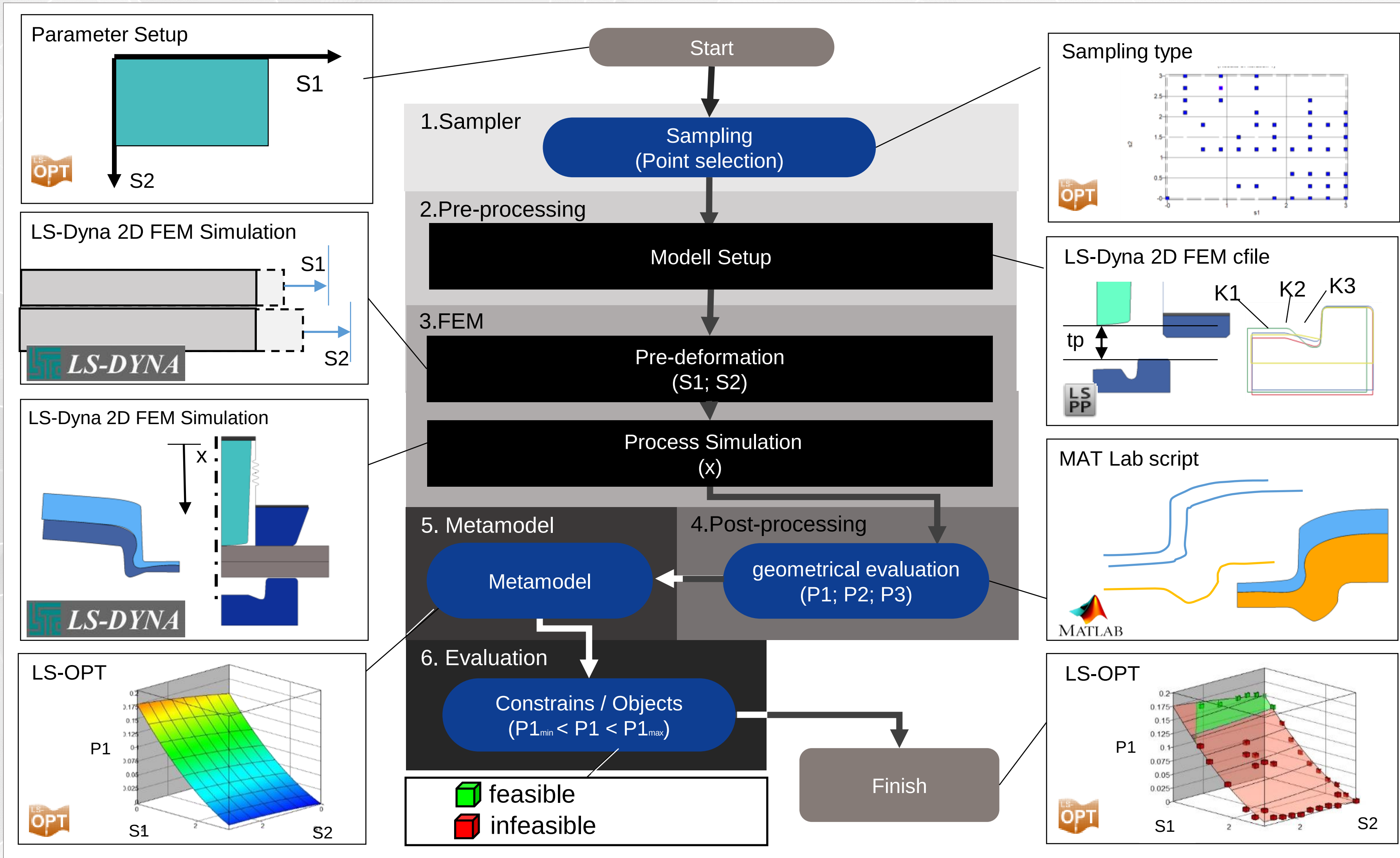
Tool geometries depending on the combination

Validation without pre-straining

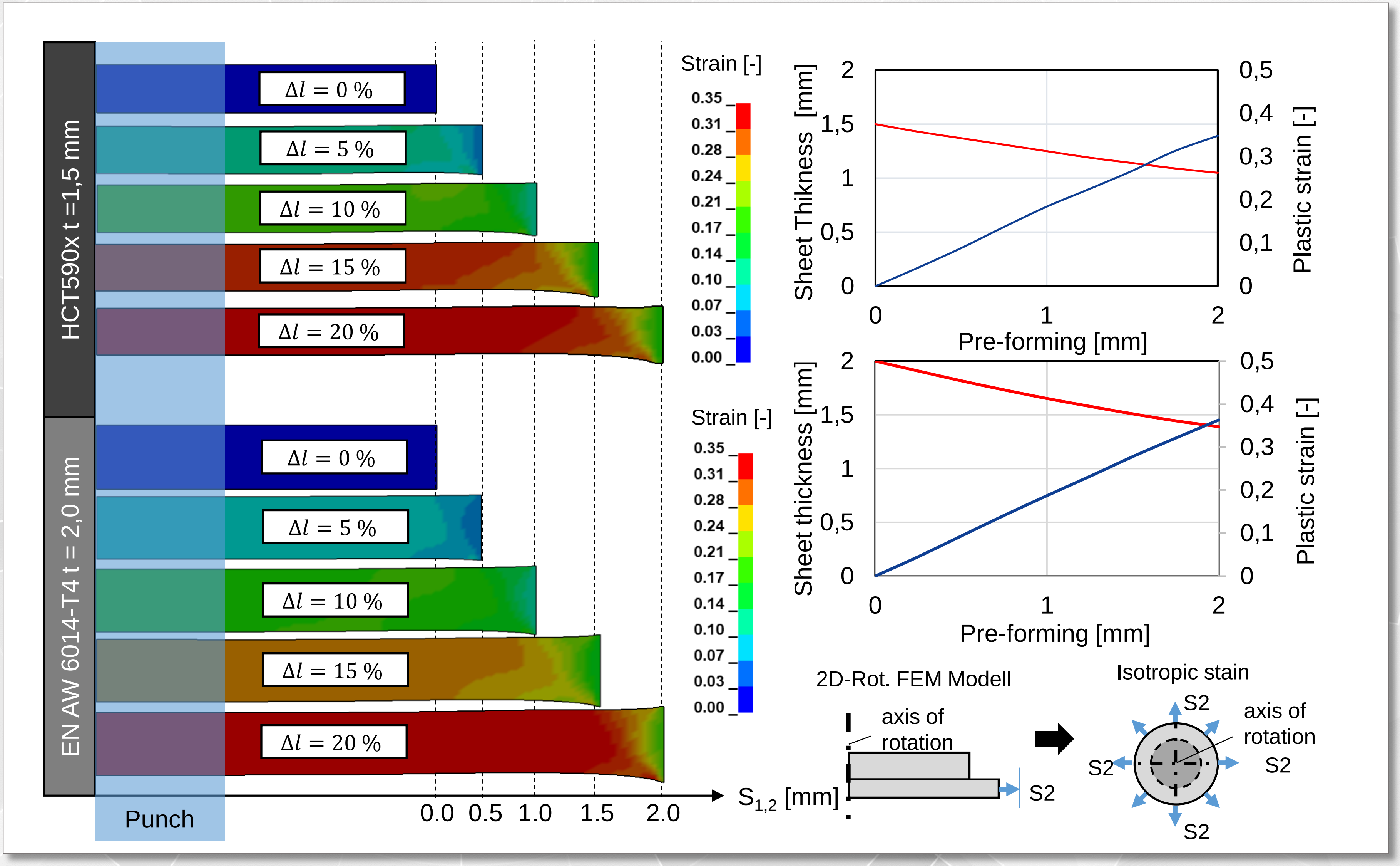




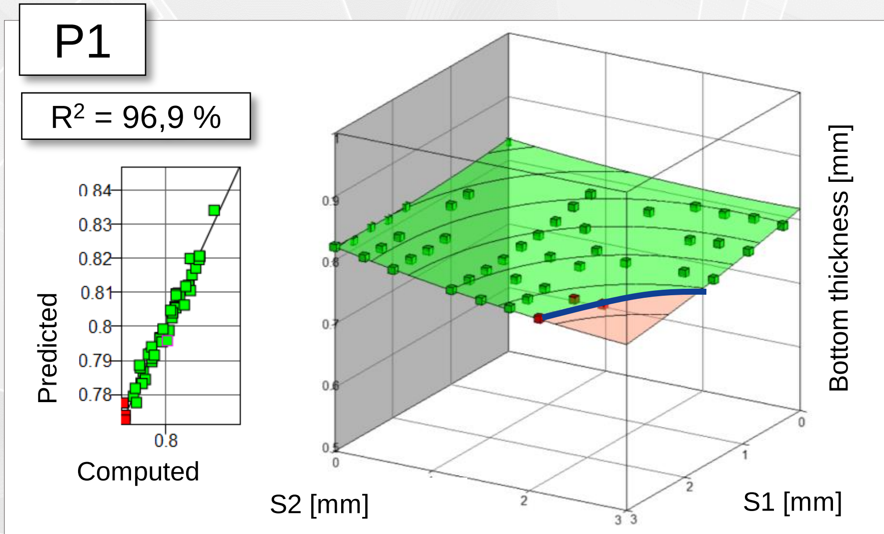
Simulation model and method

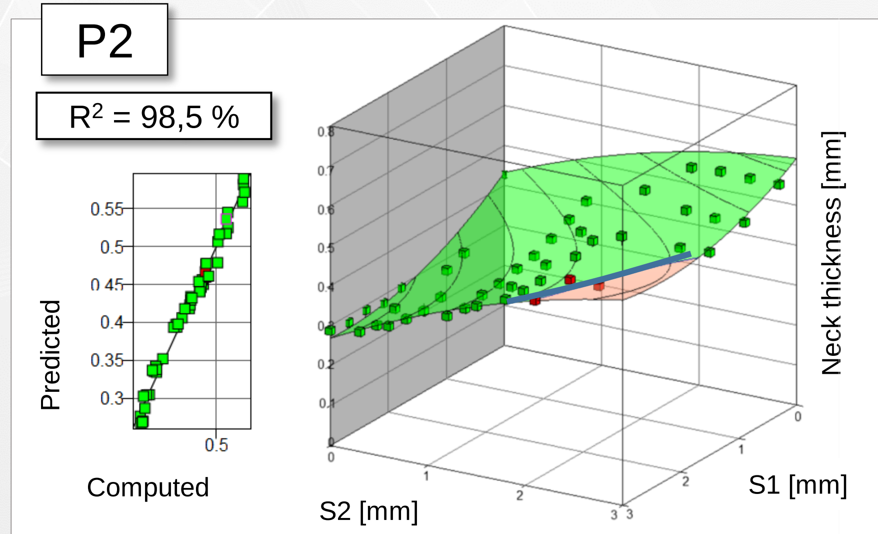


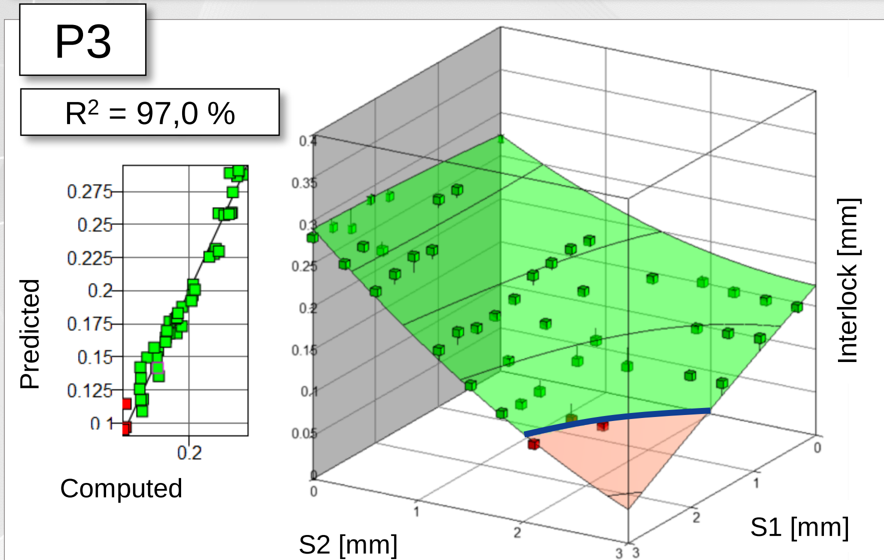
Results and discussion



Results and Discussion

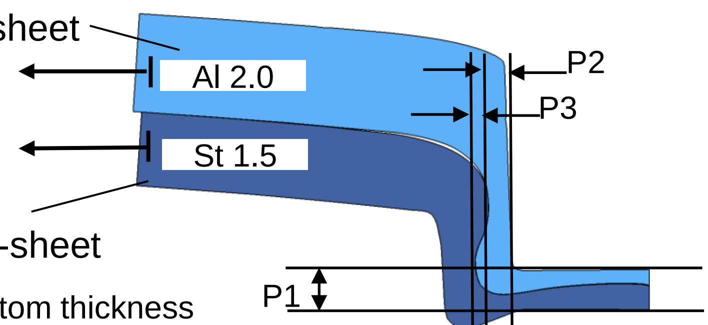






feasible
infeasible

> 0.15 mm Neck thickness
> 0.10 mm Interlock



P1: Bottom thickness
P2: Neck thickness
P3: Interlock

S1: Pre-strain top-sheet
S2: Pre-strain bottom-sheet

Conclusion

Summary

- Basic material characterization and flow curve identification were carried out
- 2D clinching simulation model was built up and validated
- Automatic method for analyzing the influence of pre-forming the sheet metal in clinching processes was developed
- Functionality demonstrated by investigating the influence of preforming sheet metal in clinching process on the geometric characteristics of the joint

Future Research

- Further investigation of material behavior concerning temperature- and strain rate-dependency
- Development of a 3D simulation model for clinching processes
- Expansion of the developed method on other process parameters

Thank you for your attention!

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