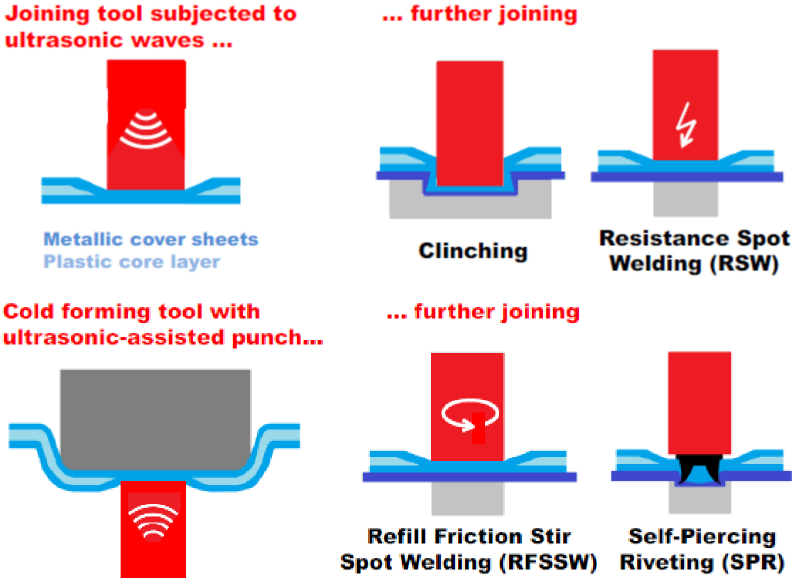
cornet

3rd User Committee

HybriSonic

Ultrasonic supported processing of hybrid materials

Web-Meeting, 08.12.2020



Joining tool subjected to ultrasonic waves ...

Metallic cover sheets
Plastic core layer

... further joining

Clinching

Resistance Spot Welding (RSW)

Cold forming tool with ultrasonic-assisted punch...

... further joining

Refill Friction Stir Spot Welding (RFSSW)

Self-Piercing Riveting (SPR)

Gefördert durch:
Bundesministerium für Wirtschaft und Energie
aufgrund eines Beschlusses des Deutschen Bundestages

AiF FOSTA DVS

Fraunhofer IWU
Fraunhofer IVV
Wrocław University of Science and Technology
IBS research

AGENDA

- **TOP 1 – Welcome / short introduction**
- TOP 2 – Project goals and work plan
- TOP 3 – Project results
- TOP 4 – Conclusions, decisions

Project consortium

European collaborative research - 4 institutes / 3 countries

US-design

Fraunhofer IVV

- FE-Modelling of polymer heating and displacement process
- Analysis of US-wave transmission
- Determination of US system parameters
- Integration of US process in joining and forming process

Speaker:
Mathias Kott
Marc Götz

Mechanical Joining

Fraunhofer IWU

- Tool design for SPR and clinching by numerical and experimental methods
- Manufacturing of reference joints
- Experimental investigation of US-supported Clinching
- Manufacturing of demonstrator parts

Speaker:
Christian Kraus
Matthias Riemer

Joint Quality

Wrocław University of Science and Technology

- Mechanical characterization of the raw materials
- Investigation of the US supported resistance spot welding process
- Mechanical testing of the joints
- Non-destructive testing of the joints

Speaker:
Koen Faes

Friction based proc.

research

- Investigation of refill friction stir spot welding
- Manufacturing and evaluation of demonstrators
- Evaluation of results

Speaker:
Marcin Korzeniowski

AGENDA

- TOP 1 – Welcome / short introduction
- **TOP 2 – Project goals and work plan**
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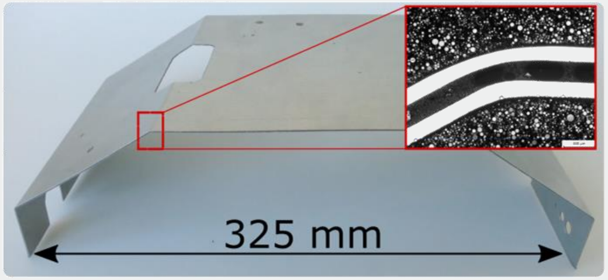
Initial situation and state of the art

Initial situation

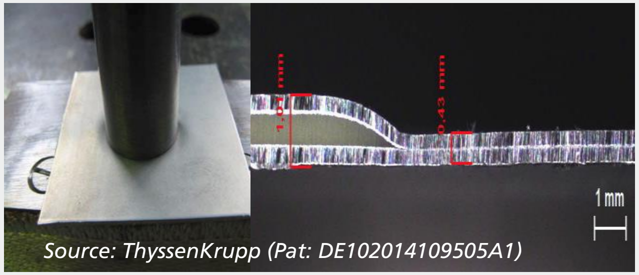
- Multi layered metal-plastic composites (MPC) offer a high potential for lightweight construction
- Necessity to process the MPCs efficiently with high quality and join them with other materials
- Properties of the polymer core limit the use for conventional manufacturing processes especially joining methods



State of the art solution

Thermal joining

→ Thermally supported displacement of the polymeric core layer

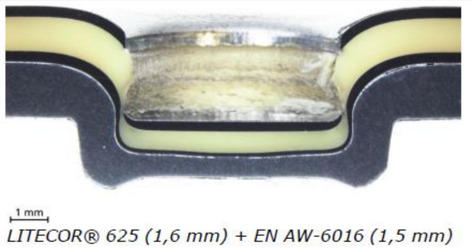


Source: ThyssenKrupp (Pat: DE102014109505A1)

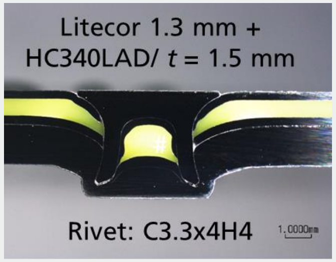
Mechanical joining

→ Clinching hardly possible (joining direction!)

→ SPR with limited quality (creeping of polymer?)



LITECOR® 625 (1,6 mm) + EN AW-6016 (1,5 mm)



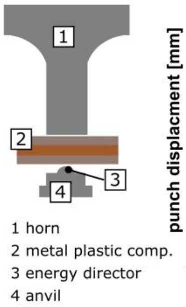
Litecor 1.3 mm + HC340LAD/ t = 1.5 mm

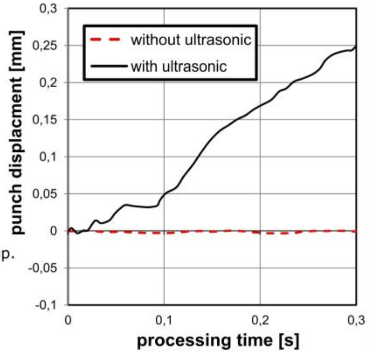
Rivet: C3.3x4H4

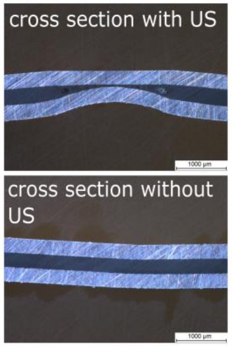
Presentation of the HybriSonic approach

Solution approach

- Application of improved conventional joining technologies to MPCs without a significant increase of process time and decrease quality
- Local melting of the polymer layer by ultrasonic vibrations
- Displacement of the of the molten polymer material by pressure on the cover sheets







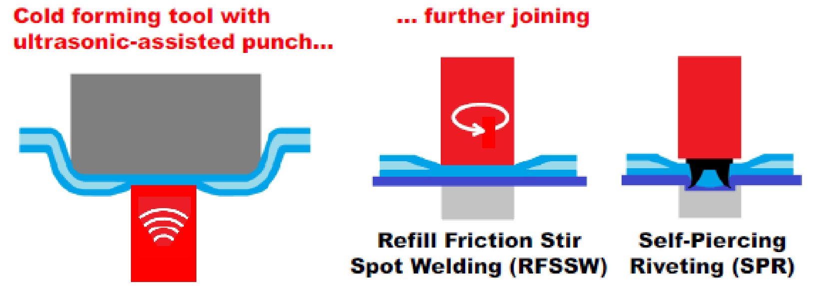
Process variants

'One-Step-Approach'

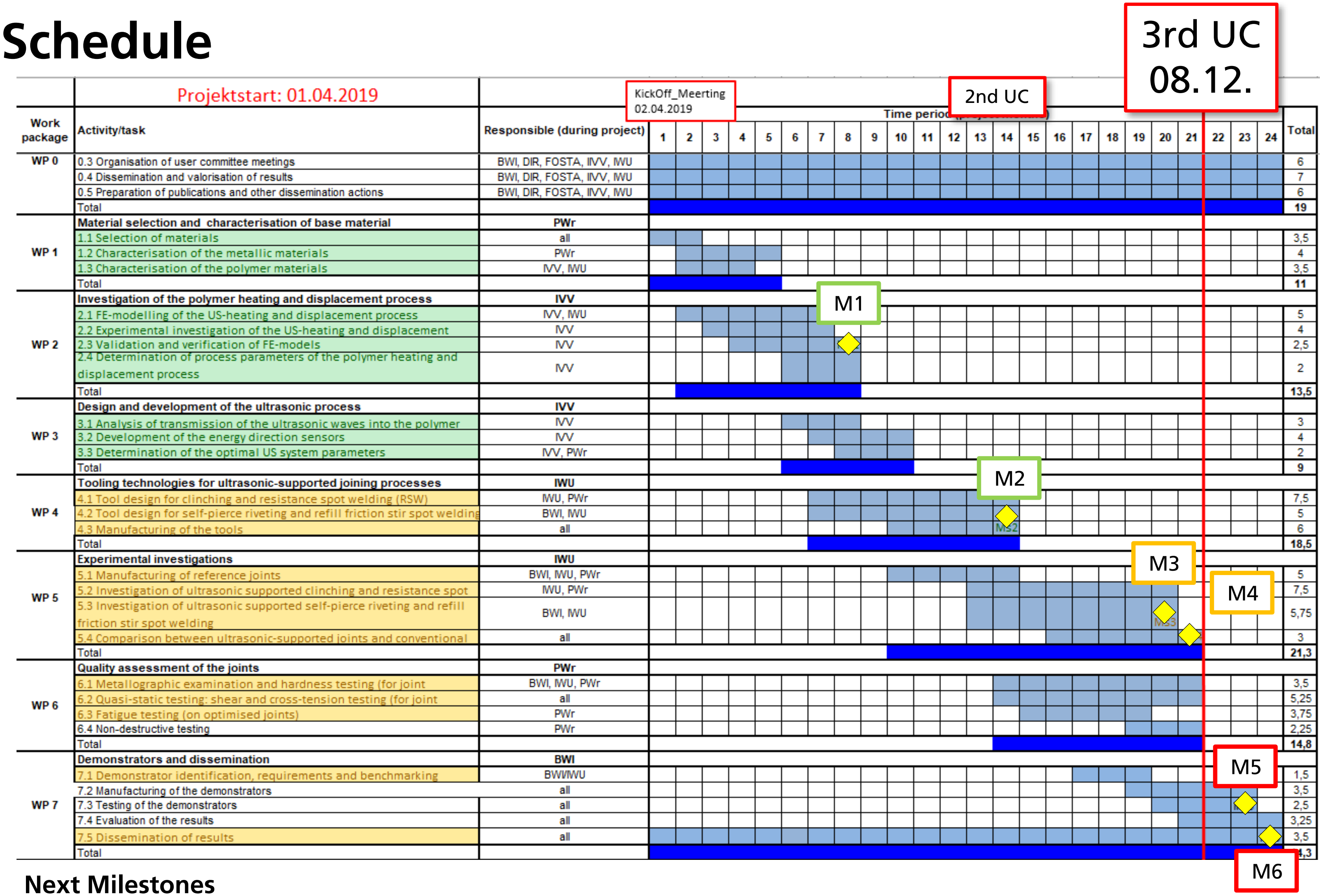
→ Joining tool directly superimposed by ultrasonic waves

'Two-Step-Approach'

→ Polymer layer is suppressed during a prior forming process



Schedule



3rd UC
08.12.

2nd UC

KickOff_Meerting
02.04.2019

M1

M2

Ms2

M3

Ms3

M4

M5

M6

Work package	Activity/task	Responsible (during project)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Total
	Projektstart: 01.04.2019		Time perio																								
WP 0	0.3 Organisation of user committee meetings	BWI, DIR, FOSTA, IVV, IWU	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	6
	0.4 Dissemination and valorisation of results	BWI, DIR, FOSTA, IVV, IWU	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	7
	0.5 Preparation of publications and other dissemination actions	BWI, DIR, FOSTA, IVV, IWU	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	6
	Total		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	**19**
WP 1	**Material selection and characterisation of base material**	**PWr**																									
	1.1 Selection of materials	all	▨	▨																							3,5
	1.2 Characterisation of the metallic materials	PWr		▨	▨	▨	▨																				4
	1.3 Characterisation of the polymer materials	IVV, IWU		▨	▨	▨																					3,5
	Total		■	■	■	■	■																				**11**
WP 2	**Investigation of the polymer heating and displacement process**	**IVV**																									
	2.1 FE-modelling of the US-heating and displacement process	IVV, IWU		▨	▨	▨	▨	▨	▨																		5
	2.2 Experimental investigation of the US-heating and displacement	IVV			▨	▨	▨	▨	▨																		4
	2.3 Validation and verification of FE-models	IVV				▨	▨	▨	▨																		2,5
	2.4 Determination of process parameters of the polymer heating and displacement process	IVV						▨	▨	▨																	2
	Total			■	■	■	■	■	■	■																	**13,5**
WP 3	**Design and development of the ultrasonic process**	**IVV**																									
	3.1 Analysis of transmission of the ultrasonic waves into the polymer	IVV						▨	▨	▨																	3
	3.2 Development of the energy direction sensors	IVV							▨	▨	▨	▨															4
	3.3 Determination of the optimal US system parameters	IVV, PWr								▨	▨	▨															2
	Total							■	■	■	■	■															**9**
WP 4	**Tooling technologies for ultrasonic-supported joining processes**	**IWU**																									
	4.1 Tool design for clinching and resistance spot welding (RSW)	IWU, PWr							▨	▨	▨	▨	▨	▨	▨	▨											7,5
	4.2 Tool design for self-pierce riveting and refill friction stir spot welding	BWI, IWU							▨	▨	▨	▨	▨	▨	▨	▨											5
	4.3 Manufacturing of the tools	all										▨	▨	▨	▨	▨											6
	Total								■	■	■	■	■	■	■	■											**18,5**
WP 5	**Experimental investigations**	**IWU**																									
	5.1 Manufacturing of reference joints	BWI, IWU, PWr										▨	▨	▨	▨	▨											5
	5.2 Investigation of ultrasonic supported clinching and resistance spot	IWU, PWr													▨	▨	▨	▨	▨	▨	▨	▨					7,5
	5.3 Investigation of ultrasonic supported self-pierce riveting and refill friction stir spot welding	BWI, IWU													▨	▨	▨	▨	▨	▨	▨	▨					5,75
	5.4 Comparison between ultrasonic-supported joints and conventional	all																▨	▨	▨	▨	▨	▨				3
	Total											■	■	■	■	■	■	■	■	■	■	■	■				**21,3**
WP 6	**Quality assessment of the joints**	**PWr**																									
	6.1 Metallographic examination and hardness testing (for joint	BWI, IWU, PWr														▨	▨	▨	▨	▨	▨	▨	▨				3,5
	6.2 Quasi-static testing: shear and cross-tension testing (for joint	all														▨	▨	▨	▨	▨	▨	▨	▨				5,25
	6.3 Fatigue testing (on optimised joints)	PWr															▨	▨	▨	▨	▨						3,75
	6.4 Non-destructive testing	PWr																			▨	▨	▨				2,25
	Total															■	■	■	■	■	■	■	■				**14,8**
WP 7	**Demonstrators and dissemination**	**BWI**																									
	7.1 Demonstrator identification, requirements and benchmarking	BWI/IWU																	▨	▨	▨						1,5
	7.2 Manufacturing of the demonstrators	all																			▨	▨	▨	▨	▨		3,5
	7.3 Testing of the demonstrators	all																				▨	▨	▨	▨		2,5
	7.4 Evaluation of the results	all																					▨	▨	▨	▨	3,25
	7.5 Dissemination of results	all	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	3,5
	Total		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	**4,3**

Next Milestones

- M3 in 03/2021: Assessment of the feasibility of the different processes for the selected materials
- M4 in 04/2021: Benchmark investigation is finalized, with the comparison of the joining methods

AGENDA

- TOP 1 – Welcome, short introduction (BWI, IVV, IWU, PWr)
- TOP 2 – Project goals and work plan
- **TOP 3 – Project results**
  - **Investigated metal-plastic composite materials**
  - Design and development of the ultrasonic process (IVV)
  - Conventional and solid state joining processes (BWI)
  - Resistance spot welding (PWr)
  - Mechanical joining (IWU)
  - Tool integrated US-process (IWU, IVV)
- TOP 4 – Conclusions, decisions

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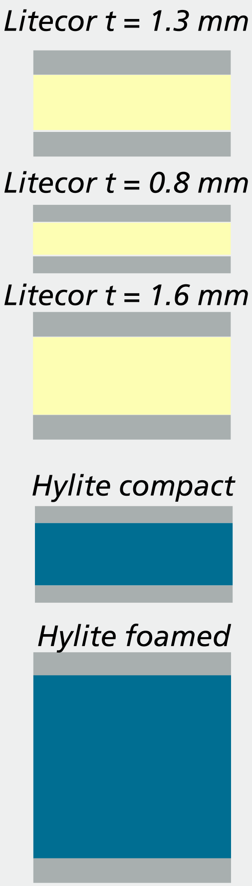
Investigated Materials

Selection of materials

- Materials with **steel** cover layers
  - Litecor t = 1.3 mm, cover layers: HC220 t = 0.3 mm, core layer: PE/PA compound t = 0.7 mm
  - Litecor t = 0.8 mm, cover layers: HC220 t = 0.2 mm, core layer: PE/PA compound t = 0.4 mm
  - Litecor t = 1.6 mm, cover layers: HC220 t = 0.3 mm, core layer: PE/PA compound t = 1 mm
- Materials with **aluminium** cover layers
  - Hylite – compact t = 1.2 mm, cover layers: EN-AW-5182 t = 0.2 mm, core layer: PP t = 0.8 mm
  - Hylite – foamed t = 3 mm, cover layers: EN-AW-5005A t = 0.3 mm, core layer: foamed PP t = 2.4 mm



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- TOP 4 – Conclusions, demonstrator, decisions

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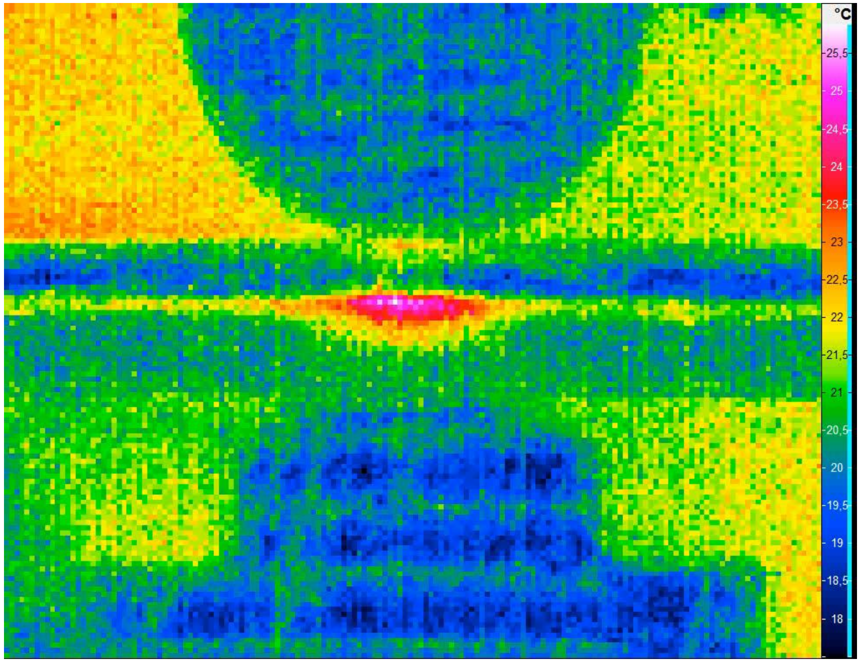
Detailed workload

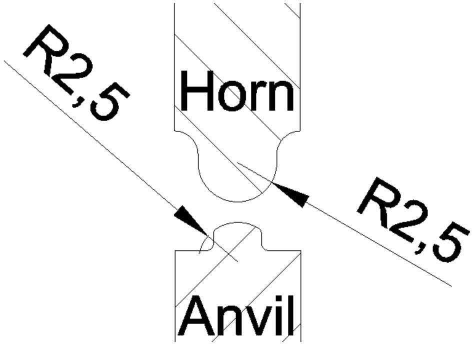
Investigation of the polymer heating and displacement process | IVV: M2-M8

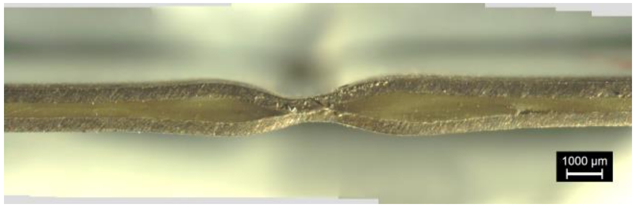
- FE-modelling of the US-heating and displacement process
- Experimental investigation of the US-heating and displacement process
- Validation and verification of FE-models
- Determination of process parameters of the polymer heating and displacement process

Displacement of the polymer layer by ultrasonic waves



Infrared video: Intrinsic heating of the plastic layer of a hybrid composite by an upper tool exposed to ultrasound

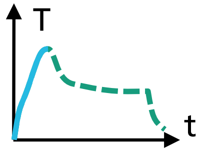




Displacement of the polymer layer by ultrasonic waves

Heating mechanisms

- Heat generation rate due to intermolecular friction



$$\dot{Q} = \pi \cdot f \cdot {\varepsilon_0}^2 \cdot E''$$

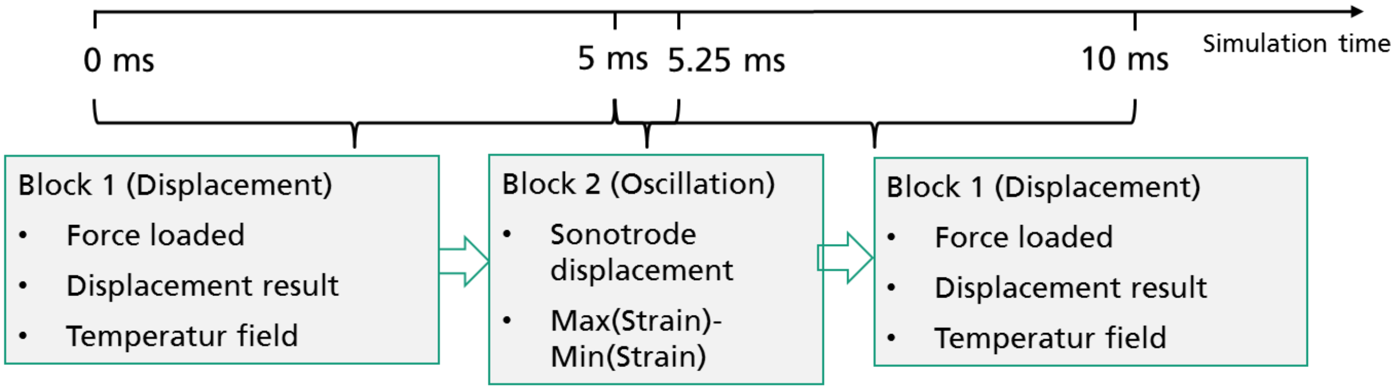
  - f = frequency → fixed
  - ε_0 = strain amplitude → influenced by horn amplitude and sealing force
  - E'' = loss modulus → material property

  - Source: Tolunay et al., Heating and Bonding Mechanisms in Ultrasonic Welding of Thermoplastics. Polymer Engineering & Science, Volume 23, Issue 13, pages 726–733, September 1983

Displacement of the polymer layer by ultrasonic waves

Simulation

- Simulation of oscillation not possible due to
  - Remeshing → Heat generation cannot be applied
  - No calculation of heat generation from strain possible → needs new material model
  - Small necessary time step → Long simulation time



Simulation time

0 ms

5 ms

5.25 ms

10 ms

Block 1 (Displacement)
- Force loaded
- Displacement result
- Temperatur field

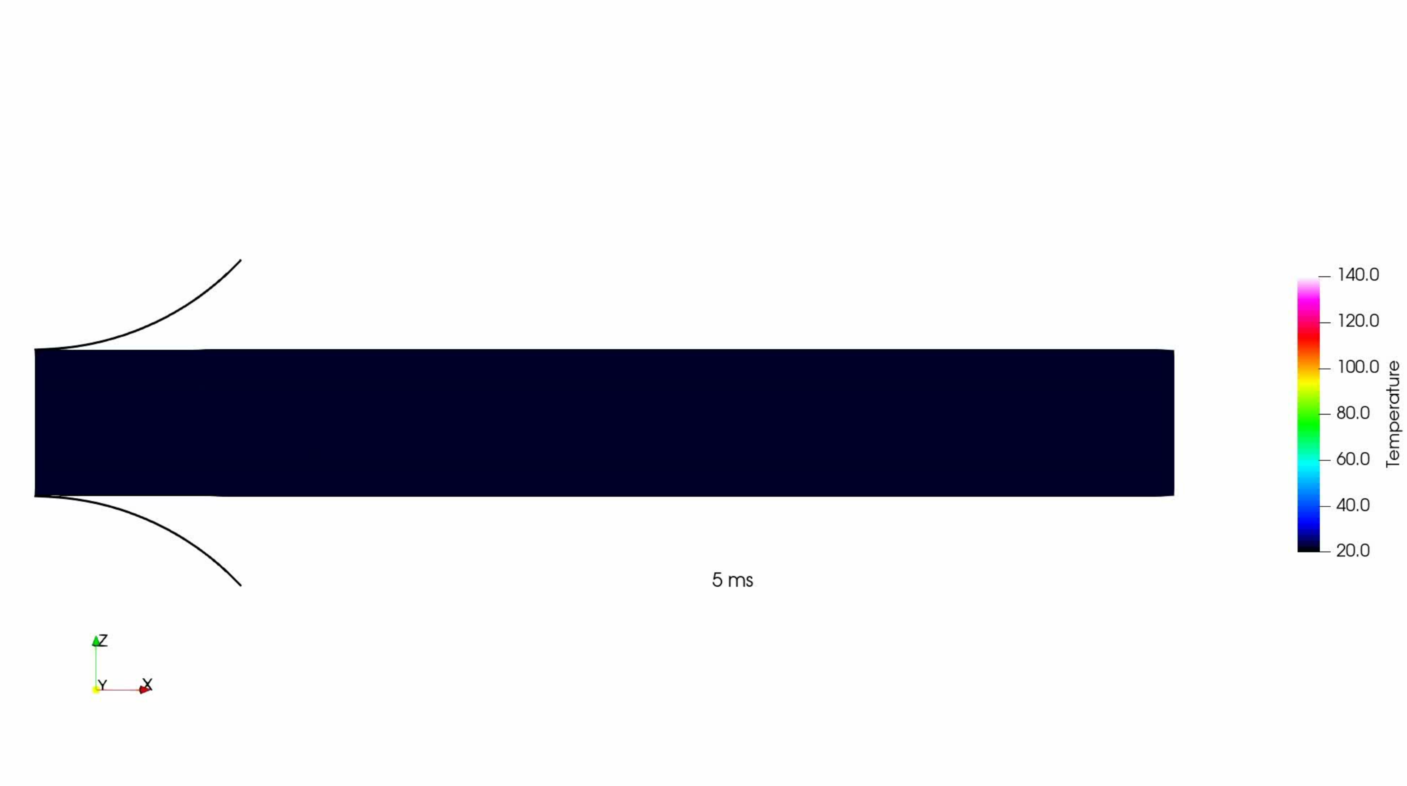
Block 2 (Oscillation)
- Sonotrode displacement
- Max(Strain)-Min(Strain)

Block 1 (Displacement)
- Force loaded
- Displacement result
- Temperatur field

$$\dot{Q} = \pi \cdot f \cdot {\varepsilon_0}^2 \cdot E''$$

Displacement of the polymer layer by ultrasonic waves

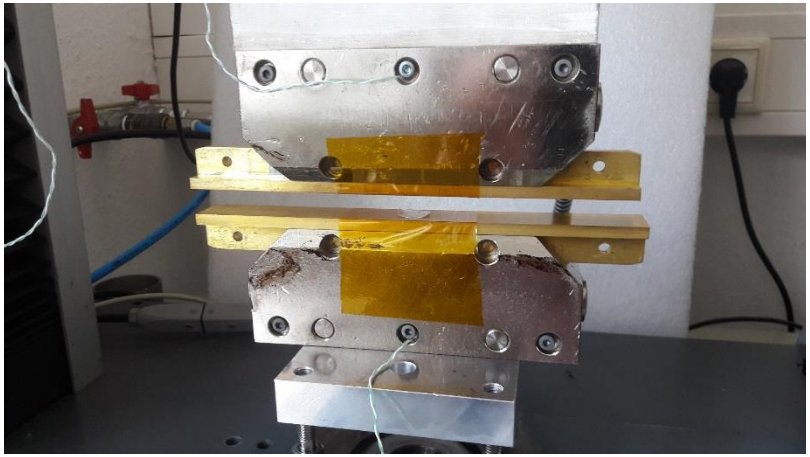
Simulation



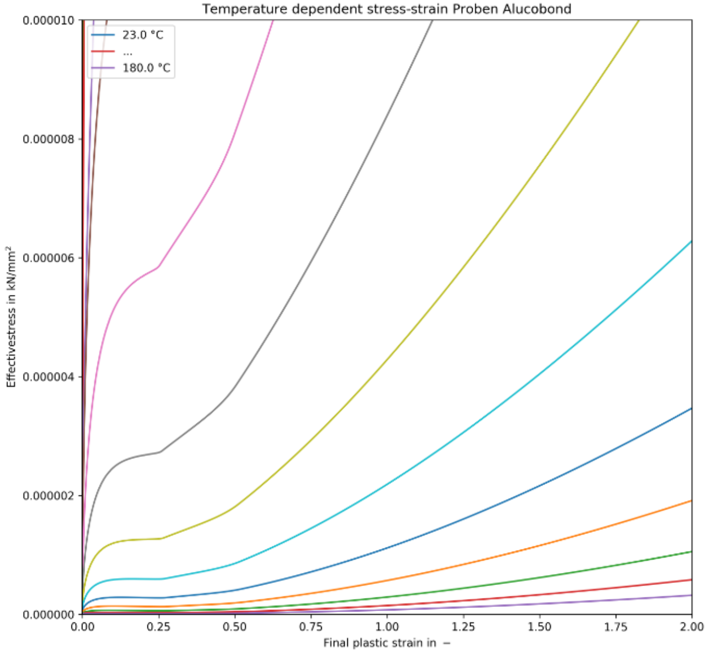
Displacement of the polymer layer by ultrasonic waves

Material characterization

- Temperature-dependent compression tests on a tensile testing machine
- Smoothing and averaging of the curves
- Extrapolation of the curves



Compression tests (temperature dependent)



Material curves for simulation

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Detailed workload

WP 3 – Design and development of the ultrasonic process | **IVV: M6-M10**

- Analysis of transmission of the ultrasonic waves into the polymer layer
- Development of the energy direction sensors
- Determination of the optimal US system parameters

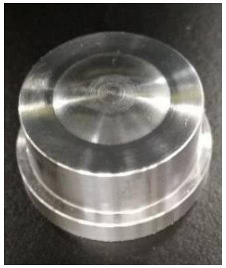
Displacement of the polymer layer by ultrasonic waves - Experimental investigations with shaped anvils

Ultrasonic welding machine - MS Ultrasonic:

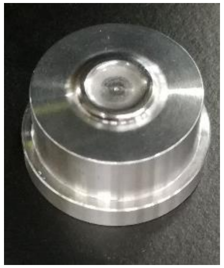
20 kHz, 6 kW, F_{max} 9 kN

Roundsonotrode D=16mm

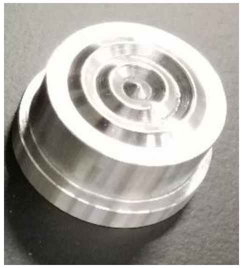
Energy directors:



spherical



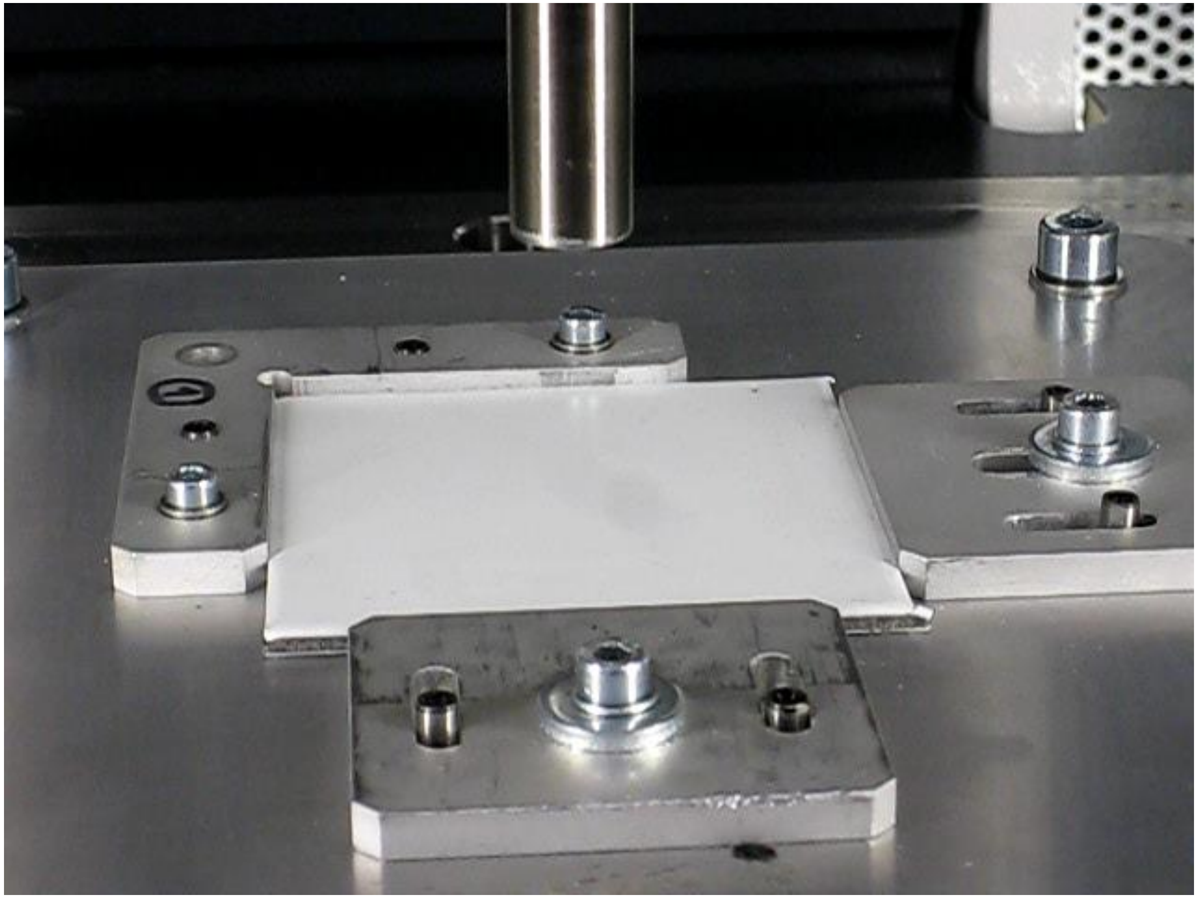
Ring-shaped



Wave-shaped

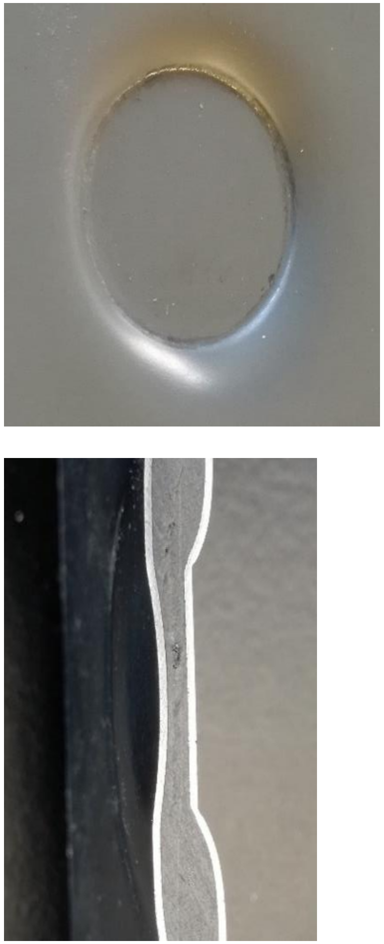
without

Displacement of the polymer layer by ultrasonic waves - Experimental investigations with shaped anvils

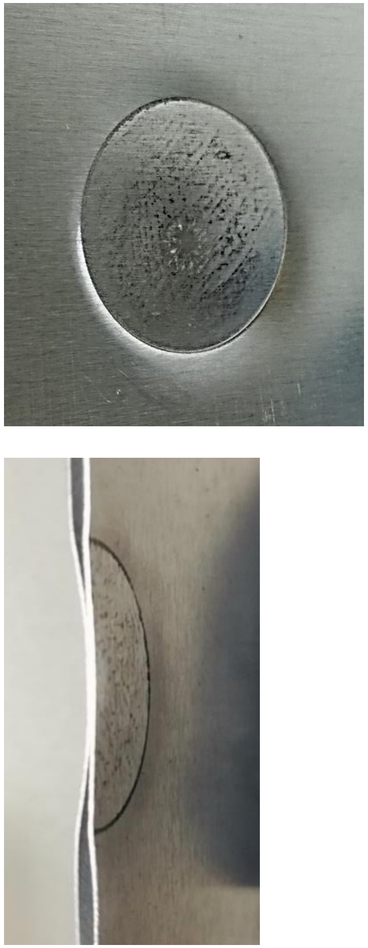


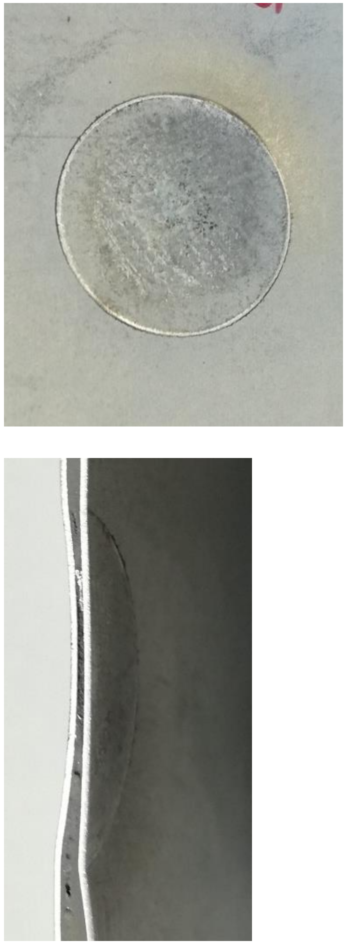
Heating and displacement (video)

Displacement of the polymer layer by ultrasonic waves - Experimental investigations with <u>spherical director</u>


ALUCOBOND® 4mm

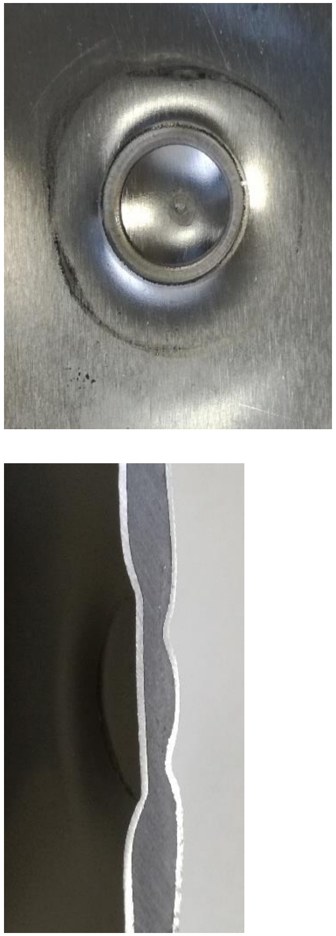

HYLITE® 3mm


HYLITE® 1.2mm

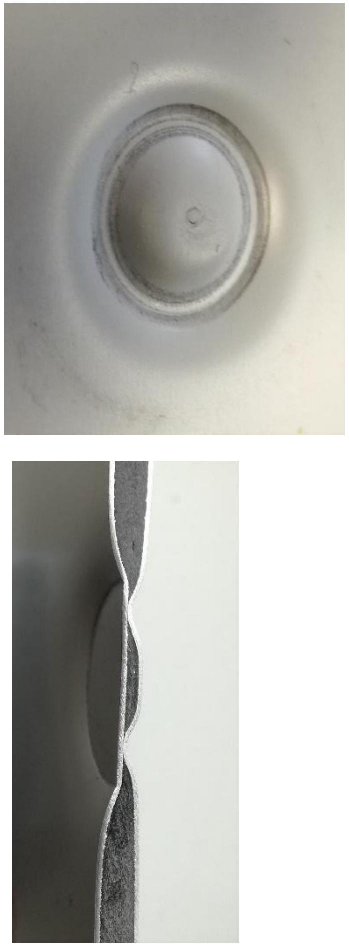

Litecor® 1.3mm

Displacement of the polymer layer by ultrasonic waves - Experimental investigations with <u>ring-shaped director</u>

ALUCOBOND® 4mm

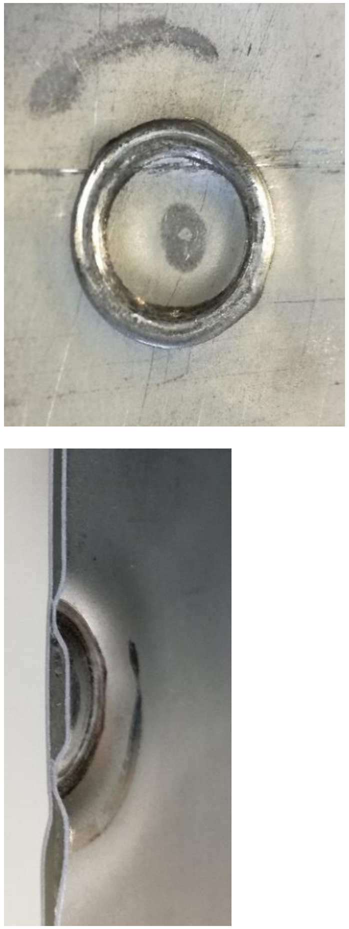


HYLITE® 3mm



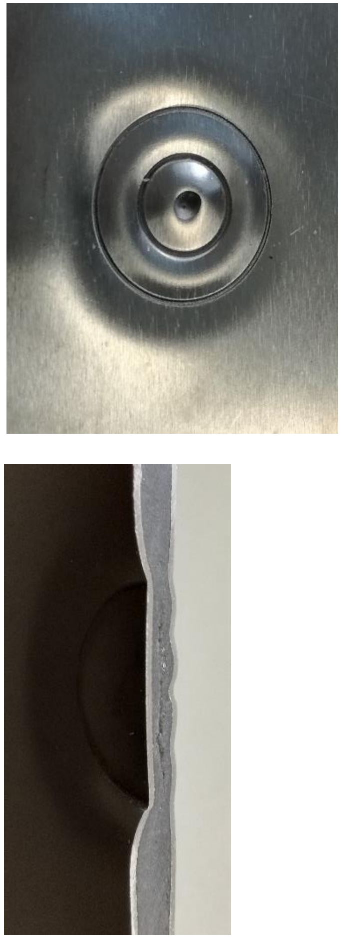
HYLITE® 1.2mm

Litecor® 1.3mm



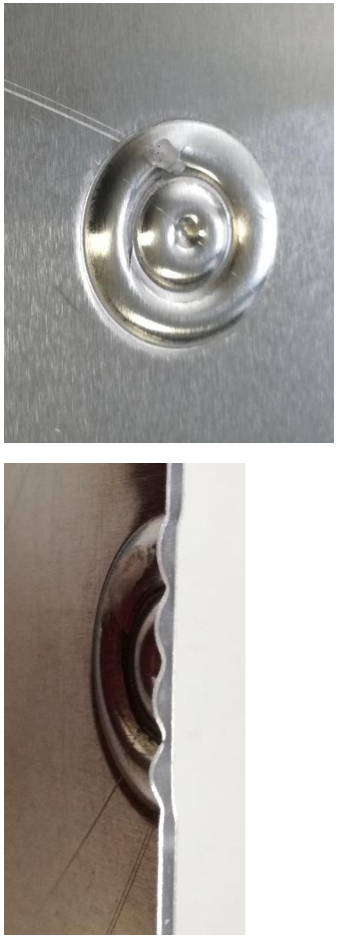
Displacement of the polymer layer by ultrasonic waves - Experimental investigations with wave-shaped director

ALUCOBOND® 4mm



HYLITE® 3mm

HYLITE® 1.2mm

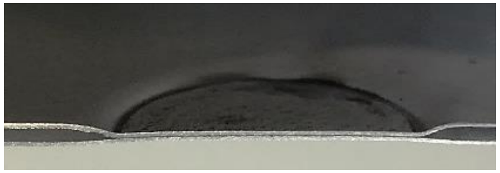


Litecor® 1.3mm

Displacement of the polymer layer by ultrasonic waves - Experimental investigations without anvil

HYLITE® 3mm

HYLITE® 1.2mm



Litecor® 1.3mm

Results of the experimental investigations:

	spherical	Ring-shaped	Wave shaped	without anvil
ALU COBOND® 4mm	no contact of outer layers because of the early crack of sheet metal	no contact of outer layers because of the early crack of sheet metal	no contact of outer layers because of the early crack of sheet metal	early crack of sheet metal
HYLITE® 3mm	contact of outer layers, good results	contact of outer layers, best results, good behaviour of the foamed polymer	no contact of outer layers because of the early crack of sheet metal	no contact of outer layers because of the early crack of sheet metal
HYLITE® 1.2mm	contact of outer layers, undefined movement of the liquid plastic	contact of outer layers, best results, undefined movement of the liquid plastic	relatvly high forming force Crack of sheat metal, chambers of melting polymer should be larger	high forming force and processtime; contact of outher layers but spring back; **very high tool load**
Litecor® 1.3mm	Good result, no contact because of the setback of the sheat metall	contact of outer layers, **best results**	Contact of the outer layers, s.t. amplitude overload	high forming force and processtime; contact of outher layers but spring back; **very high tool load**

Results of Experimental investigations

- The heating of polymer layer is generally possible (processtime for heating the polymer is 0.8 sec – 1.5 sec)

- Contact between the both outer layers with litecor and Hylite 1.2mm/ 3mm is possible (proven by el. contact).

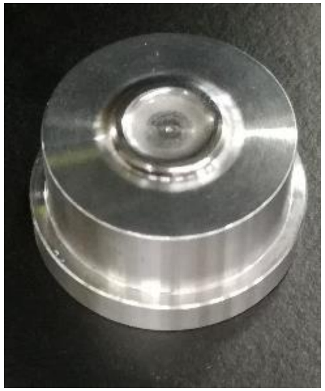
- The limit for the process is the formability of the sheet metal layer (for thicker plastic layers) or the overload of the mashine (when both sheet metal layers lie on top of each other).

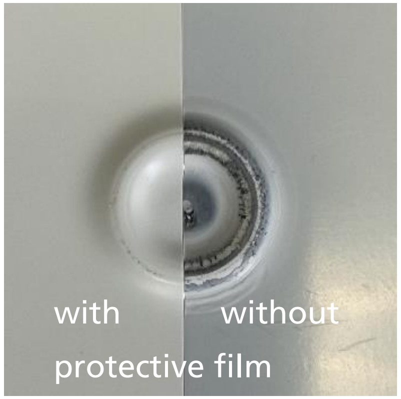

Litecor® 1.3mm


HYLITE® 3mm

Results of Experimental investigations

- The biggest influence on the coupling of the ultrasonic waves is the form of the energy director in connection with the pressing force
- The best coupling is provided by the ring-shaped anvil -the coupling of ultrasonic waves via flat geometries is possible, but requires approx. 3 times more force (4 kN) than e.g. the spherical anvil (1,5kN)
- Additional benefit: It is possible to process the hybrid materials with there protective films

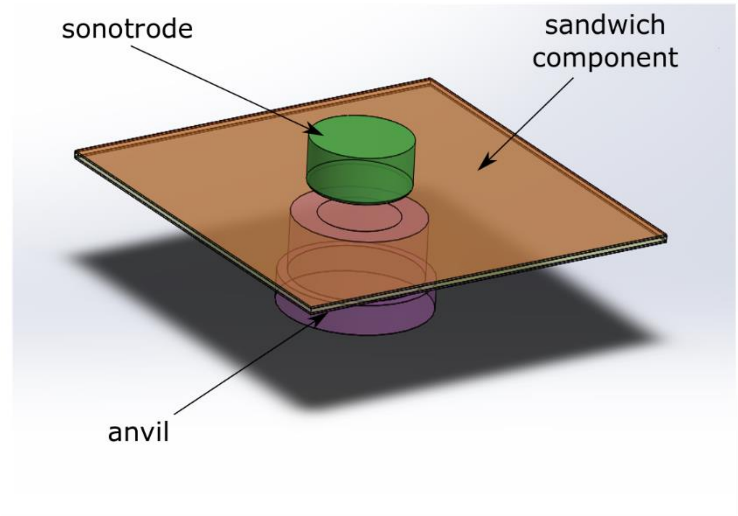


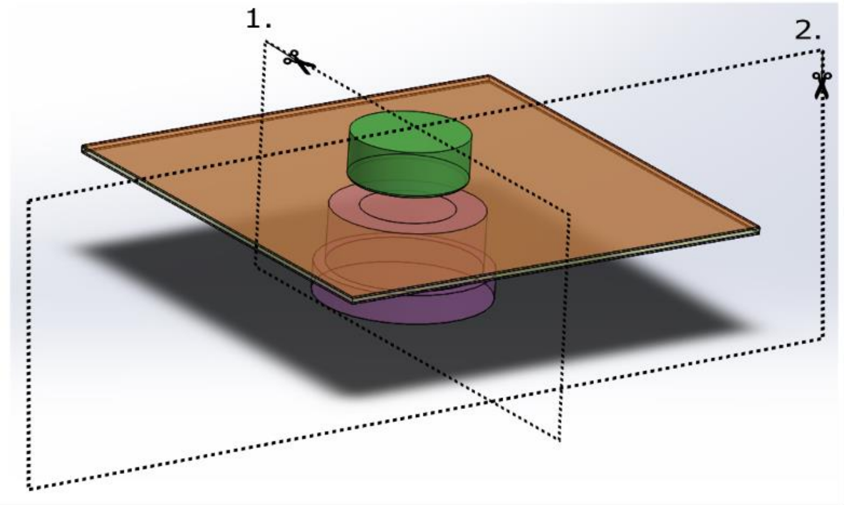


Simulation of shaped anvils with LS-Dyna®

Simulation Setup

- Simplify simulation geometry from 3D to 2D



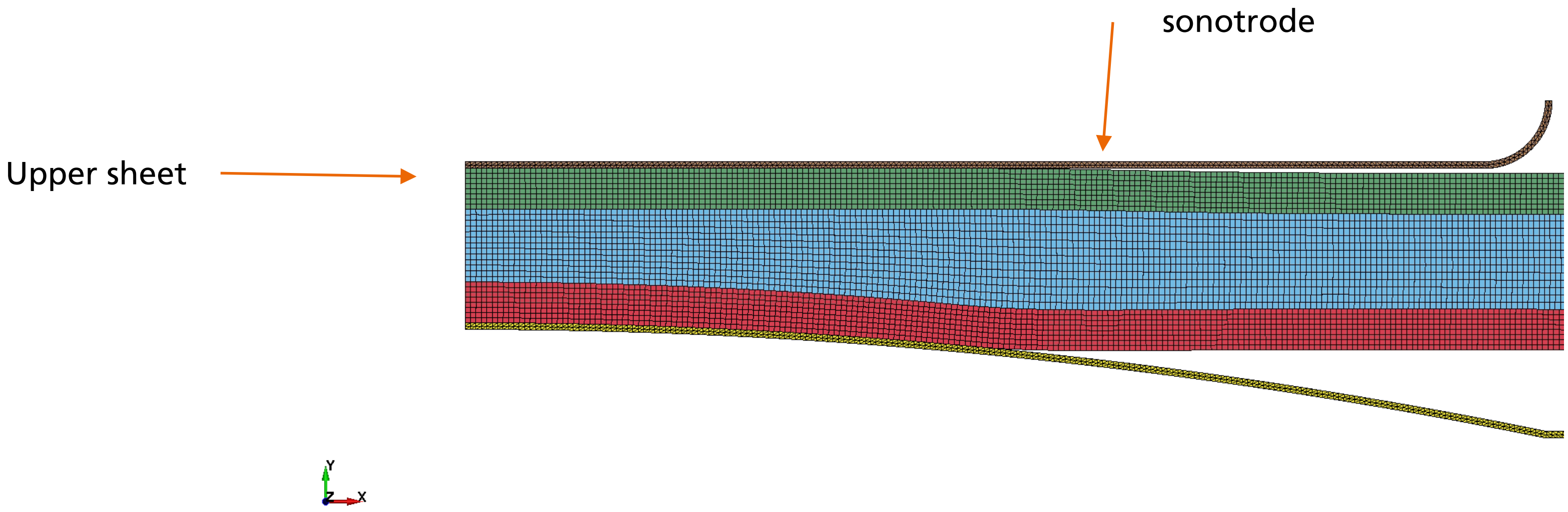


- Consider a quarter cross- section of the setup

Calculation of welding force from simulation

Force controlled process

- Reaction force between sontrode and upper sheet



- Due to axial-symmetric property of the process:

$$F_w = F_{Reac} \times 2\pi$$

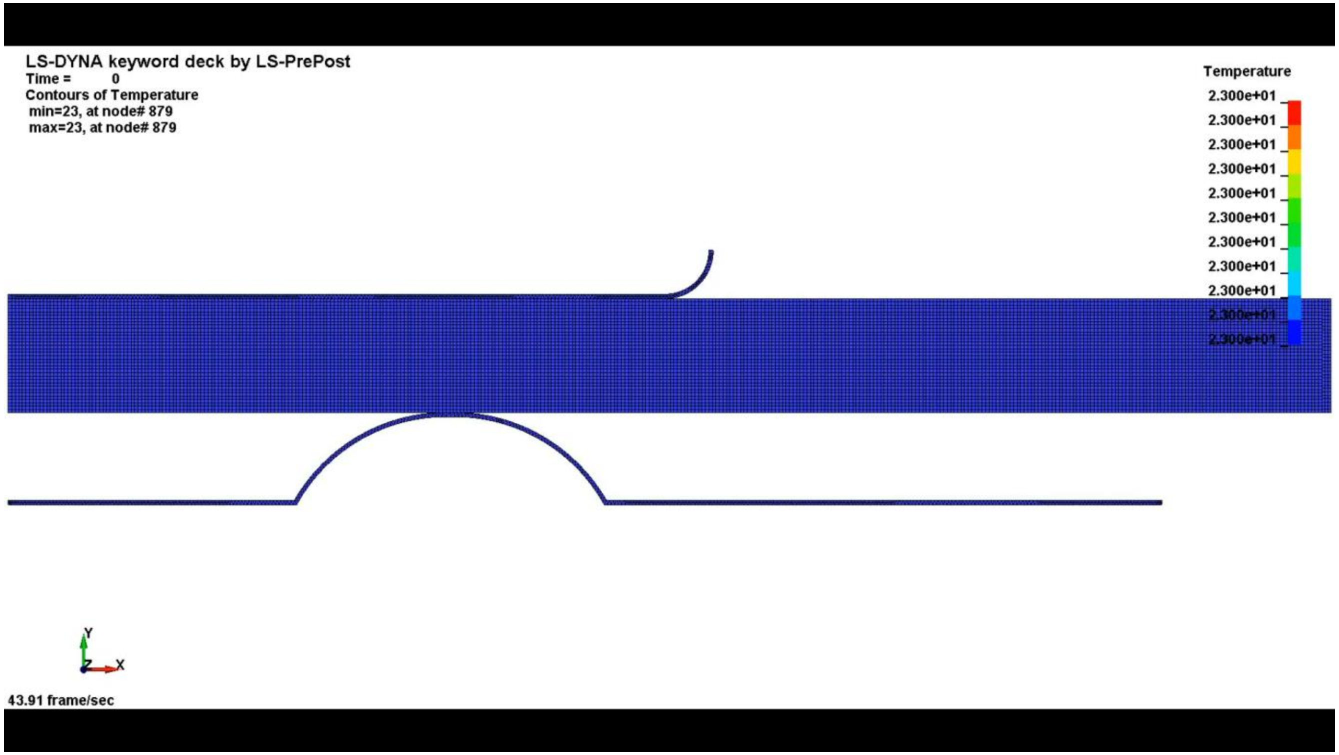
State of simulation of displacement process

- New contact formulation TIETYP=1 in *CONTACT_TIED_THERMAL_2D prevents prematurly abort of the simulation (since LSPP Version 4.7.18; July 2020)

- Phase transition solid-> liquid difficult. -> Testing of multiple remeshing-strategies due to Lagrangian view.
  - Remeshing is not allowed as often as disired due to heat calculation with strain differences (needs the same mesh)
  - $\dot{Q} = f * (\Delta\varepsilon)^2 * \pi * E'' = f * (\varepsilon_2 - \varepsilon_1)^2 * \pi * E''$

State of simulation of displacement process- Tool 2

- Tool 2 less problematic due to defomation before phase transition deploys



LS-DYNA keyword deck by LS-PrePost
Time = 0
Contours of Temperature
min=23, at node# 879
max=23, at node# 879

Outlook

- Testing of further remeshing strategies
- Simulation with EFG (Element-Free-Galerkin Method)
- Testing another sections (axialsymmetric)

AGENDA

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  - **Conventional and solid state joining processes (BWI)**
  - Resistance spot welding (PWr)
  - Mechanical joining (IWU)
  - Tool integrated US-process (IWU, IVV)
- TOP 4 – Conclusions, demonstrator, decisions

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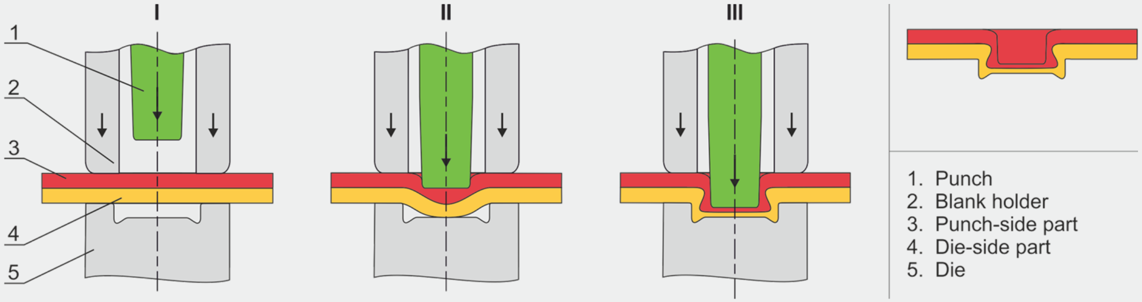
CORNET HybriSonic
Detailed workload

WP 5 – Experimental investigations | Reference joints

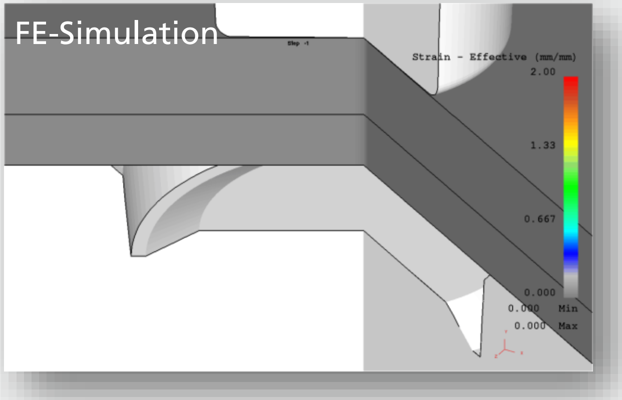
IWU: M10-M21

Clinching

- Joining by forming
- No rivet needed
- Large plastic strains
- Challenge: local thinning/cracking of sheet layers!



1. Punch
2. Blank holder
3. Punch-side part
4. Die-side part
5. Die



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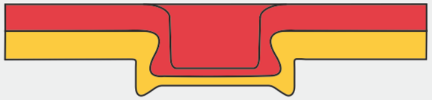
Detailed workload

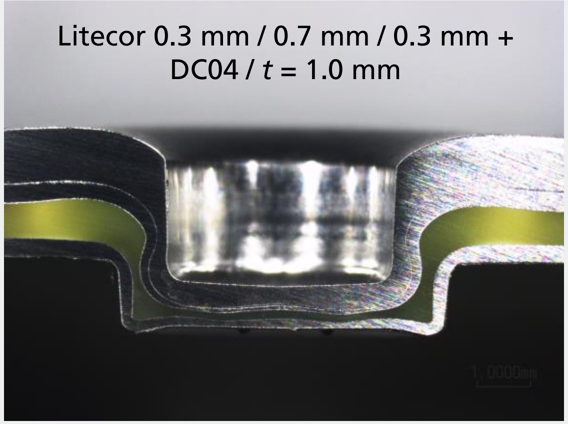
WP 5 – Experimental investigations | Reference joints

IWU: M10-M21

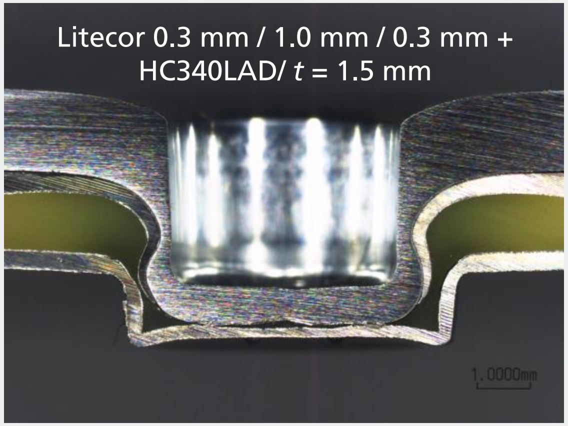
Reference Joints – Clinching



- Preferred joining direction → MPC on bottom side, sheet metal on the top side
- Depending on material strength and tool parameters, cover sheet can be formed without damage



Litecor 0.3 mm / 0.7 mm / 0.3 mm + DC04 / *t* = 1.0 mm



Litecor 0.3 mm / 1.0 mm / 0.3 mm + HC340LAD/ *t* = 1.5 mm

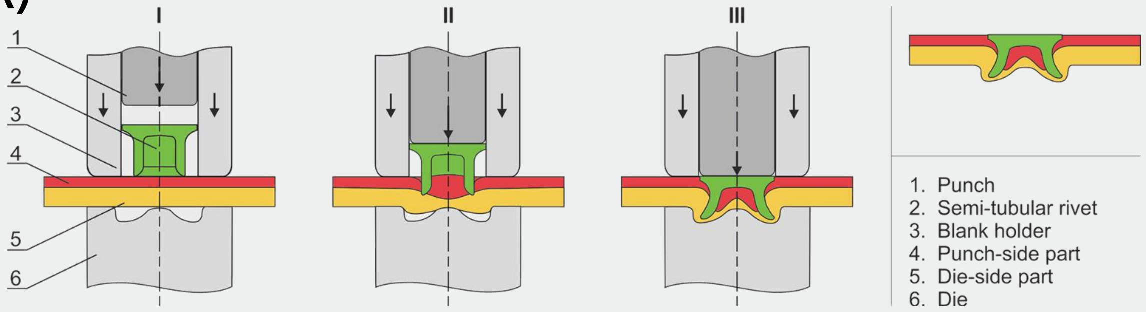
CORNET HybriSonic
Detailed workload

WP 5 – Experimental investigations | Reference joints

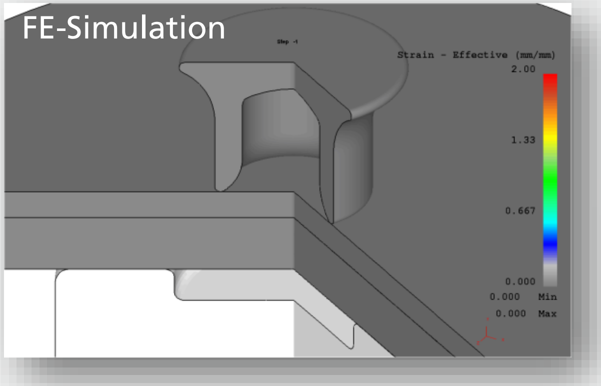
IWU: M10-M21

Self-piercing riveting (SPR)

- Riveting process
- Rivet is piercing upper part
- Challenge: warping of upper part; creeping of polymer layer



1. Punch
2. Semi-tubular rivet
3. Blank holder
4. Punch-side part
5. Die-side part
6. Die


FE-Simulation


Litecor + steel


Litecor + aluminum

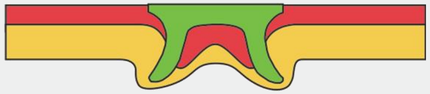

Litecor + Aluminium

CORNET HybriSonic

Detailed workload

WP 5 – Experimental investigations | Reference joints IWU: M10-M21

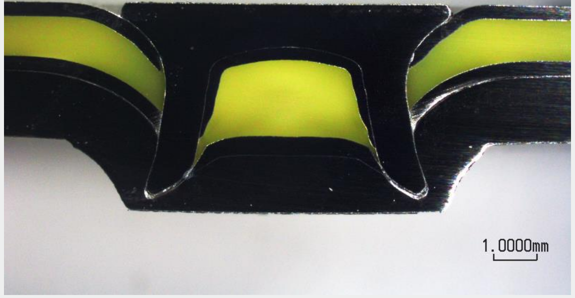
Reference Joints – SPR



- Preferred joining direction → MPC on top side, sheet metal on the bottom
- Accumulation of plastic material around the rivet head
- Two different rivet diameters were applied: 5.3 mm and 3.3 mm

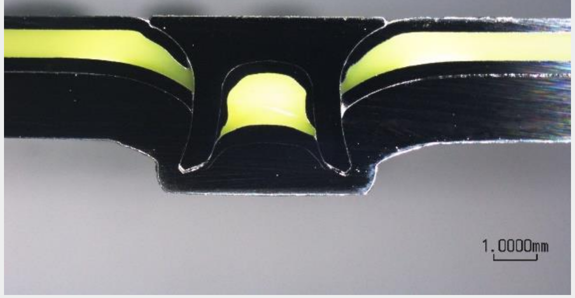
Litecor 0.3 mm / 1.0 mm / 0.3 mm + HC340LAD/ *t* = 1.5 mm

Rivet: C5.3x5H4



Litecor 0.3 mm / 0.7 mm / 0.3 mm + HC340LAD/ *t* = 1.5 mm

Rivet: C3.3x4H4



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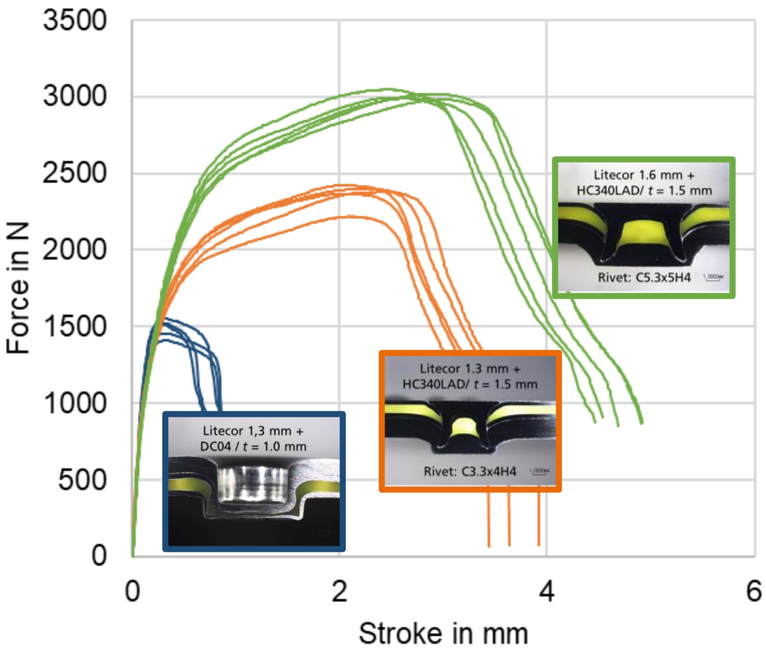
Detailed workload

WP 5 – Experimental investigations | Reference joints

IWU: M10-M21

Shear tensile testing of clinched and riveted joints

- Maximum force depends on mechanical joining technology, process parameters and parts to be joined
- Higher maximum forces with SPR compared to clinching
- Larger values can be reached by increasing rivet diameter



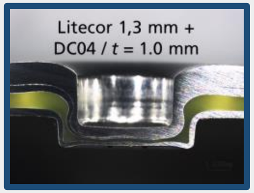
CORNET HybriSonic

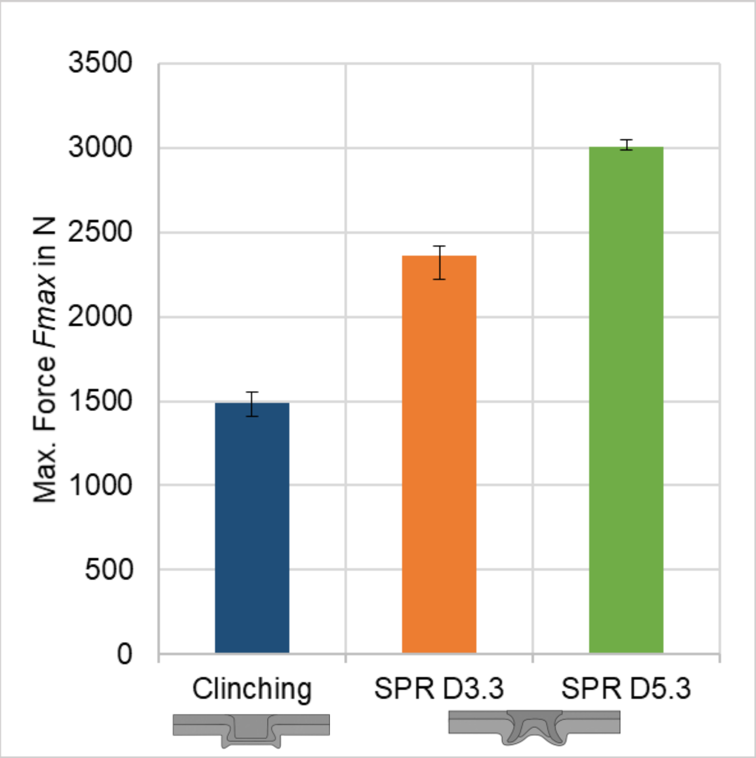
Detailed workload

WP 5 – Experimental investigations | Reference joints **IWU: M10-M21**

Shear tensile tests of clinched and riveted joints

Failure modes:





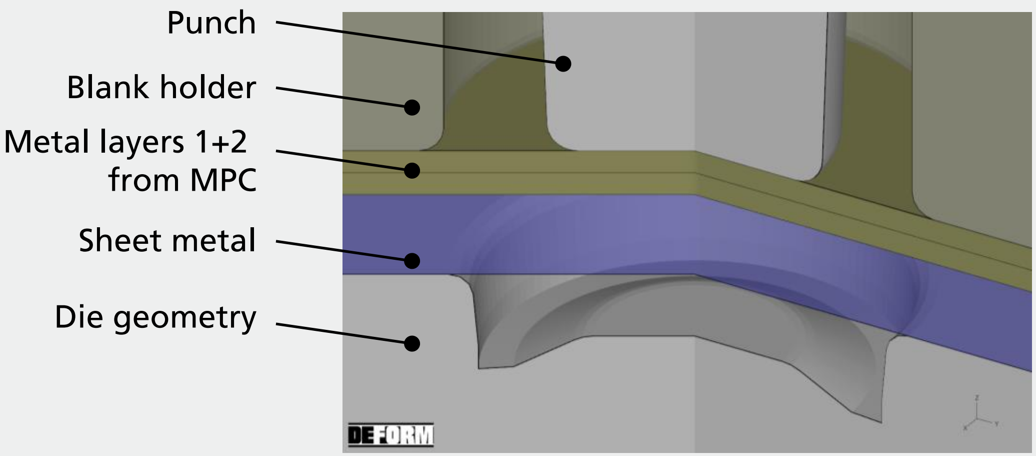
CORNET HybriSonic

Detailed workload

WP 4 – Tooling technologies for US-supported joining processes | **IWU: M7-M14**

Objective of the simulation of mechanical joining: tool parameters for clinching and self-piercing riveting

- **Assumptions in the FE-model (example: clinching)**
  - No polymer material between the parts to be joined
  - Three-sheet stack: MPC metal layers 1+2 to be joined with sheet metal (aluminum or steel)
  - Rigid tools (punch, die, blank holder)
  - Flow curves from tensile testing of metal layers



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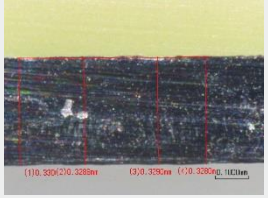
Detailed workload

WP 4 – Tooling technologies for US-supported joining processes | **IWU: M7-M14**

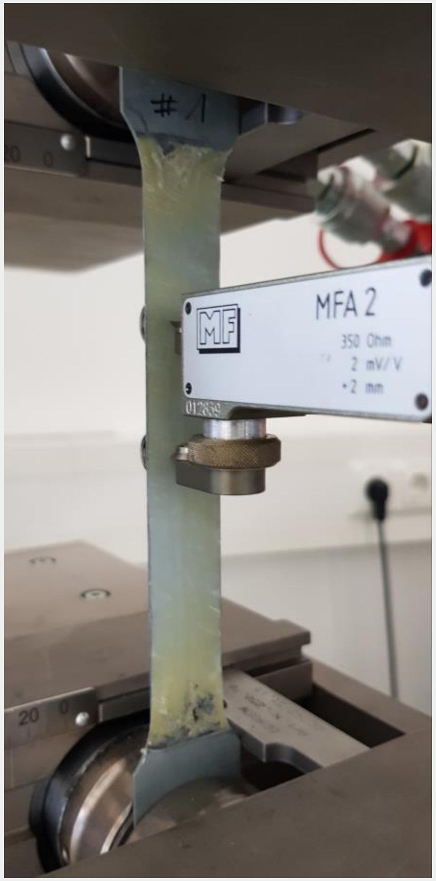
Tensile tests with new batch of LITECOR

- Measurement of thickness of metal layer for each specimen (n = 5)
    - Removing cover sheet on one side by milling
    - Scraping of plastic layer (manual with firmer chisel)
- Determination of flow curve data

Specimen for tensile test (Litecor 1.3 mm)



Thickness of metal layer



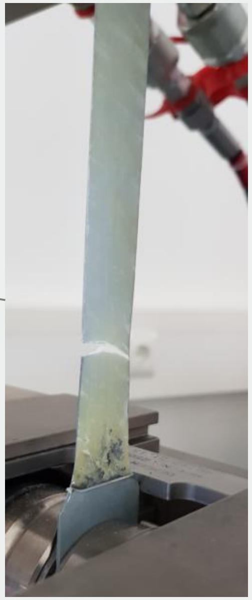
Test setup, strain extensometer

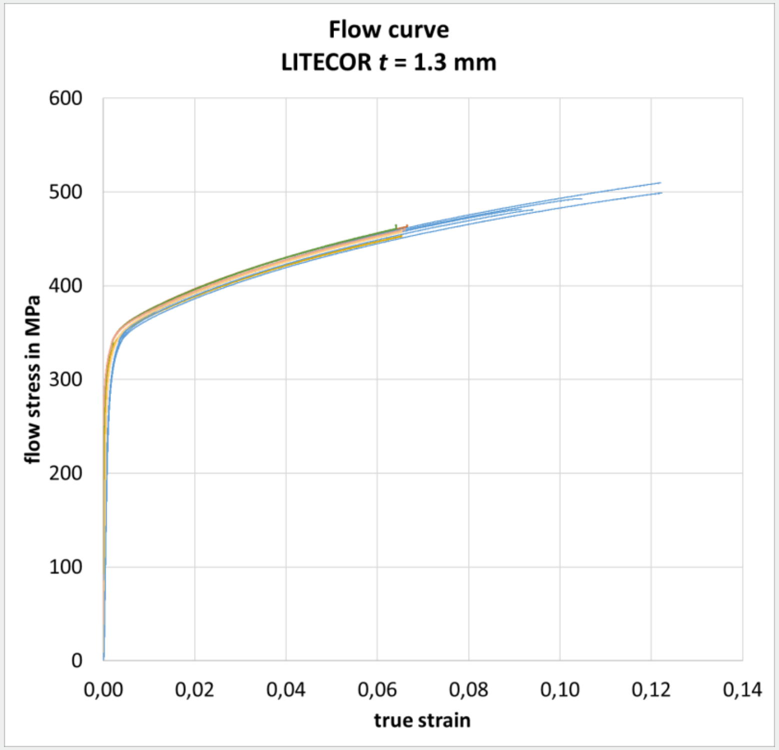
CORNET HybriSonic
Detailed workload

WP 4 – Tooling technologies for US-supported joining processes **IWU: M7-M14**

Tensile tests with new batch of LITECOR

- Good reproducibility flow curves
- Strain values up to 0.12
- Failure location within tapered section





Flow curve for sheet metal layer material from LITECOR 1.3 mm (blue: traverse; colors: strain extensometer)

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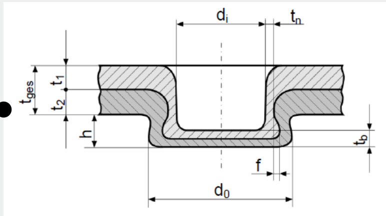
Detailed workload

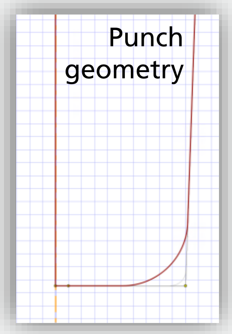
WP 4 – Tooling technologies for US-supported joining processes

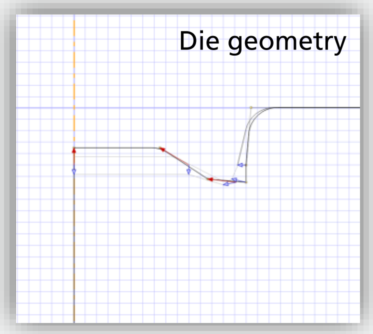
IWU: M7-M14

- **DOE tool is used to find suitable geometry parameters**
- First approach:
    - Avoid thinning and cracks in the MPC metal layer sheets
    - Find parameter sets with interlocking joint
    - **Neck thickness (t_n) and interlock (f)** to be maximized

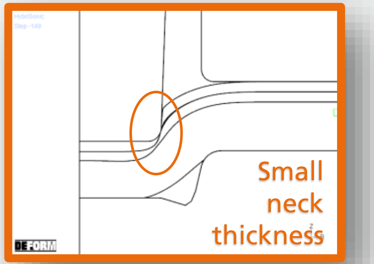


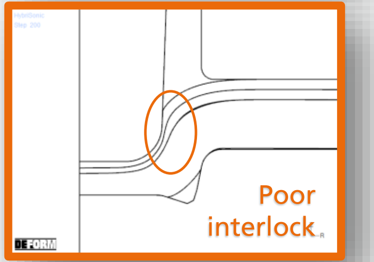
Quality values of clinching joint

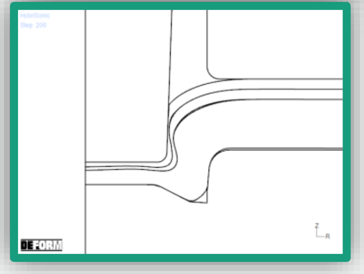




INPUT → FE model → OUTPUT







CORNET HybriSonic

Detailed workload

WP 4 – Tooling technologies for US-supported joining processes

IWU: M7-M14

- Manufacturing of the tools for mechanical joining
- Validation of FE model (interim results)
  - Thinning and cracks in the neck area for MPC (HYLITE, Litecor)
  - Further work on validation
  - Fokus on different MPC and tool concepts (e. g. clinching with movable blades, flat anvil)
  - Remaining Polymer layer between sheets impairs accuracy of FE model

Manufacturing of clinching tools

Initial state (polymer layer existent)

Polymer layer displaced by US-process

Litecor C (0.3 mm / 0.7 mm / 0.3 mm)
+ EN AW 5183 / *t* = 1.1 mm

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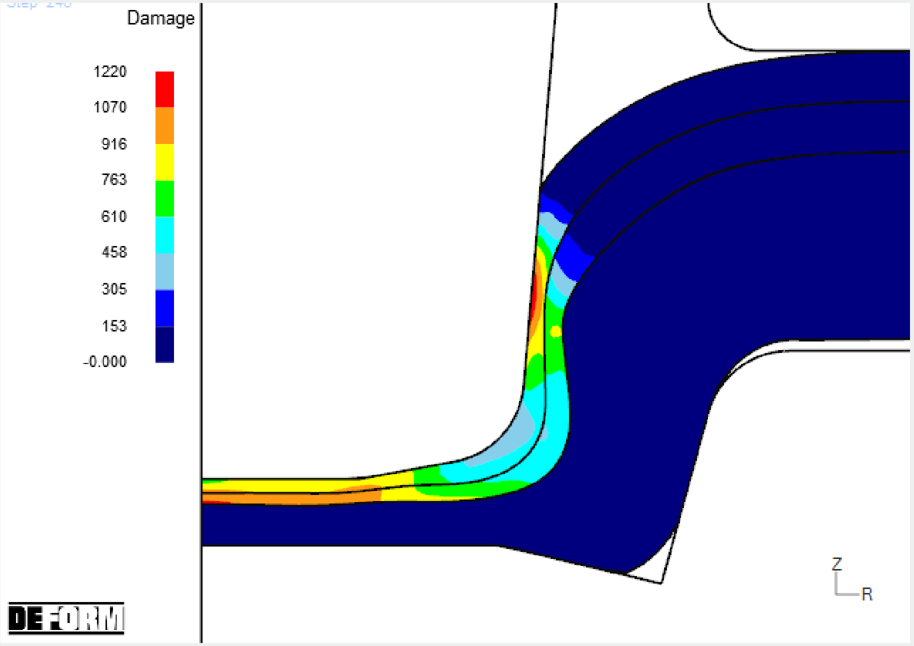
Detailed workload

WP 4 – Tooling technologies for US-supported joining processes | **IWU: M7-M14**



Litecor (2x0.3 mm steel cover sheet + 1.1 mm EN AW- 5083)

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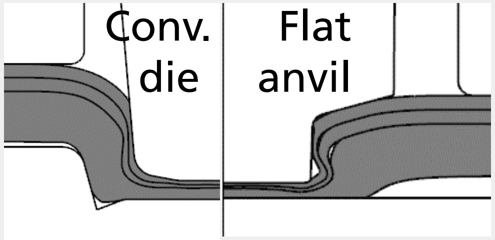
Detailed workload

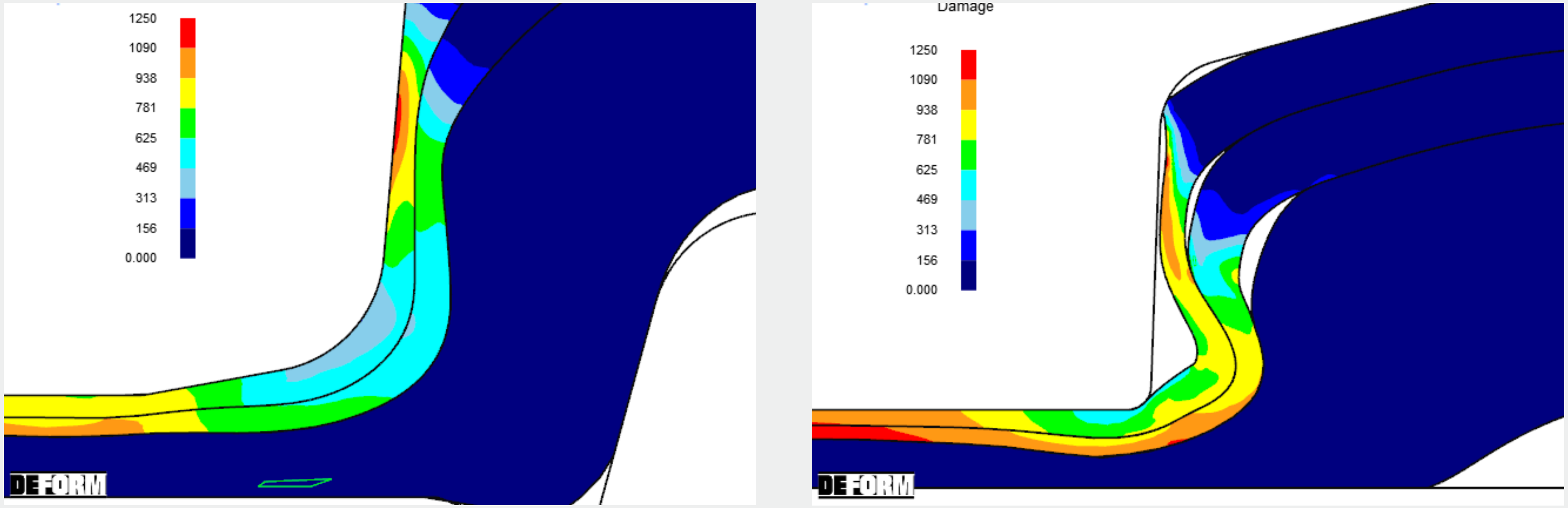
WP 4 / WP 5 - Next steps

Further tests with dieless clinching process

- Additional tests with dieless clinching concept
- **Objective: reducing material damage**



Conventional die **Flat anvil**



Litecor (2x0.3 mm steel cover sheet + 1.1 mm EN AW-5083), displayed value: Damage *(Freudenthal)*

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Detailed workload

WP 4 / WP 5 - Next steps

Further tests with Self-pierce riveting

- Additional tests with displaced plastic core (as specimen available)
- Comparison to reference joints

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CORNET HybriSonic

WP 4 – Tooling technologies for US-supported joining processes

IWU: M7-M14

One-step Approach:

- Tool design for joining processes
    - Clinching and resistance spot welding
- Geometry of punch and die in clinching based on FE-studies
- Connection of the ultrasonic components and joining tools developed in WP 3 in a test setup


Transducer 20 kHz


RSW with US-generator


Joining tool subjected to ultrasonic waves ...

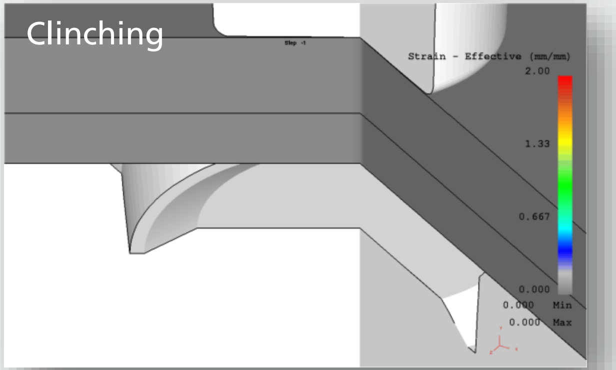
... further joining

Metallic cover sheets

Plastic core layer

Clinching

Resistance Spot Welding (RSW)


Clinching

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WP 4 – Tooling technologies for US-supported joining processes

IWU: M7-M14

Two-step Approach:

Development of forming tool with integrated US supported displacement

Approach:

- Definition of demonstrator geometry
- Definition of spot size for joining
- FE based process design and tool development
- Manufacturing of test specimens

Boundary Conditions:

- US welding machine from MS Ultrasonic will be used for the combined forming and displacement process

→maximum Force is 9 kN

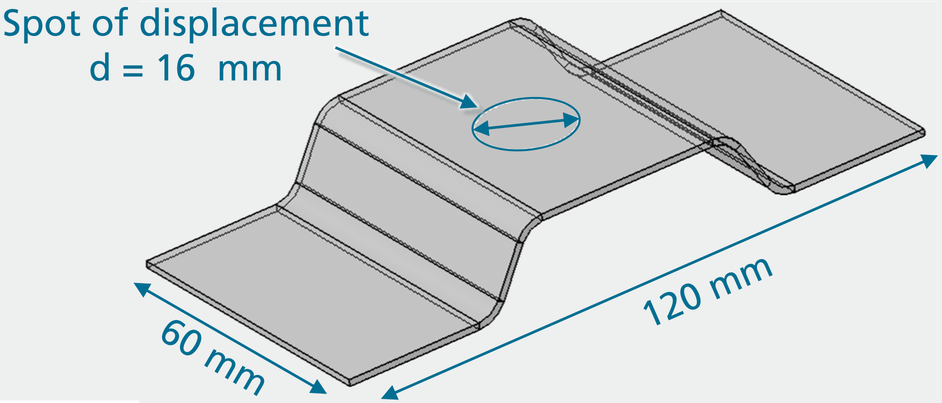
CORNET HybriSonic

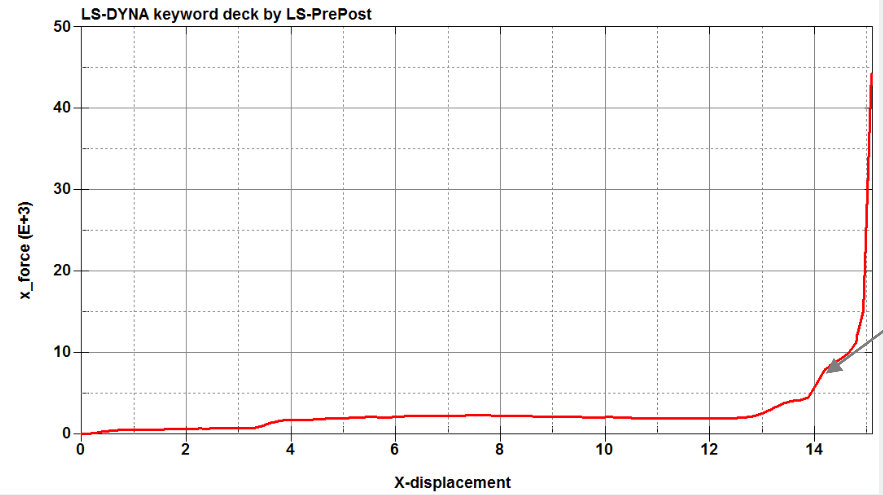
WP 4 – Tooling technologies for US-supported joining processes

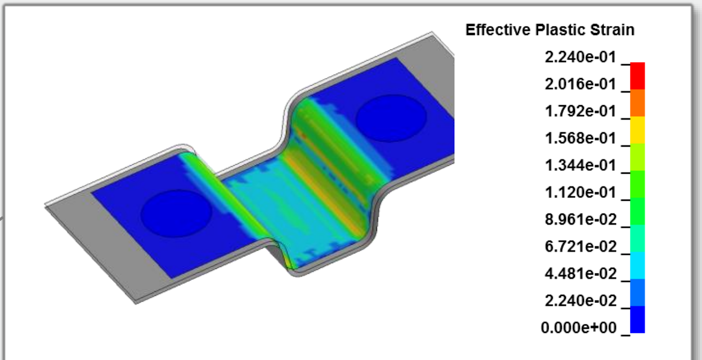
IWU: M7-M14

Two-step Approach:

- U-shaped profile is used as demonstrator part
- Spot size is set to 16 mm
- FE modelling of forming operation to determine required the force







7 kN at 14.4 mm drawing depth

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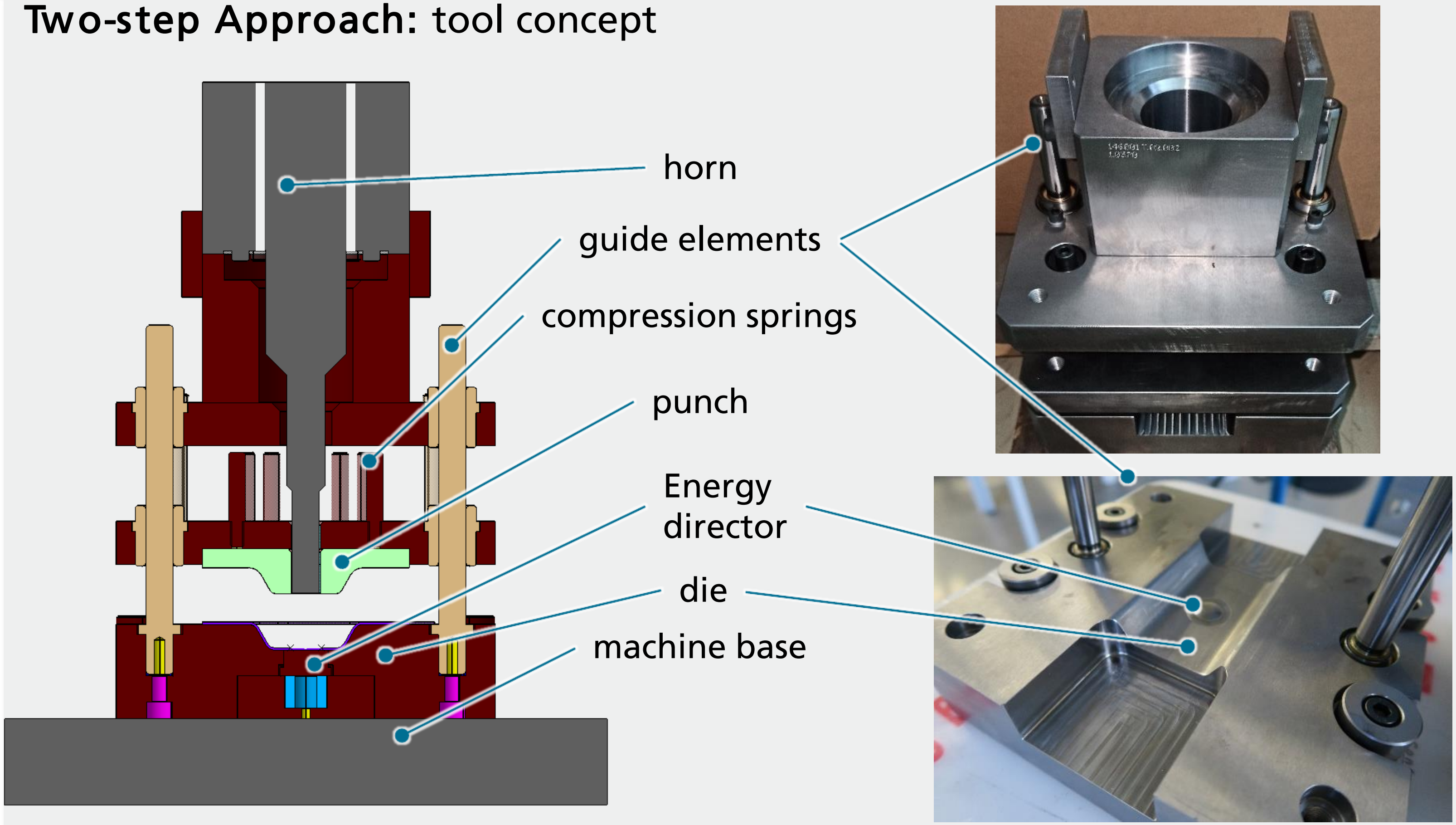
WP 4 – Tooling technologies for US-supported joining processes

IWU: M7-M14

Two-step Approach: tool concept



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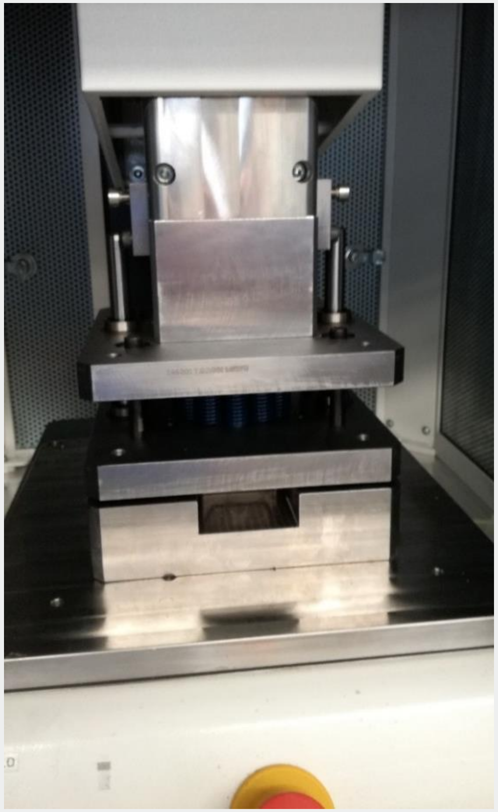
WP 4 – Tooling technologies for US-supported joining processes

IWU: M7-M14

Two-step Approach:

- Installation of the tool Ultrasonic welding machine - MS Ultrasonic



AiF cornet FOSTA DIB IBS research Wrocław University of Science and Technology Fraunhofer IVV Fraunhofer IWU

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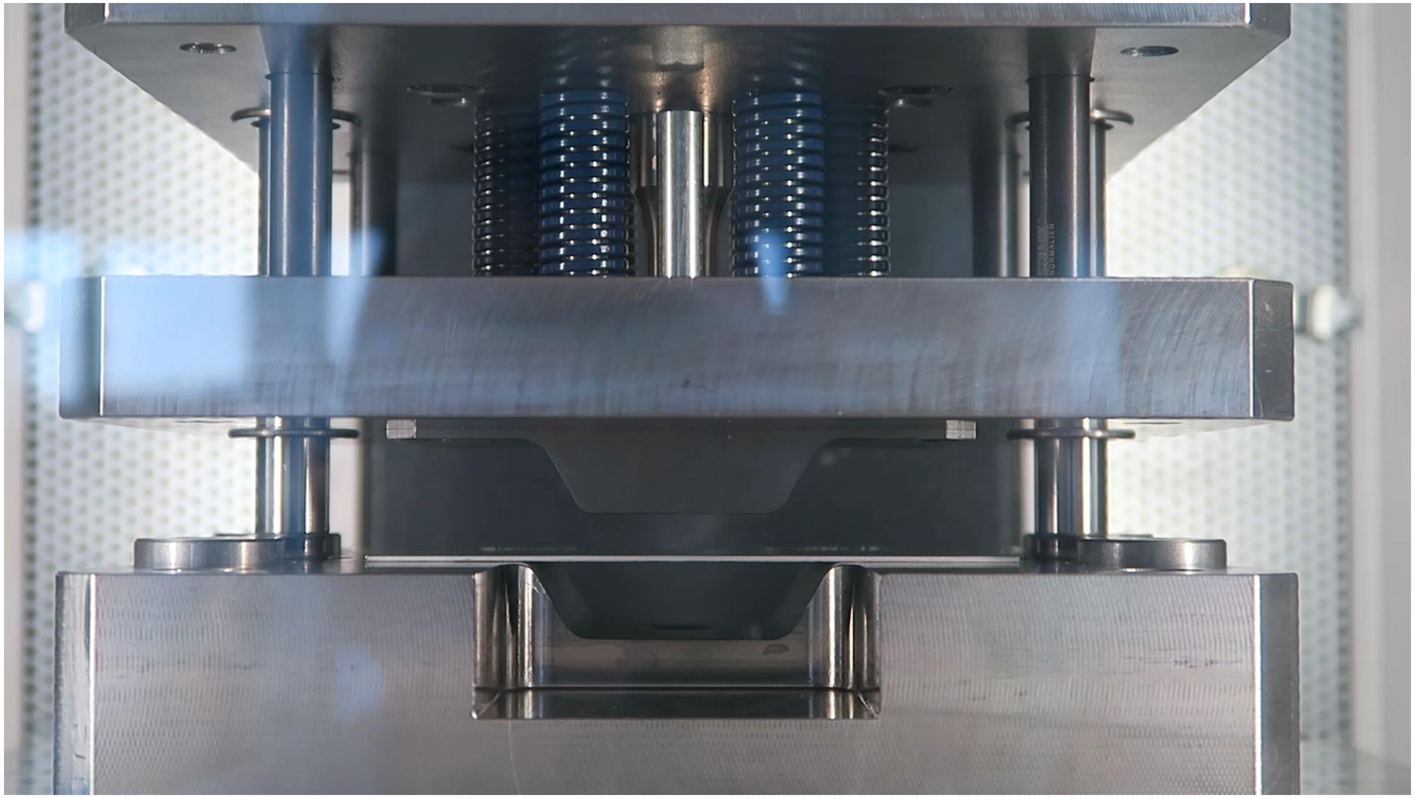
WP 4 – Tooling technologies for US-supported joining processes

IWU: M7-M14

Two-step Approach:

- US-supported forming process



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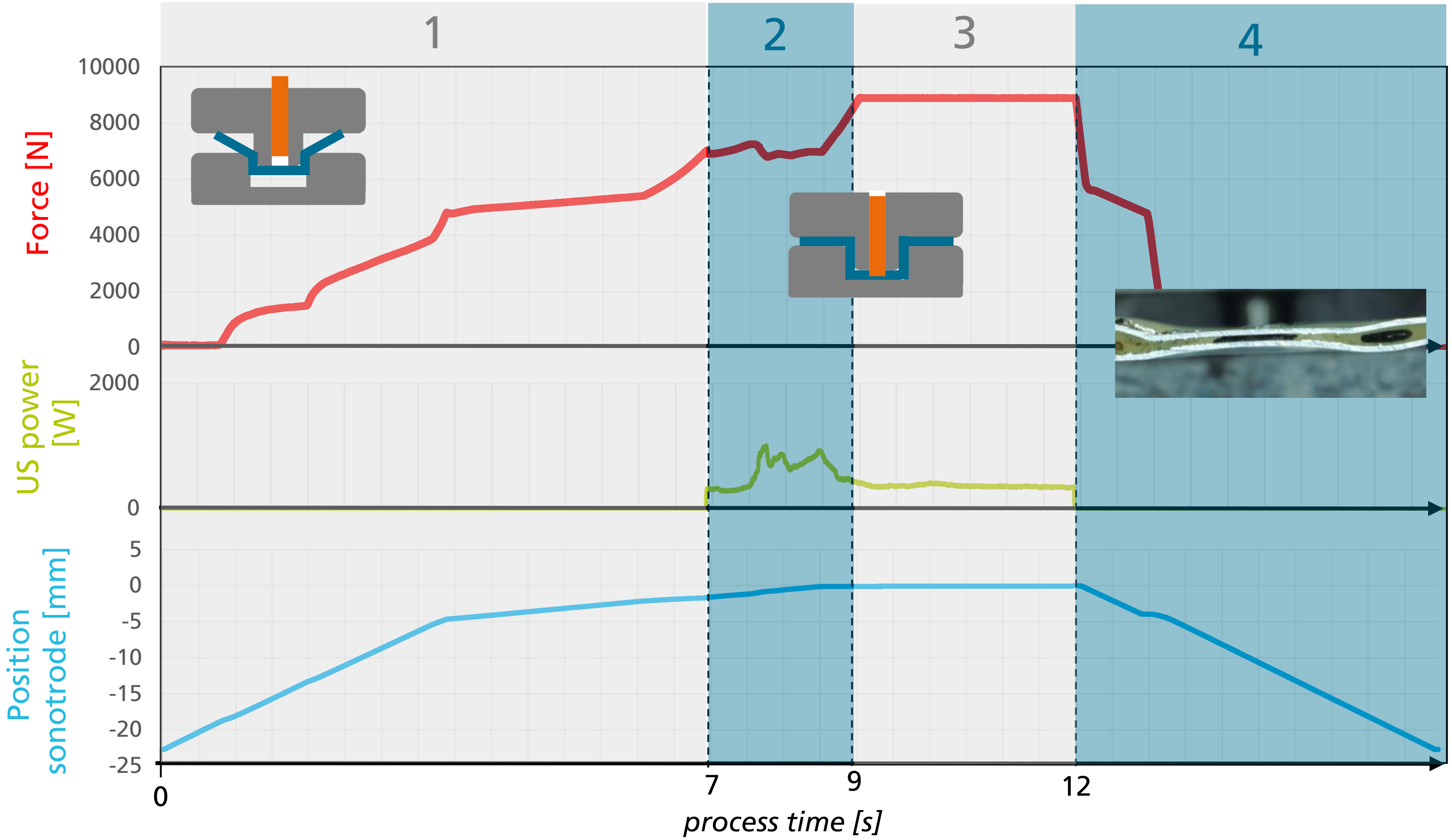
WP 4 – Tooling technologies for US-supported joining processes | IWU: M7-M14

- Development of process parameters during process



1 forming

2 heating and displacement of polymer layer

3 crystallization of polymer

4 tool opening

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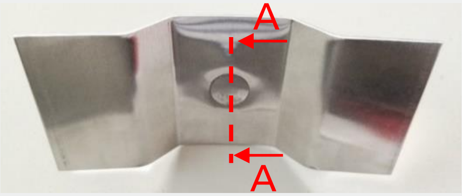
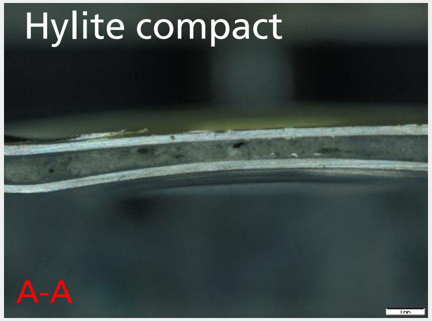
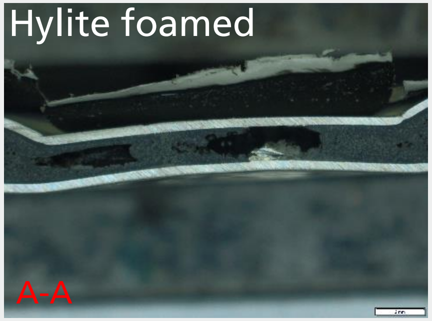
WP 4 – Tooling technologies for US-supported joining processes

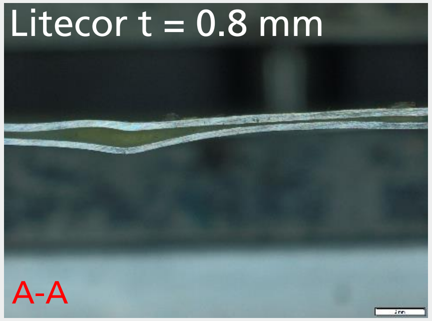
IWU: M7-M14

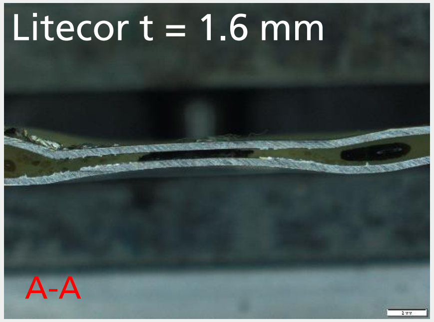
- Test were run with different materials (Hylite compact, Hylite foamed, Litecor t = 0.8 mm, Litecor t = 1.6mm)
- Cross section after forming and US supported displacement




Hylite compact

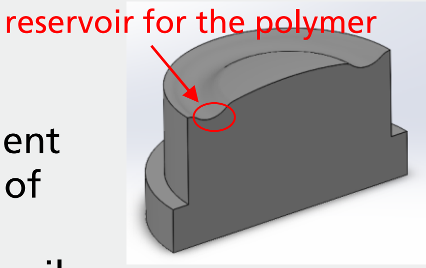

Hylite foamed


Litecor t = 0.8 mm


Litecor t = 1.6 mm

Results:

- Core Material can be displaced however not complet
  → Maximal Force of machine restricts the maximal displacement
- Local deformation of the cover sheets by uncontrolled displacement of the molten polymer
  → Control of displacement by integrating a reservoir in the anvil



AGENDA

- TOP 1 – Welcome, short introduction (BWI, IVV, IWU, PWr)
- TOP 2 – Project goals and work plan
- TOP 3 – Project results
  - Investigated metal-plastic composite materials
  - Design and development of the ultrasonic process (IVV)
  - Conventional and solid state joining processes (BWI)
  - Resistance spot welding (PWr)
  - Mechanical joining (IWU)
  - Tool integrated US-process (IWU, IVV)
- **TOP 4 – Conclusions, demonstrator, decisions**

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Conclusions, demonstrator, decisions

Conclusions

- US supported polymer displacement process can now be simulated
  Next Step: using results for tool design, determination of process parameters
- Further investigation joining technologies
- US supported displacement was integrated in forming tool

Demonstrator

- Suggestions from UC?
- Examples from proposal:

Mudguard, Source: Curana

Outdoor signs (Source: SignTec)

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Next steps

WP2

- Combined simulation of forming and joining

WP4

- Tool development for mechanical joining test (IWU)
- Preparation of specimens for SPR (IWU)

WP5

- Manufacturing of reference joints for mechanical joining (IWU)
- Integration of tool in US machine from Fraunhofer IVV (IWU / IVV)
- Preperation of specimens for SPR and RFSSW (IWU)