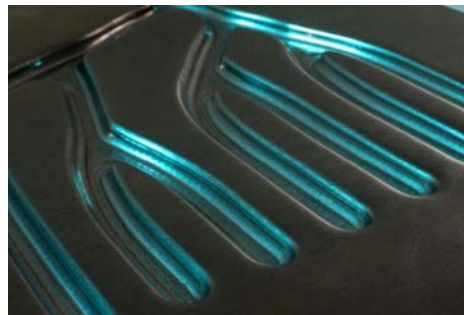
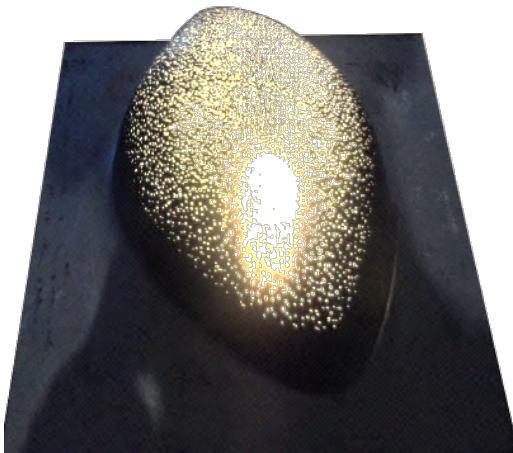
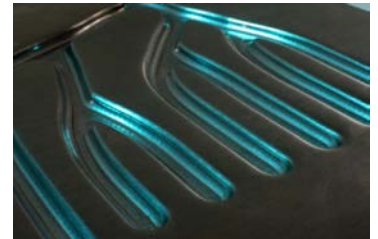
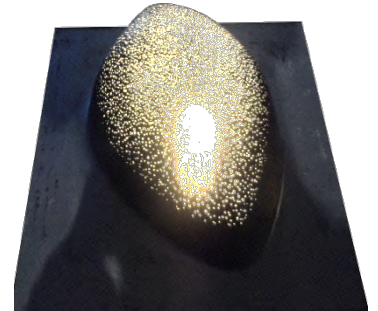

DEVELOPMENT OF A NEW VARIANT OF INCREMENTAL SHEET METAL FORMING USING HEATED AIR

Dr.-Ing. R. Müller, Dipl.-Ing. D. Weise, Prof. Dr.-Ing. D. Landgrebe



AGENDA

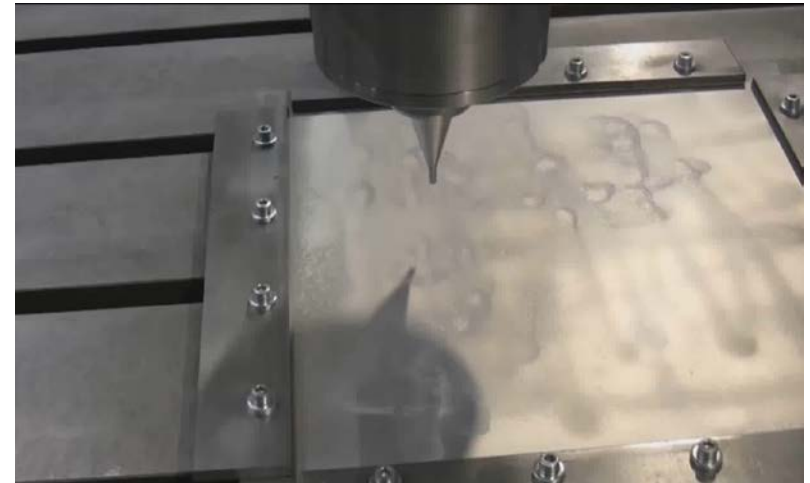
1. Introduction
2. ISF at Fraunhofer IWU
3. ISF using heated air
4. Conclusions



ISF at Fraunhofer IWU

Introduction

- gradual kinematic shape generation
- several successive tool movements
- very small proportion: deformation zone to component volume
- tools with a low shape memory degree
- examples:
 - pressure forming
 - swaging
 - peening
- incremental sheet metal forming:
 - mandrel forms metal sheets by moving along predetermined lines

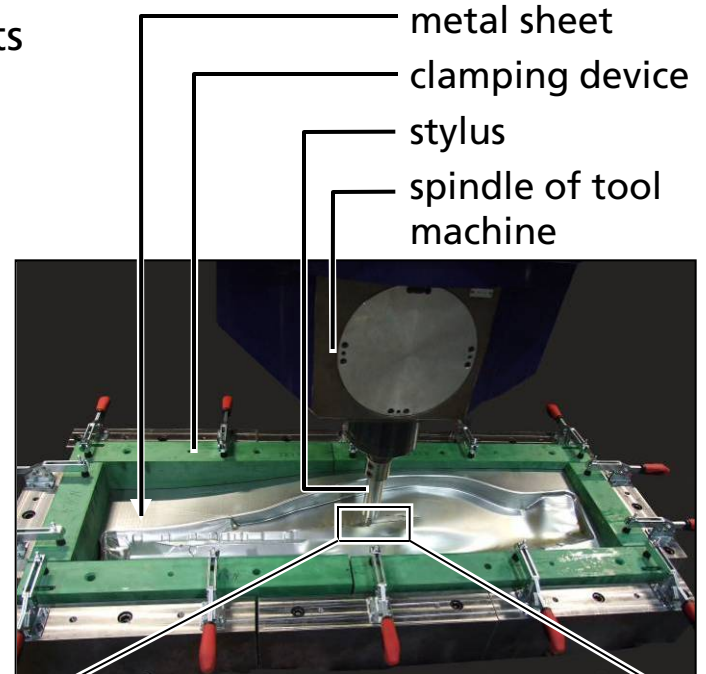


incremental sheet metal forming at IWU

ISF at Fraunhofer IWU

General process

- tool machines and robots for mandrel movements
- use of different stylus alternatives
- predominantly rotating stylus
- use of various blank holder
- use of partial or full dies

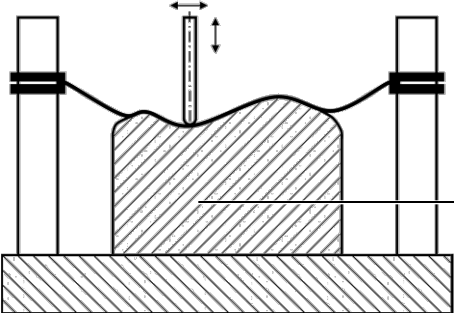
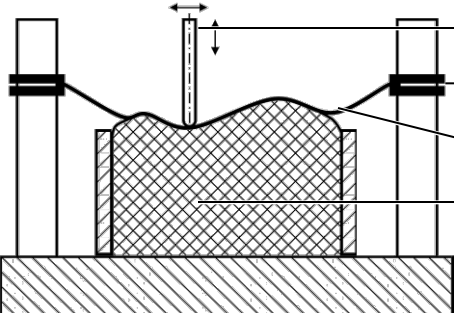
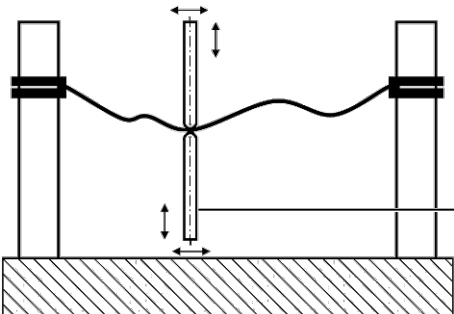
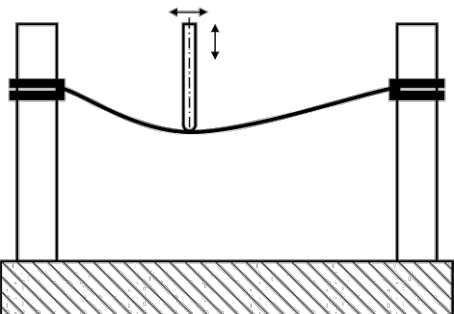


universal machining centre Dynapod at IWU

incremental sheet metal forming at IWU

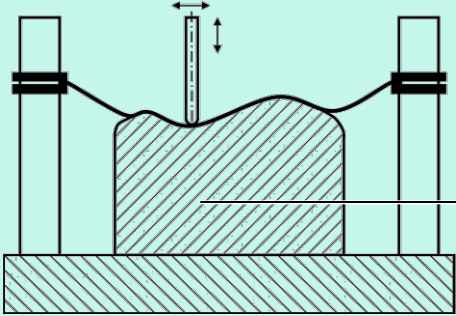
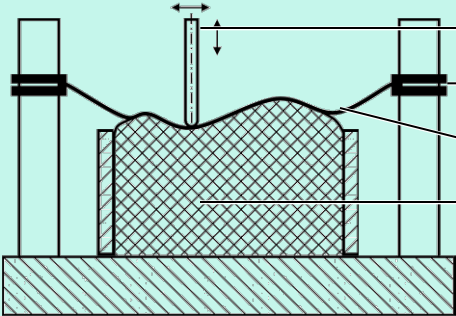
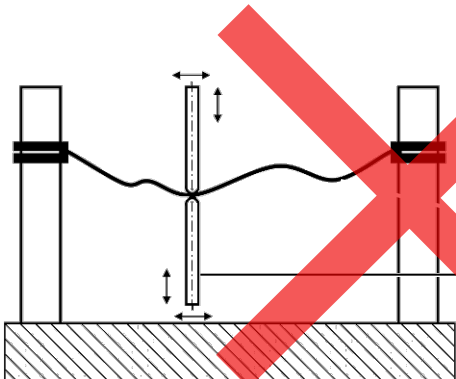
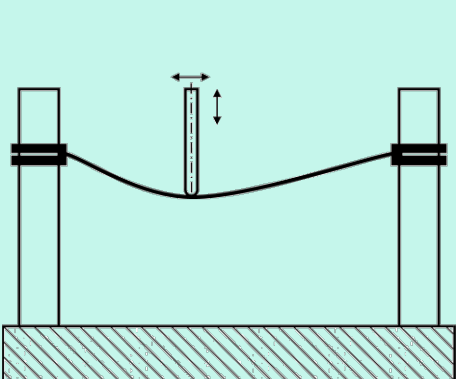
ISF at Fraunhofer IWU

Process Variants of IFS

Use of a (partial) die/ support	Use of an elastic cushion
 <p>A cross-sectional diagram showing a stylus (a vertical rod with a horizontal arrow indicating lateral movement) pressing down on a hatched, semi-circular die/support. The die/support is mounted on a base. The stylus is held in place by two vertical guides on either side, which are clamped to the base. A label 'die/ support' points to the hatched area.</p>	 <p>A cross-sectional diagram showing a stylus pressing down on a hatched, semi-circular elastic cushion. The cushion is mounted on a base. The stylus is held in place by two vertical guides on either side, which are clamped to the base. Labels 'stylus', 'sheet clamping', 'sheet', and 'elastic cushion' point to their respective components.</p>
Use of a counter holder or second stylus	Use of no support
 <p>A cross-sectional diagram showing a stylus pressing down on a sheet. A second stylus/counter holder is positioned below the sheet, with a label 'second stylus/ counter holder' pointing to it. The sheet is held in place by two vertical guides on either side, which are clamped to the base.</p>	 <p>A cross-sectional diagram showing a stylus pressing down on a sheet. The sheet is held in place by two vertical guides on either side, which are clamped to the base. There is no support or counter holder below the sheet.</p>

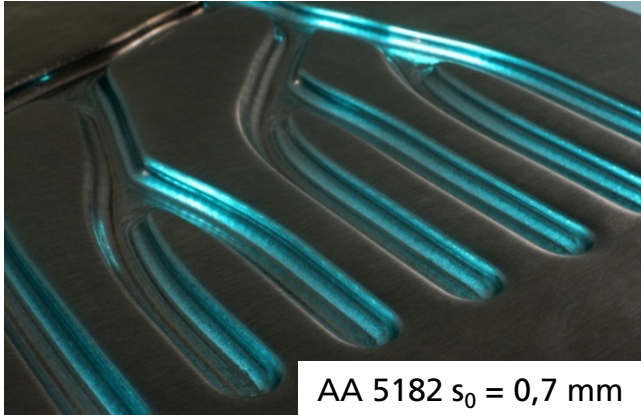
ISF at Fraunhofer IWU

Process Variants of IFS

Use of a (partial) die/ support	Use of an elastic cushion
 <p>die/ support</p>	 <p>stylus sheet clamping sheet elastic cushion</p>
Use of a counter holder or second stylus	Use of no support
 <p>second stylus/ counter holder</p>	

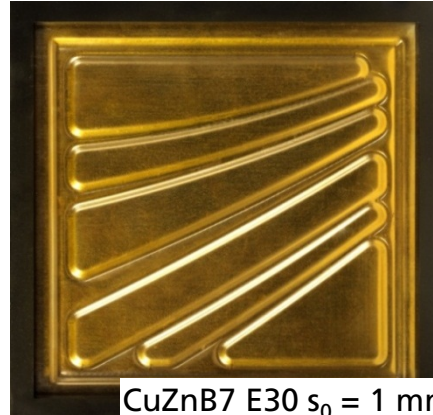
ISF at Fraunhofer IWU

Spectrum of parts I



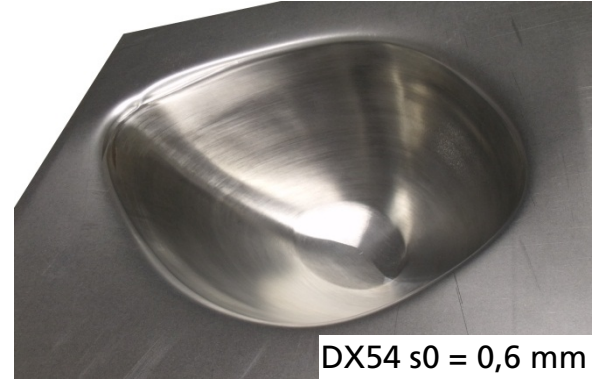
AA 5182 $s_0 = 0,7$ mm

„channel structure“



CuZnB7 E30 $s_0 = 1$ mm

„FhG logo“



DX54 $s_0 = 0,6$ mm

„Schale“



H400TD Z100
 $s_0 = 1,6$ mm

„transmission bracket“



Al99,5 $s_0 = 5$ mm

„casing“



conventional



incremental

AA5182 $s_0 = 1$ mm

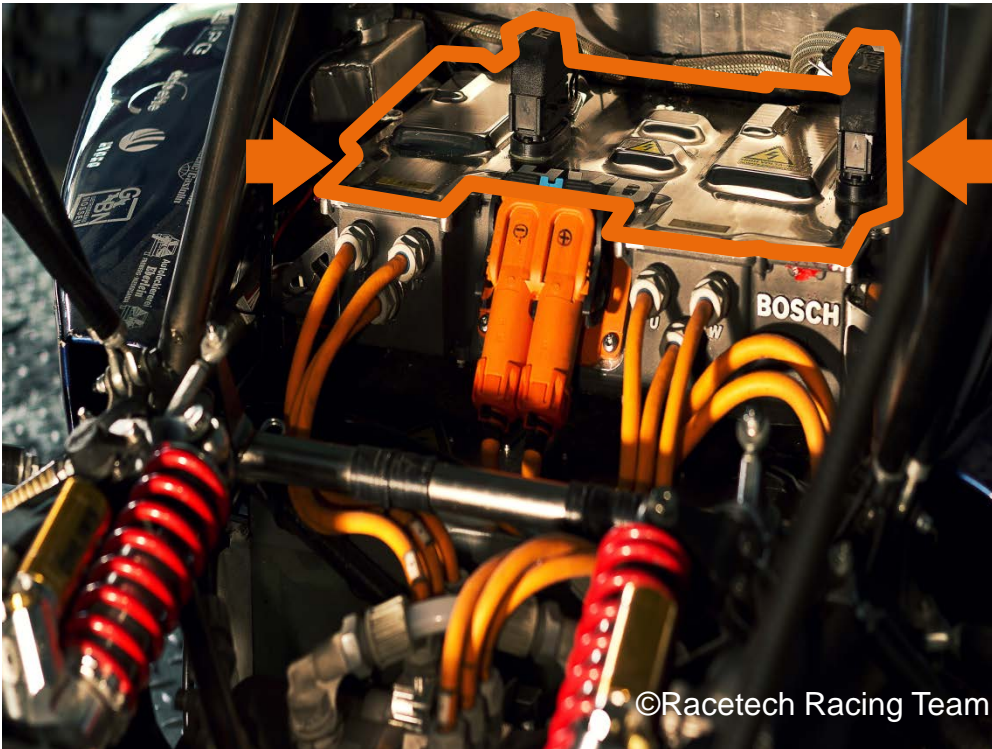
„bowl“



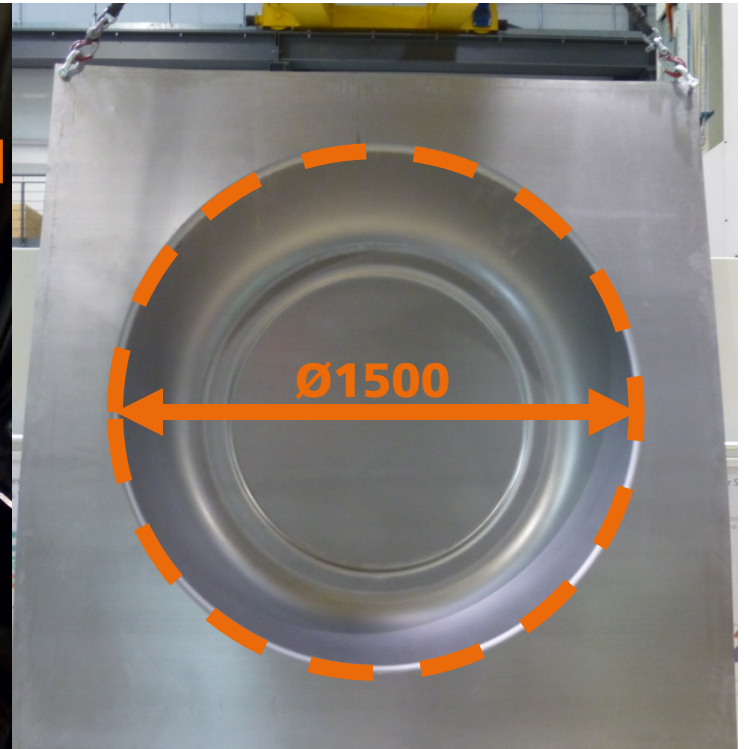
DC04 $s_0 = 0,7$ mm

ISF at Fraunhofer IWU

Spectrum of parts II



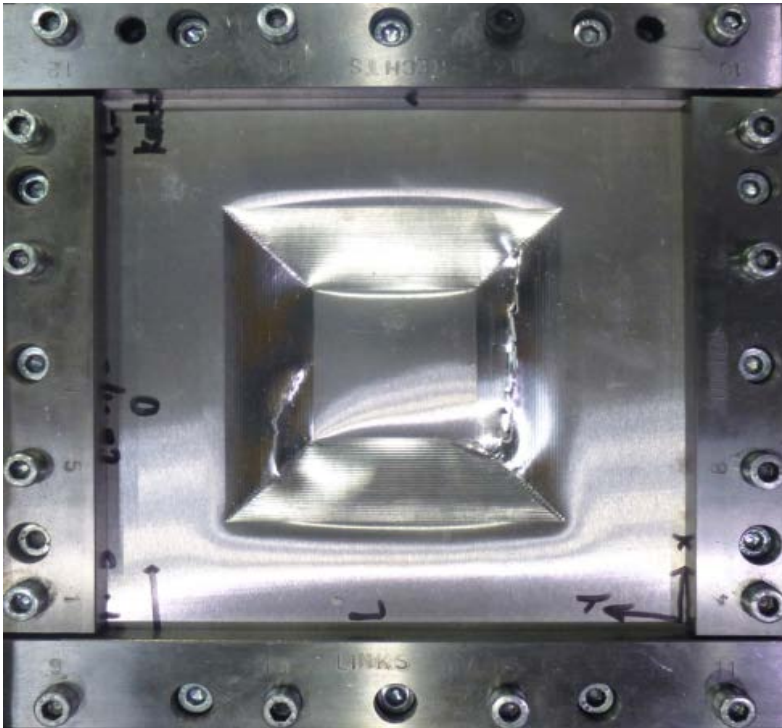
battery hood (A6016 $s_0 = 0,6$ mm)



Windmill housing element (DC04 $s_0 = 1,5$ mm)

ISF using heated air

Challenge



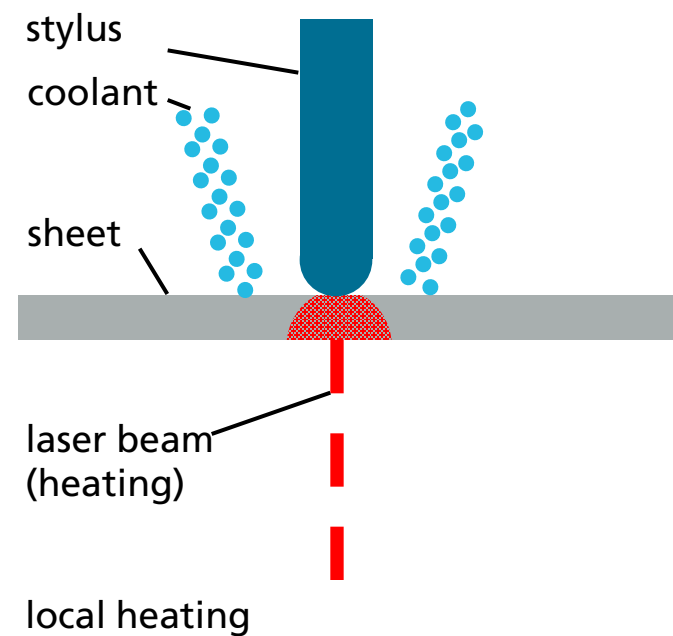
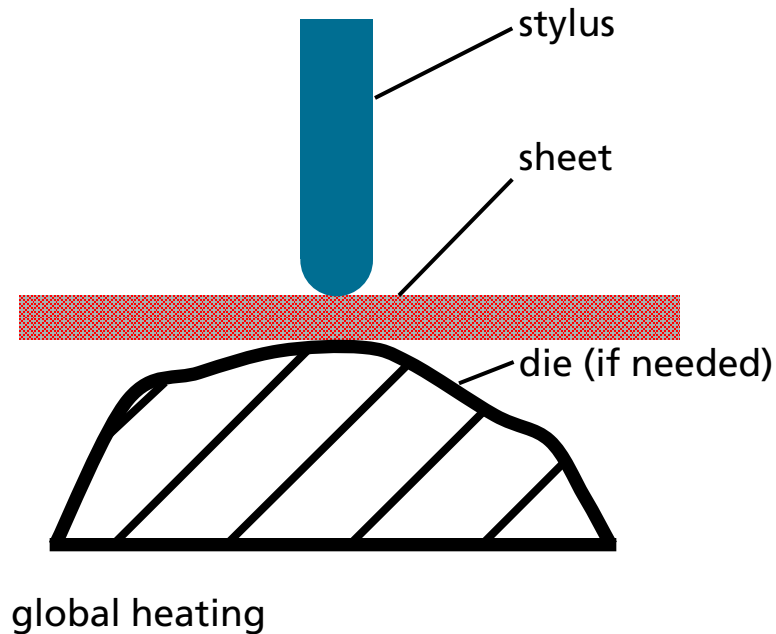
- challenge: high risk of failures in cold forming
- new method of temperature-assisted incremental sheet metal forming (ISF) of lightweight materials was developed at Fraunhofer IWU
- basic idea: combination of conventional single-point incremental forming (SPIF) with evenly distributed heated air flow under the sheet
- result of heated air: whole sheet receives approximately same temperature
- part quality significantly better in comparison to conventional ISF

test components truncated pyramids at 20 °C

ISF using heated air

Heating strategy

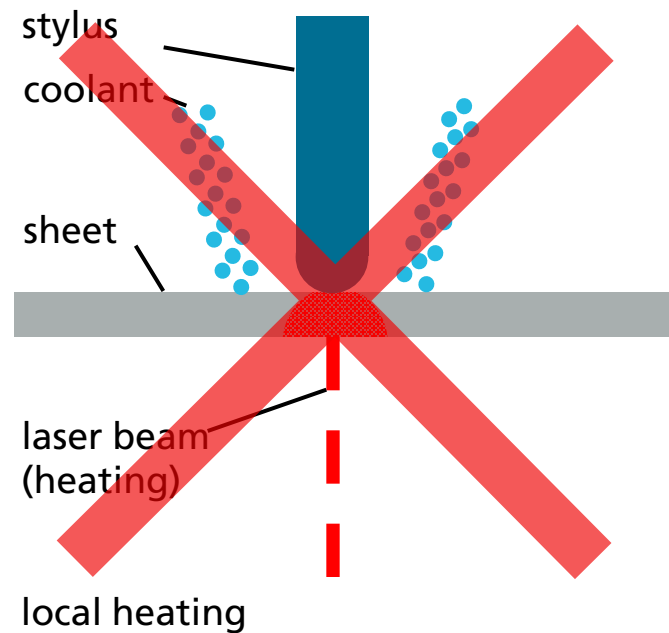
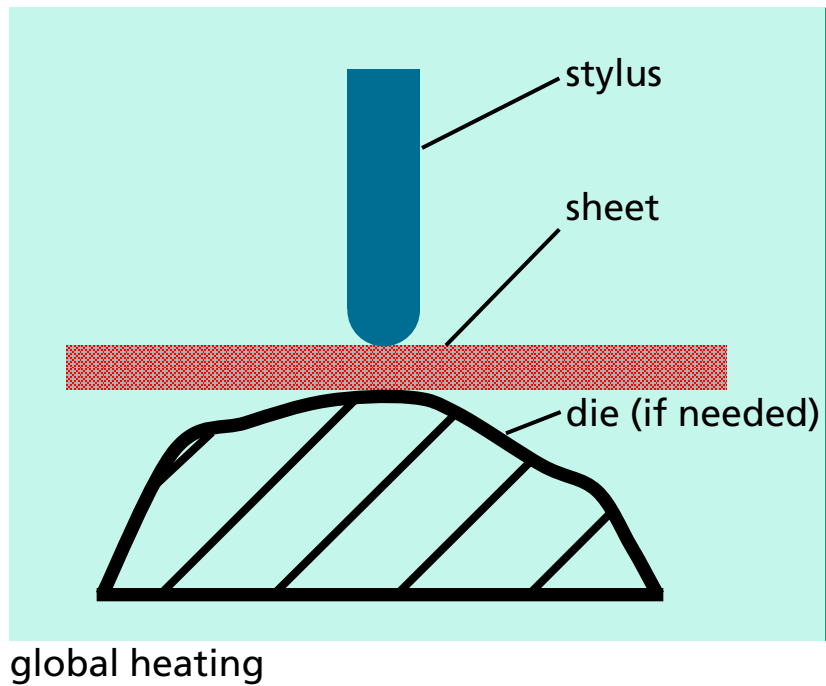
- two different strategies:
 - global heating (IWU)
 - local heating (Sirris/KUL)



ISF using heated air

Heating strategy

- two different strategies:
 - global heating (IWU)
 - local heating (Sirris/KUL)



ISF using heated air

Global heating strategy – Simulation model

upper boundary: opening, $T_0 = 25^\circ\text{C}$

model size: 1.4M fluid cells,
200k solid elements

surrounding air,
 $T_0 = 25^\circ\text{C}$

side boundaries:
adiabatic wall,
no slip

input:
flow rate = 1750 l/min,
 $T = 500^\circ\text{C}$ (hot-air unit)

lower boundary $T = 25^\circ\text{C}$

steel, insulation,
 $T_0 = 25^\circ\text{C}$

air, $T_0 = 25^\circ\text{C}$

heated air – constraints

ISF using heated air

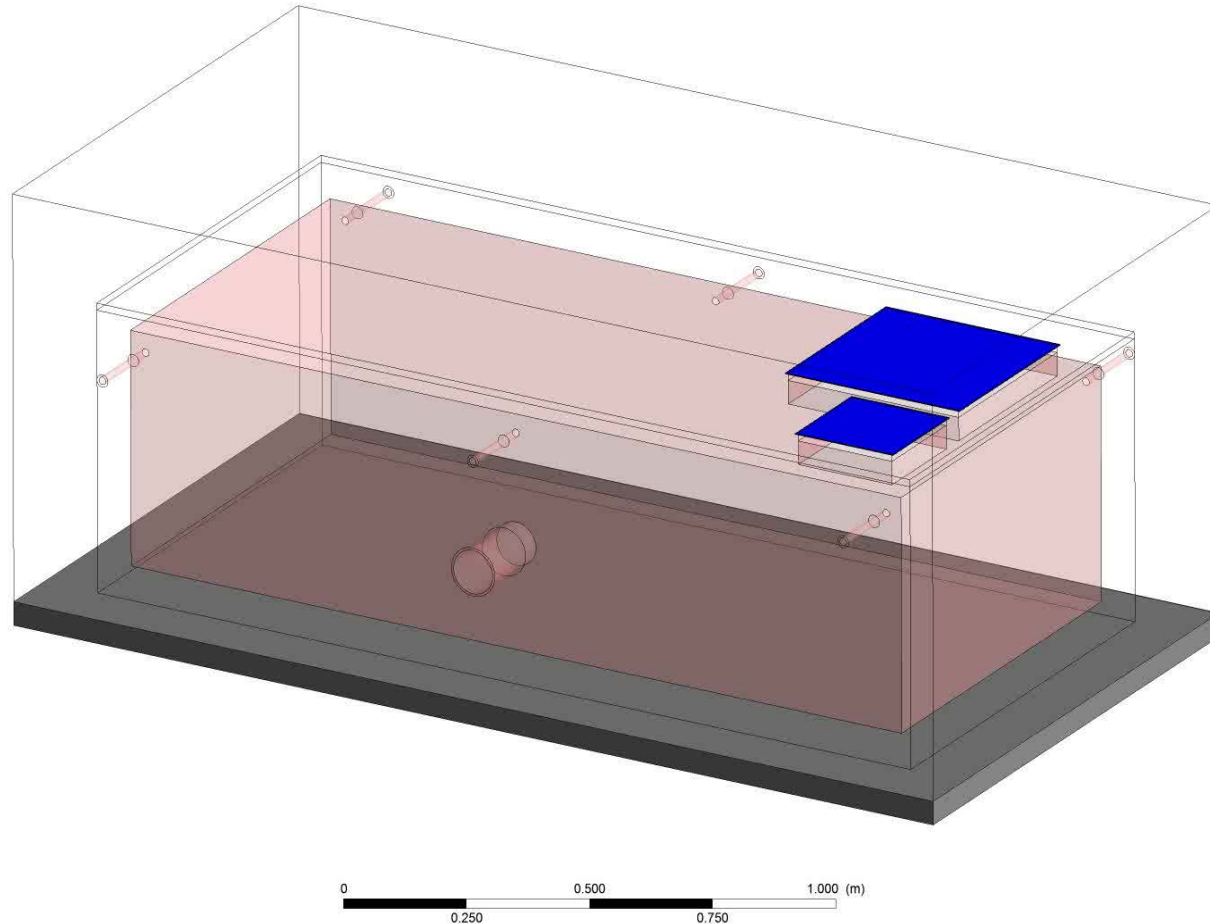
Global heating strategy – Simulation results (1)

ANSYS

Temperature
Contour 3

6.800e+001
6.370e+001
5.940e+001
5.510e+001
5.080e+001
4.650e+001
4.220e+001
3.790e+001
3.360e+001
2.930e+001
2.500e+001

[C]



ISF using heated air

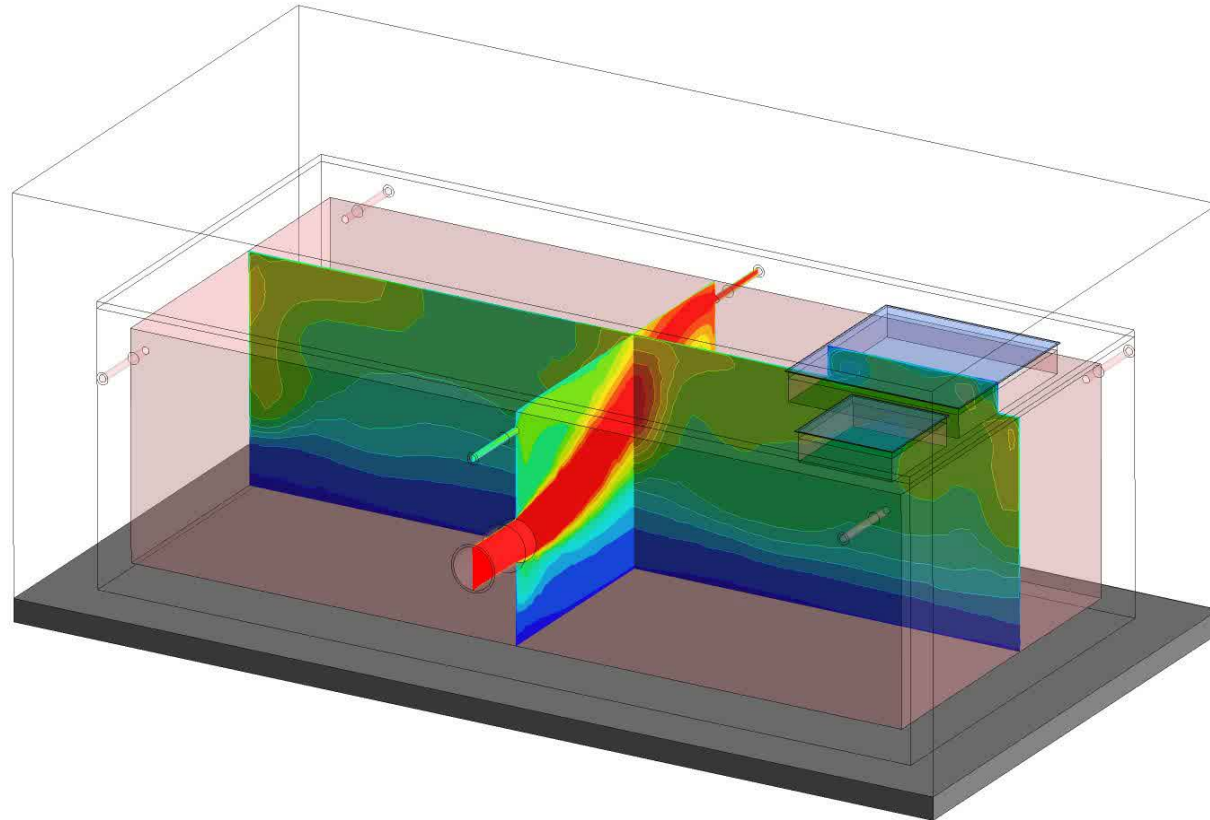
Global heating strategy – Simulation results (2)

ANSYS

Temperature
Contour 2

2.500e+002
2.275e+002
2.050e+002
1.825e+002
1.600e+002
1.375e+002
1.150e+002
9.250e+001
7.000e+001
4.750e+001
2.500e+001

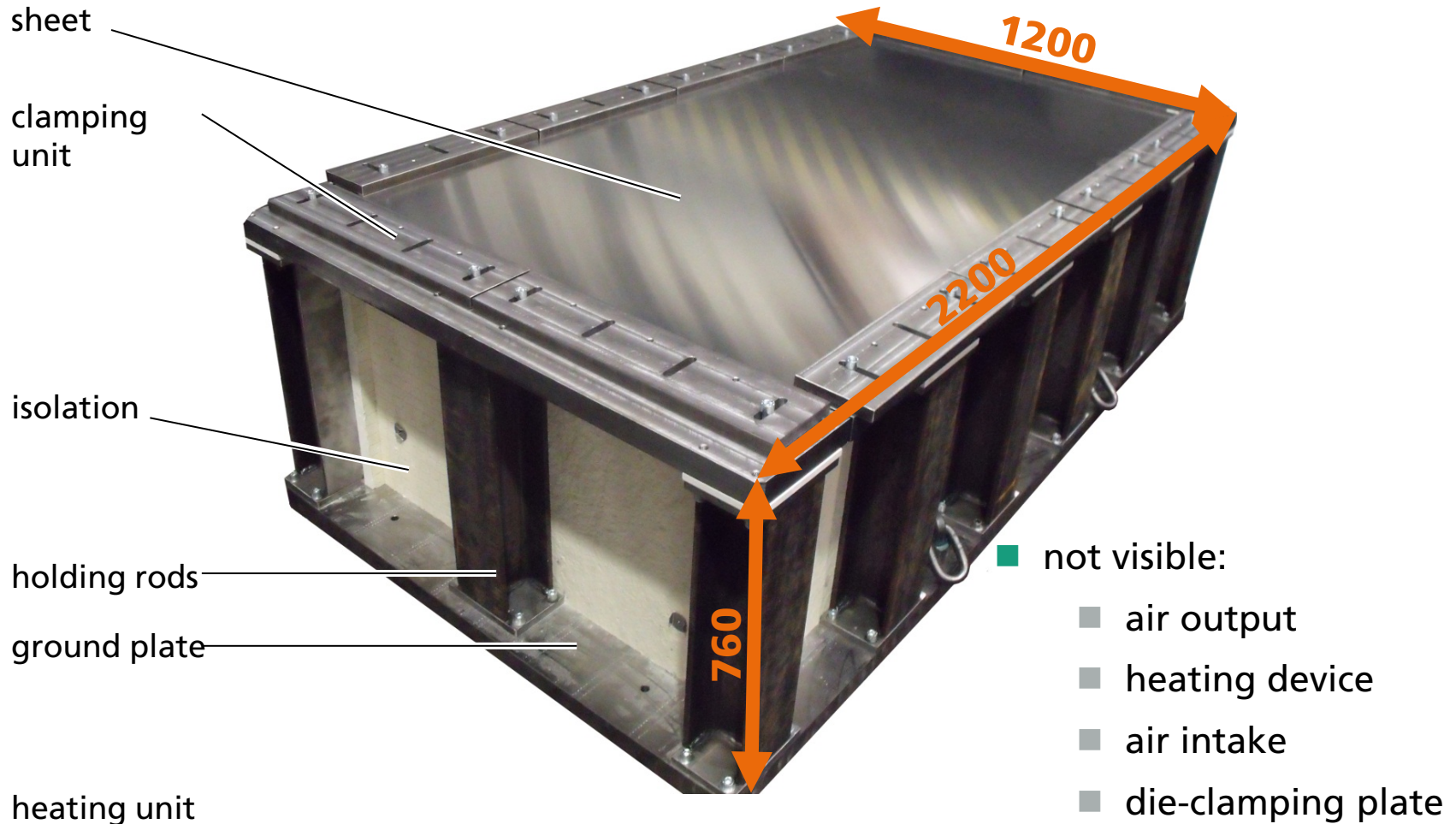
[C]



0 0.250 0.500 0.750 1.000 (m)

ISF using heated air

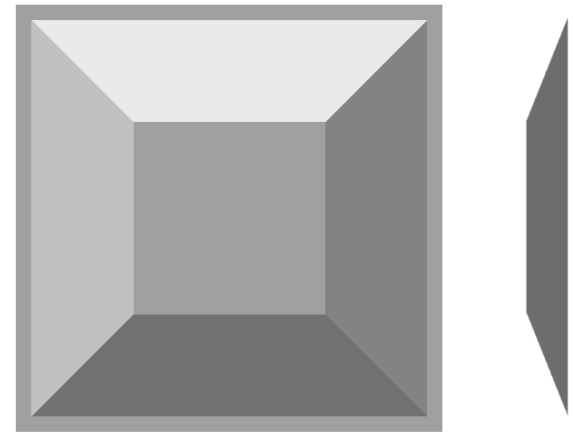
Heat assisted ISF set-up



Temperature-supported incremental sheet forming

Test conditions

- experiments on the magnesium alloys AM50 und AZ31
- using of a uniform international test component
 - truncated pyramid with
 - 20° flank angle
 - 128 mm length of edge (big edge)
 - sheet thickness 1,2 mm
- test parameters
 - 2 m/min feed rate
 - 10 mm stylus diameter
 - z-constant course set-up
 - stable path direction
 - 0,394 mm adjusting increment (z-direction)

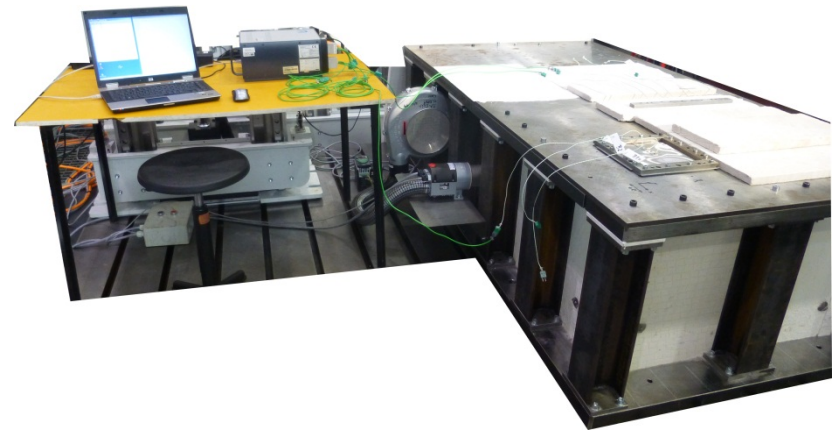
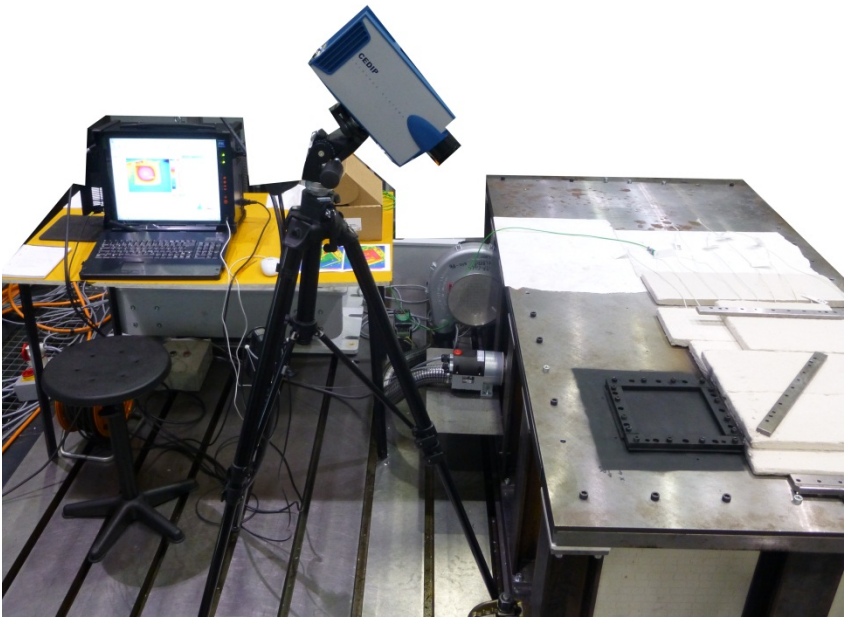


Test component „truncated pyramid“

ISF using heated air

Test setup

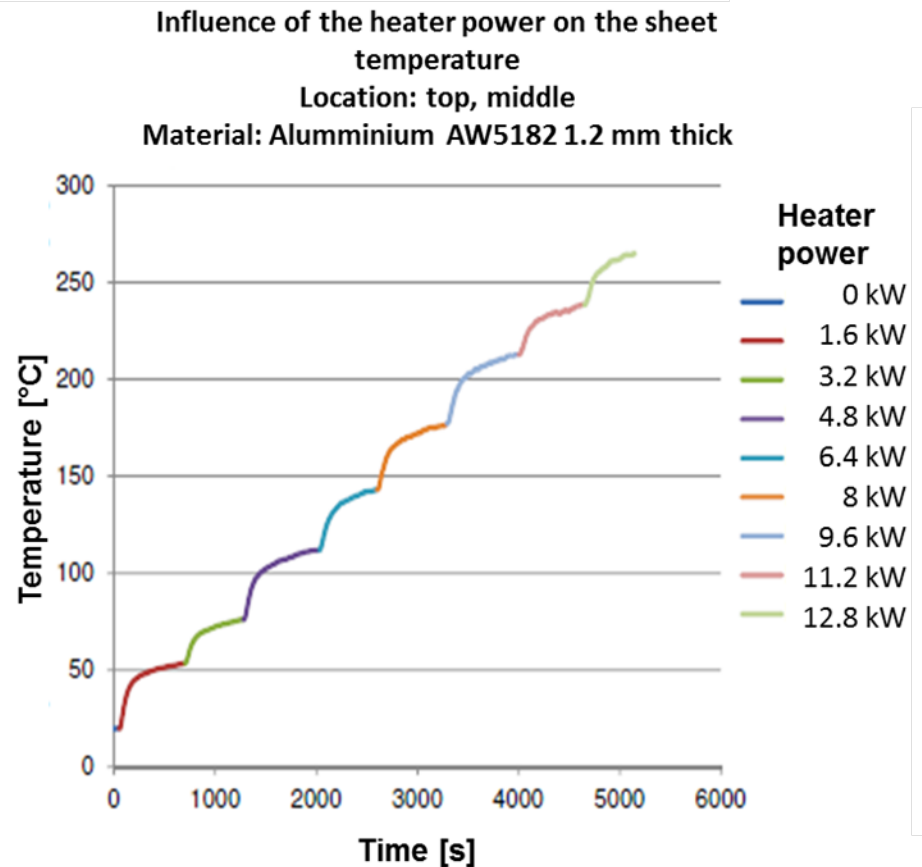
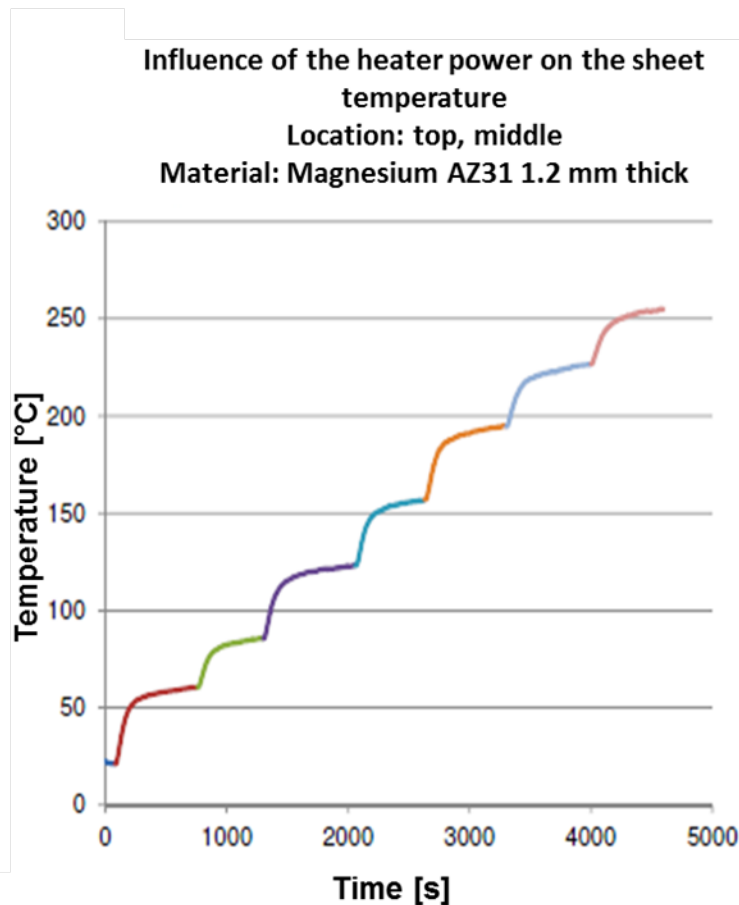
- measurement by thermocouple and thermographic camera



Test setup with thermographic camera (left) and thermocouple (right)

ISF using heated air

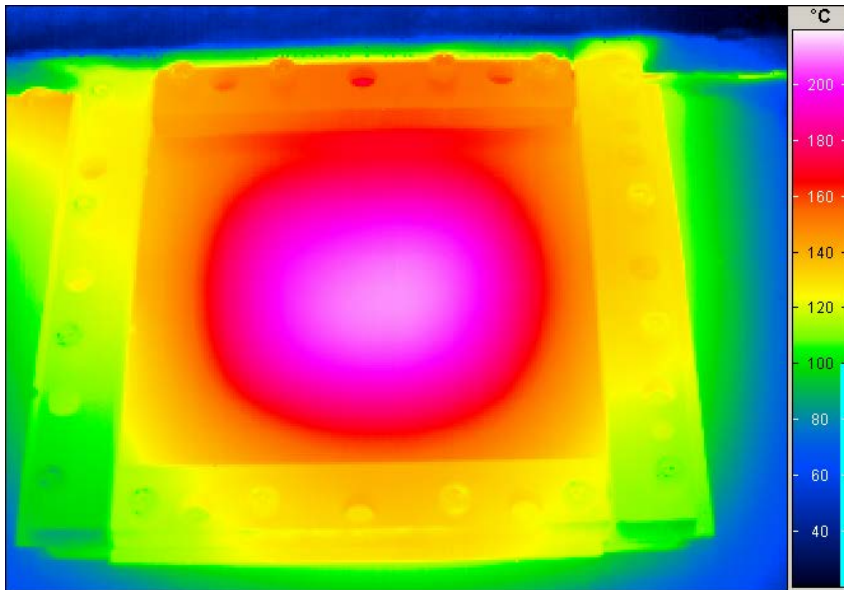
Influence of the heater power on sheet temperature



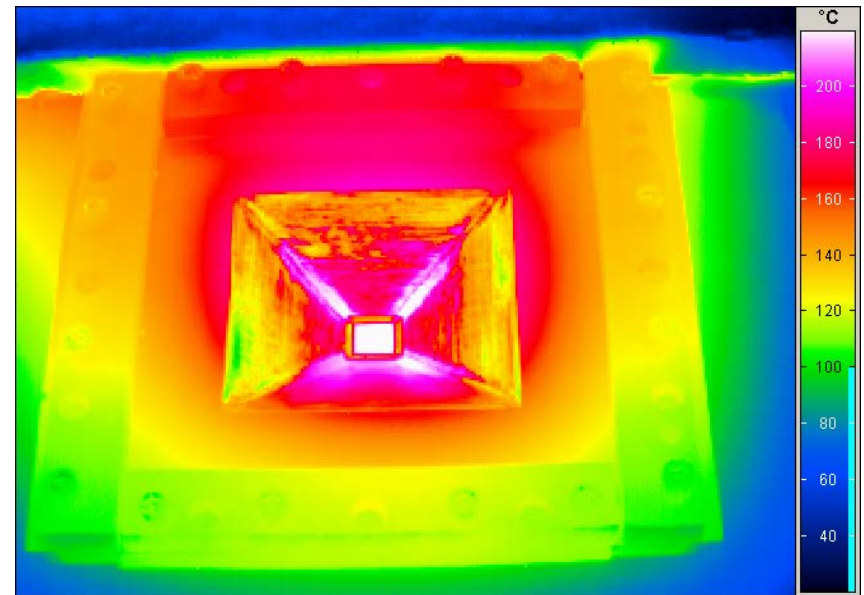
ISF using heated air

Forming experiments

Before start of experiments



After 521 s

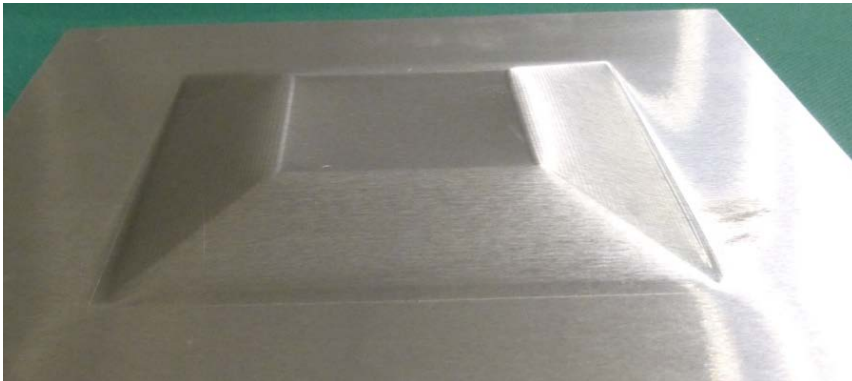


ISF using heated air

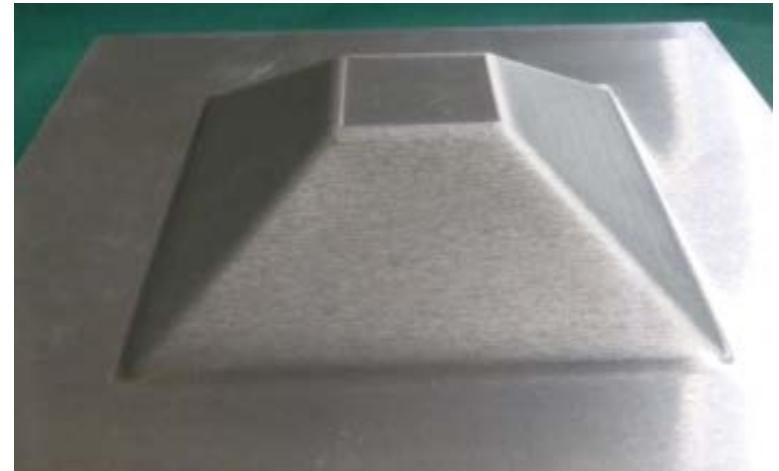
Forming results

- truncated pyramids (only sides formed)
- two different variants:

Variant	Depth	Angle
„flat“ truncated pyramid	12 mm	20°
„deep“ truncated pyramid	30 mm	determination of the maximum angle



„flat“ truncated pyramid



„deep“ truncated pyramid

ISF using heated air

Maximum angle

- comparison of forming results at 210 °C:

Formed sheet	Maximal angle
AZ31 ($s_0 = 1,2$ mm)	30°
AZ31 ($s_0 = 2,0$ mm)	30°
AM50 ($s_0 = 1,2$ mm)	26°
AM50 ($s_0 = 2,0$ mm)	26°

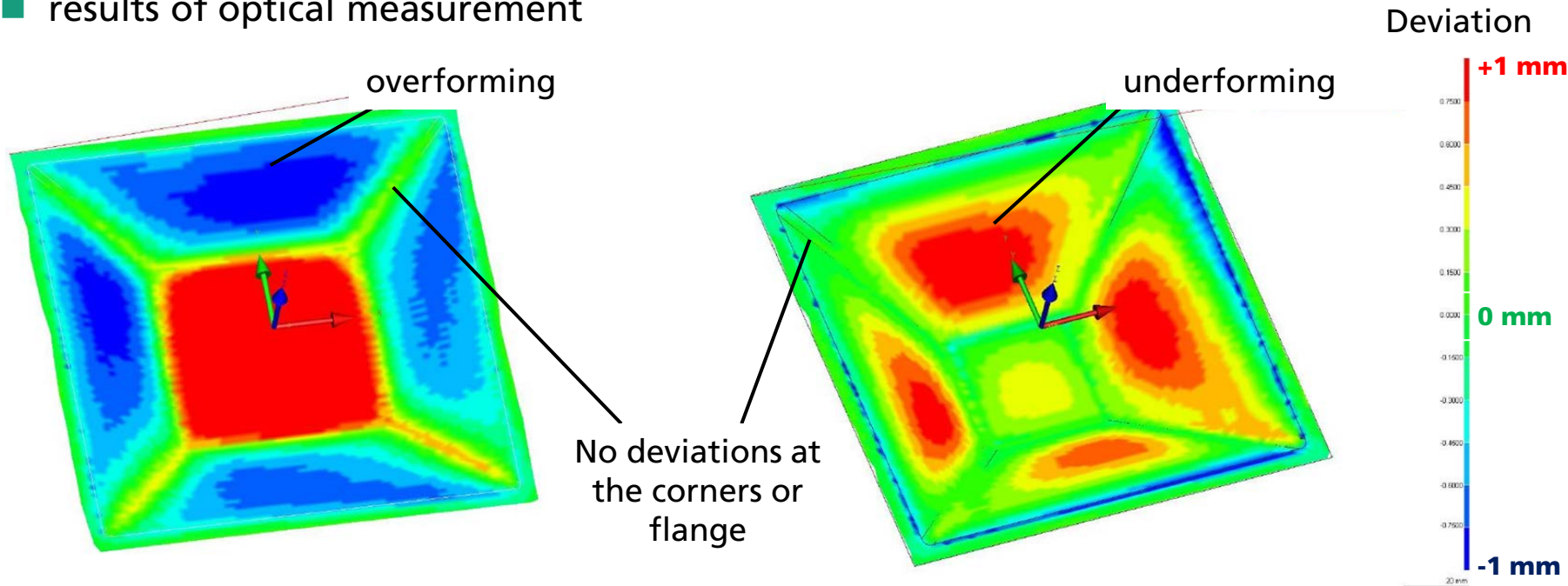
- influence of the sheet temperature (AZ31, $s_0 = 1,2$ mm):

Heating power	Sheet temperature	Maximal angle
6,4 kW	160 °C	26°
8 kW	185 °C	30°
9,6 kW	210 °C	30°
11,2 kW	235 °C	35°
12,8 kW	260 °C	35°

ISF using heated air

shape accuracy

■ results of optical measurement



■ influence of temperature

- different effects on different component geometries
- flat truncated pyramid (left): small deviation at rising temperature
- deep truncated (right): bigger deviation at rising temperature

Conclusions

- new variant of ISF for lightweight materials was developed
- difference to many other heat assisted variants of ISF: discussed process allows SPIF and TPIF without any changes of heating equipment
- second advance: heated air support is even temperature distribution on whole sheet
- temperature gradients in areas to form are not relevant for the process and part geometry afterwards
- proposed globally heated sheet allows a slim design of the stylus (without any heating equipment) and a fast ISF
- new ISF variant leads to common properties of soft aluminum ISF parts formed under room temperature
- quality of the flange area: no deviations can be detected → integration of new ISF process in manufacturing chains without any impact on peripheral processes

Thank you for your kind attention.

Dr.-Ing. Roland Müller

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