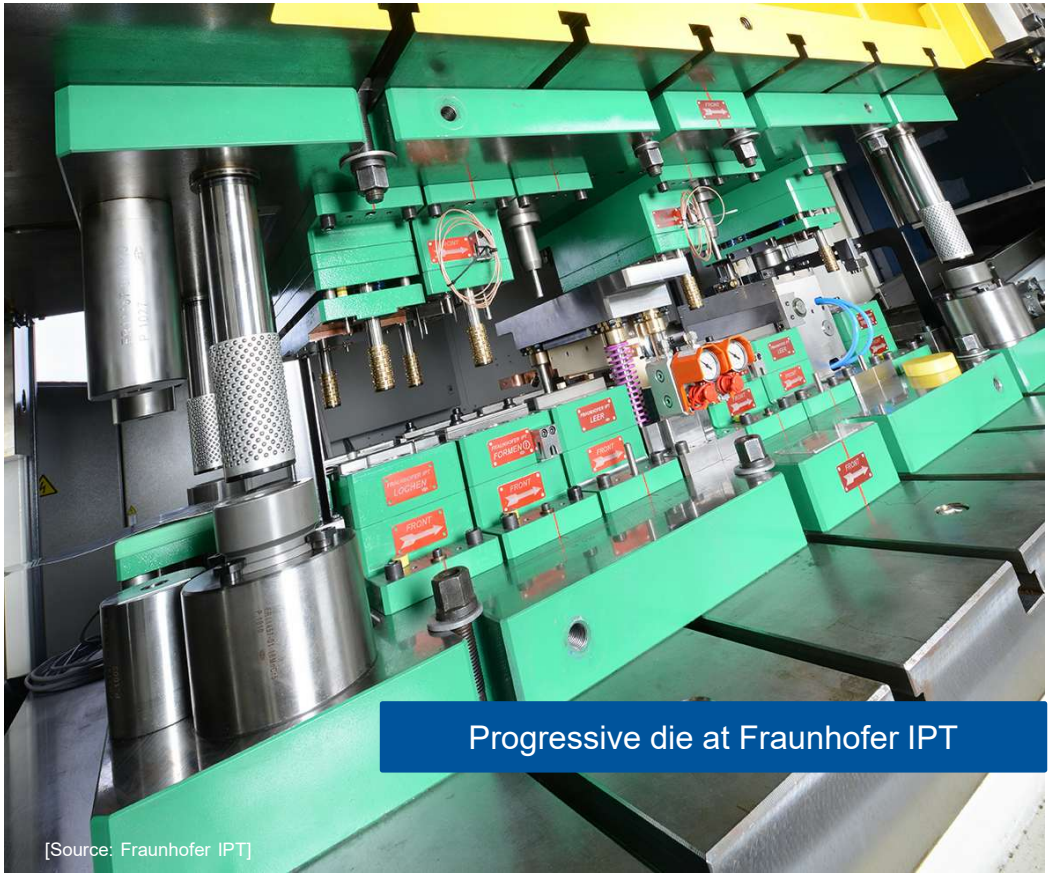
AIDA: Bipolar plate day
AIDA & Fraunhofer IPT die Test

Challenge &Starting Point

The forming of bipolar plates requires high pressing forces which place a heavy load on the overall system of the machine elements

This results in deflections and tilting in the die and press during forming on conventional presses

Thanks to the possibility that AIDA offers us, industry near BPP forming can be practiced on a specialized press



Progressive die at Fraunhofer IPT

[Source: Fraunhofer IPT]

AIDA: Bipolar plate day
Summary of the die test

Project aims

- Testing of high-volume forming of bipolar plates under industrial conditions
- Developing an understanding of the interactions between the tool, press, and process parameters during bipolar plate forming
- Testing a method for measuring the static stiffness of a press within the tool
- Exchange of experience and collaboration with AIDA, a leading global manufacturer of forming presses

[Source: Fraunhofer IPT]

Approach

Step 1 – Die Setup

- Determination of a strip theme
- Adaptation of the existing progressive die
- Design of the processing stages
- Manufacturing the components
- Assembly and test run

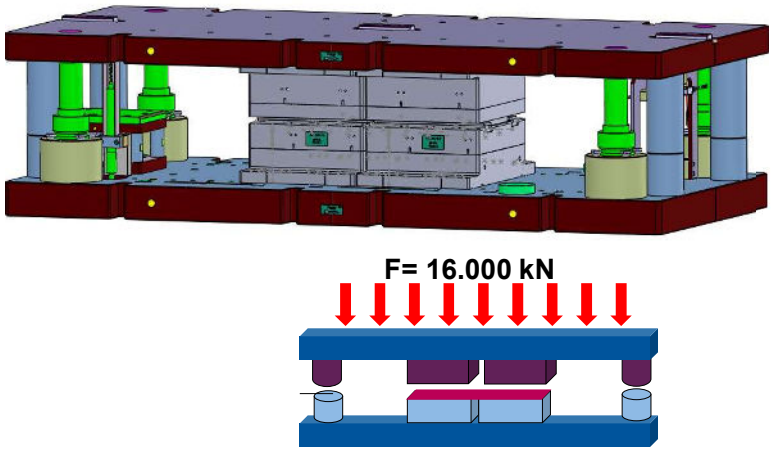
Step 2 – Die Testing at AIDA Italy

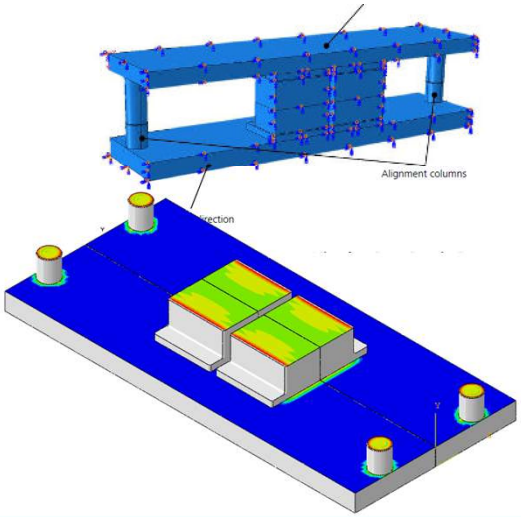
- Joint development of a test plan
- Shipping of tools and equipment to Pavone Mella, Italy
- Performing the die test for five days in June 2025
- Taking the bipolar plates and evaluation at Fraunhofer IPT

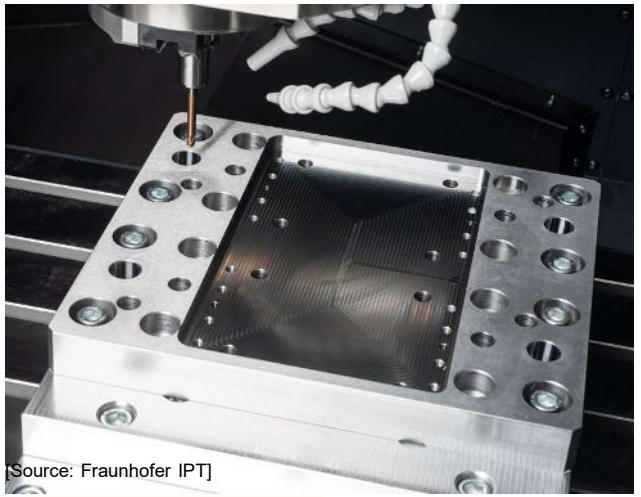
Step 3 – Evaluation of the results

- Recording of data and transport to Aachen
- Evaluating the manufactured BPP at the Fraunhofer IPT in Aachen
- Creating the report
- Derive further process improvements and adjustments

AIDA & Fraunhofer IPT: Die Test
Set-up and toolmaking







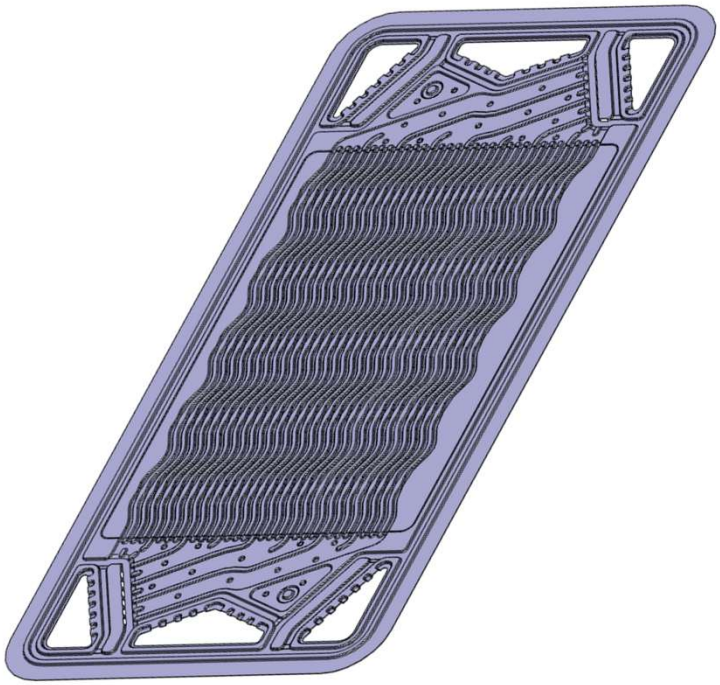
[Source: Fraunhofer IPT]

Set-up and toolmaking

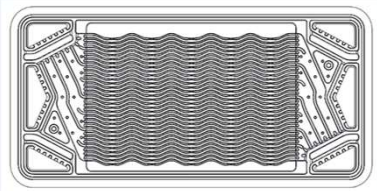
- Adaptation of the existing progressive die for bipolar plates
- Forming of the FCI BPP design for fuel cells
- Design of modules for the die for two-stage forming
- Equipping the tool with sensor technology
- Simulation of the tool load to ensure defect-free use in the AIDA press
- CAD modeling and setting up the tolerance chain in the tool

AIDA & Fraunhofer IPT: Die Test
Bipolar plate design

FCI – Fuel Cell BPP Design

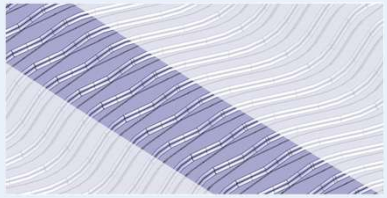


Characteristic values of the BPP



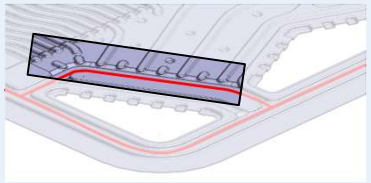
- Dimensions are 200 x 100 mm
- Downscaled version of a fuel cell bipolar plate
- Design Developed at Fraunhofer IPT
- Material thickness 80 µm made of 316L stainless steel

Design Improvements compared to the first version



- Introduction of zig-zag structure of flow channels to homogenize the flow distribution
- Introduction of partially narrowed, staggered channels
- Enhance diffusion of reactants to GDL

Improvement of weldability – Port area



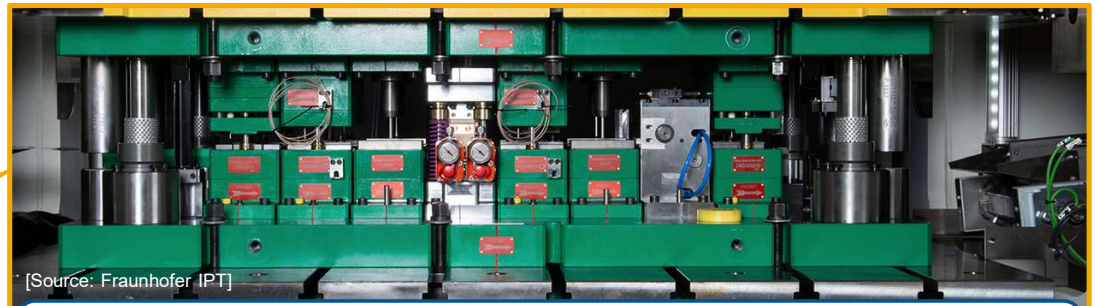
- Reducing the distance between the channels of the distribution structure to half of the previous length
- Compromise of optimization for flow and optimization for weldability

AIDA & Fraunhofer IPT: Die Test
Adaption of the progressive die

AIDA die setup

- The existing progressive tool for bipolar plates at Fraunhofer IPT has 8 stages, allowing forming on an area of 123 mm x 110 mm
- The limitation of the formable area is due to the low tonnage of the press at Fraunhofer IPT of 2000 kN
- In order to take advantage of the capabilities of the AIDA DSF-BE1 press, larger machining stages for the tool were designed, constructed, and built as part of the project.


[Source: Fraunhofer IPT]


[Source: Fraunhofer IPT]

- Progressive die with 8 Stages
- Formable area: 123 x 110 mm
- Servo press with 2000 kN
- Standard automatic punching press

[Source: AIDA]


[Source: Fraunhofer IPT]

- Progressive die with 5 Stages
- Enlarge the formable area to 123 x 245 mm
- Servo press with 16000 kN
- Specialized press for high-precision forming of thin sheets

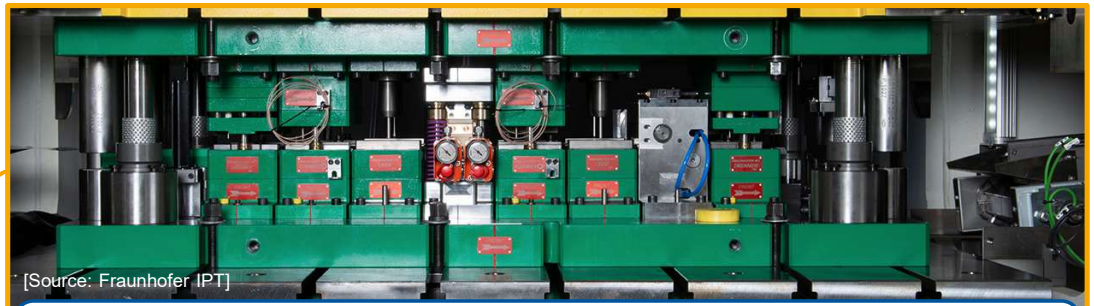
AIDA & Fraunhofer IPT: Die Test

Adaption of the progressive die

AIDA die setup

Fraunhofer IPT

- Test setup at Fraunhofer IPT Aachen, Germany



- Progressive die with 8 Stages
- Formable area: 123 x 110 mm
- Servo press with **2000 kN**
- **Standard automatic punching press**

AIDA

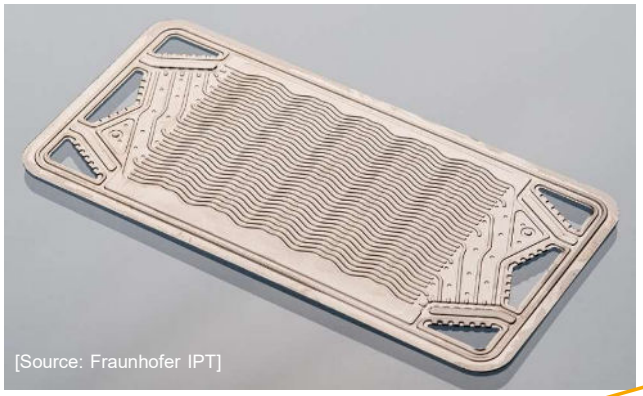
- Test setup at AIDA S.r.l Pavone Mella, Italy

- Progressive die with 5 Stages
- Enlarge the formable area to 123 x 245 mm
- Servo press with **16000 kN**
- **Specialized press for high-precision forming of thin sheets**

AIDA & Fraunhofer IPT: Die Test

Experimental setup and die preparation

AIDA die setup



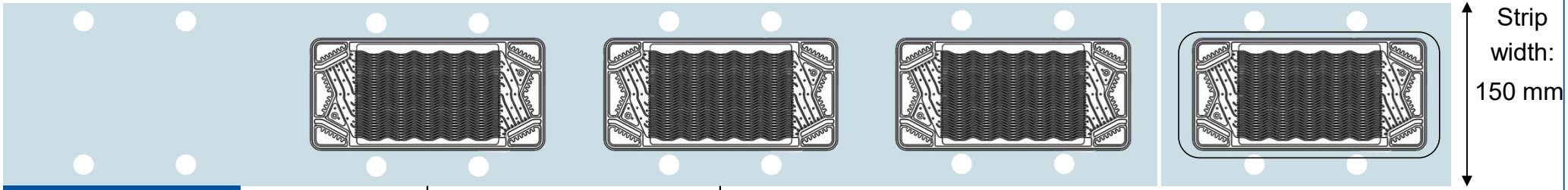
Pre- punching

Preforming

Finish forming

Roller Feed
(No processing step)

Cutting (separation)

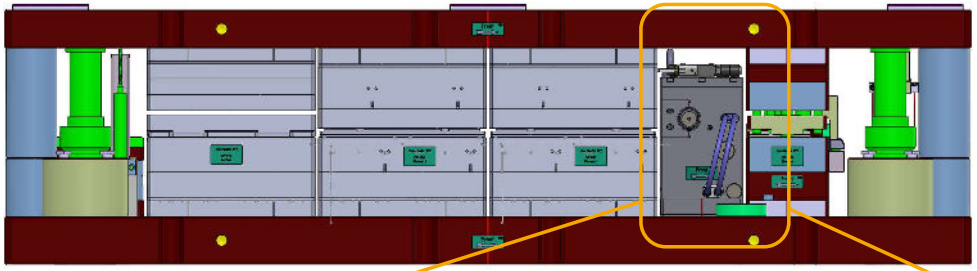


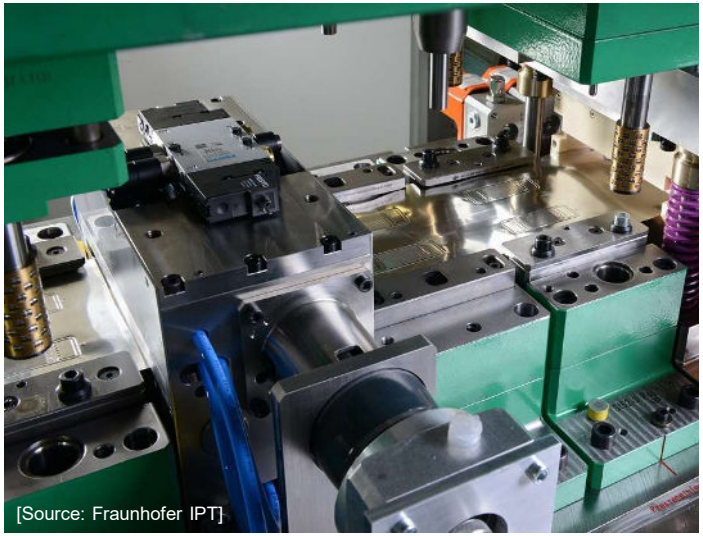
Strip scheme

AIDA & Fraunhofer IPT: Die Test
Die internal roller feed

AIDA die setup – Die internal feed

- Low stiffness of the thin strip metal – strip feeding is carried out by pulling the strip
- To reduce the interfaces between the press and the tool, the tool should independently feed material out of the strip loop

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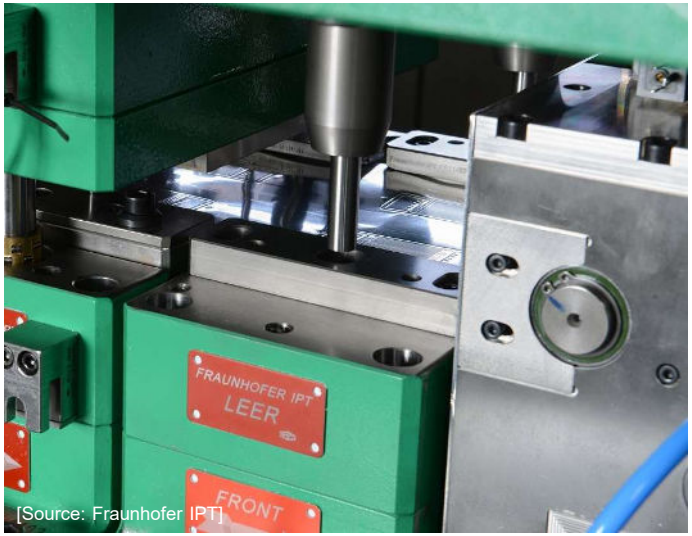

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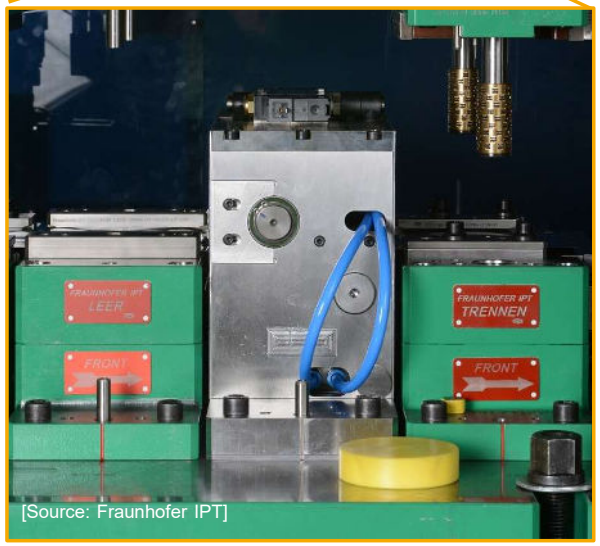
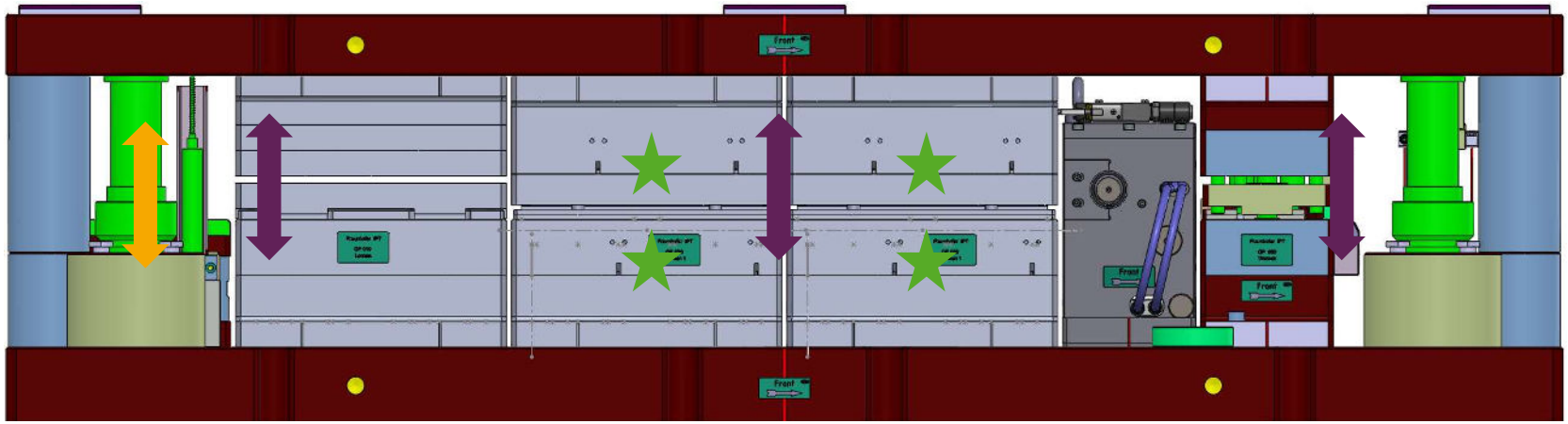


[Source: Fraunhofer IPT]

AIDA & Fraunhofer IPT: Die Test
Measurement setup

AIDA die setup – measurement setup



Stroke height measurement

- Laser distance sensor
- Balluff photoelectric sensor
- Resolution < 100 µm

Distance measurement

- Measurement of the distance between tool head plate and base plate to measure deflection of the tool
- Balluff photoelectric sensor
- Resolution < 10 µm

Piezoelectric sensors

- Measurement of the forming force at four measuring points per forming stage
- Deviation of the forming force from stroke to stroke and within a embossing set

AIDA & Fraunhofer IPT: Die Test
Assembly and test run

Construction and design

CAD modeling and tolerance determination

Manufacturing and procurement

Our in-house micro-machining capabilities, including a Makino IQ500, were used to manufacture the high-precision components

Assembly and test run

After completion of the tool components, the entire die was assembled at the Fraunhofer IPT

Ship to AIDA, italy

After a successful test run, the tool was shipped to AIDA in Pavone Mella, Italy

[Source: Fraunhofer IPT]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AIDA & Fraunhofer IPT: Die Test

Summary of the die test

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AIDA & Fraunhofer IPT: Die Test

Die test Results: Component validation

Approach

- During the test days at AIDA in Italy, several different parameter sets, and test conditions were tested
- A number of 2000 bipolar plates were manufactured and subsequently examined at the Fraunhofer IPT
- The following section discusses correlations with regard to the results from component measurement, thinning analysis, and sensor values

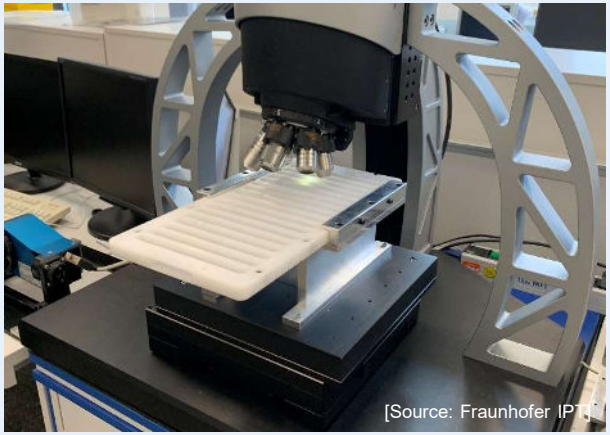
[Source: Fraunhofer IPT]

Experimental Setup								Explanation
Material Type	1.4404 / SS 316L							Material thickness 85 µm
Die shut hight	Variation from 400 mm to 398.4 mm							Highest possible forming force
Forming Rate	10	20	30	40	50	60	70	Forming rate in strokes per minute
Operation Mode	Single Stroke		Continuous stroke		Pendulum stroke			Shut height is the distance form top of the press bed to the bottom of the slide when the ram is at its lowest point. A Critical dimension for accommodating the die.
Motion	0.1 seconds in Bottom death Center			0.2 seconds in Bottom death Center				Time the force of 2000kN was imprinted onto the BPP

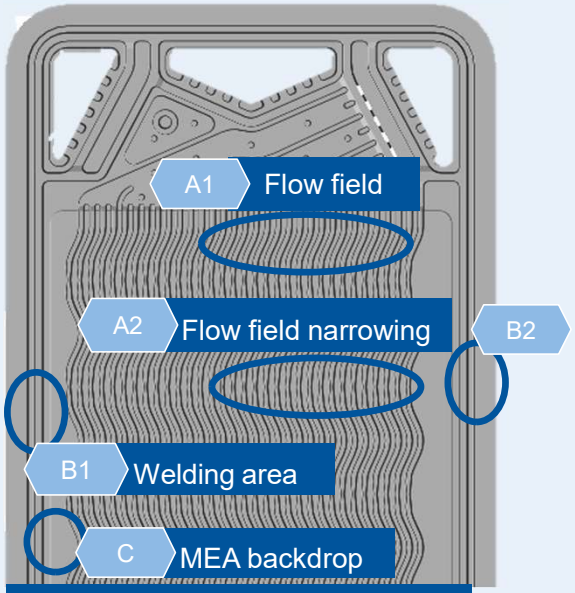
Progressive die for BPP
Die test Results: Component validation

Capturing the 3D surface

- Clamping the BPP in the clamping fixture for flat alignment under the microscope
- Capture of the 3D surface

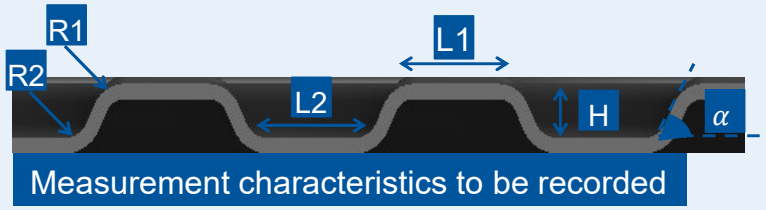


Evaluating the cross-section



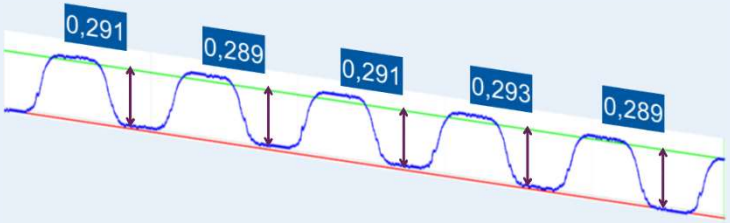
Measuring areas on the plate

- Three functional areas of the BPP are measured



Measurement characteristics to be recorded

- Two measuring points per functional area
- Determine the average geometric values of at five neighboring channels



- Measurement of the cross-sections and comparison with the target values
- Statistical evaluation and assessment of the forming quality

Progressive die for BPP
Die test Results: Component validation

Single stroke mode

Target

- Break in the tool with different die shut heights
- Adjusting component quality depending on die shut height respectively pressing force
- Observation of different slide curves / motions in a single stroke

Continuous stroke & Pendulum stroke

Target

- Operation of the tool in production mode / continuous manufacture of BPP
- Examining the influence of different forming rates (SPM) on component quality
- Investigating the influence of ram movement on component quality

Eccentricity test

Target

- Move the tool 100 mm perpendicular to the strip running direction
- Operating the tool outside the center of the slide (off-center force application)
- Considering the effects of testing on component quality

Comparison test with standard press

Target

- Comparison of the results with non-specific bipolar plate press
- Forming tests were carried out on the 2000 kN servo press at the Fraunhofer IPT
- Using the same operating conditions: press force, tool, ram curve, forming rate

Progressive die for BPP
Die test Results: Component validation

- Single stroke mode
- Continuous stroke & Pendulum stroke
- Eccentricity test
- Comparison test with standard press

Target

- Break in the tool with different die shut heights
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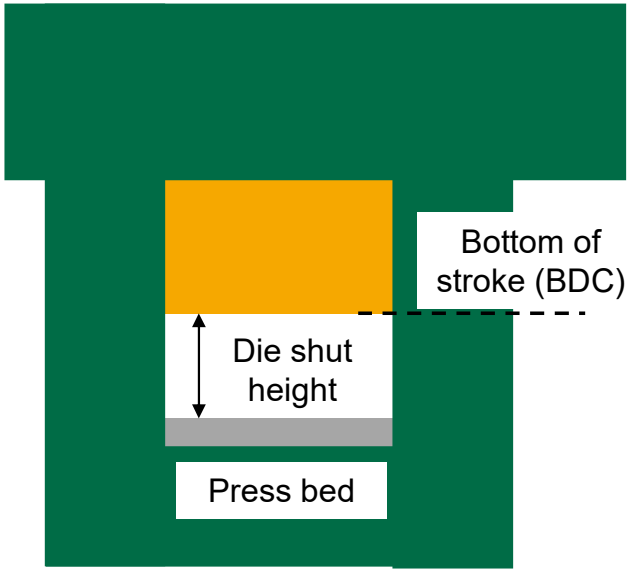
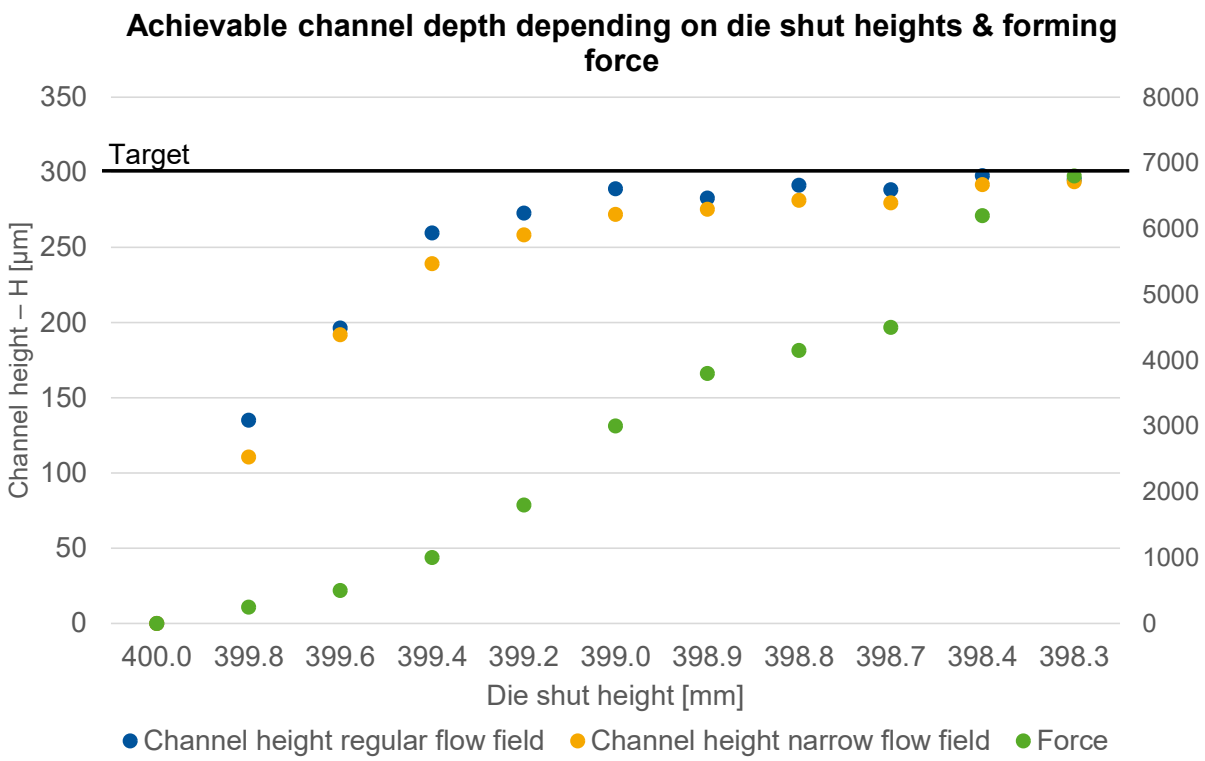


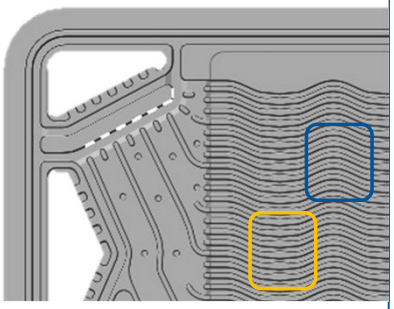
- Shut height is the distance form top of the press bed to the bottom of the slide when the ram is at its lowest point
- Critical dimension for accommodating the die
- As the Press cycles, force applied to the ram and the bolster plate cause both to deflect slightly
- Lowering the shut height ensures fully closing of the die
- A proper Shut height setting is essential for quality components production, preventing die damage, ensuring correct die clearances and Press performance
- Overall height of the Fraunhofer IPT BPP Die in fully closed position is 400 mm

Progressive die for BPP
Die test Results: Component validation

- Single stroke mode
- Continuous stroke & Pendulum stroke
- Eccentricity test
- Comparison test with standard press



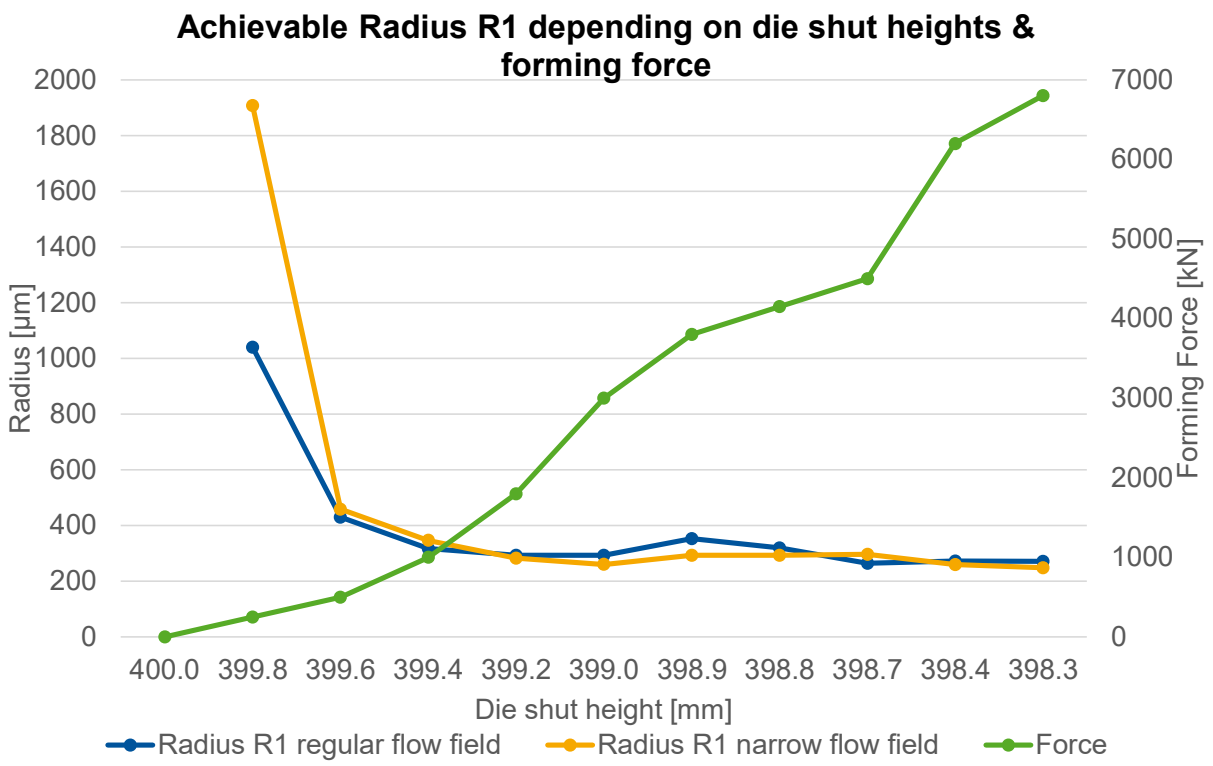
Parameters	Value
Forming rate	10 spm
Operating mode	Single stroke
Slide motion	Crank motion



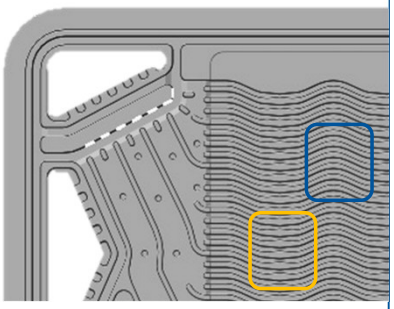
With decreasing die shut height the forming force increases, and with it the maximum formable channel depth. Higher forming forces are necessary, especially for narrow channel cross-sections

Progressive die for BPP
Die test Results: Component validation

- Single stroke mode
- Continuous stroke & Pendulum stroke
- Eccentricity test
- Comparison test with standard press



Parameters	Value
Forming rate	10 spm
Operating mode	Single stroke
Slide motion	Crank motion



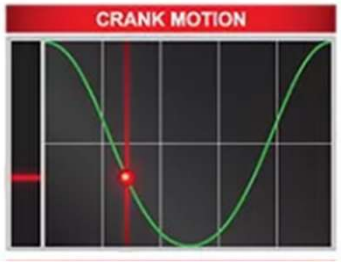
Similarly, higher forming forces can be used to form more precise forming radii, but the force dependence of the channel radii is smaller in comparison to the channel height. The tool compensation setting is crucial for this

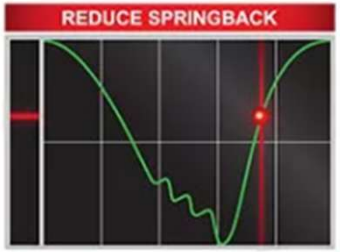
Progressive die for BPP
Die test Results: Component validation

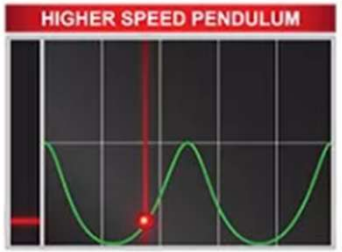
- Single stroke mode
- **Continuous stroke & Pendulum stroke**
- Eccentricity test
- Comparison test with standard press

Target

- Operation of the tool in production mode / continuous manufacture of BPP
- Examining the influence of different forming rates (SPM) on component quality
- Investigating the influence of ram movement on component quality



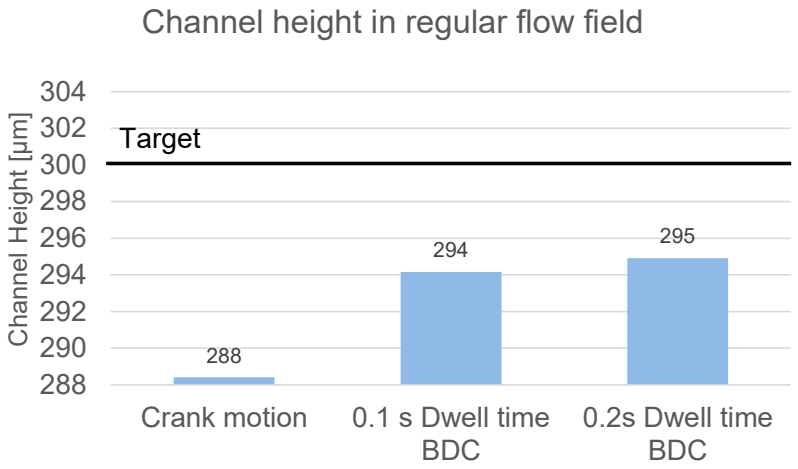


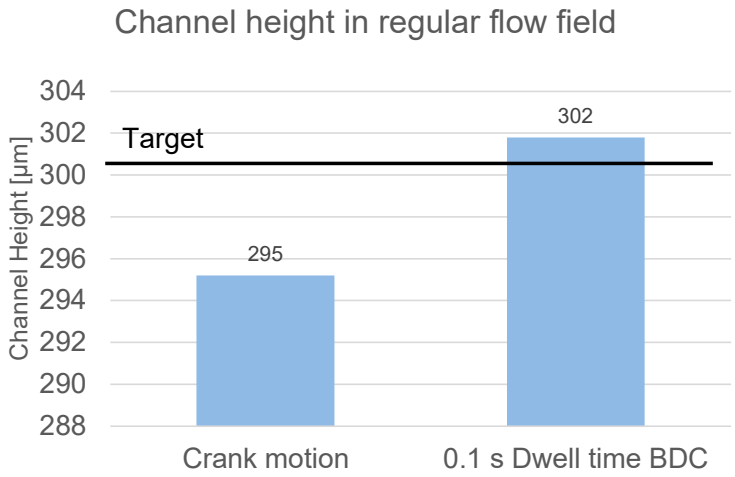


Progressive die for BPP
Die test Results: Component validation

- Single stroke mode
- Continuous stroke & Pendulum stroke
- Eccentricity test
- Comparison test with standard press

Influence of the slide motion component quality – Stop in BDC





Parameters	Value
Forming rate	10 spm
Operating mode	**Single stroke**
Die shut height	398.7

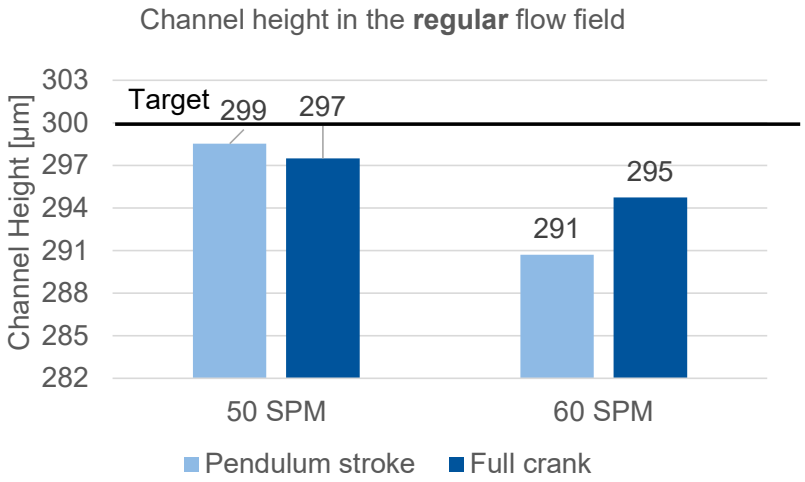
Parameters	Value
Forming rate	40 spm
Operating mode	**Continuous stroke**
Die shut height	398.7

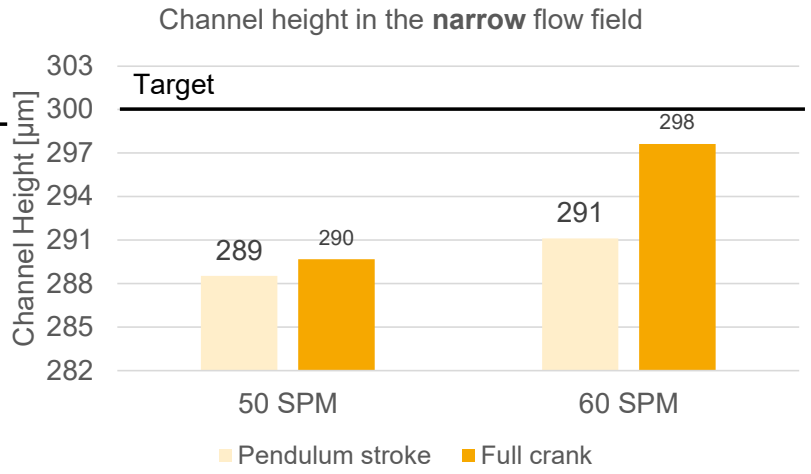
In singe stroke mode, a significant influence of the holding time in BDC can be observed. This can improve the forming of the channel. This effect can also be seen in continuous operation.

Progressive die for BPP
Die test Results: Component validation

- Single stroke mode
- Continuous stroke & Pendulum stroke
- Eccentricity test
- Comparison test with standard press

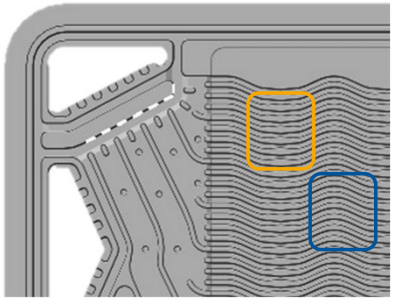
Influence of the slide motion component quality – Pendulum stroke





Parameters	Value
Slide motion	Crank motion
Die shut height	398.7
Forming force	4500 kN

No significant disadvantages in terms of component quality can be observed with the pendulum stroke; at a stroke rate of 60 SPM, a slight reduction in channel height can be observed.



Progressive die for BPP
Die test Results: Component validation

- Single stroke mode
- Continuous stroke & Pendulum stroke
- **Eccentricity test**
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Target

- Move the tool 100 mm perpendicular to the strip running direction
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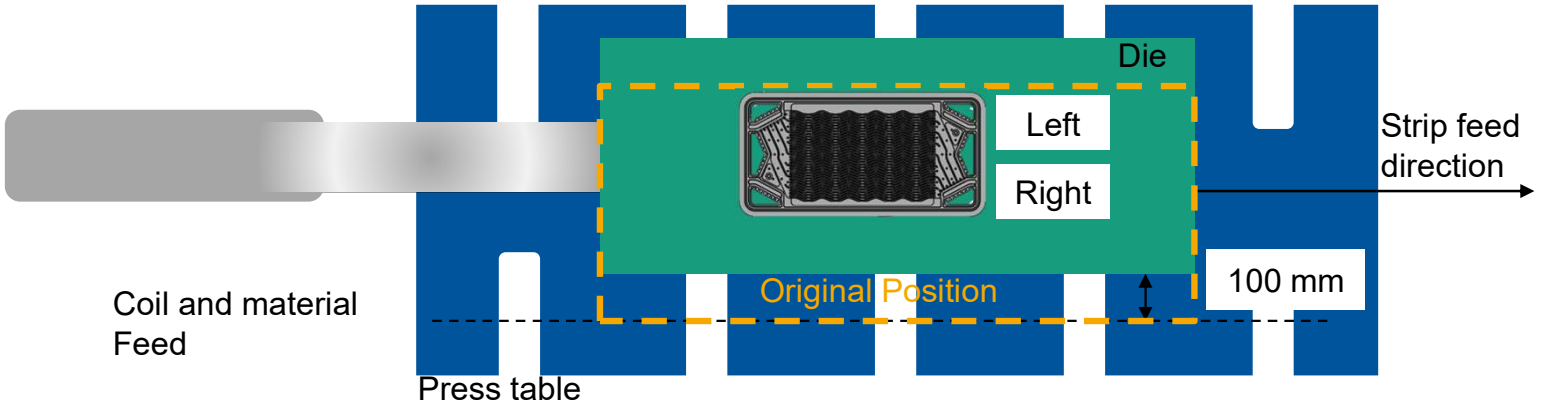
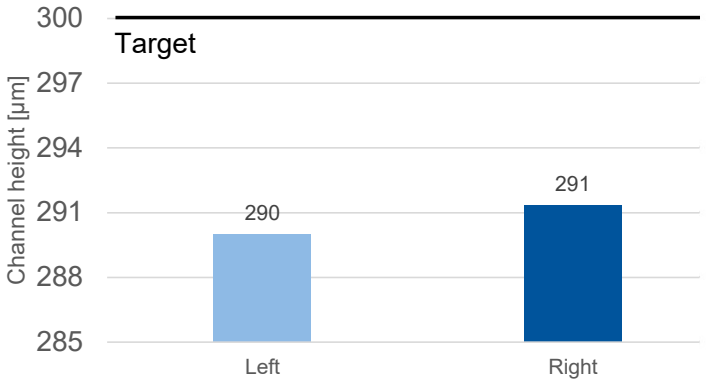
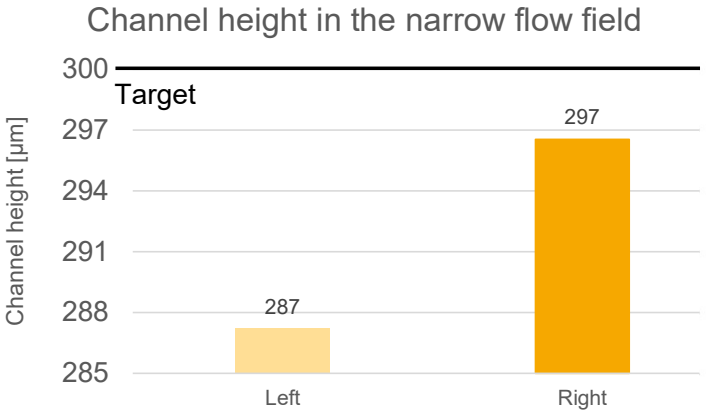
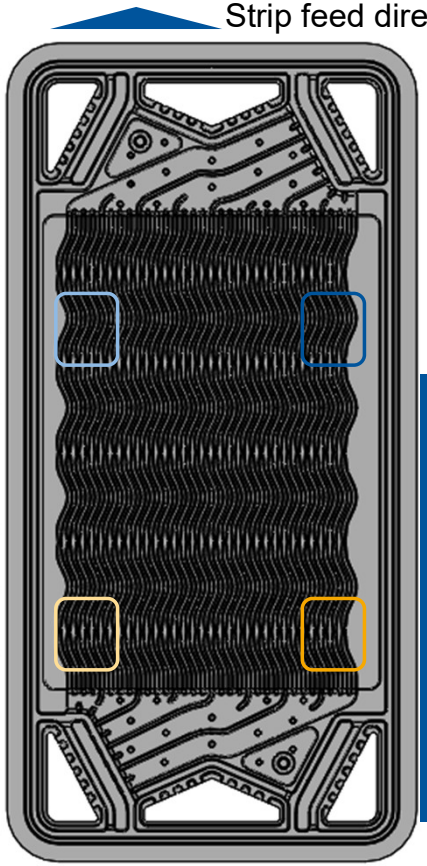


Progressive die for BPP
Die test Results: Component validation

- Single stroke mode
- Continuous stroke & Pendulum stroke
- Eccentricity test
- Comparison test with standard press





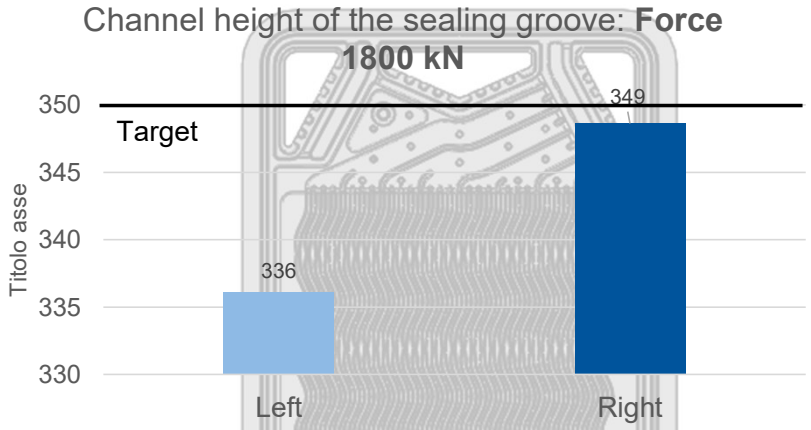


Parameters	Value
Forming rate	10 spm
Operating mode	Single stroke
Slide motion	Crank motion
Die shut height	398.7 mm
Forming force	4700 kN

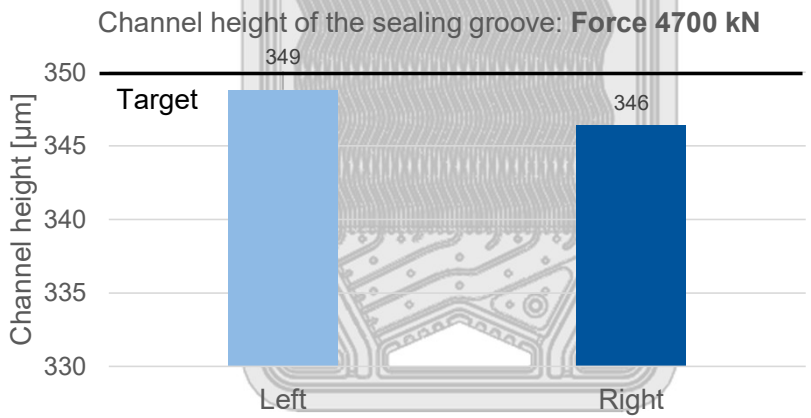
Asymmetrical position of the tool in the press results in asymmetrical force application. The forming force on the left side is lower, resulting in a shallower channel depth.

Progressive die for BPP
Die test Results: Component validation

- Single stroke mode
- Continuous stroke & Pendulum stroke
- **Eccentricity test**
- Comparison test with Schuler MSC 2000



Parameters	Value
Forming rate	10 spm
Operating mode	Single stroke
Slide motion	Crank motion
Die shut height	399.2 mm
Forming Force	1800 kN



Parameters	Value
Forming rate	10 spm
Operating mode	Single stroke
Slide motion	Crank motion
Die shut height	398.7 mm
Forming Force	4700 kN

Progressive die for BPP
Die test Results: Component validation

Single stroke mode

Continuous stroke & Pendulum stroke

Eccentricity test

Comparison test with standard press

Target

- Comparison of the results with non-specific bipolar plate press
- Forming tests were carried out on the 2000 kN servo press at the Fraunhofer IPT
- Using the same operating conditions: press force, tool, ram curve, forming rate


[Source: Fraunhofer IPT]

Parameter	Value
Strokes per minute	20
Operating mode	Pendulum stroke
Forming Force	1800 kN
Die shut height	**397.5 mm**

[Source: AIDA]

Parameter	Value
Strokes per minute	20
Operating mode	Pendulum stroke
Forming Force	1800 kN
Die shut height	**399.2 mm**

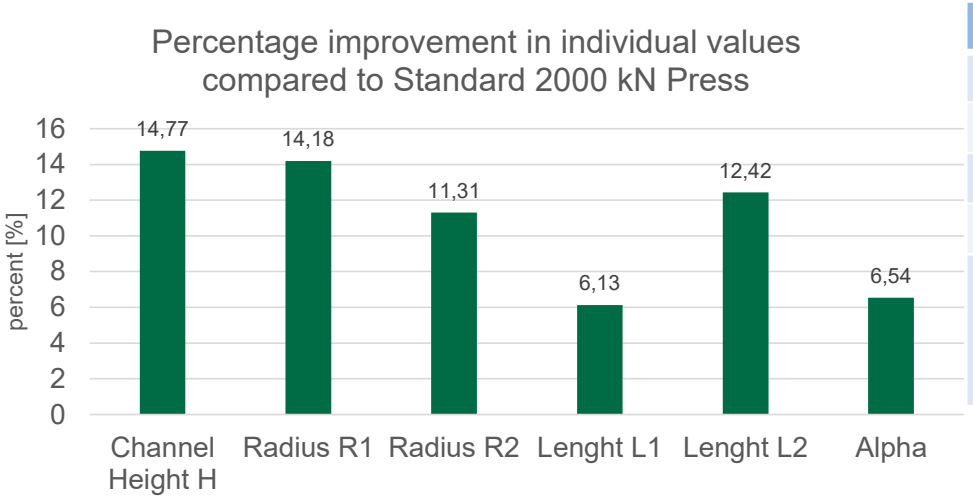
Progressive die for BPP
Die test Results: Component validation

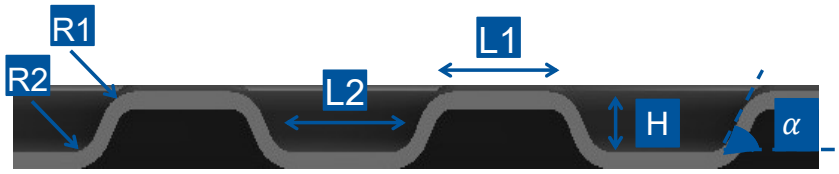
Single stroke mode

Continuous stroke & Pendulum stroke

Eccentricity test

Comparison test with standard press





Parameter	Value
Strokes per minute	20
Slide motion	Crank motion
Operating mode	Pendulum stroke
Forming Force	1800 kN
Die shut height	AIDA BEX 16000: 399.2 mm 2000 kN servo press: 397.5 mm

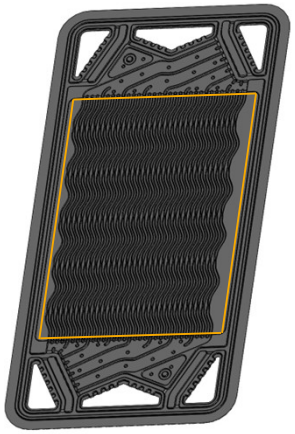
Within the measured values in the flow field, all parameters can be formed more accurately in the direct comparison test.

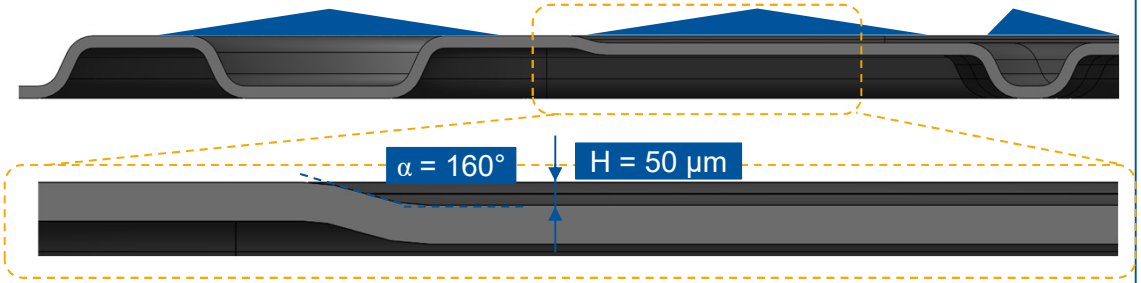
Progressive die for BPP

Die test Results: Component validation

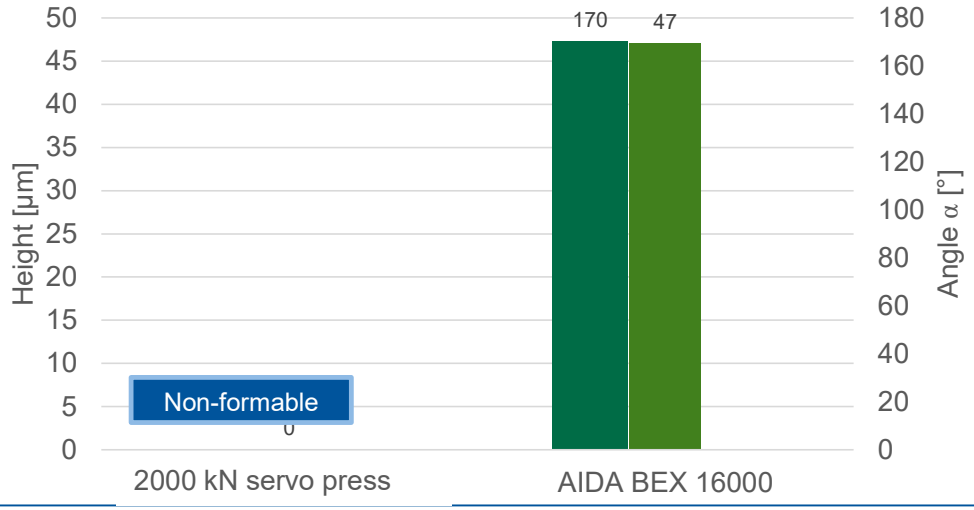
- Single stroke mode
- Continuous stroke & Pendulum stroke
- Eccentricity test
- Comparison test with standard press

Forming difficult features





The fine setback of the flow field used in the FCI-Design to insert the MEA can be easily formed even with small tonnage. This feature cannot be formed with the 2000 kN servo press.

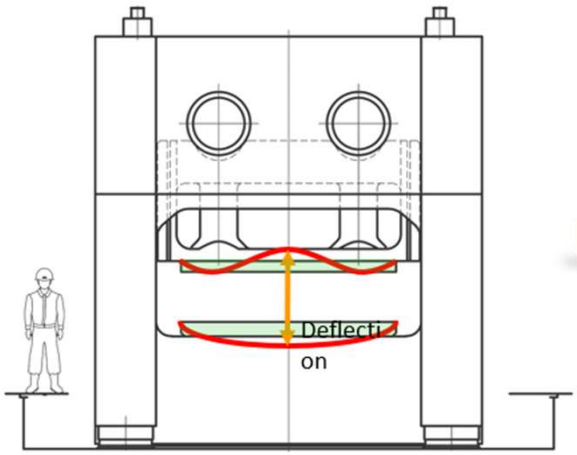


Progressive die for BPP
Die test Results: Component validation

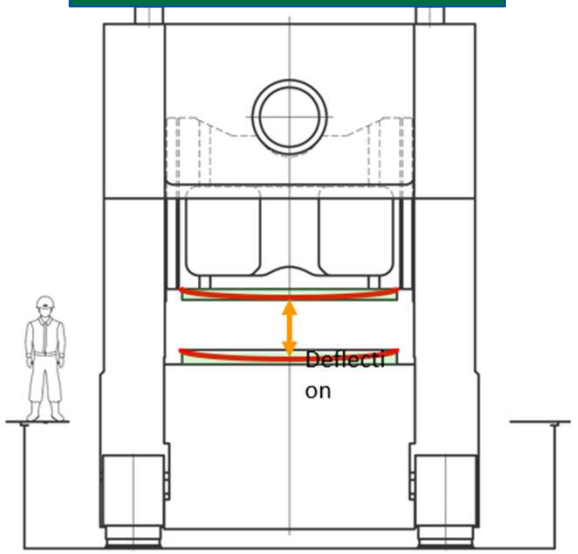
- Single stroke mode
- Continuous stroke & Pendulum stroke
- Eccentricity test
- Comparison test with standard press

Presses and tool deflection

Standard Press



AIDA DSF-BE1-16000



[Source:AIDA]

The deviations in component quality can be explained by the design of the press. The deflection of the standard press is very high in the middle, which results in a loss of component quality.

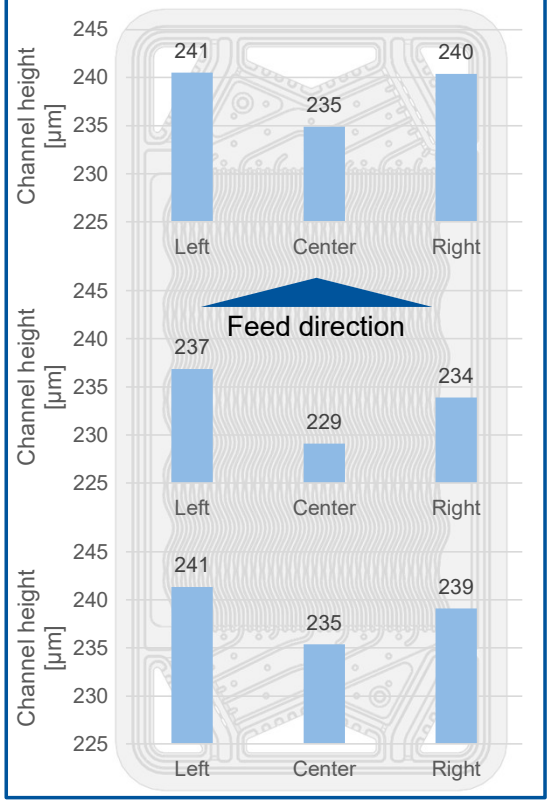
Progressive die for BPP

Die test Results: Component validation

- Single stroke mode
- Continuous stroke & Pendulum stroke
- Eccentricity test
- Comparison test with standard press

Homogeneity of the forming process

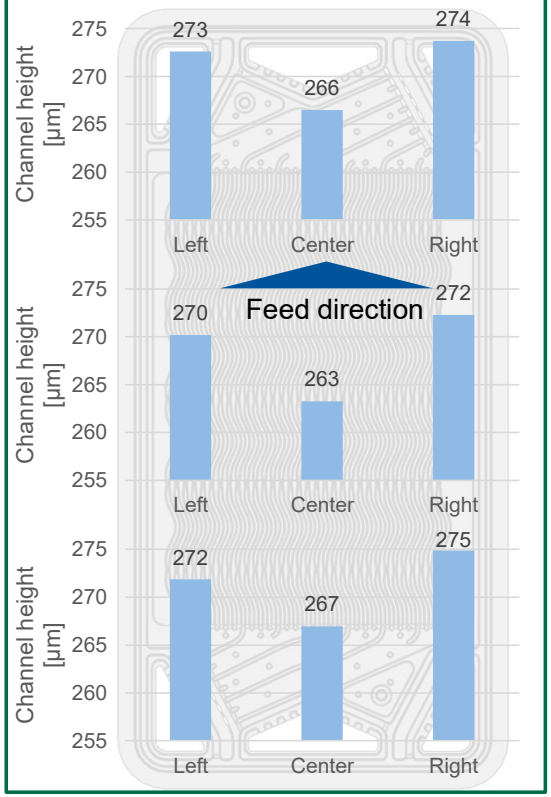
Standard 2000 kN Press



To assess the homogeneity of component quality and the distribution of force from the press onto the component, the flow field was measured in nine areas.

The worst forming result is produced in the middle of the BPP due to tool deflection in the area of highest load.

AIDA BEX 16000



Progressive die for BPP
Summary

Key Findings:

Progressive die for BPP

- The shut height has a very large influence on the achievable BPP quality, but there is still a limit to how deep a channel can be drawn despite higher forming force
- The forming quality can be minimally improved by holding at the bottom dead center
- An asymmetrical force application has a major impact on component quality, and the achievable channel height within a bipolar plate varies greatly
- Under the same conditions, significantly better results are achieved with the AIDA DSF-BE1 press than with a standard press
- The homogeneity of the channel depth achieved across the plate could not be significantly improved. It must be investigated whether this is due to the influence of the tool or the press

Outlook:

- Improvement of the sensor setup to determine the static stiffness of the press/tool as a function of force
- Observing long-term stiffness over a high number of strokes

Progressive die for BPP
Summary

Thank you very much for the ongoing cooperation.