cooliance

Thermal Management Expo

Stuttgart

4 December 2024

About Cooliance

- 2008: Cooliance, Inc (North and South America)
  - Product development, applications, assembly, logistics
  - Warwick, Rhode Island (USA)
- 2012: Cooliance GmbH (Europe)
  - Applications, logistics
  - Karlsruhe (Germany)
- 2017: Cooliance China (Asia)
  - Manufacturing, quality control, logistics
  - Dongguan (China)

LED lighting - active

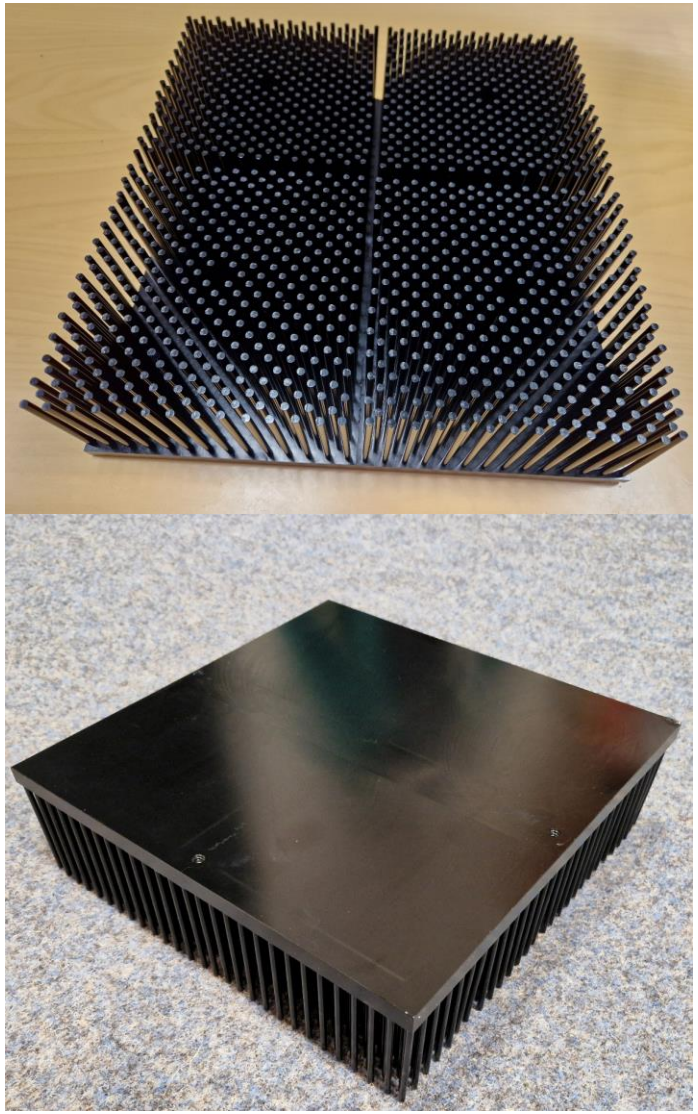
- Coolstrate
  - 50W to 300W cooling
  - Compact and light-weight
  - Optimized to slow fan-speed for long life and silent operation
  - Control system eliminates the need for separate power source
  - Forged heat sink optimized for active cooling
  - Reduces heat sink volume by factor of three vs. passive cooling

LED lighting - passive

- CPL range
  - Forged heat sink range optimized for passive cooling
  - 20W to 100W cooling
  - Efficient pin fin design
  - Forged from single piece of aluminum
  - Complete freedom in mounting options

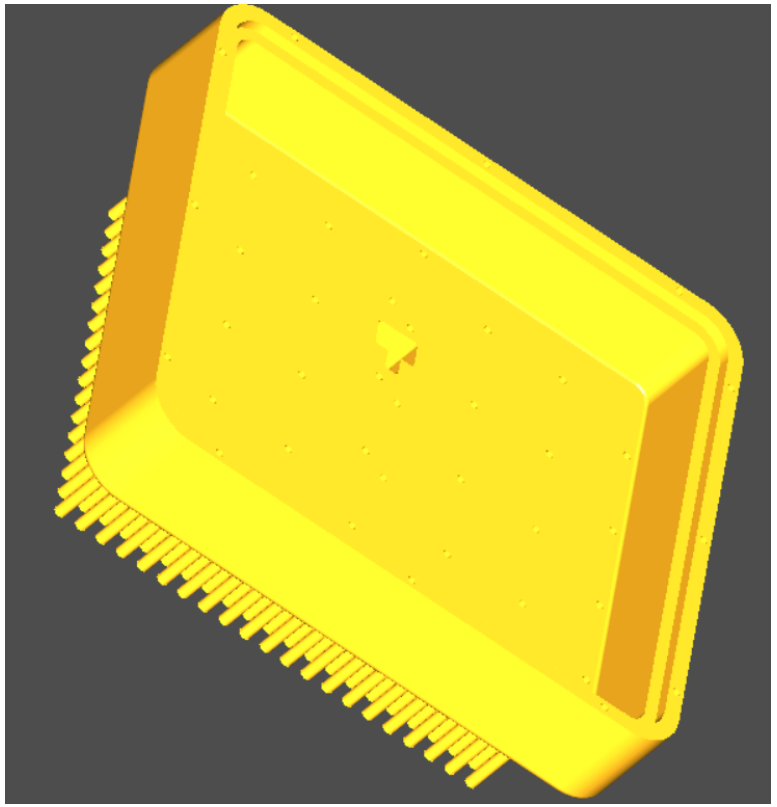
Friction welding

- Modular large format heat sinks
  - Standard heat sink as building block
  - Large format using friction welding
  - Overcomes limitations of cold forge press capacity
  - Efficient pin fin design
  - Seamless base surface
  - Pre-tooled for low-quantity applications



Cold-forging vs. Milling

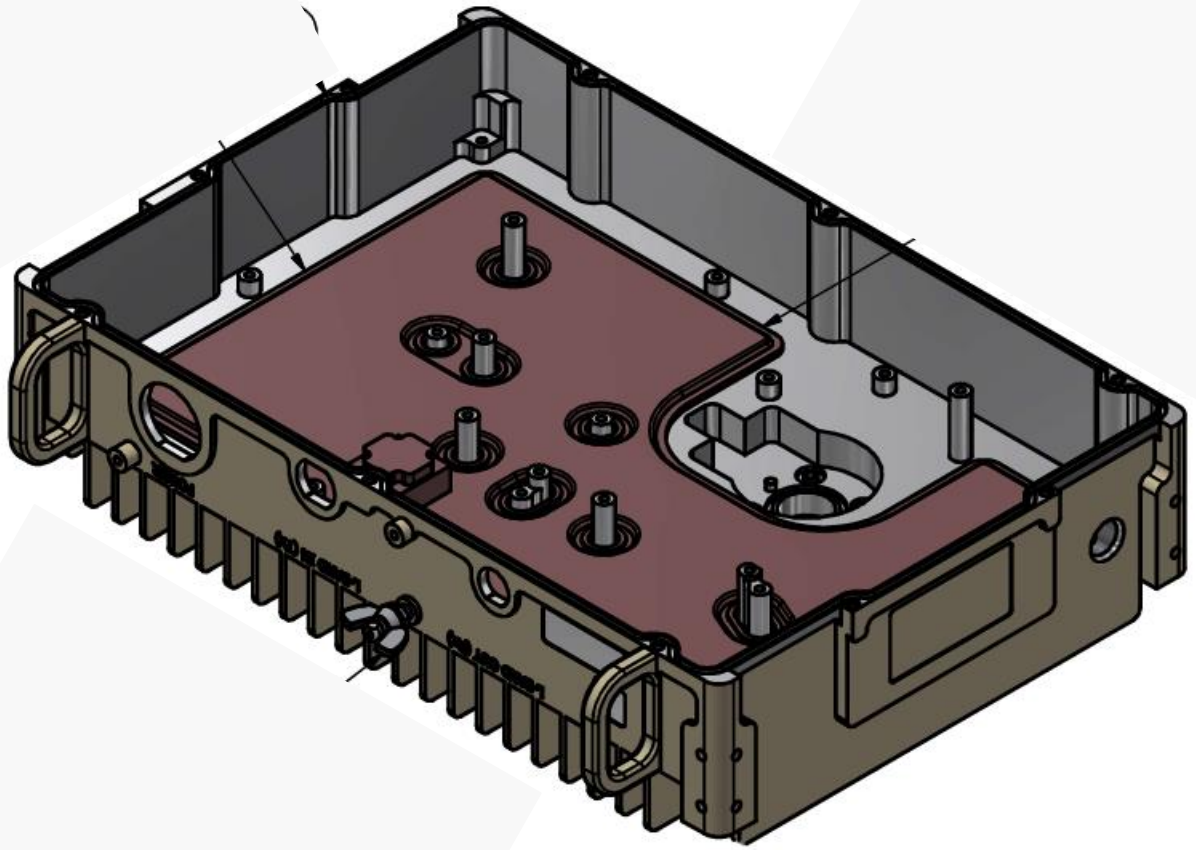
- Complex forging to reduce cost
  - Single-piece cold forging
  - Combination of deep base and pin-fin cooling
  - Initial forging to reduce milling time



Vapor chamber assembly

- Large format vapor chamber
  - Robust field application
  - Custom vapor chamber mounted in single-piece aluminum housing
  - Global supply chain (US / Asia)
  - In-house assembly and testing

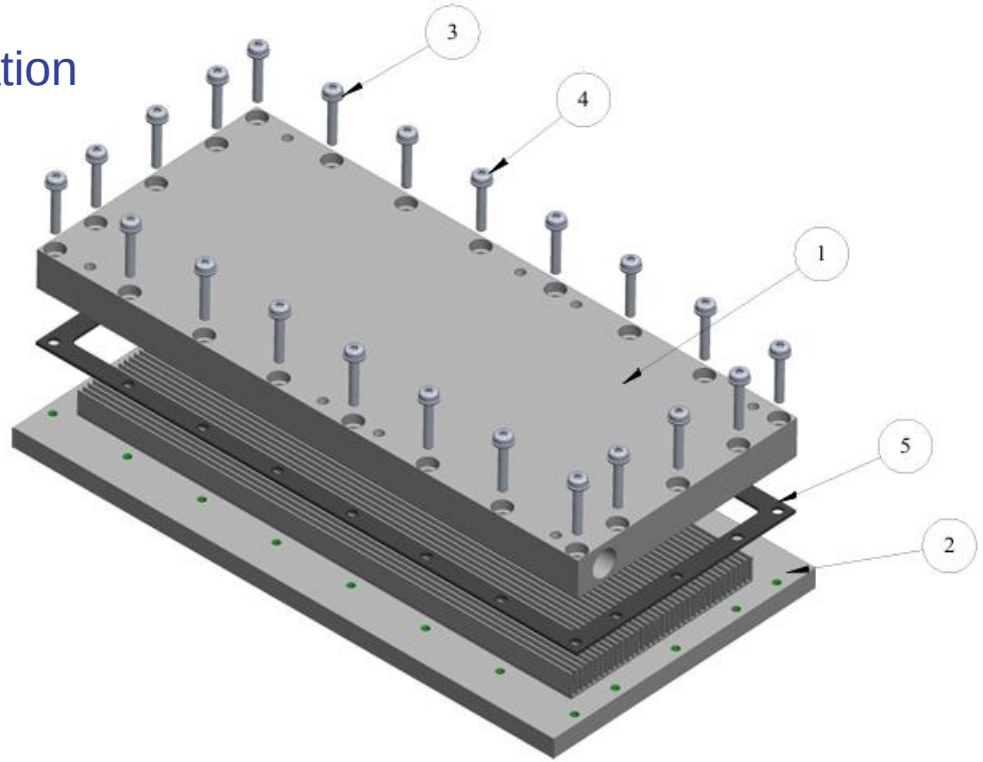
Vapor chamber assembly



Vapor chamber assembly

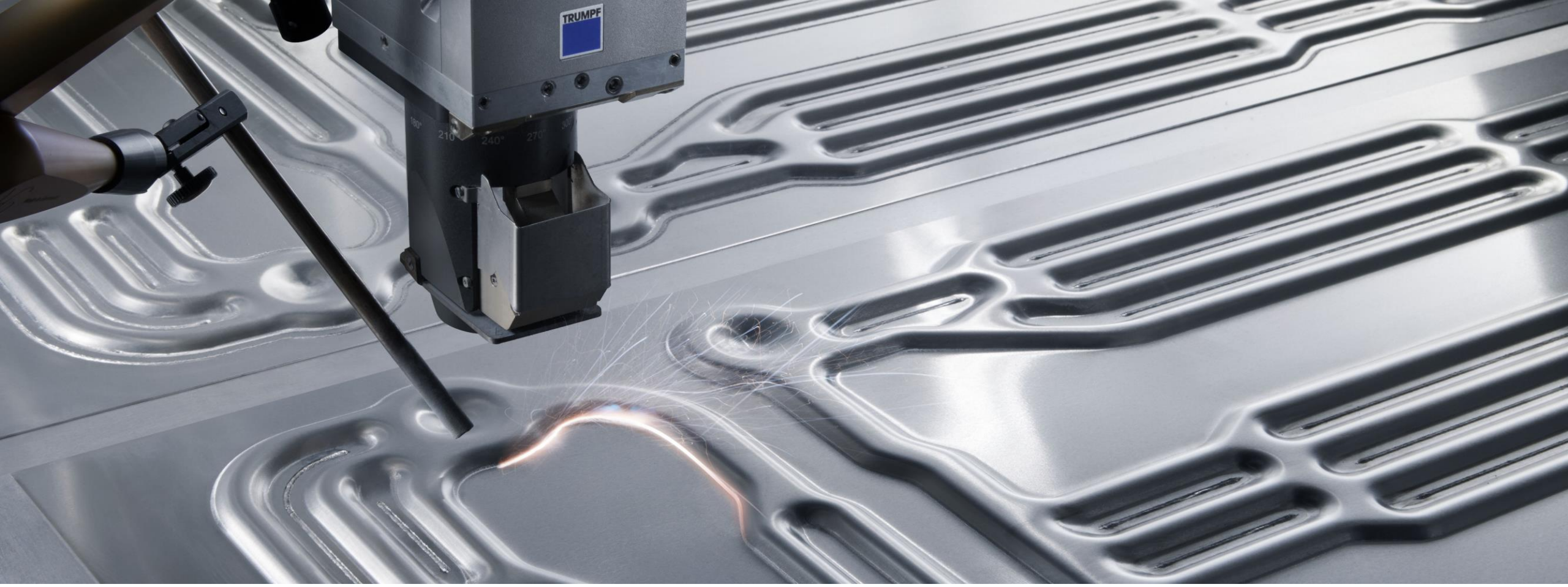
Cold-plate assembly

- Conventional approach
  - Gasket sealing
  - Extruded cooling plate
  - Relatively low-cost
  - Customer specification
  - Industrial equipment application



What we have learned

- Small company with global presence
- Large-company principles:
  - Quality control
  - Health and safety
  - Reliability
- “Western” innovation and low-cost manufacturing
- Broad range of in-house and third-party capabilities
  - Cold-forging and aluminum extrusions
  - Vapor chambers and heat pipes
  - Precision machining



Gaining an Edge in Cold Plate and Heat Sink Assembly

Industrial solutions for full scale aluminum (battery) cooling plates

TRUMPF Laser- und Systemtechnik SE
Industry Management Automotive | Battery Pack
Dipl.-Ing. Oliver Quirin, MBE

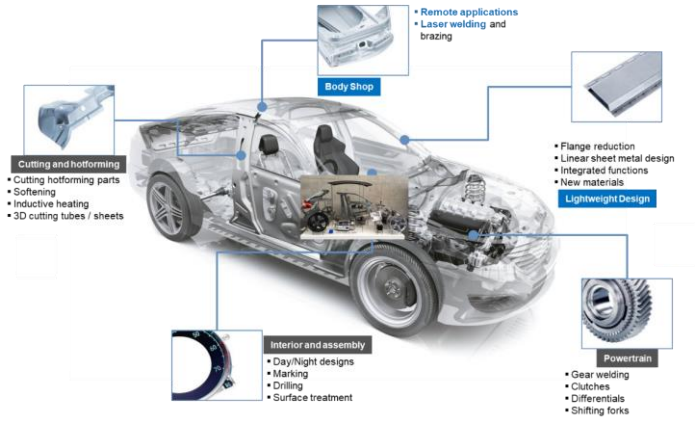
TRUMPF 100 1923 – 2023

Agenda

Introduction - Laser welding and battery cooling plates

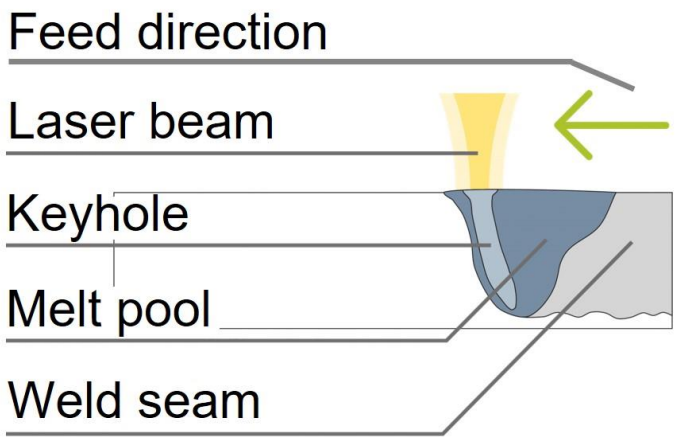
Established automotive process

1. Cutting with focus on hot-forming
2. (Remote) welding / brazing BIW
3. Powertrain welding
4. Interior application



Deep penetration welding

1. High intensity, multiple reflections
2. Metal vapour and multiple reflections open up a Keyhole
3. Common for joining steel & aluminum

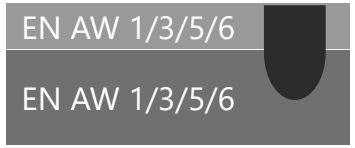


Mechanical requirements +

1. **Leak-tightness**
   - **partial penetration in thin sheets**
   - **not cracks and reduced pores**
   - **increased quality and testing**

Task: Formed (channels, dimples, fins) + flat sheet metal (base plate, tray)

Alloys: EN AW1xxx, AW3xxx, **AW5xxx** or AC6xxx[1], different steel grades,



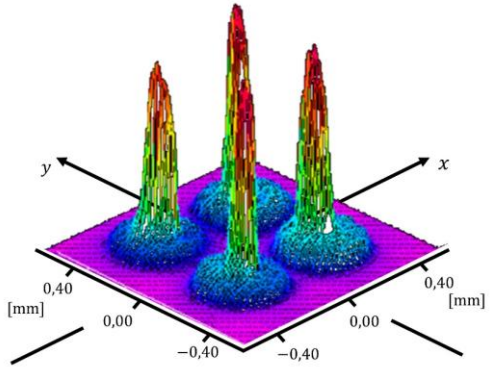
Emobility generates new requirements for laser welding, such as gas-tight aluminum welds

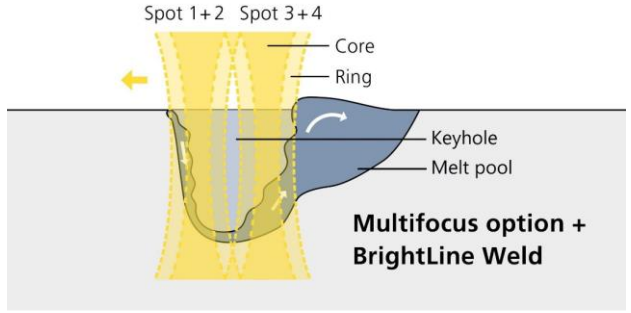
[1]Depending on the material combination -> avoiding material mixture compositions susceptible to hot cracking

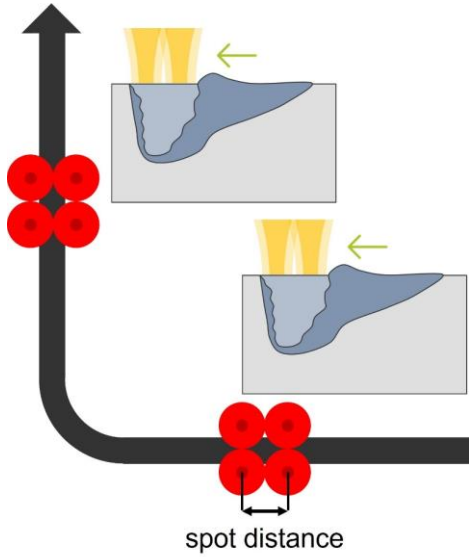
Solutions for aluminium leak-tight welding – patented approach

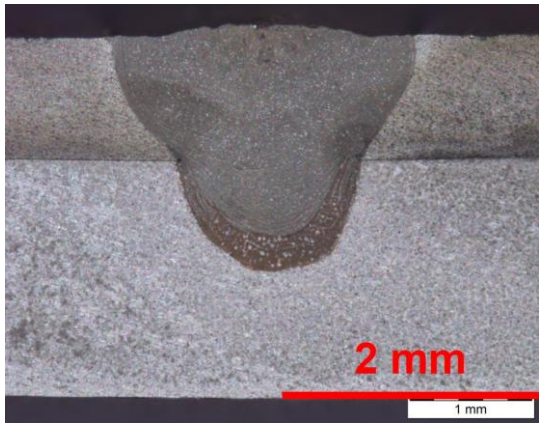
- **Patented Tailored beam shaping** approach
  - **4 focus points** in **combination with**
  - **BrightLine Weld technology**
- **Process stabilization** through large capillary opening **mitigates pores**
- **Lowest heat input & highest productivity** through focus design
- **Unidirectional** processing result
- High productivity with **feed rate >14m/min** on straight lines

Multifocus technology as enabling technology for gas-tight weld seams through pore mitigation





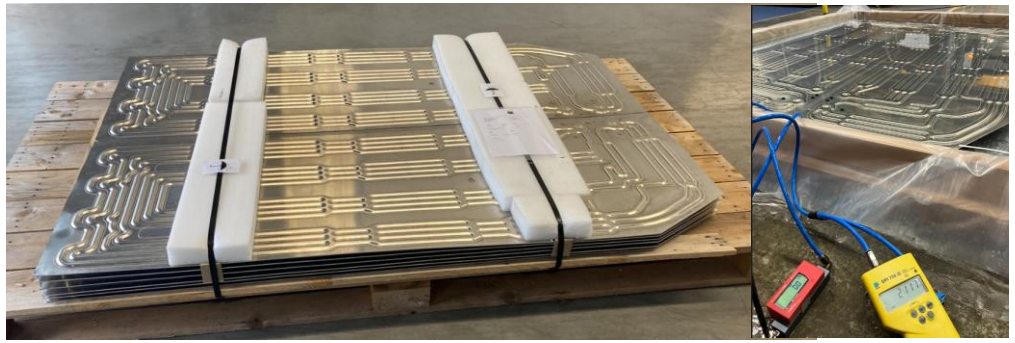




Industrialization progress & customer benefits

Full scale Laserwelded battery cooling plate

1. **TLC7040**, ~12-14m/min, ~11kW
2. **2x 1,5m, AA5754, 1-2mm**,
3. **12 of 12 leak tight** parts (<0,6ml/min @ 1bar)
4. **>100.000 cycles**, water 2,5bar
5. **5 – 8 bar** burst pressure
6. **no** corrosion[1]
7. distortion **(acceptable) w/o optimization**



USP's compared to competitor technologies

USP structural materials that can't be brazed

USP no flux, no filler material = no corrosion[1]

USP scalable with demand (customer request)

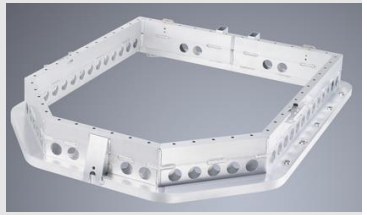
USP weld functional parts to cooling plate

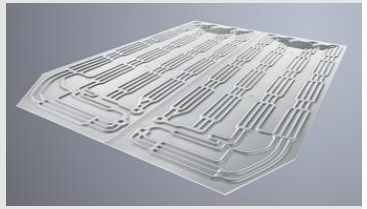
USP Integration of structural cooling plates to

- replace floor panel, reduce crossbeams
- "sandwich" cooling of battery cells

Cost savings

⊕
- Lower footprint and less energy**
- -20% for mono material
- high OK rate and rework is possible
- No additional cutting step / costs necessary

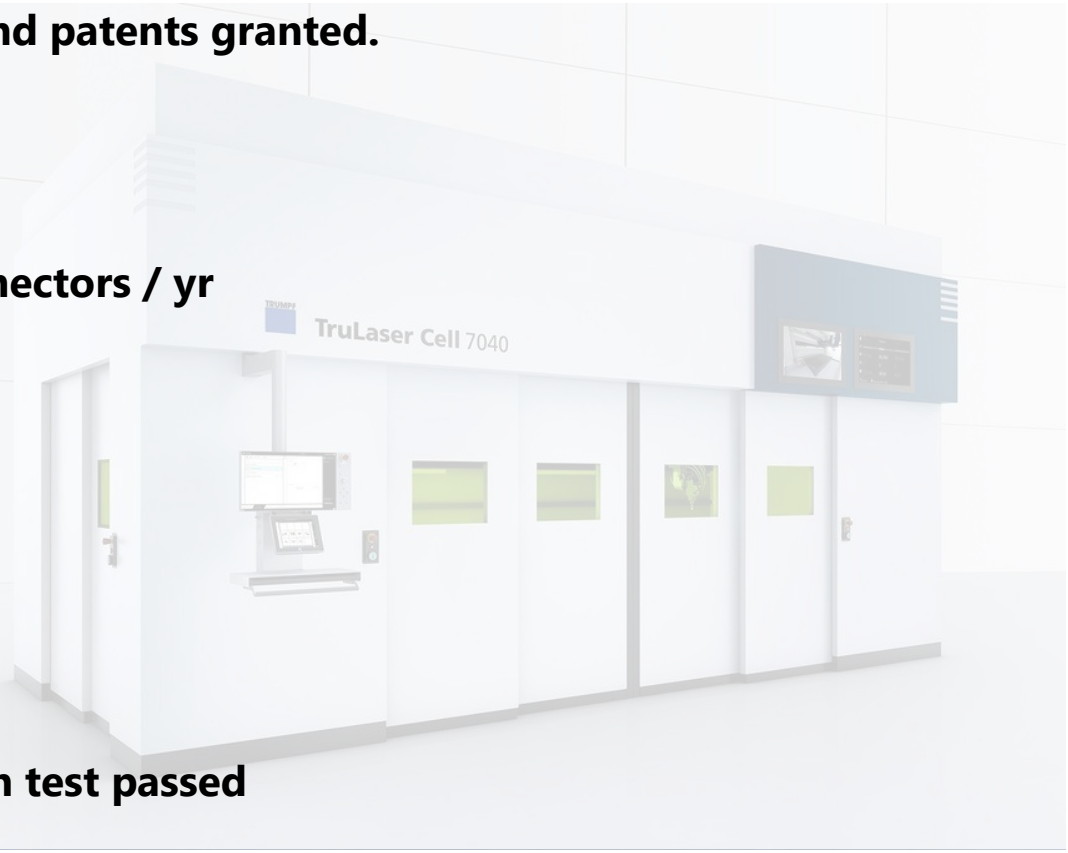




[1]Needs to be confirmed with application specific material combination
** Compared to conventional CAB process

Series Applications – Breakthrough to large parts

Development of leak-tight aluminum laser welding	Technology development finished and patents granted. Start of customer projects
Customer 1: welding of cooling plate connectors	Series production of ~ 0,2 Mio. connectors / yr
Customer 2: welding of small leak tight cooling plates	Series production of 1 Mio. pcs./yr
Customer 3: welding small cooling plates to large assembly	Series production of ~0,9 Mio. parts
2x1,5m laserwelded cooling plate	Tightness, cyclic, burst and corrosion test passed



TRUMPF aproach is used for all process steps of series leak-tight cooling plates

Summary and outlook – Our know how and offering

Application video

Our offering

- Industry proven machines for lab and series production
- Cycle time studies based on your CAD data
- Application consultancy and basic weld trials
- Full scale cooling plates LAC trials from Q4/2024 on
- First prototypes and partners for larger quantities

We are looking forward to qualify your small to large battery cooling plate application in our lab

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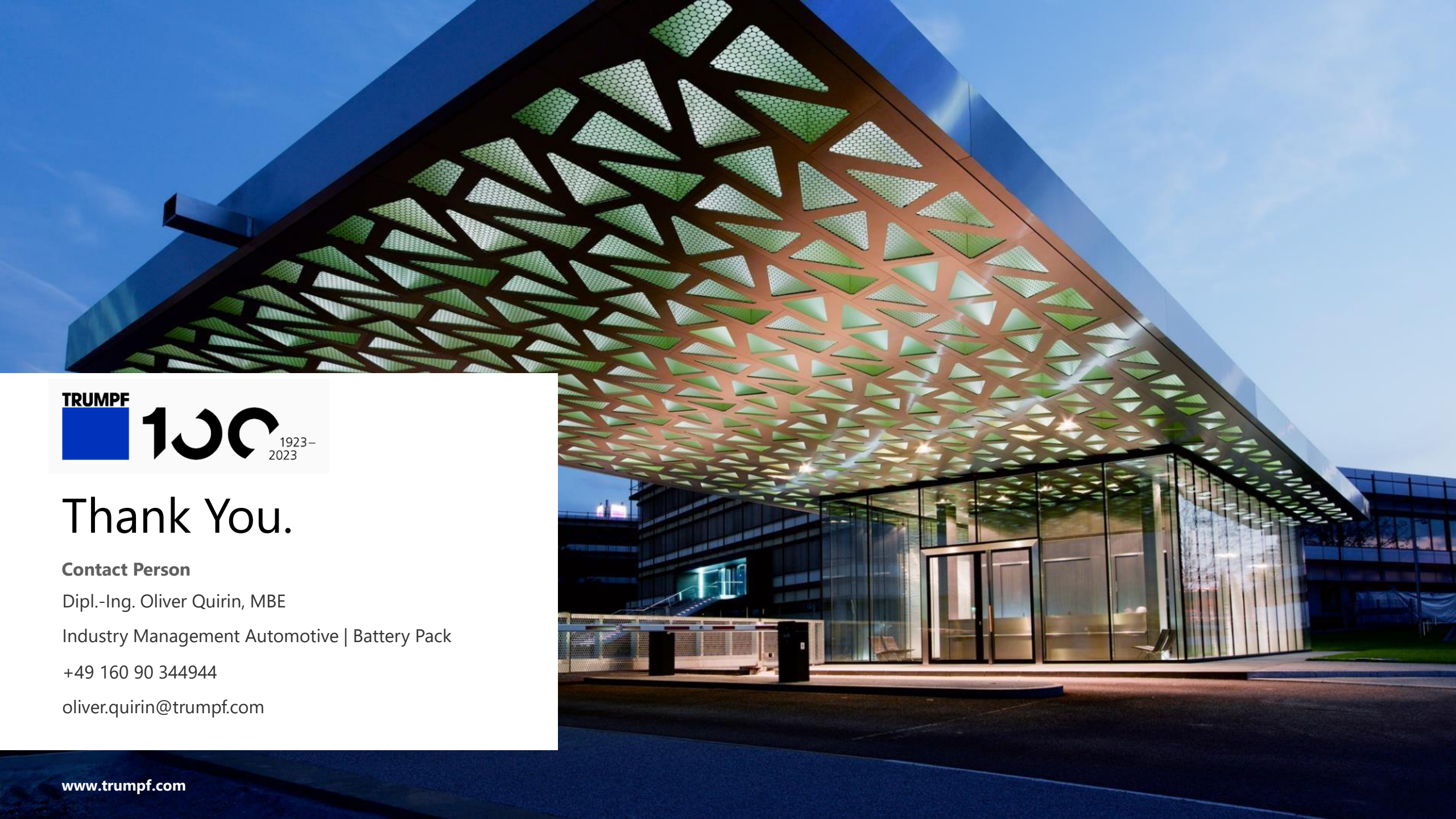

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Thank You.

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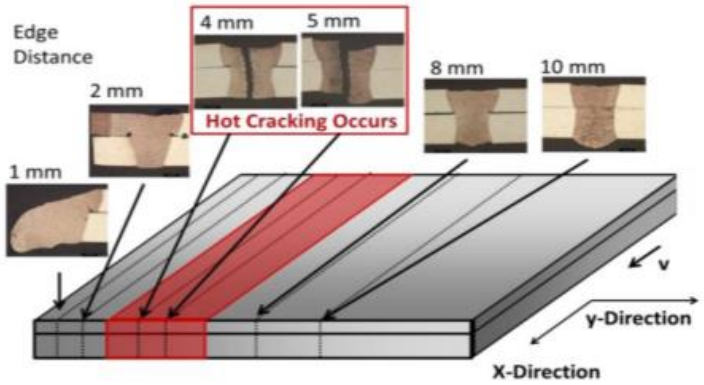
Solutions for aluminium leak-tight welding - influence factors

Influencing factors on gas tightness

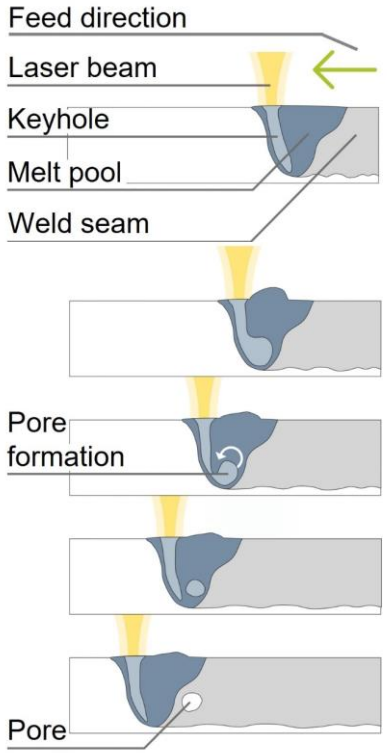
1. Used alloy and quality of the **material** (inherent pores, crack sensitive alloy, viscosity, etc.)
2. Technical **cleanliness** of surfaces
3. **Clamping** situation and missing filler material
4. Higher **process dynamics** of typical e-mobility alloys (aluminum, copper, etc.)

Design / material leads to cracks



Quelle: IFSW-Stuttgart

Collapsing keyhole locks in pores



Material, quality, design and processing can lead to cracks and pores (=leakages)

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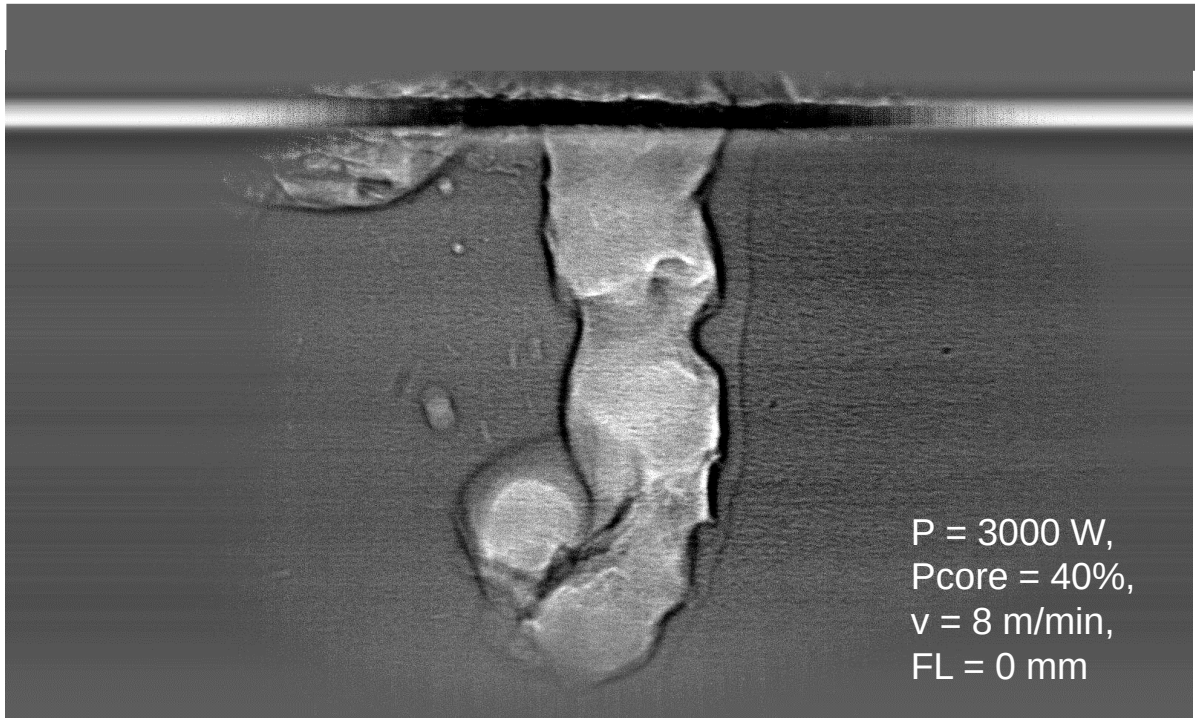
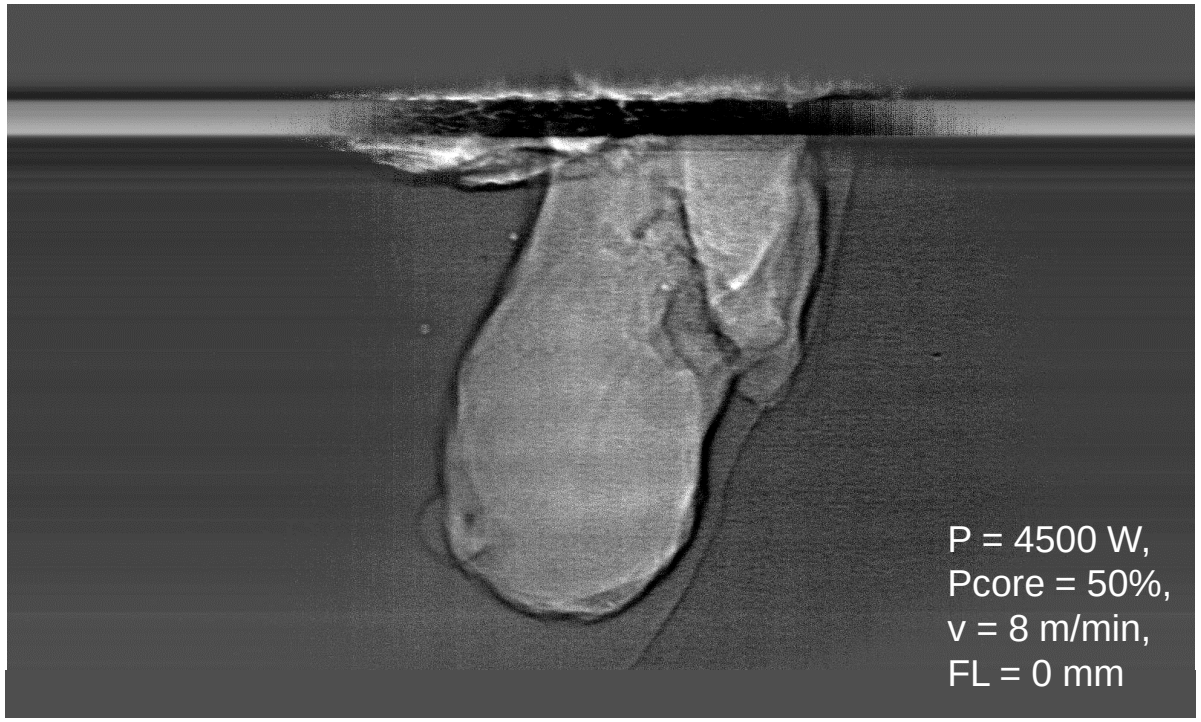
Solutions for aluminium leak-tight welding – analysis

Single Spot BLW	Multifocus BLW
	
P = 3000 W, Pcore = 40%, v = 8 m/min, FL = 0 mm	P = 4500 W, Pcore = 50%, v = 8 m/min, FL = 0 mm

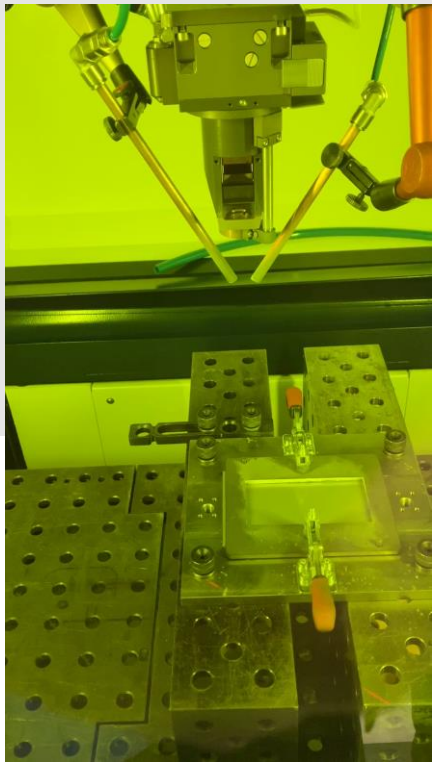
Synchrotron X-raying allows detailed analysis of process dynamics

Industrialization progress – last steps for large series parts

What happens now – small sample / demonstrator

1. **Develop series gas nozzle**
- ✓ Material influence on tightness
- ✓ Increase process productivity
- ✓ Improve cyclic loads
- ✓ Quality Assurance approach

14m / min, ~11kW

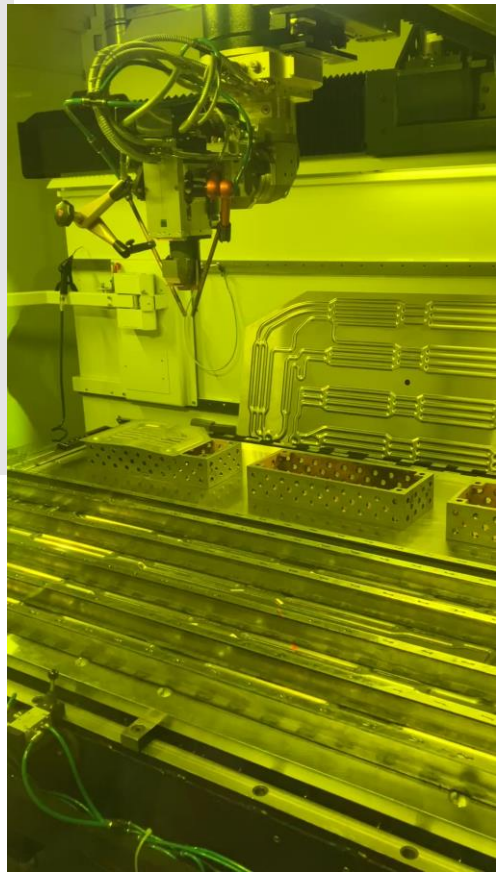


What happens now – real scale cooling plate

- ✓ Transfer results on large scale
- ✓ Improve welding strategies
- ✓ Increase productivity
- ✓ Assess rework approaches
- ✓ Proof of concept for clamping solution

5. **Prototyping for OEM end customer**

12-14m / min, ~11kW



Final steps for industrialization of large cooling plates and solution package

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Material combination - Medium tight weld seam for die-casted Al

MultiFocus Optic (MFO)

General information

Cover material

- Aluminum wrought alloy
- Al1xxx, Al3xxx, Al5xxx, Al6xxx
- Thickness t = 1 – 4 mm

Housing material

- Hypoeutectic AlSi with Si < 12% (e.g. AlSi10, AlSi12)
- Cu content < 3% due to corrosion
- Wall thickness: t = 1 – 4 mm

Preferable joint configuration

- Butt joint
- Overlap joint

Material combination

Die-casted Al housing

Cover lid	AlSi10	AlSi11	AlSi12
Al1060		✓	
Al5052		✓	
Al5754	✓		
Al6061	✓		
Al6063		✓	
Al6082	✓		✓

**Quality checklist

- Good quality of die-casted Al
- Weld zone with low contamination and porosity
- Dry milled surface of weld zone
- Max. gap tolerance 0.3 mm (Butt joint)

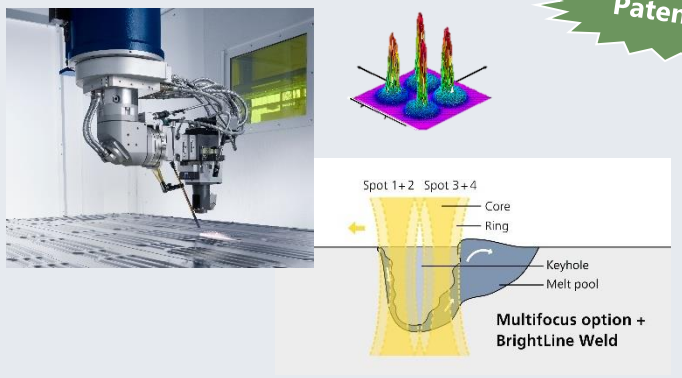
✓ Tested materials combination with MFO **but** the medium tightness of the weld seam is strongly influenced by the quality** of the casted Al housing

Summary and outlook – TRUMPF Solution portfolio

Laser welding as a suitable solution to face these challenges!

TRUMPF Solution Portfolio enables a successful gas-tight welding process

Patented



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Patented

Multifocus & BrightLine Weld

- Special beam shaping creates wide-open keyhole
  - Process stability w/ less weld defect
  - Larger weld interfaces
- Directional independence using four partial beams

TruLaser Cell 7040

- Highly dynamic 5-axis machine kinematics
- Proven reliability & quality in high-volume series product
- TRUMPF Turn-key solution

New Vacuum fixture concept

- Fast & reliable clamping
- Technical zero gap over the entire part size
- Secure clamping without interfering contours

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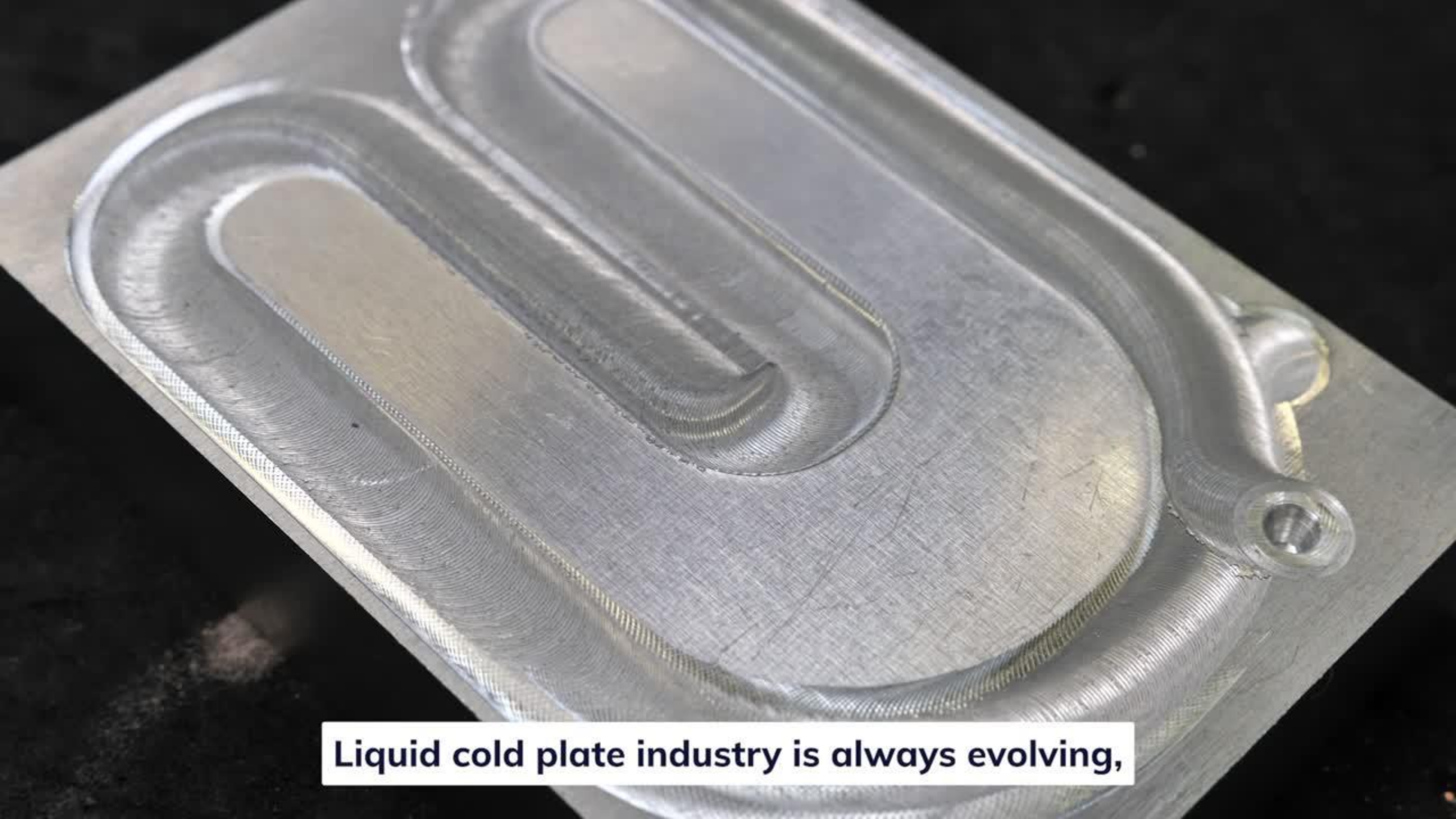
FRICTION STIR WELDING:

A GAME CHANGER FOR THERMAL EFFICIENCY AND COST REDUCTION OF LIQUID COLD PLATES


Liquid cold plate industry is always evolving,

LIQUID COLD PLATE MARKET CHALLENGE?

-> Small batch size from a few to 200 parts only

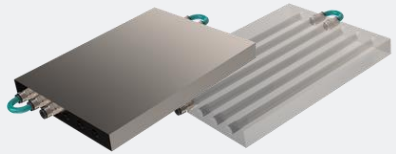
-> Very wide range of design

-> Need of a flexible and cost killer production solution

FSW is the answer

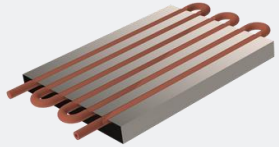
Space | Aeronautics | Data center | Defense | Solar energy | Wind energy | Rail

FSW IS MORE COST-EFFECTIVE THAN TRADITIONAL ASSEMBLY TECHNIQUES



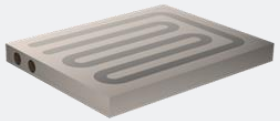
GUN DRILLING

- ✗ Design restrictions limiting cooling surface by forcing liquid paths to be straight lines.
- ✗ Accuracy and consistency issues over 500mm-length.
- ✗ Vulnerability at the connectors making them highly suseptible to leakage issues.



COPPER TUBING COLD PLATE

- ✗ Difficult to achieve high channel density due to limited cooling performance.
- ✗ A lot of manufacturing steps : costly and time consuming.

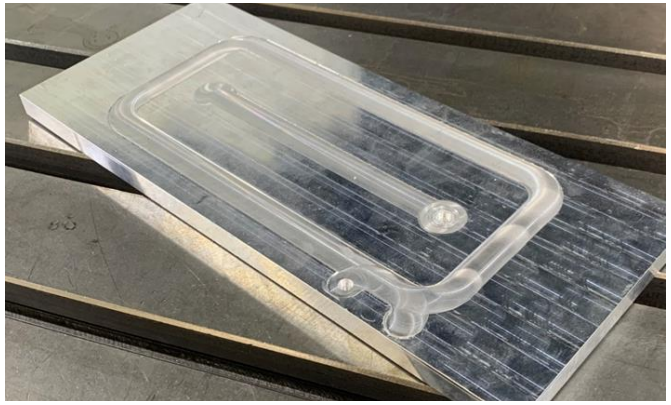


FSW COLD PLATE

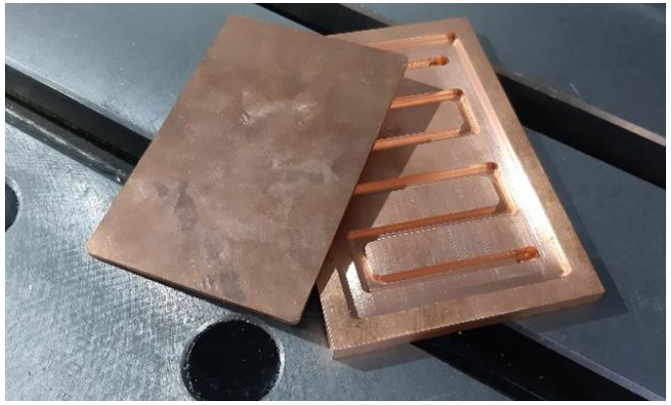
- ✓ Eliminates the need for welding between the tube and end connectors (manifold).
- ✓ End connectors are directly machined into the housing, streamlining production.
- ✓ Free channel design for optimum thermal management
- ✓ FSW offers the versatility to create more complex cooling paths, handles long plates with ease, and establishes secure, leak-proof connectors, thereby delivering a more reliable and effective cooling solution.

DIVERSITY OF COLD PLATE DESIGN WITH FSW

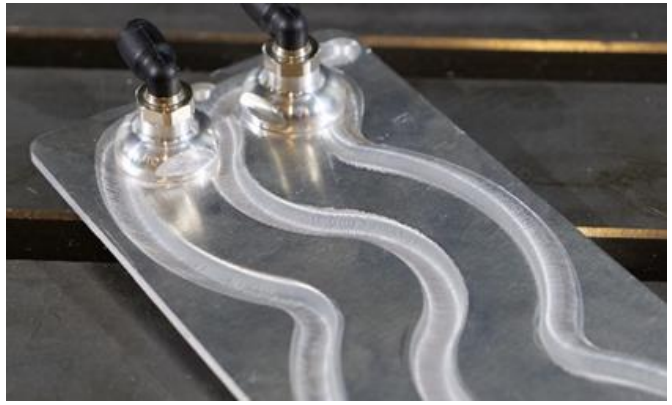
Standard Liquid Cold Plate



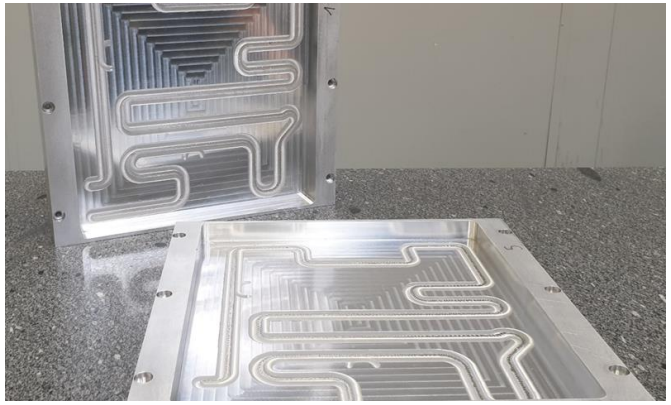
Copper Liquid Cold Plate



Thin Liquid Cold Plate

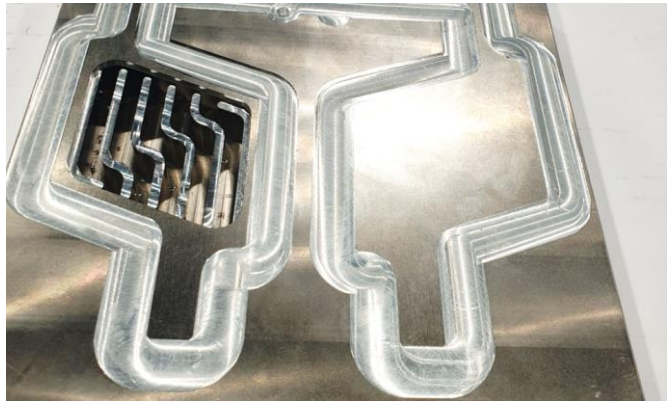


Large Liquid Cold Plate



Cylindrical Liquid Cold Plate

Ni-Coated Liquid Cold Plate



WHO ARE WE?

OUR FACILITIES

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Scan to discover more about Stirweld

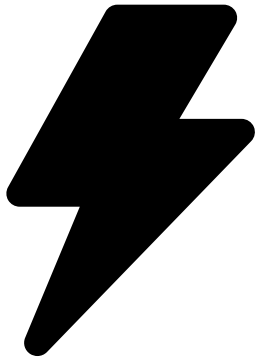
Leveraging generative design to maximize flexibility and performance

Gaining an Edge in Cold Plate and Heat Sink Assembly

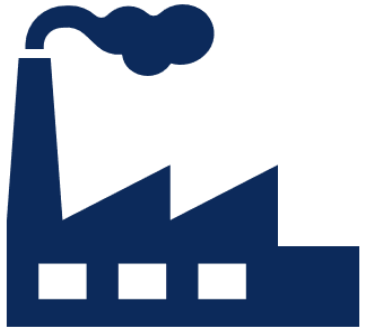
Dr. Lieven Vervecken

CEO

Design considerations



Maximize power density

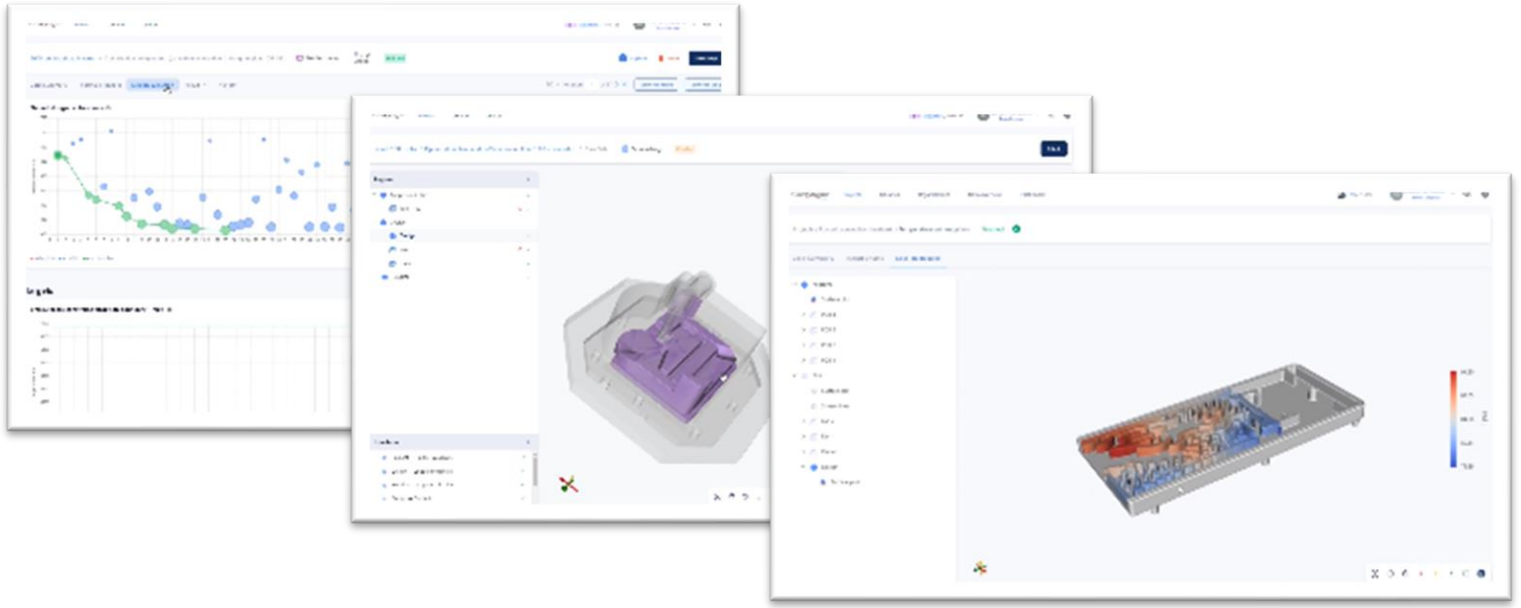


Manufacturing

Minimize cycle time

The #1 generative design platform for cooling design

ColdStream



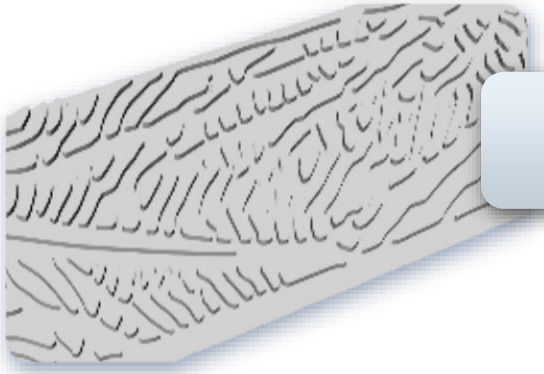
Ultimate workflow efficiency

SaaS solution

99% of cooling applications supported

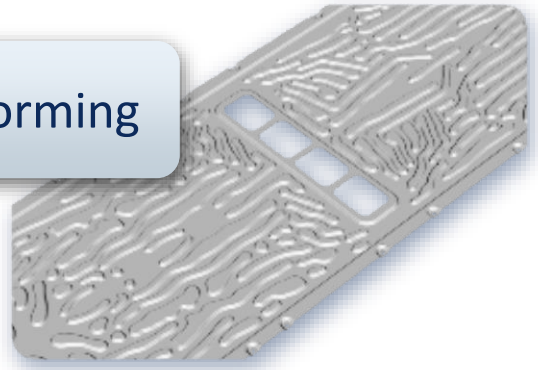
Democratizing technology

Limitless Design Freedom for Optimal Design



Machining

Sheet metal forming

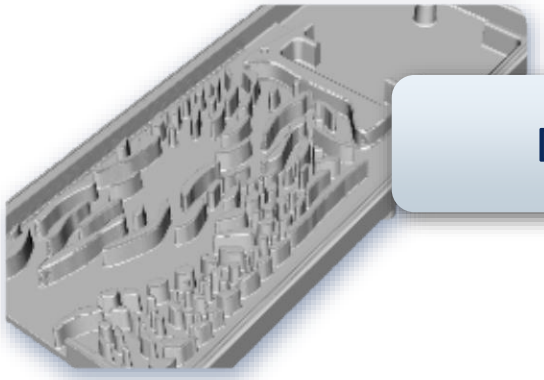


Stamping

Skiving

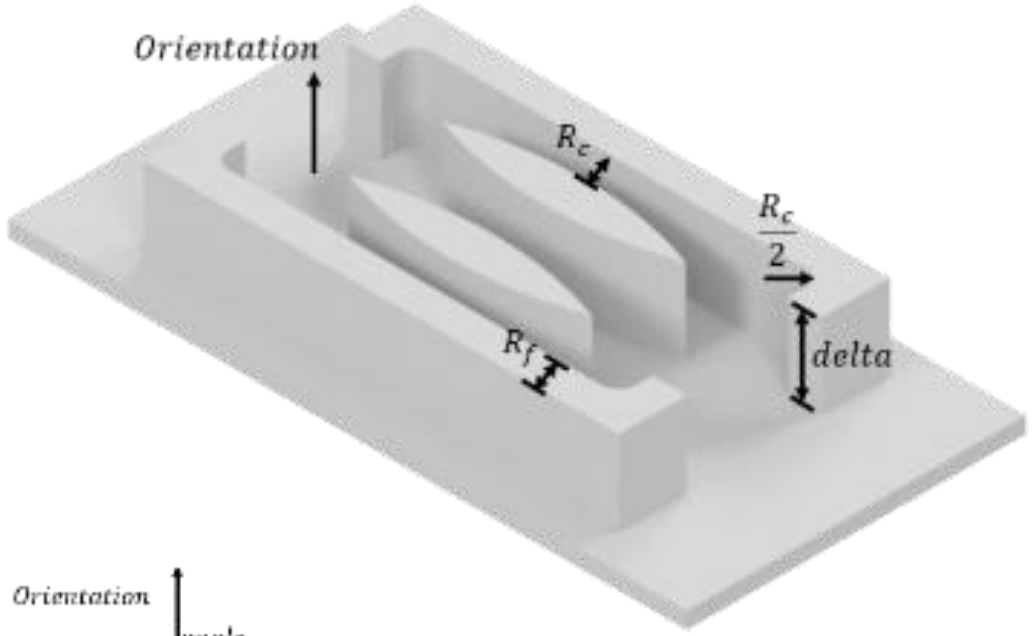
Roll-bonding

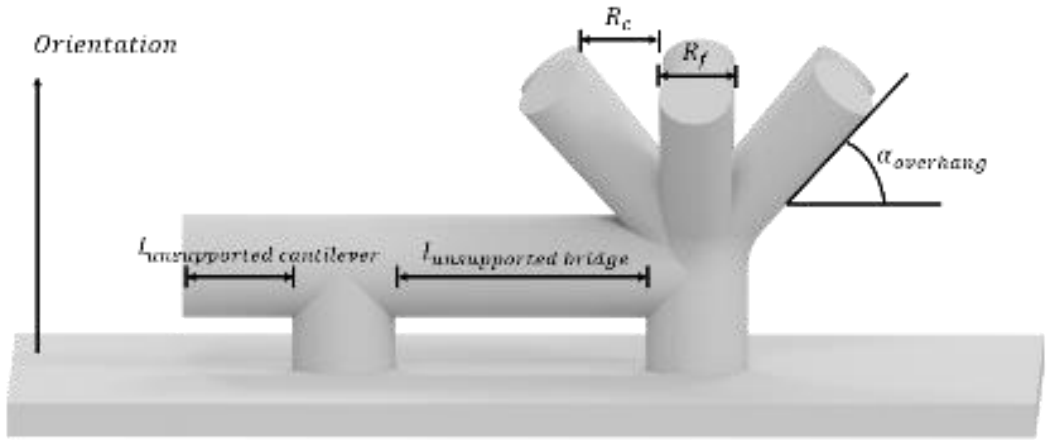
Injection molding

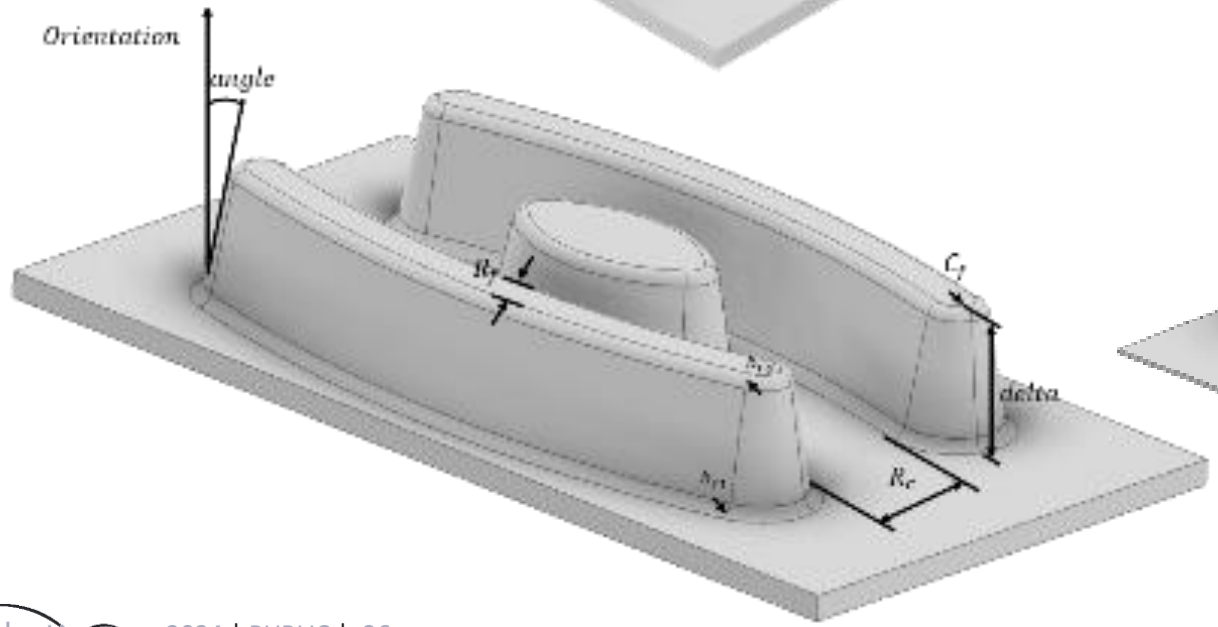


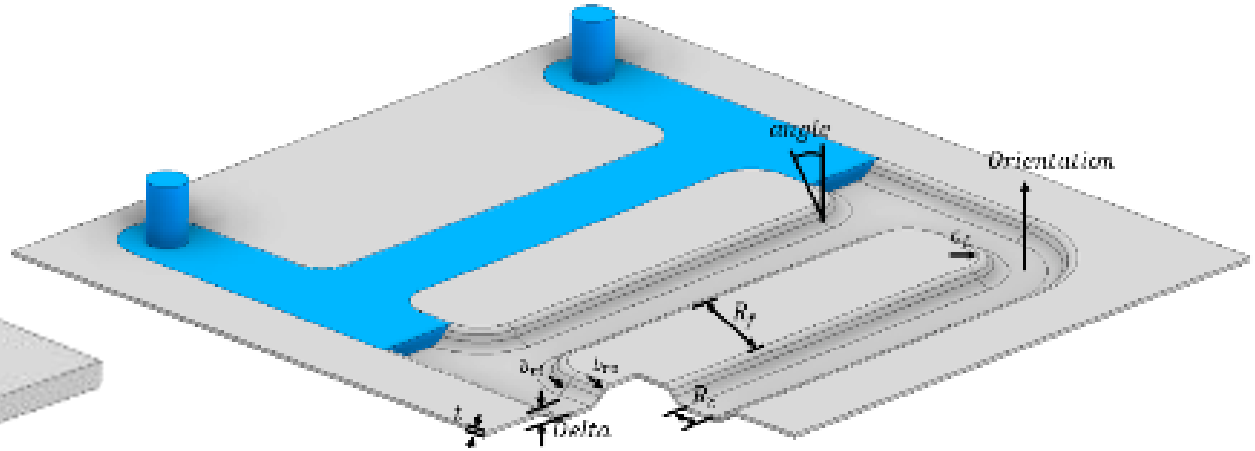
Die casting

3D printing


Orientation
R_c
$\frac{R_c}{2}$
R_f
delta

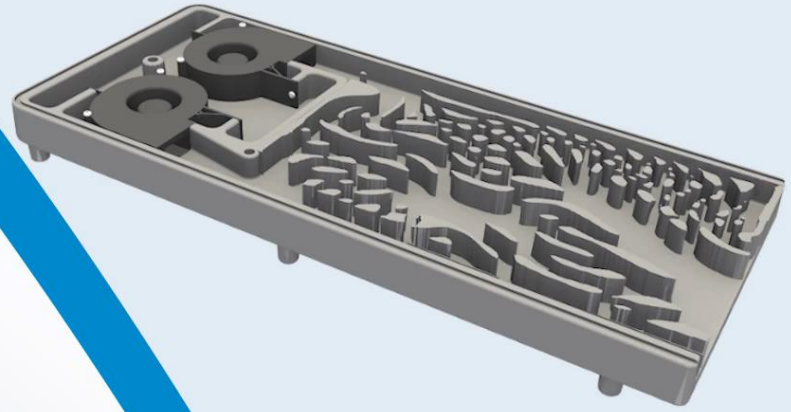

Orientation
R_c
R_f
$\alpha_{overhang}$
$l_{unsupported\ cantilever}$
$l_{unsupported\ bridge}$

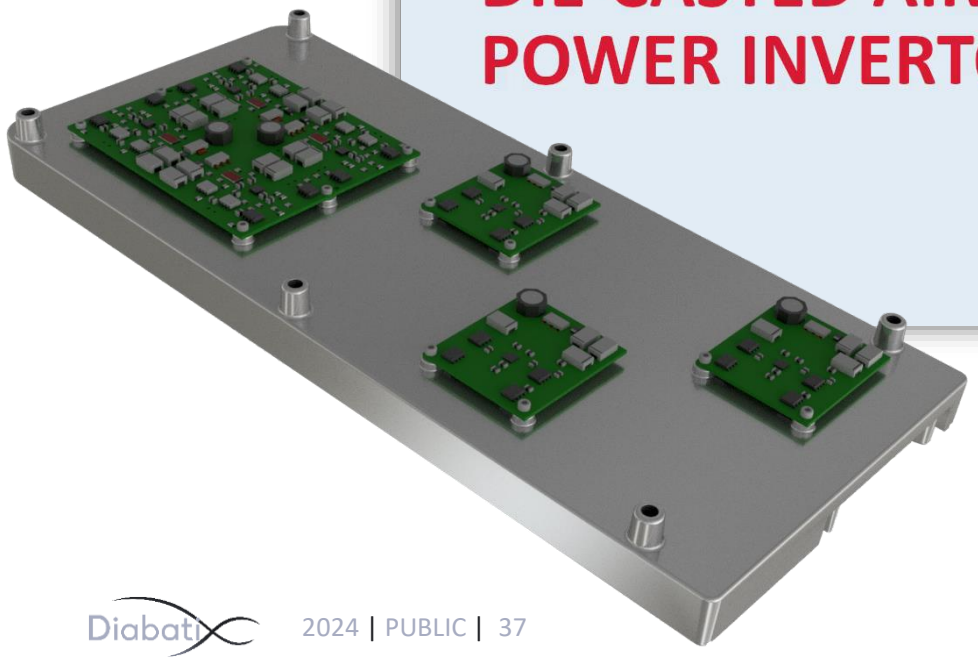

Orientation
angle
R_f
C_f
delta
R_c

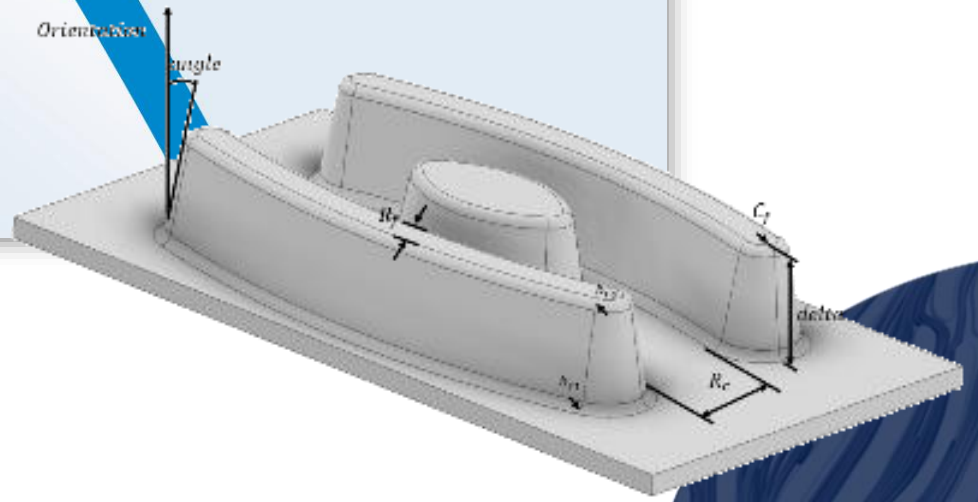

angle
Orientation
R_f
R_c
Delta

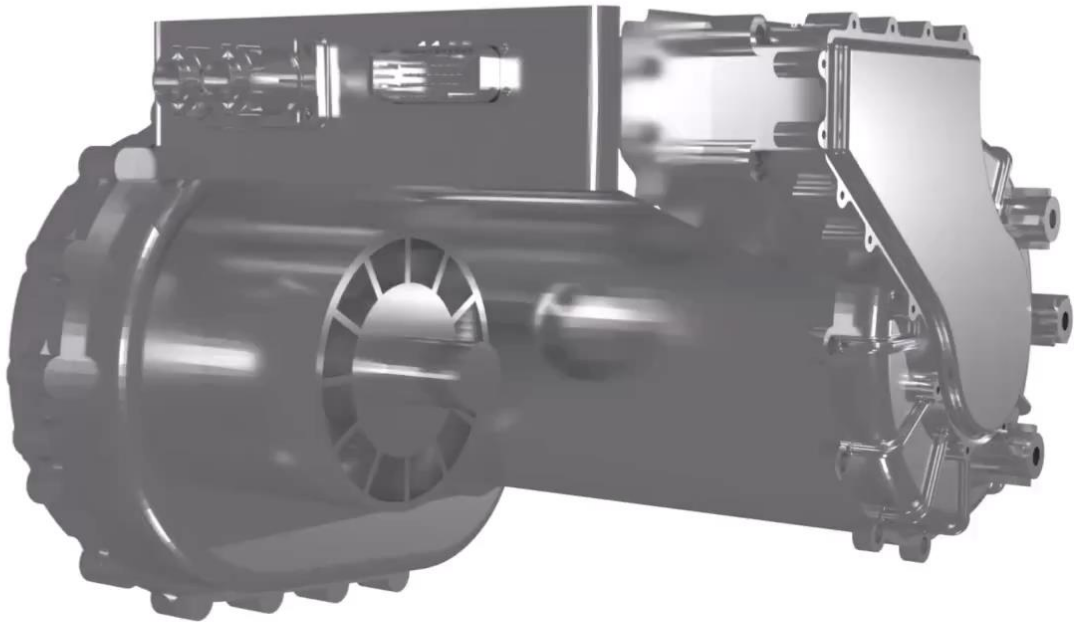
GENERATIVE DESIGN

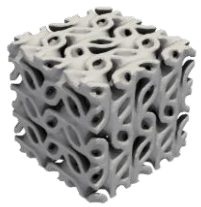
DIE-CASTED AIR COOLED POWER INVERTOR

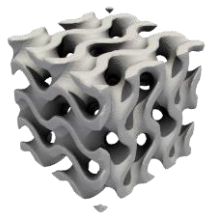


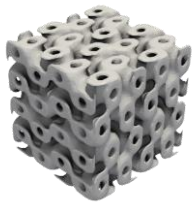


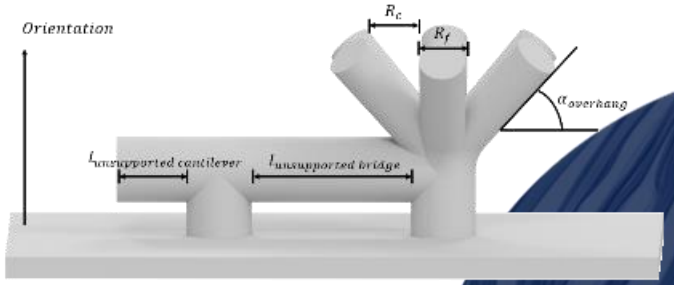






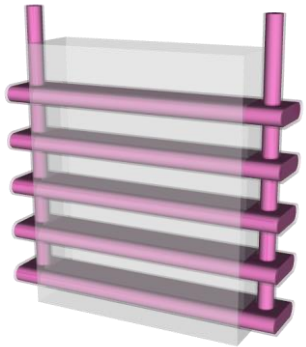





Orientation
R_c
R_f
$\alpha_{overhang}$
$L_{unsupported\ cantilever}$
$L_{unsupported\ bridge}$

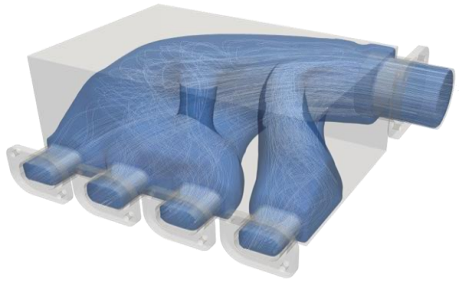
Broad Range of Applications

Air Cooled Electronics



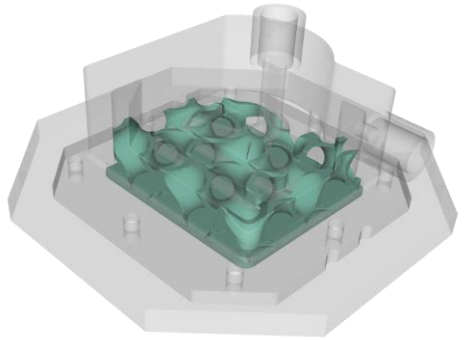
Heat Exchangers

Battery Cooling



Flow Optimization

E-motor Cooling



CPU Cooling

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