# Cost efficient manufacturing of bipolar plates

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Kimi He, Jan Jonasson, AP&T AB

# Edison did not invent the lightbulb through continuous improvement of the candle

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**Can continuous improvement of the diesel engine lead to a clean environment? NO!**

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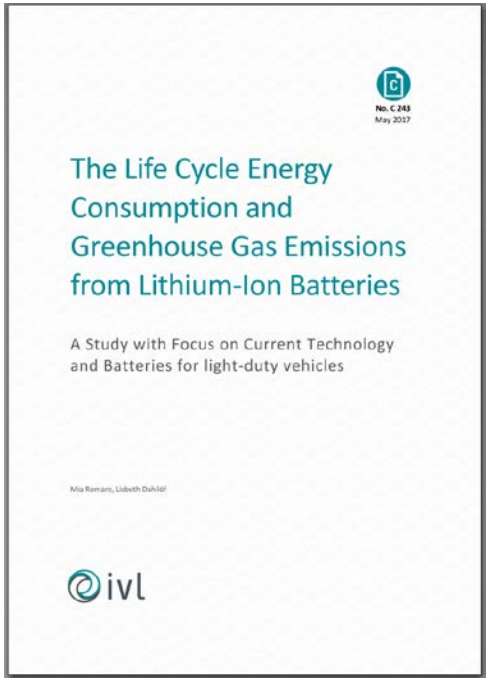
# Can battery-electric cars be the solution? NO!




**The $CO_2$ emissions from manufacturing of the batteries for a Tesla with 100 kW battery pack is the equivalent of driving 8 years with a normal car**

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# We need: a disruptive change for a sustainable future – fuel cells

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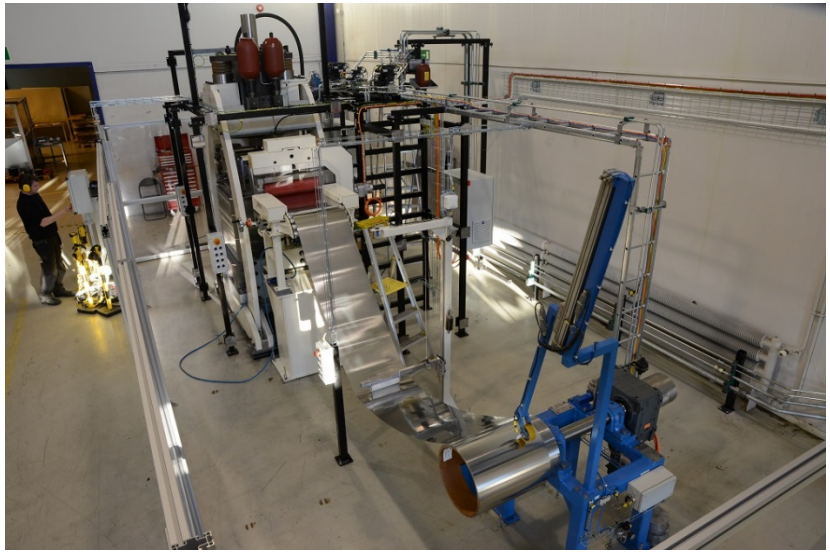
# Bipolar plates for fuel cells – conventional or disruptive?



**High-speed forming:**
**a disruptive way to manufacture bipolar plates – extremely energy efficient: less than 0.1 kWh/BPP**

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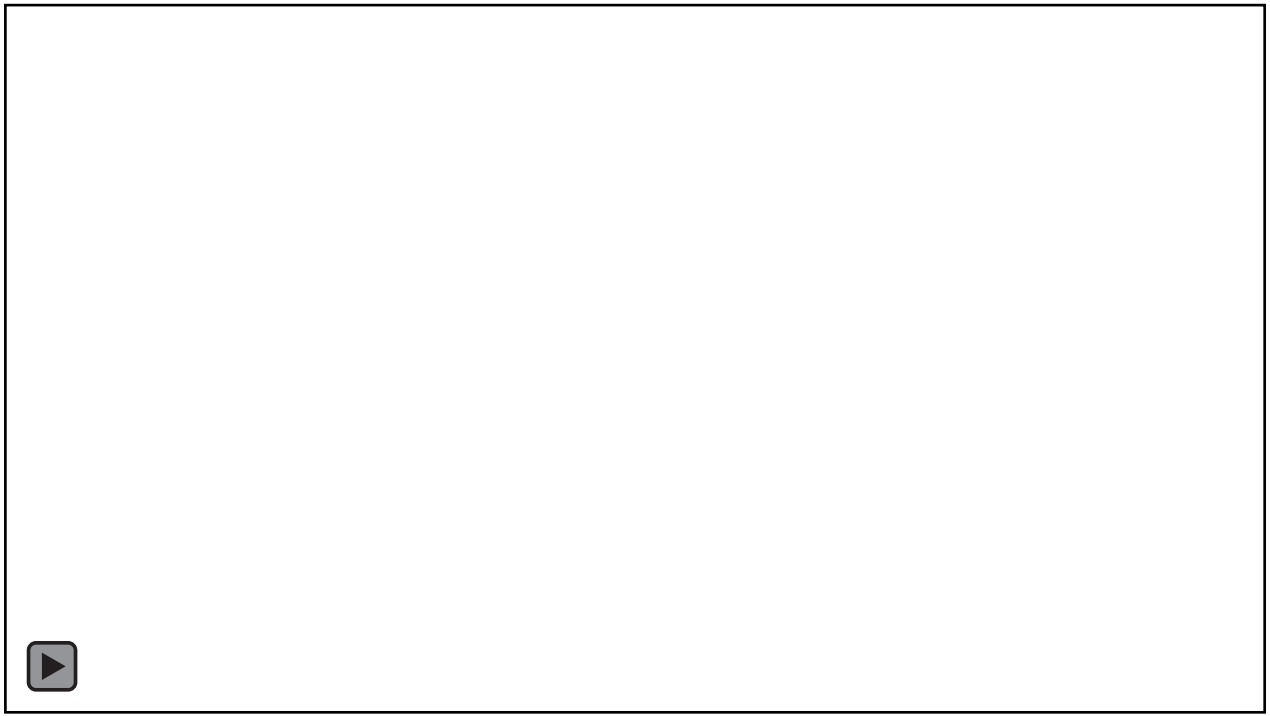
# Line for high-speed forming



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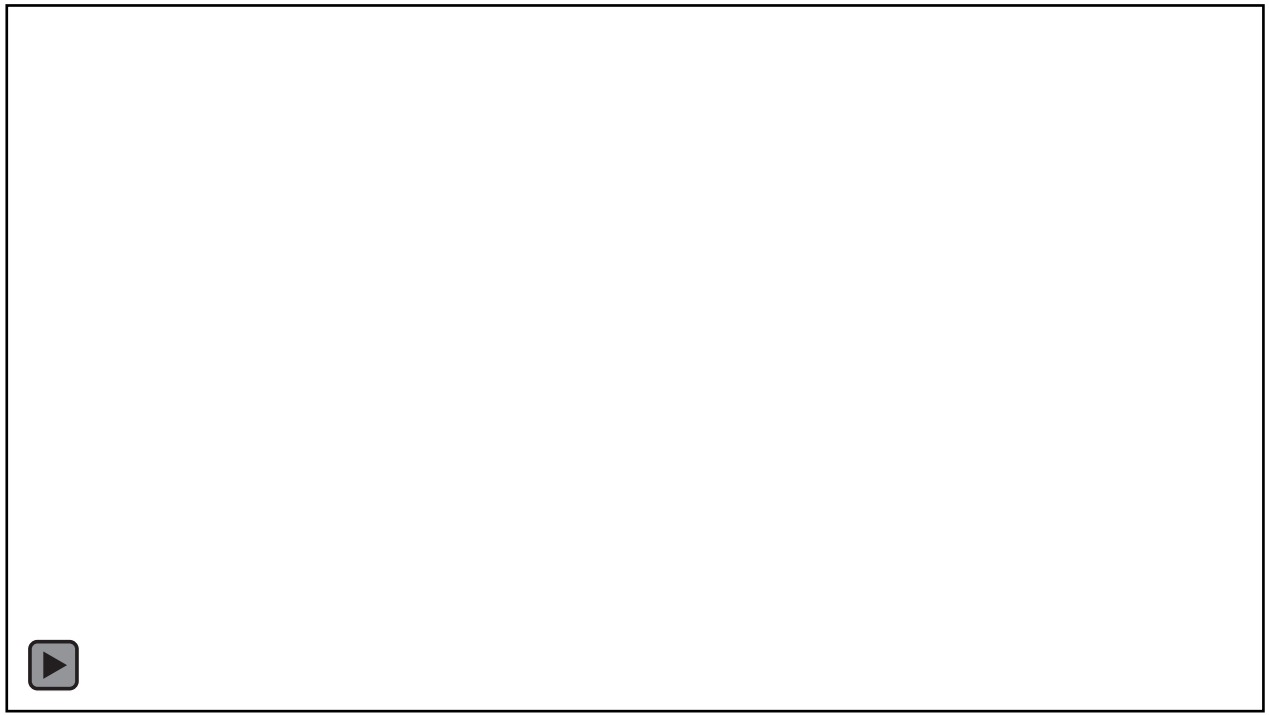
# Line for high-speed forming



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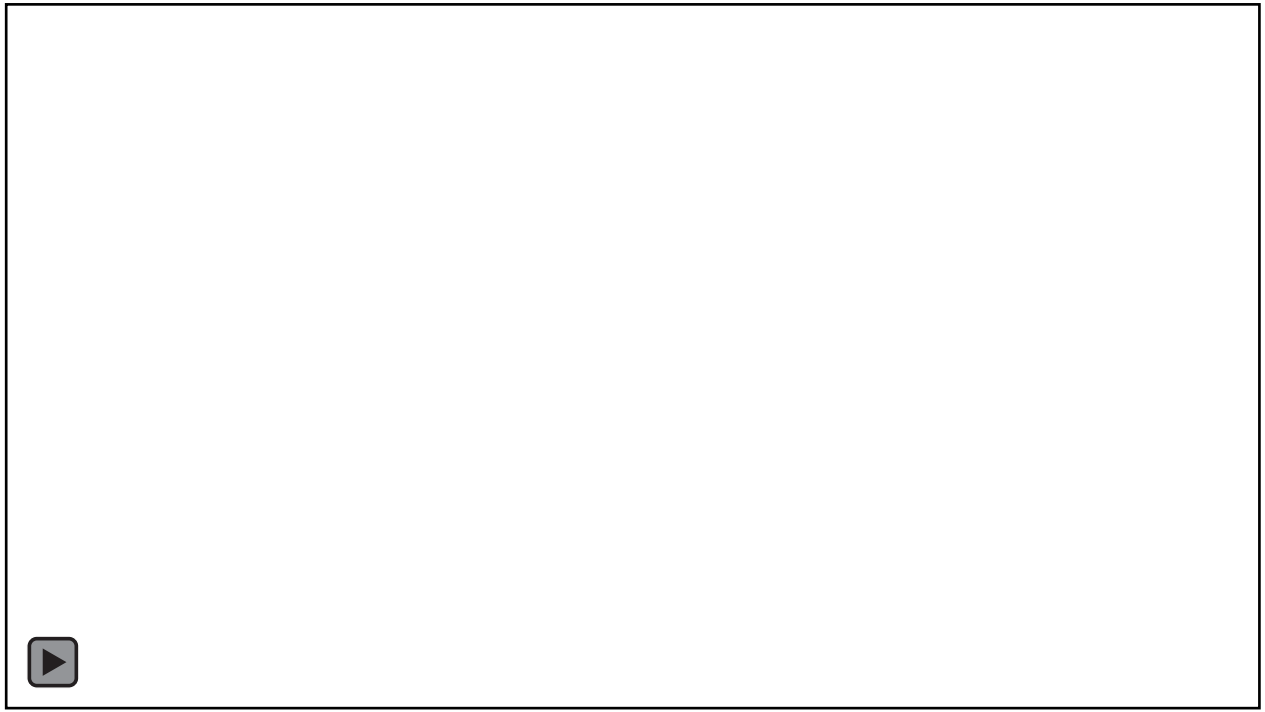
# Line for high-speed forming



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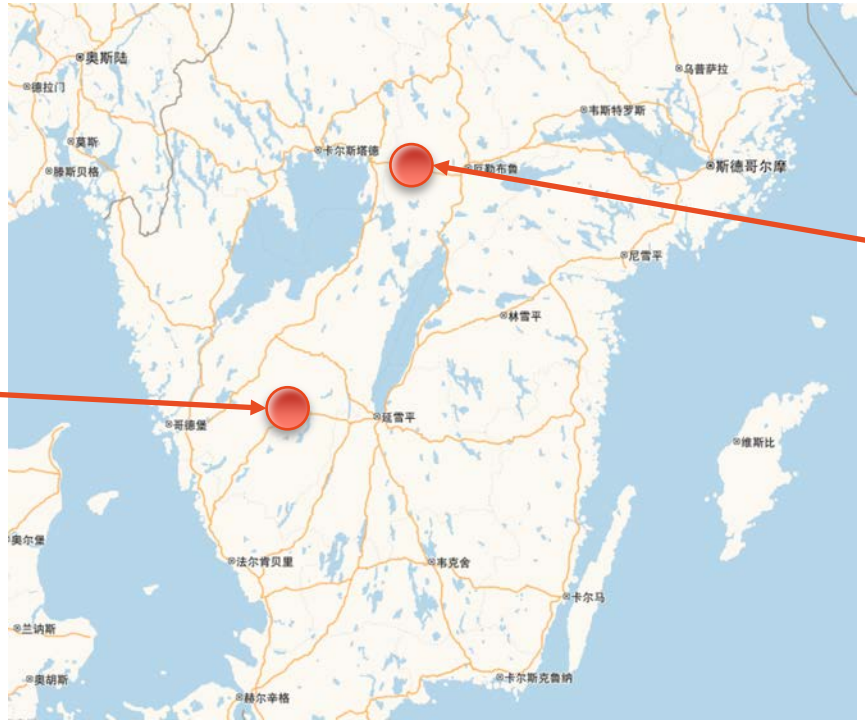
# AP&T and Cell Impact – advanced technology from Sweden




**Cell Impact**

**AP&T**

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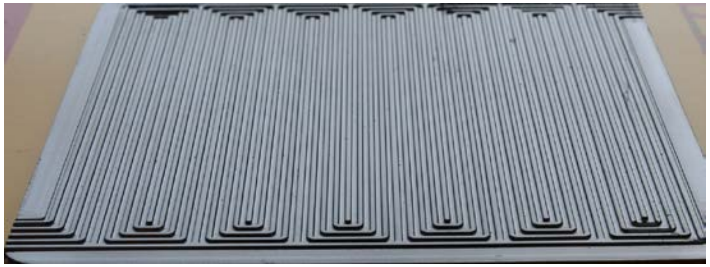
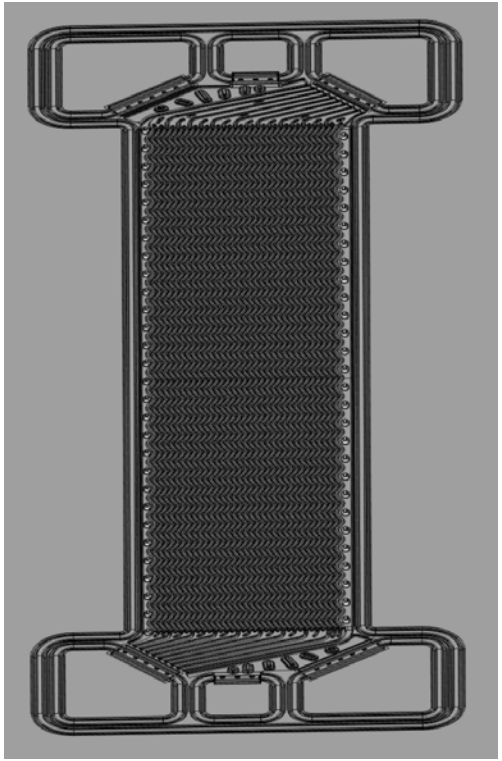
# About Cell Impact

Cell Impact can with the unique high-speed presses offer everything from design studies, through prototypes and small series production to manufacturing equipment including service and support for bipolar plates from sheet or powder.





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# About AP&T

- AP&T provides sheet metal industries worldwide with complete production systems as well as with stand-alone presses, automation and tooling.

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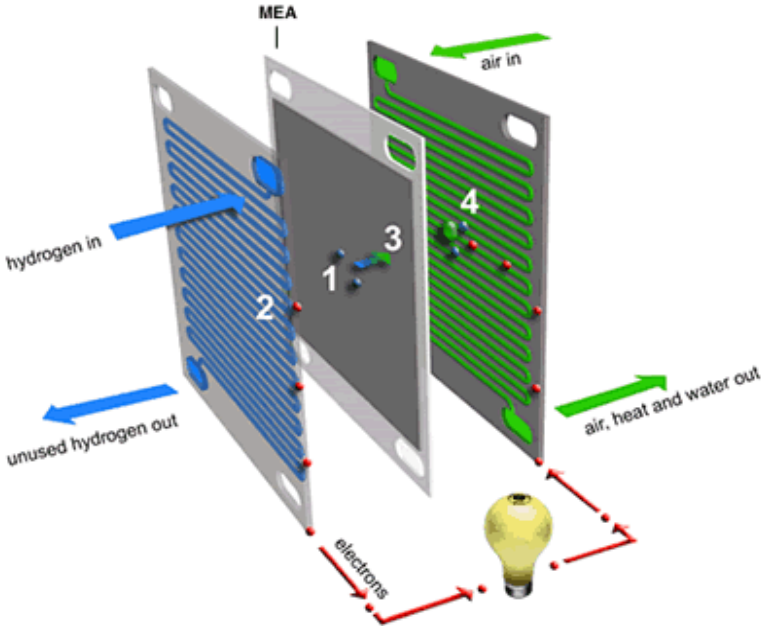
# One of the big challenges for the fuel cells is the high cost

- Bipolar plates represent a big part of the cost for fuel cells
- 2 main ways to cut the cost for the bipolar plates:
  - » Cut manufacturing cost
  - » Increase the power density (= fewer plates needed = lower total cost)

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# The history behind the technology

The “drop hammer” (left) coin mint was b based on descriptions from Leonardo da Vinci’s ideas 500 years ago.

The mint is operated by raising a 70 kg hammer to a height of app. 3 m. The coins set between the two dies are then struck with a force equivalent to 40 tons!

After the technology had been forgotten about, it was «reinvented» when developing cannons for penetrating steel (right). Karlskoga was central place for this, being the home town of Alfred Nobel.

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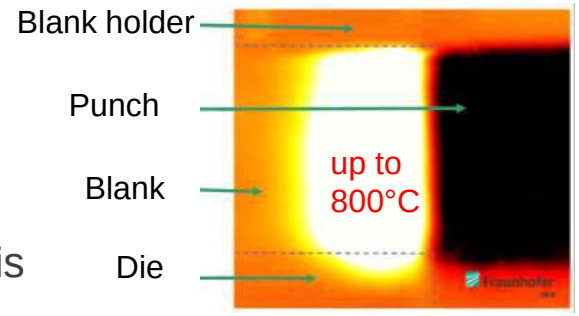
# Adiabatic softening

- According to Wikipedia:
  “In thermodynamics, an adiabatic process is one that occurs without transfer of heat or matter between a thermodynamic system and its surroundings.”
- For our applications, the reason for having a close-to-adiabatic system is that the process is so fast, so there is no time for the energy to interact with the surroundings.
- All the energy put into the stroke has to be transferred to work or heat. The heat generated during the process can be very high, very local and for a very short time.
- As temperature increases, the material gets softer.




Source: Fraunhofer IWU

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# Metal bipolar plates or graphite bipolar plates?

- Metal bipolar plates
  - » Well adopted for high volume manufacturing
  - » With high volume manufacturing, lower cost
  - » Needs coating
  - » Thinner → smaller stacks
- Graphite bipolar plates
  - » Today mainly for low volume manufacturing
  - » Lightweight
  - » Thicker
  - » Good conductivity
  - » Good corrosion protection
  - » Higher degree of freedom of design

→ We can provide both!

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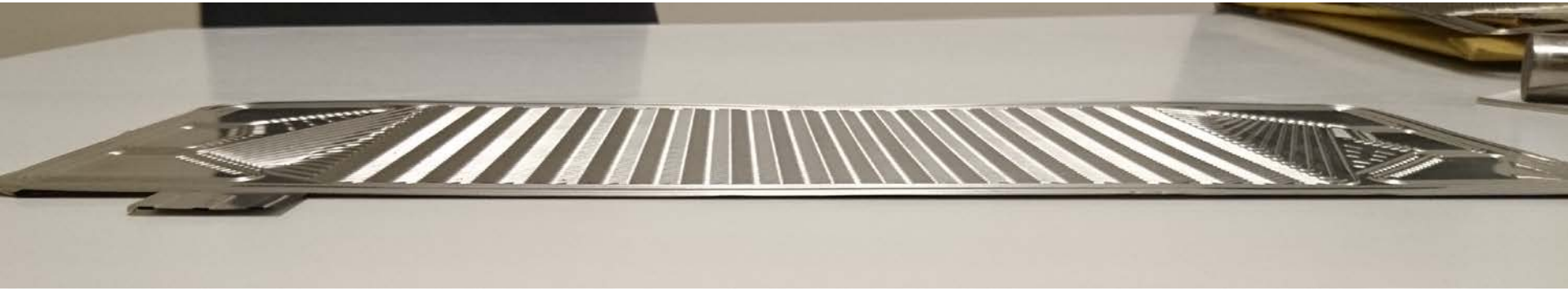

# Metal BPP

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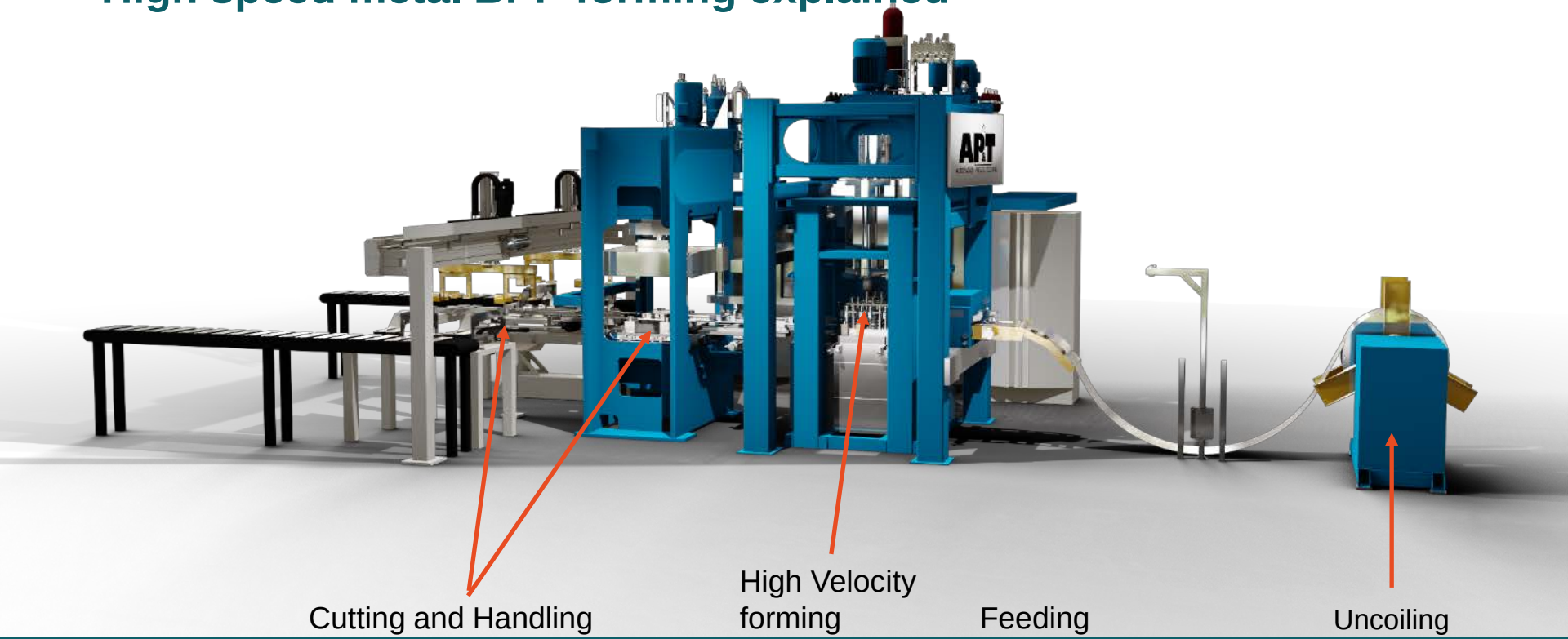
# High speed metal BPP forming explained

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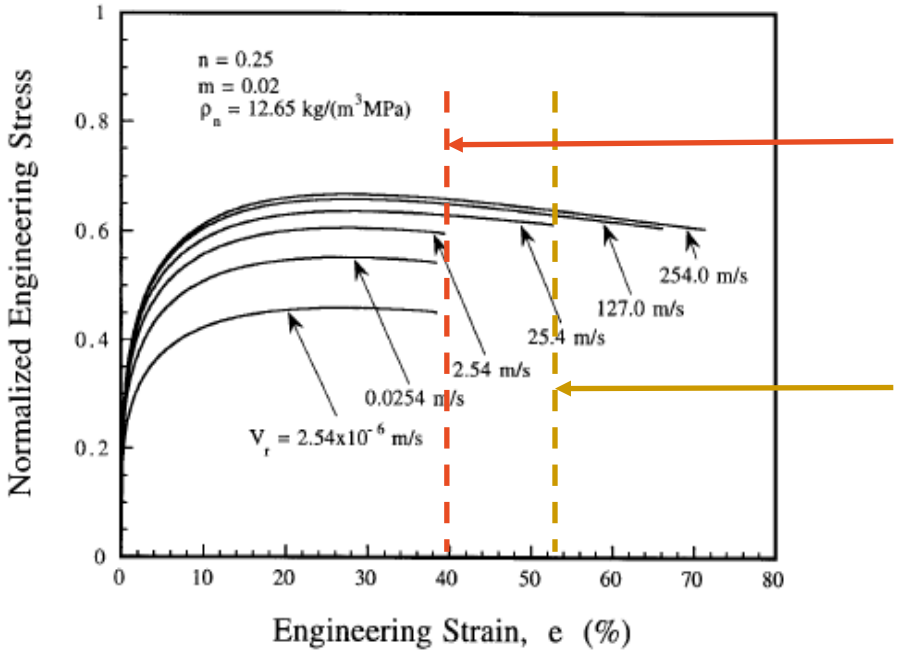
# High speed forming means more formability




Traditional forming limits the forming to app 40% strain before failure of the material

High speed forming pushes the limit for formability up by > 10 %

*Source: Balanethiram, Ohio State University "Enhanced Formability of Sheet Metals at High Workpiece Velocity"*

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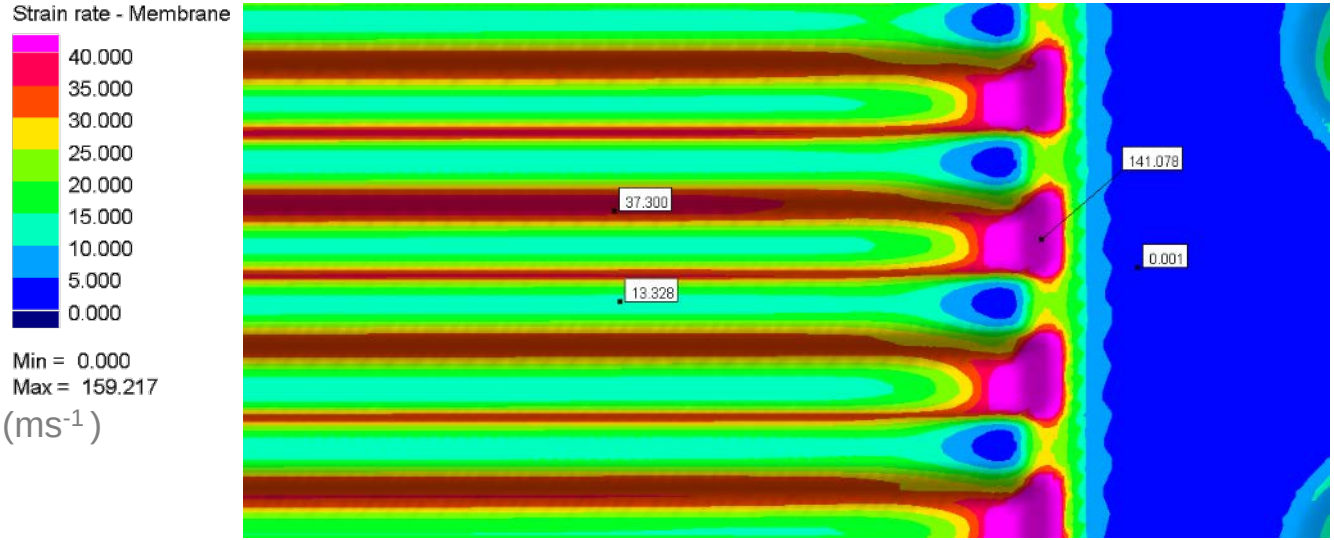
# Strain rate during the forming is very high




Max strain rate app. 160 m/s

Based on simulation done with Pam-Stamp

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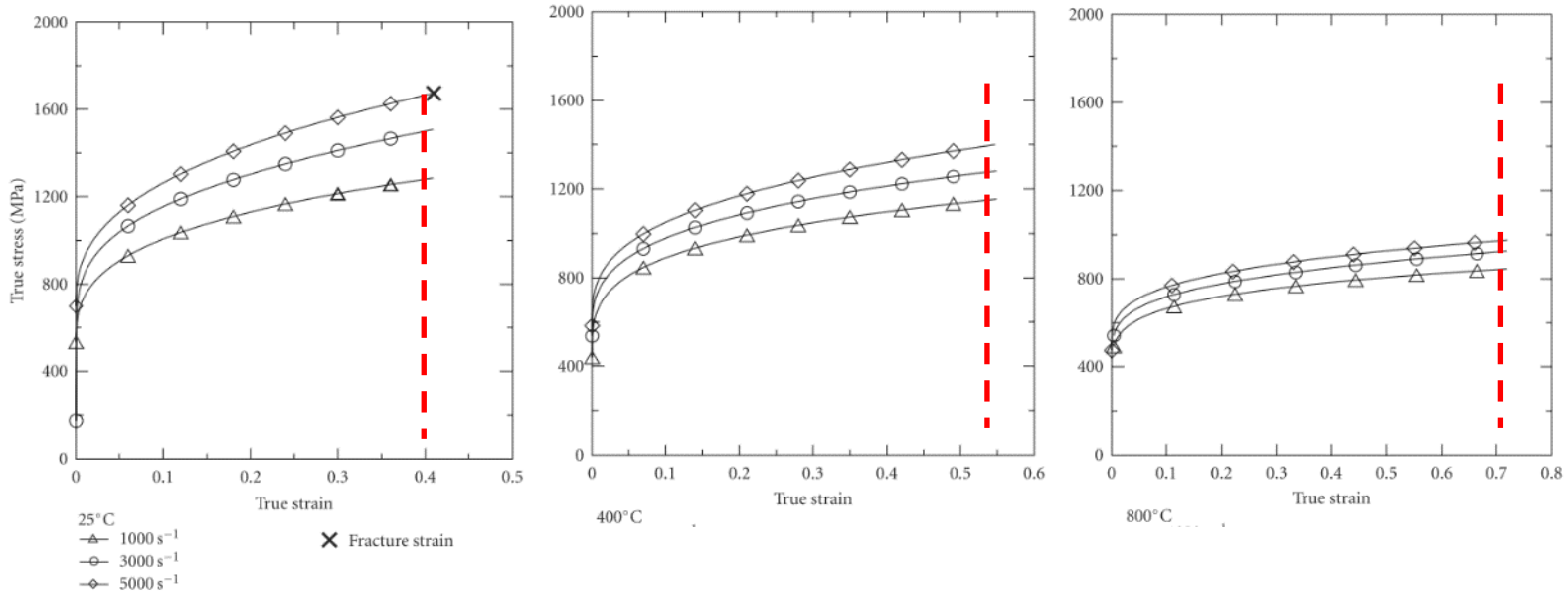
# High temperature means more formability




*Source: Lee et. al. Dynamic Mechanical Response of Biomedical 316L Stainless Steel as Function of Strain Rate and Temperature, Taiwan*

The formability of 316L increases from app. 40% to 70% at 800 °C

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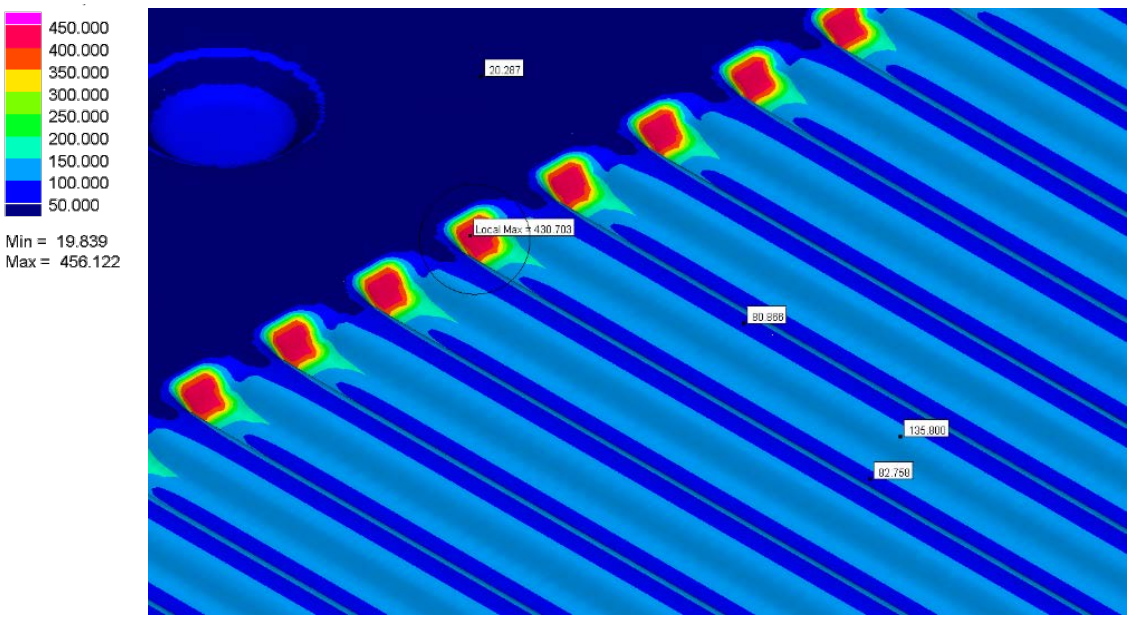
# Temperature during forming




*Based on simulation done with Pam-Stamp*

Initial Blank temperature is 20°C, max in the simulation is app. 450 °C

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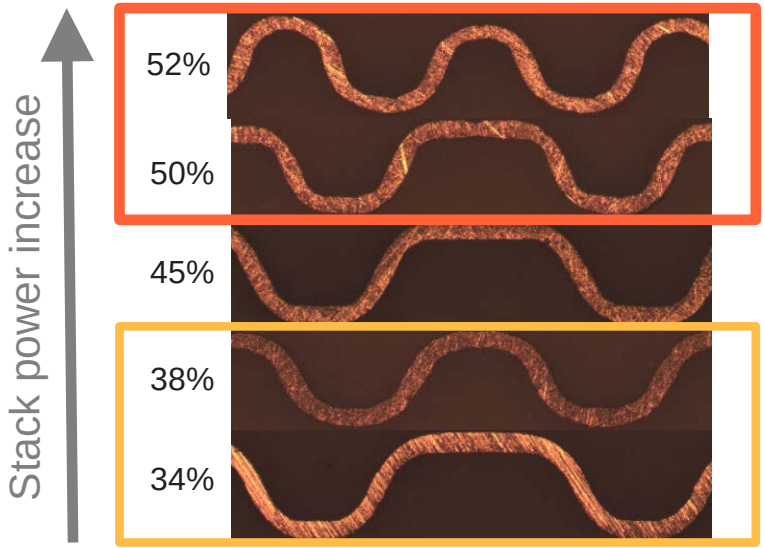
# More formability means more advanced patterns




High speed forming

Channel forming elongation increased from 34 to 52%.

Today's patterns are 30–40%, future target is 50+%.

Conventional forming

Examples of formed patterns with Sanergy LT 316L.

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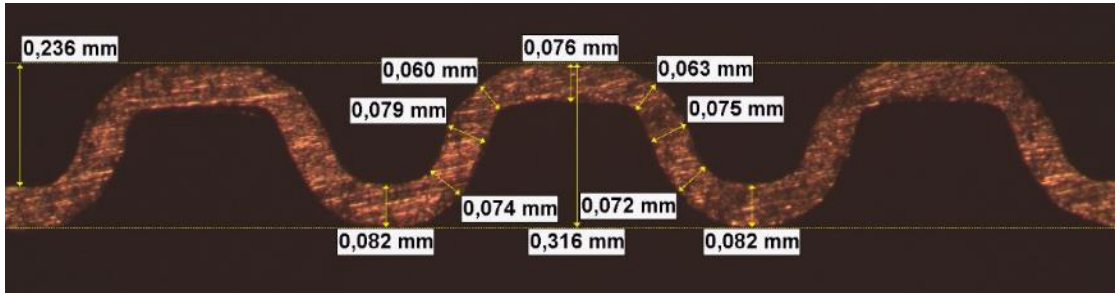
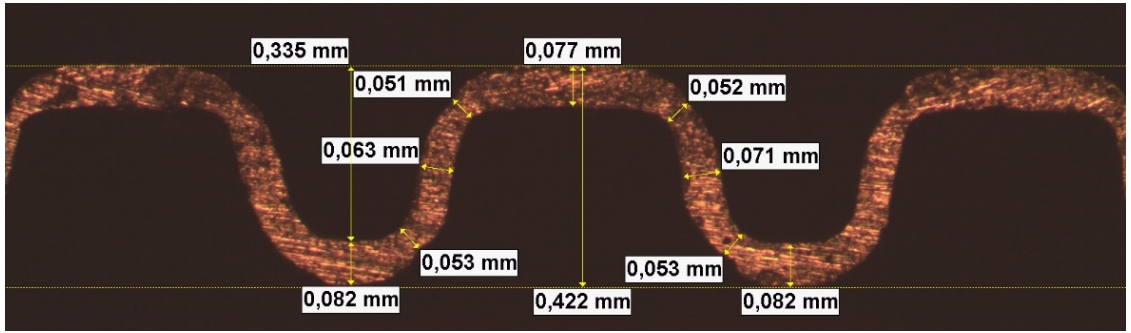
# More advanced patterns – with high-speed forming




Extremely fine pitch 0.60 mm.
Inner radius 0.04 mm.
Total elongation 47 %.
Channel elongation 57 %




Very fine pitch 0.85 mm.
Inner radius 0.08 mm.
Total elongation 52 %.
Channel elongation 72 %

More examples of formed patterns with Sanergy LT 316L.

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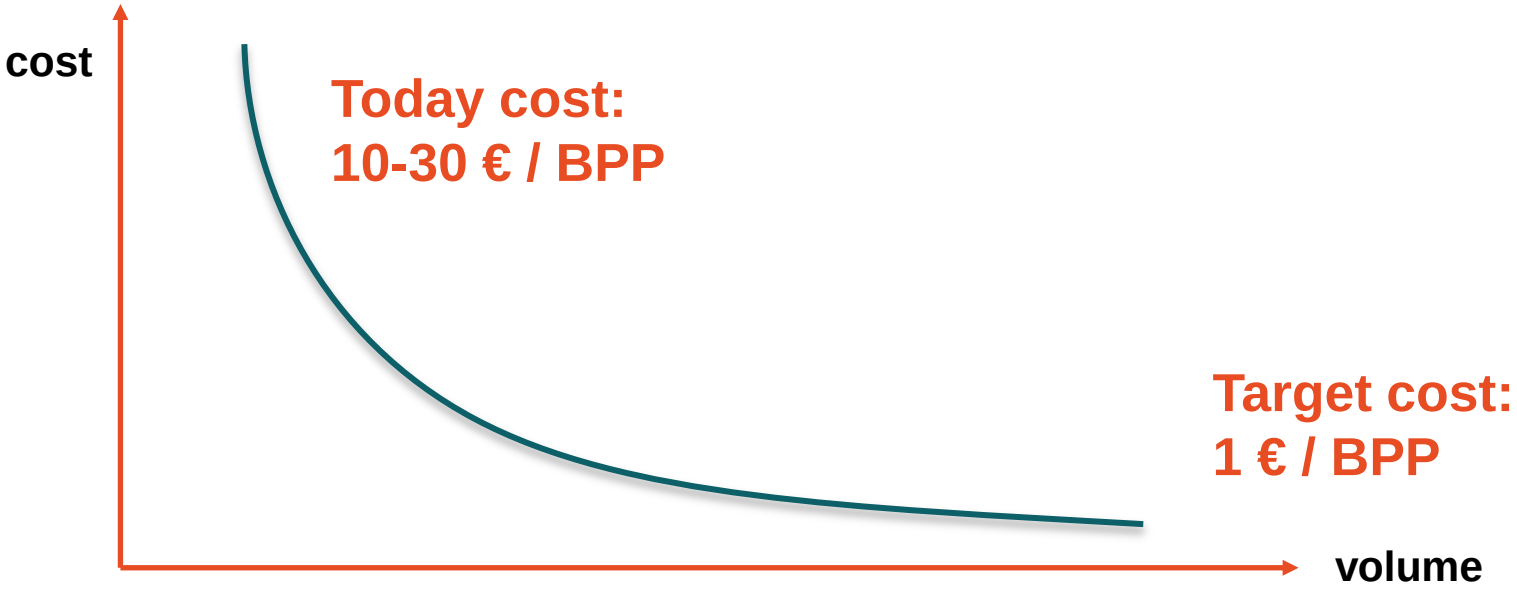
# As a result:
# Cost development curve for BPP

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# Advantages from high speed forming

- Higher formability resulting in:
  - » Better material usage; savings in material costs
  - » Forming of more advanced patterns, enabling a higher efficiency in the final product
  - » Fewer manufacturing steps mean more cost effective manufacturing
- Reduced forming forces needed through adiabatic softening, means smaller press needed
- Reduced spring back

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# Graphite BPP

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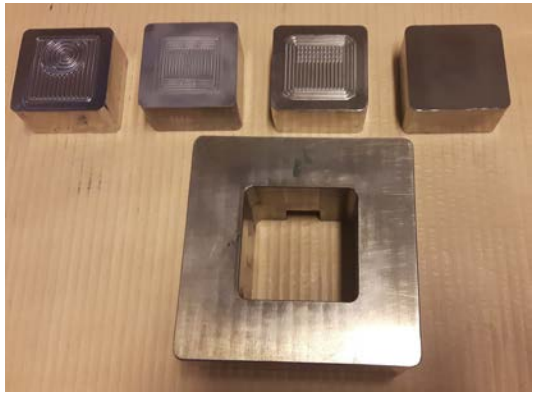
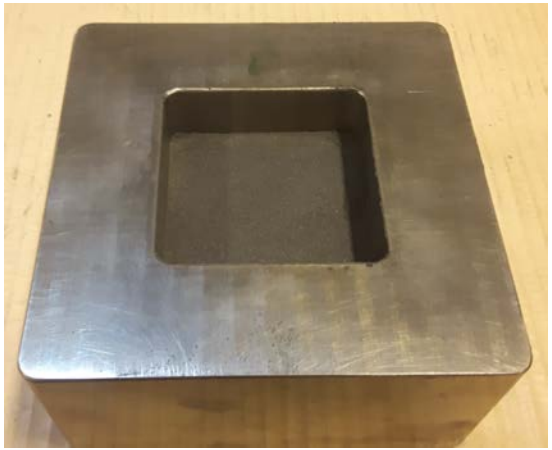
# High speed graphite compaction – explained

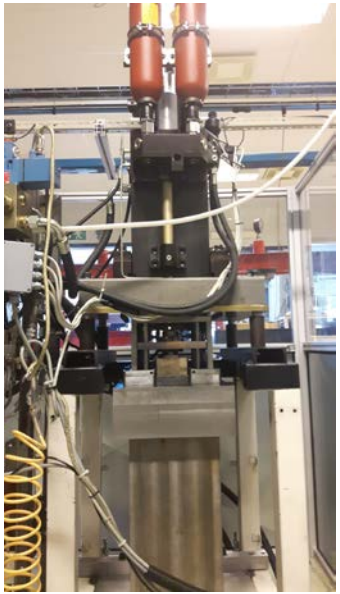


Tool housing and tools

Graphite powder



Graphite powder in the tool



Tool in high speed press
Up to 10 m/s
Impact in less than 0.1 s

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# High speed compaction of graphite

- **High Velocity compaction**
  - » Cold forming process, no heat needed
  - » No vacuum required
  - » Typical cycle time <10 sec
- **Compression moulding**
  - » Heat required to form geometry 65°C - 110°C
  - » Vacuum required to removed displaced air
  - » Typical cycle time 3 minutes
- **Milling**
  - » Cold process, no heat needed
  - » No vacuum required
  - » Typical cycle time 20-30 minutes

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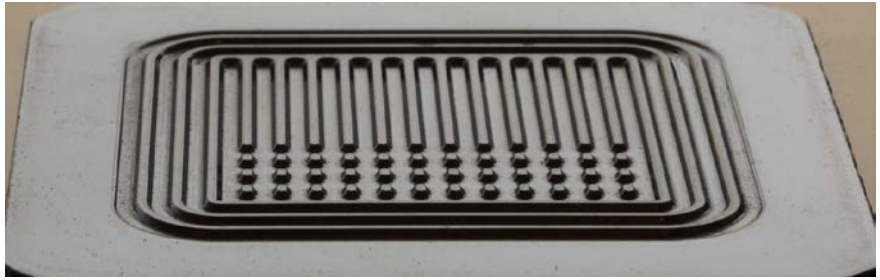
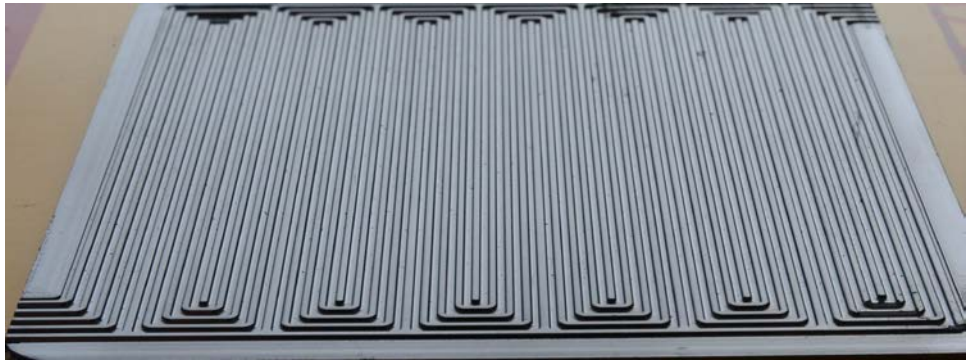
# With high-speed compaction, graphite BPP can be manufactured in seconds instead of minutes





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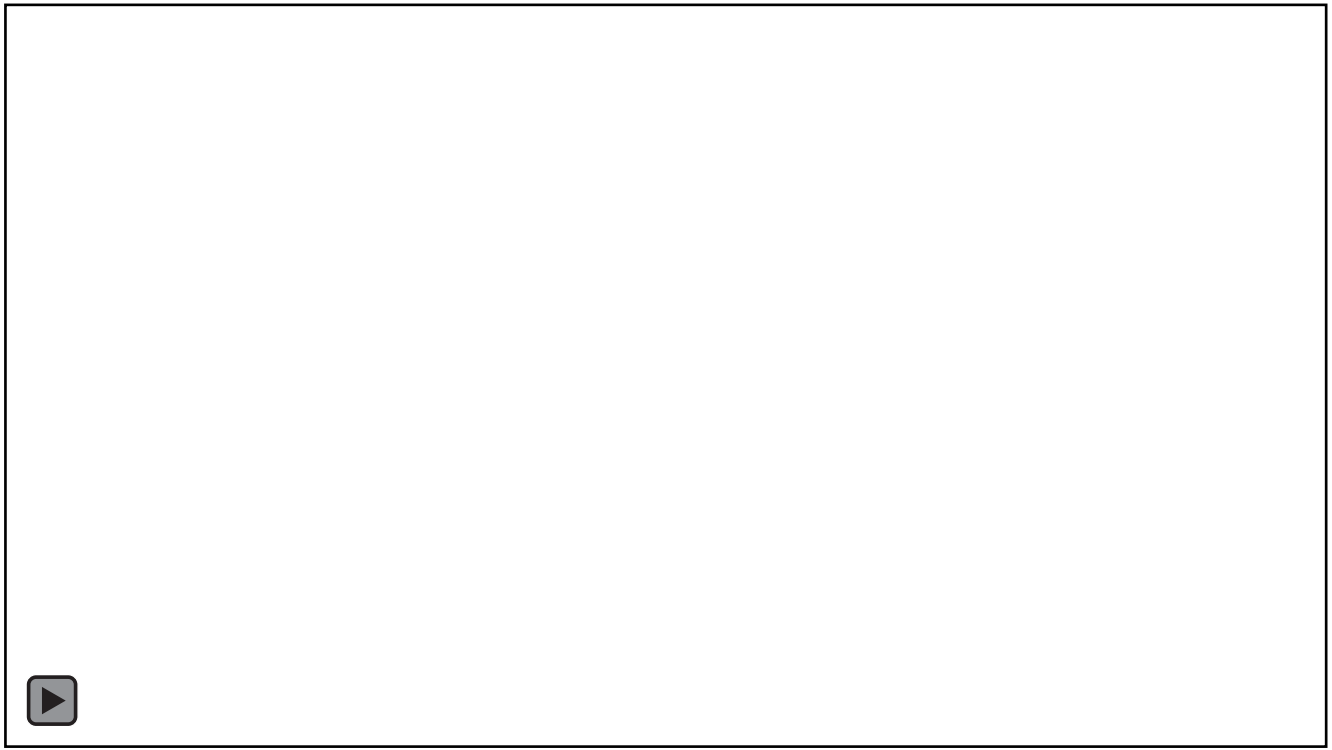
# Line concept for 4 sec cycle time production



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# Advantages from high speed powder compaction

- Improved quality
  - » Higher green density
  - » Improved material properties
  - » Lower radial spring back
  - » Lower shrinkage, improved net shape
- More cost efficient production
  - » Higher production rate
  - » Less post-processing, e.g. no delubing

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# From design to high volume production

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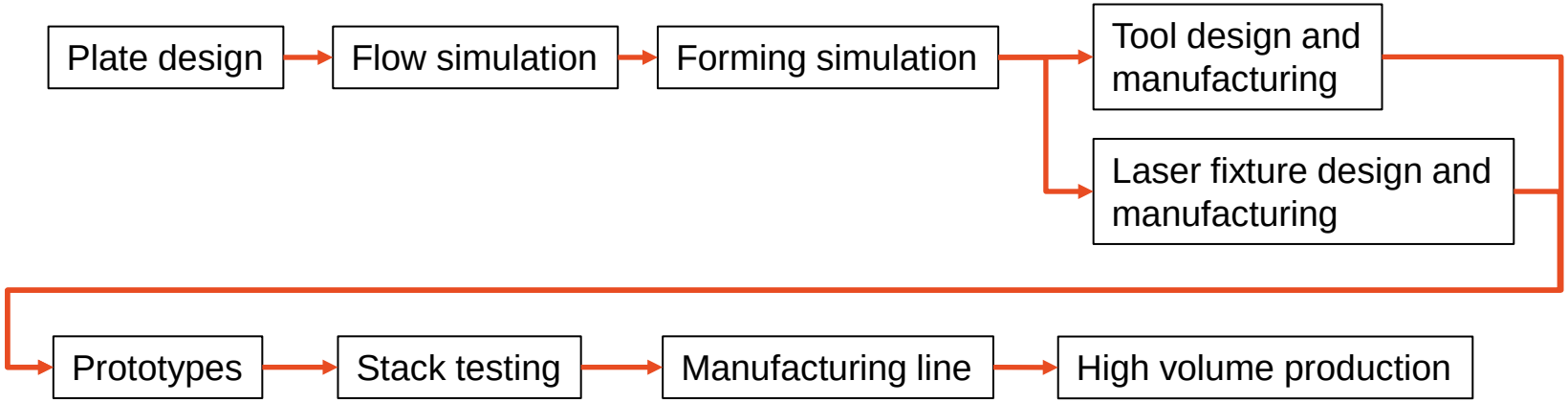
# Normal process from design to high volume production

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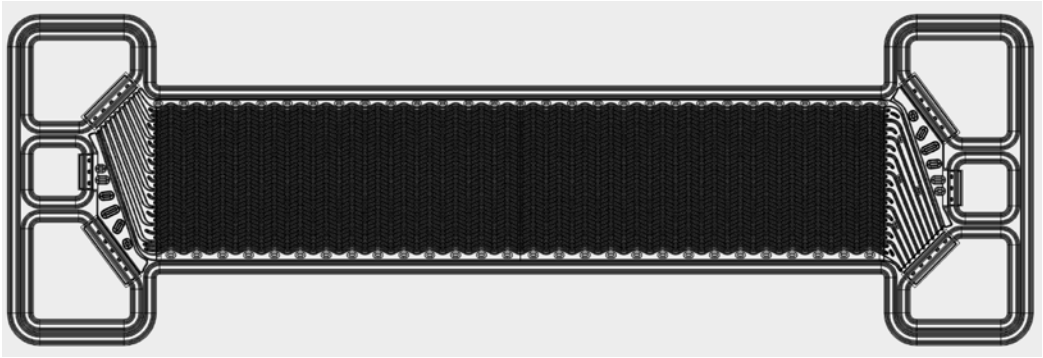
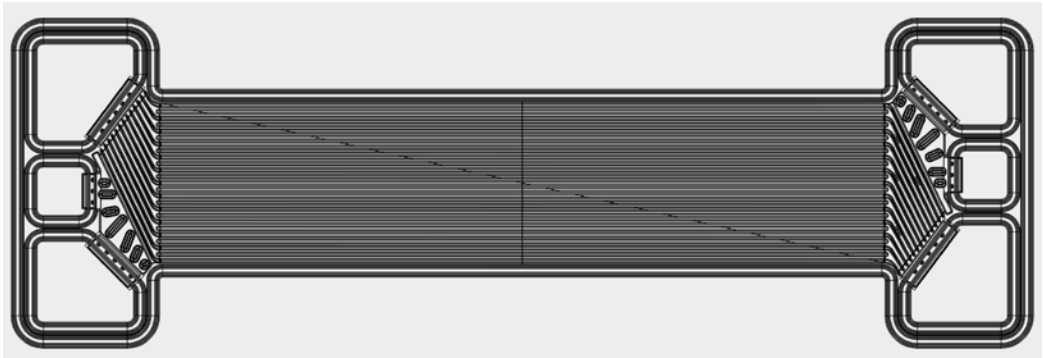
# Cell Impacts own BPP design – plate design

Anode



Cathode



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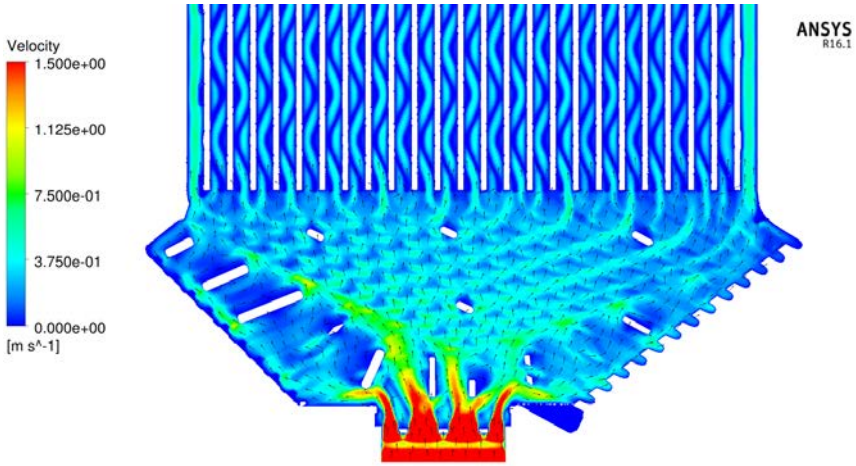
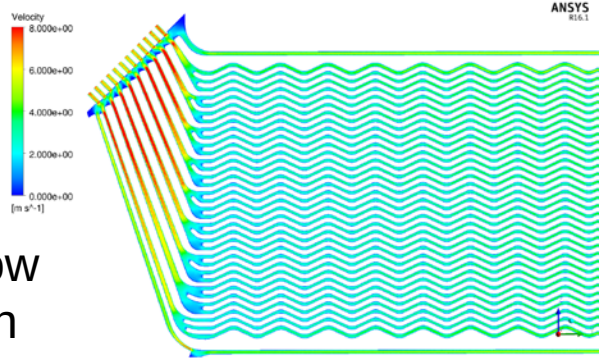
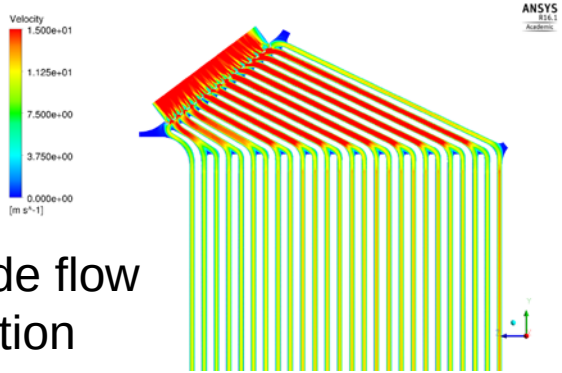
# Cell Impacts own BPP design – flow simulation




Cooling simulation




Anode flow simulation




Cathode flow simulation

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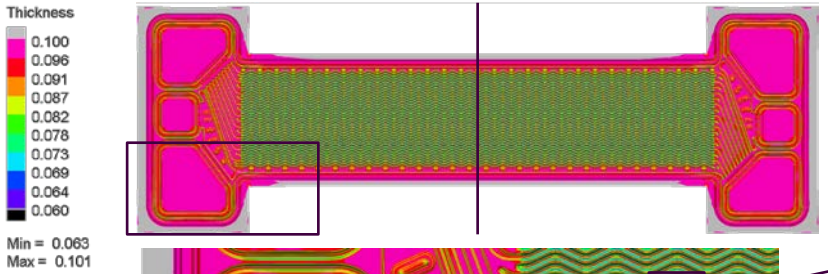
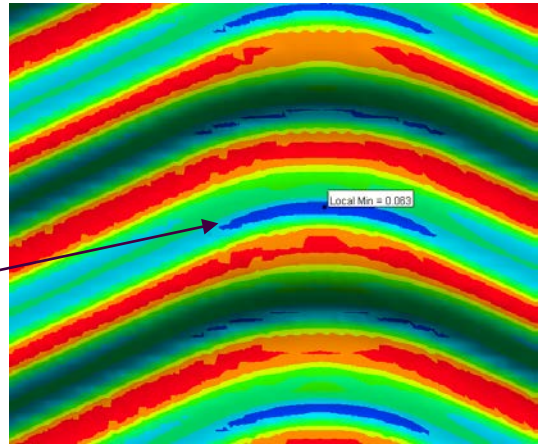
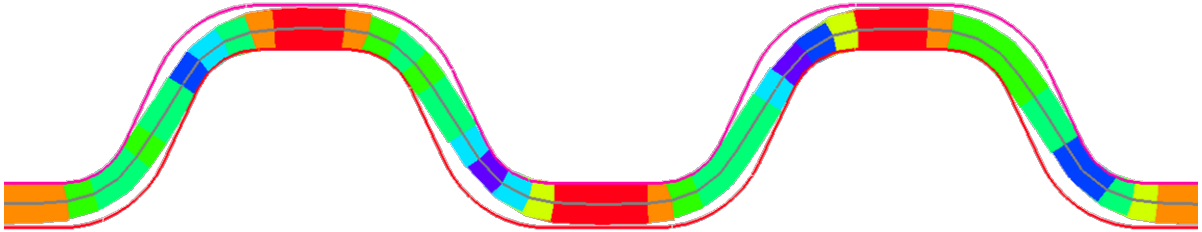
# Cell Impacts own BPP design – forming simulation




Thickness distribution



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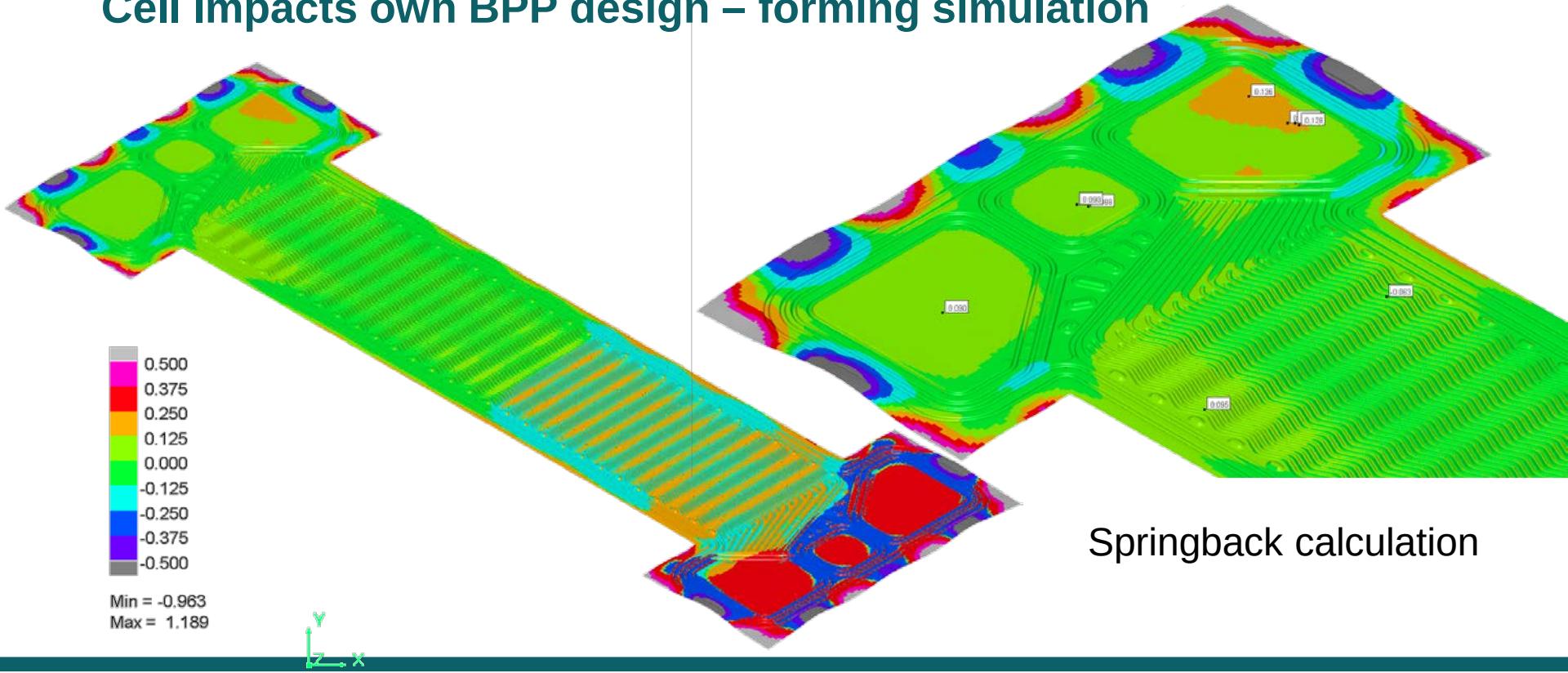
# Cell Impacts own BPP design – forming simulation




Springback calculation

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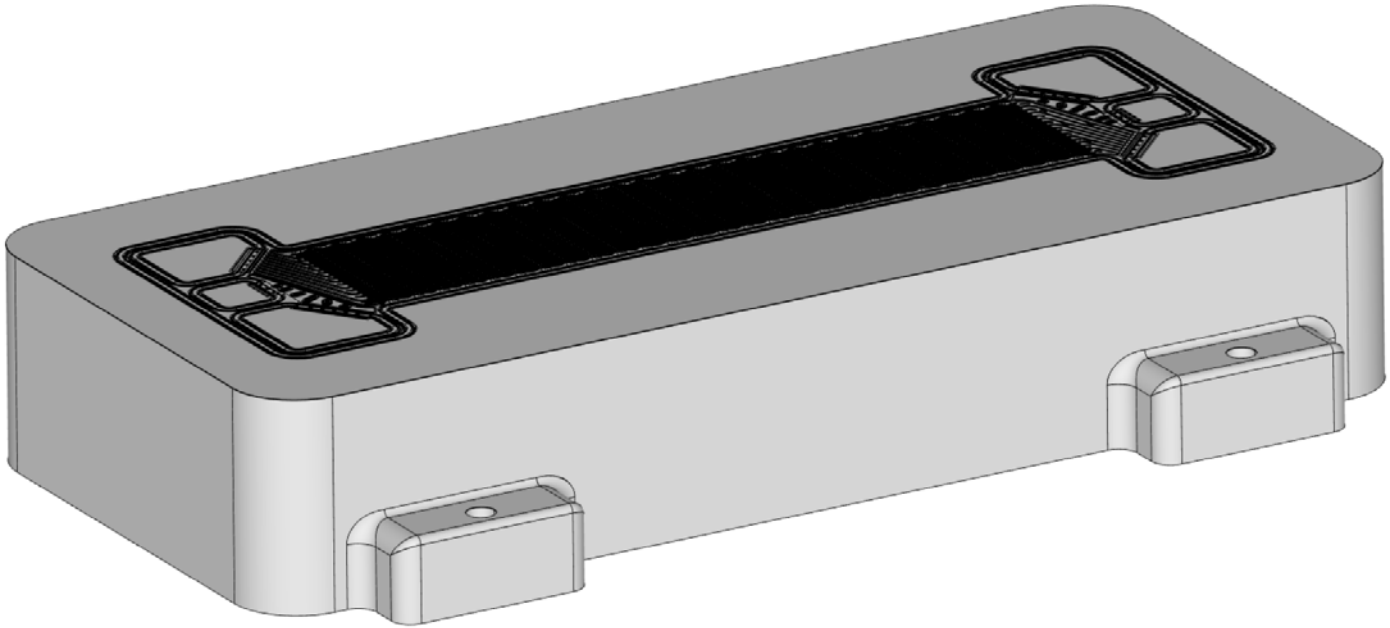
# Tool design and manufacturing



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# Summary and conclusion

- High speed technology is a disruptive way of manufacturing bipolar plates cost efficient and with low energy consumption
- High speed pressing technology can be used for both graphite and metallic bipolar plates
- Design, testing/prototyping and small series production can be offered in Sweden
- We offer a flexible solution from small series production to fully automated production lines for cost efficient manufacturing of bipolar plates

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