A Packaging Efficient Stamped Battery Tray with Zero-degree Draft Angle and Tight Radii

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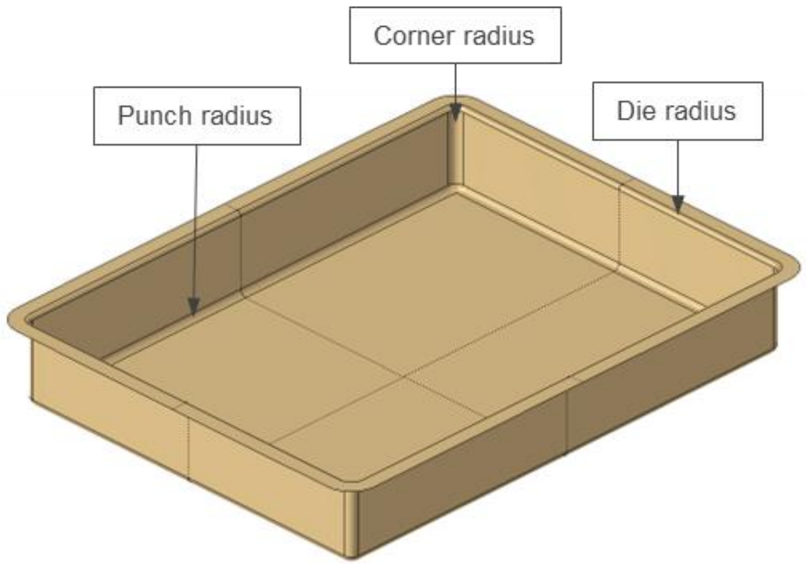
GREAT DESIGNS IN STEEL™

Outline

- Project background, motivation, and objectives
- Design details and forming process
- Proof-of-concept part creation and results
- Benefits of the packaging efficient stamped battery tray
- Applications using the packaging efficient stamped battery tray
- Summary and conclusion

What problems or concerns are we trying to address?

- OEMs are motivated to create packaging efficient battery enclosures for their electrified vehicles.
  - Increasing the enclosure volume allows for more battery cells, which leads to added range.
  - Additional space makes assembly easier since there is more room for wiring, connectors, cooling, etc.
- Enclosures based on stamped tray concepts are attractive due to their inherent watertightness advantage.
- Traditional stamped tray concepts focused on ease-of-manufacturing to minimize cost.
  - Draft angles up to 7° are seen in steel and aluminum designs.
  - Generous punch, die, and corner radii for reduced part and process complexity.
- Draft angle and tray radii are critical factors controlling the packaging efficiency of an enclosure.
  - Smaller is better!
  - Can we create a stamped tray with vertical walls (0° draft angles)?
  - How small can we make the punch, die, and corner radii?



Project goals and objectives

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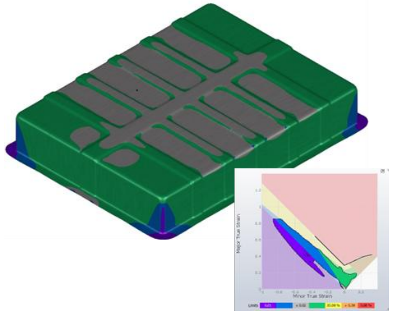
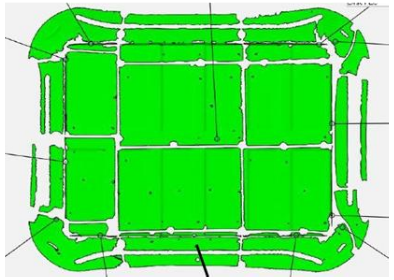
- Create a manufacturable concept for a battery enclosure stamped tray that maximizes packaging efficiency.
  - 0° draft angle for the walls.
  - Minimize punch, die, and corner radii based on material formability considerations.
  - Employ design features as needed to control part shape and formability.
  - Use traditional, non-patented stamping processes that are well-established in the forming community.
    - Formed using a single draw operation in a single-action mechanical press.
    - Draw beads and stake beads to control material flow.
- Use forming simulation to iteratively develop the design and identify the tightest combinations of radii and draft angles for a given material grade.
- Fabricate proof-of-concept parts to validate the tray design and forming process.
  - Argus / circle grid analysis evaluations to quantify thinning and strains in the fabricated parts.
  - Dimensional analysis to capture the as-produced shape of the parts.

SIMULATION



PROTOTYPE

ARGUS EVALUATION

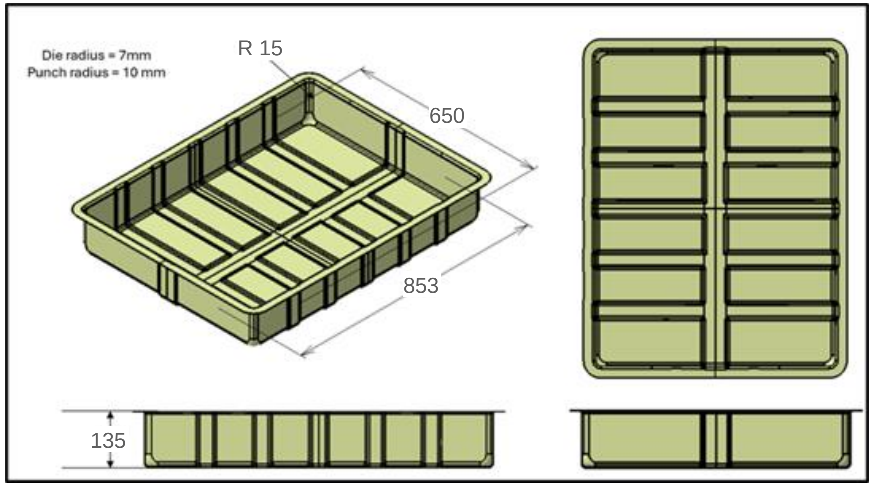


Project specific information

- Material grade and gauge considerations -
  - Initial focus is on highly formable drawing steels – CRx grades.
  - Thin gauges for producing lightweight solutions.
- The material used for this project is a CR5-GI, nominal gauge = 0.63 mm.
- Proof-of-concept parts are based on a sub-scale model of a typical battery tray.
  - Radii and full draw depth are maintained; length and width dimensions are halved.
  - Forming simulations demonstrate the forming concerns of the smaller size part match those of the full-size tray.
    - In other words, demonstrating proof-of-concept with the smaller part gives high confidence in the feasibility of the full-size tray.

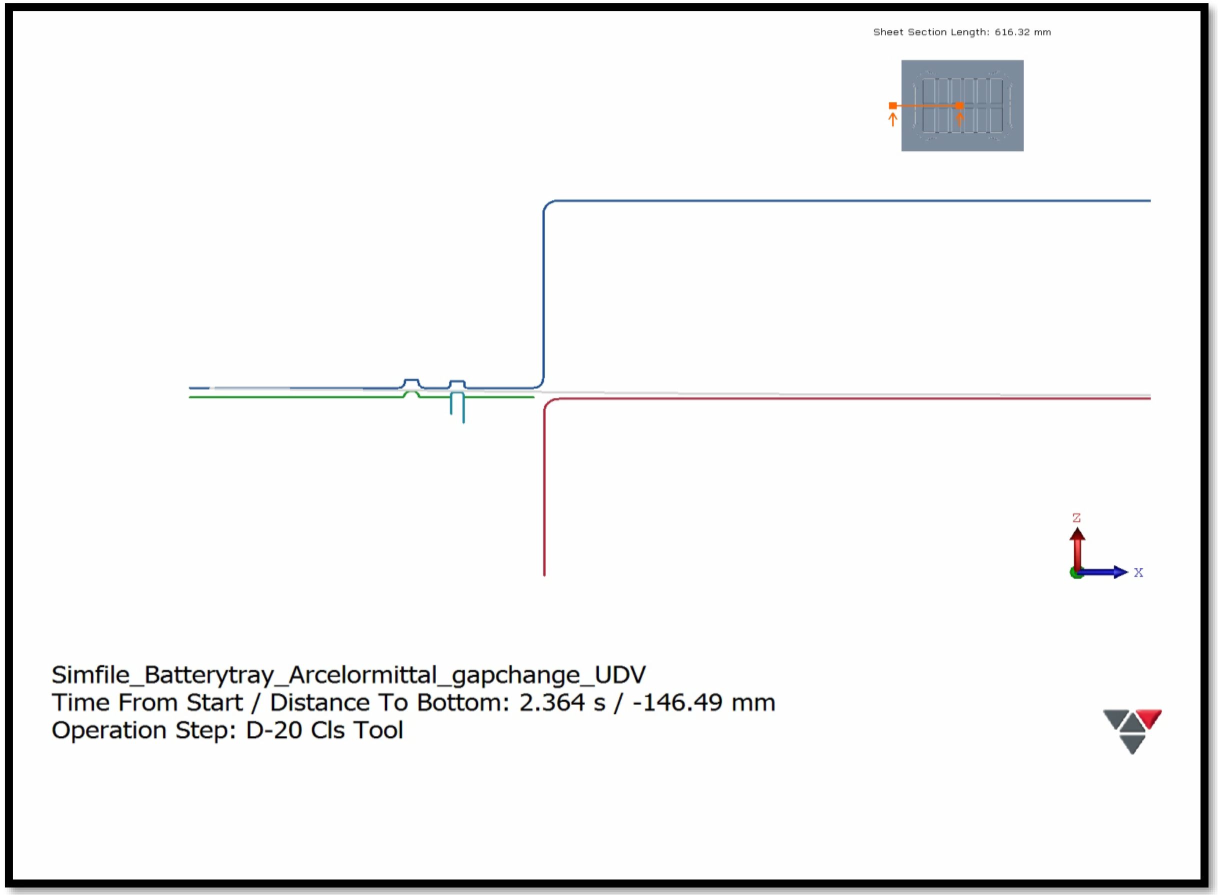
Material			
Material Name		CR5	
Coating		GI	
Thickness		0.634 mm	
Elastic Properties			
Young's Modulus [MPa]		210000	
Plastic Properties			
Yield Stress [MPa]		153 MPa	
Tensile Strength [MPa]		298 MPa	
Uniform Elongation [%]		23.5%	
Work Hardening			
n (0 - Ag)		0.226	
Anisotropy			
r0	r45	r90	rbar
2.020	1.830	2.520	2.050
FLC_0		Safety Margin	
28.4%		AF default	

Dimensions (mm)	
Length	853
Width	650
Depth	135
Corner Radius	15
Die Radius	7
Punch Radius	10
Draft angle	0 deg



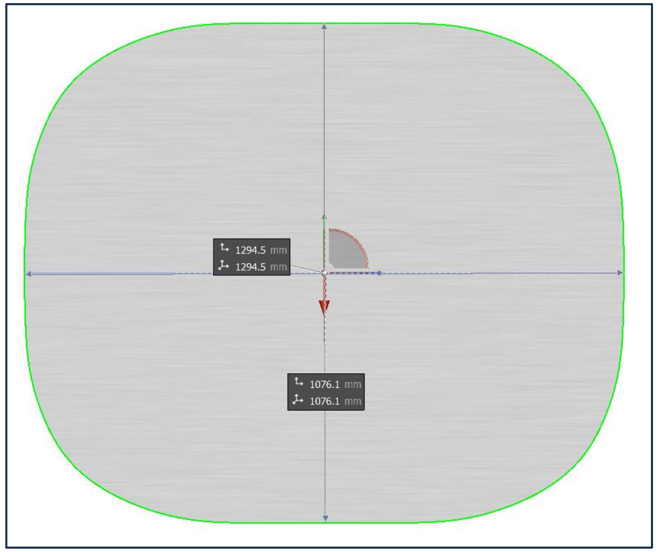
Design details and stamping process

- A simple stamping process is developed in simulation using 3-piece tooling with the addition of a shape set (stake) bead.
- Stake beads and stiffening features are used to provide dimensional stability.
- A single draw operation is performed using a mechanical press.
- Laser trimming is performed on the drawn panel. However, mechanical trimming can also be easily implemented.
- Stake beads are used only on the short edge of the battery enclosure to understand its effect on springback.

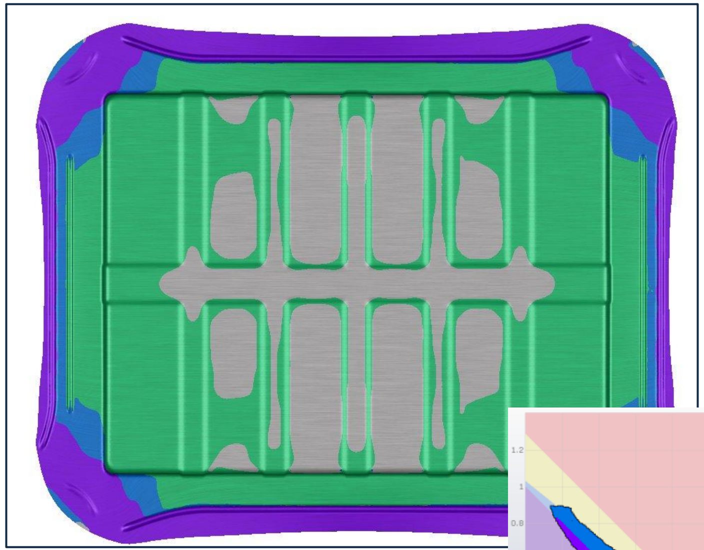


Simulation and results

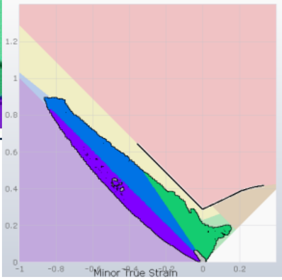
In simulation, a robust process was built to accommodate material and process variability with a target to minimize springback and retain safe forming feasibility.

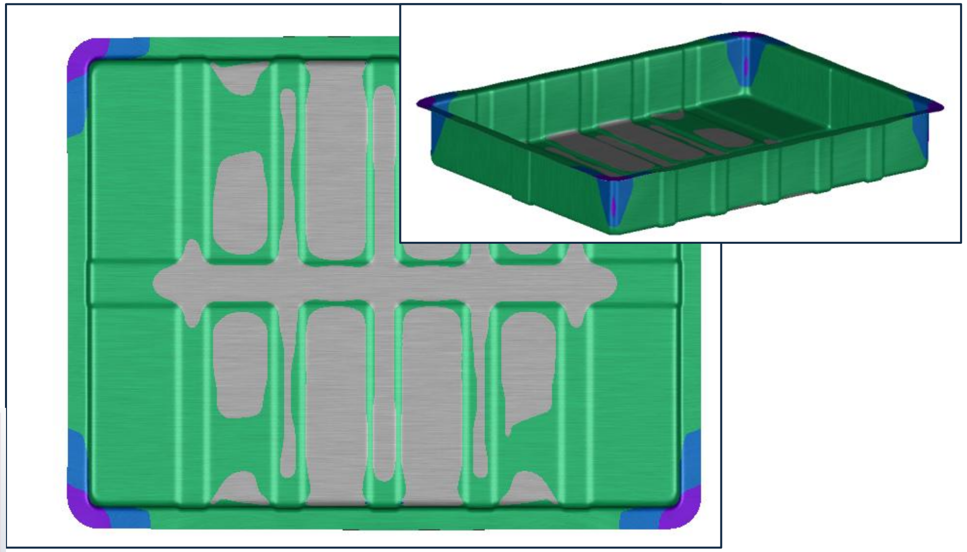


Blank dimensions	1300 mm x 1076 mm
Blank weight	5.9 kg
Part weight	4.84 kg



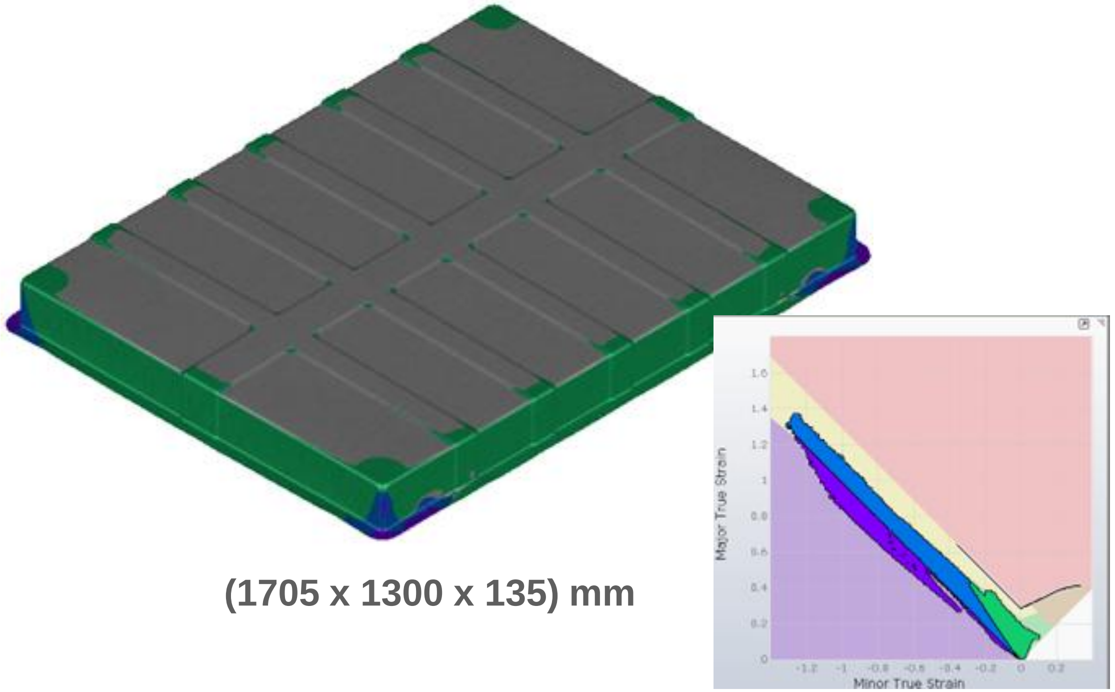
Draw Panel



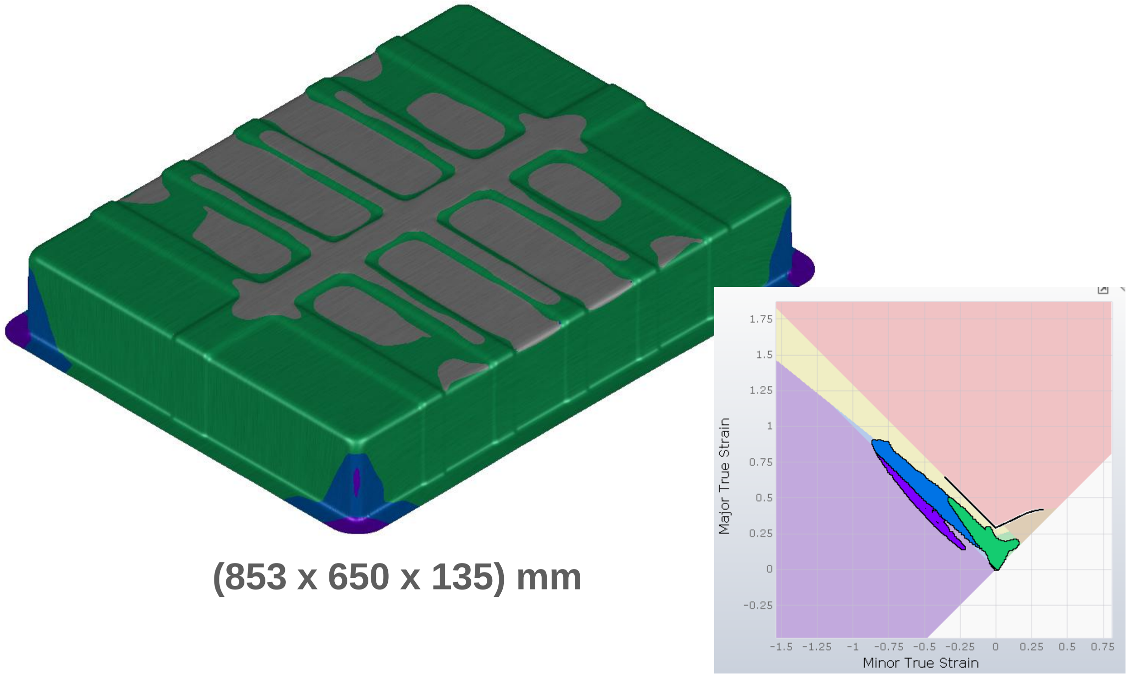


Trimmed Panel

Full-size enclosure compared to the scaled prototype



(1705 x 1300 x 135) mm



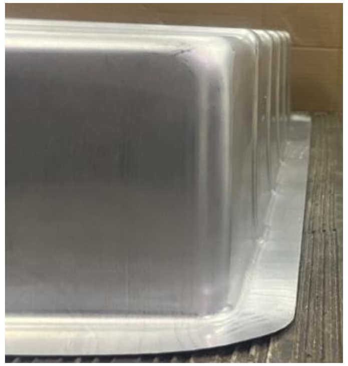
(853 x 650 x 135) mm

- A full-size model based on internal benchmarking studies was assessed via forming simulation.
- For the scaled model, the depth-of-draw and radii remain unchanged, while the length and width are halved from the original dimensions.
- The Forming Limit Diagrams (FLDs) for both the full-size and scaled models exhibit similar strain paths overall, suggesting that the results from the scaled model can be reliably replicated in the full-size model.

Proof-of-concept part creation

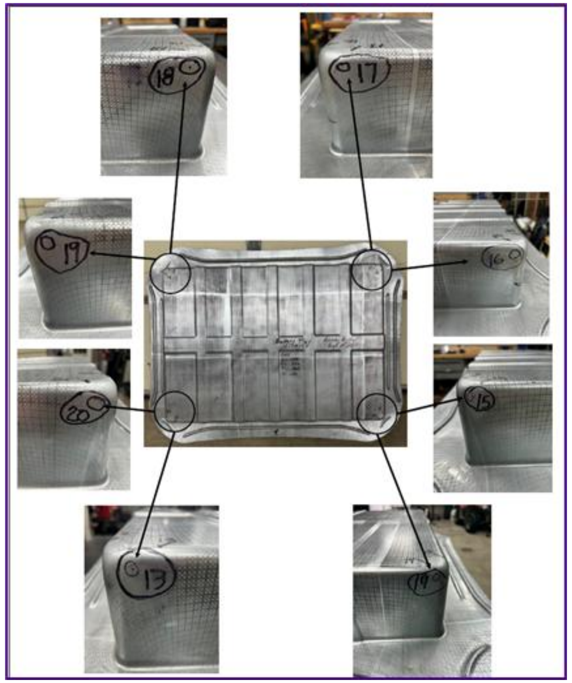
- Using a single action mechanical press, the panel is drawn to its home position in a single hit.
- A production intent stamping process was used.

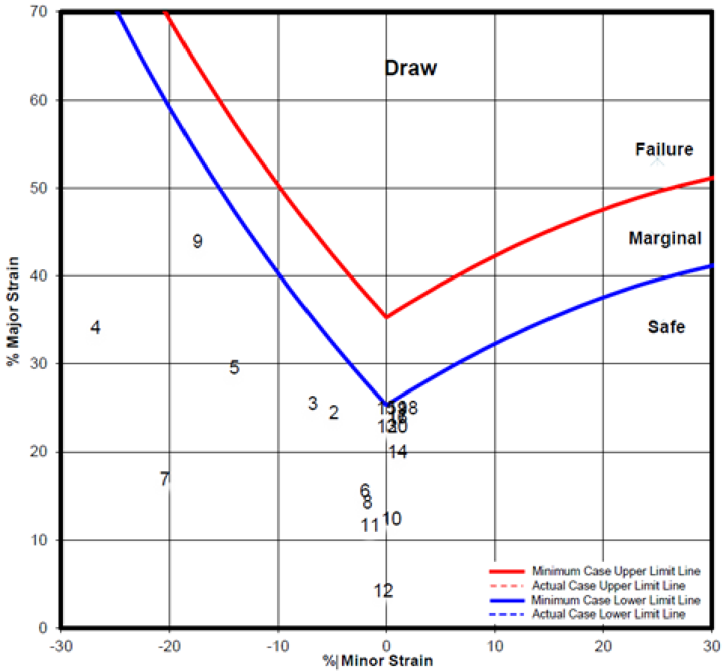
Stamping process

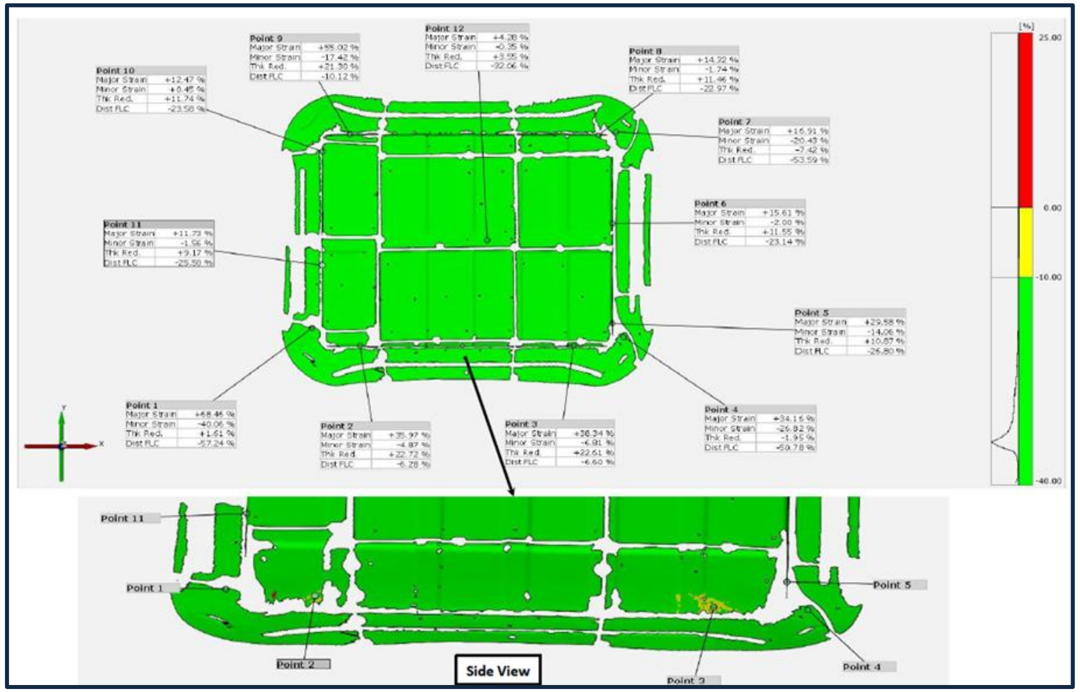


Proof-of-concept part results

- A clean tight panel with no obvious defects and minimal sidewall curl was successfully stamped.
- Argus evaluation confirms the panel to be in the safe zone of the FLC.
- Circle grid analysis (CGA) was used for thickness measurements in areas that could not be captured by Argus.



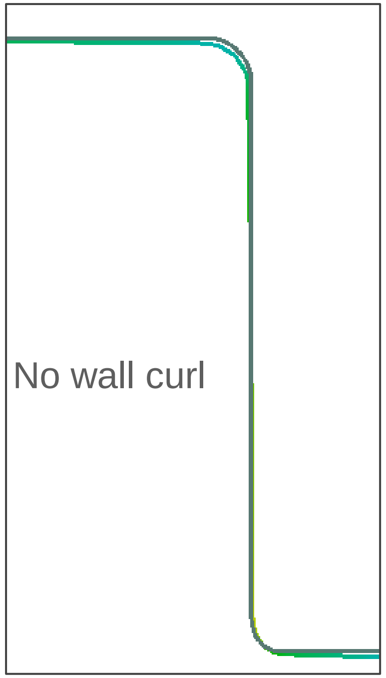


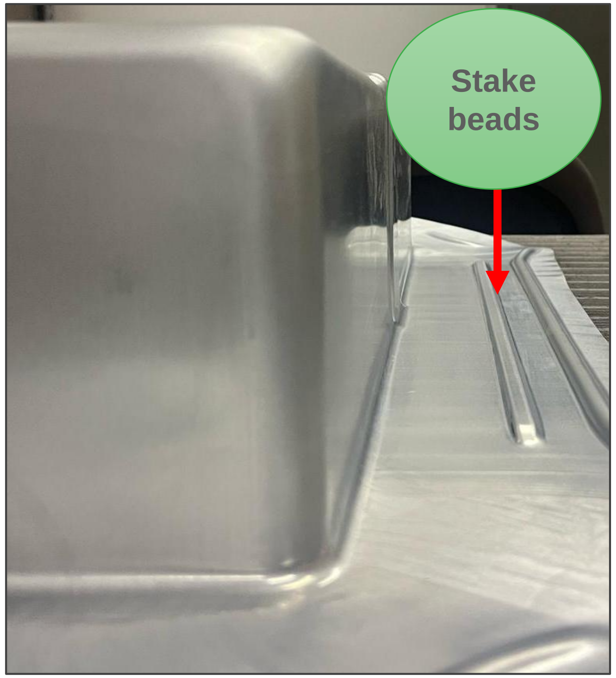


Proof-of-concept part results

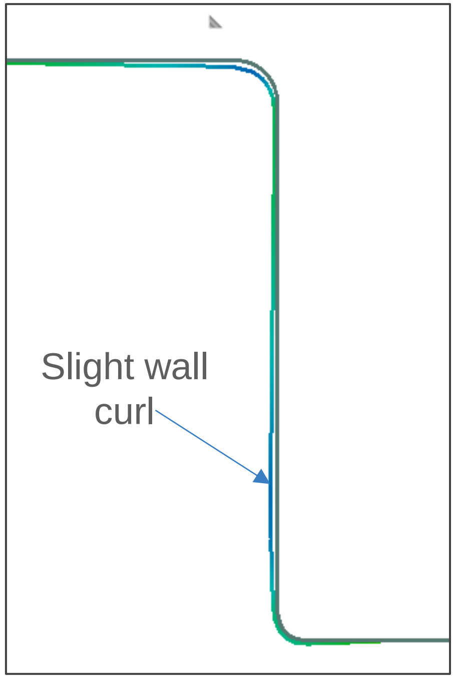
- Stake beads were only applied to the short edge of the tray and significantly improve sidewall curl.
- Results demonstrate that the conventional requirement of a draft angle in stamping is not always necessary.

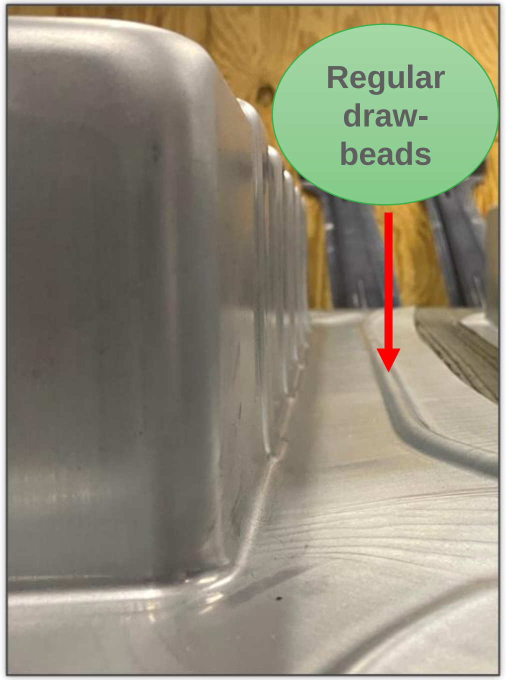
Short edge – stake bead





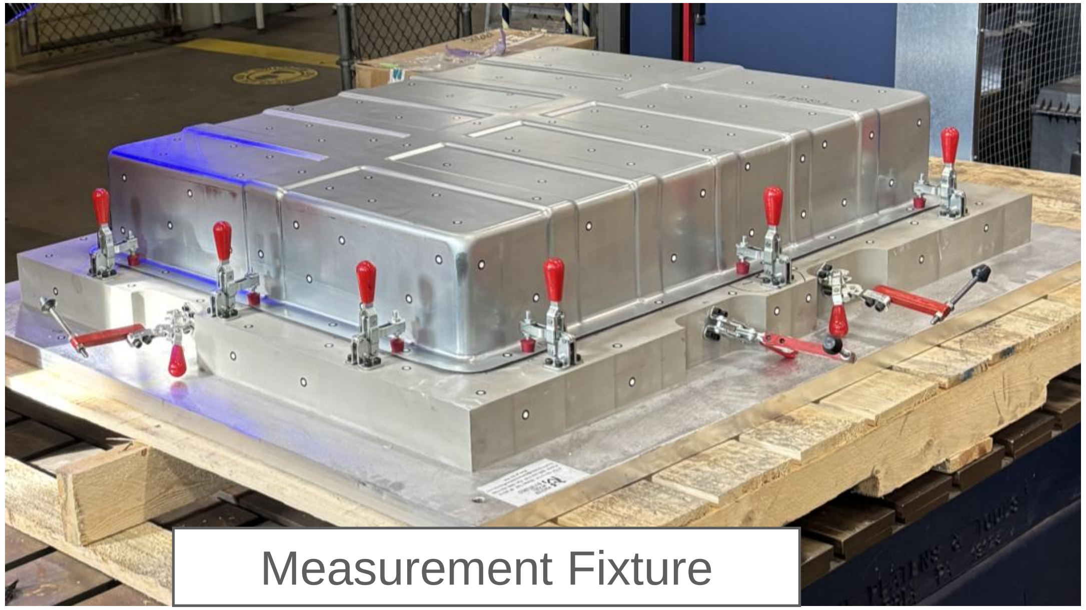
Long edge – NO stake bead





Dimensional analysis measurements

- The stamped battery tray is measured in free state as well as in a constrained state.
- The enclosure is placed on a fixture in an inverted position and clamped to measure the dimensional deviation.
- Flatness of the flange and straightness of the wall are measured.

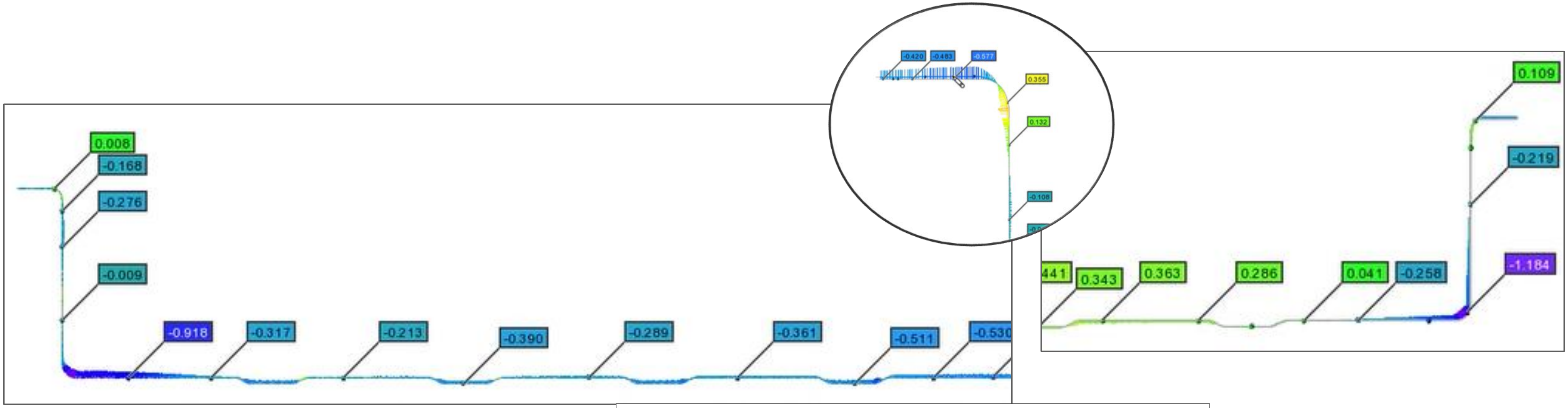


Measurement Fixture

Free-state measurement

Dimensional analysis results

- A mesh for the as-produced tray was produced using Creaform HandySCAN 3D.
- Dimensional deviation was calculated using PolyWorks | Inspector.
- The walls with stake beads show a final wall angle on product ranging from **0.07** degrees to **0.35** degrees.
- Good flatness is observed on the flange areas.
- The concept of building a battery tray with near vertical walls is demonstrated via prototype parts having good dimensional tolerance on the mating surfaces.

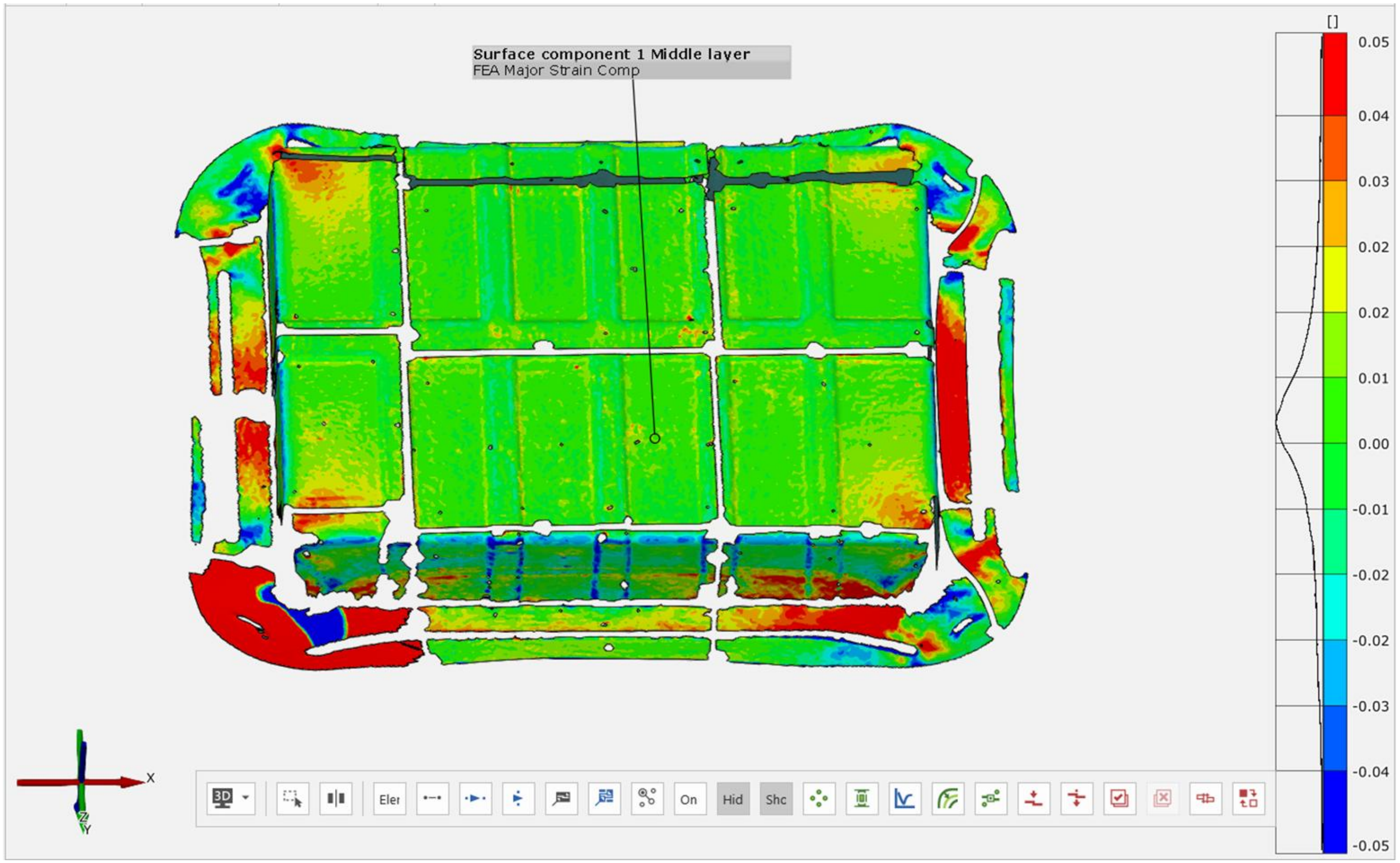


Section views – Deviation from nominal geometry

Correlation between simulation and physical part

- The initial assessment shows good correlation between simulation and physical part.

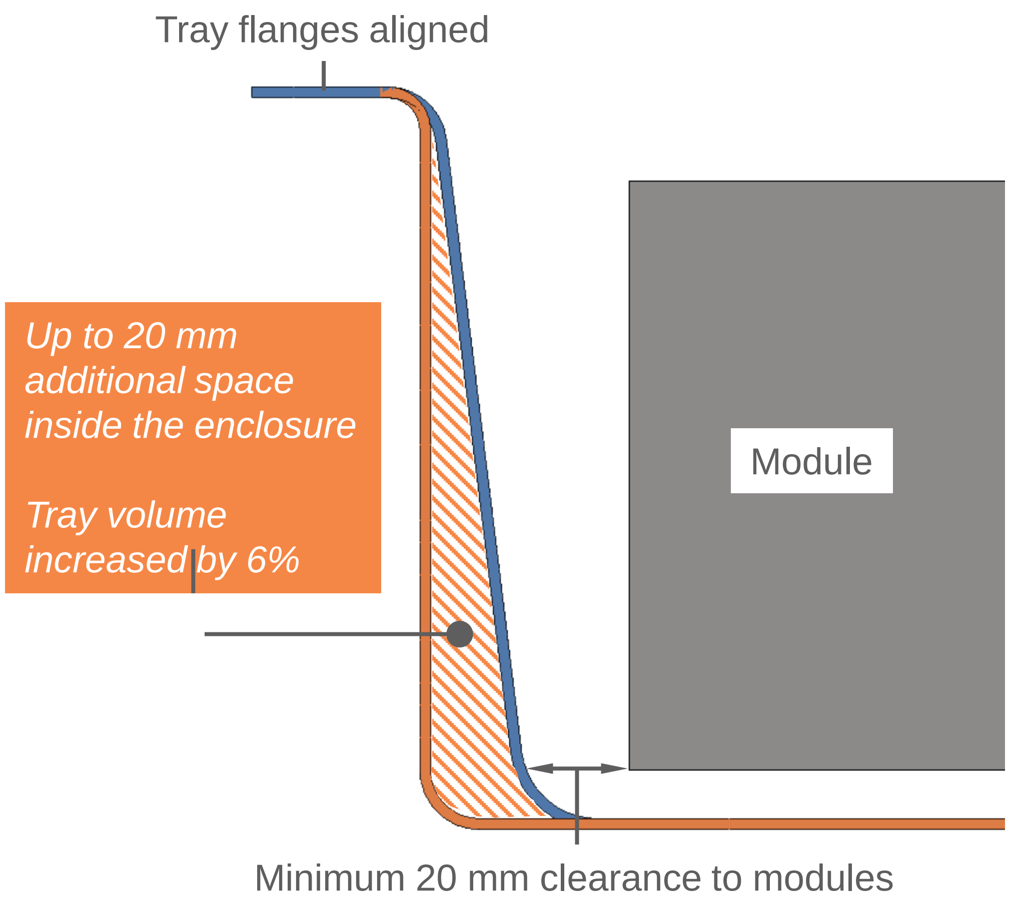
- The plot shows the difference in major strains predicted by AutoForm and those measured by Argus.



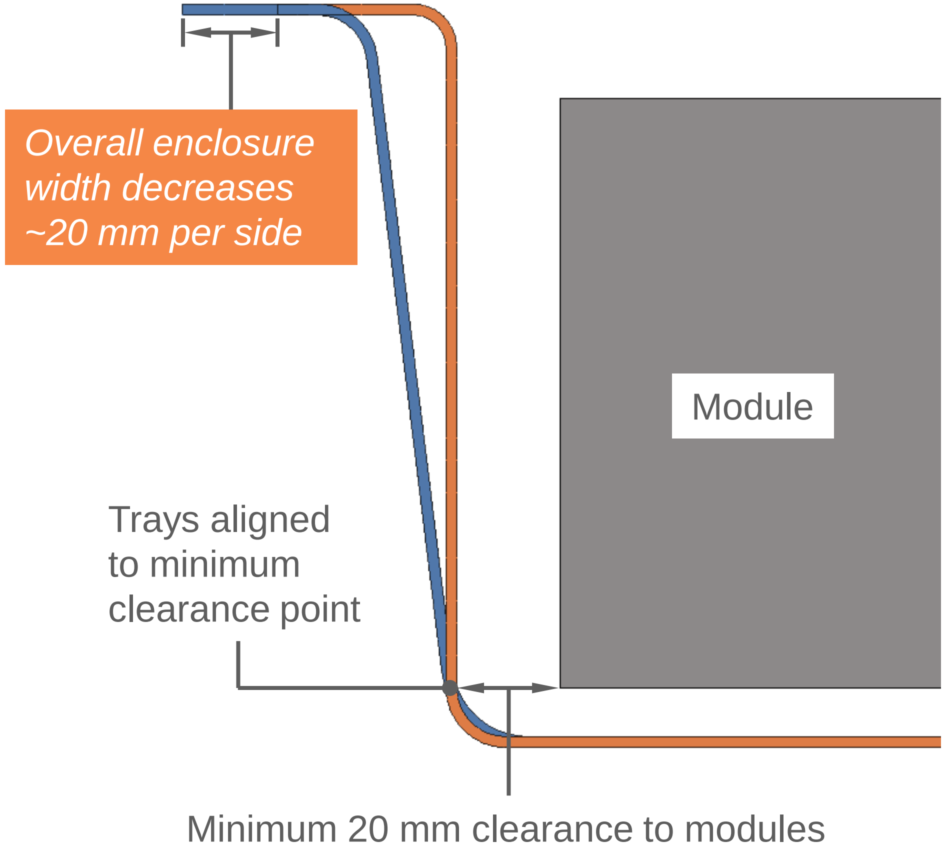
True Major Strain

The packaging efficient tray offers more space, either inside or outside the enclosure

More space inside the enclosure



More space outside the enclosure



Comparisons based on a stamped tray with a 7° draft angle

Packaging efficient battery enclosure assembly

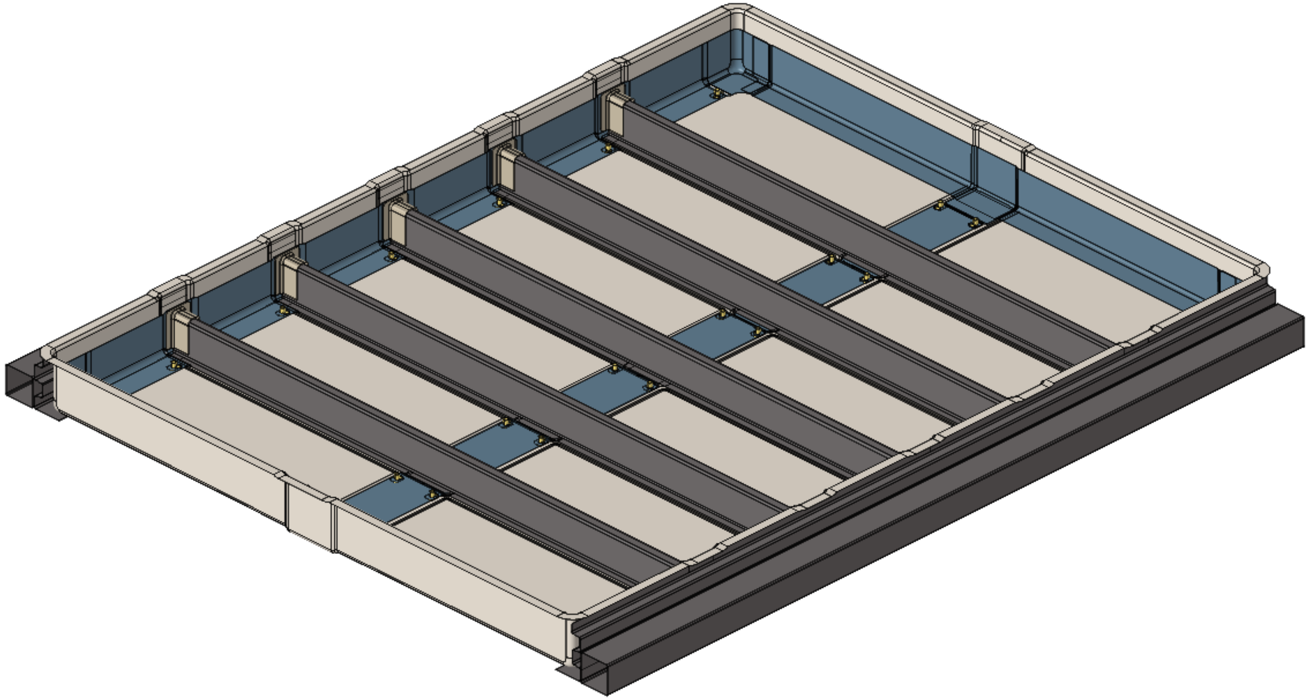
- External steel cooling attached to the stamped tray bottom

- Inner reinforcements added to the tray sub-assembly
  - Side reinforcements
  - Front/rear reinforcements
  - Floor center reinforcement

- Locate and attach crossmembers

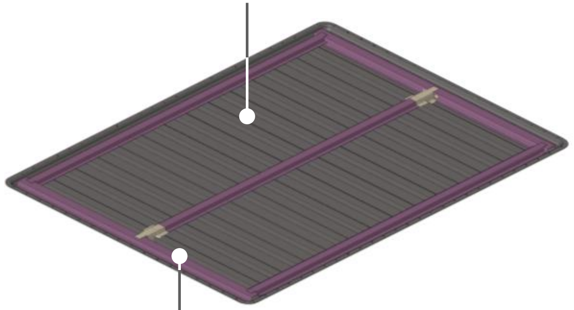
- Add crossmember brackets

- Outer rails attached

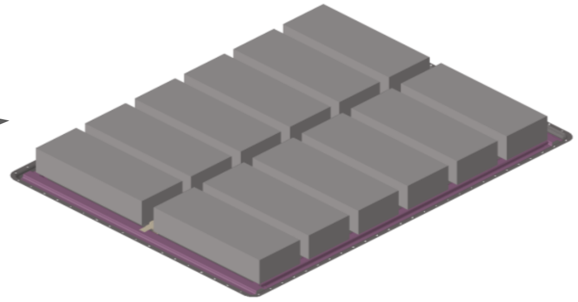


The packaging efficient stamped tray is an excellent choice for a battery enclosure cover

UHSS bottom for superior underbody impingement protection

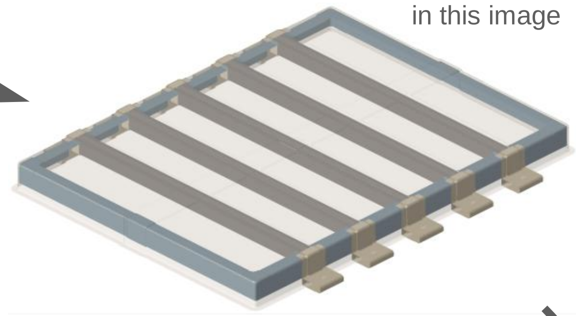


AHSS reinforcing frame for intrusion space and module attachments

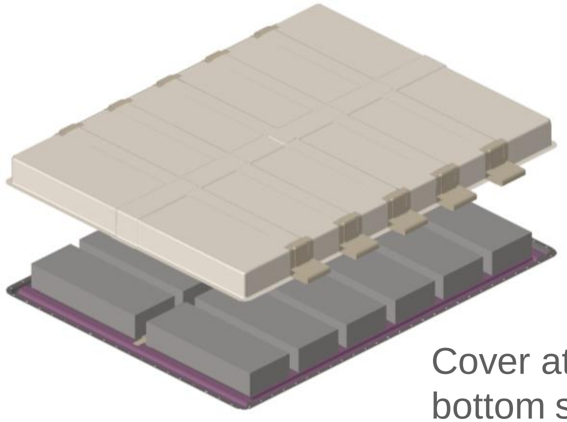


Bottom tray assembly with modules installed

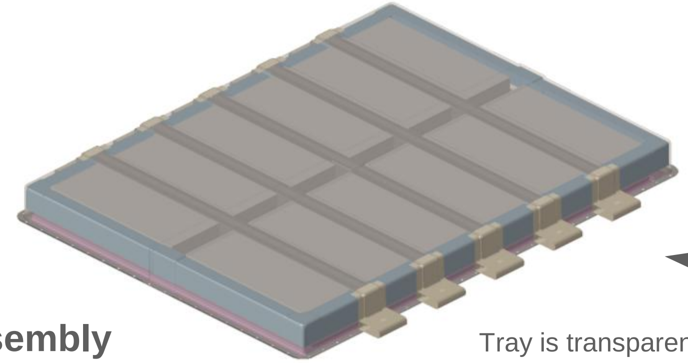
Tray is transparent in this image



Packaging efficient cover with inner reinforcements and crossmembers



Cover attaches to tray bottom sub-assembly



Finished assembly

Tray is transparent in this image

Summary and conclusion

- A battery enclosure with zero-degree draft angles and tight punch, die and corner radii was designed to maximize packaging efficiency.
  - Forming simulation (AutoForm) was used extensively to develop the design and to evaluate process robustness.
- Proof-of-concept parts were successfully produced to demonstrate the feasibility of the design.
  - Process is based on traditional stamping techniques that are well-established in the forming community.
  - Produced using a single draw operation in a mechanical press.
- Argus and circle grid analysis confirm acceptable strains and thinning for the as-produced parts.
- Dimensional analysis using 3D scanning shows good correlation between the as-designed and the proof-of-concept parts.
- Results demonstrate the conventional requirement of a draft angle in stamping is not always necessary.

For more information

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