Optimization of High-Volume Warm Forming for Lightweight Sheet Alloys

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Project ID # LM061

Overview

Timeline

- Project start date: January 1, 2010
- Project end date: September 30, 2012*
- Percent complete: 70%

** Original project proposal end date*

Budget

	Amount
Total Project Funding	$1,188K
-DOE Share @ 50% Funding	*$594K*
-USAMP Share @ 50% Funding	*$594K*
DOE Funding Received in FY2011	$367K
DOE Funding Received in FY2012	$107K

Barriers

- *Cost:* Low cost approach to warm forming
- *Performance:* Preserving the part complexity when forming an aluminum alloy vs. steel
- *Manufacturability:* Accounting for die heat-up during continuous production

Partners/Contributors

Ford, GM, Chrysler, Fuchs, Alcoa

Troy Tooling Technologies LLC

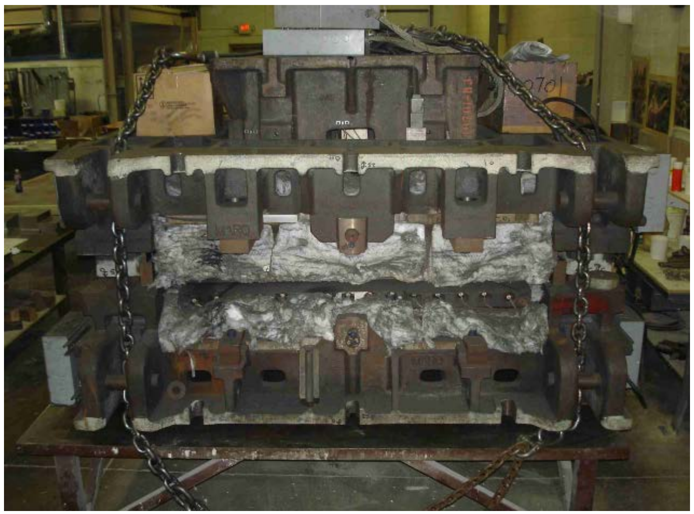
Magna Cosma Body & Chassis Systems

Aditya Birla Novelis

Project Lead: Nia Harrison/Peter Friedman

Review Past Warm Forming AMD Projects

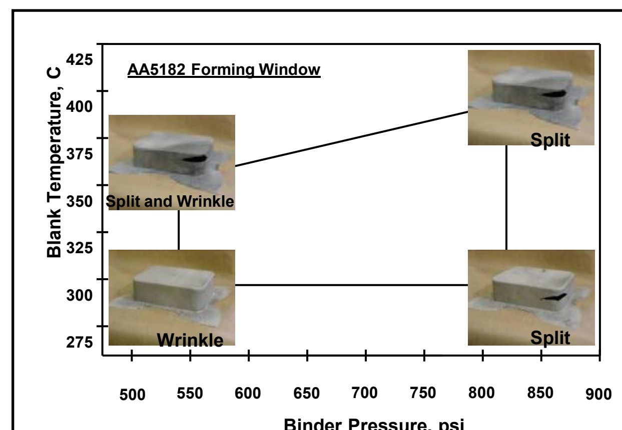
AMD307 Conventional Stamping Die Refitted for Warm Forming



Aluminum
Warm Forming

Aluminum
Room Temperature

AMD602 Purpose-Built Integrated Warm Forming Die



Review of Warm Forming AMD307/602 Project Accomplishments

- Developed and demonstrated key elements of warm forming technology with the forming of a door inner panel from commodity Al and Mg alloys.
- Developed die architecture and process to provide thermal stability / uniformity to minimize dimensional distortion during steady state production conditions.
- Performed fundamental material characterization work on magnesium sheet from five different suppliers.
- Established forming process limits for both commercial Al and Mg sheet.
- Developed finite element prediction of forming and failure during warm forming.
- Developed fully-automated warm forming cell capable of demonstrating the process under run-at-rate conditions at 5 jobs per minute for both aluminum and magnesium.

AMD307 closed FY2007, AMD602 closed FY2009

Objectives of Current Project – AMD905

- Phase 1: Develop an Optimized Warm Forming Process
  - Investigate the formability limits by producing a more intricate part
  - Lower die temperatures allowing for lower cost heating methods

Metric: ***Formability of aluminum sheet equivalent to steel at room temperature using a die at lower temperature***

- Phase 2: Scale-up and Demonstration of the Optimized Process
  - Design and build full-scale die based on optimized process
  - Conduct forming trials to demonstrate improved WF process

Metric: ***Successful scale-up and demonstration of repeatability at a production partner***

Milestones

Month/Year	Milestone
November/2010	Go/No-Go Decision: Optimized process approach decided (Go with non-isothermal for production scale-up).
July/2011	Milestone: FEA sheet formability study, die modifications, die design completed.
October/2011	Milestone: Die construction completed. Initial target date of August (2011) was missed due to cutting error in one of the four die components.
November/2011	Milestone: Initial forming trial completed at Vehma–Cosma. This event identified areas of the die that required modifications and initial proof of concept. Upon completion of the trial, the die was modified by Troy Tooling Technologies.
December/2011	Milestone: Second forming trial completed at Vehma–Cosma. This event established the baseline for forming feasibility. No further die modifications were necessary so the die was shipped from Vehma directly to Promatek.
January/2012	Milestone: Third forming trial completed at Promatek-Cosma. Formability window with respect to temperature was investigated and the optimal forming parameters established.
March/2012	Milestone: Post forming material properties determined.
June/2012	Milestone: Project close-out report completed.

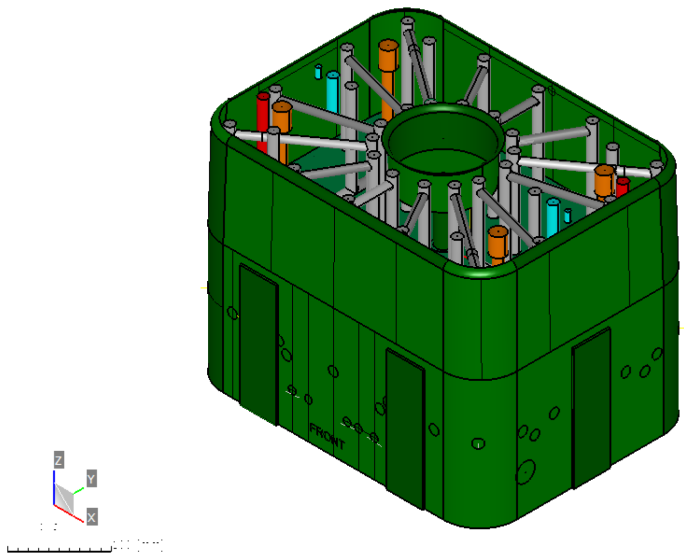
Technical Approach – Phase 1

- Objective: Develop an Optimized Warm Forming Process
  - Investigate the formability limits by producing a more intricate part
  - Lower die temperatures allowing for lower cost heating methods

- Approach:
  - Modify existing die from AMD602 to add a reverse feature at the bottom of the pan die, simulating a typical automotive panel.
  - Investigate non-isothermal processes:
    - Cold die / Cold blank (baseline)
    - Cold die / Warm blank
    - Warm die / Hot blank

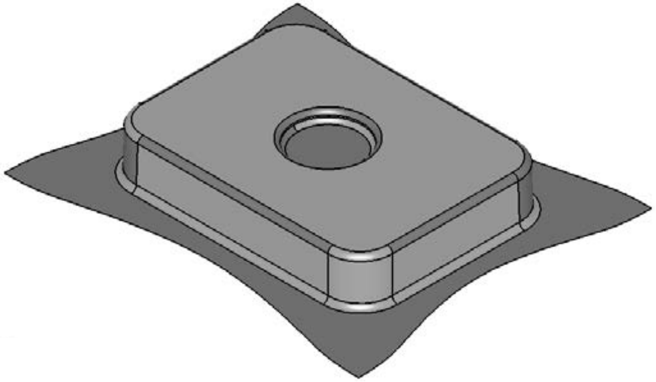
Die Modification

Modification of Pan Die to Include Mid-Panel Stretch



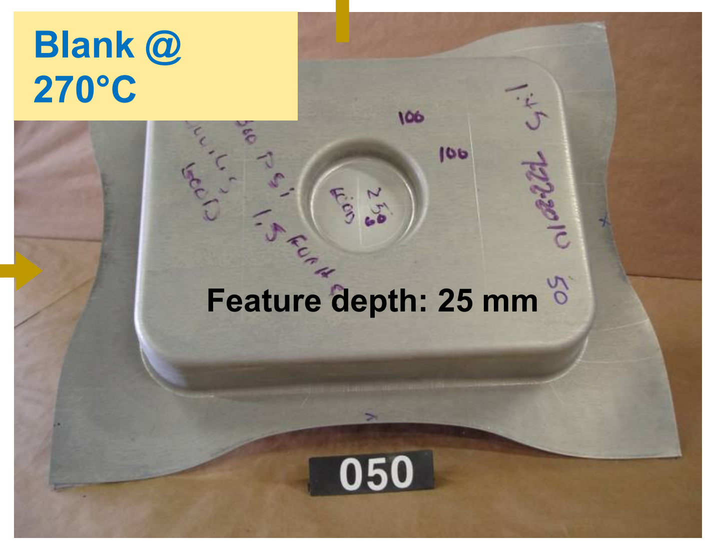
New punch with heating and water cooling capability developed

Previous panel design formed in the AMD602 warm forming die

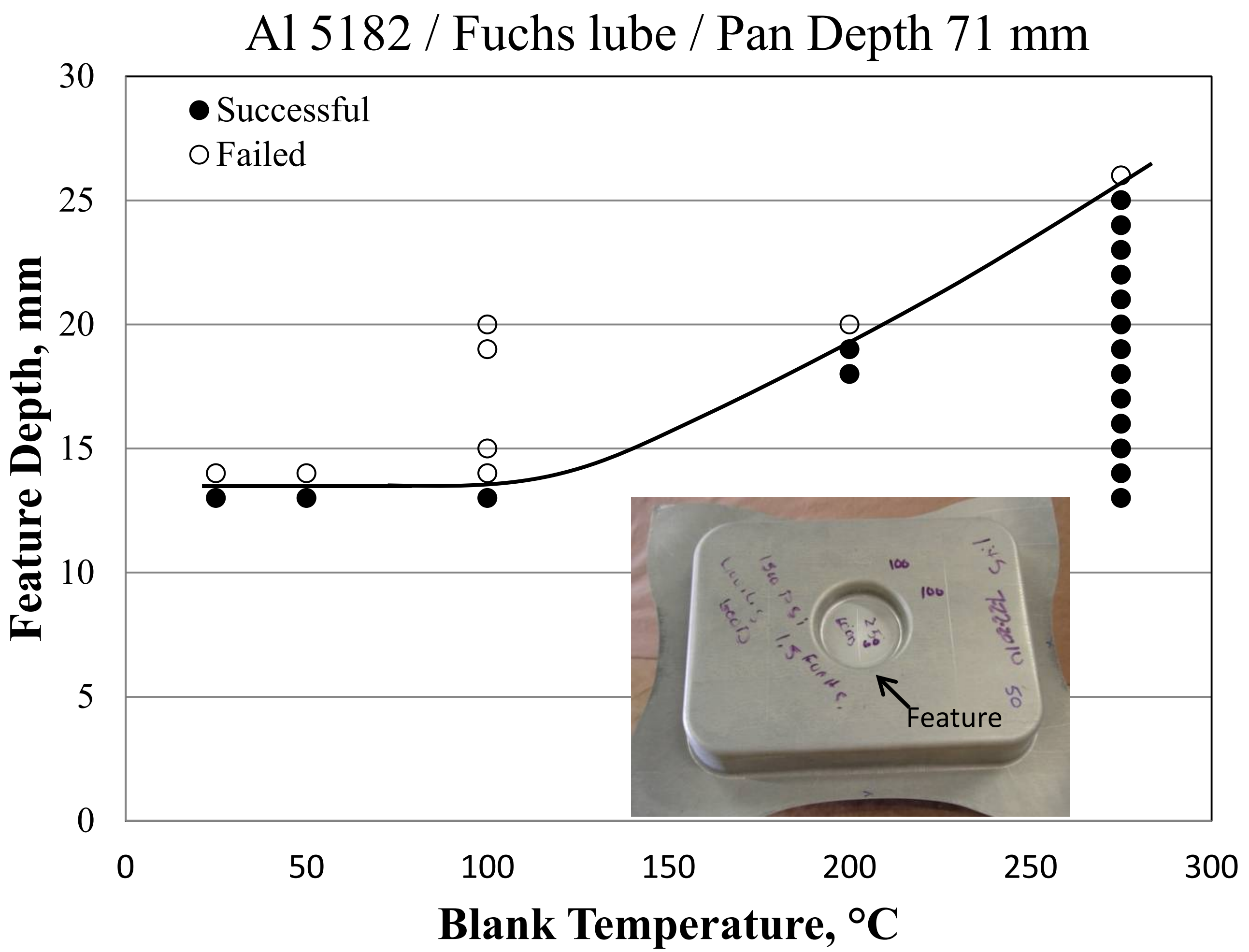


New trial part developed to simulate a typical automotive panel

Cold Die Forming: 71 mm depth

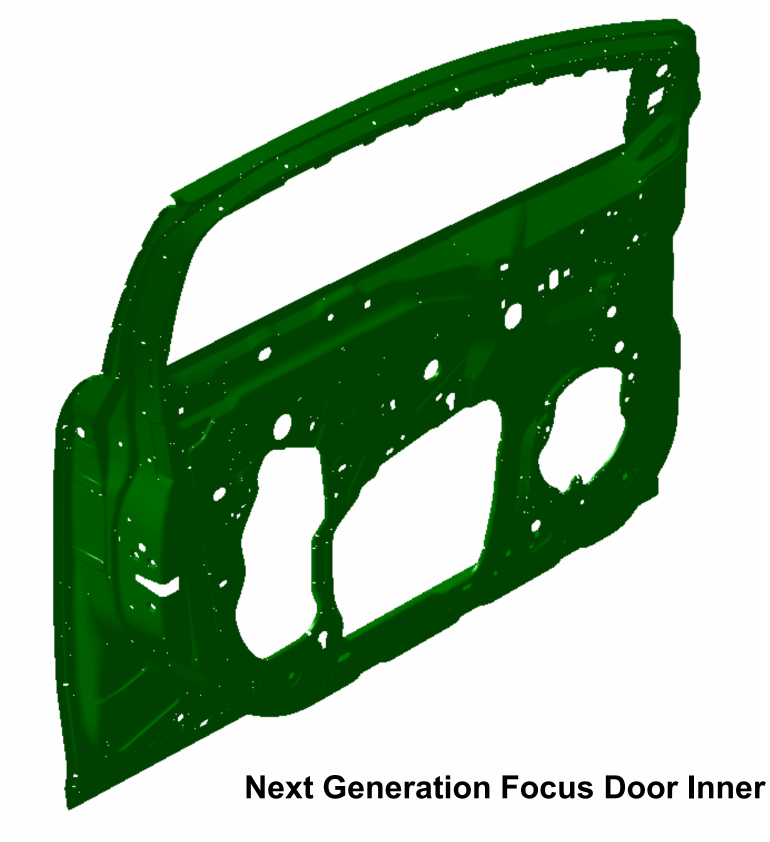


Cold Die Forming Limits



AMD905 – Phase 2

Demonstration Part

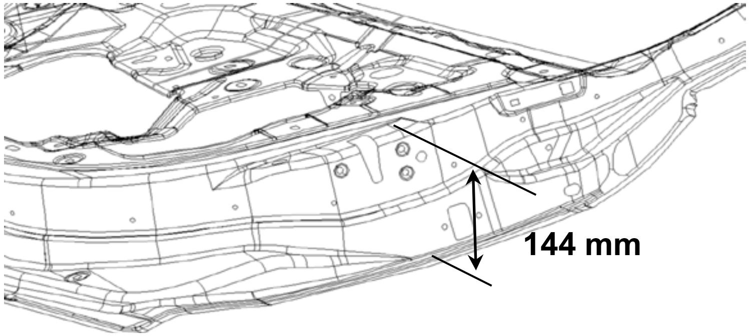


Next Generation Focus Door Inner

	Area(m^2)	Material	Gauge (mm)	Weight (Kg)	Weight save
Current design	0.948	EDDQ	0.8	5.92	
Proposed design	0.948	5182-O	1.4	3.58	40%

Production Process

- **144mm Draw Depth**
- **4 Ops., Single Draw**



Benefits of using this part in Phase 2 are that it cannot be formed in aluminum with conventional processes and much of the die engineering is available.

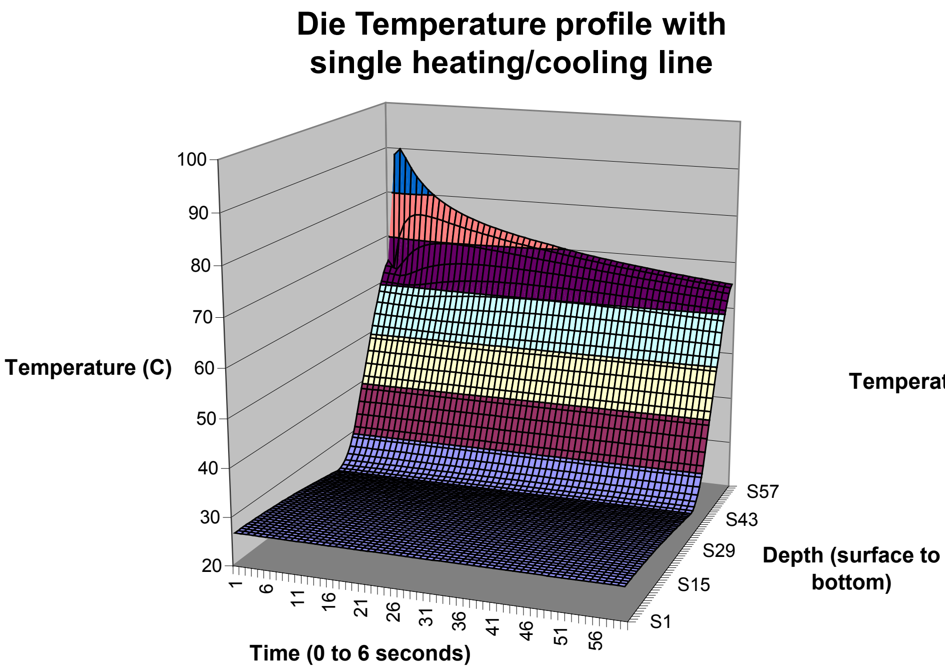
Technical Approach – Phase 2

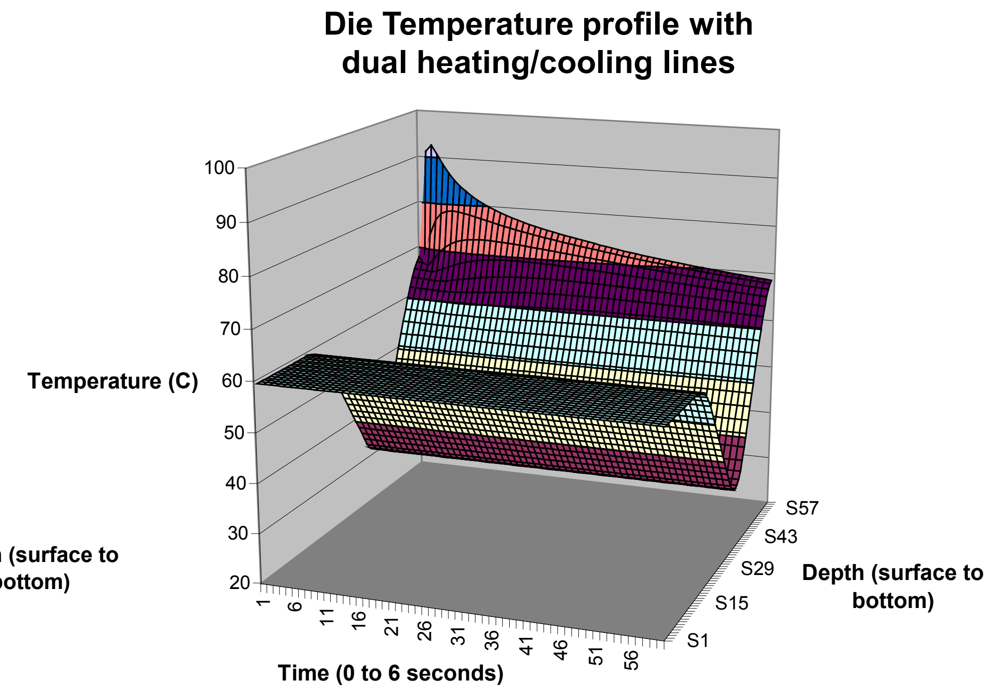
- Objective: Scale-up and Demonstration of the Optimized Process
  - Design and build full-scale die based on optimized process
  - Conduct forming trials to demonstrate improved WF process

- Approach:
  - Thermal Simulation – evaluation of die heat-up
  - CAE Simulation – evaluation of sheet formability
  - Die Development – preserving conventional practices
  - Vehma Forming Trial (trial 1) – die performance evaluation
  - Vehma Forming Trial (trial 2) – die performance evaluation
  - Promatek Forming Trail (trial 3) – manufacturing process repeatability

Thermal Simulation

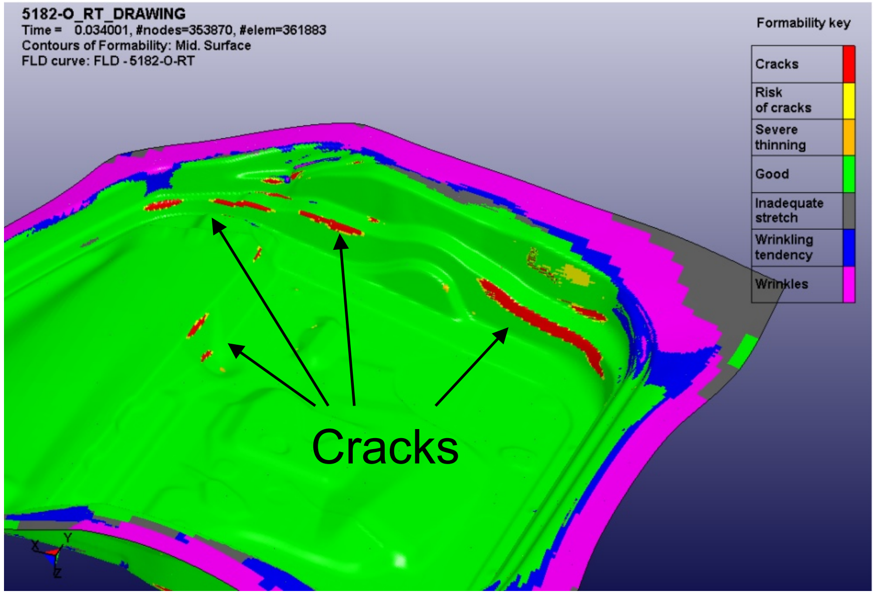
- Accomplishments:
  - Utilized die heating/cooling lines to attain a steady-state production at start-up.
  - Utilized die heating/cooling lines to maintain a steady-state condition during production.
  - Minimized distortion within the die.
  - Reduce the number of defective panels during forming startup.



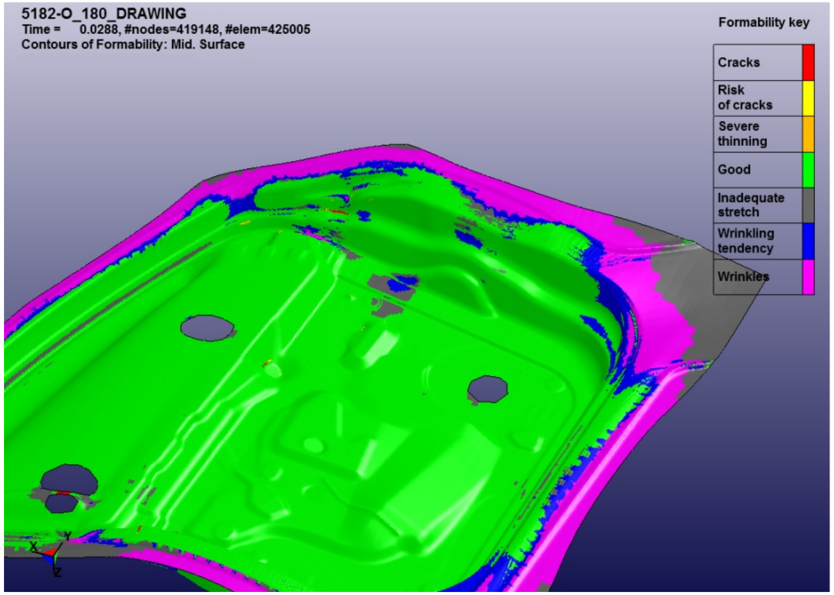


CAE Simulation

- Accomplishments:
  - Performed FEA of the process at room temperature and at elevated temperatures with isothermal assumptions.
  - Provided FEA feedback to the die design and modification process.
  - Optimized draw bead design and locations.
  - Optimized relief window configuration.



Initial die geometry, 20°C

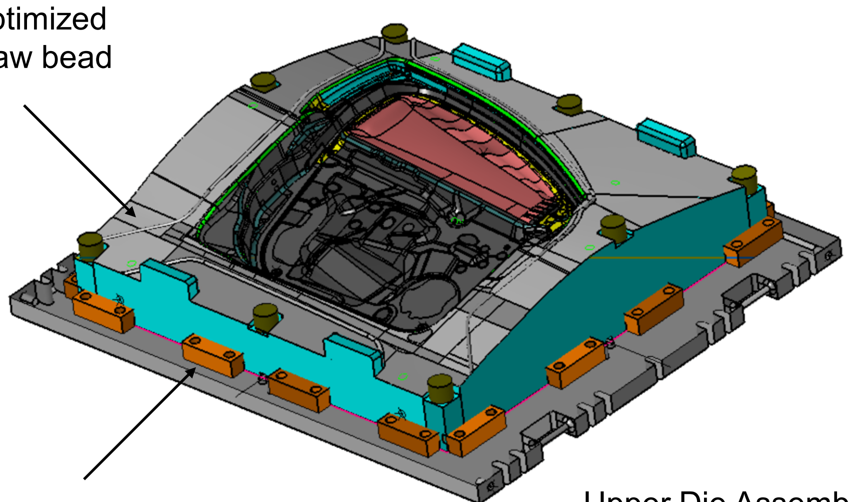


Final die geometry, 180°C

Die Development

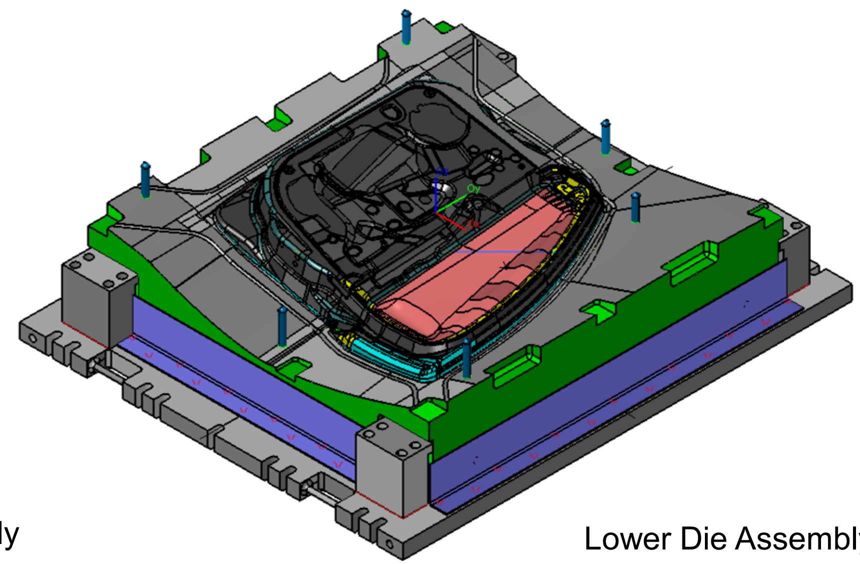
- Accomplishments:
  - Utilized traditional die construction practices that were optimized for aluminum sheet.
  - Delivered steel intent design and geometry by limiting the on part radii modifications to specific areas to improve drawability.
  - Modified draw beads to assist with material flow.

Optimized draw bead



Keepers – secure the die to press

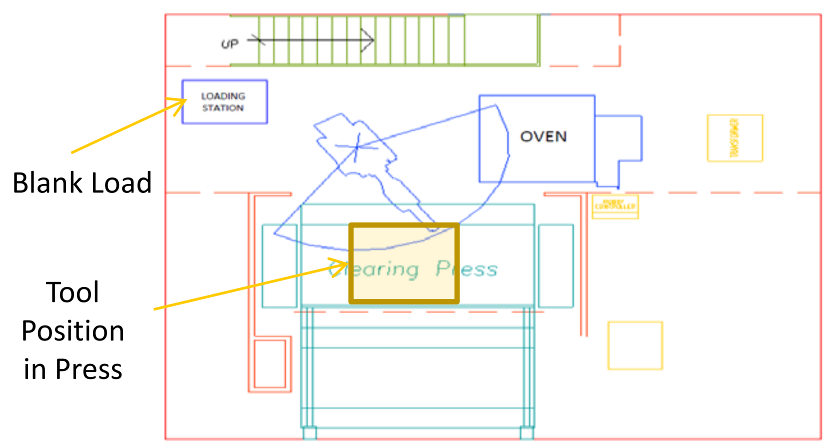
Upper Die Assembly



Lower Die Assembly

Promatek Forming Trial

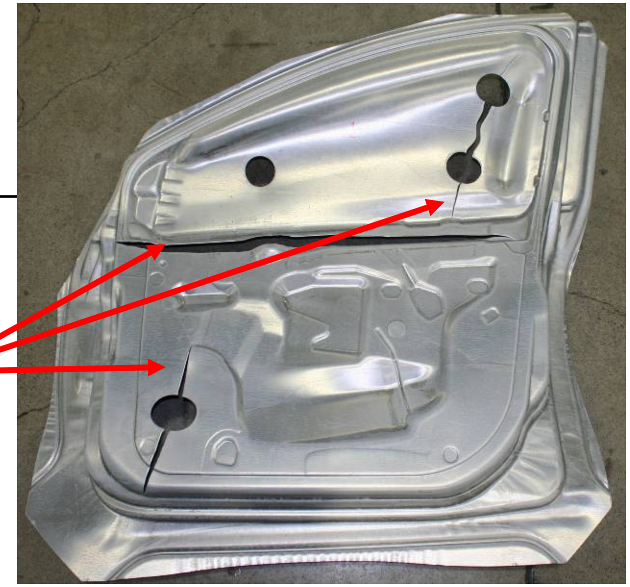
- Trial Parameters:
  - Two alloy suppliers of 5182-O: Alocoa & Novelis
  - Two directions: Rolling Direction & Transverse
  - Temperature range: Between 200°C - 300°C
- Press Parameters:
  - Press tonnage: 1475 tons
  - Cushion pressure: 270 tons
- Cycle time:
  - Pre-heat blank: 180 seconds
  - Furnace to forming: 15 seconds
- See Movie



Forming Trial Results:

	Alcoa (L)		Novelis (L)	
	L	T	L	T
200°C	1	2	3	4
225°C	5	6	7	8
230°C	21		22	
240°C	23	31	24	32
250°C	9	10	11	12
260°C	25	33	26	34
270°C	27		28	
275°C	13	14	15	16
280°C	29		30	
300°C	17	18	19	20

Formability Window



Room temperature

Temperature: 250 C

Collaborations/Partners

- **Ford Motor Company**
  - Peter Friedman
  - Nia Harrison
  - Andrey Ilinich
  - George Luckey
- **General Motors Corporation**
  - Paul Krajewski
  - Ravi Verma
- **Chrysler Group, LLC**
  - Jugraj Singh
  - DJ Zhou
- **Troy Tooling Technologies, LLC**
  - Dennis Cedar, tool maker
  - Richard Hammar, thermal analyst for die system
- **Fuchs Lubricants**
  - Jim Wiederholt, lubricant supplier
- **Alcoa**
  - Glen Jarvis, material supplier
- **Novelis**
  - Mike Bull, material supplier
- **Vehma – Cosma**
  - Scott Gayeski, production partner
  - Timothy Skszek, production partner
- **Promatek - Cosma**
  - Jonathan Hook, production partner
  - Jagdeep Jhajj, production partner
  - Darren Womack, production partner
  - Alex Zak, production partner

Proposed Future Work

- FEA Development
  - Gap: No established coupled thermo-mechanical simulation model for formability studies.
- Design Guidelines
  - Gap: Identifying the radii limitations as a function of temperature for design purposes.
- Continuous Production
  - Gap: Run-at-rate production cell has not been established to verify die performance in a non-isothermal environment.

Technical Accomplishments

- Established WF process for Phase 2 for significantly lower cost and enhanced formability.

- Completed die engineering and development for door inner
  - Modified die for aluminum gauge and draw bead design
  - Completed formability simulation
  - Completed thermal analysis of steady state forming process
  - Established heating strategy for the Phase 2 forming trials

- Identified Cosma as the collaboration supplier-partner for Phase 2
  - Defined roles and responsibilities
  - Successfully executed forming trials at Cosma's Vehma facility (manual load trial)
  - Developed a loading process for repeatable forming trials
  - Successfully executed forming trials at Cosma's Promatek facility (automated load trial)

Summary

- <u>Key deliverables of the project:</u>
  - Established a low-cost warm forming process.
  - Implemented traditional die construction practices which were optimized for aluminum sheet.
  - Demonstrated that the optimized forming process is repeatable.
  - Demonstrated a cycle time consistent with conventional stamping.

- <u>Significance of the results:</u>
  - The ability to use aluminum versus steel resulted in a weight savings of ~5 lbs (~40% wt savings).
  - A non-isothermal warm forming process demonstrates a low cost approach to forming aluminum which is consistent with existing conventional stamping practices.