Development of Low Cost, High Strength Automotive Aluminum Sheet

Russell Long – Principal Investigator

Project ID: LM108

2017 Annual Merit Review

June 6, 2017

ARCONIC

Innovation, engineered.

MAGNA

COSMA INTERNATIONAL

OAK RIDGE National Laboratory

HONDA

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Overview

Timeline

- Start Date: Oct. 1, 2014
- End Date: June 30, 2018
- 60% complete

Barriers

- Demonstrate a warm formed part made using a new alloy with an ultimate strength of 600 MPa, 8% minimum elongation with acceptable corrosion.
- Cost premium of less than $2/lb saved over baseline UHSS component

Budget

- Total project funding (50/50): $4,783,541
  - Govt share: $2,391,771
  - Partner share: $2,391,771
- Funding in FY2016: $380,000
- Funding for FY2017: $600,000

Partners

- Arconic – Lead
- Honda
- Cosma
- ORNL

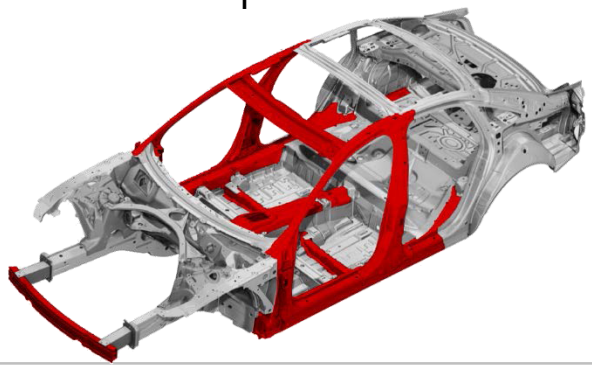
Project Objectives/Relevance

Project Objectives:

- Develop a high strength aluminum automotive alloy and processing to provide Ultimate tensile strength in the finished stamped component greater than 600 MPa and 8% total elongation
- Produce a representative part at forming temperatures less than 225 deg C with cost of finished, stamped component at less than $2/lb saved compared to a baseline part.

Relevance:

- Reducing weight is a key enabler to reduce fuel consumption thereby reducing green house gas emissions and the dependence on foreign oil.
- 5xxx and 6xxx alloys currently used in automotive BIW are not competitive with Ultra High Strength Steels (UHSS) used for the safety cage components.
- High Strength 7xxx alloys can provide weight savings over hot stamped UHSS components.



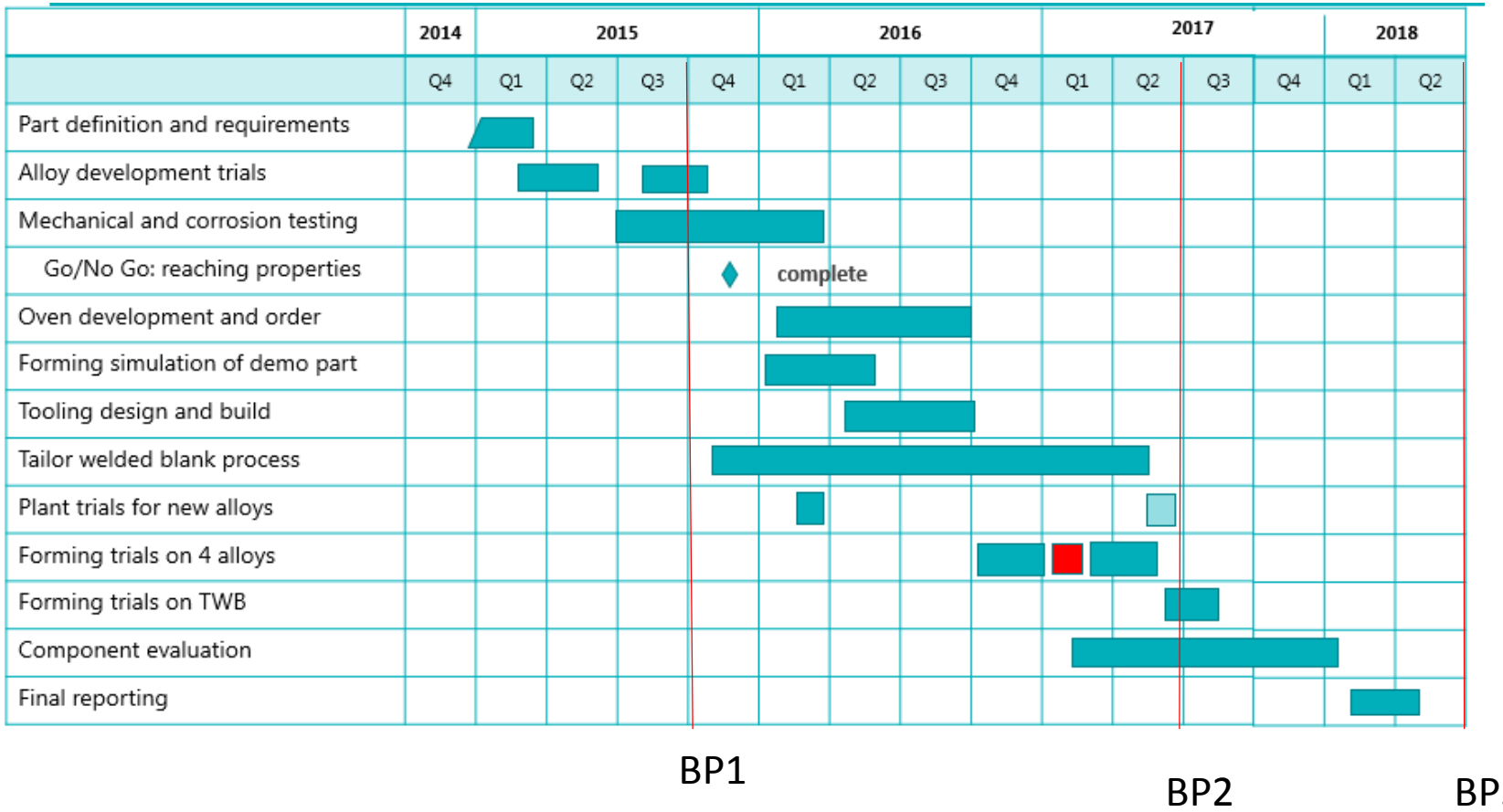
Baseline Part - Honda

Door ring used on multiple Honda/Acura models (shown here on the TLX for illustration)

State of the Art
Hot Stamped door ring
UHSS (1500 MPa)
1.4 mm thick
12.5kg

New aluminum alloy
2.5 mm thick
7.5 kg
38% weight savings

Milestones


2014
2015
2016
2017
2018
Q4
Q1
Q2
Q3
Q4
Q1
Q2
Q3
Q4
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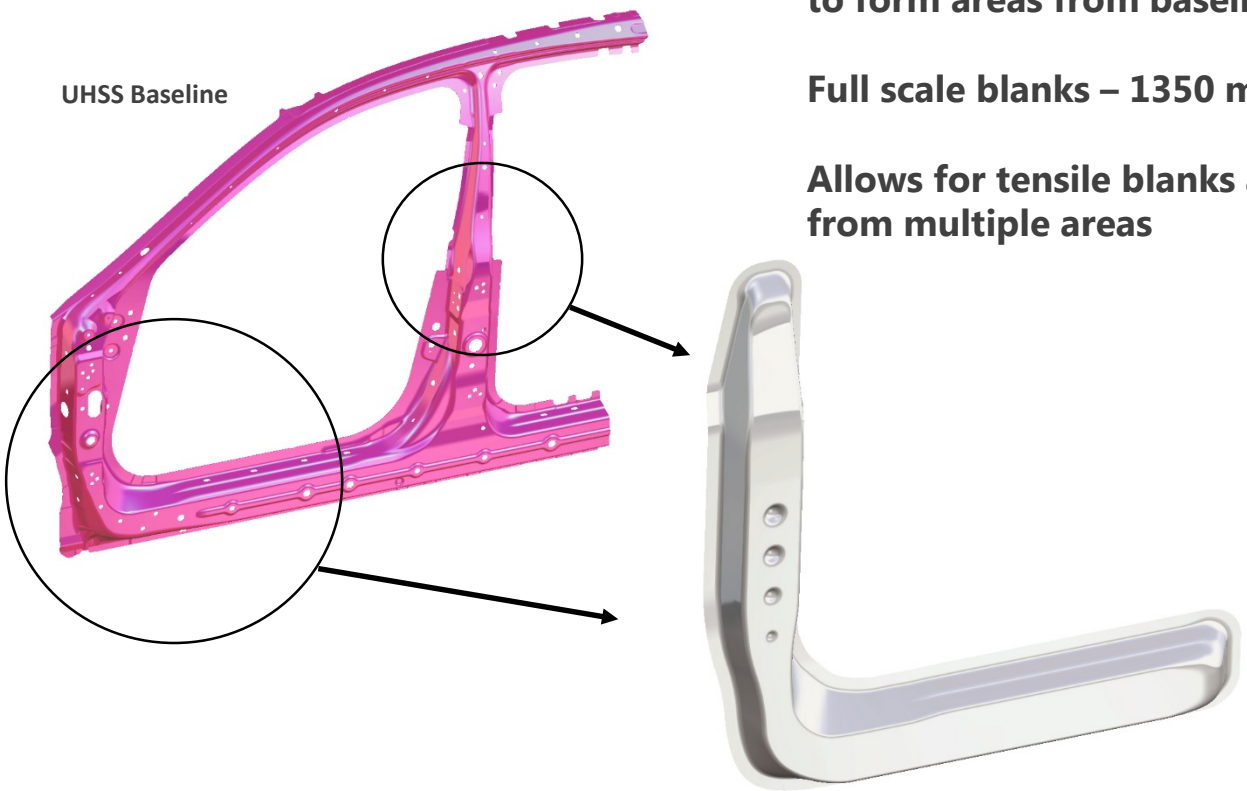
Q3
Q4
Q1
Q2
Part definition and requirements
Alloy development trials
Mechanical and corrosion testing
Go/No Go: reaching properties
complete
Oven development and order
Forming simulation of demo part
Tooling design and build
Tailor welded blank process
Plant trials for new alloys
Forming trials on 4 alloys
Forming trials on TWB
Component evaluation
Final reporting
BP1
BP2
BP3

Approach/Strategy

- Conduct alloy development trials. The strength and elongation targets are based on DOE requirements. The formability and corrosion targets are based upon the Honda part design.
- Purchase warm forming oven and install in existing press line along with robotic blank transfer to the tooling
- Design and build tooling for warm forming of material.
- Produce full coils of experimental alloys for use in forming trials
- Conduct warm forming trials on development alloys (without tailor welding)
- Develop Friction stir welding process for tailor welded blanks to improve material utilization.
- Conduct warm forming trials on development alloys with tailor welding
- Characterize properties and performance of final warm formed parts after paint bake cycle

Demonstration Part Definition - Honda

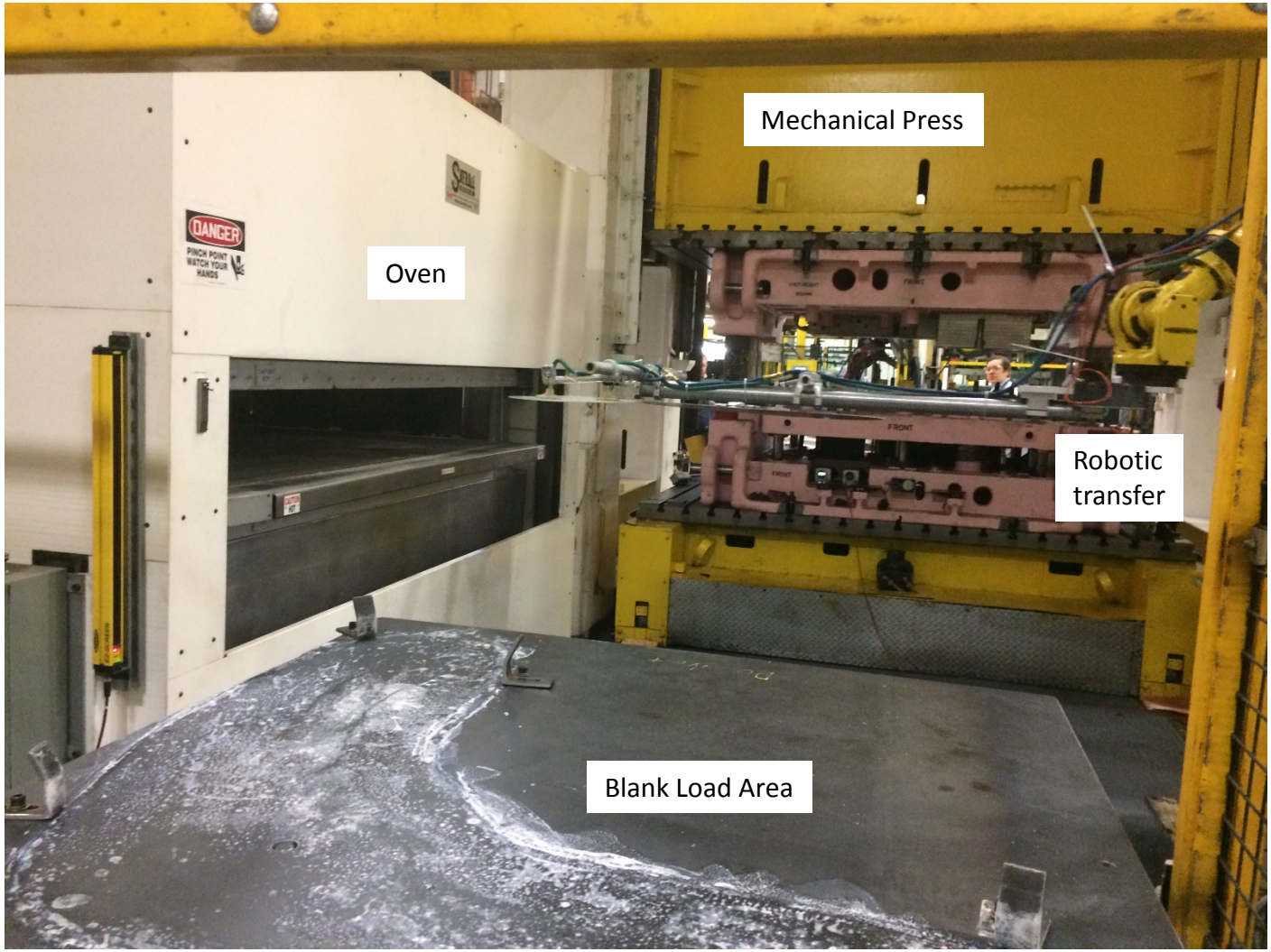


Demonstration part includes difficult to form areas from baseline

Full scale blanks – 1350 mm x 1350 mm

Allows for tensile blanks and corrosion samples from multiple areas

FY2016 Accomplishments:
Forming Cell and Tooling Complete - Cosma



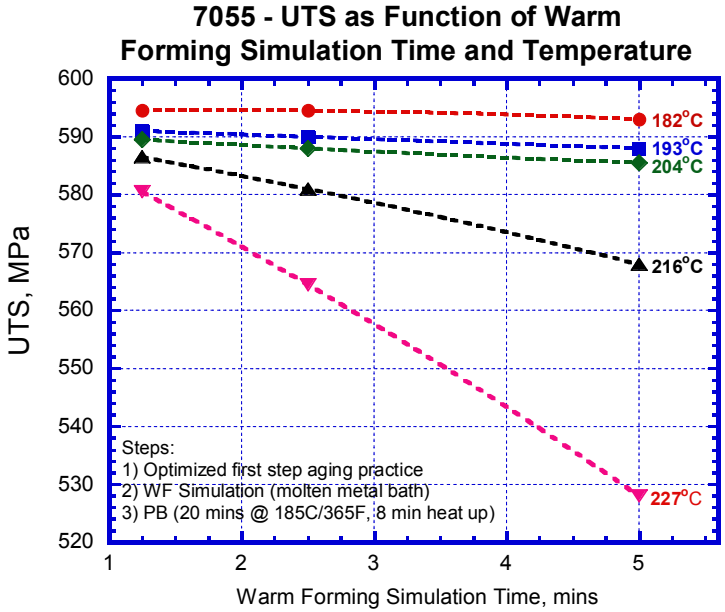
FY2016 Accomplishments:
Two Forming trials have been conducted- Cosma

Forming trial steps:

- Blank shape optimization
- Forming temperature effects
- Alloy/temper performance comparison during forming trial
- Properties measured in part after forming and paint bake

Temperature effects:

- Heating time is critical to maintaining material strength through the warm forming process
- Platen oven has been developed to minimize heating time and reduce any heating effect on the alloy temper
- Testing have shown close correlation between coupons removed from parts and lab samples



FY2016 Accomplishments: Forming trials - Cosma

Out of the 6 alloy/tempers, two gave the best forming results:

- 180-101
- 111a

Formability dramatically improved as the blank temp increased:

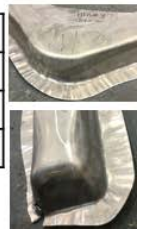
- Heating at 180 degree C oven caused large cracks
- Part was formable at 230 deg C

	Pillar end
	Inside elbow
	Outside elbow
	Sill End

	Pillar end
	Inside elbow
	Outside elbow
	Sill End

	Pillar end
	Inside elbow
	Outside elbow
	Sill End

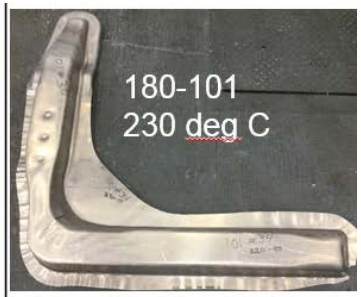
	Pillar end
	Inside elbow
	Outside elbow
	Sill End



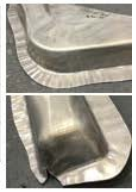
	Pillar end
	Inside elbow
	Outside elbow
	Sill End

	Pillar end
	Inside elbow
	Outside elbow
	Sill End

	Pillar end
	Inside elbow
	Outside elbow
	Sill End

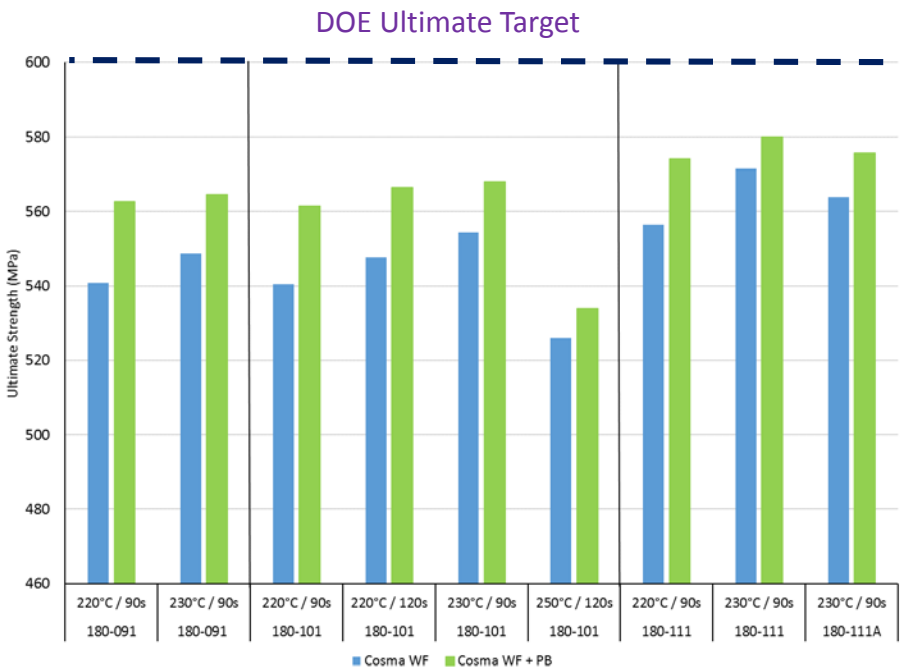


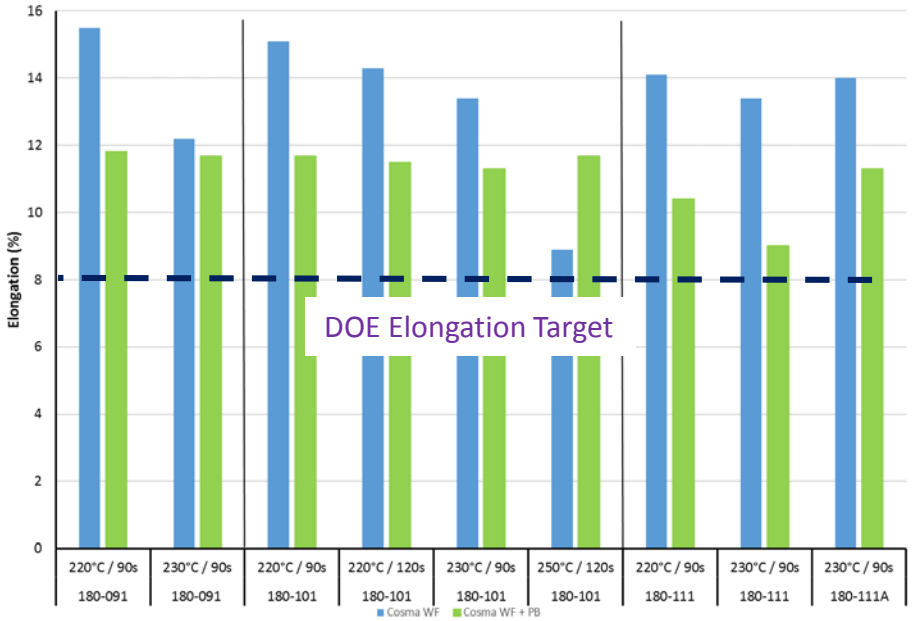
	Pillar end
	Inside elbow
	Outside elbow
	Sill End



Properties have been measured on Warm Formed parts from Cosma Eagle Bend trials

Warm Forming at 250°C/120s shows low TYS and UTS properties (overaged)
Limited impact on properties at 220°C and 230°C(oven temperature)

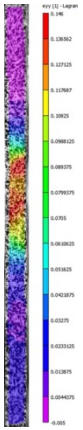


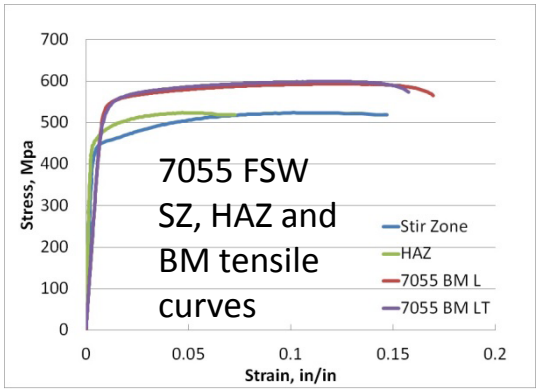


Alloy 111 has shown the best formability and highest strengths – about 20 MPa below DOE Ultimate Strength Target

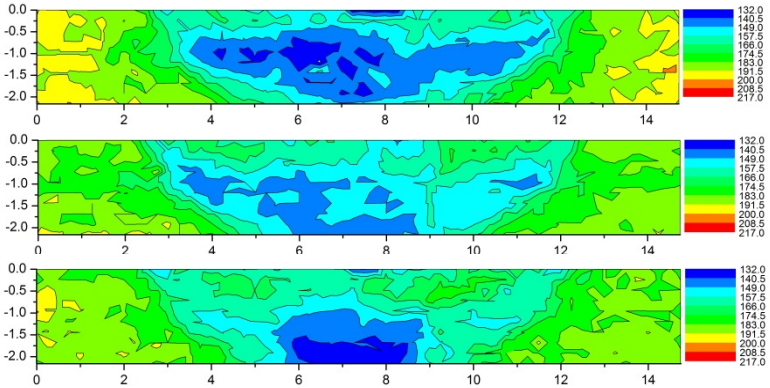
FY2016 Accomplishments: Tailor Welded Blank Development

- Developed friction stir welding process conditions appropriate to weld 7xxx Al alloys developed in this project
  - Four 7xxx experimental heats of different chemistries and heat treat schedules
  - Defect free welds
  - Passed crown and root bend tests (6t radius)
  - Effect of warm forming and paint baking on properties were evaluated.
- Obtained local tensile properties in different zones of Al FSW by DIC technique





7055 FSW SZ, HAZ and BM tensile curves

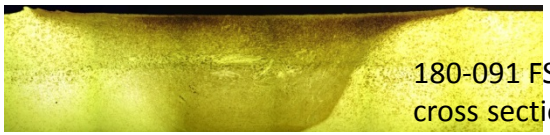


7055 FSW

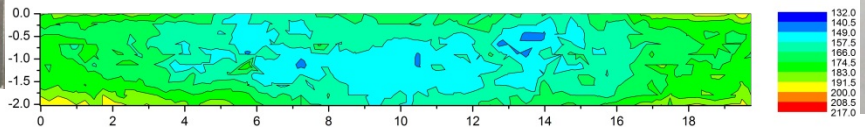
7055 FSW + warm forming

7055 FSW + warm forming + paint baking

180-091 FSW joint



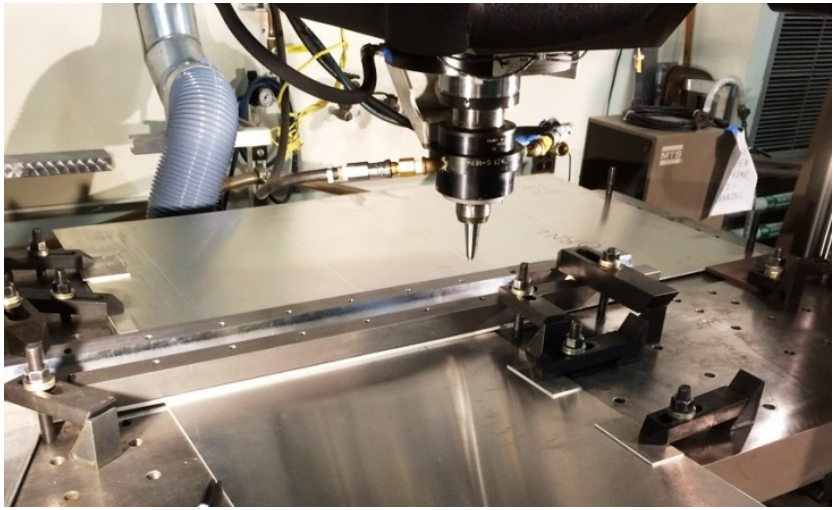
180-091 FSW cross section

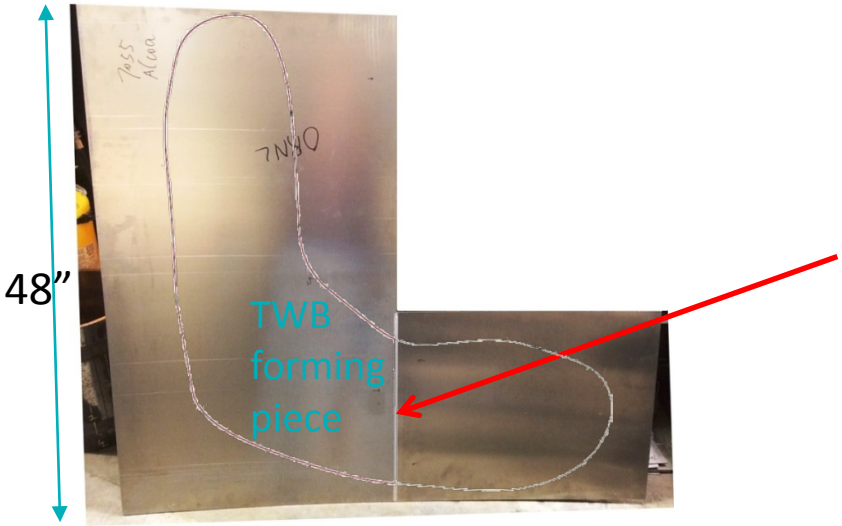


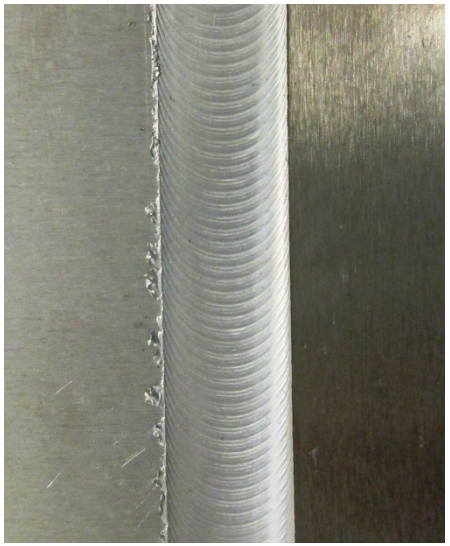
180-091 FSW bend test samples

FY2016 Accomplishments: Tailor Welded Blank Development

- Process scale up for tailor welded blank FSW
- Initial scale up development at ORNL
  - 7055 alloy was used for now for scale up to produce TWB for subsequent warm forming
  - Blank size: 27x48" (688 mm X 1219mm) and 20x26" (517mm X 656 mm)
- Transferred the FSW process conditions, weld quality and property requirements to TWB Co
- TWBs for subsequent warm forming and testing will be made at TWB Co







Responses to Reviewer Comments

Reviewer Comment:

- Could work done by PNNL and TWB be used to further the efforts on tailor welded blanks for this project?

TWB Co is involved in FSW technology commercialization. ORNL has been closely working with TWB Co to transfer the knowledge of FSW 7xxx alloys gained at ORNL. TWB will produce the full scale friction stir welded blanks with the assistance from ORNL.

- Reviewer recommended that the tight radii be maintained on the closed ends of the part to allow for correlation to the warm forming simulation all the way to splitting.

The radii on the closed end of the part were maintained and we do see cracking on all alloys in that area.

Partnerships/Collaborations

ARCONIC	Arconic will develop compositions, processing and thermal treatments to reach the target DOE/Honda requirements on a lab scale. Alcoa will select the most promising alloys and produce full-scale blanks for forming trials.
HONDA	Honda will provide specifications for the component and test criteria, as well as functional performance expectations. Honda will provide specifications for related coupon testing that will be conducted by Honda, industry partners, and ORNL. Finally, Honda will assess functional performance of the component.
MAGNA COSMA INTERNATIONAL	Cosma will develop the tool surface and perform forming simulations of the 7XXX alloy component to successfully develop the forming tool. Cosma will construct the forming die for trials. Operating parameters of the tool/oven will be developed. Finally, Cosma will integrate both the oven and forming tools on an existing press line for demonstration.
OAK RIDGE National Laboratory	ORNL will develop the friction stir welding (FSW) process and produce initial samples for forming characterization at warm forming temperatures. Once the weld strengths and forming characteristics are understood, ORNL will produce the TWB for the forming trials.

Remaining Challenges and Barriers

- There are additional items that need to be explored during the forming trials:
  - Impact of warming the tooling
  - Correlation between forming simulation and part forming experience
  - Springback during warm forming
- Understand the balance between strength, elongation and corrosion performance for the final product. The part functional assessment will be completed in 2017.
- Impact of the Friction Stir weld seam on the forming of the demonstration part.

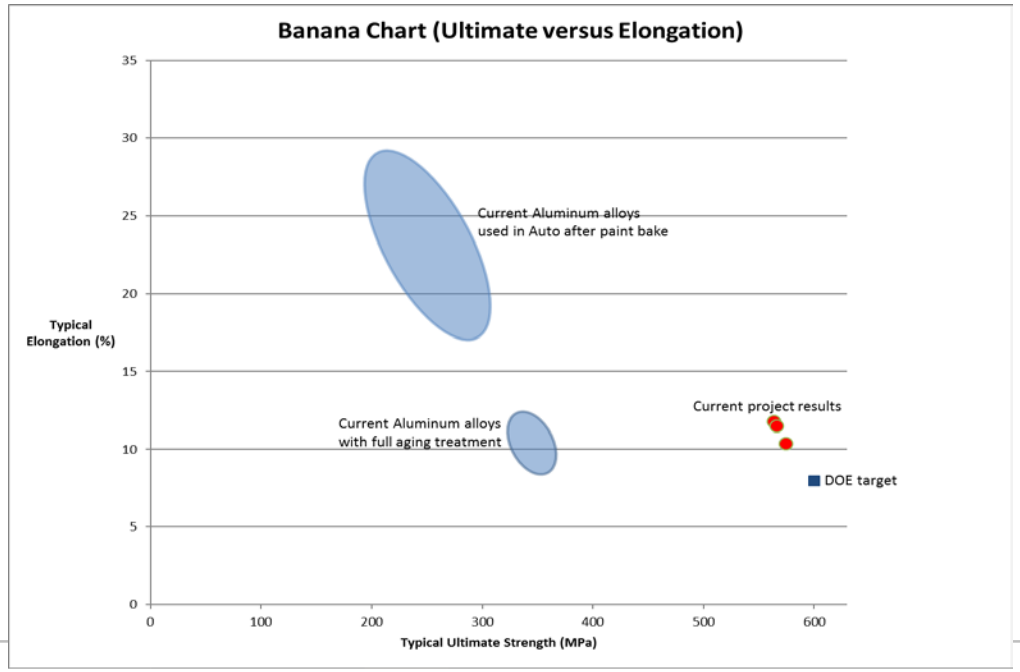
Proposed Future Work

- Complete warm forming trials on 3 new alloys.
- Test samples cut from formed components (after simulated paint bake cycle – for corrosion testing)
- Complete warm forming trials using heated tooling
- Provide tailor welded blanks for warm forming trial
- Repeat warm forming trial using tailor welded blanks
- Make final recommendation on alloy and temper for future work
- Cost study using final alloy and forming information

Any future work is subject to change based on funding levels

Summary

- A warm forming cell has been installed including an oven, robotic transfer and forming press.
- Warm forming trials on a representative demonstration part have been conducted on 7055 and 4 new alloys.
- Properties have been measured from from the formed parts. Corrosion testing is ongoing.
- Friction stir welding has been used to produce TWB samples at high welding rates that reach 75% of the base metal strength.
- Full scale TWBs will be produced for forming trials and forming trials of TWBs are planned.
- Close to DOE ultimate strength target and exceeding the elongation target



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