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Aerodynamic Lightweight Cab Structure Components

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Project ID#
LM60

Outline

- Project Overview
- Relevance
- Approach
- Milestones
- Technical Approach
- Results and Accomplishments
- Summary
- Publications/Presentations

Project Overview

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Project Timeline

- Start: 10/01/2010
- Finish: 12/30/2014

Budget

- Total project funding
  - DOE – $1220K
- FY11 Funding - $375K
- FY12 Funding - $365K
- FY13 Funding - $415K
- FY14 Funding - $65K

PACCAR and Magna SCFI (Stronach Centre For Innovation) providing 50% cost share as in-kind materials and effort

Barriers

- Suitable aluminum alloys meeting strength and durability requirements for heavy duty trucks lack formability
- Forming and manufacturing process must be compatible with PACCAR cab assembly and finishing methods
- Moderate production volumes limit tooling options

Partners

- PACCAR Technical Center
- Magna International – Stronach Centre for Innovation (SCFI)
- Novelis Aluminum

Relevance

- The objective of the project is to develop and demonstrate a thermo-mechanical forming process that will allow a standard aluminum sheet alloy to be formed into complex, aerodynamic shapes and components, reducing component weight by up to 40%
- The development of the hot/cold forming process for aluminum sheet will allow commercial truck designers to replace heavier glass fiber reinforced plastics and sheet steel in complex-shaped components while meeting required strength, durability and finish requirements
- This project will develop a unique forming process that produces desirable strength and residual ductility from a highly corrosion resistant 6000-series containing low levels of Cu and Mg alloying elements

Approach

- Evaluate warm forming process that is compatible with PACCAR-selected 6XXX-series aluminum alloy
- Demonstrate extended formability that will allow forming of aerodynamic body components
- Demonstrate compatibility with PACCAR paint bake cycle and required component property and surface finish requirements
- Form full-scale component using 6XXX alloy and PNNL-developed process and conduct cab durability test evaluation

Milestones – FY2013 Current Status

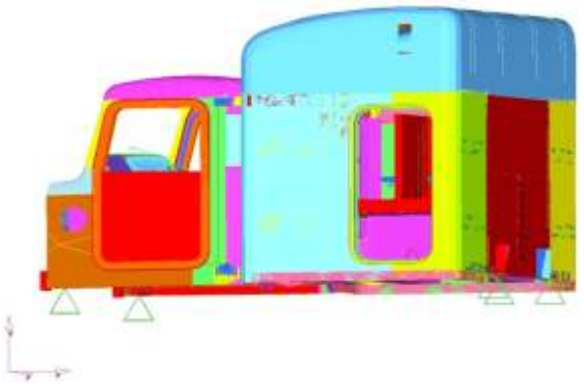
Complete forming of 25 left- and right-hand aerodynamic truck prototype components and deliver to PACCAR Technical Center (June, 2013)

- Milestone has been revised and re-scheduled due to development issues
- Modeling of forming process identified requirement for separate class A forming and flanging and trim steps
- Magna required to develop 2-die forming process with additional upgrades to equipment capabilities
- Magna selected three forming approaches (options 1, 2, and 3)
- Prototype formed parts using option 1-3 produce dimensionally compliant A-pillar components, but yield strengths below target levels
- Prototype forming identified the need for higher temperature blank heating (>500 C) in order to solutionize the X608 sheet prior to final forming
- **Revised Milestone:**

Complete warm forming of 25 left and 25 right cab exterior components meeting dimensional criteria and minimum 160 MPa tensile yield strength and deliver to PACCAR and PNNL for test and evaluation. Revised completion June 2014

Project Background

- Focused on Class 8 Truck cab components that provide weight savings and contribute to aerodynamic optimization
- Aluminum can provide >40% weight savings compared to SMC and steel
- Aluminum is not used in potential stamped component applications because it:
  - Lacks formability required for aerodynamic panels
  - Must be compatible with established manufacturing and finishing processes



Prototype Development and Testing Phase

- Prototype component currently made in glass-reinforced plastic (SMC) to be formed in aluminum using X608 alloy
- Magna – Stronach Centre For Innovation (SCFI) engaged to utilize their preforming technology for preforming step + RT final forming
- Requesting 25-30 each of left hand and right hand cab components
- Cab components will be used for:
  - Demonstrating compatibility with cab assembly and finishing process
  - On-cab component testing (cab shake or on the road)
  - Formed components for property testing and characterization

PACCAR Prototype Component –
Cab A-Pillar Cover

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PACCAR Prototype Component – Peterbilt 579

PACCAR Prototype Component – Kenworth T680

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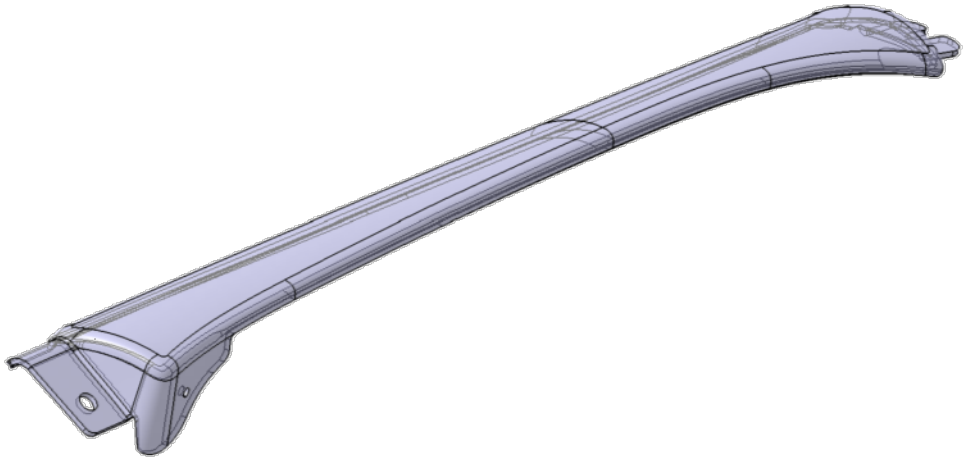
Aluminum A-Pillar Forming Results – Technical Accomplishments and Progress (FY2013)

- PACCAR and Magna SCFI have selected a truck cab components for demonstration of forming process
- A cost-shared contract with Magna SCFI was been placed to produce 25 each of a left and right cab aerodynamic component that will demonstrate assembly and finishing compatibility and cab structural performance
- Magna SCFI completed development of a 2-die forming system and demonstrated three optional forming processes (option 1, 2, and 3)
- Components formed by optional forming processes meet dimensional and functional criteria for A-pillar application
- PNNL tensile testing of formed A-pillar components indicated tensile yield strengths below target values
- Technical review of forming process indicates the need for higher X608 sheet preheat temperatures to promote solutionization and improved paint bake response

Aluminum A-Pillar Forming Results – Technical Accomplishments and Progress (FY2013)

Paccar A-Pillar
Material: X608 Alum
Thickness: 1.4 mm



Tooling required - One forming station and One restrike station.

Perform trials using the following options

Option 1:
Load blank, preheat and form at 430-475C. Restrike flanges immediately thereafter at 430-475C. Both tools running in common “HotBox”

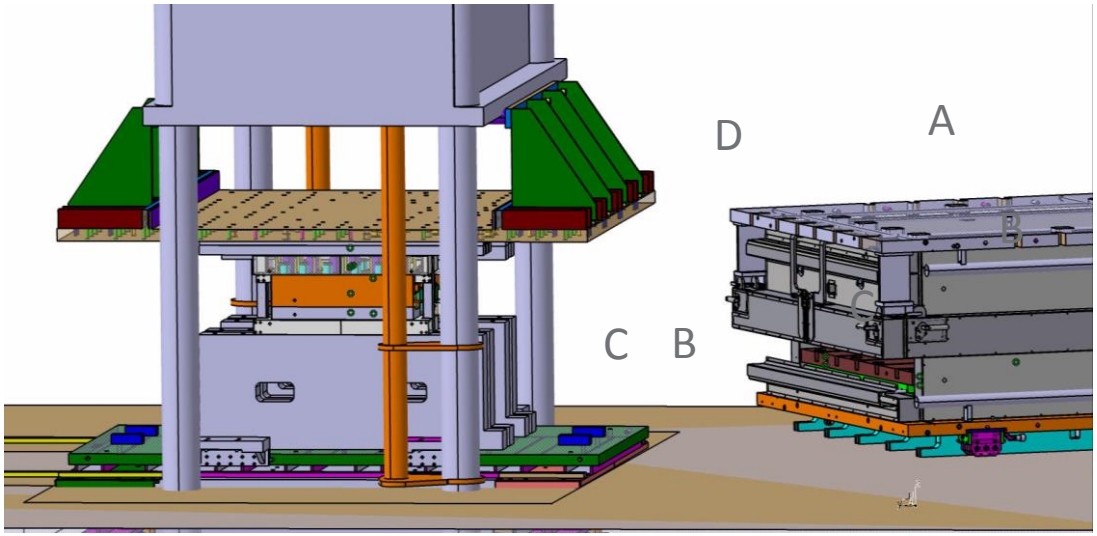
Option 2:
Heat blank to 400-475C. Quench and immediately form in cold die. Restrike flanges thereafter in cold die.

Option 3:
Heat blank to 400-475C. Quench and immediately form in cold die. Reheat partial form to 400-475C again. Quench and immediately restrike flanges in cold die.

Aluminum A-Pillar Forming Results – Technical Accomplishments and Progress (FY2013)

Dies Setup in Press for Options 2 & 3

A. HotBox preheat oven
B. Move to quench tank
C. Move to die
D. Move to laser trim



Option 2 method

1. Preheat heat
2. Quench heated blank
3. Load blank into station 1 and form
4. Remove formed panel for laser trim
5. Finish flange in station 2 die

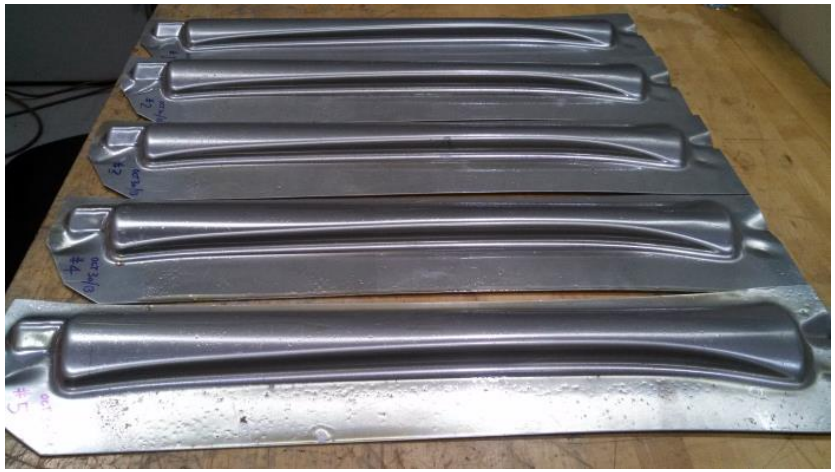
Option 3 method

1. Preheat heat
2. Quench heated blank
3. Load blank into station 1 and form
4. Remove formed panel for laser trim
5. Preheat trimmed form panel
6. Quench panel
7. Load panel into station 2 and form

Aluminum A-Pillar Forming Results – Technical Accomplishments and Progress (FY2013)

Initial trials 10/30/13 – Option 2 (form die only)

Successful forming using preheated X608 blank, quench and form in cold die
Forming depth per engineered simulation and development



Aluminum A-Pillar Forming Results – Technical Accomplishments and Progress (FY2013)

Trials – Option 1 Using Two-Die Forming Process

Option 1				
Sample	Preheat/Tool temp C	Time to preheat (min)	Time after quench for forming	Successful forming
5	360	2	N/A	Yes
6	360	2	N/A	Yes
7	360	2	N/A	Yes

Option 1 preheats the sheet prior to both forming steps in a common "hot box" enclosed furnace. After the first forming die step the furnace box is opened and the sheet transferred to the second forming tool, and allowed to re-heat to the furnace temperature. There is no quenching of the formed component in the Option 1 process.

Aluminum A-Pillar Forming Results – Technical Accomplishments and Progress (FY2013)

Trials – Option 2 Using Two-Die Forming Process

Option 2

Sample	Preheat temp C	Time to preheat (min)	Time after quench for forming	Successful forming
11	410	5	1	Yes
13	410	5	10	Yes
15	410	5	20	Yes

Option 2 preheats the sheet prior to forming in first die. Preform is formed in second tool at room temperature to form flange end features. Class A outer surface formed in first forming tool

Aluminum A-Pillar Forming Results – Technical Accomplishments and Progress (FY2013)

Trials – Option 3 Using Two-Die Forming Process

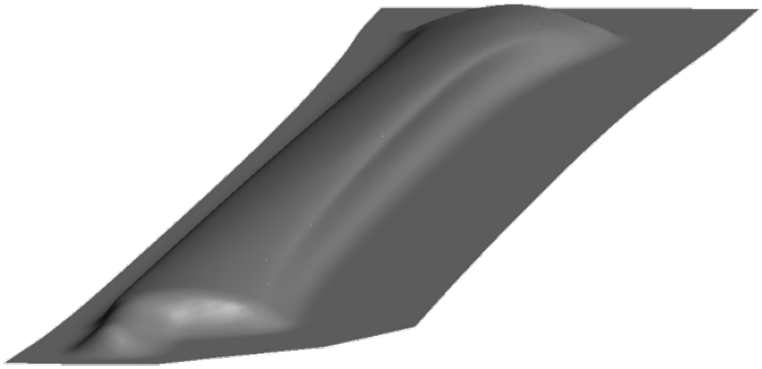
Option 3

Sample	Preheat temp C	Time to preheat (min)	Time after quench for forming	Successful forming
16	410	5	1	Yes
18	410	5	10	Yes
20	410	5	20	Yes

Option 3 preheats the sheet prior to first forming die hit. Preformed shape from die 1 is preheated prior to second forming tool. Second forming tool to form flange end features. Class A outer surface formed in first forming tool

Aluminum A-Pillar Forming Results – Technical Accomplishments and Progress (FY2013)

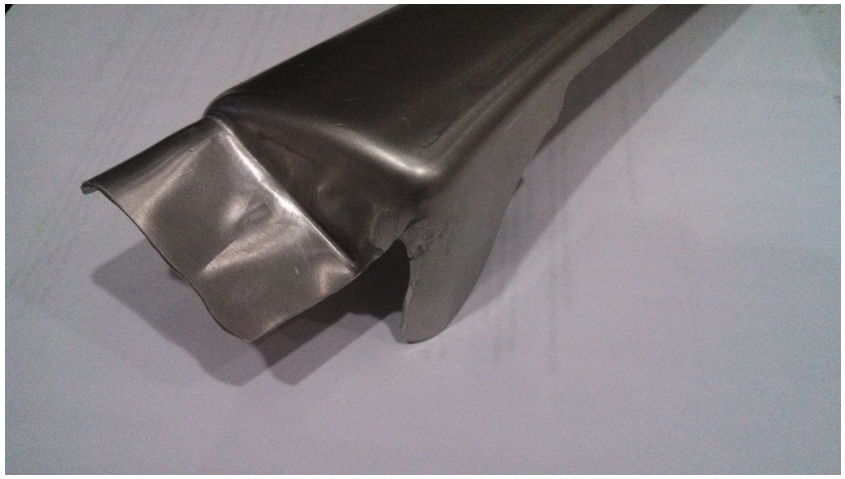
Trials – Forming Process for all options (1, 2, and 3)



Form shape after first die station. Top Class A Area is formed

Further flanging is then required at both ends to bring those areas home. This is performed in second die station

Finished flanging of ends is shown in pictures



Aluminum A-Pillar Forming Results – Technical Accomplishments and Progress (FY2013)

PNNL Tensile Test Results for Samples From Option 1, 2, and 3 Formed Components

Forming Process	Forming Process Variables	Yield Stress (MPa)	Ultimate Tensile Strength (MPa)	Failure Strain (%)
Process 1	2 Tool HotBox	85.08	191.50	22.2
		82.99	188.30	22.0
Process 2	TAQ 0 min.	95.62	201.36	22.8
	TAQ 20 min.	98.35	202.61	22.1
Process 3	TAQ 0 min.	81.34	194.17	22.8
	TAQ 20 min.	109.62	218.54	21.6

TAQ = Time after Quench for forming step
Forming Process Description:
Forming Process 1 – Load blank, preheat and form at 430-475 C. Restrike flanges at 430-475 C in common HotBox. Parts 5, 6, 7 Tested 5 and 6
Forming Process 2 – Heat blank to 430-475 C. Quench and cold form, restrike flanges in cold die. Parts 11, 13, 15 Tested 11 and 15 Cold
Forming Process 3 – Heat blank to 475 C. Quench and form in cold die, partial reheat to 475 C. Quench and restrike flanges in cold die. Parts 16, 18, 20 Tested 16 and 20 PreHeat

Aluminum A-Pillar Forming Results – Technical Accomplishments and Progress (FY2013)

- Option 1 prototype forming completed in January 2014, but resulted in low tensile yield strengths
- Option 3 forming process down-selected for forming of 25 left and 25 right A-pillar components
- New furnace heating equipment identified by Magna SCFI for component forming using process 3 (sheet pre-heating at 500 C)
- New prototype forming trials for Option 3 with new furnace scheduled for April 2014 with PNNL tensile testing to confirm >160 MPa yield strength
- PACCAR evaluating production processing of components and cab testing procedures

Response to Reviewers FY2012 Comments

Question 1: Approach to Performing the Work (3.80)

- Reviewer comments were positive on approach to technical barriers, project design and integration

Response – Project will maintain current approach with increased focus on potential commercial demonstration

Question 2: Technical Accomplishments and Progress (3.60)

- Reviewer comments were positive with additional input that project scope and impact could be improved if a wider view of options (other alloys and forming combinations) were considered

Response - We agree that consideration of other alloys and potential forming processes could have benefits for broader applications. However, the key industry partner (PACCAR) has required that their standard production alloy (X608) be the focus of the forming development because of its proven corrosion and durability in commercial vehicle applications

Question 3: Collaboration and Coordination With Other Institutions (3.60)

- Reviewers had positive comments, but recommended expanding industry collaboration and range of applications

Response – The project collaborations have been largely restricted to partners and suppliers that are currently engaged in the production of the PACCAR cab. However, Magna and Novelis are international suppliers to the transportation industry which should result in a broader range of applications and vehicle volumes

Response to Reviewers FY2012 Comments

Question 4: Proposed Future Research (3.40)

- Reviewer comments were positive, but emphasized the potential of further development and application of the forming technology for alternate alloys and production volumes

Response – We agree with the reviewers suggestions and feel that the involvement of Magna SCFI as a Tier 1 supplier is key to further development and applications of the forming technology

Question 5: Does This Project Support The Overall DOE Objectives

- Reviewers stated that the project will provide weight savings and improved aerodynamic performance and is supportive of DOE's petroleum displacement objectives

Response – A key to meeting the DOE objectives is to expand the use of the technology to multiple applications on commercial vehicles which will yield larger weight savings and enhanced aerodynamics

Collaboration

- PACCAR Technical Center
  - Principal industry partner – contributing component design, design requirements, material specifications, assembly and testing
- Magna SCFI – Research and development arm for major Tier 1 supplier to automotive and commercial vehicle OEM's
- Novelis Aluminum – supply and specification of aluminum sheet materials

Summary

- This is a project with PNNL, PACCAR Tech Center, Novelis Aluminum and Magna SCFI collaborating
- Project is addressing a key challenge of reducing truck cab component weight by >40% through application of aluminum aerodynamic panels in place of steel and SMC
- Warm/cold and cold/warm forming processing sequences have been demonstrated using tensile specimen-based test methods and tray forming experiments
- Magna SCFI is engaged for prototype development of cab aerodynamic component (A-pillar)
- Additional process development has delayed forming of A-pillar component sets and will require use of higher sheet pre-heat temperatures
- PACCAR to evaluate components on production truck cabs to demonstrate compatibility with assembly, E-coat and paint bake steps, and perform cab structural testing