Development of High-Volume Warm Forming of Low-Cost Magnesium Sheet

USAMP
2008 DOE Peer Review Presentation
February 28, 2008

Eric McCarty, Chrysler Corporation (Presenter)

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USAMP AMD 602 – Development of High Volume Warm Forming of Low Cost Magnesium Sheet

- This material is based upon work supported by the Department of Energy National Energy Technology Laboratory under Award Number DE-FC26-02OR22910.

AMD 602 Project Team

- **OEM's**
  - **Chrysler** – Jugraj Singh
  - **Ford** – Peter Friedman, Yingbing Luo, George Luckey
  - **GM** – Paul Krajewski, Ravi Verma

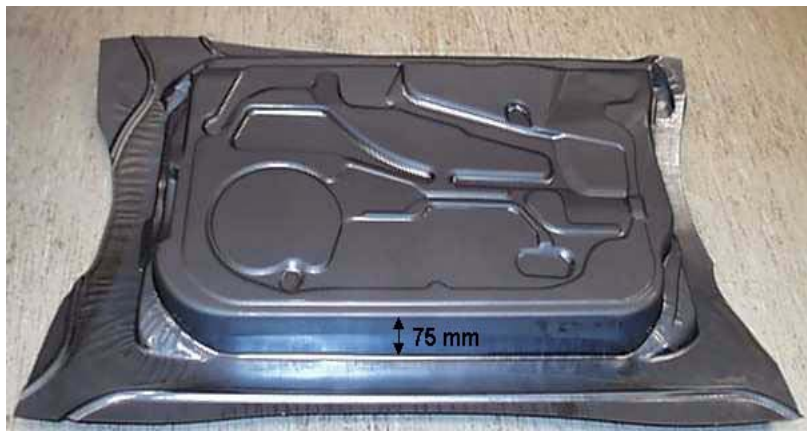
- **Contracts**
  - **Troy Tooling Technologies** – Dennis Cedar
  - **Materials Suppliers**
    - Magnesium Elektron
    - POSCO
    - Thyssen
    - CSIRO
    - Luoyang CU
  - **U. of Virginia** - Sean Agnew
  - **CANMET** - Kevin Boyle, RIno Canaj
  - **PNNL –** Darrell Herling, Glenn Grant
  - **Fuchs Lubricants** – Jim Mieczkowski, Marvin Phillips, Anand Kakar
  - **Jay and Kay Manufacturing** – Carol Young, Scott McKean
  - **Ricardo Meda** – Dajun Zuo

Key Issues in Magnesium sheet

- **Determination of process parameters for warm forming of magnesium sheet.**
  - Material Behavior
  - Formability
  - Lubrication
  - Post formed properties
- **Demonstration of fully-integrated process for warm forming of magnesium sheet.**
- **Need to develop a supply base for cost effective magnesium sheet.**

Warm Forming Phase 1 86X-SU544C

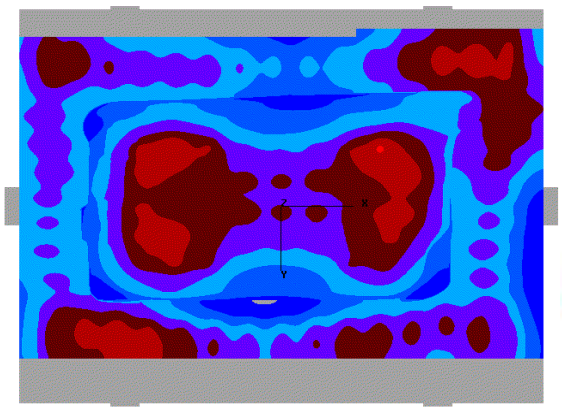
- **Successfully made Dodge Neon door inner panel**
- **Technology Utilized**
  - Specially processed Al alloy
  - MoS_2 lubricant
  - Poor thermal control
  - In die preheating
  - Poor panel quality
- **Need to develop production viable process, lubricant, material**

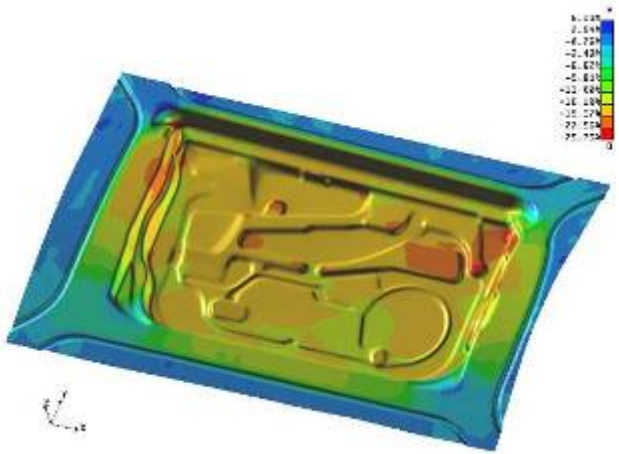


edm2@chrysler.com

Warm Forming Phase 2 AMD307

- Redesigned die incorporating thermal modeling
- Selected AA5182 as production alloy
- Developed new lubricant
- Conduction preheating selected as preferred method
- Aluminum and magnesium door Inner panels formed
- Pan die designed and built
- Aluminum forming window established





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Key technology development

- **Gap analysis: Where are we now and where do we want to be.**
  - *Low cost Mg sheet does not currently exist* – Mg sheet currently costs >$4.00/lb. The goal of the project is push the supply base to develop materials which cost ~$2.00/lb which would make Mg an attractive material for vehicle lightweighting.
  - *A high volume magnesium warm forming process does not exist* – Key elements of the warm forming process have been developed in the soon to be completed Al project. However production rates similar to conventional stamping have not been demonstrated. This project would create an integrated forming process which demonstrates high volume stamping rates on a small part.

- **What are the key technical developments that will close this gap? (For example, a new material or process that allows the developer to reach the proposed requirements.)**
  - Continuous casting (CC) is a key technology for enabling the development of low cost Mg sheet. This project will drive this work in the supply base by giving them a mechanism for evaluating their materials.
  - Novel die systems will be designed and developed that enable the use of warm forming in conventional single-action presses.
  - Full automation including loading of pre-heated sheet and part extraction will be developed to achieve acceptable cycle times (5-10 jpm).

Relationship to FreedomCAR

"Enable the high volume production of vehicles that are: half the mass, are more recyclable, match or surpass quality & durability versus today's vehicles"

- **The proposed project will be very important to allow FreedomCAR to meet their goals. Mg is the only structural metal which allows 50% or greater mass reduction.**

- **This project will drive the production of low cost Mg sheet making it a cost effective solution for vehicle lightweighting and developing the manufacturing process necessary to convert the sheet into vehicle components at high volume.**

Metrics and gates

- **<u>Gate 1:</u> Complete design and build of a new warm forming die and demonstrate deep draw capability on conventional DC material.**
  - Demonstrate pan forming of at least 100mm.

- **<u>Gate 2:</u> Complete material evaluation and demonstrate comparable formability between CC and DC materials.**
  - High temperature elongation equal or greater in CC material compared to DC material.

- **<u>Gate 3:</u> Demonstrate high volume cycle time with CC material on integrated forming cell.**
  - Part to part cycle time with CC material of 5-10 jpm.

Risks and challenges remaining

Risk/challenge	Plan to overcome challenge
Low cost magnesium sheet is unavailable.	Use of continuous casting has been shown to remove significant cost from the manufacture of Mg sheet. Project has commitments from four (4) magnesium suppliers who are developing continuous casting facilities to donate material as in-kind support.
No established method of forming magnesium sheet.	As demonstrated in the previous warm forming project (AMD307), magnesium has ample formability at elevated temperatures for the manufacture of difficult panels such as door inners.
Forming simulation capability for magnesium sheet does not exist.	Simulation work at Ford Motor Company has shown that forming of magnesium can be accurately predicted. Constitutive equations which are required for accurate simulation will be developed for each test material in this project.
Fully integrated, high volume process for magnesium panels does not exist.	A fully-integrated warm forming cell including preheating of blanks and automation capable of 5 to 10 jpm will be demonstrated in the last phase of this project.

Project Plan

- TASK 1: Acquire Low-Cost Magnesium Sheet
- TASK 2: Design and Build Warm Forming Tool
- TASK 3: Material Characterization
- TASK 4: Lubrication
- TASK 5: Die Tryout and First Phase Trials
- TASK 6: Automated Cell
- TASK 7: Cost Model
- TASK 8: Forming Trials on Integrated System
- TASK 9: Report Results

Gate 1:

- **Complete design and build of a new warm forming die and demonstrate deep draw capability on conventional DC material.**
  - Demonstrate pan forming of at least 100mm.
- **Tasks**
  - Preliminary characterization of Mg sheet 4Q06
  - Refurbish die for improved data acquisition 2-3Q07
  - Complete Mg Baseline study 4Q 07
  - Perform detailed material comparison 1-3Q 08

Gate 2:

- **Complete material evaluation and demonstrate comparable formability between CC and DC materials.**
  - High temperature elongation equal or greater in CC material compared to DC material.
    - **Materials provided "in-kind" by:**
      - Magnesium Elektron
      - POSCO
      - Thyssen Krupp
      - CSIRO*
      - LY Copper
    - **Description**
      - AZ31B (3Al – 1 Zn)
      - 1.0 mm x 550 mm x 600 mm
      - O temper
      - 100 blanks
      - Material coded to not reveal supplier

Gate 3:

- **Demonstrate high volume cycle time with CC material on integrated forming cell.**
  - Part to part cycle time with CC material of 5-10 jpm.

- **Decision made to have dedicated press**
  - Avoids dependence on outside press shop
  - Consistent system for all trials
  - Enables long term set up of warm forming cell
- **Press purchased by Troy Tooling Technologies**
- **Installation to be completed 4Q07**
- **Preheater donated by GM**
- **Press will be used for all material trials**
- **Integration / automation to begin in 2008**