Cost Savings for Rocker Reinforcement through Material Conversion

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Outline

- Project Objective
- Martensitic Steel Overview
- Spot Weld Verification
- Summary
Project Objective

- 2004 Calendar Year MCR Project
  Replace bolt-on aluminum rocker beam with spot-welded martensitic roll form beam for targeted cost savings.
Prior: Aluminum Extrusion bolted to Underbody at Assembly Plant with 9 bolts
Extruded Aluminum Multi-Cell Cross-Section with compound cuts, and Structure Adhesive Tape, bolted on at Assembly Plant

Roll-Form Hat-Section Martensitic Beam, Spot-Welded to Floor Side Inner at Supplier Site.
Costs

- **Benefit**
  - Piece Cost Save
  - Labor Save

- **Expense**
  - New Part Tooling
  - Assembly Plant Modifications
  - Shipping Racks
  - Engineering
Risk Management

• Tooling kick-off concurrent with Vehicle Testing.

• Check points in the time line to stop the project, if something went wrong in testing.
Design Verification

- Safety CAE
  - Section Sizing
    - Full Vehicle Analysis
      - Front Offset
      - Side Impact

- Body CAE
  - Vehicle Durability
  - Body Stiffness
  - Seat Pull
  - Seat/Body Mount Attachment Stiffness

- Vehicle Durability
Full Crash Program

Front Offset, Side Impact, Sensor Calibration
Martensitic Steel Overview

- Conventional HSS
- IF
- IF
- HSLA
- DP, CP
- AHSS
- MART

Yield Strength (MPa) vs. Elongation (%)

Engineering Stress (MPa) vs. Engineering Strain
History of Martensitic Steel Applications

- 1980s  Door Beams
- 1990s  Bumper Beams (typically M190, M220)
- 2004  Underbody Rocker Beam  (M130)
Martensitic Steels

- C < 0.25 wt%
- Martensite Matrix
- Strengthening
  - Phase Transformation
  - Solid Solution
- Ultra-High Strength, Low Formability
  - TS: 960-1550 MPa
  - YS: 900-1330 MPa;
  - T-EL: 5%
- Very high strength to weight ratio.
- Relatively small total elongation.
  - Ductile Fracture
Martensitic Steels - Processing

- The microstructure must be fully austenitized (>\(A_{c3}\))

- Rapid quenching is required.
  - The austenite \(\Rightarrow\) martensite transformation is diffusionless.
  - Must avoid the “nose” in the TTT-curve
  - \(~1000^\circ\)C/sec

- Tempering of the martensite is required to add ductility.
  - Martensite \(\Rightarrow\) Tempered Martensite (Ferrite + Fe\(_3\)C)
Martensitic Steels - Processing

I-T Diagram

(a)
Martensitic Steel Processing

Mittal Steel CAL Production Route

ENTRY END PROCESSING

STRIP CLEANING

WATER QUENCH

STRIP PICKLING

DELIVERY END PROCESSING

Anneal

Temper
## Typical Martensite Chemistries

<table>
<thead>
<tr>
<th>Grade</th>
<th>SAE J2340 Designation</th>
<th>C</th>
<th>Mn</th>
<th>S</th>
<th>P</th>
<th>Si</th>
<th>Other</th>
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<tbody>
<tr>
<td>M130</td>
<td>900 M</td>
<td>0.08</td>
<td>0.45</td>
<td>0.015</td>
<td>0.01</td>
<td>-</td>
<td>B, Ti</td>
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<td>1100 M</td>
<td>0.12</td>
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<td>B, Ti</td>
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<tr>
<td>M190</td>
<td>1300 M</td>
<td>0.19</td>
<td>0.45</td>
<td>0.015</td>
<td>0.01</td>
<td>-</td>
<td>B, Ti</td>
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<tr>
<td>M220</td>
<td>1500 M</td>
<td>0.25</td>
<td>0.45</td>
<td>0.015</td>
<td>0.01</td>
<td>-</td>
<td>B, Ti</td>
</tr>
</tbody>
</table>
Manufacturing Methods

- All grades amenable to roll forming
- Weldable with conventional processes
  - Modified practices recommended for higher strength levels
- Design parts with recommended minimum bend radius to ensure manufacturability
  - 4*T for all Martensitic grades
Resistance Spot Welding

Nugget Hardness = f (Chem. composition, cooling rate)

HAZ Hardness = f(Chem. composition, base material microstructure, cooling rate)
Spot-Weld Certification

- Weld Lobe, Electrode Life, Microhardness

Production Controls
- Weld teardowns, SPC on welds, Weld Controls
Weld Schedule for
2.0 M130 - 1.75 DQSK Joint Stack-up

Power Mode : AC (60 Hz)
Electrode Force : 1200 lbf
Nominal weld time : 21 cycles
Hold Time : 05 cycles
Spot-Weld Certification

Weld Lobe

Current Range

www.autosteel.org
Weld Evaluation

Cross tension sample
Schematic diagram of various samples used to evaluate the spot weld strength

Tension (lap) shear sample.
### Static Strength

**M130 CR - DQSK GA**

- **CT (Min):** 2487 lbf
- **CT (Max):** 3021 lbf
- **TS (Min):** 3657 lbf
- **TS (Max):** 4299 lbf

**M130 CR - DDQ HDG**

- **CT (Min):** 2054 lbf
- **CT (Max):** 2824 lbf
- **TS (Min):** 2858 lbf
- **TS (Max):** 3141 lbf
Peel Testing

M130 gripped in Vice

DDQ gripped in Vice

Fracture is always in DQSK HDG
Weld Testing - Peel Button

I_{MAX} \quad I_{MID.} \quad I_{MIN}
Microhardness Profile of Weld Joint

M130

DQSK

Distance (in)

Hardness (KHN)

0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7

100 150 200 250 300 350 400 450

M130

DQSK
• Animation
Summary

• Martensitic Steels can be used for Body Structure applications
• Implemented in Production Dec. 2004
• Early involvement of various disciplines as well as suppliers helped accomplish this task in time

• Achieved $significant cost savings
Acknowledgement

- Williamsburg Manufacturing (Magna/Cosma)
- Buffalo Stamping Plant
- Wixom & St Thomas Assembly Plants
- Ford Product Development & Purchasing