Advanced High Strength Steels and Tubular MultiWall™ Technology in a Twist Axle Application

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The presentation will illustrate the application of Advanced High Strength Steel and variable wall tubular design, in the rear twist axle structure for a high volume small size car (B segment).

The design hereby represents a very attractive alternative to the previous high/middle strength steel structure, resulting in significant weight savings, while exhibiting similar performance at competitive cost.

Extended focus will be given to different design and processing aspects, highlighting the combined benefit of Q&T Boron steel, Multiphase steel and MultiWall™ technology on various product requirements, such as Kinematics & Compliance characteristics, Strength, and Durability.
OBJECTIVES AND TEAM

• Develop a generic steel solution to demonstrate the potential of ArcelorMittal products and processes for twist axle applications, and support it by CAE investigations.

• Assist our customer base by proposing innovative and efficient designs for chassis components.

• Joint development project between two AM divisions:
  – Global R&D Europe (steel implementation)
  – ArcelorMittal Tubular Product North America (tube technology and industrial validations)

• Engineering development was a joint effort between Europe and North America groups, with vehicle expertise and support from Lotus Engineering.
BENCHMARK

• 13 B-segment vehicles benchmarked
  Mix of platforms from both North America and Europe

  ➔ 100% of steel (HSLA, Ferrite-Bainite, Q&T steels)

• Baseline selection:
  Among the best in class axle among B-class market - Worldwide platform

  - V profile
  - Stamped tube

  Spring pans & Shock brackets
  2.6 mm – FB590
  YS = 480 MPa
  UTS = 590 MPa

  Trailing arms
  3.2 mm – FB450
  YS = 320 MPa
  UTS = 450 MPa

  Twist beam
  2.9 mm tube – Q&T 22MnB5
  YS=1,100 MPa
  UTS= 1,500 MPa

  Baseline weight = 17.5 Kg
  Without rubber bushings and parking brake cable brackets = 15.8 Kg
• **Inspection and material investigations**

- Design volume generation
- Investigation of surface treatments
- Hardness measurements
- Micrographs to measure decarburization level

• **CAD generation and FE model building**

  - 3D scanning
  - Meshing
  - FEA

  Bushing rates were measured and integrated into the model
TECHNICAL SPECIFICATIONS

K&C characteristics
- Parallel lateral stiffness
- Opposite lateral stiffness
- Roll stiffness

Local stiffness

Load cases and targets definition
Necessary basis for the validation of a new steel solution

@ suspension attachments

Non-linear
- Toe change
- Camber change
- Permanent Set

Abuse loads

Generic set of specifications

Normal modes

Free-free analysis
Up to 200 Hz

Durability loads

Max loads

Stress analysis
3g parallel bump

Target:
- Life ≥ Baseline
- Torsion test and Road Load Data

Target:
- 7 proof loads
- Safety factors ≥ Baseline

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AHSS TUBULAR CONCEPT

- **Q&T 22MnB5** crossmember with varying thickness along its length: **MultiWall™ technology**.
- Having a MultiWall tube provided the design flexibility necessary to find the right stiffness/strength compromise while saving mass.
- Intensive use of **Hot Rolled Multiphase 800 High Yield (M800HY)** to downgage spring pans and shock brackets.

**Hub plates**
- HSLA550
- YS=550MPa
- UTS=650MPa

**Spring pans & Shock brackets**
- M800HY
- YS=680MPa
- UTS=800MPa

**Twist beam**
- MultiWall tube – Q&T 22MnB5
- YS=1100MPa
- UTS=1500MPa

**C-shaped Trailing Arms**
- FB450
- YS=320MPa
- UTS=450MPa

**M800HY main properties**
- Ultra high yield
- Good cut-edge properties
- Excellent fatigue properties
- Good hole flanging capacity

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Range of ArcelorMittal hot rolled steels for the automotive sector

**Q&T 22MnB5**
- YS=1,100 MPa
- UTS= 1,500 MPa
- 100% martensitic microstructure.
- The addition of Carbon, Manganese, Chromium and Boron ensure good quenchability.

**Multiphase 800 High Yield (M800HY)**
- YS=680 MPa
- UTS=800 MPa
- Excellent combination of high strength and ductility, due to its multiphase microstructure.

**Ferrite-bainite 450/540/560/590**
- YS from 320 to 480 MPa
- UTS from 450 to 590 MPa
- This family combines high Tensile Strength (UTS) with excellent formability and hole expansion (stretch flangeability) based on their ferrite-bainite microstructure.
## DESIGN COMPARISON

<table>
<thead>
<tr>
<th>Part Description</th>
<th>Qty</th>
<th>Material</th>
<th>Total weight (Kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Twist Beam</td>
<td>1</td>
<td>22MnB5</td>
<td>11.44</td>
</tr>
<tr>
<td>Trailing Arm</td>
<td>2</td>
<td>FB450</td>
<td>2.04</td>
</tr>
<tr>
<td>Spring Pan</td>
<td>2</td>
<td>FB590</td>
<td>2.27</td>
</tr>
<tr>
<td>Shock Bracket</td>
<td>2</td>
<td>FB590</td>
<td></td>
</tr>
<tr>
<td>Bush Housing</td>
<td>2</td>
<td>Mild steel</td>
<td></td>
</tr>
<tr>
<td>Hub Plate</td>
<td>2</td>
<td>S550MC</td>
<td>15.75</td>
</tr>
</tbody>
</table>

Baseline

<table>
<thead>
<tr>
<th>Part Description</th>
<th>Qty</th>
<th>Material</th>
<th>Total weight (Kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Twist Beam</td>
<td>1</td>
<td>22MnB5</td>
<td>9.61</td>
</tr>
<tr>
<td>Trailing Arm</td>
<td>2</td>
<td>FB450</td>
<td></td>
</tr>
<tr>
<td>Spring Pan</td>
<td>2</td>
<td>M800HY</td>
<td>1.86</td>
</tr>
<tr>
<td>Shock Bracket</td>
<td>2</td>
<td>M800HY</td>
<td></td>
</tr>
<tr>
<td>Bush Housing</td>
<td>2</td>
<td>HSLA 320</td>
<td>1.88</td>
</tr>
<tr>
<td>Hub Plate</td>
<td>2</td>
<td>S550MC</td>
<td>13.35</td>
</tr>
</tbody>
</table>

AHSS MultiWall

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WEIGHT, COST & PERFORMANCE

-15.2%
2.4kg saved

Brackets = spring pans + shock brackets
Other = hub plate, bush housing

Competitive cost
Less weight
Similar performance

-2.6%
savings per axle

Volume assumption: 300,000 veh/year

Max stress twist LC (MPa) ✓
Abuse load, residual deflection (mm) ✓
Parallel lateral stiffness (N/mm) ✓
Opposite lateral stiffness (N/mm) ✓
Roll stiffness (Nm/deg) ✓
shock mount stiffness (kN/mm) ✓
RLD fatigue (km) ✓
Torsion test fatigue (repeats) ✓
We relied on Lotus Engineering vehicle expertise for the target setting task.

Based on benchmark results and past experience, generic targets were set. The ArcelorMittal solution was designed to satisfy these targets.

### K&C CHARACTERISTICS

<table>
<thead>
<tr>
<th>Linear Kinematic characteristics</th>
<th>Units</th>
<th>Baseline performance</th>
<th>Targets</th>
<th>AHSS MultiWall concept</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roll Centre Height</td>
<td>mm</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Roll Steer</td>
<td>deg/deg</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Roll Camber Change</td>
<td>deg/deg</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Parallel Bump Steer</td>
<td>deg/m</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Camber Change</td>
<td>deg/m</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Stiffness characteristics

| Camber Compliance                | deg/KN |                      |         |                        |
| Toe Compliance                   | deg/KN |                      |         |                        |
| Parallel Lateral Stiffness       | N/mm   |                      |         |                        |
| Opposed Lateral Stiffness        | N/mm   |                      |         |                        |
| Roll Stiffness                   | Nm/deg |                      |         |                        |

Proprietary information can be shared upon request.
90mm OD 22MnB5 MultiWall™ tube
- Bent tube reaching out to the 2 wheels:
  → Better load path;
  → Lower stress induced into welds between the trailing arms and the beam;
  → Simpler and cost efficient trailing arms.
- New shock bracket design with improved mount stiffness.
- Reduced total weld length from 2,410 mm to 2,280 mm.
DESIGN CHALLENGES

• The design was developed within the context of a generic study illustrating the benefits of AHSS and MultiWall technologies, starting from a benchmarked best-in-class solution.

• If design were to be optimized for a specific production application, the following areas will require further attention:

  Effects of position of the Shear Center on suspension kinematics (e.g., roll steer)

  Springback of the center section, and effects on torsional rate

  Orientation of the center section, and impact on volume packaging conditions (e.g., tank, floorpan, exhaust system, …)
ArcelorMittal Tubular Products promotes the application of its unique MultiWall T3™ (Tunable Tube Technology) in the production of a variety of tubular automotive parts.

- Proprietary process used to produce single piece formed tubes of varied thickness along their length, according to the structural requirements of a specific design application.
- Successfully applied in its straight form to axle housings (more than 20M parts produced) for numerous light truck, SUV and van vehicles.
- Mass savings of up to 30%.
- In addition to straight MultiWall™ tubes, ArcelorMittal has recently developed products with fully variable cross sections (diameter, wall thickness, geometry) and tailored strength and formability properties.
- Benefits include:
  - Product (mass reduction, energy management, NVH)
  - Process (improved dimensional control, forming, welding)
  - Design Flexibility (adaptable tooling)
Optimization tools (Optistruct) were used to define the best thickness profile, while matching stiffness requirements.

- Very tight thickness tolerances (±0.05 mm) combined with highly precise positioning of transition area yield high precision roll rates.

- Highest thickness in the bends to reduce stresses in the arm joint, and to improve process (e.g. bending, welding).
- Thickness transitions were developed to reduce stress concentrations.
- TUNABILITY: different torsional stiffness variants within a vehicle platform can be achieved by producing different thickness distributions from the same blank size, using a common set of MultiWall tooling.
### Normal Modes Analysis

**MultiWall concept**

<table>
<thead>
<tr>
<th>Mode</th>
<th>Freq. (Hz)</th>
<th>Modal Separation (Hz)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>36.5</td>
<td></td>
<td>Global twist.</td>
</tr>
<tr>
<td>2</td>
<td>93.7</td>
<td>57.2</td>
<td>Global fore/aft and vertical bend of C-beam</td>
</tr>
<tr>
<td>3</td>
<td>151.7</td>
<td>58.0</td>
<td>Global fore/aft and vertical bend of C-beam</td>
</tr>
</tbody>
</table>

**Baseline design**

<table>
<thead>
<tr>
<th>Mode</th>
<th>Freq. (Hz)</th>
<th>Modal Separation (Hz)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>29.6</td>
<td></td>
<td>Global twist.</td>
</tr>
<tr>
<td>2</td>
<td>106.2</td>
<td>76.6</td>
<td>Fore/aft bend</td>
</tr>
<tr>
<td>3</td>
<td>115.7</td>
<td>9.5</td>
<td>Vertical bend</td>
</tr>
</tbody>
</table>

ArcelorMittal concept results in larger modal separation ➔ improved NVH conditions
• Loads were generated by using an analytical model
• GVW = 1,535 Kg (heaviest platform variant)
• 7 typical static loadcases applied to the axle
• Stress distribution computed by linear static analysis (Nastran Sol 101)

ArcelorMittal Q&T 22MnB5, M800HY and FB450 provide same or better safety factors than Baseline
DURABILITY ASSESSMENTS

- We considered 2 durability load cases: Torsion Test and Road Load Data (RLD).
- RLD were provided by Lotus Engineering (displacements and forces), measured on a 1.45km long pave track.

- ε-N solution used for main shell material (Manson-Coffin curves)
- S-N solution used for the welds

ArcelorMittal Q&T 22MnB5, M800HY and FB450 enable same or higher fatigue life than baseline, while reducing thickness (hence weight)
CROSSMEMBER VALIDATIONS

- Crossmember manufacturing process:
  1) Produce MultiWall tube
  2) Bend the tube using CNC bender
  3) Induction heat treat (centre only)
  4) Hot form center-section “V” profile
  5) Quench center-section in the die
  6) Sand Blasting
  7) Trim tube ends and cut holes

Heat treated
Not heat treated

Hot Forming - Process Simulation
FE Model

22MnB5 tube 90mm OD

Thinning (engineering units)

Mn = 0.198
Max = 0.274
STAMPING VALIDATIONS

- Forming simulations with Autoform 4.2
- Example: M800HY spring pan
- Forming Limit Diagram method is valid for most of the stamping area, but should not be used for the assessment of Small Radii and Cut Edge regions:
  - Typical small radii values are defined by flanging tests
  - Typical cut edges values are defined by hole expansion tests

M800HY spring pan stamping process

Initial blank  Cutting  Hole flanging  Flanging
DESIGN ACHIEVEMENTS

• Mass saving: **2.4 Kg** (or **15.2%**) lighter than Baseline.

• Cost saving: **2.6%** according to a cost estimate comparison with Baseline.

• Efficient combination of Q&T **22MnB5** and **MultiWall™** technologies to reach an adequate stress/stiffness balance for the twist axle crossmember.

• Innovative tube design with thickness ratios \((t/t_{max})\) varying between 0.76 and 1.0 along the length of the tube, with optimized thickness transitions.

• Excellent light-weight opportunities for Trailing Arms, Spring Pan and Shock Bracket with **Multiphase 800 High Yield** and **Ferrite-Bainite** steels.

• Reduced weld length.

• Met K&C, modal and durability targets.

• Currently validating design concept and process via prototype builds.
THANK YOU FOR YOUR ATTENTION!
ANY QUESTIONS?