TUBULAR DESIGN DEVELOPMENT AND APPLICATION OF HSLA AND DP600 STEELS, FOR THE REAR SUSPENSION STRUCTURE OF THE 2006 CADILLAC DTS AND BUICK LUCERNE

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• The presentation will illustrate the application of advanced high-strength steel technologies and tubular design, in the rear suspension support structure for the 2006 Cadillac DTS and Buick Lucerne (combined volumes of 185,000 vehicles/year).

• The design hereby presented successfully replaced the previous low-carbon stamped steel structure, resulting in significant weight savings.

• Extended focus will be given to different design aspects, highlighting the combined benefit of HSLA materials and tubular design on various product requirements, such as durability, energy management, NVH and Ride and Handling metrics.

• Last, additional potential weight savings are identified with the introduction of MultiWall™ technology and DP600 steel.
Design objective was to replace existing low-carbon steel stamped structure with an alternative, which would provide:

- Mass reductions
- Improved Durability Performance
- Cost reductions
- Compliance with all other requirements of existing structure (e.g., packaging, stiffness, point mobility, energy management)

This project started from a Dofasco initiative to benchmark, and redesign the existing production component to support the business case.
• Extensive usage of HSLA materials.
• Tubular die-formed main crossmember – 3.7 mm wall thickness, 3” OD.
• 2-piece stamping end bracket (common LH/RH).
• Implements existing geometry of heat shield, tail structure, in order to minimize packaging impact.
• Easily adapting to PV version of the platform (reinforced structure for Professional Vehicles).
• Eliminated cam bracket by using notched lenses formed into tail stamping.
The design fits all existing systems of the RR suspension package, in respect of all required clearances, including:

- Control arm mounts
- Toe link mounts
- Body mounts and clearances
- Stabilizer bar
- Fuel tank
- Exhaust systems
- Parking cable routes
- Ground clearances

This allowed General Motors to minimize turn over costs, with virtually no retooling required on the mating components.
Stabilizer Bar Mount
Bracket mounts to the cross-structure by means of a tapping plate, which is welded on to the tubular xbar. The anti-rotation tabs are supported by the upper edge of the plate.
Bushing Sleeves

- Design improves body mount retention by providing accommodations for additional tabs.
- The bushing tabs are bent down over the sleeve.

In the center of the structure, Support Brackets provide connection between the Crossbar and the Tunnel. Ribs were added for increased stiffness.
Pro-Active approach to Stamping Design

Tail Bracket
- In the original design, the Tail Bracket stamping had two small brackets welded on, to accommodate the toe adjustment cam bolts.
- Dofasco adopted notched embossment features in lieu of additional cam W-Brackets.
- Part count was reduced to 1 stamping (was 3 stampings, plus additional welding and assembly costs)
• The design is also easily adapted to fit the needs of the Professional Vehicles (PV).
• The same mainstream structure constitutes the “skeleton” of the PV subframe, while being reinforced by several additional stampings, in order to meet the heavier vehicle product requirements.
• The flexibility embedded in the PV design allowed Dofasco/GM to contain the tooling costs and the investment required for this lower volume product.
Overview

- Stress analysis for durability events
  Linear static analysis
  NASTRAN sol 101 w/ inertia relief

- Static Stiffness Rates
  Linear static analysis
  NASTRAN sol 101

- Structural dynamics
  Normal mode analysis
  NASTRAN sol 103 w/ linear bushings

- Side Impact Studies
  Explicit nonlinear code
  LSDYNA

Material Properties

**Dofasco Design:**
- HSLA 55F - YS 380 MPa as strip (stampings)
- HSLA 55F - YS 480 MPa as welded (tube)
- 1008 - YS 240 MPa as strip (stampings)
- 1020 - YS 300 MPa as strip (stampings)
- 1026 - YS 435 MPa as welded (tube)
- SAE J1392 050 XLF - YS 345 MPa as strip (stampings)

**Stamped Design:**
- 1008 - YS 240 MPa as strip (stampings)
- 1026 - YS 435 MPa as welded (tube)
- GMW2M-ST S HR - YS 180 MPa as strip (stampings)
DURABILITY: STRESS ANALYSIS

- Based on material S-N curves, the cycle targets were converted in stress targets for each of the components in both the original and the Dofasco design.
- Mean stress effects are accounted for (Goodman’s equation).
- The stress maps are normalized with respect to each component’s target.
- Did analyze existing design.
Normal Mode Analysis - Natural Frequencies
NASTRAN Sol 103 w/ Linear Bushings

• **Normal Mode Analysis** – natural frequencies, together with Point Mobilities, are one of the main NVH requirements of subframe structures.

• Design met all frequency targets.

• **Static Stiffness Rates** – this metric is quite relevant for the correct Ride & Handling behavior of the vehicle. The rates of both stamped and Dofasco designs, measured at the suspension attachments points, were very similar, and satisfy the product requirements.
Dofasco successfully achieved impact performance requirements.

Scope of Work:

- To provide crash analysis to meet impact targets.
- Analyze different design alternatives.
- Report results, based on performance, cost, weight and timing impact.
Initially, a subsystem was developed, in order to reduce run time on each design iteration.

The subsystem was composed of the suspension model, including the rear body structure.

Prescribed motion was assigned to both wheels, and to segments of siderails, in order to represent the inertial effects of the body being impacted by the bullet vehicle.

Load curves used for the prescribed motion were extracted from the nodal output of the General Motors FEA run.

Different design alternatives were investigated, and examined together with General Motors Engineering team.

Deformed shapes showed similar behavior.
A Drop Silo test was used to prove out the design without having to conduct a full vehicle test.

A model was therefore developed to simulate this test.

An FEA model has been prepared to simulate a prescribed mass dropping on the side of the cross structure, with a prescribed velocity at time of impact.

Cross Structure Assembly has been truncated to reflect physical testing.

Initial conditions (Velocity) were defined for the rigid wall. Lower side of structure has been fully constrained.

Lateral reaction force at the wall has been measured to evaluate the peak load response of the structure. Comparable response between baseline test and simulation results was established.
The identified design alternatives were:

- Geometry changes in the tube section.
- Tube wall thickness increase (from original 3.0 mm to final 3.7 mm);
- Local stamping reinforcement:
  - MultiWall™ tube design (or local sleeve pressed inside tube).
Test results showed a 50% improvement in side impact performance.

CAE predictions proved to be within 6% of actual test results.

<table>
<thead>
<tr>
<th>Tube Characteristics</th>
<th>FEA Results Normalized (based on correlation)</th>
<th>Test Results Normalized</th>
<th>% Difference (Scaled Vs. Test Results)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Original Tube Geometry</td>
<td>1.00</td>
<td>1.00</td>
<td>—</td>
</tr>
<tr>
<td>3.7 mm</td>
<td>1.43</td>
<td>1.48</td>
<td>3.5%</td>
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<tr>
<td>Mild Geometry + 3.7 mm</td>
<td>1.50</td>
<td>1.59</td>
<td>5.5%</td>
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</tbody>
</table>

Lateral Peak Loads
Dofasco promotes the application of its unique MultiWall T3™ (Tunable Tube Technology) in the production of a variety of tubular automotive parts.

The MultiWall T3™ is a proprietary process, developed in the 80’s, which involves a combination of metal extruding principles with simultaneous tool manipulation.

As a result, the tube wall thickness will vary along the part’s length in accordance with the structural performance requirements of the part as applied in the vehicle.

The cold working process increases yield strength, improves dimensional control of diameter, wall thickness, and tube straightness.

Additional flexibility is introduced by selective heat treating to enhance material formability where needed, while retaining the yield strength achieved through cold working.

Achieved mass savings are in the order of 15 to 45%, depending on the specific case.

Considerable design flexibility (mass, energy mgmt, NVH);

Successfully applied to axle housings for M-Van, C/K truck, Ford PN-102, GMT800, GMT820, and other straight round concentric products, such as suspension bushings.
MULTIWALL DESIGN PROPOSAL

- Introduced MultiWall™ design into tubular cross member
- Constant wall (3.7 mm) cross member design: 9.2 Kg.
- MultiWall™ cross member design: 7.9 Kg.
- Mass savings = 1.3 Kg (2.9 lbs., or 14% weight reduction on tube)
- Minimum wall thickness = 2.7 mm
- Maximum wall thickness = 3.7 mm
- Heat treatment required on outboard area, where major forming occurs.
- It meets or improves same durability and energy management requirements as constant wall design version.
MultiWall Design has been fully investigated by Dofasco CAE group.
• An additional study was conducted to investigate the potentials of higher grade steels.
• DP600, a dual phase steel, was introduced in the design of the following four components:

  - Upper End Bracket
    From 3.0 to 2.5 mm
    Mass Savings: 0.2 Kg

  - Bushing Sleeve
    From 4.375 to 3.5 mm
    Mass Savings: 0.2 Kg

  - Tunnel
    From 3.0 to 2.5 mm
    Mass Savings: 0.7 Kg

  - Tunnel Reinforcement
    From 3.0 to 2.5 mm
    Mass Savings: 0.1 Kg

• The higher strength of the DP600 allows down-gauging of the material thickness, producing an additional overall mass savings of 1.2 Kg (2.6 lbs).
• Material properties:
  - Yield Strength: 55 ksi
  - Ultimate Tensile Strength: 90 ksi
  - Tot. Elongation: 27%
  - Unif. Elongation: 16%
• DP600 design meets same durability requirements, while producing mass savings.
• Improved condition at Tail Bracket.

Color scale set to
1.0 x component stress target

Dofasco tubular HSLA design
(current production)

DP600 Design
Mass saving: 1.8 Kg (4.0 lbs) after tube engineering change driven by Side Impact tests.
- Stamped baseline was 23.0 Kg;
- Dofasco design is 21.2 Kg.

A potential of additional 2.5 Kg mass savings is identified, if MultiWall tube design and DP600 steels were implemented.

Weld Length reduced by 1.5 meters.

Cost reduced.

Durability Life target was met.

Fully responsible for Design and Investigation activities, Prototype builds, Part Layouts, definition of GD&T strategies for the component, including datum references for the assembly operations, Key Product Characteristics and all Fit/Function measurables.

Extensive support to GM Product Engineering team, including both durability and crash analysis to GM.