Light-Weighting the 2013 Cadillac ATS Body Structure

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Body Structures
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Introduction to the Cadillac ATS

• Introduction is late summer of 2012
• All new luxury compact sport sedan; new architecture
• Latest expression of “Art & Science” design
  – Long wheelbase
  – Short Overhangs
  – Bodyside Drama; narrow at middle, flaring at the wheels
  – Tight surfacing at the front and rear wheels
• Nimble, fun to drive dynamics
• Over-all theme of efficiency
VEHICLE OVERVIEW
Introduction to the Cadillac ATS
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# Features and Dimensions

<table>
<thead>
<tr>
<th></th>
<th>2013 Cadillac ATS</th>
<th>2012 BMW 328i</th>
<th>2012 Mercedes C</th>
<th>2012 Audi A4</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Drivetrain</strong></td>
<td>RWD/AWD</td>
<td>RWD/AWD</td>
<td>RWD/AWD</td>
<td>FWD/AWD</td>
</tr>
<tr>
<td><strong>Front Suspension</strong></td>
<td>Independent Strut</td>
<td>Independent Strut</td>
<td>Independent Strut</td>
<td>Independent 5-Link</td>
</tr>
<tr>
<td><strong>Rear Suspension</strong></td>
<td>Independent 5-Link</td>
<td>Independent 5-Link</td>
<td>Independent Multi-Link</td>
<td>Independent Trapezoidal Link</td>
</tr>
<tr>
<td><strong>Overall Length (mm)</strong></td>
<td>4643</td>
<td>4636</td>
<td>4592</td>
<td>4703</td>
</tr>
<tr>
<td><strong>Wheelbase (mm)</strong></td>
<td>2775</td>
<td>2809</td>
<td>2761</td>
<td>2808</td>
</tr>
<tr>
<td><strong>Width (mm)</strong></td>
<td>1806</td>
<td>1811</td>
<td>1770</td>
<td>1829</td>
</tr>
<tr>
<td><strong>Height (mm)</strong></td>
<td>1420</td>
<td>1430</td>
<td>1423</td>
<td>1427</td>
</tr>
<tr>
<td><strong>Front Track (mm)</strong></td>
<td>1512</td>
<td>1532</td>
<td>1531</td>
<td>1564</td>
</tr>
<tr>
<td><strong>Rear Track (mm)</strong></td>
<td>1548</td>
<td>1572</td>
<td>1535</td>
<td>1551</td>
</tr>
<tr>
<td><strong>Frt Overhang</strong></td>
<td>825</td>
<td>776</td>
<td>765</td>
<td>866</td>
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<tr>
<td><strong>Rr Overhang</strong></td>
<td>1043</td>
<td>1038</td>
<td>1056</td>
<td>1029</td>
</tr>
<tr>
<td><strong>Head Room</strong></td>
<td>980/935</td>
<td>1024/947</td>
<td>942/937</td>
<td>1016/953</td>
</tr>
<tr>
<td><strong>Shoulder Room</strong></td>
<td>1402/1369</td>
<td>1400/1400</td>
<td>1389/1397</td>
<td>1410/1379</td>
</tr>
<tr>
<td><strong>Leg Room</strong></td>
<td>1079/851</td>
<td>1067/892</td>
<td>1059/848</td>
<td>1049/894</td>
</tr>
<tr>
<td><strong>Cargo Volume (l)</strong></td>
<td>289</td>
<td>480</td>
<td>351</td>
<td>351</td>
</tr>
<tr>
<td><strong>Weight Distribution</strong></td>
<td>51 / 49</td>
<td>52/48</td>
<td>N.A.</td>
<td>N.A.</td>
</tr>
<tr>
<td><strong>Curb Weight (kg, auto.)</strong></td>
<td>Under 1542</td>
<td>1570</td>
<td>1555</td>
<td>1590</td>
</tr>
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</table>
# Powertrain

<table>
<thead>
<tr>
<th>Engine</th>
<th>2.0 L I-4 Turbo DI VVT</th>
<th>2.5 L I-4 DI VVT</th>
<th>3.6 L V-6 DI VVT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Displacement (cu in / cc)</td>
<td>122 / 1998</td>
<td>150 / 2457</td>
<td>217 / 3564</td>
</tr>
<tr>
<td>Bore &amp; Stroke (in / mm)</td>
<td>3.39 x 3.39 86 x 86</td>
<td>3.46 x 3.97 88 x 101</td>
<td>3.7 x 3.37 94 x 85.6</td>
</tr>
<tr>
<td>Block Material</td>
<td>cast aluminum</td>
<td>cast aluminum</td>
<td>cast aluminum</td>
</tr>
<tr>
<td>Cylinder Head Material</td>
<td>cast aluminum</td>
<td>cast aluminum</td>
<td>cast aluminum</td>
</tr>
<tr>
<td>Valvetrain</td>
<td>DOHC, four valves per cylinder, continuously variable valve timing</td>
<td>DOHC, four valves per cylinder, continuously variable valve timing</td>
<td>DOHC, four valves per cylinder, continuously variable valve timing</td>
</tr>
<tr>
<td>Fuel Delivery</td>
<td>Direct high pressure fuel injection</td>
<td>Direct high pressure fuel injection</td>
<td>Direct high pressure fuel injection</td>
</tr>
<tr>
<td>Compression Ratio</td>
<td>9.2:1</td>
<td>11.4:1</td>
<td>11.5:1</td>
</tr>
<tr>
<td>Horsepower (hp / kW @ rpm)</td>
<td>270 / 201 @ 5300 (est.)</td>
<td>200 / 149 @ 6200 (est.)</td>
<td>318 / 237 @ 6800 (est. Gas)</td>
</tr>
<tr>
<td>Torque (lb-ft / Nm @ rpm)</td>
<td>260 / 353 @ 2400 (est.)</td>
<td>188 / 255 @ 4500 (est.)</td>
<td>267 / 362 @ 4900 (est. gas)</td>
</tr>
<tr>
<td>Recommended Fuel</td>
<td>Premium recommended but not required</td>
<td>Regular unleaded</td>
<td>Regular unleaded or E85</td>
</tr>
<tr>
<td>Maximum Engine Speed (rpm)</td>
<td>7000</td>
<td>7000</td>
<td>7200</td>
</tr>
</tbody>
</table>
## Available Features

### 2013 CADILLAC ATS PACKAGING AT-A-GLANCE

<table>
<thead>
<tr>
<th>Feature</th>
<th>Standard</th>
<th>Luxury</th>
<th>Performance</th>
<th>Premium</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.5L RWD Auto</td>
<td>✓</td>
<td>✓</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2.0L Turbo RWD Auto or Manual</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>2.0L Turbo AWD Auto</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>3.6L RWD Auto</td>
<td>-</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>3.6L AWD Auto</td>
<td>-</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>CUE</td>
<td>A</td>
<td>Incl</td>
<td>Incl</td>
<td>Incl</td>
</tr>
<tr>
<td>Navigation</td>
<td>-</td>
<td>A</td>
<td>A</td>
<td>Incl</td>
</tr>
<tr>
<td>Surround Sound</td>
<td>Incl w/ CUE</td>
<td>Incl w/ Navigation</td>
<td>Incl</td>
<td>Incl</td>
</tr>
<tr>
<td>Driver Awareness Pkg</td>
<td>-</td>
<td>A</td>
<td>Incl</td>
<td>Incl</td>
</tr>
<tr>
<td>Driver Assist Pkg</td>
<td>-</td>
<td>-</td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>Advanced Security Pkg</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>Performance Pkg</td>
<td>-</td>
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<td>Incl</td>
<td>A</td>
</tr>
<tr>
<td>Premium Pkg</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Incl</td>
</tr>
<tr>
<td>Luxury Pkg</td>
<td>-</td>
<td>Incl</td>
<td>-</td>
<td>Incl</td>
</tr>
<tr>
<td>Heated Seats</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>Sunroof</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
</tr>
</tbody>
</table>

- = Not Available  
A = Available
BODY STRUCTURE DEVELOPMENT
Objectives of the Body in White Design

ATS BIW goal is to achieve “Best in Class” touring sedan performance at “Best in Class” sedan mass
Objectives of the Body in White Design

- Performance goals of the BIW:
  - Achieve high ratings on all global governmental and consumer safety metrics.
  - Class competitive overall and local stiffness's for handling and isolation
  - Best in Class BIW mass

- Manufacturing Goals
  - Integrate into GM’s Global Manufacturing Bill of Process
  - Quality of Execution
  - Investment and Overall Cost Reduction
Dominant Load Cases

U.S. Roof Strength:
- IIHS 4X
- Two Sided (MVSS 216A)

Rear Impact:
- 88 kph offset
- AZT (Danner)

Static Torsional Stiffness & 1st Trimmed Body Modes

Mobility at Isolated Interfaces for Noise:
- Shock Absorber
- Cradle mounts
- Transmission cross member
- Exhaust hangers
- Electric Park Brake Actuator

Frontal Impact:
- NCAP
- IIHS Offset
- Euro NCAP
- AZT (Danner)

Side Impact:
- IIHS
- Side NCAP
- Side Pole
- Tier 2 Fuel system

Pedestrian Protection

Front Shock Tower Stiffness
Design Optimization Methodology

1. Architectural optimization for the bandwidth of gross vehicle mass, powertrains and performance requirements
2. Integration of efficient load paths and geometry
3. Assessment of sub-system targets
4. Additive part design
1. Architectural optimization for the bandwidth of gross vehicle mass, powertrains and performance requirements:

- Platforms typically are constrained by the most challenging scenarios, often more limited in volume.
- Platform bandwidths are driven by the economics of volume production; increased return on the investment.
  - Penalizes the high volume vehicles, compromising the opportunity for mass reduction.
High Bandwidth Example

- Design Point
  - Heaviest P/T
  - Heaviest GVM
  - Most Restrictive Package
  - Lowest Volume

- High volume FE leaders penalized
  - Added Mass
  - Uncompetitive Geometry

Bubble size represents global volume

17% of total annual vol

60% of total annual vol
Design Optimization Methodology

1. Architectural optimization for the bandwidth of gross vehicle mass, powertrains and performance requirements
   - ATS
     - I-4 and V-6 cylinder engines with manual or automatic transmissions, rear and all wheel drive variants were required
     - GVM ranges from 1910 to 2125 kg
     - V8 engines were not treated as part of the bandwidth
Design Optimization Methodology

2. Integration of efficient load paths and geometry:
   - Placement of the occupants, components, component motion envelopes and masses relative to the major structural elements
   - Avoid disruptions in the structural elements to maximize section capacities with minimum material thickness
     • Suspension and powertrain envelopes cause abrupt disruptions in the shapes of front and rear rails, imposing a need for reinforcements (5.3 kg penalty) and gauge increases
   - Optimize the chassis and body structures together.
     • Utilize the front cradle for crash performance and stiffness;
       » Solid Mount & Aluminum
   - The team was cognizant structural inefficiencies driven by packaging challenges and insured efficient structural load paths were maintained
Rear Rail Comparison

Isometric

LEGACY

ATS

Top

Side-looking out from center

Superior integration avoided reinforcements due to suspension envelope
3. **Assessment of sub-system targets;**

- The mass target is a requirement, not a result
  
  - In past developments, mass has often been a lower priority imperative
  
  - Mass is now among the highest priority imperatives;
    
    - “**Every Gram, Every Day**”
      
      - Trade off analysis is required before accepting increases
    
    - Subsystem specifications must be clearly defined and defendable
      
      - Overall system performance is a primary consideration
        
        » Component requirements are evaluated with respect to the total system effects

    Overall deck lid system stiffness requirements met by balancing individual components
3. Assessment of sub-system targets (continued);

- Over achievement of performance requirements is not always OK:
  - Increases mass
  - The design must be robust enough to perform with anticipated variation, but without waste
Design Optimization Methodology

4. Additive Part Design:
   - Optimize part sections by iteration to reduce reinforcements and material thickness
     • Began with large scale multivariate mass optimization analysis
     • Progressed to specific analysis and issues (roof crush, side impact, etc.)
     • Utilized the entire material portfolio
       - Aluminum for the front shock tower, bumper beams and crush cans
         » Favorable Mass reduction / dollar
         » Packaging advantages
       - High Strength steels
         » Martensitic: rocker panels, many underbody cross car parts
         » Dual Phase: front, rear and roof rail inners
         » Press Hardened Steel: center pillar, roof reinforcement panels
Material Selection

- Mild Steel
- Bake Hardenable
- HSLA
- Dual-Phase/Multi-Phase
- Martensitic
- Press Hardened Steel
- Aluminum
Material Selection

- Mild Steel
- Bake Hardenable
- HSLA
- Dual-Phase/Multi-Phase
- Martensitic
- Press Hardened Steel
- Aluminum
Material Selection

Material Breakdown by Mass

- Press Hardened / Hot Stamped: 5.70%
- Aluminum: 2.90%
- Dual or Multiphase: 17%
- Bake Hardened: 4.80%
- High Strength Low Alloy: 22.60%
- Maternsite: 17.50%
- Mild / Low Carbon: 29.60%
4. Additive Part Design (con’t.):

- Part Detail Design
  - Beads and flanges for load capacity and stiffness
  - Joining techniques to allow minimal part gauges and flange lengths
    - Arc brazing for shorter flanges, thinner material
    - Weld bonding for stiffness
  - Part design to allow reduced gauges
    - Folded child tether bracket allowed thin gauge shelf panel
  - Lightening features
    - Scalloped flanges, lightening holes, small flanges, extensive trimming, etc.
ATS Weld Bonding

<table>
<thead>
<tr>
<th>Legacy</th>
<th>New to ATS</th>
</tr>
</thead>
</table>

90 Meters Total
Part Detail Design

- Scalloped flanges
- Lightening holes
- Smallest parts possible
- Part designs modified to enable gage reduction of mating parts; i.e., folded bracket for welding ratio
Summary

• Narrow the bandwidth
• Package the vehicle to control loads and avoid compromising load paths and part geometry
• Be realistic in setting and meeting targets; balance is critical to meet requirements without waste
• WORK THE DESIGN DETAILS
THE RESULTS
European Mass Efficiency Measurement

• Lightweight design coefficient offers a performance based measure of efficiency.
• Used and reported widely by OEM’s in European body conferences.

Lightweight design coefficient = \frac{\text{Area (m}^2\text{)} \times \text{Torsion stiffness (N-m/deg)}}{\text{Body-in-white mass (kg)}}
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Great Designs in Steel is Sponsored by:

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ArcelorMittal
Severstal
NUCOR
ThyssenKrupp
USS

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