Weight Reduction and Safety Implications

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American Honda Motor Co.

Passenger Vehicle GHG Symposium
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1. Drivers & driving environment

“crashworthiness factors are overwhelmed in importance by driver factors. Crashworthiness factors are relevant only when crashes occur.”

- Leonard Evans, “CAFE – why it is so difficult to estimate its effect on traffic fatalities and fuel use”, Presented at TRB, Jan 2003

2. Crashworthiness

   Vehicle design and compatibility

3. All else being equal:

   Vehicle size and weight
1. Minimize occupant deceleration:
   – Vehicle weight
   – Space for crush and to absorb energy

2. Occupant protection inside compartment:
   – Strength and rigidity to prevent intrusion
   – Cushion and protect occupants within the passenger compartment
Crash Compatibility Factors

- Vehicle protective structure **geometry**
  - Differences in vehicle structural geometry increases intrusion into occupant compartment of one vehicle
  - Unlike cars, light trucks have few “mating surface” requirements
- Relative vehicle and occupant compartment **stiffness**
  - The stiffer vehicle will crush less than the softer vehicle
  - Can increase intrusion into the occupant compartment of the softer vehicle
- Relative vehicle **weight**
  - Heavier vehicle has lower crash energy absorption
  - Lighter vehicle has higher energy absorption
Honda original research in real-world: Compatibility

- Laboratory research
- Field study

Honda R&D Japan

Honda R&D America

Honda Inova Fairfax Hospital CIREN Center
Falls Church, Virginia

Pedestrian protection

Vehicle compatibility

- Pedestrian
- Motorcycle crash
- Vehicle crash

University of Virginia

Honda R&D
Honda original research in real-world: Vehicle Compatibility – Fit to Ridgeline
Honda original research in real-world: Compatibility - Pedestrian
Case Study – 2006 Civic
• Safety is primarily a design issue. 2006 Civic is a case study of how to engineer a small car for highest safety performance.

The ACE structure achieves its advantages by moving from concentration to dispersion of crash force, and optimizing crush stroke and energy management.
High Strength Steel Utilization

- High strength steel allows weight reduction and/or improved performance
- Usage of 590 MPa steel has more than tripled (11% → 38%)

05MY Civic

Usage Rate: 32%

Grade
- 590
- 440
- 340
- 270

50% of body now high strength steel
Side Impact Construction (Coupe)

- Most of side impact construction is high strength steel
- Concept is similar to previous model – but had to be optimized to account for NHTSA & IIHS modes

IIHS Side Impact score*
improved one rating
category with addition of high strength steel

* Internal test data
**Magnesium Steering Wheel Hub**

Magnesium is lightweight (low inertia) & highly tunable for breakaway

<table>
<thead>
<tr>
<th>FMVSS 208 Modes</th>
<th>Belted</th>
<th>Unbelted</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rigid Flat Barrier</td>
<td>AM50</td>
<td>AF5</td>
</tr>
<tr>
<td>Deformable Barrier</td>
<td>AF5</td>
<td></td>
</tr>
<tr>
<td>Rigid Flat Barrier</td>
<td>AM50</td>
<td>AF5</td>
</tr>
<tr>
<td>Rigid Angle Barrier</td>
<td>R30° AM50</td>
<td>L30° AM50</td>
</tr>
</tbody>
</table>

**Target:** Reduce chest deflection & g

**Tune seat belts**

**Tune steering wheel**

**Target Zone**

- **Breakaway force (N)**
- **Displacement (mm)**

3-spk. Steering Wheel

Mg hub/core
Aluminum

- Aluminum application for chassis parts usually available
- Potential weight savings big; usually not applied for cost

- 3.0 kg / car

Additional performance benefits:
1. Unsprung mass reduced
2. Improves tuning envelope of the suspension damper for enhanced ride comfort and handling

Bumper Beams

Material:
Aluminum (Beam)
High Strength Steel (Extn.)

Total system (FR & RR) reduced ~ 1.5 kg

Performance improvements using extruded aluminum:
1. Increased absorption efficiency = enhanced design flexibility
2. Reduced system weight with improved performance
Lightweight NVH Package

<table>
<thead>
<tr>
<th>Component</th>
<th>Δ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dash Insulator</td>
<td>- 5.6 kg</td>
</tr>
<tr>
<td>Floor Carpet</td>
<td>- 1.9 kg</td>
</tr>
<tr>
<td>Floor Mats</td>
<td>- 1.2 kg</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>- 8.7 kg</td>
</tr>
</tbody>
</table>

Vehicle acoustics improved with enhanced absorption

05MY → 06MY acoustic package yielded a significant reduction in weight

Sound Insulation

05MY Civic

GOOD

High frequency range

-5dB

Interior Sound Absorption

05MY Civic

Good
2006 Civic Overview

- Overall dimensions up; features added

<table>
<thead>
<tr>
<th>Dimension</th>
<th>05MY Civic</th>
<th>2006 Civic</th>
<th>Δ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall Length (mm)</td>
<td>4455</td>
<td>4488</td>
<td>33</td>
</tr>
<tr>
<td>Wheelbase (mm)</td>
<td>2619</td>
<td>2700</td>
<td>81</td>
</tr>
<tr>
<td>Overall Width (mm)</td>
<td>1715</td>
<td>1753</td>
<td>38</td>
</tr>
<tr>
<td>Curb Weight - EX (kg)</td>
<td>1213</td>
<td>1275</td>
<td>62</td>
</tr>
</tbody>
</table>

New Features
- Side Air Bag
- Side Curtain Air bag
- 16” wheels
- 1.8L (larger) Engine
- 5-Speed Automatic
- Telescoping Steering

Good design and material innovations help reduce magnitude of weight increase from additional features

White body weight = +4%
- ACE™ (Front) Body Structure
- Side Impact Improvements
- Rigidity (for handling)
<table>
<thead>
<tr>
<th>Test Mode</th>
<th>Published Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Front NCAP</td>
<td>Driver Pass 5 stars</td>
</tr>
<tr>
<td></td>
<td>Front 4 stars</td>
</tr>
<tr>
<td></td>
<td>Rear 4 stars</td>
</tr>
<tr>
<td>Side NCAP</td>
<td>Front 4 stars</td>
</tr>
<tr>
<td></td>
<td>Rear 4 stars</td>
</tr>
<tr>
<td>Offset</td>
<td>GOOD</td>
</tr>
<tr>
<td>Side Impact</td>
<td>GOLD</td>
</tr>
<tr>
<td>Neck Injury Reduction</td>
<td>GOOD</td>
</tr>
</tbody>
</table>
Importance of Weight and Size in Safety
Vehicle Interactions with FE

**Increase Efficiency or Decrease Performance**

**Crash Effects**
- Does Not Affect Safety
  - Taller vehicles tend to have less structural compatibility - safer for occupants, but does more harm to occupants of other vehicles
  - Taller vehicles may inflict greater harm on pedestrians and cyclists

**Pre-Crash**
- No effect

**Vehicle configuration / geometry**
- Increases deceleration in crashes with other vehicles or yielding object
  - Deceleration of other vehicle is lower
  - Little effect on rigid barrier impacts

**Decrease Weight**
- Can effect interior “survival” space
- Can affect exterior “crush” space to mitigate deceleration
- Survival and crush space also depends on vehicle structure design and materials used

**Decrease Size**
- Vehicle with higher center of gravity are more likely to rollover

Taller vehicles may inflict greater harm on pedestrians and cyclists

Lighter vehicles of comparable size can handle and brake better

May be more likely to avoid collisions including with pedestrians and cyclists
Results of the Kahane study are not wrong, but Kahane asked the questions incorrectly:
- Assumed size and weight are completely correlated
- Assumed a direct correlation between size/weight and safety

Advances in crash technology and materials require a more sophisticated analysis.
- Critical to analyze separately the effect of size and weight on safety

If you do that analysis, you get a very different answer
DRI Results: SAE 2005-01-1354

- Independent effects of Passenger Car and LTV “Curb Weight”, “wheelbase”, and “track” reduction on fatalities were assessed
- Overall conclusions were that weight and size reductions have opposite effects on fatalities
  - “Curb weight” reduction decreases fatalities
  - “Wheelbase” and “track” reduction increases fatalities
DRI: Additional Car Results

• Results for the 1991 to 1998 MY 4-door cars only:
  – Using logistic regression method to estimate IE/VRY*
  – Data removed for:
    • 1985-90 MY cars
    • Non 4-door cars
    • “Police” cars
  – Results may not be representative of other car types
  – But weight and size reduction trends are opposite and stable

![Graph showing estimated net change in US fatalities](image-url)

- Based on data for 1985 to 1998 Model Year Cars
- Based on data for 1991 to 199x Model Year 4-door Cars


Legend:
- Curb Weight-and-Size
- Curb Weight
- Wheelbase
- Track
DRI: Additional LT Results

• Sensitivity of the LT results to:
  – Measure of exposure
  – IE/VRY regression method
  – LT model years

• Weight vs size trends are opposite and are stable
  – “Weight” reduction decreases fatalities
  – “Wheelbase” and/or “track” reduction increases fatalities

Based on data for 1985 to 1997 Model Year LTVs

Estimated Net Change in US Fatalities

Based on data for 1991 to 1997 Model Year LTVs

-1000
0
1000
-1000
0
1000
Vehicle-Year Exposure
Vehicle-Miles Exposure

Curb Weight-and-Size
Curb Weight
Wheelbase
Track

(DRI 2003)
(DRI 2005)
For American Honda Motor Co.

2002 – DRI-TR-02-02 (16318-2)*
2003 – DRI-TR-03-01 (16318-3)*
2004 – DRI-TR-04-02 (16318-7)*
2005 – DRI-TR-05-01 (16318-17)*

For the Aluminum Association

2004 – DRI-TR-04-04-2 (16128-1452)*

* NHTSA Docket Number
Growing Awareness

There is a growing body of researchers who are coming to the same conclusion – that modern safety is primarily a design issue, not a weight issue

– Dr. Leonard Evans
  • 1982 - Car mass and likelihood of occupant fatality, SAE 820807
    – “the likelihood that a car has an occupant or driver fatality is related to the mass of the car.”
  • 2004 - How to Make a Car Lighter and Safer, SAE 2004-01-1172
  • “Overall results suggest that while there may have been an association between fleet fuel efficiency improvements and traffic fatalities in the 1970s, this has largely disappeared.”
Lightweight Material Opportunities
Lightweight Materials

- High strength steel
  - Over 50% of the steel in most Honda vehicles
  - Also improves safety

- Aluminum
  - Requires lots of electricity, price has been going up

- Plastic
  - Cheap, color goes below surface
  - Less rigid and must paint

- Carbon fiber
  - Very strong and light
  - Difficult to work with and expensive

- Safety is extremely important
- Must be able to manufacturer on assembly line
- Must be able to recycle or reuse
Impact of Weight on FE

• FE improvement for reducing weight (at equal performance levels):
  – NAS (2002): +3-4% FE for 5% mass reduction
  – EEA (2001): +3.3% FE for 5% mass reduction
  – MIT (Oct 2007): -6-7% fuel consumption for 10% mass reduction

• Potential weight reduction:
  – MIT (Oct 2007): 28% by 2035
    • Aggressive use of substitute materials (HHS, aluminum, plastics, polymer composites): 20%
    • Vehicle redesign (enabled by substitute materials): 10%
Leadtime & Customers

• Must allow time to ensure quality and reliability
  – Rigorous product development process – 2-3 years after feasibility has been demonstrated
  – Prove in production on a limited number of vehicles – 2-3 years
  – Assess impact of higher volume and further development on costs before committing to a single technology
  – Spread across fleet – 5-year minimum product cycles

• Longer leadtime is needed for switch to new body structure materials – safety

• Even if safety is assured, will customers accept that an extremely lightweight vehicle is safe?

• Must also assure repair capability in the field
The Power of Dreams

HONDA