Strategic Steel Application in the Acura NSX Space Frame

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Honda R&D Americas, Inc.
Presentation Contents

- Background
- Design Requirements
- Technology Selection
- Three Dimensional Hot Bending and Direct Quench (3DQ) Technology
- Summary and Conclusion
Recreating an Icon

New Sports eXperimental

NSX
Human-centered

Rigid & Lightweight
- All aluminum body

Visibility & Stability
- Advanced sport package

Quality, Reliability and Durability
New Sports eXperience

- Instant Acceleration (Incredible G-feeling)
- Direct Yaw Control (Super Handling)
- Integrated Dynamics System (Wide Range)

Grand Concept

Driver-centric Cockpit
- Superior Visibility
- Ergonomic with Simple Driver Interface
- Secure Driver Fit and Freedom of Movement

Peak Performance
- Lap Time
- 0-100 kph

Timeless Sports Car Values
New Sports eXperience

- Driver-centric
- Styling
- Instant Response
- Honda DNA
- Precision Craftsmanship
New Sports eXperience

- Driver-centric
  - Package
  - Visibility

- Styling
  - Thin A Pillar
  - Sash-less Door

- Instant Response
  - High Rigidity

- Honda DNA
  - Crashworthiness
  - No-Sacrifice Supercar DQR

- Precision Craftsmanship
  - High Accuracy
  - High Efficiency
New Sports eXperience

A Pillar Design Concept Aligned with Vehicle Concept

- **Driver-centric**
  - Styling
  - Instant Response
  - Honda DNA
  - Precision Craftsmanship

**Minimize Weight and View Obstructions**

**Maximize Interior Space and Safety**
Interior Packaging Concept

- Compact High Strength Steel Front Roof Rail
- Optimized visibility
- Low instrument panel surface
- Thin A Pillar
- Thin Pillar
- Low Dash
Forward Visibility

NSX

Standard Car

Competitor
Small design space and high accuracy requirements for surrounding part interfaces

- Exterior Garnish
- Seal
- Door Glass
- Air Bag
- Front Windshield
- Interior Garnish
- Harness
Correct Material in Correct Location

<table>
<thead>
<tr>
<th>Material</th>
<th>PHS</th>
<th>Hydro-Forming</th>
<th>Aluminum Casting</th>
<th>Aluminum Extrusion</th>
<th>3DQ 3-D Quench</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PHS</strong></td>
<td><img src="image1" alt="PHS" /></td>
<td><img src="image2" alt="Hydro-Forming" /></td>
<td><img src="image3" alt="Aluminum Casting" /></td>
<td><img src="image4" alt="Aluminum Extrusion" /></td>
<td><img src="image5" alt="3DQ 3-D Quench" /></td>
</tr>
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<td><strong>Hydro-Forming</strong></td>
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<td><img src="image2" alt="Hydro-Forming" /></td>
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<td><img src="image4" alt="Hydro-Forming" /></td>
<td><img src="image5" alt="Hydro-Forming" /></td>
</tr>
<tr>
<td><strong>Aluminum Casting</strong></td>
<td><img src="image1" alt="Aluminum Casting" /></td>
<td><img src="image2" alt="Aluminum Casting" /></td>
<td><img src="image3" alt="Aluminum Casting" /></td>
<td><img src="image4" alt="Aluminum Casting" /></td>
<td><img src="image5" alt="Aluminum Casting" /></td>
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<tr>
<td><strong>Aluminum Extrusion</strong></td>
<td><img src="image1" alt="Aluminum Extrusion" /></td>
<td><img src="image2" alt="Aluminum Extrusion" /></td>
<td><img src="image3" alt="Aluminum Extrusion" /></td>
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<td><img src="image5" alt="Aluminum Extrusion" /></td>
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<td><strong>3DQ 3-D Quench</strong></td>
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<td><img src="image3" alt="3DQ 3-D Quench" /></td>
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<td><img src="image5" alt="3DQ 3-D Quench" /></td>
</tr>
</tbody>
</table>

- **Performance**:
  - Steel: ![Steel](image1)
  - Aluminum: ![Aluminum](image2)
  - 3DQ: ![3DQ](image3)

- **Weight**:
  - Steel: ![Steel](image1)
  - Aluminum: ![Aluminum](image2)
  - 3DQ: ![3DQ](image3)

- **Pillar Size**:
  - Steel: ![Steel](image1)
  - Aluminum: ![Aluminum](image2)
  - 3DQ: ![3DQ](image3)

- **Productivity**:
  - Steel: ![Steel](image1)
  - Aluminum: ![Aluminum](image2)
  - 3DQ: ![3DQ](image3)

Optimum material selection

- **Weight**:
  - Steel: ![Steel](image1)
  - Aluminum: ![Aluminum](image2)

- **Width**:
  - Steel: ![Steel](image1)
  - Aluminum: ![Aluminum](image2)

- **3DQ**:
  - ![3DQ](image1)

- **6063T6AL Extrusion**:
  - ![6063T6AL Extrusion](image1)
### 3DQ Technology Considerations

#### Strengths

<table>
<thead>
<tr>
<th>Material Properties</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>• High Strength</td>
<td></td>
</tr>
<tr>
<td>• High Stiffness</td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Productivity</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>• Fast maturation</td>
<td></td>
</tr>
<tr>
<td>• Low die investment</td>
<td></td>
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</table>

<table>
<thead>
<tr>
<th>Low Weight</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>• Hollow tubular structure</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Variable Curvature</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>• Conforms to styling shape</td>
<td></td>
</tr>
</tbody>
</table>

#### Design Challenges

<table>
<thead>
<tr>
<th>Constant Cross Section</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>• Cross section can not vary with mating part requirements</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Fastening</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>• Laser welding</td>
<td></td>
</tr>
<tr>
<td>• Bolting</td>
<td></td>
</tr>
<tr>
<td>• Projection stud welding</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Corrosion</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>• Multi-material joining</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Part Accuracy</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>• Assembly sequence</td>
<td></td>
</tr>
<tr>
<td>• Manufacturing process</td>
<td></td>
</tr>
</tbody>
</table>
A-Pillar Construction Overview

Steel substructure separately e-coated to prevent corrosion

Sheet metal stampings transition to A-pillar structure

- **Bolts**
- **Laser Welds**
- **590 MPa Steel 1.4mm**
- **A356 T6 Aluminum Casting**
- **590 MPa Steel 2.0mm**
- **1500 MPa Steel 2.4mm**
Joining Challenges

Mechanical Joining Strategy

• Joining Location
• Optimize joint strength for each attachment
### Crashworthiness – Achievement Summary

NSX meets NCAP world test mode standard, hybrid protection, and Honda safety commitment

<table>
<thead>
<tr>
<th>Mode</th>
<th>Target</th>
<th>Achievement (In-House Results)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>US NCAP</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OVERALL</td>
<td>5 ★</td>
<td>5 ★</td>
</tr>
<tr>
<td>Front Collision</td>
<td>4 ★</td>
<td>4 ★</td>
</tr>
<tr>
<td>Side Collision</td>
<td>5 ★</td>
<td>5 ★</td>
</tr>
<tr>
<td>Roll over</td>
<td>5 ★</td>
<td>5 ★</td>
</tr>
<tr>
<td><strong>EU NCAP (Collision Modes)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OVERALL</td>
<td>5 ★</td>
<td>5 ★</td>
</tr>
<tr>
<td>Front Collision</td>
<td>≥ 13.0 pts</td>
<td>13.8 pts</td>
</tr>
<tr>
<td>Side Collision</td>
<td>≥ 14.0 pts</td>
<td>16.0 pts</td>
</tr>
<tr>
<td><strong>Other</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Roof Crush</td>
<td>FMVSS 216</td>
<td>OK</td>
</tr>
<tr>
<td>Pedestrian</td>
<td>GTR9 Regulation</td>
<td>OK</td>
</tr>
<tr>
<td><strong>Honda Safety Commitment</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SUV Side Impact</td>
<td></td>
<td>OK</td>
</tr>
<tr>
<td>Side Pole at IPU location</td>
<td></td>
<td>OK</td>
</tr>
<tr>
<td>Car to Car (50kph) NSX vs MDX SUV</td>
<td>Cabin Integrity, Hybrid Protection</td>
<td>OK (CAE)</td>
</tr>
</tbody>
</table>

* ISOFIX, ISA, LDW, & AEB features are not applied
BIW Concept

New Sports eXperience

Driver-centric

Requirements
- Package
- Visibility

Styling

- Thin A Pillar
- Sash-less Door

Instant Response

- High Rigidity

Honda DNA

- Crashworthiness
- No-Sacrifice Supercar DQR

Precision Craftsmanship

- High Accuracy
- High Efficiency
A-Pillar Manufacturing Flow

1. Tube Making
2. 3DQ Process
3. Part Accuracy Check
4. Laser Cutting & Welding
5. ED Coating
6. AL Node Assembly
7. Quality Inspection
3DQ Process Overview

1. Feed Tube

2. Induction Heat Tube

3. Rapidly Quench Tube

4. Robotically Bend Tube
   - Multi axis robot
   - Numerical Controlled Path
3DQ Process Details

High Formability & Low Residual Stress

- No Wrinkling
- No Section Collapse
- No Spring Back
- No Delayed Fracture

Quenched Product

Processing Details:
- Tensile Strength > 1500 MPa
- Yield Strength > 980 MPa
Ultra high strength due to Martensitic grain structure

Heated Portion

Processing Details:
- Temperature > 850°C
- Tensile Strength ≈ 50 MPa
- Yield Strength ≈ 40 MPa

Processing Details:
- Tensile Strength > 1500 MPa
- Yield Strength > 980 MPa

Ultra high strength due to Martensitic grain structure

Support Device
Shielding Gas
Induction Coil
Water Jet

High Strength Tube

Processing Details:
- Tensile Strength ≈ 600 MPa
- Yield Strength ≈ 400 MPa
### 3DQ Production Line

3DQ can produce parts without dies and with minimal space.

<table>
<thead>
<tr>
<th>Process</th>
<th>Production Line Size</th>
<th>Dies</th>
</tr>
</thead>
<tbody>
<tr>
<td>2500ton Transfer Press</td>
<td><img src="image" alt="Stamping Press 21m" /></td>
<td><img src="image" alt="DRAW" /> <img src="image" alt="TRIM" /> <img src="image" alt="RESTRIKE" /> <img src="image" alt="PIERCCE" /></td>
</tr>
<tr>
<td>3DQ</td>
<td><img src="image" alt="3DQ Line 12m" /></td>
<td>Dies are not used</td>
</tr>
</tbody>
</table>

At minimum, 4 processes are needed.
A-Pillar Construction Accuracy

**Accuracy Correction Process**

- **Start correction**
- Generate robot trajectory
- **3DQ process**
- Measure shape
- **NG**
- **OK**
- Finalize trajectory

**Process trajectory correction achieves ±0.3mm accuracy**

- **3DQ process**
- **Trajectory correction**
- Compensation check and correction for shape variation after every part
- **Shape measurement**
- 72 digital measurement points
Three-Dimensional Hot Bending and Direct Quench
Summary

New Sports eXperience

Driver-centric

Styling

Instant Response

Honda DNA

Precision Craftsmanship

Requirements

- Package
- Visibility
- Thin A Pillar
- Sash-less Door
- High Rigidity
- Crashworthiness
- No-Sacrifice Supercar DQR
- High Accuracy
- High Efficiency
Body Accuracy Strategy

Transverse Adjustment

Horizontal Adjustment

3DQ comp is the datum for the roof sub-comp
A-Pillar Achievement

Obstructed View Comparison

Obstructed View (Deg)

- NSX (1st Gen)
- NSX
- A
- B
- C

- 11.7
- 7.8
- 10.6
- 12.7
- 15.6

- 61% Smaller than average

Acura Internal Data
Conclusion

Utilization of the 3DQ Technology allowed us to achieve our goals

☑ Minimize Pillar Size
  Provided best in class obstructed view

☑ Maximize Interior Space
  Enabled low roof and interior packaging requirements

☑ Minimize Weight
  Best balance of performance and weight for NSX

☑ Achieve Occupant Safety
  Projected best in class safety performance

Ultra High Strength, Rigid Uniform Cross Section, the best option…
3-Dimensional Hot Bending and Direct Quench Technology.
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