Accelerated Concept to Product (ACP) Process

Highly Optimized Longitudinal Rail
Achieving 45% Mass Reduction

FutureSteelVehicle (FSV) Design Methodology

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AGENDA

• Introduction
• Background
• Objective
• FSV Methodology (ACP Process)
• FSV Pilot Rail Project
• FSV Pilot Project Process, Results and outcome
• Conclusion
• Q/A
Future Steel Vehicle program introduce steel solutions for the next generation of advanced powertrain vehicles utilizing the most advanced steels, manufacturing technology and Design Optimization Technology.
**BACKGROUND**

- **FGPC** (Future Generation Passenger Compartment)  
  Phase 1 & 2 projects supported by A/SP have previously validated the major portions of this design and development process if starting point is an existing structure (Current Production or Benchmarking vehicle)
  - Phase 1- Used ULSAB-AVC (Donor) with 30% potential mass reduction
  - Phase 2- Used GM (Donor) vehicle with 15% to 20% potential mass reduction
The Accelerated Concept to Product (ACP) Process looks into a fresh new product with no information from the producer.

- The method first defines the optimum loadpath of a clean sheet design by blocking out the initial structure.
- It continues with the previous proven methods developed by FGPC Phase 1 & 2.
- New tasks have been added to the ACP Process since the completion of this project.
First objective of FSV Pilot Project is to validate the proposed methodology.

ACP Pilot Project Development Process

- Design Confirmation
- Envelope & Target Setting (Calibration)
- Multidisciplinary (MD) 3G (Geometry, Gauge & Grade) Design Optimization
- Multidisciplinary (MD) Topology Optimization
PILOT PROJECT OBJECTIVES

Second objective is apply methodology to A/SP LWFE Front Rail & establish additional mass savings

Donor Vehicle

Rail: 16.34kg

System mass reductions:
- TWT No. 2: -26.5%
- TWT No. 3: -31.8%

Pilot Project Baseline

A/SP LWB Concept

System mass reduction: -22.4%
- Rail: 12.25kg
Fresh Product and New Architecture

Styling/Packaging/Topology/Geometry/Grade/Gage

Advantages/Returns
- Comprehensive Goals Achievable.
- Synchronized Engineering Design, CAE and CAD.
- Greatest Possible Mass Reduction.
- Robust Design & overall efficiency improvements.
- Reduce # of Parts, Efficient Manufacturing (reduce cost of Labor, Material and Tooling).

Investment
New Process, tooling/manufacturing process/prototyping and Testing
PROJECT OVERVIEW

Approx definition of Design Space

MD Topology Optimization

Primary Design Envelope

Concept Design

Parameterized Design Envelope

MD 3G Design Optimization
Front Rail Pilot Project to validate methodology
1. Block out Design Envelope
2. Topology Optimization
3. Parameterize Geometry
4. Design Optimization constraints
5. Detailed Geometry (Shape), Gauge (thickness) & Grades (material)

MD 3G Optimization

Optimization MD Load Cases
- NCAP Front Impact
- IIHS Front Impact 40% ODB
- Static Stiffness
  - Torsional
  - Bending
Existing Front Rail Geometry (shown only for reference)

Design Space, the extreme packaging volume available to the optimization. New Front Longitudinal Rail must fit within this space.

Top View

Bottom View
TOPOLOGY OPTIMIZATION RESULTS

Design Space & Optimization

Original Rail & Optimization

Design Space

Side View

Original Rail Geometry

Optimization

Top View

Optimization
• 1st Topology Optimization provides:
  – An initial load path, the base for Optimum Dynamic Load path and MD 3G optimization
  – Insight into how the structure should be designed (free from traditional design thought process)

• Topology optimization is an iterative process
GEOMETRY
PARAMETERIZATION

• Longitudinal Rail must fit within Design Space

  Planes cut through mesh

  Equivalent planes cut through Design Space

• 15 cross-sectional stations along length of B-Spline

• Baseline longitudinal Rail within design space
CROSS-SECTIONAL DESCRIPTIONS

- Cross-sectional shape governed by 12 control points
- Limits of Cross-section shape change
  - Max: Outer limit of Design Space
  - Min: 60% of outer boundary
PROBLEM STATEMENT

Maximize: Mass Reduction
Subject to: Section Force <= 35 kN
By Varying: Shape (106 variables)
  Material: DP350/600, DP500/800, DP700/1000 (7 variables)
  Thickness: 0.6 → 2.3mm (7 variables)

➤ Rail divided into 7 sections. Gauge & material choice is independent for each section

➤ Gauge & Material options:

<table>
<thead>
<tr>
<th>MATERIAL &amp; GAUGE VARIABLES</th>
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<tbody>
<tr>
<td>MATERIAL</td>
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<tr>
<td>DP350/600</td>
</tr>
<tr>
<td>DP500/800</td>
</tr>
<tr>
<td>DP700/1000</td>
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As shown, Rail’s shape variables at full extent of Design Space
### FINAL DESIGN

**Mass:**

Baseline A/SP LWFE-LWB: 12.25kg

Final Design: 8.98kg (-27% baseline)

<table>
<thead>
<tr>
<th>SECTION</th>
<th>MATERIAL</th>
<th>GAUGE (mm)</th>
<th>MASS (kg)</th>
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<tr>
<td>9</td>
<td>DP700/1000</td>
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<td>0.26</td>
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<td><strong>TOTAL</strong></td>
<td></td>
<td></td>
<td><strong>8.98</strong></td>
</tr>
</tbody>
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Manufacturing constraints were not applied.
FINAL DESIGN: NCAP PERFORMANCE

Baseline

Final Design
FINAL DESIGN: NCAP PERFORMANCE

Baseline

Final Design
FINAL DESIGN:
40% ODB PERFORMANCE

- Good
- Acceptable
- Marginal
- Poor

A FINAL DESIGN
B BASELINE

1: Footwell  2: LeftToe  3: CenterToe  4: RightToe  5: BrakePedal  6: Left IP  7: Right IP  8: Door

www.autosteel.org
FINAL DESIGN: STATIC STIFFNESS

**Torsional Stiffness**
- Final Design: 17,094 Nm/deg
- Baseline: 17,788 Nm.deg

**Bending Stiffness**
- Final Design: 11,870 N/mm
- Baseline: 12,122 N/mm
SUMMARY of RESULTS

Front Rail: Donor Vehicle, LWFE & FSV Pilot Project Comparison

New Design Optimization Method (Topology & 3G) proven effective
Mass reduction: 27% over LWFE-LWB (A/SP optimized design)
45% over Donor Vehicle
CONCLUSION

ACP Design Process

• Provides guidance for optimum load path unconstrained by historical engineering judgment.

• Develops non-intuitive solutions for structural performance.

• Develops non-intuitive optimized shapes and component configuration.

• ACP Design Process applied to Future Steel Vehicle program will be applied to the full structure and address manufacturing constraints.