MAXIMIZING LIGHT WEIGHTING IN STEEL AUTOMOTIVE BODIES AND FRAMES WITH STEEL TUBE AIR FORMING (STAF) PROCESS

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Sumitomo Heavy Industries, USA Inc.
Sales Engineer
AGENDA

1. Introduction of STAF
2. STAF’s benefit
3. Case Study for verification of STAF’s benefit
4. What SHI can support to the new produced items
1. INTRODUCTION OF STAF

- Form high strength and high rigidity auto parts in one-pack.
- Form flanges, drastically the assembly processes are reduced.

**Forming Process**

I) Setting

II) Heating

III) 1st blow forming (Projecting a flange portion)

IV) Forming cross section and die quenching

[Diagram showing the forming process with illustrations of each step]
1. INTRODUCTION OF STAF
1. INTRODUCTION OF STAF

Position of STAF technology

- **Hot stampeing**
  - Low rigidity due to spot welding

- **Cold-press**

- **Hydro forming**
  - Low strength and need other parts for assembly

**Strength**

**Rigidity**

Notes:
- Spot welding
- PHS
- HSS
2. STAF’S BENEFITS

◆ Flanged closed section
  ①. Drastically weight reduction
  ②. Performance can be controlled by flanges
  ③. Simplification (Reduction of num of parts, simplified process = compact equipment)
  +. High versatility of spot welding connection

①. Drastically weight reduction  ②. Performance controlled by flanges  ③. Simplification
2. STAF’S BENEFITS

1. Drastically weight reduction; Improved basic performance
The basic performance can be improved by eliminating the peeling of spot welds. (24.3%↑)

【Drop Weight Test I】

Specimen’s Cross section (t1.6&t1.2)

After collision

Side view

STAF(t1.6)

Hot stamp(t1.6)
2. STAF’S BENEFITS

① Drastically weight reduction; Improved basic performance
The basic performance is improved by eliminating the peeling of spot welds.

【Drop Weight Test II】
Specimen’s Information (t1.6mm, 22MnB5)

1. STAF
2. Hot stamping

Cross section

Test image

Conditions
Height: 6.3m
Collision speed: 40km/h

Weight: 500kg
Collision energy: 31kJ
2. STAF’S BENEFITS

① Drastically weight reduction; Improved basic performance
The basic performance is improved by eliminating the peeling of spot welds.(250%)
2. STAF’S BENEFITS

① Drastically weight reduction; Improved basic performance
The basic performance is improved by eliminating the peeling of spot welds.(60.0%↑)

【Torsion】

Forming video clip

End restraint Rotated

<table>
<thead>
<tr>
<th>①STAF</th>
<th>②Hot stamping</th>
</tr>
</thead>
</table>

Cross section Specimen

40mm Spot welding
270mm

The nugget diameter $4.5\sqrt{t}$ (=5.69mm)

Conditions

<table>
<thead>
<tr>
<th>Torque(N/M)</th>
<th>Twist angle(°)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>500</td>
<td>10</td>
</tr>
<tr>
<td>1500</td>
<td>20</td>
</tr>
<tr>
<td>2500</td>
<td>30</td>
</tr>
<tr>
<td>3000</td>
<td>40</td>
</tr>
</tbody>
</table>

60.0%↑
2. STAF’S BENEFITS

**Performance can be controlled by flanges**
The flange that enables spot joining with other parts can also control the deformation mode of the cross section. The following is the difference in cross-sectional deformation due to the placement of the minimum flange in the three-point bending test for the beam.

<table>
<thead>
<tr>
<th>Models</th>
<th>No Flanged model</th>
<th>Minimum Flanged model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Criteria Cross-section</td>
<td><img src="image1.png" alt="Image" /></td>
<td><img src="image2.png" alt="Image" /></td>
</tr>
<tr>
<td>Stroke 20mm</td>
<td><img src="image3.png" alt="Image" /></td>
<td><img src="image4.png" alt="Image" /></td>
</tr>
<tr>
<td>Stroke 40mm</td>
<td><img src="image5.png" alt="Image" /></td>
<td><img src="image6.png" alt="Image" /></td>
</tr>
<tr>
<td>Stroke 60mm</td>
<td><img src="image7.png" alt="Image" /></td>
<td><img src="image8.png" alt="Image" /></td>
</tr>
</tbody>
</table>
# 2. STAF’S BENEFITS

### ③ Simplification
Efficient and compact process due to the reduced number of parts and dies, the simplification of the heating process and the welding subassembly process.

<table>
<thead>
<tr>
<th></th>
<th>Hydroforming</th>
<th>Hot stamping</th>
<th>STAF</th>
<th>Hot gas forming</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Strength</strong></td>
<td>~980MPa</td>
<td>1,500MPa~</td>
<td>1,500MPa~</td>
<td>1,500MPa~</td>
</tr>
<tr>
<td><strong>Parts</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>construction</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pressed &amp; Hydro parts</td>
<td>Pressed parts (2Parts)</td>
<td>STAF part (1 part)</td>
<td>Pressed &amp; Tube parts</td>
</tr>
<tr>
<td><strong>Cross section image</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Outer</td>
<td>2~3 Parts</td>
<td>2 Parts</td>
<td>1 Part</td>
<td>2~3 Parts</td>
</tr>
<tr>
<td>2~3 parts</td>
<td></td>
<td>2 parts</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Process</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Preforming</td>
<td>Blanking</td>
<td>Preforming</td>
<td>Preforming</td>
</tr>
<tr>
<td></td>
<td>Hydroforming (3000Ton~)</td>
<td>Heating furnace</td>
<td>STAF form (800Ton~)</td>
<td>Heating furnace</td>
</tr>
<tr>
<td></td>
<td>Laser cutting</td>
<td>Hot stamping (2 Sheets &amp;2 Dies)</td>
<td>Laser cutting</td>
<td>Gas forming</td>
</tr>
<tr>
<td></td>
<td>Press forming</td>
<td>Laser cutting</td>
<td>Welding(ass’y)</td>
<td>Laser cutting</td>
</tr>
<tr>
<td></td>
<td>Welding(ass’y)</td>
<td>Welding(ass’y)</td>
<td></td>
<td>Press forming</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Welding(ass’y)</td>
</tr>
</tbody>
</table>
CASE STUDY FOR A PILLAR VERIFICATION OF STAF’S BENEFITS
3. CASE STUDY

Model description

Replaced A-pillars and roof side rails section with STAF for the market vehicles that consist of hot stamped parts. For STAF, A pillar and roof side rail is welded and connected with brackets.

Market model

STAF

Roof Side Rail
A-PLR

A-PLR
0.8t 1.8t 1.0t

1.8t 1.0t

A-PLR
0.8t 1.2t

1.0t

Roof Side Rail
3. CASE STUDY

Evaluation conditions

We selected a market car and replaced the A-pillar and roof rail parts with the STAF design. The cross section shape is slightly changed, depending on the formability. (Same layout) Also, plate thickness was reduced. Then Full-wrap collision was performed.

◊ Static press test (CAE)
Solver: LS-DYNA
Methods: Forcibly the contact area is moved at 0.5 mm / sec to evaluate the load and energy absorption.
*The contact area is set as the rigid.
3. CASE STUDY

### Resultant Force Comparison Graph

**Displacement (mm)**

- **Market**: 86.2kN
- **STAF**: 82.9kN

<table>
<thead>
<tr>
<th></th>
<th>A-PLR Thickness</th>
<th>Roof Side Rail Thickness</th>
<th>Weight (kg)</th>
<th>Light weight ratio (%)</th>
<th>Max reaction force(kN)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Market</td>
<td>1.8mm/1.0mm</td>
<td>1.8mm/1.0mm</td>
<td>8.387</td>
<td>-</td>
<td>82.9</td>
</tr>
<tr>
<td>STAF</td>
<td>1.0mm</td>
<td>1.0mm</td>
<td><strong>6.532</strong></td>
<td><strong>22.1</strong></td>
<td><strong>86.2</strong></td>
</tr>
</tbody>
</table>
In the case study of strength evaluation, we could confirm a high weight reduction effect even with the same shape. This page introduces the characteristic cross sections that can be achieved with only STAF. (Single flanged model)

① High strength and high rigidity because spot welding is not required for the body frame
② By changing the flange on one side to a flat shape, the shape can only be achieved with STAF. And since the plate used for the flange can be brought to the cross section, the weight can be further reduced.
3. CASE STUDY

<table>
<thead>
<tr>
<th>Parts structure of FR pillar</th>
</tr>
</thead>
</table>

### Manufacturing Cost (SHI’s estimation)

<table>
<thead>
<tr>
<th></th>
<th>Hydro forming</th>
<th>Hot forming</th>
<th>STAF</th>
</tr>
</thead>
<tbody>
<tr>
<td>100%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>90%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>80%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>70%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>60%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>50%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>40%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30%</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>20%</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>10%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0%</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

These cost numbers are calculated based on SHI’s standard, not guaranteed for actual mass production.
3. CASE STUDY

Summary

STAF applicability to A-pillar test

1. In this test condition (Front crush test), it is possible to reduce the weight by 22%, compared with conventional A pillar of hot stamped. (Apple to Apple same profile comparison)

2. By reducing the number of parts, production efficiency and the number of dies, manufacturing cost will be reduced by 21.4%.

3. Structure that cannot be manufactured by other forming process
CASE STUDY FOR BUMPER
VERIFICATION OF STAF’S BENEFITS
3. CASE STUDY

Evaluation conditions

We selected a market car and replaced a conventional bumper beam with STAF design. Section shape is designed under the same layout. We tested this evaluation with several strength evaluation, for this page introduce the basic beam performance improvement.

◇ 3 point bending test (CAE evaluation) Solver : LS-DYNA

Criteria for performance of STAF applied part
Achieve the target load as shown on right and lighter weight than Market model with keeping the same beam cross section area.
3. CASE STUDY

**Test results**

<table>
<thead>
<tr>
<th>Model</th>
<th>Market model</th>
<th>STAF model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pipe diameter (㎜)</td>
<td>—</td>
<td>φ114.3</td>
</tr>
<tr>
<td>Thickness (㎜)</td>
<td>①Camber surface 590MPa,t1.25 ②Beam 1800MPa,t1.6</td>
<td>t1.2</td>
</tr>
<tr>
<td>Cross section</td>
<td>[Cross section diagram]</td>
<td>[Cross section diagram]</td>
</tr>
<tr>
<td>Weight(kg)</td>
<td>5.15</td>
<td>3.72 (−27.7%)</td>
</tr>
</tbody>
</table>

Achieve target reaction force of Market model (1.8G material) with 1.5G material.
## 3. CASE STUDY

### Cost Comparison

**Parts structure of FR pillar**

<table>
<thead>
<tr>
<th></th>
<th>Hot forming</th>
<th>STAF</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 Parts</td>
<td></td>
<td>1 Part</td>
</tr>
</tbody>
</table>

### Manufacturing Cost (SHI’s estimation)

<table>
<thead>
<tr>
<th>Component</th>
<th>Material</th>
<th>Press</th>
<th>Weld</th>
<th>Total</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>CLOSING PLATE</td>
<td>HOT</td>
<td></td>
<td></td>
<td></td>
<td>100%</td>
</tr>
<tr>
<td>BUMPER</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>STAF-BEAM</td>
<td>STAF</td>
<td></td>
<td></td>
<td></td>
<td>80.3%</td>
</tr>
</tbody>
</table>

These cost numbers are calculated based on SHI’s standard, not guaranteed for actual mass production.
3. CASE STUDY

Summary

STAF applicability to Bumper beam

1. In this test condition (3-point bending), it is possible to reduce the weight by 27.7%, compared with conventional bumper of hot stamped. (Apple to Apple same layout design comparison)

2. By reducing the number of parts, production efficiency and the number of dies, manufacturing cost will be reduced by 19.65%.

3. Structure that cannot be manufactured by other forming process
Currently, several projects are underway with Tier1s and OEMs to adopt STAF. We, Sumitomo, an equipment manufacturer, not only provides equipment, but also supports the technology required for adoption of STAF.

The parts below are just an example of the prototype parts that we are studying with our customers.

**FR Pillar Prototype sample**

**Bumper Beam Prototype sample**

Green: Body frame parts to which STAF is applicable.

- Side sill
- B PLR
- Battery's cross mem
- Roof rail
4. WHAT SHI CAN SUPPORT TO THE NEW DEVELOPMENTS

This is a summary that we can support for customer’s development. STAF is a newly developed forming process, so just installing equipment is not the best solution for OEMs or Tier1 suppliers. We can support customer’s adoption of STAF in design and provide technical support for solving the problems for introducing STAF.

**CAE X Design support & Engineering support**

Through these activities, Sumitomo can provide the technical know-how in the feasibility and strength confirmation CAE that have already been verified, and the confirmation results such as the weldability, formability and corrosion protection of STAF product, etc., The adoption of STAF by OEMs and Tier1 suppliers can be strongly promoted.

**Technical support**
THANK YOU

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