A Study of Joining Conditions in Self Piercing Riveting of Aluminum Alloy Sheets

Purpose
- Joining process by both experiment and finite element simulation
- Influence of various joining conditions on joint performance

Advantages of SPR
- Simple and fast process
- Possibility of joining different materials: aluminum, steel

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Light weight

Aluminum car Audi A8

Self piercing riveting

Punch

Rivet

Holder

Upper sheet

Lower sheet

Die
Experimental method of SPR

Sheet holder

Punch

Rivet (Boron steel)

Upper Sheet
(Aluminum alloy, mild steel)

Die

Lower Sheet
(Aluminum alloy, mild steel)

5.0

7.8

9.8

1.6

3.2

5.4
## Experimental conditions of SPR

1. **Thickness of sheet**

<table>
<thead>
<tr>
<th>Sheet</th>
<th>Thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminum alloy: A5052-H34</td>
<td>1.0mm, 1.5mm, 2.0mm</td>
</tr>
<tr>
<td>Mild steel: SPCC</td>
<td>0.8mm, 1.2mm, 1.6mm, 2.0mm</td>
</tr>
</tbody>
</table>

2. **Combination of sheets:**

<table>
<thead>
<tr>
<th></th>
<th>Upper sheet</th>
<th>Lower sheet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminum-aluminum</td>
<td>Aluminum</td>
<td>Aluminum</td>
</tr>
<tr>
<td>Aluminum-steel</td>
<td>Aluminum</td>
<td>Steel</td>
</tr>
<tr>
<td>Steel-aluminum</td>
<td>Steel</td>
<td>Aluminum</td>
</tr>
</tbody>
</table>
Conditions of calculation of SPR

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td><strong>Solver</strong></td>
<td>LS-DYNA</td>
</tr>
<tr>
<td><strong>Rivet and sheets</strong></td>
<td>Solid</td>
</tr>
<tr>
<td><strong>Coefficient of friction</strong></td>
<td>0.20</td>
</tr>
<tr>
<td><strong>Calculation time</strong></td>
<td>75min</td>
</tr>
</tbody>
</table>

- Punch (Rigid)
- Sheet holder (Rigid)
- Upper sheet
- Lower sheet
- Die (Rigid)
- Axi-symmetry
Animation of joining process of SPR obtained by finite element simulation for aluminum-aluminum
Comparison between cross-sectional shapes obtained from calculation and experiment in different strokes for aluminum-aluminum.

- Calculated
- -- Experimental

(a) $s=3.3\text{mm}$

(b) $s=4.4\text{mm}$

(c) $s=5.0\text{mm}$
Prediction of defects from calculation for aluminum-steel

Defects

Penetration
\( t_u = 1.0 \text{mm} \)
\( t_l = 0.8 \text{mm} \)

Necking
\( t_u = 2.0 \text{mm} \)
\( t_l = 0.8 \text{mm} \)

Separation
\( t_u = 1.5 \text{mm} \)
\( t_l = 1.2 \text{mm} \)

\( \Delta l \leq 0.05 \text{mm} \)

\( \Delta x \leq 0.15 \text{mm} \)

(a) Calculated

(b) Experimental
Joint performances for steel-aluminum

(a) Experimental

(b) Calculated
Evaluation of joint strength

(a) Tensile test

(b) Shearing test
Fractures observed in tensile test

(a) Fracture of upper sheet
(Steel-aluminum, $t_u=0.8\text{mm}$, $t_l=2.0\text{mm}$)

(b) Fracture of lower sheet
(Steel-aluminum, $t_u=1.2\text{mm}$, $t_l=2.0\text{mm}$)
Variation of tensile joint strength with overlapping ratio

- **Steel-aluminum**
- **Aluminum-steel**

![Graph showing the variation of tensile joint strength with overlapping ratio. The graph plots tensile joint strength in kN against the overlapping ratio Δx/r. The data points for Steel-aluminum are represented by squares, and those for Aluminum-steel by circles.](image-url)
Variation of shearing joint strength with overlapping ratio

Overlapping ratio $\Delta \frac{x}{r}$

Shearing joint strength

Steel-aluminum

Aluminum-steel
Conclusions

1. The self piercing riveting is investigated by the finite element simulation, and the necking, penetration and separation can be predicted.
2. The combination and thicknesses of the sheets have large influences on the joint performance.
3. The aluminum and steel sheets can be joined by the self piercing riveting.