Joining by plastic deformation

1. Motivation
2. Cold welding
3. Friction stir welding
4. Self-pierce riveting and mechanical clinching of sheets
5. Joining by forming
6. Future trends

Typical joining processes

- Arc welding
- Resistance welding
- Laser welding
- Welding: thermal effects
- Adhesive bonding, mechanical fastening: low strength
- High performance, high productivity, low cost, dissimilar materials

Forming processes using plastic deformation

- Rolling
- Sheet metal forming
- Shaping
- Use of plastic deformation for joining
- Drawing
- Extrusion
- Forging
- Forging

Advantages and disadvantages of joining by plastic deformation

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Wide range of joining materials, including dissimilar ones (metallic/non-metallic)</td>
<td>- Mainly overlap joint</td>
</tr>
<tr>
<td>- No distortion, embrittlement or residual stresses due to missing microstructural transformation</td>
<td>- Geometrical unevenness of joining zone due to nature of processes</td>
</tr>
<tr>
<td>- High process reliability and simple quality control</td>
<td>- More difficult correction and repair</td>
</tr>
<tr>
<td>- Environmental safety</td>
<td>- Lack of standardisation and calculation methods</td>
</tr>
</tbody>
</table>

Conventional joining processes by plastic deformation

- Riveting
- Friction welding
- Seaming for beverage cans
- Double seaming

Recent developments and progress of joining processes by plastic deformation

- Seaming for beverage cans
- Double seaming
- Riveting
- Friction welding

Joining processes by plastic deformation

Metallurgical joining (bonding):
- Cold welding by rolling, extrusion, forging, etc.
- Friction welding, Friction stir welding
- Resistance welding, etc.

Mechanical joining:
- Self-pierce riveting
- Mechanical clinching
- Joining by forming such as hydroforming, electromagnetic forming, incremental forming, etc.
- Fastening such as hemming, seaming, staking, etc.
Joining by plastic deformation

1. Motivation
2. Cold welding
3. Friction stir welding
4. Self-pierce riveting and mechanical clinching of sheets
5. Joining by forming
6. Future trends

Cold welding process

- **Solid-state welding process**
  - **Roll bonding**
    - **Roll**
    - **Soft**: large deformation
    - **Hard**: small deformation
    - Surface preparation: scratch brushing (within 10 minutes), electrochemical treatment and chemical plating
    - Plastic deformation: to create clean interface
    - Pressure: to establish welds

Roll bonding

- **Roll bonding**
  - **Base metal**
  - **Cladding metal**
  - **AlZn-Fe bearing**
  - **Martinae Honsel**

Cold welding processes

- **Roll bonding**
- **Shear welding**
- **Butt welding**
- **Air cooler**
- **Wire ends, busbars, wheel rims**

BWE Ltd.

Calculation of bond strength

- \[ \frac{\sigma_B}{\sigma_0} = (1 - \beta)^{\frac{Y - Y'}{\sigma_0}} \]
- \[ Y' = \text{threshold surface exposure for film layer} \]
- \[ \beta = \psi_f \]
- \[ \psi_f = \text{fraction of film layer on scratch brushed surface} \]

Bay

Total reduction in thickness

- \[ r = \frac{h_0 - h_1}{h_0} \]

Successful welding combinations

- **Wodara**

Total reduction in thickness

- \[ r = \frac{h_0 - h_1}{h_0} \]

Cold welding of dissimilar metals

Successful welding combinations

- **Milner et al.**

Application of friction stir welding

- **Train**
- **Automobile**
- **Airplane**
- **Ship**

Friction stir welding

- Large plastic deformation: heat generation and metal stirring
- **Material**: aluminium alloy, magnesium, copper, steel, stainless steel, dissimilar materials
Mechanical clinching for joining sheets

- Forming of interlock
- Avoidance of excessive thinning of upper sheet at neck of joint
- Avoidance of fracture of sheets

Application of mechanical clinching

- Automobile
- Electrical appliances

Sheet: steel, aluminium alloy, coated, copper, magnesium, dissimilar materials

New mechanical clinching processes

- Two-stage flat clinching: Tox
- Dieless clinching of magnesium: Neugebauer
- Clinching with prepunched sheet: Merklein

Static and fatigue strengths in tension-shearing test of aluminium sheets joined by self-pierce riveting, mechanical clinching and resistance spot welding

Joining of high strength steel and aluminium alloy sheets

- Conventional die
- Optimised die

Finite element simulation of self-pierce riveting and mechanical clinching processes

Application of joining by forming

1. Motivation
2. Cold welding
3. Friction stir welding
4. Self-pierce riveting and mechanical clinching of sheets
5. Joining by forming
6. Future trends

Mechanism of joining by forming

Joining processes by electromagnetic forming, crimping, shear spinning and rolling are similar mechanism.
Joining processes by plastic deformation

<table>
<thead>
<tr>
<th>Cold welding</th>
<th>Friction stir welding</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Base metal</strong></td>
<td><strong>Roll</strong></td>
</tr>
<tr>
<td><strong>Self-pierce riveting</strong></td>
<td><strong>Mechanical clinching</strong></td>
</tr>
</tbody>
</table>

**Joining by forming**

Acknowledgements


Thank you very much