Kawasaki Robot
A new method for light alloy joining

Friction Spot Joining

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CAUTIONS TO BE TAKEN TO ENSURE SAFETY

- For those persons involved with the operation/service of your system, including Kawasaki Robot, they must strictly observe all safety regulations at all times. They should carefully read the Manuals and other related safety documents.

- Products described in this catalogue are general industrial robots. Therefore, if a customer wishes to use the robot for special purposes, which might endanger operators or if the robot has any problems, please contact us. We will be pleased to help you.

- Be careful as photographs illustrated in this catalogue are frequently taken after removing safety fences and other safety devices stipulated in the safety regulations from the Robot operation system.
A revolutionary joining method, based on an innovative concept, opens the way for new opportunities in the light alloy world.

A simple joining mechanism consisting of plunging, stirring and withdrawal

Friction Spot Joining is an entirely new joining method developed and offered by Kawasaki Heavy Industries which is used on lap joints of aluminum, magnesium and other light metals.

The process is extremely simple. A cylindrical joining tool, with a small projection at the tip, known as the pin (pin tool), rotates while plunging and then withdrawing from the material creating a metallurgical bond.

The rotation of the tool first softens the material by means of frictional heat creating a plastic flow effect in the rotary and axial directions in the periphery of the pin, thereby stirring and joining the upper and lower plates. The whole process is completed within a matter of seconds. The material then maintains a solid state without any melting.

The joining process is carried out in the following three stages:

1. **Plunging**
   - The joining tool, while rotating, is forced against the workpiece with a specified amount of pressure. This pressure creates frictional heat between the workpiece and the pin on the tip of the tool softening the metal and allowing the pin to plunge into the workpiece.

2. **Joining**
   - The pin becomes completely embedded in the workpiece and the press force on the tool is maintained for a given interval even after the shoulder on the outer edge of the tool comes in contact with the work piece (refer to the drawing below for the joining mechanism).

3. **Withdrawal**
   - The tool and the pin are withdrawn after the joining is completed.

### Joining tool

The joining tool has a small threaded projection (pin) at the tip. The outer edge (shoulder) of the tool is convex creating a pocket in the material where the stirring is performed. This convex shape leaves a saucer-shaped dimple on one side on the joining area. Various tool configurations and dimensions can be utilized depending on the joining conditions and the desired strength.

### Joining mechanism

- **Plastic flow in the axial direction**
  - The material flows in the axial direction (through-thickness direction) due to the rotation of the threads on the pin.

- **Plastic flow in the rotational direction**
  - The material flows as if dragged by the rotation of the tool.
Both tensile strength and fatigue strength are comparable to welds created with resistance spot welding. A donut-shaped stir zone, comprised of re-crystallized material, is formed in the periphery of the pin from the high-temperature frictional heat and the plastic flow effect. The plastic flow occurs in both the rotational and axial directions due to the rotary action and shape of the tool. This zone is characterized by high strength and outstanding ductility, providing FSJ joint with excellent mechanical properties. The results of tensile shear strength, peeling strength, tensile shear fatigue strength, and other tests confirm that this method offers the strength equivalent to that of resistance spot welding.

Stir zone formation

- **Stir Zone**
- **Heat affected area**
- **Plastic flow area**
- **Boundary between plates**

Example of the microstructure of the joining area

Tensile strength comparison FSJ with clinching (6000 series alloy)

<table>
<thead>
<tr>
<th>Tensile shear test results</th>
<th>A6061 alloy</th>
</tr>
</thead>
<tbody>
<tr>
<td>FSJ</td>
<td>Resistance spot welding JIS-Z3140 required strength (grade A)</td>
</tr>
<tr>
<td>Plate thickness (mm)</td>
<td>0</td>
</tr>
<tr>
<td>Tensile shear strength (kN)</td>
<td>0</td>
</tr>
</tbody>
</table>

Fatigue strength comparison - FSJ with resistance spot welding

- **Stir zone**
- **Resistance spot welding**

![Fatigue strength comparison - FSJ with resistance spot welding](image)

Comparison of problems and advantages of various joining methods

<table>
<thead>
<tr>
<th>Joined and performance</th>
<th>Riveting</th>
<th>Self-piercing riveting</th>
<th>Resistance spot welding</th>
<th>Clinching</th>
<th>Friction Spot joining</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strength</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Adequate strength can be achieved</td>
</tr>
<tr>
<td>Quality disparities</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Not-uniform in strength</td>
</tr>
<tr>
<td>Deformation (heat warping)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Very little heat warping</td>
</tr>
<tr>
<td>Looseness / Separation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>No looseness due to vibration, etc.</td>
</tr>
<tr>
<td>Facility costs</td>
<td>Equipment is expensive</td>
<td>Equipment is expensive</td>
<td></td>
<td>No need for primary power source, cooling water or air supply</td>
<td></td>
</tr>
<tr>
<td>Cost of electrical power</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>No need for primary power source, cooling water or air supply</td>
</tr>
<tr>
<td>Environmental visibility</td>
<td>Rivet head</td>
<td>Rivet head</td>
<td></td>
<td></td>
<td>Welding current [kA]</td>
</tr>
<tr>
<td>Maintenance</td>
<td>Requires maintenance of rivet supply equipment</td>
<td>Requires maintenance of rivet supply equipment</td>
<td></td>
<td></td>
<td>Maintenance free for several thousand cycles</td>
</tr>
<tr>
<td>Pre-treatment</td>
<td>Requires hot forming</td>
<td>Requires alignment of upper and lower plate</td>
<td></td>
<td></td>
<td>Requires alignment of upper and lower plate</td>
</tr>
<tr>
<td>Operational efficiency</td>
<td>0+ seconds</td>
<td>Within a few seconds</td>
<td></td>
<td></td>
<td>Within a few seconds</td>
</tr>
<tr>
<td>Multi-spot operation</td>
<td>Not possible</td>
<td>Not possible</td>
<td></td>
<td></td>
<td>Multiple (3 or 6) possible</td>
</tr>
<tr>
<td>Workplace environment</td>
<td></td>
<td></td>
<td></td>
<td>Generalises fumes and dust</td>
<td></td>
</tr>
</tbody>
</table>

Instant solution to the problems of resistance spot welding and riveting

**Features of the FSJ system**

1. **High quality and high strength**
   - The FSJ process does not require the materials to become molten. Heat from the joining process is kept low, resulting in less heat deformation than resistance spot welding while the achieving outstanding strength characteristics.

2. **Conserves energy and reduces operating costs**
   - The energy consumed by the FSJ method is no more than the electrical power required by the two servomotors that manipulate the joining tool. In fact, the FSJ system uses less than 1/20th the power consumed by resistance spot welding equipment. In addition, there is no need for large-capacity power supply equipment, resulting in a reduction in overall equipment costs.

3. **A simple and economical system**
   - The system mechanics are very simplistic with no need for auxiliary equipment as required by the resistance spot welding process. Neither cooling water nor compressed air are required which allows for broad reductions in both equipment and running cost.

4. **Joining tool with a long lifespan**
   - The joining tool, used in the FSJ system, is not susceptible to wear and tear when used with aluminum alloys. Users have reported no tool wear during production, even after several hundred thousand spot joins.

5. **Clean workplace environment**
   - With no dust or fumes to worry about and no need for a large electrical current, the FSJ process is clean and does not generate any electromagnetic noise.
Even greater benefits can be realized when combining the FSJ system with a Kawasaki multi-axis robot!

Kawasaki Heavy Industries has developed a special FSJ gun to take advantage of the outstanding characteristics of this process of joining light alloys. KHI has achieved success and world-wide recognition for developing and perfecting stationary FSJ systems as well as flexible joining systems utilizing the Kawasaki articulated robots.

Stationary FSJ System

- This is a stationary system featuring a special mount for the gun and backing.
- Equipped with a special control device, operation is carried out by touch panel and push buttons.
- Makes one join at a time by foot switch with the workpiece either secured by jigs or held by the operator.
- It can also be used in combination with a material handling robot enabling the workpiece to be manipulated to each joining area.

FSJ Robot System

- The gun with C-frame backing is mounted on the articulated robot.
- The gun is equipped with 2 servo motors, one for the tool rotation and one for axial movement.
- The gun motors can be controlled by the robot controller as external drives, eliminating the need for additional control devices or operating panels.
- The robot manipulator can be selected to accommodate the workpiece shape and dimensions as well as the required operating range.

Example comparison of resistance spot welding and friction spot joining systems

The FSJ robot system is based on very simple mechanics and operation. For example, it has no need for the various peripheral devices required for resistance spot welding.