Welding Technology

Spot Welding

Spot welding (also known as resistance spot welding) is a resistance welding process. This welding process is used primarily for welding two or more metal sheets together by applying pressure and heat from to the weld area.

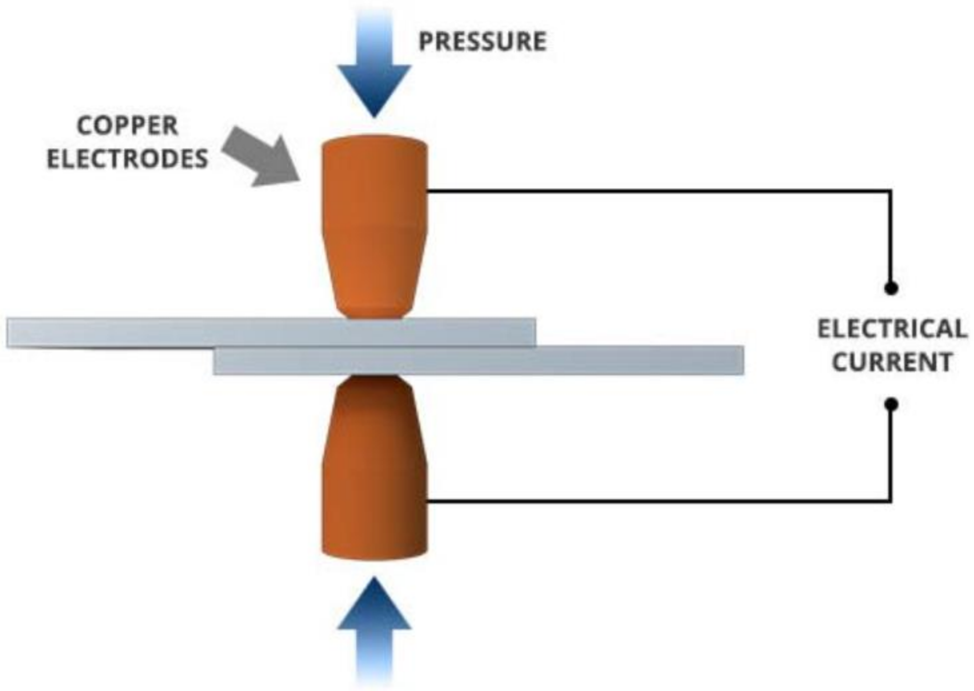
It works by contacting copper alloy electrodes to the sheet surfaces, whereby pressure and electric current are applied and heat is generated by the passage of current through resistive materials such as low carbon steels.

Spot Welding

A form of resistance welding, spot welding is one of the oldest welding processes whereby two or more sheets of metal are welded together without the use of any filler material.

The process involves applying pressure and heat to the weld area using shaped alloy copper electrodes which convey an electrical current through the weld pieces. The material melts, fusing the parts together at which point the current is turned off, pressure from the electrodes is maintained and the molten “nugget” solidifies to form the joint.

Spot Welding



Schematic diagram of resistance spot welding

Spot Welding

The welding heat is generated by the electric current, which is transferred to the workpiece through copper alloy electrodes. Copper is used for the electrodes as it has a high thermal conductivity and low electrical resistance compared to most other metals, ensuring that the heat is generated preferentially in the work pieces rather than the electrodes.

The amount of heat depends on the thermal conductivity and electrical resistance of the metal as well as the amount of time the current is applied. This heat can be expressed by the equation:

$Q = I^2Rt$

In this equation “Q” is heat energy, “I” is current, “R” is electrical resistance and “t” is the time for which the current is applied.

Materials

Due to its lower thermal conductivity and higher electrical resistance, steel is comparatively easy to spot weld, with low carbon steel being most suited to spot welding. However, high carbon content steels (Carbon equivalence > 0.4wt%) are prone to poor fracture toughness or cracking in the welds as they tend to form hard and brittle microstructures.

Galvanised steel (zinc coated) requires slightly higher welding currents to weld than uncoated steels. Also, with zinc alloys, the copper electrodes rapidly degrade the surface and lead to a loss of weld quality. When spot welding zinc coated steels, electrodes must either be frequently exchanged or the electrode tip surface should be ‘dressed’, where a cutter removes contaminated material to expose a clean copper surface and reshapes the electrode.

Other materials commonly spot welded include stainless steels (in particular austenitic and ferritic grades), nickel alloys and titanium.

Materials

Although aluminium has a thermal conductivity and electrical resistance close to that of copper, the melting point for aluminium is lower, which means welding is possible. However, due to its low resistance, very high levels of current need to be used when welding aluminium (in the order of two to three times higher than for steel of equivalent thickness).

In addition, aluminium degrades the surface of copper electrodes within a very small number of welds, meaning that stable high quality welding is very hard to achieve. For this reason, only specialist applications of aluminium spot welding are currently found in industry. Various new technology developments are emerging to help enable stable high quality spot welding in aluminium.

Copper and its alloys can also be joined by resistance spot welding, although spot welding copper cannot be easily achieved with conventional copper alloy spot welding electrodes, as heat generation in the electrodes and work piece are very similar.

The solution to welding copper is to use an electrode made of an alloy with a high electrical resistance and a melting temperature far in excess of the melting point of copper (much greater than 1080°C). Electrode materials typically used for spot welding copper include molybdenum and tungsten.

Application

Spot welding has applications in a number of industries, including automotive, aerospace, rail, white goods, metal furniture, electronics, medical building and construction.

Given the ease with which spot welding can be automated when combined with robots and manipulation systems, it is the most common joining process in high volume manufacturing lines and has in particular been the main joining process in the construction of steel cars for over 100 years.

Advantages

Resistance spot welding allows for high energy delivery to a concentrated spot in a short time

Welds any conductive metal

It’s relatively easy to perform – reduces the required operator’s skill

Saves time and effort compared to other welding processes

Best method to achieve proper weld strength with thin metal without burning

Many spot welding electrodes types are available for welding different metal alloys

Allows for swift and efficient welds

Electrodes handle the thermal conductivity problem by dissipating the heat away from the spot weld

Resistance welding creates controlled, repeatable welds

Efficient welding current usage

Disadvantages

You can’t spot weld metal if one side is not accessible

Resistance spot welding may harden the nugget and the material around it, leading to cracks

It can affect the chemical and physical properties of the workpiece metal. Corrosion resistance may be compromised with stainless steel, aluminum, and other metals

It outputs tiny voltages (1-20V). So, any fluctuation can influence the spot weld quality

Depending on the metal type and thickness, it may require frequent repairs

Spot Welding Variables

Electrode Force

Electrode force squeezes the metal sheets together and you have to apply substantial force to create a quality weld. The stronger the applied force, the lower the resistance because of better contact and less heat is generated. So if a project requires a higher electrode force, you need to increase the current to offset the lower resistance in the metal.

The typical force is around 90N per mm^2. However, thanks to the “mushroom” electrode tip on the spot welder, the contact surface area between the electrode and the sheet metal increases as the weld progresses. That’s because the metal’s surface will morph to fit the electrode tip shape, and the sides of the tip will then also come in contact with the metal. So, to keep the same electrode force on the piece during the welding process, you need to increase the applied force gradually.

Spot Welding Variables

Squeeze Time

Squeeze time is the interval between the moment you apply the electrode force and initiate the current flow. Delaying the weld current is necessary because it allows you to attain the proper electrode force. It also helps with electrode wear, arcing, and interfacial expulsion.

While increased squeeze time improves spot weld quality, it increases the cost per spot weld. This is mainly because it takes more time, and results in a reduced number of welds per unit of time.

Spot Welding Variables

Welding Time

Welding time is the period when active electric current flows through the metal pieces. It’s computed using line voltage cycles. Welding time is difficult to determine because it relies on the welding spot reaction.

Factors to consider when determining the welding time:

The weld time should be as short as possible. This prevents melt-through, warping, and protects the electrodes

Thick sheet welding should result in a nugget with a large diameter

If your equipment can’t provide the necessary weld current and electrode force, you can compensate with a longer weld time up, to a point

Welding sheet metal thicker than 2 mm may require dividing the weld time into multiple pulses to avoid excessive heat

Spot Welding Variables

Holding Time

Holding time is necessary to allow the weld nugget to solidify. This period starts after the welding time ends, and the electrodes are still applied to the metal.

The electrodes chill the weld by conducting heat away from the spot. You shouldn’t overdo the holding time because too much heat flow to the electrodes can accelerate their wear. Additionally, if the welded metal has a high carbon content, a prolonged holding time can cause brittle welds.

Friction Welding

Friction welding is solid-state welding technique for joining workpieces by producing heat through mechanical friction. They do not use external heat source to melt or convert the metal into plastic state. Instead, the welding is formed by the application of external pressure. In friction welding, one part of the pieces to be joined rotates relative to the other. Because of this movement, friction is generated that heats up the materials at the contact surfaces. Till the completion of the welding cycle, a high-pressure force is applied.

Materials

The major benefit of friction welding is that it can be used to join dissimilar metals. Friction welding is widely used with metals like steel, aluminum, copper, titanium, nickel alloy, and thermoplastics in a wide variety of aviation and automotive applications. An eco-friendly process, friction welding is also used to manufacture subassemblies for industrial printers, material handling equipment, marine, and oil applications. The components that are usually manufactured using the friction welding process are gears, axle tubes, hydraulic piston rods, drivelines, valves, connection rods, pump shafts, etc.

Working Principle

Friction welding uses the principle of heat generation by friction between two members. During the friction welding process, two surfaces to be welded are made to rub against each other at very high speed. The developed friction between the rotating and non-rotating surface produces enough heat at the weld interface. Once the required welding temperature is generated, a uniformly increasing external pressure is applied till both the workpieces form a permanent joint. This is the basic principle of all types of friction welding processes, even though the exact process may vary slightly depending on the type.

Process

All the friction welding processes mostly follow the following steps:

Step 1: One part to be welded is placed in a rotor-driven chuck and the other part is held stationary. Now the rotor is switched on to rotate at very high speed along with the workpiece.

Step 2: The rubbing of welding surfaces creates sufficient heat (of the order of 900-1300 °C for steel). Now a high pressure is applied through the stationary part.

Step 3: Once the temperature of the welding surfaces reach to the required temperature, the rotor is stopped.

Step 4: Now, the pressure is increased continuously till both the parts weld to each other.

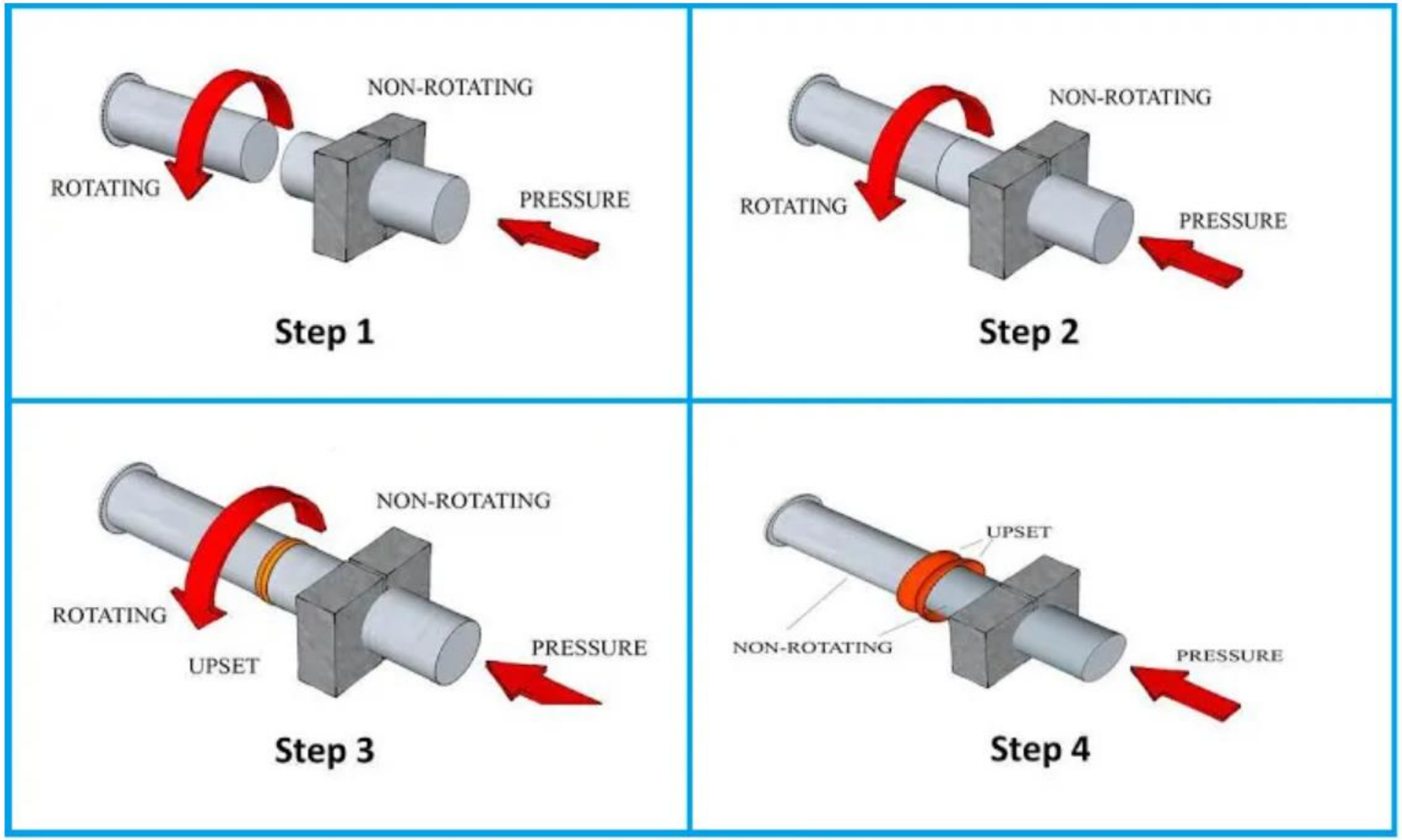


Image credit: www.mech4study.com

Fig. 1: Friction Welding Working principle

Benefits

Friction welding provides various advantages with respect to conventional welding processes. Some of the advantages of using friction welding are:

Joining Dissimilar Materials: Friction welding allows to join aluminum with steel or copper to aluminum. Similarly, various bi-metallic friction welded joints can be produced.

No external heat source or flux application

Fast and efficient process

Need very less surface preparation

As the welding process is CNC controlled, the friction welding process produces consistent quality products.

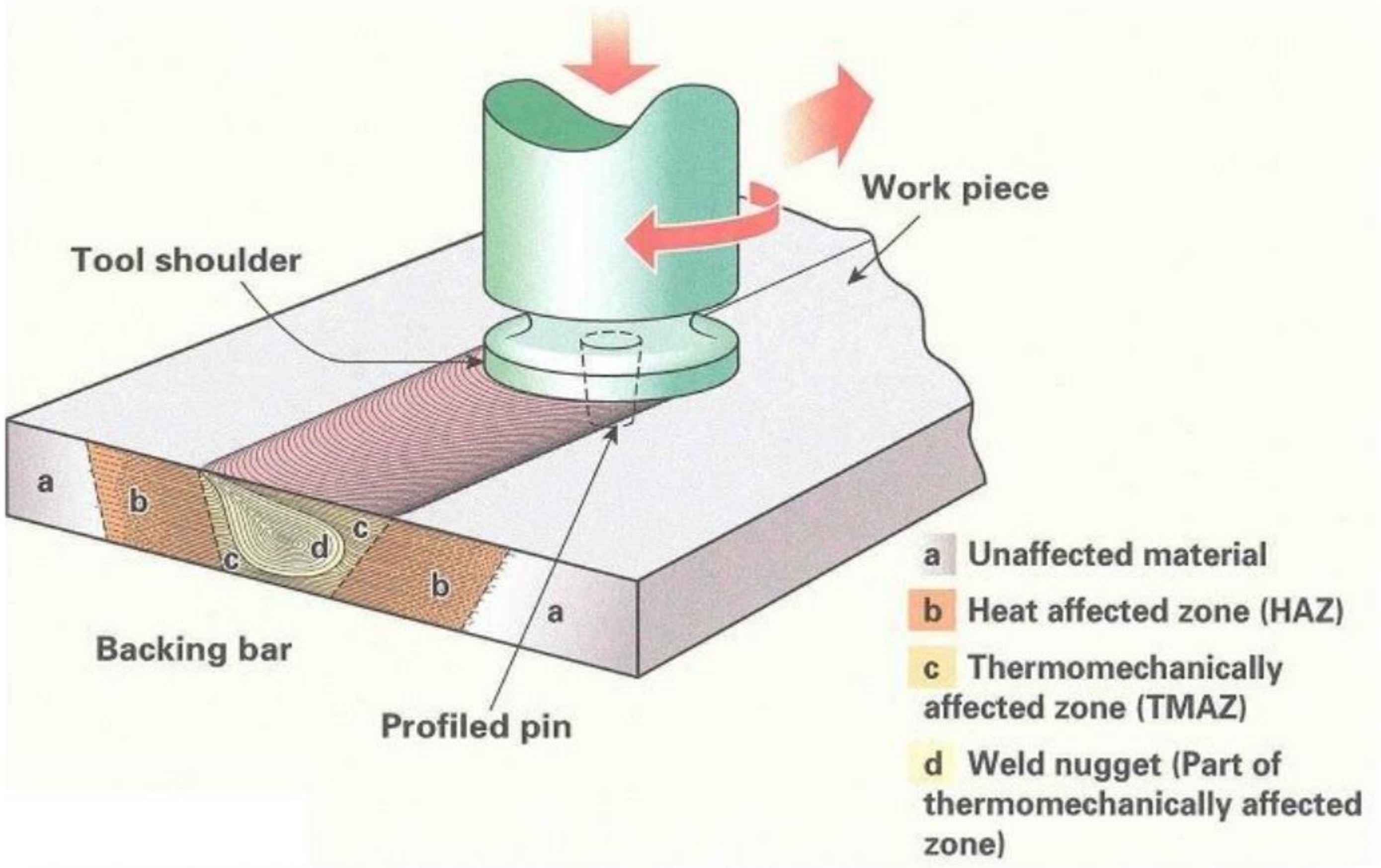
Reduced material wastage

Environment friendly process

As a solid-state welding, friction welding avoids defects associated with fusion welding.

Friction Stir Welding

Friction stir welding (FSW) is a solid-state joining process developed at 1991. FSW works by using a non-consumable tool, which is rotated and plunged into the interface of two workpieces. The tool is then moved through the interface and the frictional heat causes the material to heat and soften. The rotating tool then mechanically mixes the softened material to produce a solid-state bond. The FSW process is illustrated in Figure.


Work piece
Tool shoulder
a
b
c
d
c
b
a
Backing bar
Profiled pin
a Unaffected material
b Heat affected zone (HAZ)
c Thermomechanically affected zone (TMAZ)
d Weld nugget (Part of thermomechanically affected zone)

Application

FSW is mainly used in industry to join aluminium alloys of all grades, in cast, rolled or extruded condition. Aluminium alloy butt joints with a thickness from 0.3 mm to 75 mm have been successfully joined in a single pass (dependent on workpiece material, machine power and structural stiffness). Other materials have also been successfully joined, namely magnesium, titanium, copper, and steel alloys. Plastics and metal matrix composites (MMC) have been explored. Dissimilar combinations between these materials have also proven possible.

Since its invention, FSW has become a proven technology in most manufacturing sectors. Some of its known applications include:

Shipbuilding and Marine

Aerospace

Railway industry

Automotive

Electronics

Microstructure and Mechanical Properties

Friction stir welds typically exhibit three main microstructural regions: a weld nugget, a thermo-mechanically affected zone (TMAZ) and a heat-affected zone (HAZ). Technically, the weld nugget and TMAZ are both “thermo-mechanically affected zones,” but are considered separately for exhibiting distinct microstructural features. The weld nugget experiences dynamic recrystallisation while the TMAZ does not. The extent and microstructural composition of these zones are dependent on the material and processing conditions (parameters and tool design, for example).

Advantages

Friction stir welding offers many advantages over fusion-based joining processes, especially when joining aluminium alloys:

Remaining in the solid-state, avoiding many of the defects associated with melting and solidification during fusion welding, such as pores and solidification cracks.

The peak temperatures are lower, allowing a reduction in distortion and shrinkage.

Being able to join many ‘non-weldable’ aluminium alloys, namely from the 2xxx and 7xxx series.

Producing superior mechanical properties.

No filler metals, flux or shielding gas are required. No fumes, porosity or spatter are generated.

Fully automated, making the process highly repeatable.

Energy efficient.

Does not require special edge preparation in most applications