Friction Stir Welding

Strong, Ductile, and Environmentally Friendly

Friction Stir Welding. Cramer Studio, Inc. photo.

Benefits

FSW's ability to create a solid state bond makes it a prime candidate for materials that are difficult to join using traditional arc welding techniques. Aluminum and aluminum alloys, which can be difficult to weld due to their high thermal conductivity, large freezing range, rapid formation of oxide film over the liquid weld puddle, and tendency to form porosity and solidification cracks, were the first materials to be joined using FSW; however, the technology has also been effective on copper, lead, magnesium, titanium, zinc, mild steel, selected stainless steels, and nickel alloys.

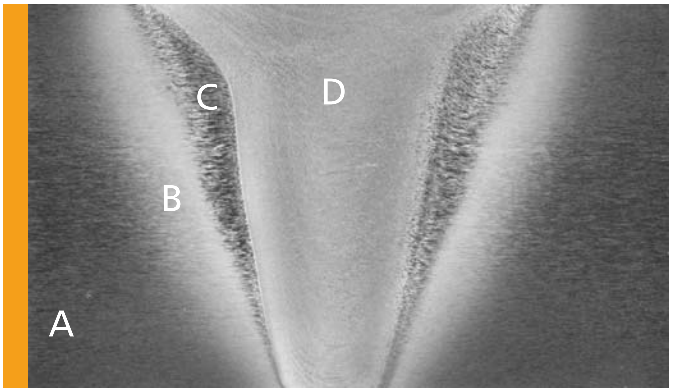
Invented in 1991 by Wayne Thomas of The Welding Institute in the United Kingdom, friction stir welding (FSW) is a joining technique that has gained attention as an attractive alternative to traditional fusion welding for many metals, but especially for joining aluminum alloys.

Background

In FSW, metal sheets or plates to be joined are aligned next to each other and clamped in place. A non-consumable cylindrical tool comprised of a profiled probe or "pin" is rotated and plunged into the joint between the plates. The probe nearly penetrates the workpiece. As the tool traverses the weld line, frictional heat from the relative motion between the tool and the workpiece, coupled with heat from the tool shoulder rubbing on the top surfaces of the plates to be joined, softens the workpieces so their material can be stirred by the probe. Because the material displays no discernible melting, the resulting bond is made in the solid state, thereby avoiding many of the problems associated with traditional fusion welding such as segregation, severe residual stresses, distortion, and evaporation of volatile elements.

Friction stir welding system. CTC photo.

Friction Stir Weld Zones



Friction stir welding affects the welded material's microstructure, resulting in four distinct zones: the Unaffected Zone (A), the Heat Affected Zone (B), the Thermomechanically Affected Zone (C), and the Stir Zone (D). CTC photo.

FSW significantly reduces residual stresses compared to traditional welding techniques and creates strong and ductile joints with low distortion, shrinkage and porosity. The FSW process is relatively simple, is fully mechanized and can function well in any position (gravity has no effect on the FSW process, as opposed to fusion welding). In addition, FSW consumes less energy than fusion welding and eliminates the need for filler wire, thereby making FSW a more environmentally friendly technique.

Characterization of Friction Stir Welds

Although tool design, speed of rotation and the material being joined can change the microstructure of a friction stir weld, most welds can be characterized using four distinct zones as shown above. In the "Unaffected Zone" (A), material may experience a thermal cycle from the weld, but is unaffected in terms of structure or material properties. Closer to the weld in the "Heat Affected Zone" (B), the material experiences changes in microstructure and material properties from the heat of welding, but not from deformation. In the "Thermomechanically Affected Zone" (C), the material is affected by the heat and is plastically deformed by the welding process. In this area, the general grain structure of the original material is retained, although in a deformed state. Finally, in the central region of the weld, known as the "Stir Zone" (D), the structure of the material is heavily deformed and refined.

Applications

Friction stir welding was rapidly adopted as a joining technique for the production of marine structures, especially in Scandinavia where high-speed ferry construction has benefited from the process since the mid-1990s. Application in the United States has been slower, but interest has gradually improved as more manufacturers have learned of the benefits of the process. FSW was used to create aluminum-stiffened panels for the U.S. Navy's FSF-1 "Sea Fighter" high-speed craft, and the process is being considered for ground combat vehicles and other Navy applications, including construction of bulkheads, superstructures, and decks.

The Navy Metalworking Center (NMC), under TARDEC sponsorship, has installed a three-story tall FSW system capable of fabricating a full-size combat vehicle. The system is able to create welds in two-inch thick aluminum plates in a single pass. NMC has been using the system to develop the process for Navy applications, and to fabricate concept trailers and Future Combat Systems combat vehicle test articles for the U.S. Army.

The increasing attention on FSW has already resulted in many variations of the welding process, each with its own benefits. The creation of additional process variants, the development of new welding tool designs, and the identification of best practices are likely to make FSW even more versatile and effective in the future. As these new methods are developed, new applications are constantly being identified and developed, making FSW an area of intense interest.

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