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Friction Welding Continues to Increase Its Dependability

Learn about the advantages and recent advancements of this joining process

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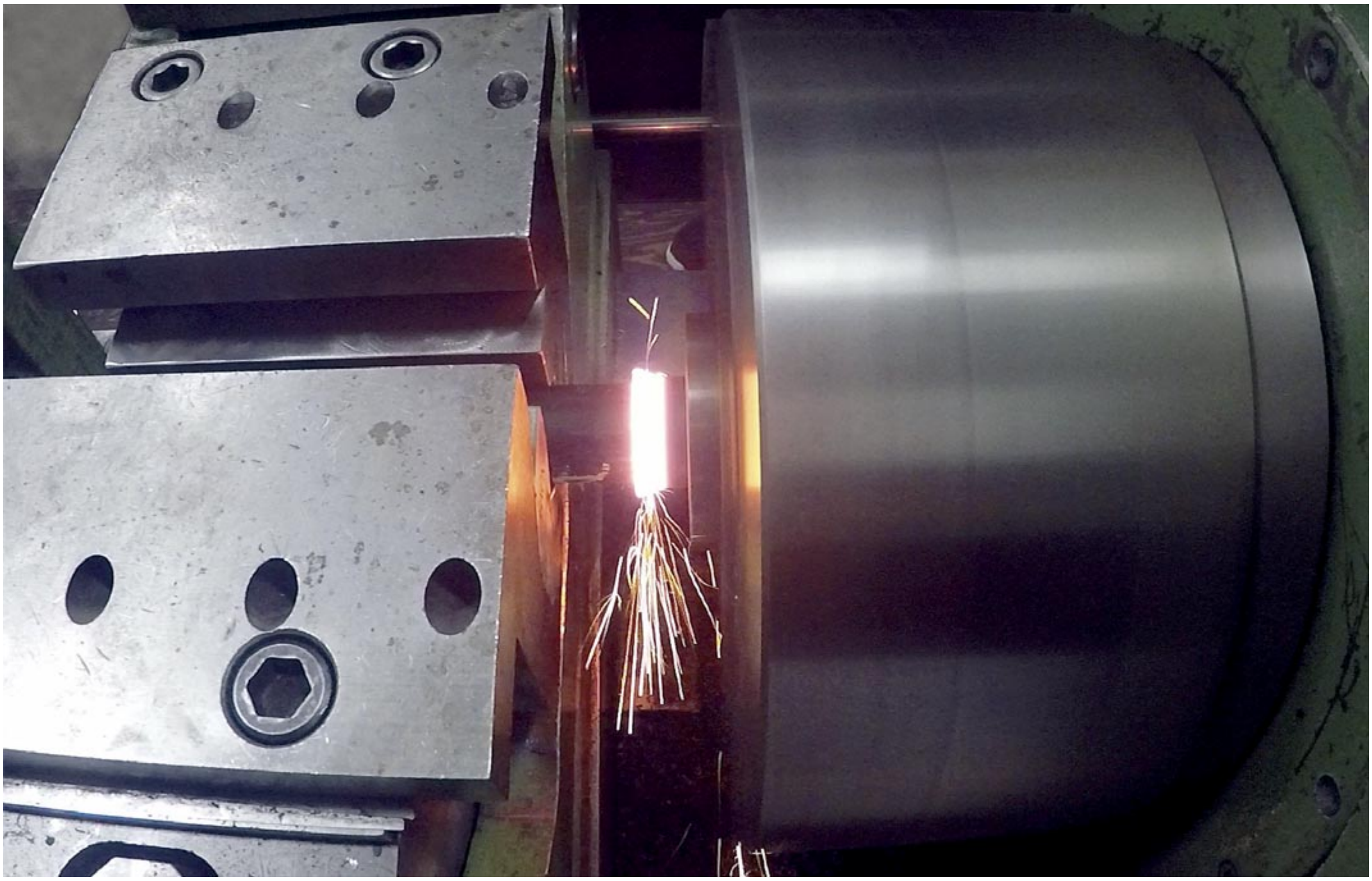
The American Welding Society C6 Committee on Friction Welding defines friction welding (FRW) as "a solid-state joining process that produces coalescence of materials under compressive force contact of workpieces rotating or moving relative to one another to produce heat and plastically displace material from the faying surfaces" (Ref. 1) — Fig. 1. Unlike with conventional fusion welding, during the FRW process, the faying surfaces do not melt. Additionally, FRW does not require filler metal, flux, or shielding gas.

The two most common types of FRW are direct-drive friction welding (FRW-DD) and inertia friction welding (FRW-IFW). In FRW-DD, one of the workpieces is attached to a part-holding chuck that is directly attached to a drive motor, while the other workpiece is restrained from rotation. FRW-IFW differs from FRW-DD through its use of a flywheel to gener-



Friction welding, which offers many more benefits than conventional welding, continues to expand its application through technological advancements.

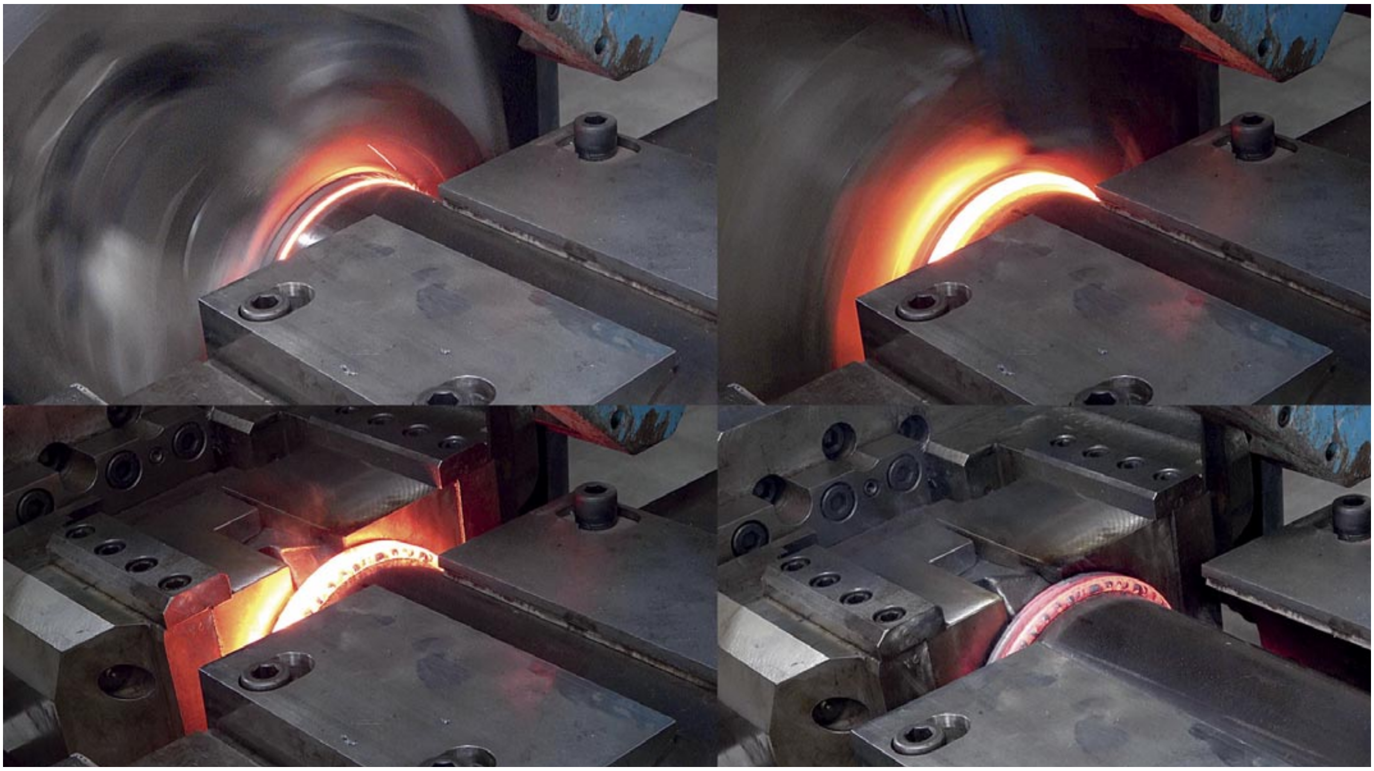


Fig. 1 — Sequence of the friction welding process.

Fig. 2 — A full-strength weld created with the FRW process.

ate the rotational momentum in the part-holding chuck.

In the United States, FRW-IFW saw most of the initial development because it could use relatively small drive motors, since the weld energy is stored in the flywheel. However, FRW-DD has gained popularity with the availability of motors and drives robust enough to deliver the horsepower and torque needed for the process.

Regardless of the type used, FRW offers numerous benefits that have continued to expand with recent technological advances.

Advantages of FRW

Some of the predominant advantages of FRW include full-strength welds, a narrow heat-affected zone (HAZ), the ability to join dissimilar metals, as well as near-net shape components, and high productivity.

Full-Strength Welds

The FRW process achieves full-strength welds that penetrate the entire cross section of the joint — Fig. 2. The resulting weldment is metallurgically a single piece of metal, free of voids and areas of nonfusion. This is in contrast to conventional welding techniques that may only produce a bond around the periphery of the materials, and have the potential for introducing defects into the joint.

Narrow HAZ

Friction welding is a rapid, solid-state process in which the temperature of the materials never exceeds their melting point. This results in a narrow HAZ with most of the base material unaffected by the welding process.

Joining of Dissimilar Metals

FRW is capable of joining both similar and dissimilar materials. It is successful in joining two different metals where conventional welding may not work — Fig. 3. The advantages of being able to join dissimilar metals can be tremendous in both engineering functionality and cost reduction.

Near-Net Shape Components

Friction welding has the ability to weld pre-machined components into a net, or near-net, shape. Internal or external splines can be machined on a shaft before being welded to a disk, making it easier to manufacture than splining a complete assembly. Simply welding a shaft to a disk can significantly reduce manufacturing costs when material and machining costs are taken into account.

Productivity

Compared to other processes, FRW has short process times. Typically, a weld that takes a minute to produce using conventional techniques can be completed in less than 20 s using a FRW machine.

Recent Advances in FRW

Recent advances in FRW involve hybrid welding, weld orientation, in-process monitoring, traceability, and in-line ultrasonic testing (UT).

Hybrid Welding

Older FRW machines relied on mechanical brakes to stop the spindle at the end of the friction phase of welding. These brakes were prone to wear, and stopping times were inconsistent.

In contrast, newer FRW machines use a drive motor for deceleration. This not only eliminates brake wear but allows the spindle stopping time to be tailored to the application. For instance, when welding materials with good high-temperature strength, it is advantageous to use a longer stopping time to promote additional displacement of the materials while forging. This feature is termed hybrid welding because it allows the direct-drive FRW machine to achieve the desirable attributes of an inertia FRW machine.

Weld Orientation

On most FRW machines, when the weld time ends, the spindle will stop in a random orientation. With newer machines, it is now possible to stop the spindle repeatedly in the same orientation. This allows for the alignment of features on the two parts being welded. For example, when welding ends onto hydraulic cylinders, the oil ports can be aligned to each other. This feature enhances design flexibility for the design engineer.

Fig. 3 — Two different metals joined by FRW.

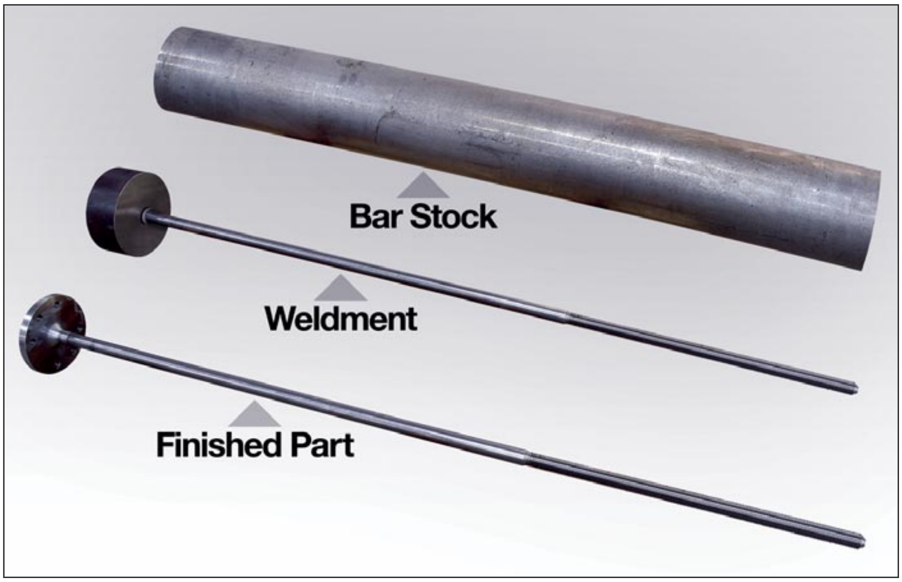


Fig. 4 — Friction welding can join pre-machined components into a net, or near-net, shape. Shown in the center of this photo is a pre-threaded shaft that was friction welded to a disk.

In-Process Monitoring

After a set of parameters have been developed and tested for a particular weld, the FRW machine employs in-process monitoring to ensure that every weld conforms to the established parameters.

The key FRW process variables are force, spindle speed, length change, and time. Traditionally, most machines monitor the minimum values of these four variables. However, newer machines are capable of more sophisticated monitoring to provide added assurance of process quality.

Force

Older, less-precise, and outdated FRW machines alert operators when a minimum pressure is not being met on the cap side of the cylinder applying the welding force. Newer, high-precision machines monitor both sides of the cylinder to calculate the actual weld force. The weld force is then monitored for both minimum and maximum values.

Spindle Speed

Older FRW machines typically use a proximity sensor and gear wheel to monitor the spindle speed. This has poor resolution and is unreliable at lower spindle speeds. Newer machines utilize a high-resolution encoder to provide accurate and consistent speed monitoring.

Length

Older FRW machines use limit

switches to monitor changes of length during welding. The limit switches are difficult to set accurately and have poor repeatability. Newer machines use digital, noncontact transducers that are robust and extremely accurate. The new machines also have the capability to measure component lengths before and after welding, alerting the operator if either the components or weldment are out of specification.

Time

Older FRW machines use discrete timers, which limit the amount of time monitoring available. Newer machines have software timers that allow for monitoring of aspects of machine performance other than just weld times. For example, with newer machines, pressure ramp times and spindle deceleration times can be monitored. This function offers more than just process monitoring; it checks on the health status of drives, brakes, belts, clutches, and pumps.

Traceability

Modern FRW machines not only monitor the process variables but also record and store them so that a record of each weld can be kept. The weld data can later be retrieved and displayed in either graphical or tabular form. The weld records can be tied to some form of part identification, such as a bar code, so that individual welds can be identified.

In-Line UT

Friction welding is a robust process that produces high weld quality. However, the problem of material defects still exists. Although modern FRW machines are extremely reliable, defects like stringers or a high concentration of contaminants can result in voids or weak areas near the weld interface.

Therefore, for critical applications, it is advisable to use some form of nondestructive examination method to identify these defects. One commonly used method is UT. The UT equipment can be integrated into the FRW machine control system, with the test results stored along with the weld data. For applications where 100% testing is not appropriate, the testing can be performed offline and the results manually entered into the weld record.

Conclusion

This article touched upon just some of the advantages offered by the FRW process, along with recent developments that have increased its dependability. The future is bright for FRW, and it will be exciting to watch the process continue to evolve.

Reference

1. ANSI/AWS C6.1-89R (R2009). *Recommended Practices for Friction Welding*. American Welding Society: Miami, Fla.

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