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FRICTION WELDING

Turning Out Forged-Quality Joints

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COVER STORY

Friction Welding: Turning Out Forged-Quality Joints

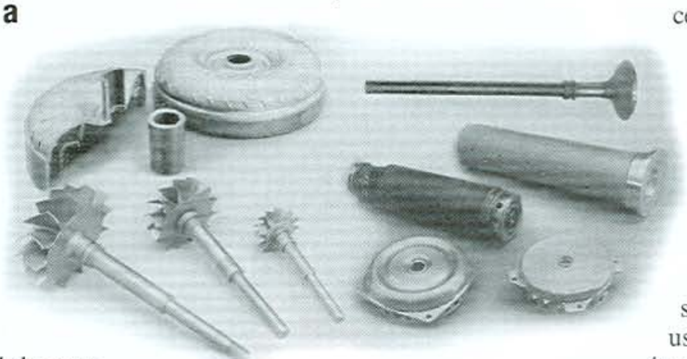
Energy-efficient friction welding involves bringing a rotating workpiece into contact with a stationary workpiece, with a compressive force creating sufficient heat to form a solid-state joint.

As the rotating and compressive forces increase, material is plastically displaced from the faying (tightly joined) surfaces without melting, under normal conditions. The weld produced is characterized by the absence of a fusion zone, and the presence of plastically deformed material around the weld (flash). Weld quality depends on proper material selection, joint design, welding variables, and postweld processing. Acceptable welds can be made in many materials using a range of weld parameters (speed, force, and time), without metal, flux, and shielding gas.

The AWS (American Welding Society) *Recommended Practices for Friction Welding* describes friction welding as follows.

In the direct drive variation of friction welding, one of the workpieces is attached to a motor-driven unit, while the other is restrained from rotation. The motor-driven workpiece is rotated at a predetermined constant speed. The workpieces to be welded are moved together, and then a fiction welding force is applied. Heat is generated as the faying surfaces rub together. This continues for a predetermined time, or until a preset amount of upset (length change) takes place. The rotational driving force is discontinued, and the rotating workpiece is stopped by the application of a braking force. The friction welding force is maintained or increased for a predetermined time after rotation ceases (forge force).

In the inertia friction welding variation, one of the workpieces is connected to a flywheel and the other is restrained from rotating. The flywheel is accelerated to a predetermined rotational speed, storing the required energy. The drive motor is disengaged, and the workpieces are forced together by a friction welding force. This causes the faying surfaces to rub together under pressure. The kinetic energy stored in the rotating flywheel is dissipated as heat through friction at the weld interface as the flywheel speed decreases. An increase in friction welding force may be applied (forge force) before rotation stops. The forge force is maintained for a predetermined time after rotation ceases.



Composite collection of parts produced using friction welding, clockwise from upper right: engine valve, air bag inflators, turbochargers, and torque converters

Further modifications of friction welding include radial, orbital, angular reciprocating, linear reciprocating friction welding, and friction surfacing. Radial friction welding can be used to join tubular sections where it is undesirable to rotate either of the tubes, or collars to shafts and tubes. Orbital motion may be used to weld non-circular parts. In this application, neither piece rotates about its central axis. The orbital motion provides uniform tangential velocity over the total interface area. When motion ceases, the workpieces are aligned rapidly.

Big Wheels Keep on Turning

Friction is created by various types of relative motion using either direct drive motors or kinetic energy from a rotating flywheel. Different friction welding processes have advantages for specific applications. However, use of newer forms of friction welding is limited to only a few machine designs: linear friction welding, rotating-oscillating friction welding, radial friction welding, orbital friction welding, friction stir welding, and friction plunge welding. In all cases, the weld is formed without producing the micro fissures or low life cycles sometimes seen with standard welding processes.

While holding great promise for future applications, stir welding is presently limited to aluminum alloys. In contrast, there are at least 3,000 rotary machines, worldwide, welding everything from hand tools to aircraft engine components. Most of these machines (about 99%) produce butt joints. Although both direct drive and inertia friction welding produce excellent solid-state bonds, there are subtle differences or advantages of one over the other that are application-dependent (size, material combination, geometric considerations).

Using a flywheel enables inertia friction welders to discharge energy over a shorter time, generally with less flash and narrow heat-affected zones. Inertia welders use two variables (speed and pressure), while direct drive friction welders use up to seven variables (speed, three pressures, three timers, or a timer/length control combination). Weld times are shorter and energy input is much higher in inertia friction welding than in direct drive friction welding. As such, inertia friction welding is usually superior in welding tube to plate combinations or super alloys.

However, direct drive friction welding also has its advantages. It is virtually impossible to achieve radial orientation on an inertia welding machine. Inertia welding also is more difficult, requiring complex controls to weld to a specific final overall parts length if the incoming parts have larger length tolerances than the required final tolerance. A direct drive friction welding machine can use a simple length control by measuring slide movement, stopping the drive when the final length is achieved.

Historically, three companies were involved in developing modern friction welding in the US, in the 1960s: AMF, Caterpillar Inc., and Rockwell International. Two or three double-ended welders were built by Rockwell for its own use to weld spindles to truck differential (banjo) housings. Caterpillar made its first machine in the toolroom to weld precombustion chambers for its diesel engines. The first two machines actually sold were by AMF for making steering worm shafts and by Caterpillar for making turbochargers. Both companies used flywheels to store all or part of the energy for welding. Caterpillar called their system "inertia friction welding," while AMF called their system "flywheel friction welding."

Most metals can be welded and post heat-treated to 100% base metal strength

Automotive Applications Leading the Way

Friction welding has many inherent advantages, including:

- No opportunity for human errors or judgments;
- Standard power requirements for electric motors;
- Energy efficient, about 250 watts per square-cm weld area under normal conditions;
- No smoke, slag, or consumables;
- Forged-quality joints;
- Complete 100% butt weld throughout contact area; and
- No solidification or inclusion (slag) defects.

(Quench hardenable materials may have to be stress-relieved or tempered to achieve full-strength welds.)

As a rule, all metallic engineering materials that are forgeable also are weldable. In addition, many castings, powdered, and metal matrix materials are weldable. Many materials can be joined to other materials such as copper to aluminum, titanium to copper, and nickel alloys to steel. Limited success has been achieved in joining ceramics to aluminum and nodular cast iron to steel.

Most metals can be welded and post heat-treated to 100% base metal strength. However, every weld application should be tested as close to its intended purpose in its final form, rather than relying on standard mechanical test results. For example, results show that a hardened SAE 10B35 or 1045 weld would be as good as any forging if used as a drive shaft to transmit torque; but the weld may be weaker by 30% in a push-pull application.

One part to be welded must have a nearly symmetrical shape (close to circular) around its axis of rotation. Hexagonal, square, octagonal, and elliptic shapes have been welded. Also, one part should have reasonable dimensions since it will be rotated in a lathe-type chuck. The second part to be joined can be of any shape or form as long as the weld contact area is a butt design. Machines are available that can spin from 1 - 1,000 mm in diameter. As for maximum weld area, machines are capable of welding from 1 - 161,000 square-mm based on medium carbon steel.

A 60 ton friction welder used to produce rear axle housings at 180 parts per hour with automated handling

The primary cause of poor weld quality is base material. Free machining constituents, such as sulfur and lead, weaken the weld since they orient themselves in the weld zone. The same is true of other base material defects such as stringers, laps, voids, slag, inclusions, etc. Friction welding cannot "repair" damaged base material nor will it be stronger than the transverse properties of the welded material.

In production, friction welding is an automated process used essentially for circular components. At present, the most active market for friction welding is the automotive industry. Among the most widely welded components in automobiles are turbochargers, airbag inflators, drive shafts, exhaust valves, hydraulic jacks, stabilizer bars, torque converters, transmission gears, axles, and axle housings. Other major applications include oil and gas drilling, aircraft engines, defense industry material, and general metalworking (hand tools, textile bobbins, etc.).

The majority of automotive applications are welded on machines ranging from 7½ - 45 ton forge force. Many of these machines are automated; that is, they work without an operator, and the loading and unloading are done by robots or dedicated automatic handling devices. One of the handicaps of friction welding equipment is the cost. A machine with a 250 square-mm welding capacity, with manual loading and unloading, will start at about $200,000. This increases rapidly as options are added, such as automation, flash removal, and computer monitoring. The user should not be surprised to pay 50% – 100% more for a "fully equipped" machine with automation.
Manufacturing Technology, Inc.

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Other products and services available from Manufacturing Technology, Inc.

Friction Welders

Manufacturing Technology, Inc. has been a leading manufacturer of Inertia Friction and Direct Drive Friction Welding equipment since 1976. Advantages of MTI's welding process include:

- Available machines can weld components from .040 in. (1mm) to 225 in^2 (145,160mm^2).
- Machines are versatile enough to join a range of part shapes, materials, and weld sizes.
- Dissimilar metals can often easily be joined, such as aluminum to steel.
- Powder metal parts can be welded together, or welded to forgings, castings, or wrought material.
- Equipment easily automated for high production rates.
- Process parameters are easily monitored; data can be stored for critical applications.
- No weld spatter and few sparks produced.
- No consumables required - no flux, fillers, or shielding gases.
- No objectionable smoke, fumes, or gases generated which need to be exhausted.

Contract Welding Services

Manufacturing Technology, Inc. maintains an in-house friction welding job shop, providing Research & Development and production welding services for customers. Capabilities include:

- Material size may range from .250 in. diameter to 6 in. diameter solid, or 43 in^2 tubular steel.
- Machines available for production runs, ranging from 6-ton to 450-ton weld force.
- Production run quantities may be large or small, depending upon your requirements.
- Pre- and Post-weld processing is available.
- Weld development and feasibility studies conducted by experienced professionals.
- Metallurgical evaluation - Experienced Metallurgist on staff to evaluate weld quality.
- Design capability for both tooling and parts by experienced Design Engineering Department.
- Computer storage of parameter data is available for critical applications.

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