31.4 Friction Welding

In the joining processes described thus far, the energy required for welding is supplied from external sources, typically chemical, electrical, or ultrasonic energy. In *friction welding* (FRW), the heat required for welding is generated through friction at the interface of the two components being joined.

Developed in the 1940s, one of the workpiece components in friction welding remains stationary while the other is placed in a chuck or collet, and rotated at a constant peripheral speed as high as 15 m/s. The two members to be joined are then brought into contact under an axial force (Fig. 31.3). After sufficient contact is established, the rotating member is brought to a quick stop (so that the weld is not destroyed by shearing) while the axial force is increased. Oxides and other contaminants at the interface are expelled by the radially outward movement of the hot metal at the interface.

The pressure at the interface and the heat resulting from friction are sufficient for a strong joint to form. The weld zone is usually confined to a narrow region, and its size and shape depend on the (a) amount of heat generated, (b) thermal conductivity of the materials, (c) mechanical properties of the materials being joined at elevated temperatures, (d) rotational speed, and (e) axial pressure applied (Fig. 31.4). These factors must be controlled to obtain a uniform and strong joint.

Friction welding can be used to join a wide variety of materials, provided that one of the components has some rotational symmetry. Solid or tubular parts can be welded, with good joint strength. Solid steel bars up to 100 mm in diameter and pipes up to 250 mm in outside diameter have been friction welded successfully. Because of the combined heat and pressure, the interface in friction welding develops

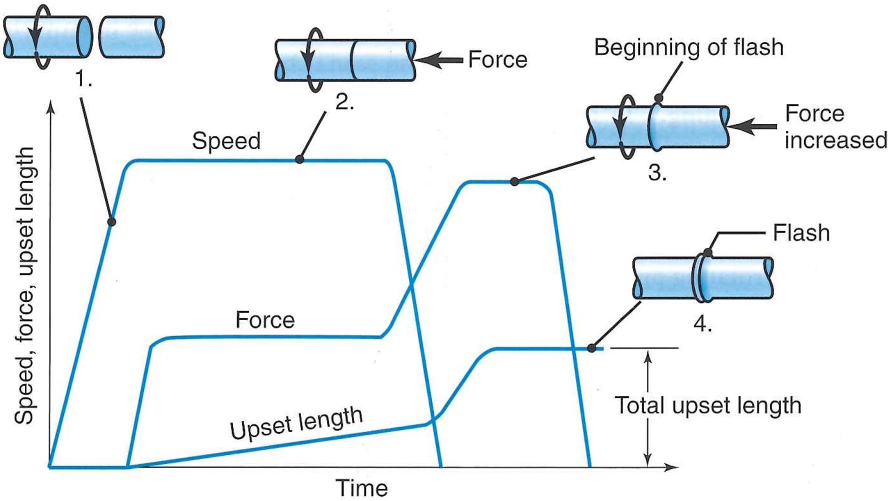

FIGURE 31.3 Sequence of operations in the friction-welding process: (1) The part on the left is rotated at high speed. (2) The part on the right is brought into contact with the part on the left under an axial force. (3) The axial force is increased, and the part on the left stops rotating; flash begins to form. (4) After a specified upset length or distance is achieved, the weld is completed. The *upset length* is the distance the two pieces move inward during welding after their initial contact; thus, the total length after welding is less than the sum of the lengths of the two pieces. The flash subsequently can be removed by machining or grinding.

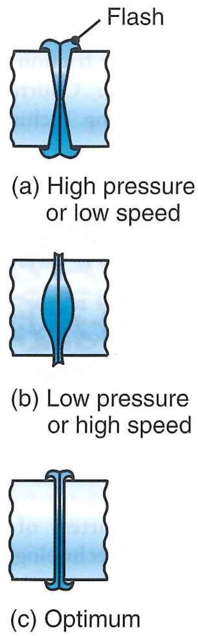

FIGURE 31.4 Shape of the fusion zones in friction welding, as a function of the axial force applied and the rotational speed.

a *flash* by plastic deformation (upsetting) of the heated zone. This flash (if objectionable) can easily be removed by machining or grinding. Frictionwelding machines are fully automated, and the operator skill required is minimal, once individual cycle times for the complete operation are set properly.

QR Code 31.1 Demonstration of inertia friction welding. (*Source:* Courtesy of Manufacturing Technology, Inc. [MTI])

QR Code 31.2 Demonstration of linear friction welding. (*Source:* Courtesy of Manufacturing Technology, Inc. [MTI])

QR Code 31.3 Demonstration of friction stir welding. (*Source:* Courtesy of Manufacturing Technology, Inc. [MTI])

Friction Stir Welding. In the *friction stir welding* (FSW) process, developed in 1991, a third body (called a *probe*) is plunged into the joint and rubs against the two surfaces to be joined. The nonconsumable rotating probe is typically made of cubic boron nitride (Section 8.2.3), 5 to 6 mm in diameter and 5 mm high. (Fig. 31.5). The contact pressure causes frictional heating, raising the temperature to 230° to 260°C. The tip of the rotating probe forces mixing or stirring of the material in the joint. No shielding gas or surface cleaning is required.

The thickness of the welded material can be as little as 1 mm and as much as 50 mm, welded in a single pass. Aluminum, magnesium, nickel, copper, steel, stainless steel, and titanium have been welded successfully, and developments are taking place to extend FSW applications also to polymers and composite materials. The FSW process is now being applied to aerospace, automotive, shipbuilding, and military vehicles, using sheet or plates. With developments in rotating-tool design, other possible applications include inducing microstructural changes, refining grain in materials, and improving localized toughness in castings.

The welding equipment can be a conventional, vertical-spindle milling machine (see Fig. 24.15b), and the process is relatively easy to implement. For special applications, machinery dedicated to friction stir welding is also available (Fig. 31.5b). Welds produced by FSW have high quality, minimal pores, and a uniform material structure. Because the welds are produced with low heat input, there is low distortion and little microstructural changes.

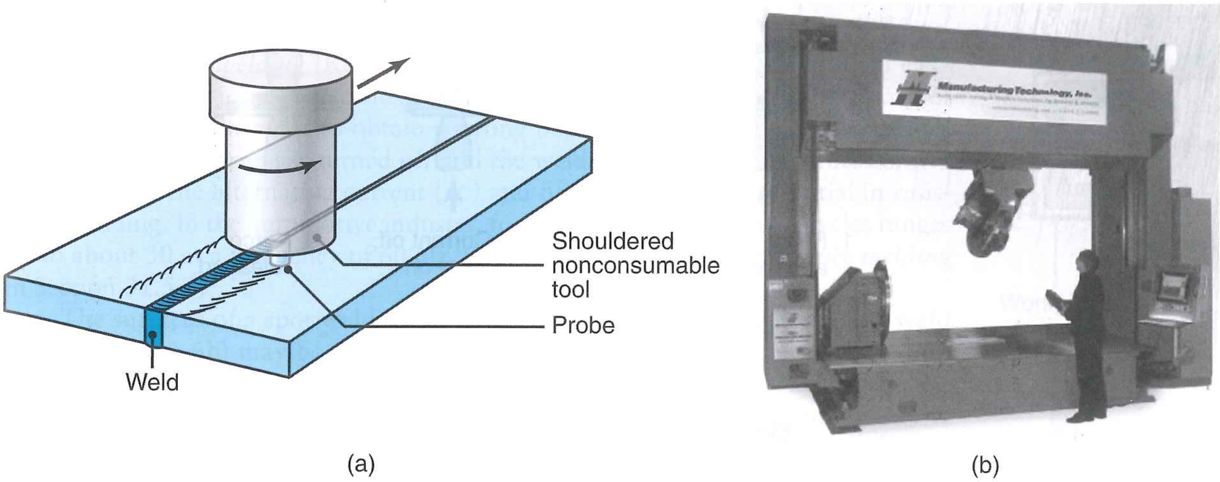

FIGURE 31.5 The friction-stir-welding process. (a) Schematic illustration of friction stir welding; aluminum-alloy plates up to 75 mm thick have been welded by this process. (b) Multi-axis friction stir welding machine for large workpieces, such as aircraft wing and fuselage structures, that can develop 67 kN axial forces, is powered by a 15 kW spindle motor, and can achieve welding speeds up to 1.8 m/s. *Source:* (b) Courtesy of Manufacturing Technology, Inc.