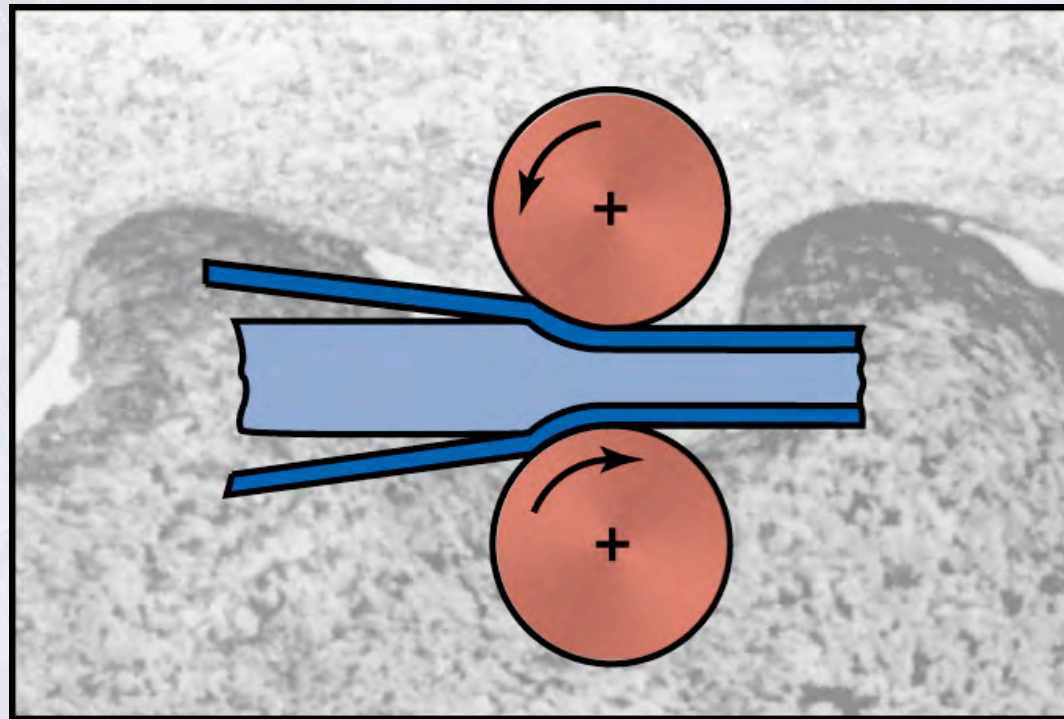


# Chapter 31

## Solid-State Welding Processes



# Roll Bonding

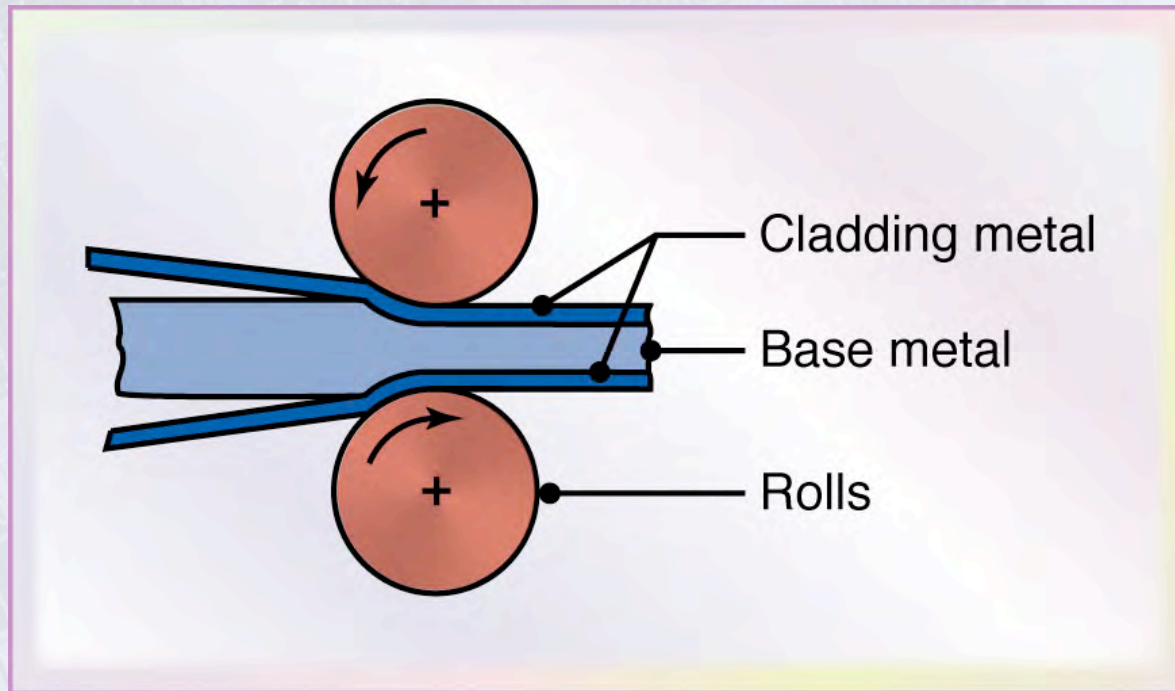


Figure 31.1 Schematic illustration of the roll bonding or cladding process.



# Ultrasonic Welding

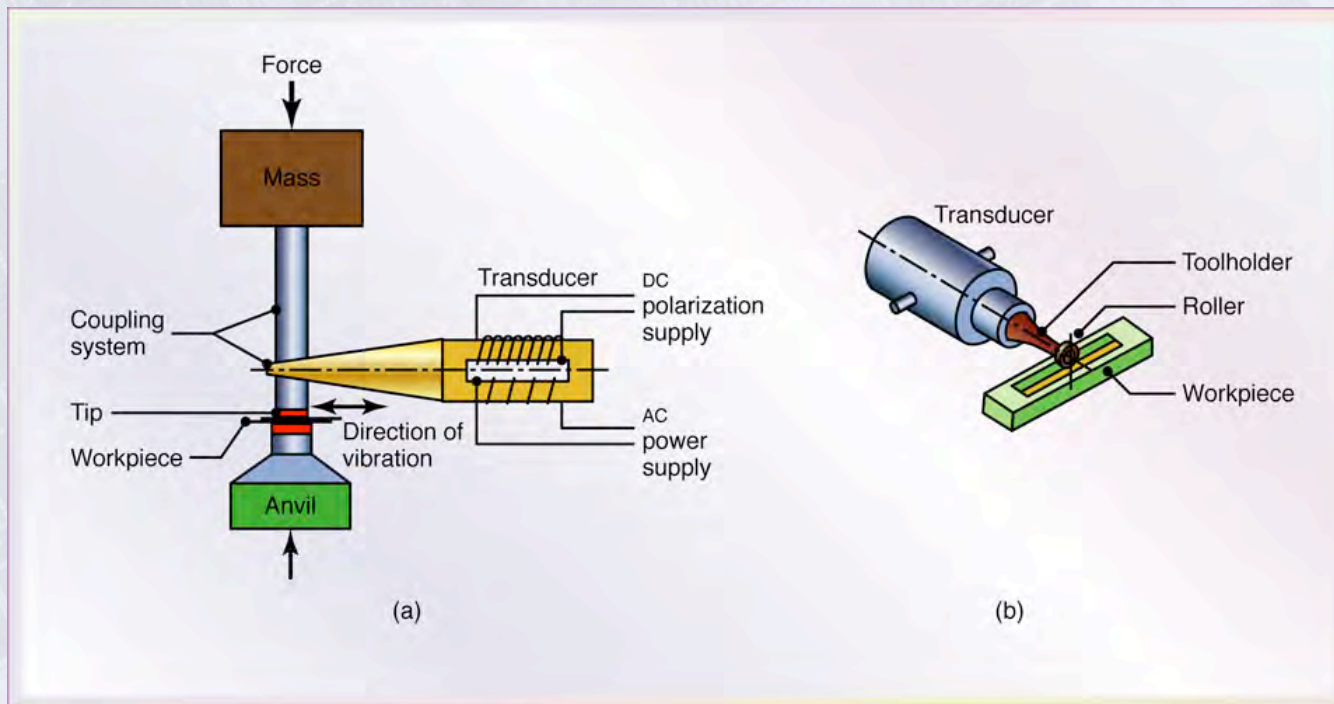


Figure 31.2 (a) Components of an ultrasonic welding machine for making lap welds. The lateral vibrations of the tool tip cause plastic deformation and bonding at the interface of the workpieces. (b) Ultrasonic seam welding using a roller as the *sonotrode*.

# Friction Welding

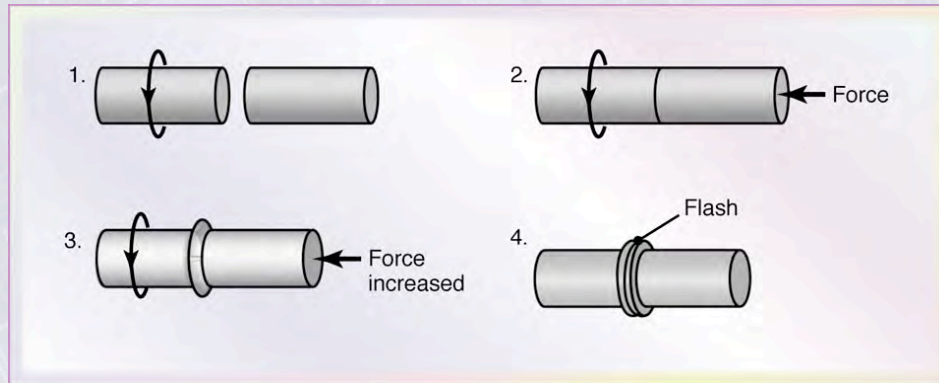
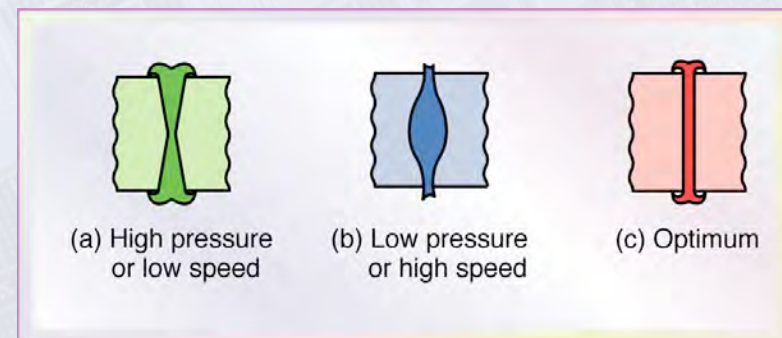


Figure 31.3 (a) Sequence of operations in the friction welding process: (1) Left-hand component is rotated at high speed. (2) Right-hand component is brought into contact under an axial force. (3) Axial force is increased; flash begins to form. (4) Left-hand component stops rotating; weld is completed. The flash can subsequently 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.





# Friction Stir Welding

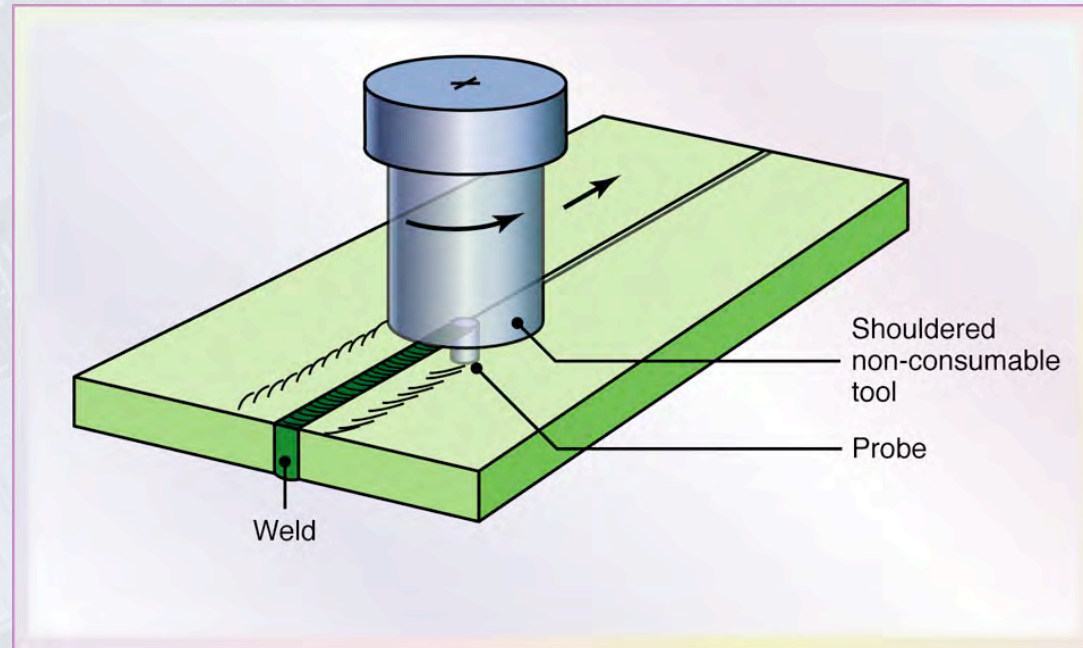


Figure 31.4 The principle of the friction stir welding process. Aluminum-alloy plates up to 75 mm (3 in.) thick have been welded by this process.

# Spot Welding

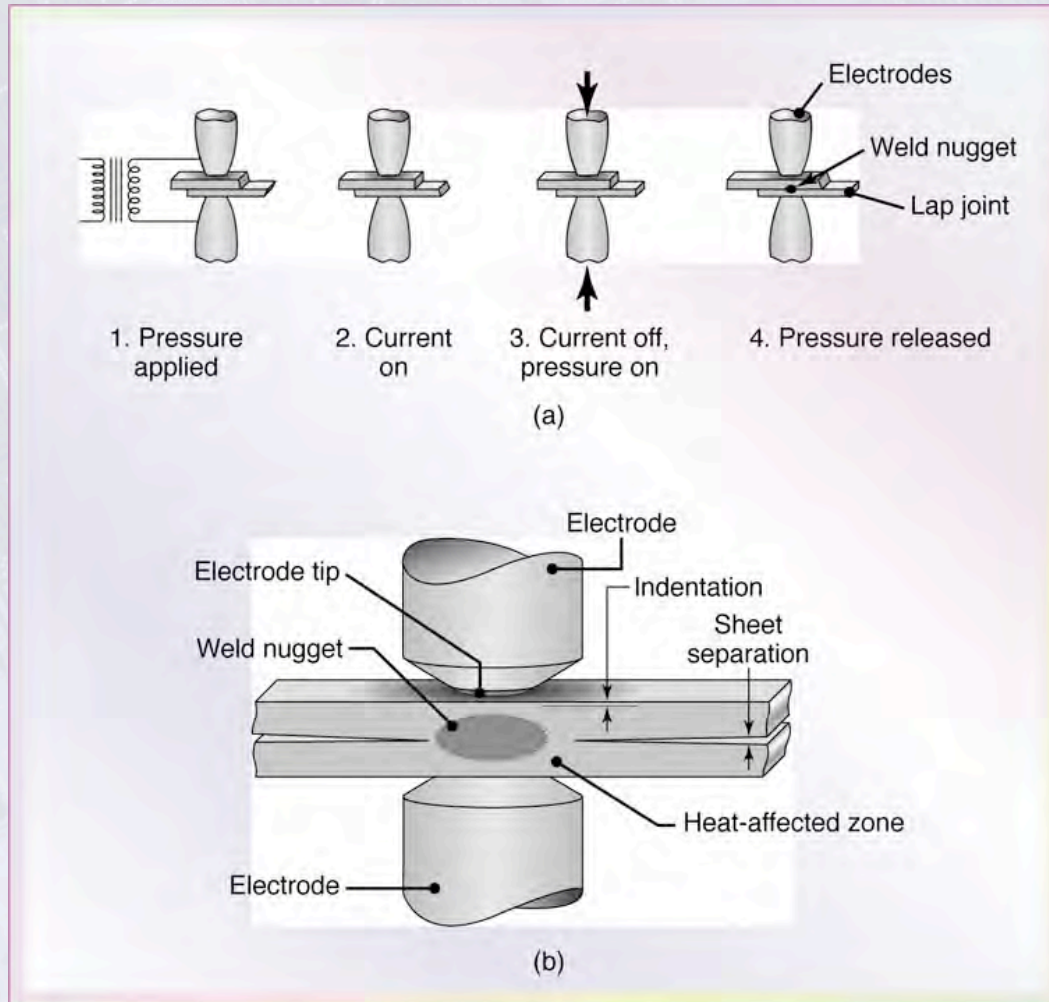


Figure 31.6 (a) Sequence of events in resistance spot welding. (b) Cross-section of a spot weld, showing the weld nugget and the indentation of the electrode on the sheet surfaces. This is one of the most commonly used processes in sheet-metal fabrication and in automotive-body assembly.



# Spot Welding Configurations

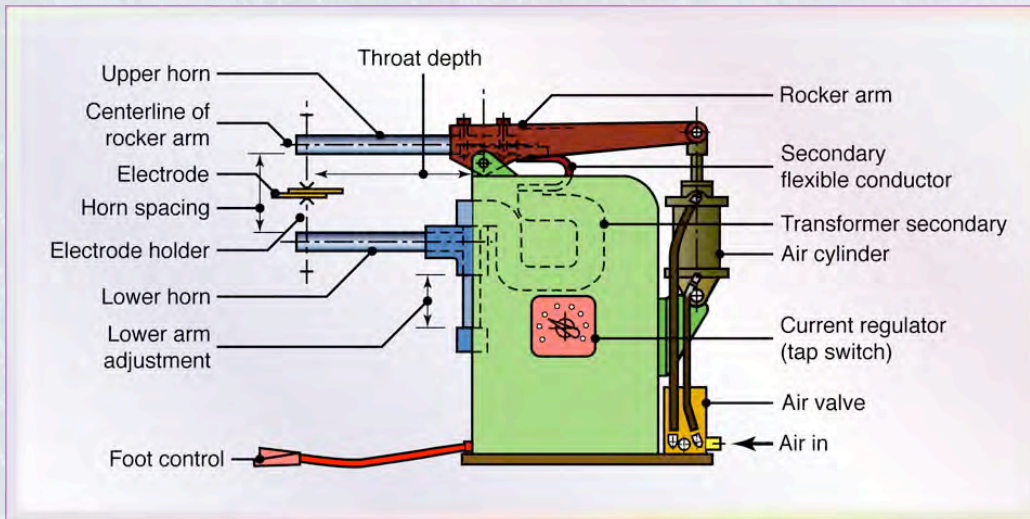


Figure 31.7 (a) Schematic illustration of an air-operated, rocker-arm, spot welding machine. (b) and (c) Two electrode designs for easy access into components to be welded.

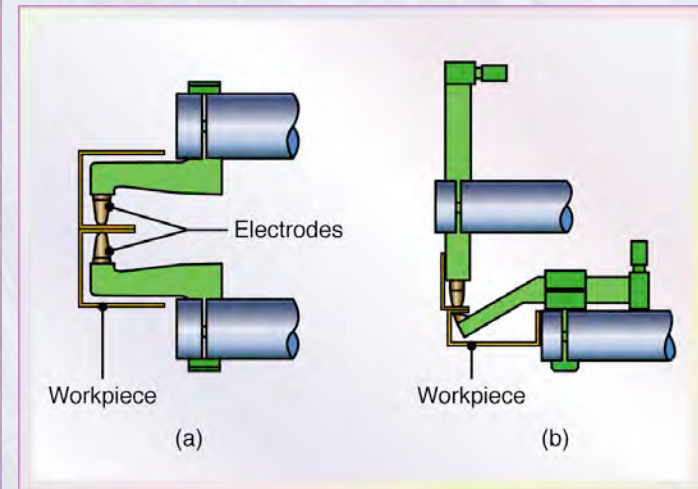


Figure 31.8 Two electrode designs for easy access to the components to be welded.

# Spot Welding

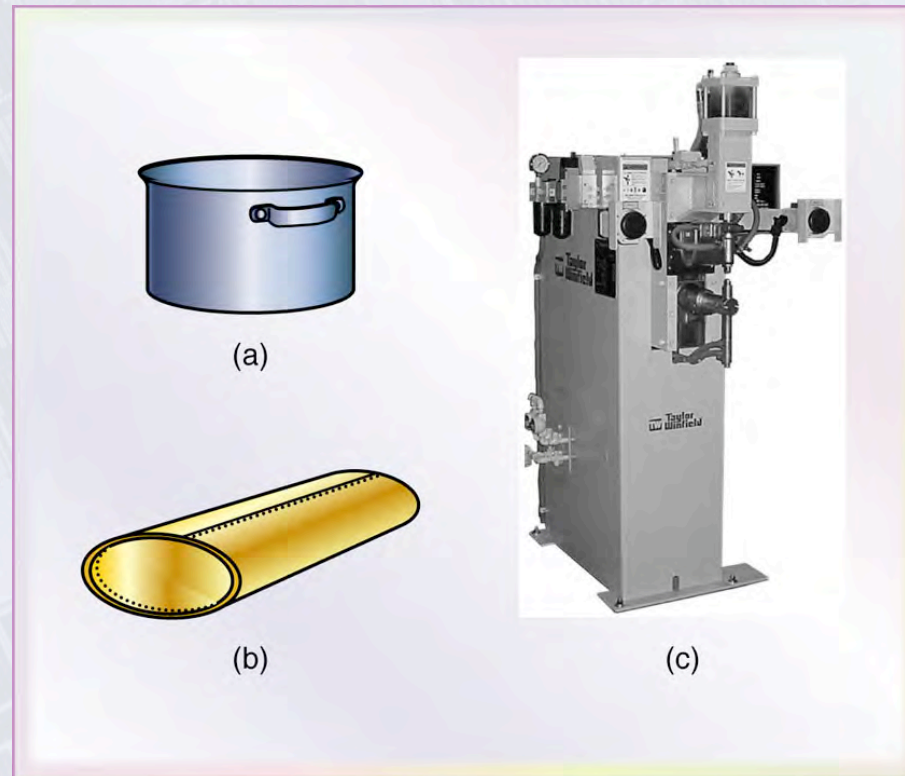


Figure 31.9 (a) and (b) Spot-welded cookware and muffler. (c) An automated spot-welding machine with a programmable robot; the welding tip can move in three principal directions. Sheets as large as 2.2 m × 0.55 m (88 in. × 22 in.) can be accommodated in this machine. *Source:* Courtesy of Taylor–Winfield Corporation.



# Spot Weld Testing

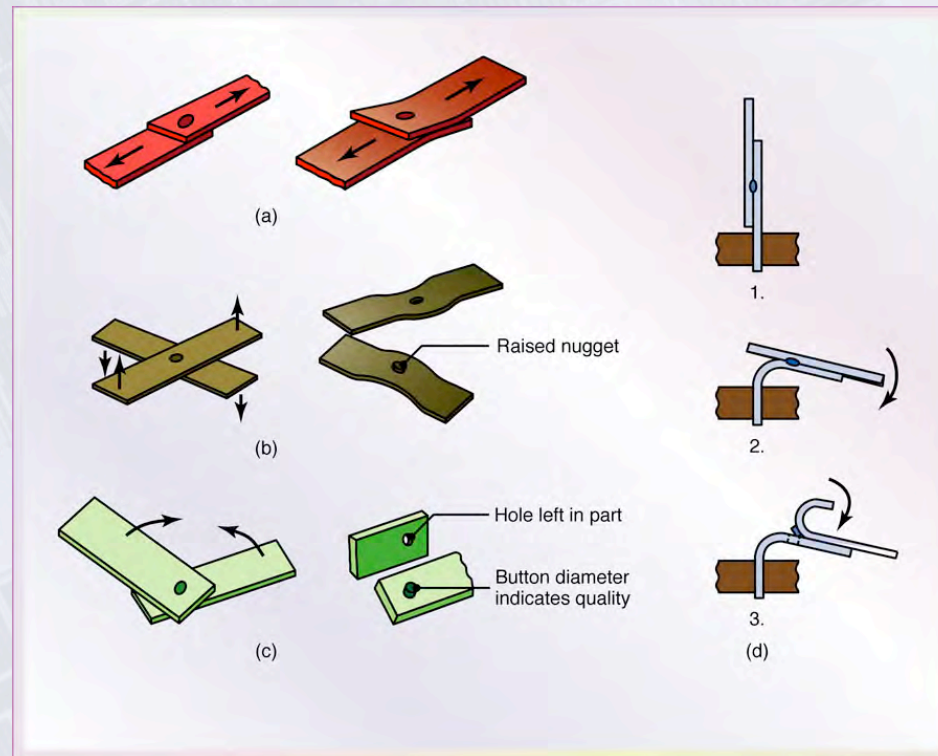


Figure 31.10 Test methods for spot welds: (a) tension-shear test, (b) cross-tension test, (c) twist test, (d) peel test. (see also Fig. 32.9).

# Seam Welding

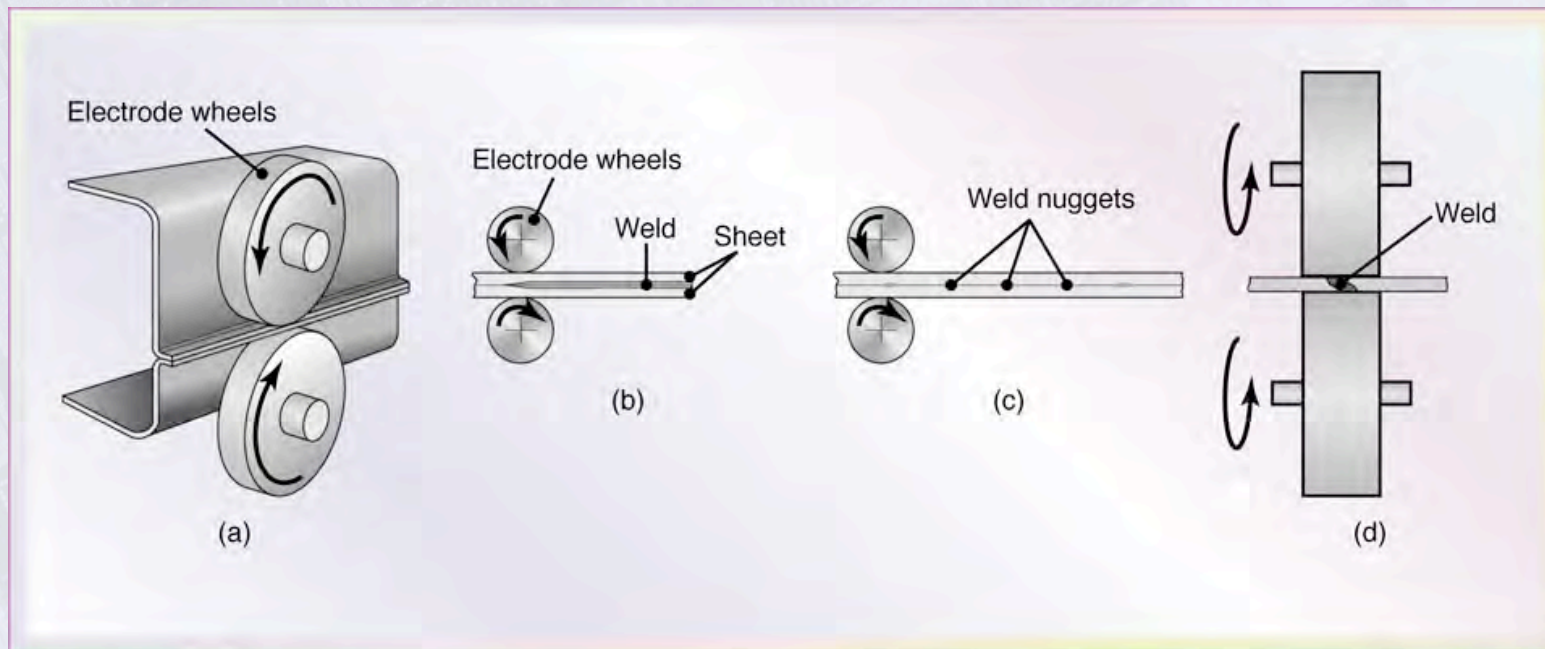


Figure 31.11 (a) Seam-welding process in which rotating rolls act as electrodes; (b) overlapping spots in a seam weld; (c) roll spot welds; (d) mash-seam welding.



# High-Frequency Butt Welding

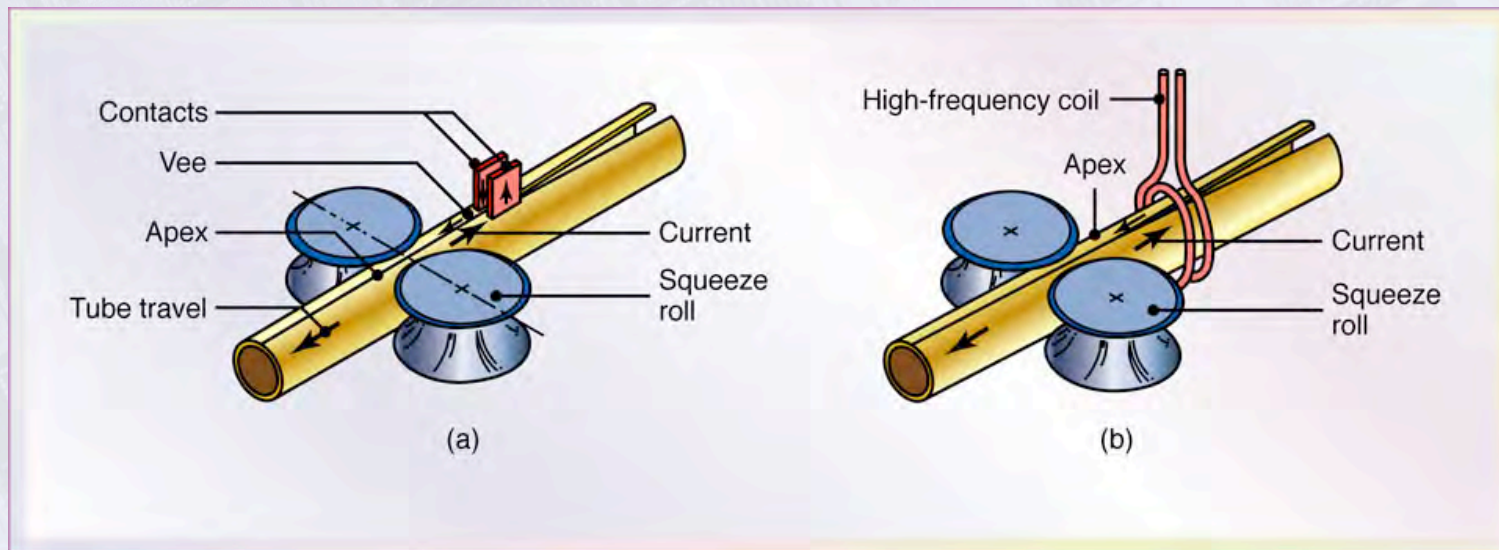


Figure 31.12 Two methods of high-frequency continuous butt welding of tubes.

# Resistance Projection Welding

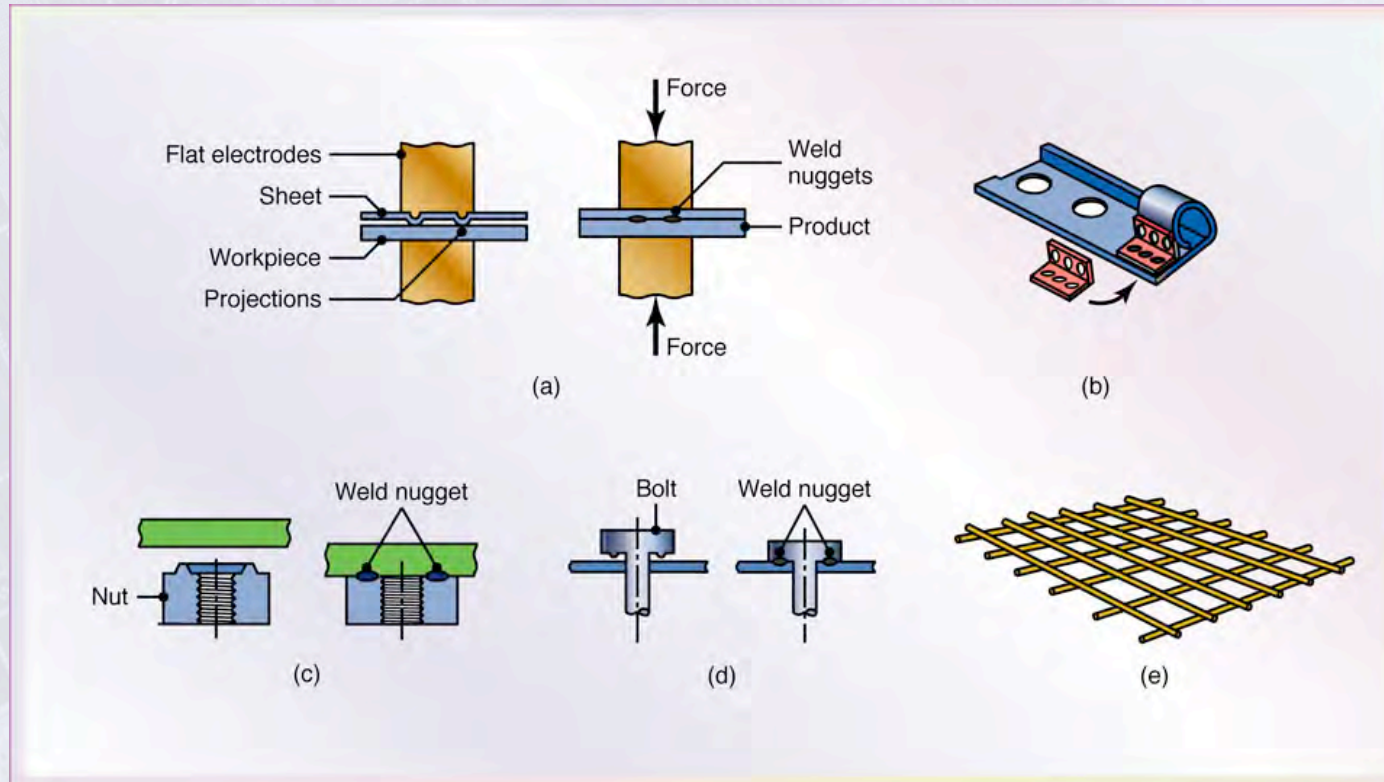


Figure 31.13 (a) Schematic illustration of resistance projection welding. (b) A welded bracket. (c) and (d) Projection welding of nuts or threaded bosses and studs. (e) Resistance-projection-welded grills.



# Flash Welding

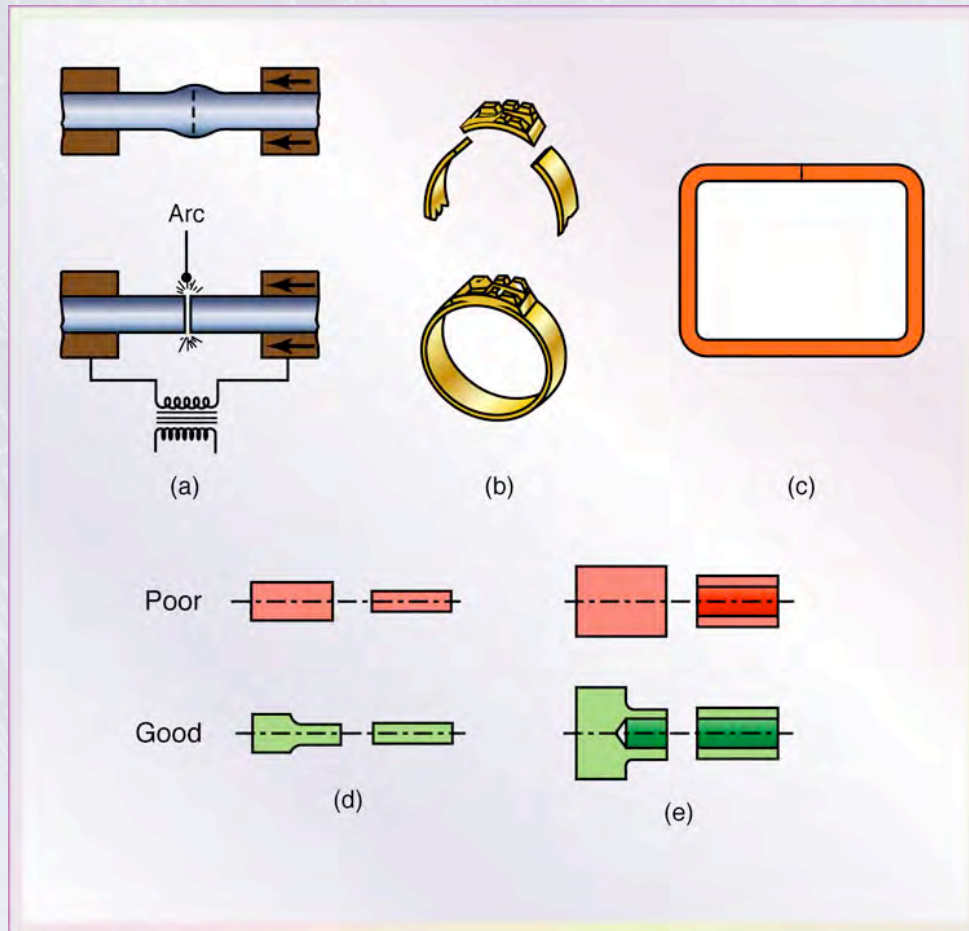


Figure 31.14 (a) Flash-welding process for end-to-end welding of solid rods or tubular parts. (b) and (c) Typical parts made by flash welding. (d) Some design guidelines for flash welding.

# Stud Welding

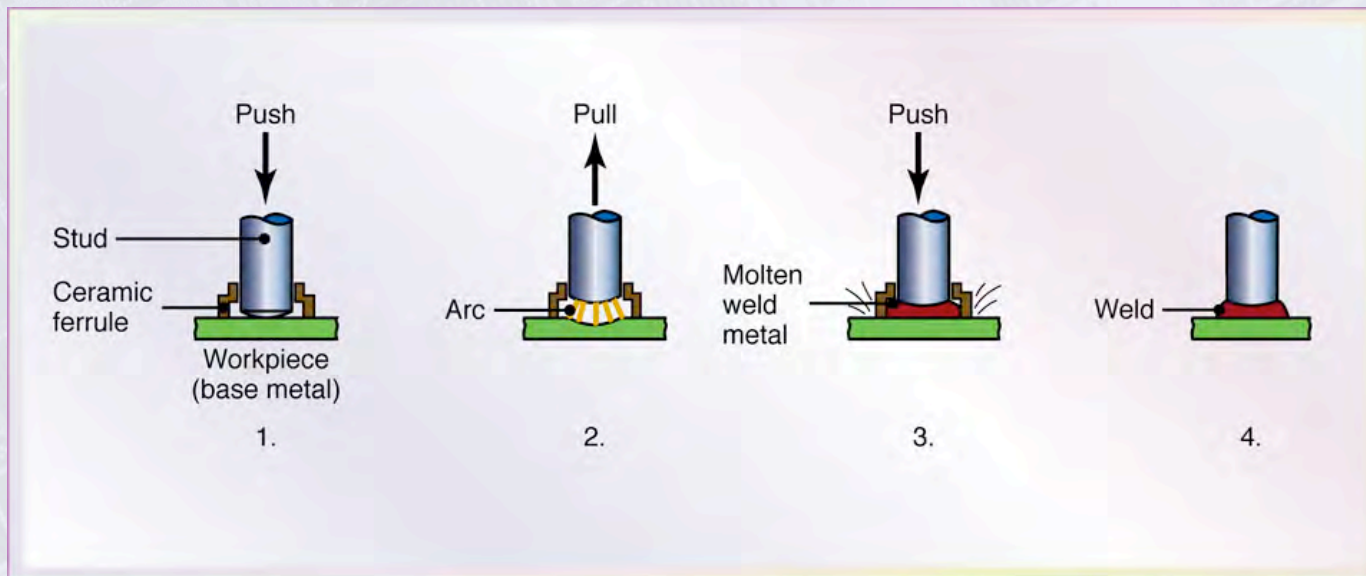


Figure 31.15 The sequence of operations in stud welding, commonly used for welding bars, threaded rods, and various fasteners onto metal plates.



# Weld Sizes

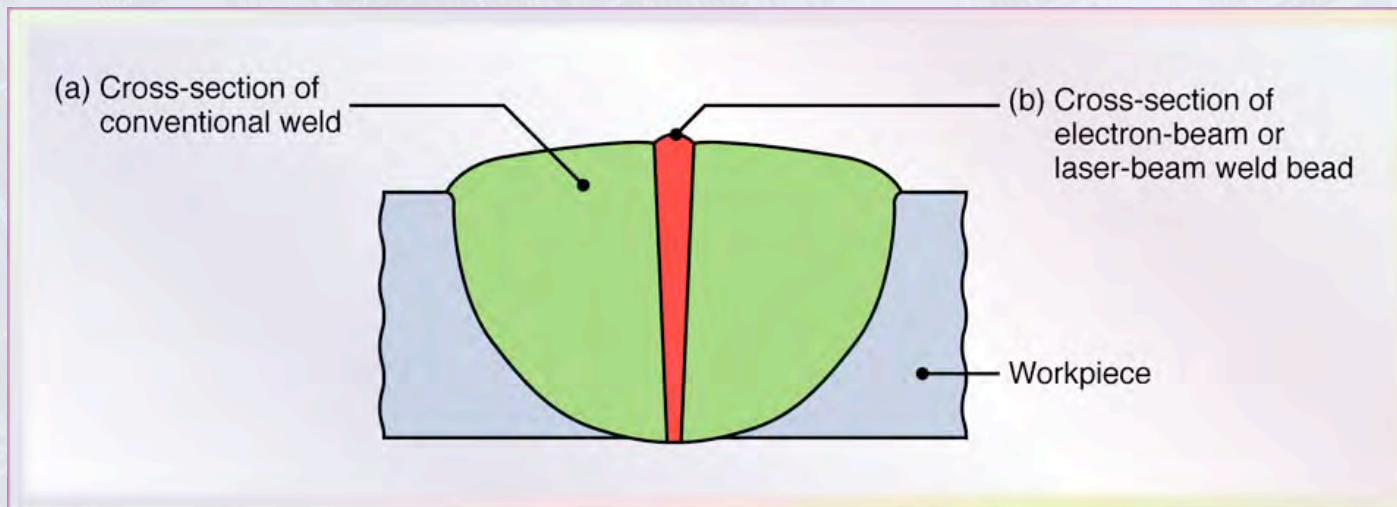


Figure 31.16 The relative sizes of the weld beads obtained by tungsten-arc and by electron-beam or laser-beam welding.

# Explosion Welding

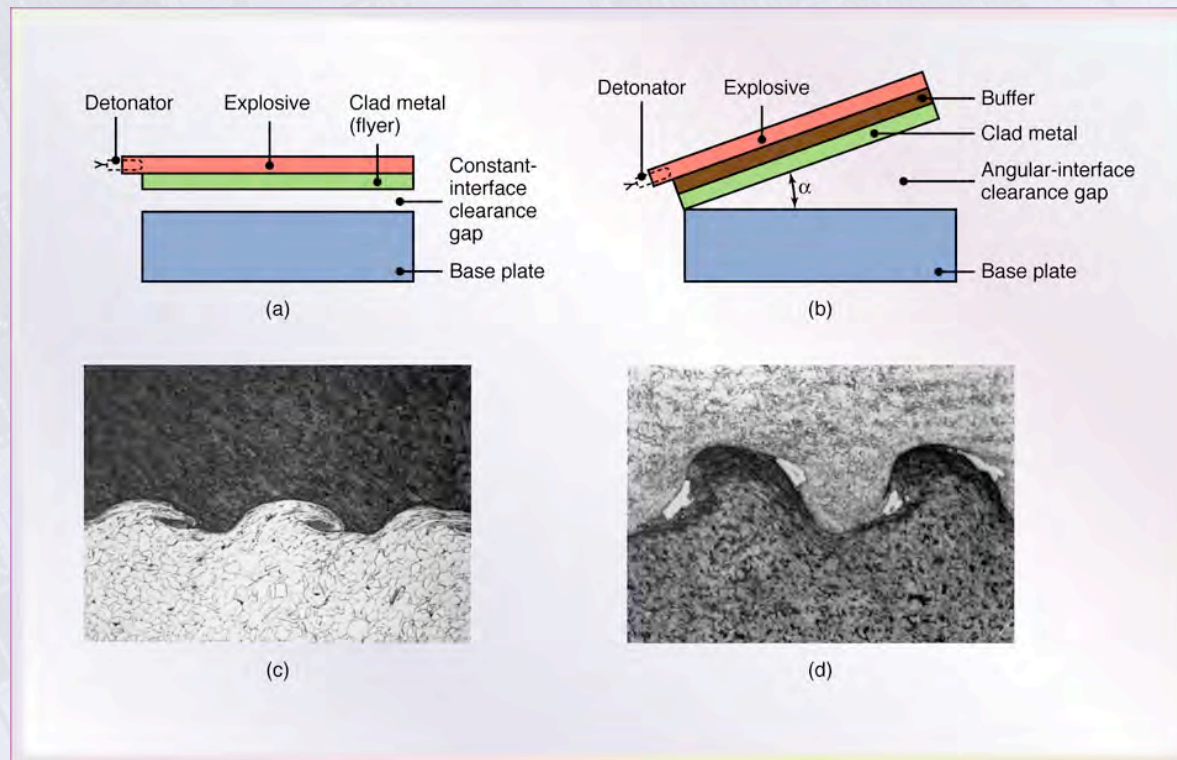


Figure 31.17 Schematic illustration of the explosion welding process: (a) constant interface clearance gap and (b) angular interface clearance gap; (c) cross-section of explosion-welded joint; titanium (top) and low-carbon steel (bottom); (d) iron-nickel alloy (top) and low-carbon steel.



# Aerospace Diffusion Bonding Applications

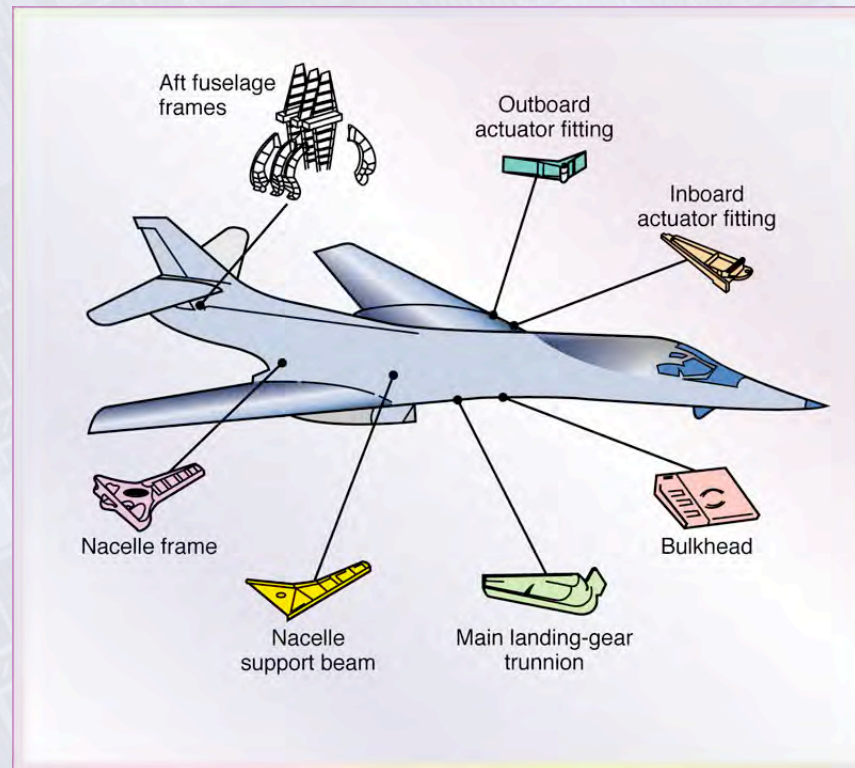


Figure 31.18 Aerospace diffusion bonding applications.

# Diffusion Bonding and Superplastic Forming

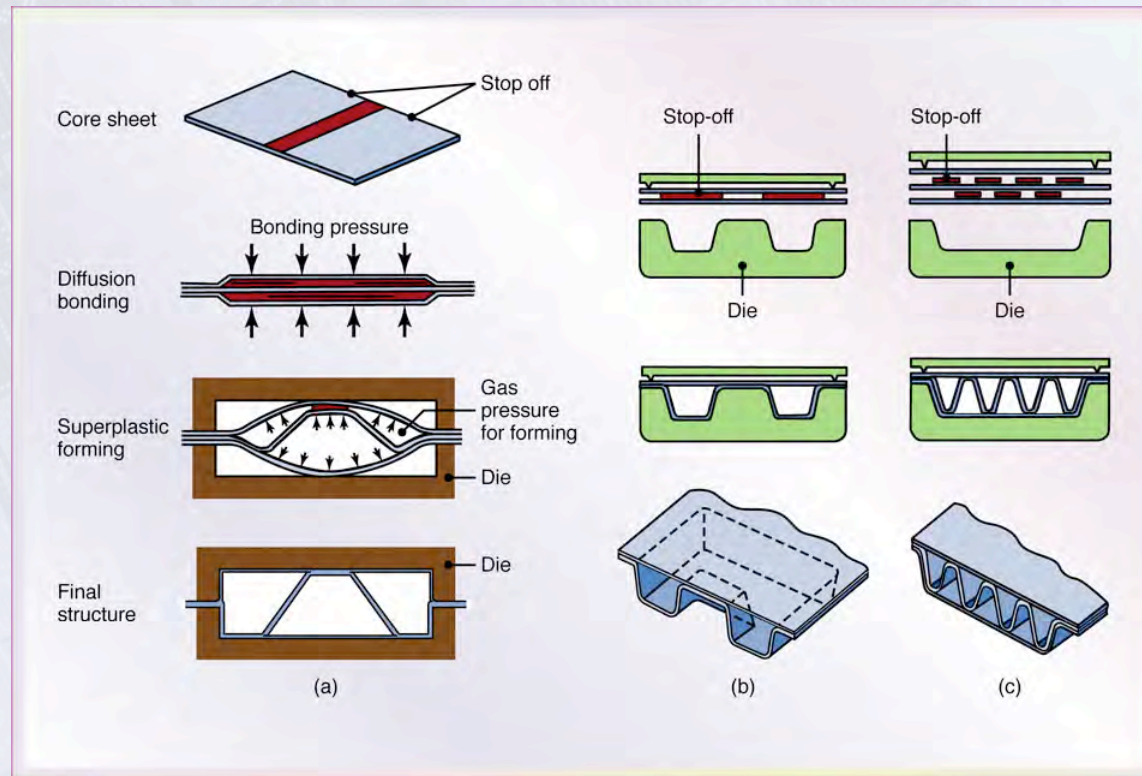


Figure 31.19 The sequence of operations in the fabrication of a structure by diffusion bonding and superplastic forming of three, originally flat sheets. *Sources:* (a) After D. Stephen and S.J. Swadling. (b) and (c) Rockwell International Corp.



# Roll Bonding

Figure 31.1 Schematic illustration of the roll bonding or cladding process.