

CHAPTER 28

Solid-State Welding Processes

Roll Bonding

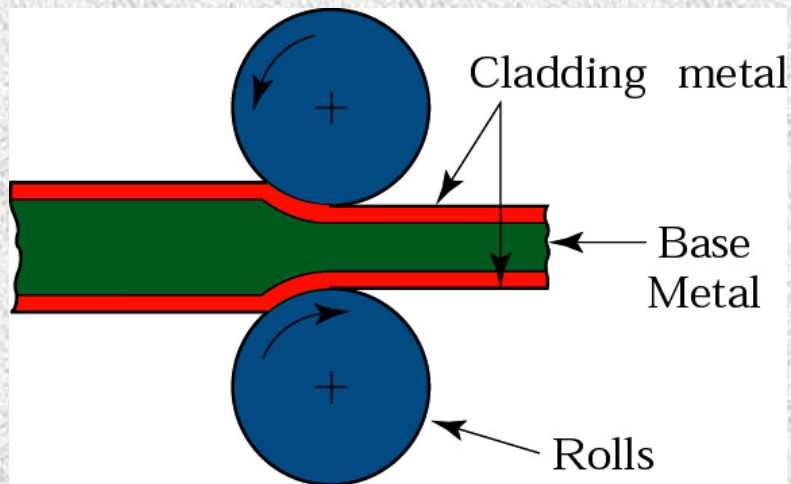


Figure 28.1 Schematic illustration of the roll bonding, or cladding, process

Ultrasonic Welding

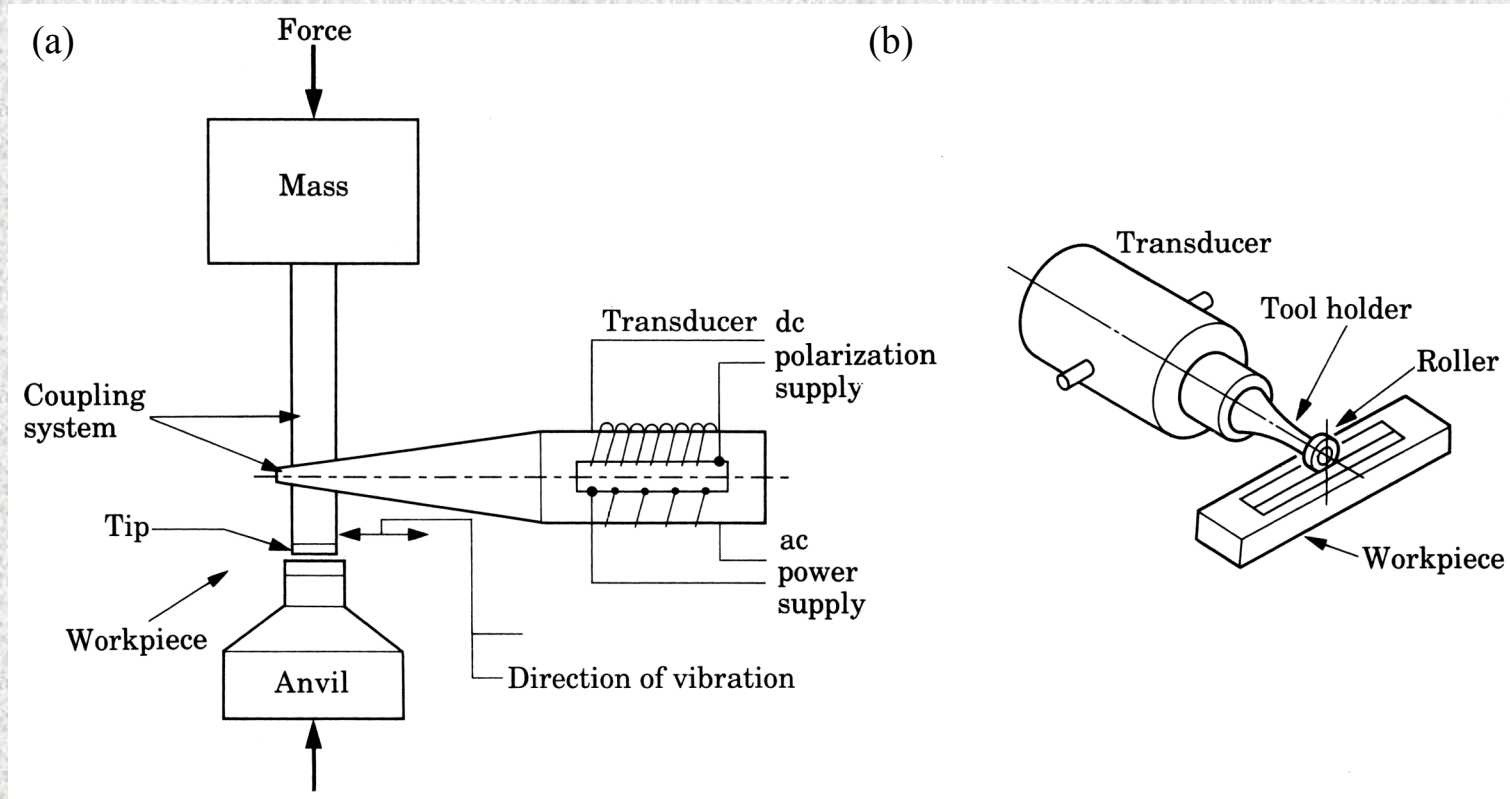


Figure 28.2 (a) Components of an ultrasonic welding machine for lap welds. The lateral vibrations of the tool tip cause plastic deformation and bonding at the interface of the workpieces. (b) Ultrasonic seam welding using a roller. (c) An ultrasonically welded part.

Friction Welding

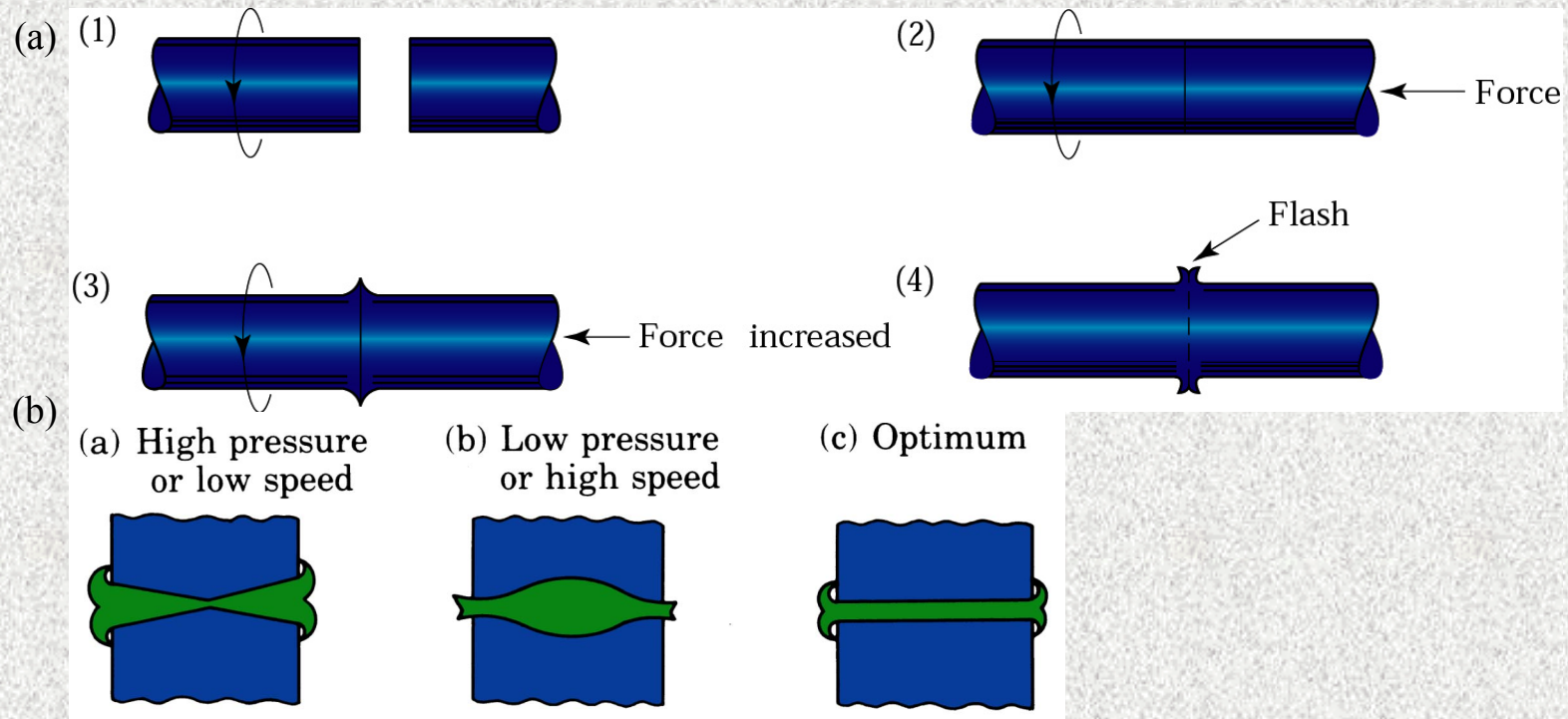


Figure 28.3 (a) Sequence of operations in the friction welding process: (1) Left-hand component is rotated at high speed. (2) Right-hand component is brought into contact under an axial force. (3) Axial force is increased; flash begins to form. (4) Left-hand component stops rotating; weld is completed. The flash can subsequently be removed by machining or grinding. (b) Shape of fusion zone in friction welding, as a function of the force applied and the rotational speed.

Friction Stir Welding

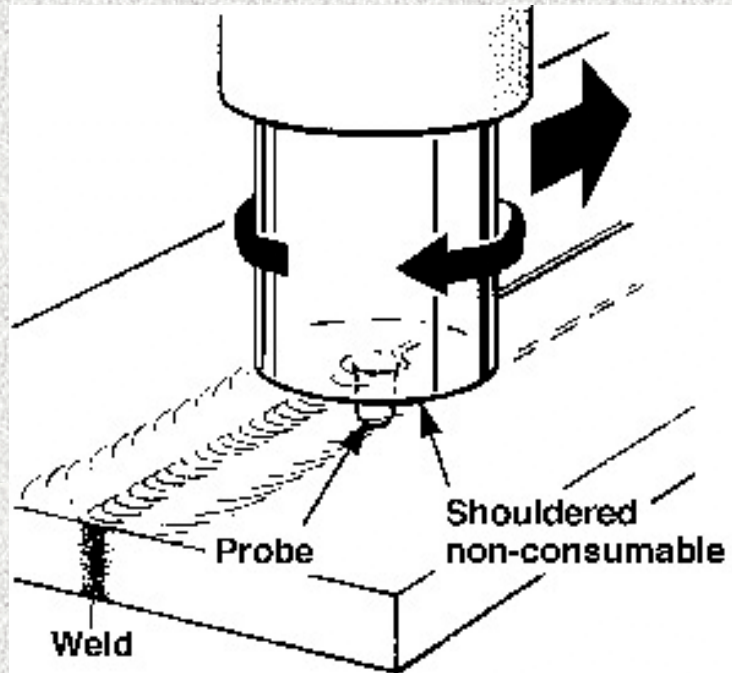
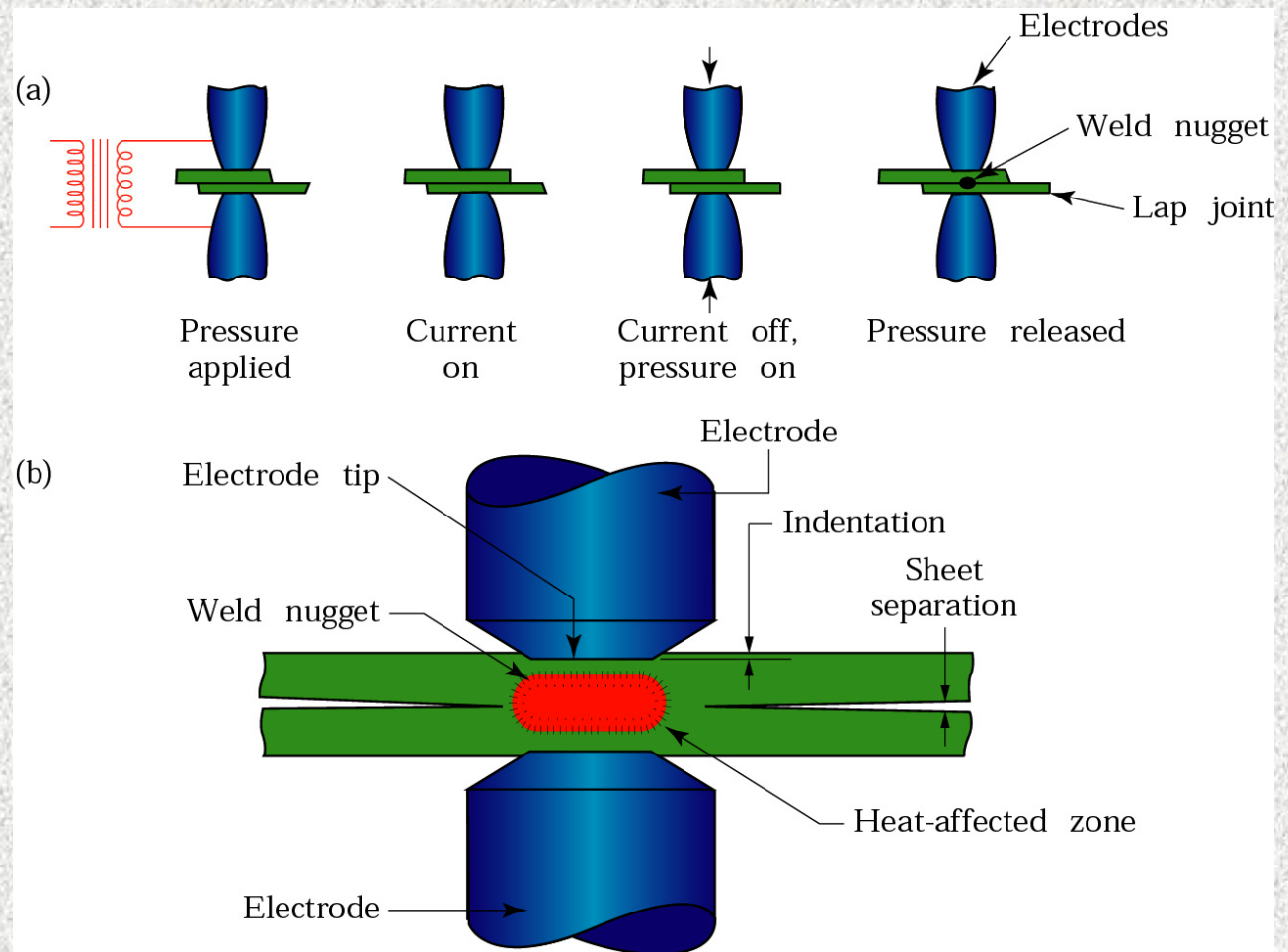


Figure 28.4 The principle of the friction stir welding process. Aluminum-alloy plates up to 75 mm (3 in.) thick have been welded by this process. *Source:* TWI, Cambridge, U.K.

Resistance Spot Welding

Figure 28.5 (a) Sequence 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 process in sheet-metal fabrication and in automotive-body assembly.



Welding Machine Design

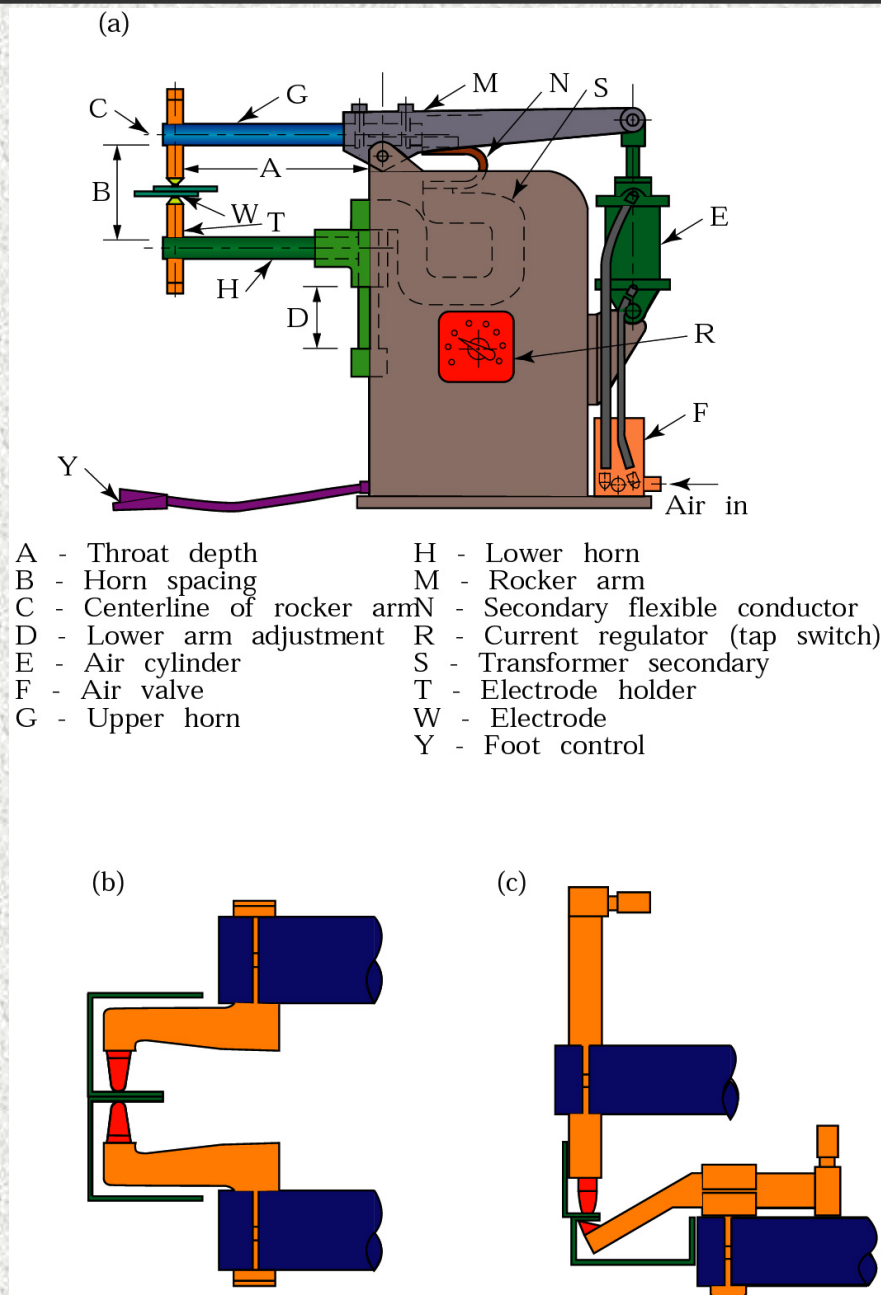


Figure 28.6 (a) Schematic illustration of an air-operated rocker-arm spot-welding machine. *Source:* American Welding Society. (b) and (c) Electrode designs for easy access into components to be welded.

Examples of Spot Welding

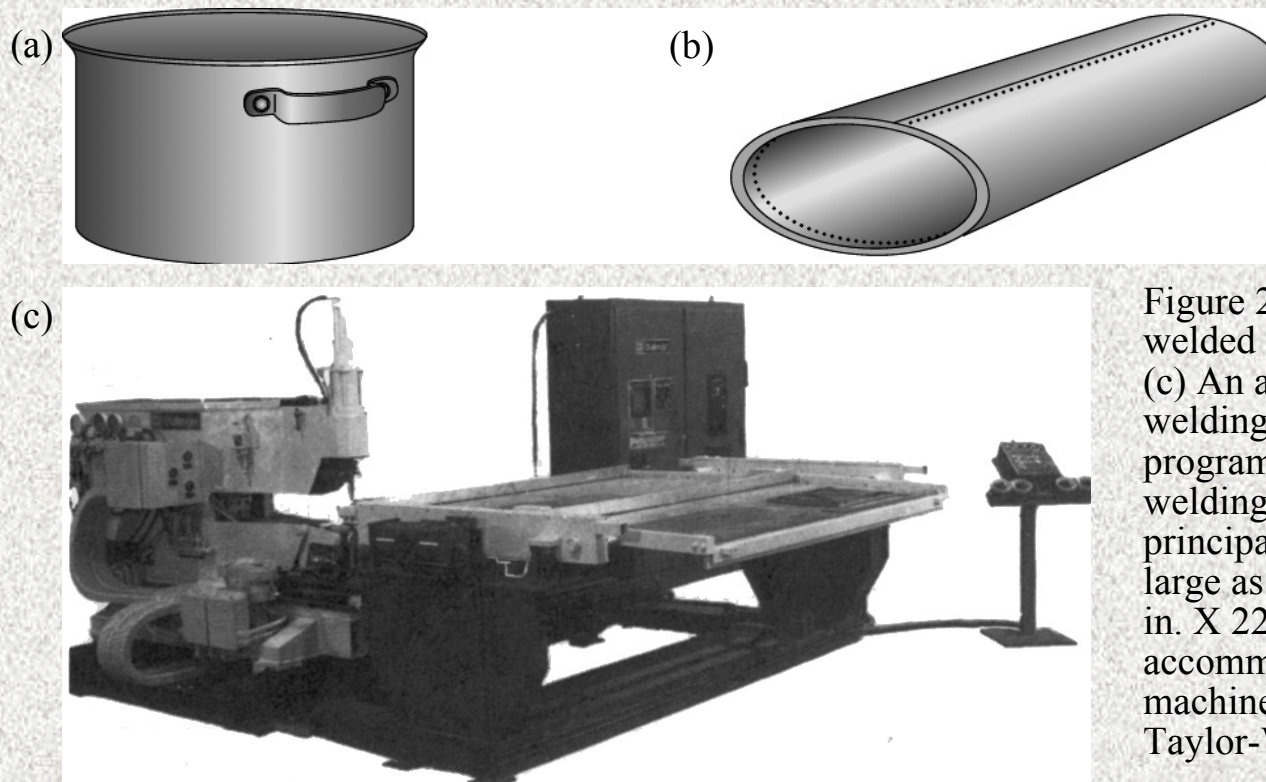


Figure 28.7 (a) and (b) Spot-welded cookware and muffler. (c) An automated spot-welding machine with a programmable robot; the welding tip can move in three principal directions. Sheets as large as 2.2 m X 0.55 m (88 in. X 22 in.) can be accommodated in this machine. *Source:* Courtesy of Taylor-Winfield Corporation.

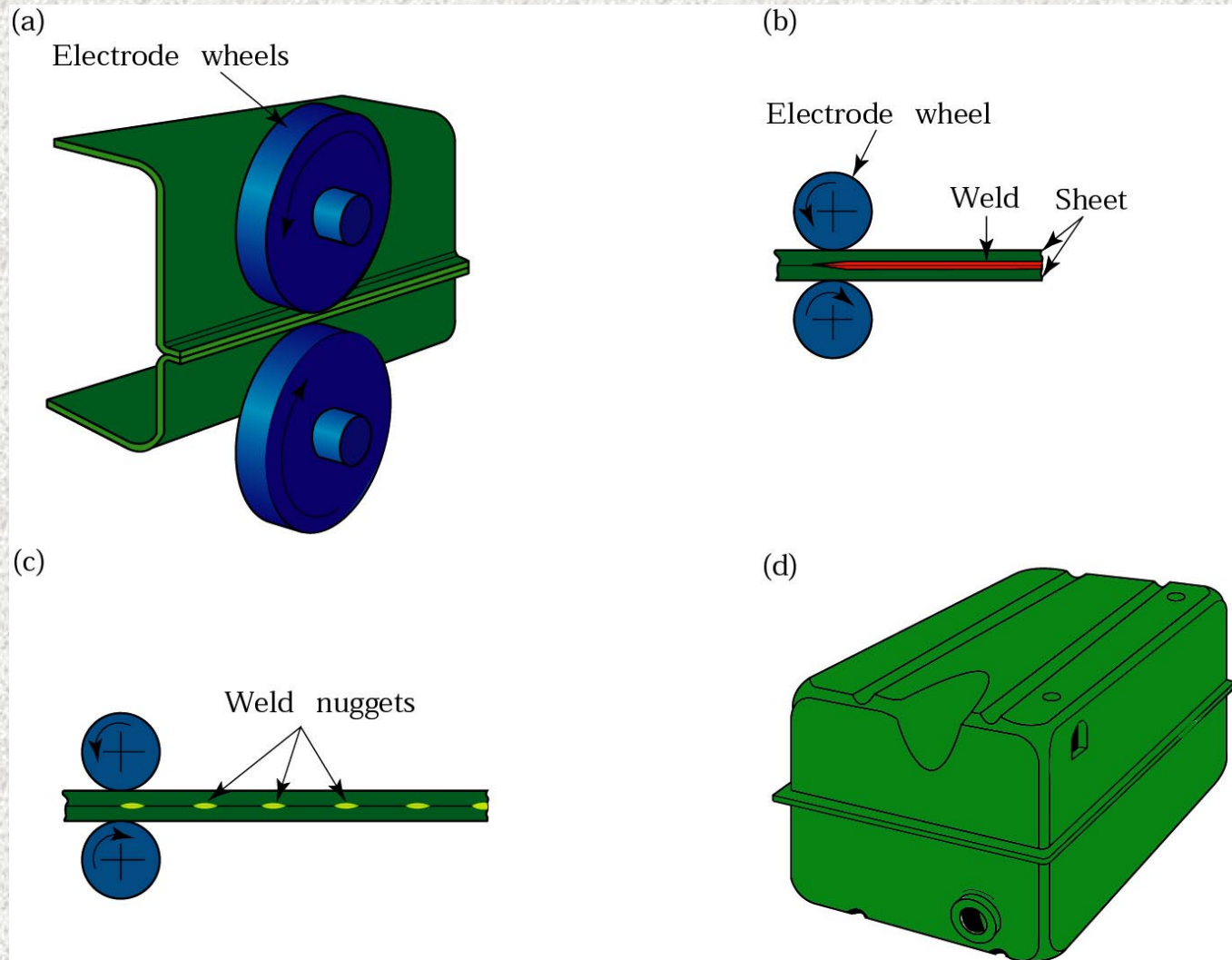
Spot Welding Example

Figure 28.8 Robots equipped with spot-welding guns and operated by computer controls, in a mass-production line for automotive bodies. *Source:* Courtesy of Cincinnati Milacron, Inc.



Resistance Seam Welding

Figure 28.9 (a) Seam-welding process in which rotating rolls act as electrodes. (b) Overlapping spots in a seam weld. (c) Roll spot welds. (d) Resistance-welded gasoline tank.



High-Frequency Butt Welding

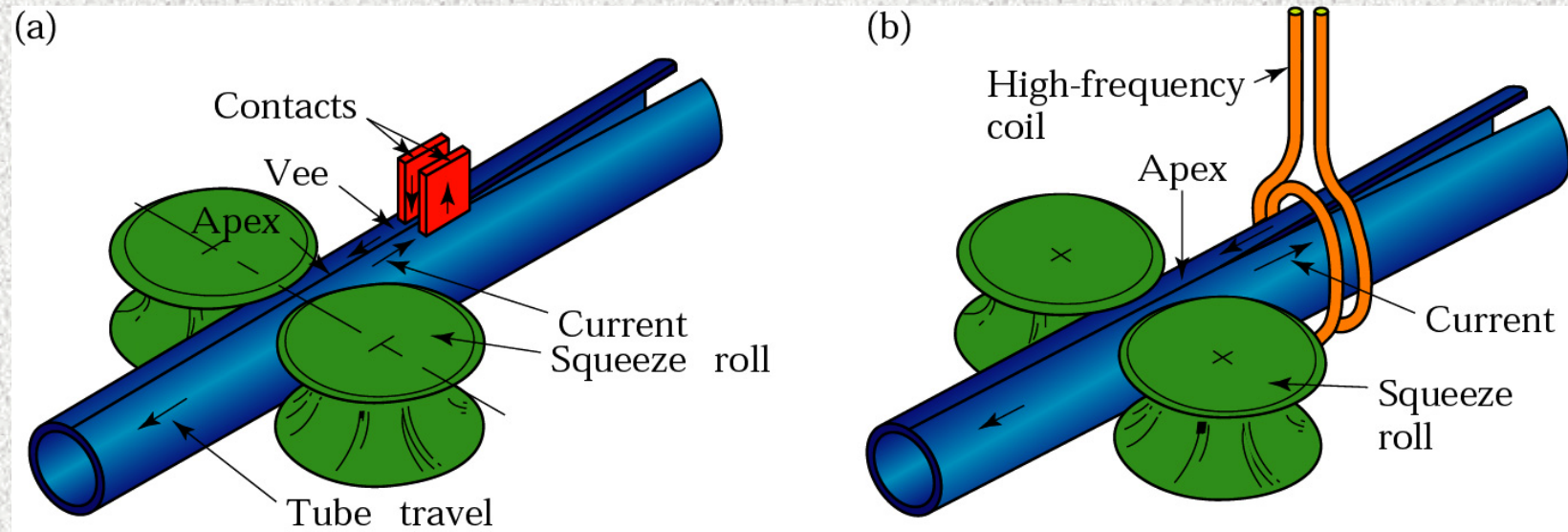


Figure 28.10 Two methods of high-frequency butt welding of tubes.

Resistance Projection Welding

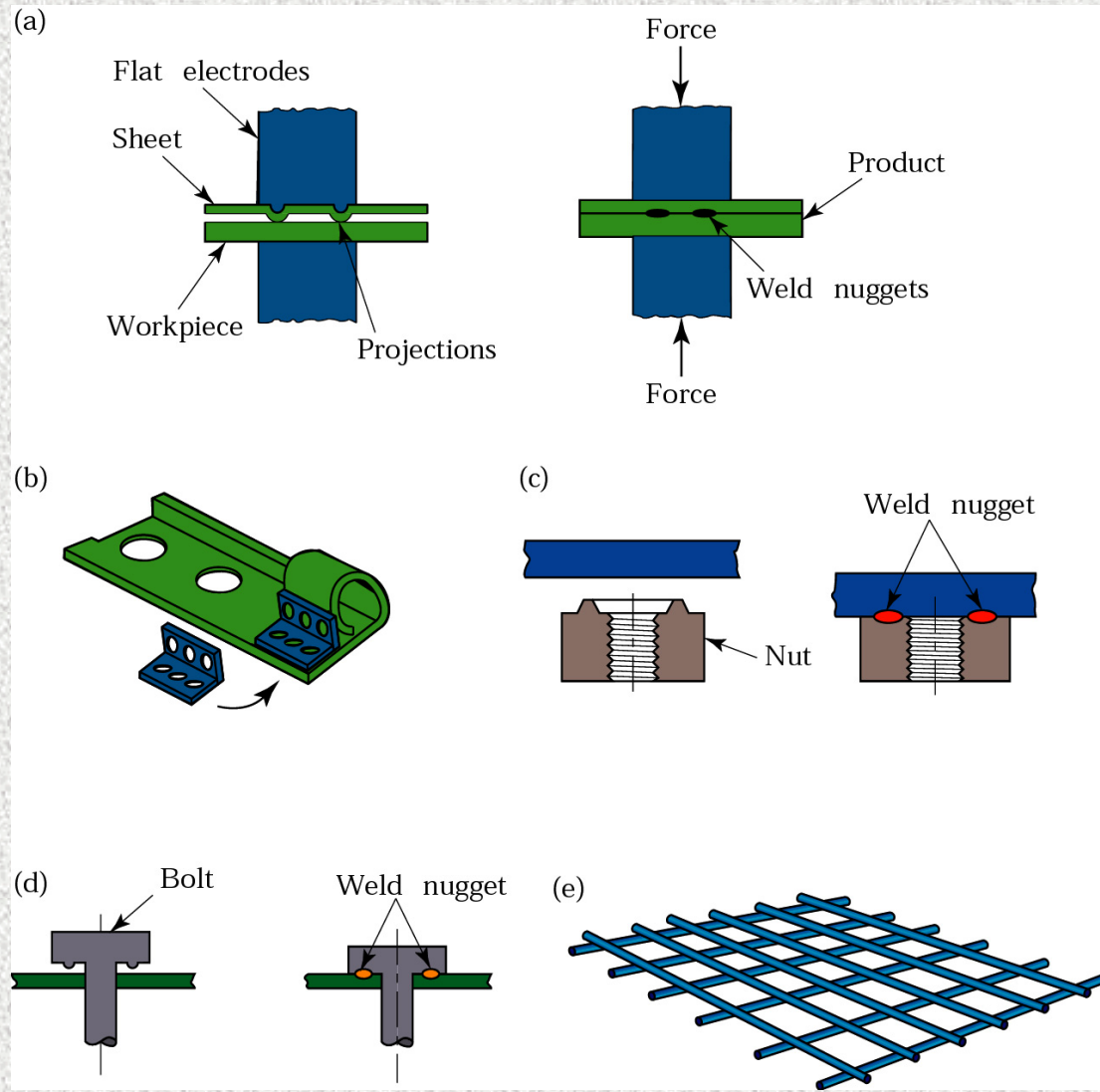
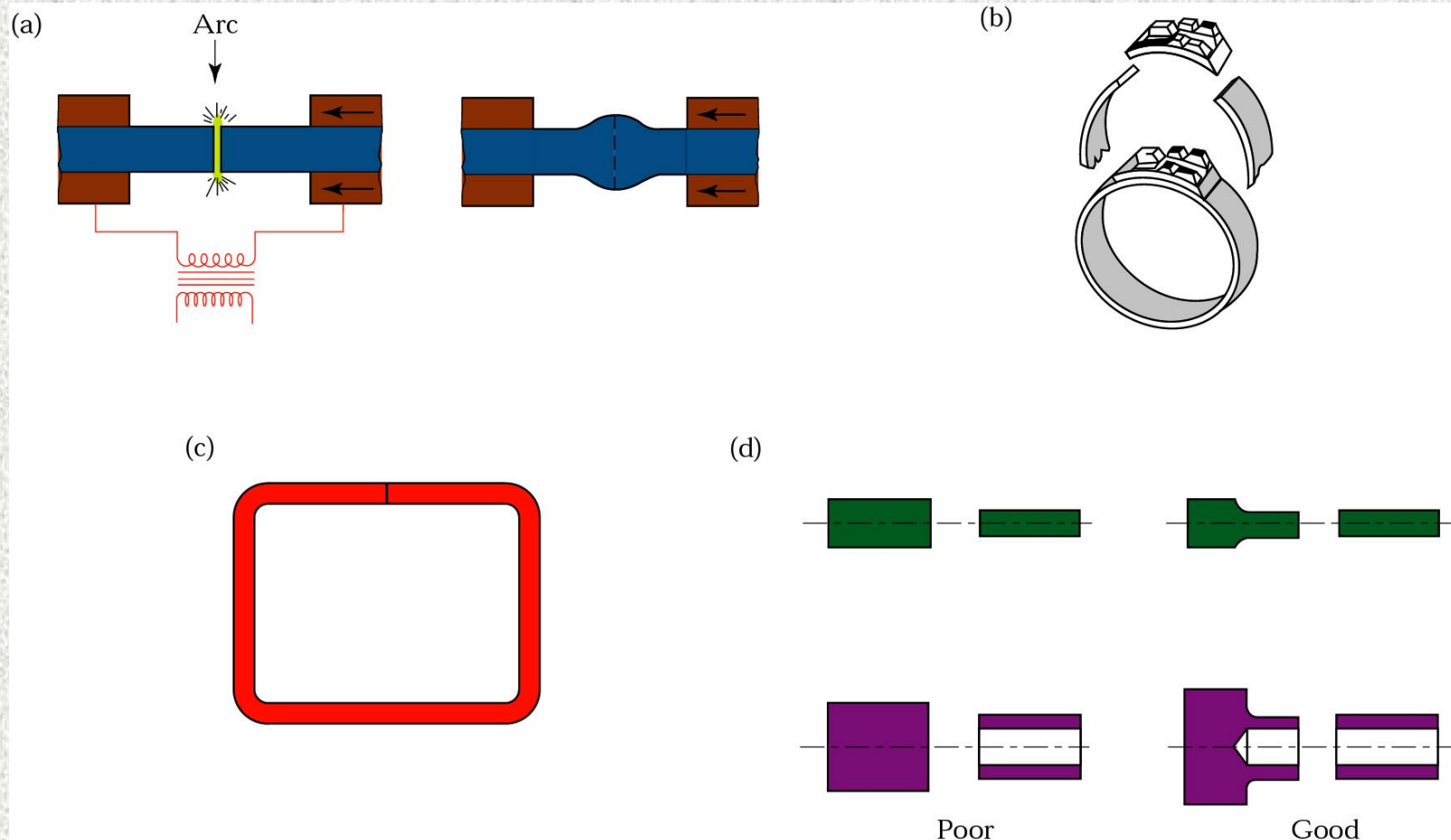


Figure 28.11 (a) Schematic illustration of resistance projection welding. (b) A welded bracket. (c) and (d) Projection welding of nuts or threaded bosses and studs. *Source:* American Welding Society. (e) Resistance-projection-welded grills.

Flash Welding

Figure 28.12 (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) Design Guidelines for flash welding.



Stud Welding

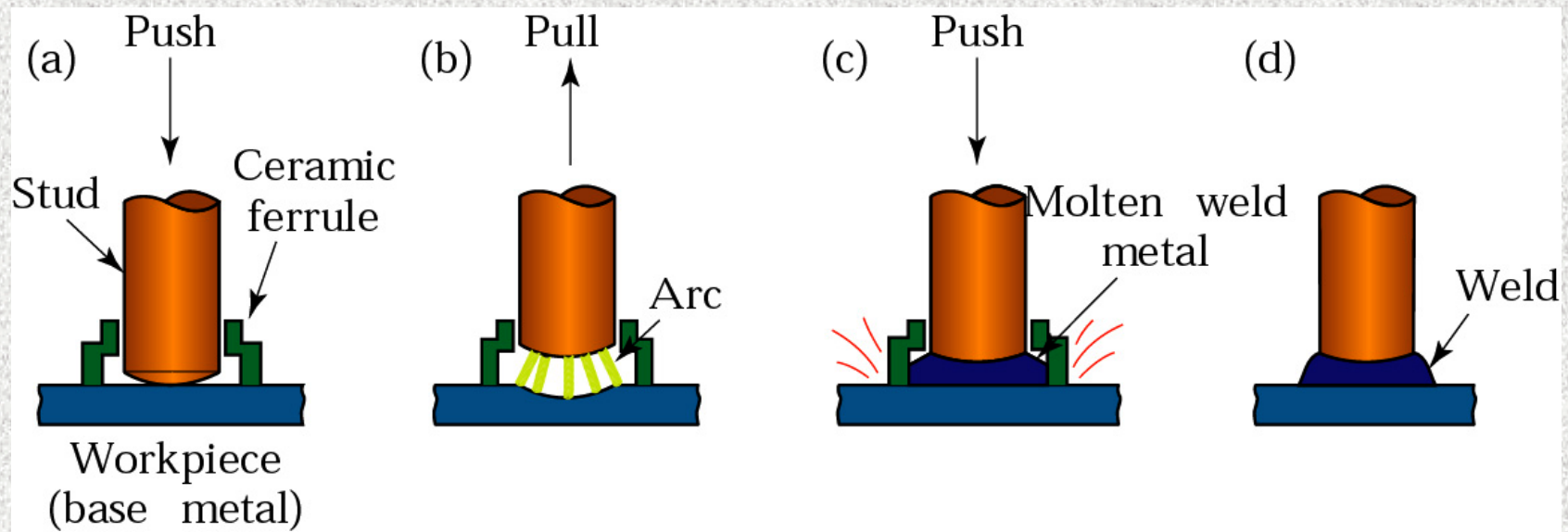


Figure 28.13 The sequence of operations in stud welding, which is used for welding bars, threaded rods, and various fasteners onto metal plates.

Comparison of Conventional and Laser-Beam Welding

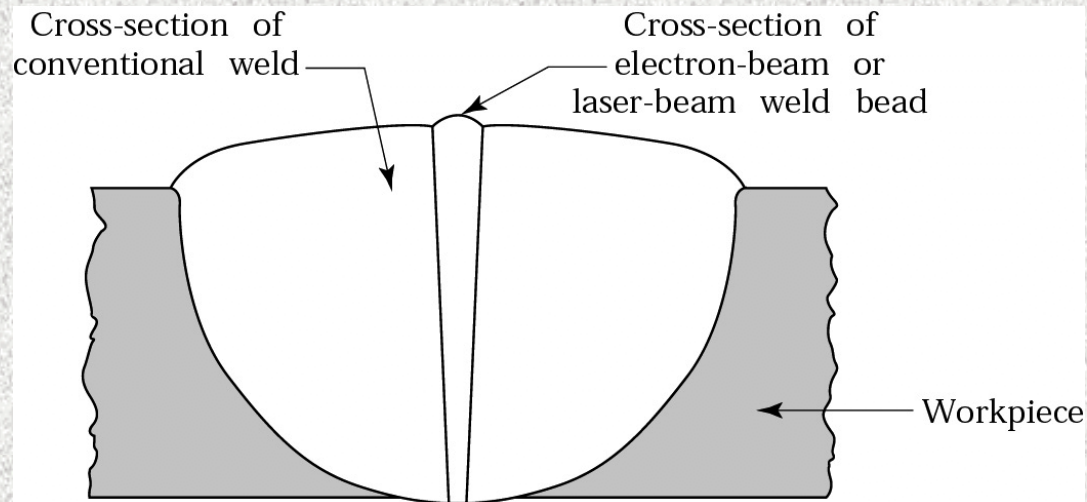


Figure 28.14 The relative sizes of the weld beads obtained by conventional (tungsten arc) and by electron-beam or laser-beam welding.

Explosion Welding

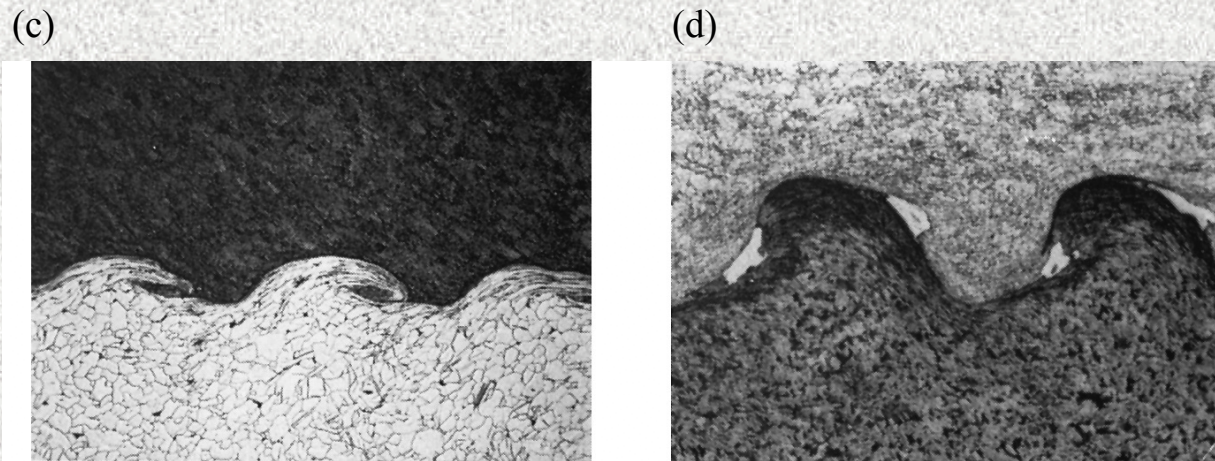
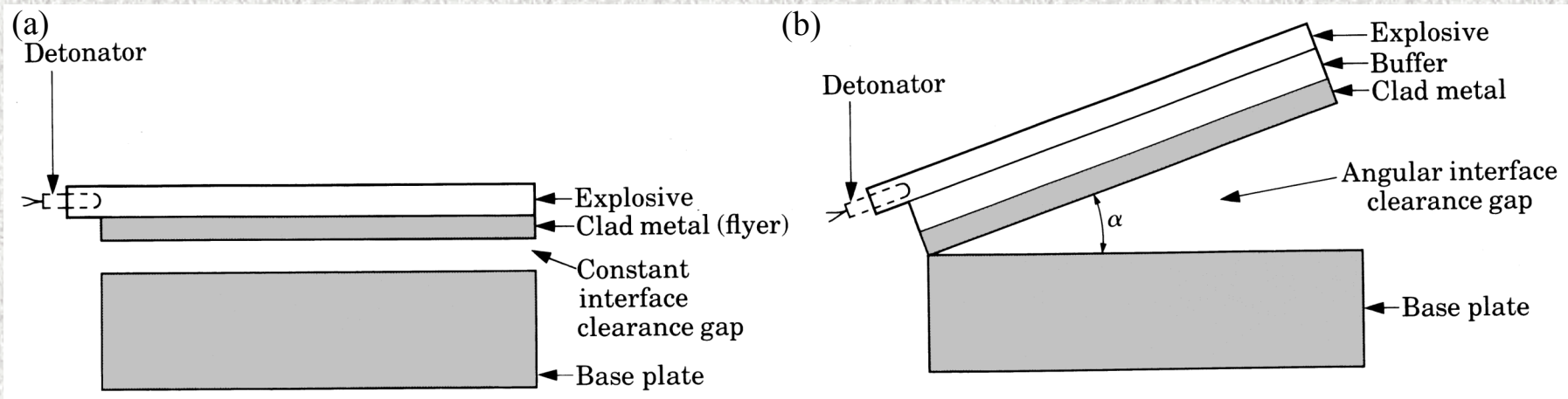


Figure 28.15 Schematic illustration of the explosion welding process: (a) constant interface clearance gap and (b) angular interface clearance gap. (c) and (d) Cross-sections of explosion-welded joints. (c) titanium (top piece) on low-carbon steel (bottom). (d) Incoloy 800 (an iron-nickel-based alloy) on low-carbon steel. *Source:* Courtesy of E. I. Du Pont de Nemours & Co.

Diffusion Bonding Applications

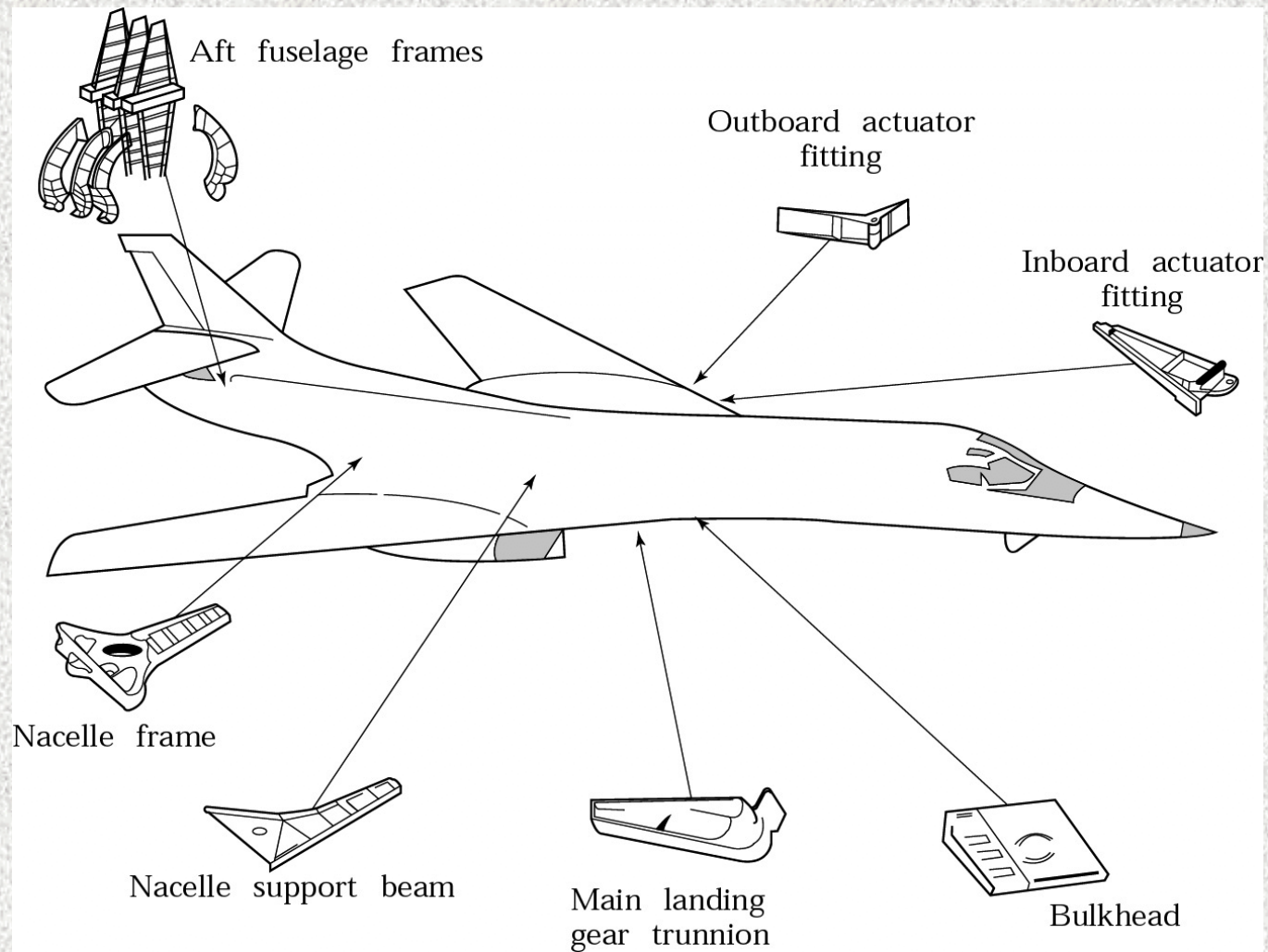


Figure 28.16

Diffusion Bonding/Superplastic Forming

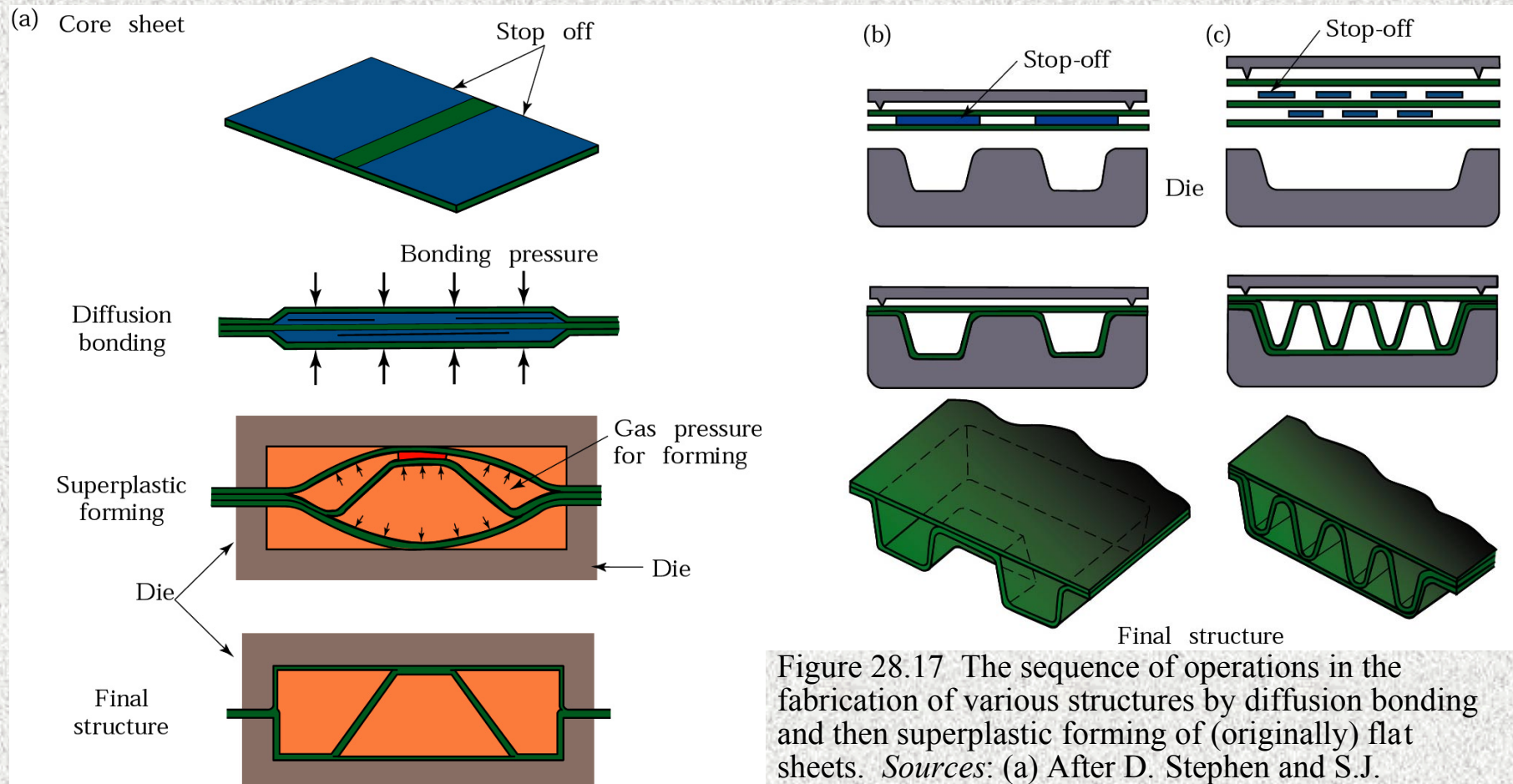


Figure 28.17 The sequence of operations in the fabrication of various structures by diffusion bonding and then superplastic forming of (originally) flat sheets. *Sources:* (a) After D. Stephen and S.J. Swadling. (b) and (c) Rockwell International Corp.