(2) Resistance Welding

- Resistance welding (RW) is a group of fusion-welding processes that uses a combination of heat (it causes melting of the faying surfaces) and pressure to accomplish coalescence.
- The heat is generated by electrical resistance to current flow at the junction to be welded.
- The principal components in RW are shown in Figure (5-18) for a resistance spot-welding operation.

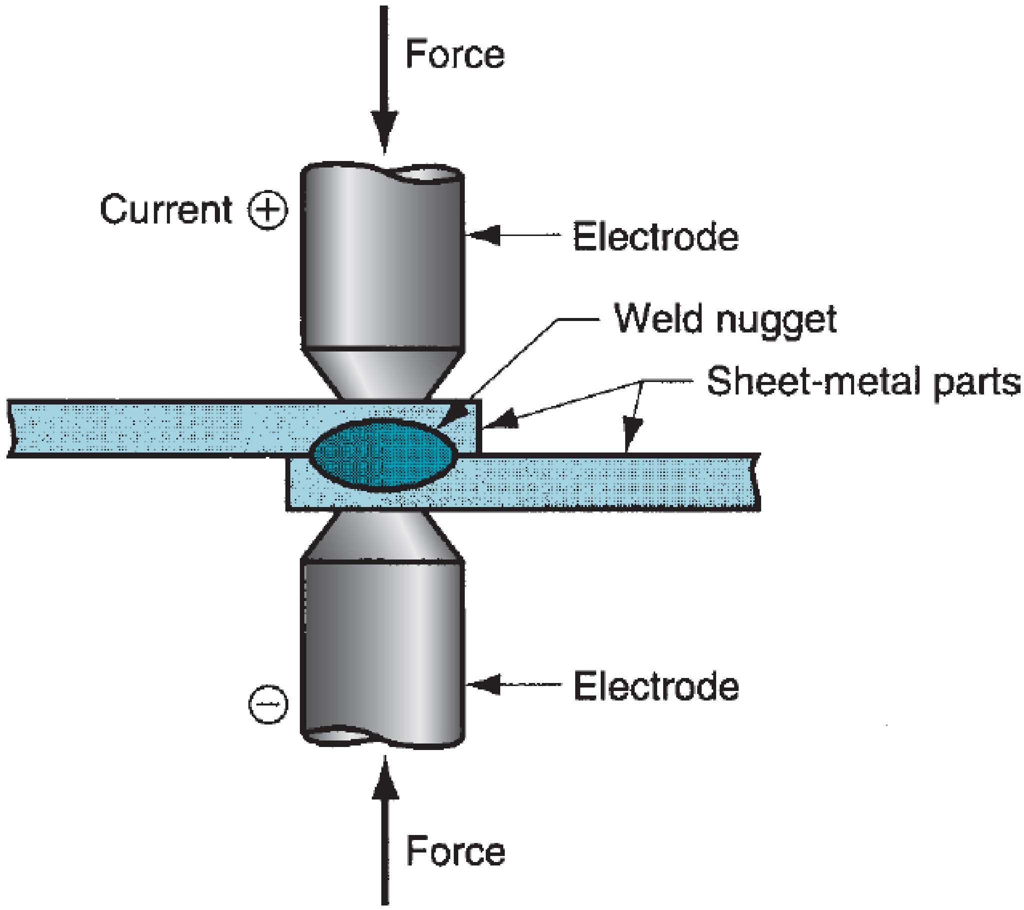


Figure (5-18) Resistance welding (RW), showing the components in spot welding, the predominant process in the RW group.

- The components include:
1. Workpieces to be welded (usually sheet metal parts).
2. Two opposing electrodes.
3. A means of applying pressure to squeeze the parts between the electrodes.
4. AC power supply from which a controlled current can be applied.

- The operation results in a fused zone between the two parts, called a weld nugget in spot welding.
- By comparison to arc welding, resistance welding uses no shielding gases, flux, or filler metal; and the electrodes that conduct electrical power to the process are non-consumable.
- Some welding operations based on resistance heating use temperatures below the melting points of the base metals, so fusion does not occur.

<u>Power Source In Resistance Welding:</u>

- The heat energy supplied to the welding operation depends on current flow, resistance of the circuit, and length of time the current is applied.
- This can be expressed by the equation:

$$\boldsymbol{H = I^2 R t}$$

H: heat generated, J (to convert to Btu divide by 1055).
I: current, A.
R: electrical resistance, Ω.
t: time, s.

- The current used in RW is very high (5000 to 20,000 A, typically), although voltage is relatively low (usually below 10V).
- The duration t of the current is short (0.1 to 0.4 s).
- The reason why such a high current is used in RW is because:
  (1) the squared term in above Eq. amplifies the effect of current.
  (2) the resistance is very low (around 0.0001 Ω).
- Resistance in the welding circuit is the sum of:
  (1) resistance of the electrodes, (2) resistances of the workpieces, (3) contact resistances between electrodes and workpieces, and (4) contact resistance of the faying surfaces.

- The ideal situation is for the faying surfaces to be the largest resistance in the sum, since this is the desired location of the weld.
- The resistance of the electrodes (often water cooled to dissipate the heat) is minimized by using metals with very low resistivities, such as copper.
- The workpiece resistances are a function of the resistivities of the base metals and the part thicknesses.
- The contact resistances between the electrodes and the parts are determined by: (1) the contact areas (i.e., size and shape of the electrode).

(2) the condition of the surfaces (e.g., cleanliness of the work surfaces and scale on the electrode).

- The resistance at the faying surfaces depends on:
  (1) surface finish, (2) cleanliness, (3) contact area, and (4) pressure.
- No paint, oil, dirt, or other contaminants should be present to separate the contacting surfaces.

Example (8):

A resistance spot-welding operation is performed on two pieces of 1.5-mm-thick sheet steel using 12,000 A for a 0.2 s duration. The electrodes are 6 mm in diameter at the contacting surfaces. Resistance is assumed to be 0.0001 **Ω**, and the resulting weld nugget is 6 mm in diameter and 2.5 mm thick. The unit melting energy for the metal U_m=12 J/ mm^3. What portion of the heat generated was used to form the weld nugget, and what portion was dissipated into the work metal, electrodes, and surrounding air?

Solution:

The heat generated in the operation is given by Eq.:

$$H = I^2Rt = 12000^2(0.0001)(0.2) = 2880\,J$$

The volume of the weld nugget (assumed disc-shaped) is

$$V = \frac{\pi 6^2}{4}(2.5) = 70.7\,mm^3$$

The heat required to melt this volume of metal is:

$$H_m = VU_m = 70.7(12) = 848.4\,J$$ **Answer**

The remaining heat = **2880 – 848.4 = 2032 J** (70.6% of the total), is lost into the work metal, electrodes, and surrounding air. **Answer**

- Success in resistance welding depends on pressure and heat.
- **The principal functions of pressure in RW are to:**
  (1) force contact between the electrodes and the workpieces and between the two work surfaces prior to applying current,
  (2) press the faying surfaces together to accomplish coalescence when the proper welding temperature has been reached.

- **Advantages of Resistance Welding:**

(1) no filler metal is required,
(2) high production rates are possible,
(3) lends itself to mechanization and automation,
(4) operator skill level is lower than that required for arc welding,

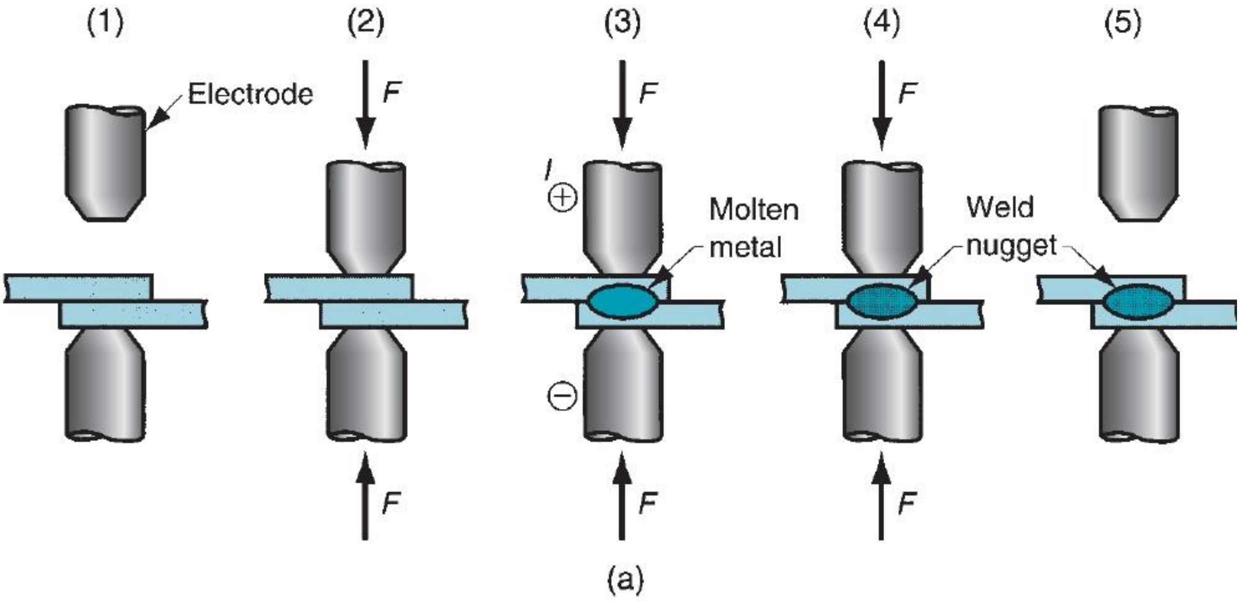
(5) good repeatability and reliability.

- **Drawbacks of Resistance Welding:**
  (1) equipment cost is high—usually much higher than most arc-welding,
  (2) types of joints that can be welded are limited to lap joints for most RW.

Resistance-Welding Processes

(a) Resistance Spot Welding:

- It is widely used in mass production of automobiles, appliances, metal furniture, and other products made of sheet metal.
- Resistance spot welding (RSW) in which fusion of the faying surfaces of a lap joint is achieved at one location by opposing electrodes.
- The process is used to join sheet-metal parts of thickness 3 mm or less, using a series of spot welds, in situations where an airtight assembly is not required.
- The size and shape of the weld spot is determined by the electrode tip, the most common electrode shape being round, but hexagonal, square, and other shapes are also used.
- The resulting weld nugget is typically 5 to 10 mm in diameter, with a heat-affected zone extending slightly beyond the nugget into the base metals.
- The steps in a spot welding cycle are depicted in Figure (5-19).



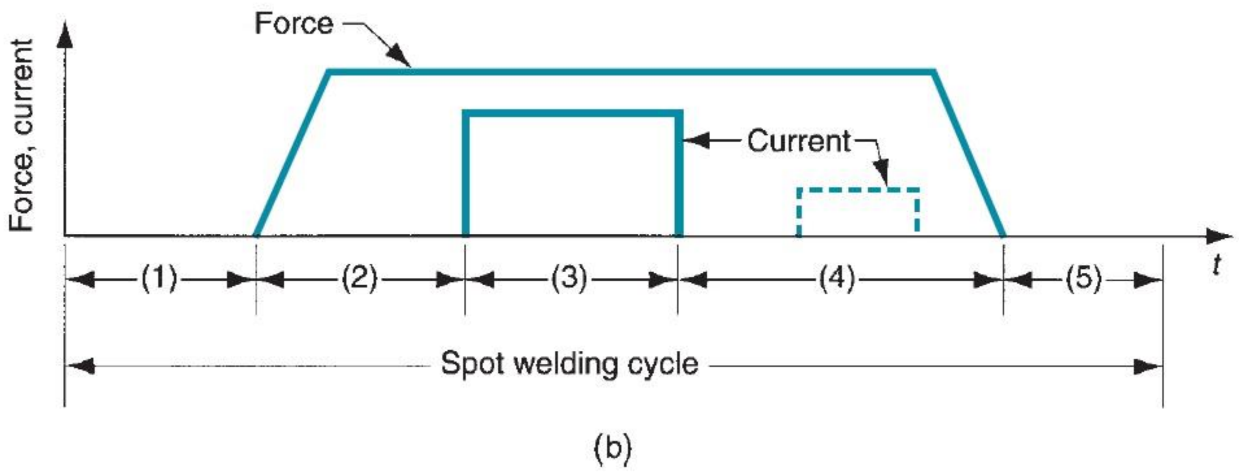


Figure (5-19) (a) Steps in a spot-welding cycle, and (b) plot of squeezing force and current during cycle. The sequence is: (1) parts inserted between open electrodes, (2) electrodes close and force is applied, (3) weld time—current is switched on, (4) current is turned off but force is maintained or increased (a reduced current is sometimes applied near the end of this step for stress relief in the weld region), and (5) electrodes are opened, and the welded assembly is removed.

- Materials used for RSW electrodes consist of two main groups: (1) copper-based alloys and (2) refractory metal compositions such as copper and tungsten combinations.
- The second group is noted for superior wear resistance.
- The tooling in spot welding gradually wears out.
- Whenever practical, the electrodes are designed with internal passageways for water cooling.
- The equipment includes rocker-arm and press-type spot-welding machines, and portable spot-welding guns.
- Rocker-arm spot welders, shown in Figure (5-20), have a stationary lower electrode and a movable upper electrode that can be raised and lowered for loading and unloading w.p.
- The upper electrode is mounted on a rocker arm (hence the name) whose movement is controlled by a foot pedal operated by the worker.
- Modern machines can be programmed to control force and current during the weld cycle.
- Press-type spot welders are intended for larger work. The upper electrode has a straight-line motion provided by a vertical press that is pneumatically or hydraulically powered.

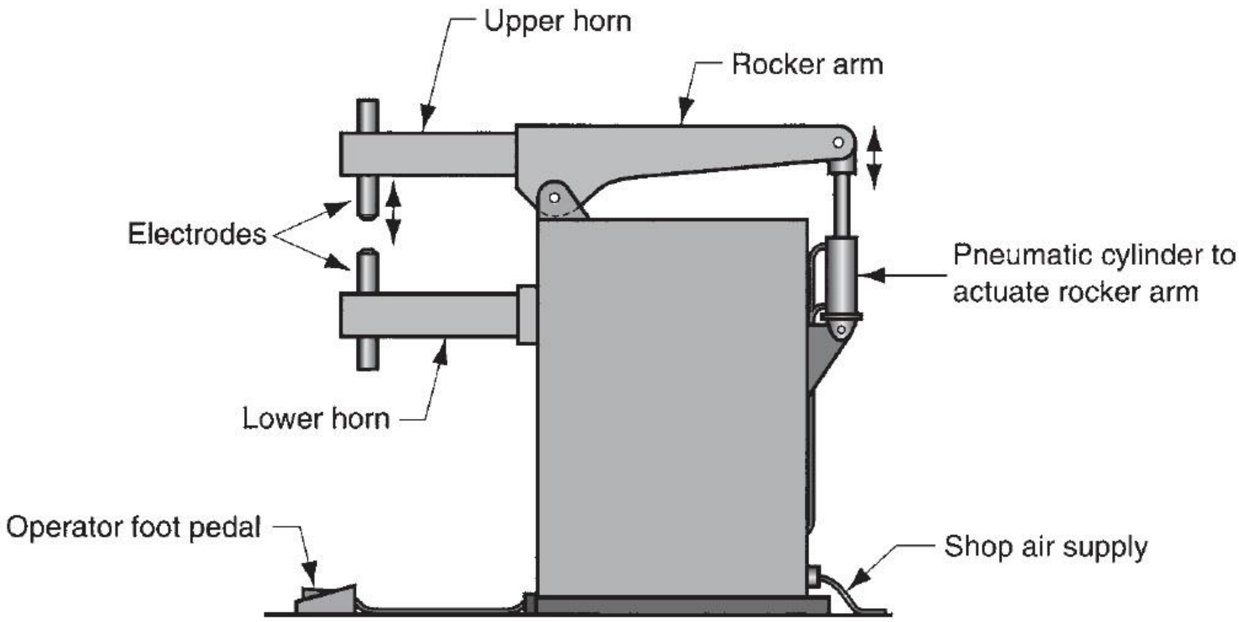


Figure (5-20) Rocker-arm spot-welding machine.

- For large, heavy w.p., a portable spot-welding guns are available in various sizes and configurations.
- These devices consist of two opposing electrodes contained in a pincer mechanism.
- Each unit is lightweight so that it can be held and manipulated by a human worker or an industrial robot.
- The gun is connected to its own power and control source by means of flexible electrical cables and air hoses.
- Water cooling for the electrodes, can also be provided.
- Portable spot-welding guns are widely used in automobile final assembly plants to spot weld car bodies.
- The industrial robots used this type of machine.

(b)<u>Resistance Seam Welding:</u>

- In resistance seam welding (RSEW), the stick-shaped electrodes in spot welding are replaced by rotating wheels, as shown in Figure (5-21), and a series of overlapping spotwelds are made along the lap joint.
- The process is capable of producing air-tight joints, and its industrial applications include the production of gasoline tanks, automobile mufflers, and various other fabricated sheet metal containers.
- Since the operation is usually carried out continuously, rather than discretely, the seams should be along a straight or uniformly curved line.

- **Disadvantages of RSEW:**
  (1) sharp corners and similar discontinuities are difficult to deal with,
  (2) warping of the parts becomes more of a factor in RSEW,
  (3) fixtures are required to hold w.p. in position and minimize distortion.

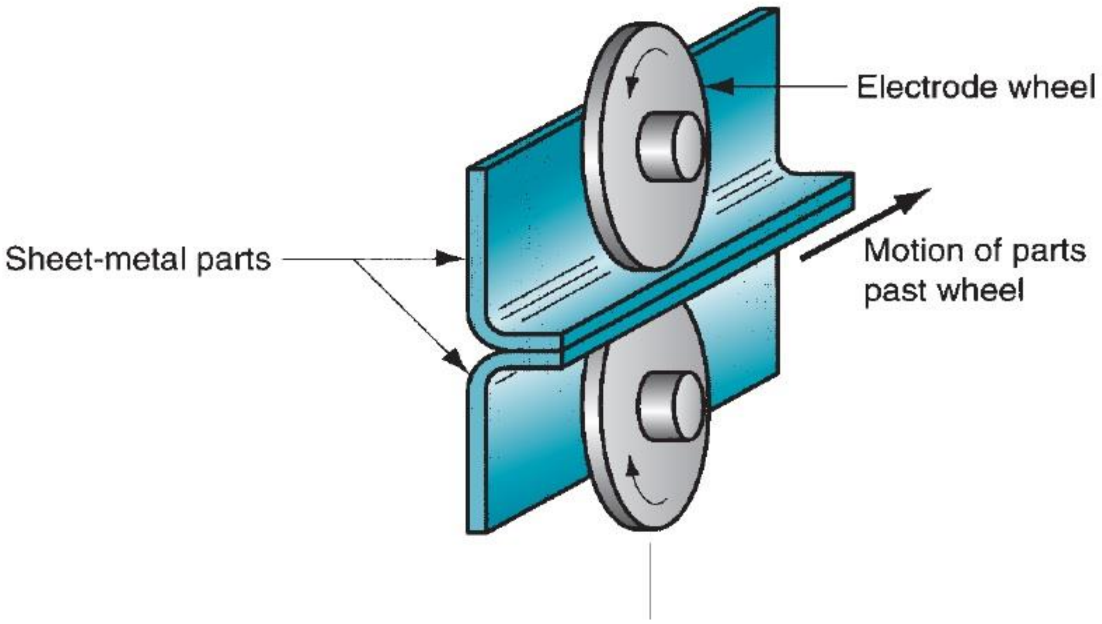


Figure (5-21) Resistance Seam Welding RSEW.

- The spacing between the weld nuggets in RSEW depends on the motion of the electrode wheels relative to the weld current.
- In continuous motion welding, the wheel is rotated continuously at a constant velocity, and current is turned on at timing intervals consistent with the desired spacing between spot welds along the seam.
- Frequency of the current discharges is normally set so that overlapping weld spots are produced, Figure (5-22a).
- If the frequency is reduced sufficiently, then there will be spaces between the weld spots - roll spot welding - Figure (5-22b).
- If the welding current remains on at a constant level (rather than being pulsed) so that a truly continuous welding seam is produced, Figure (5-22c).

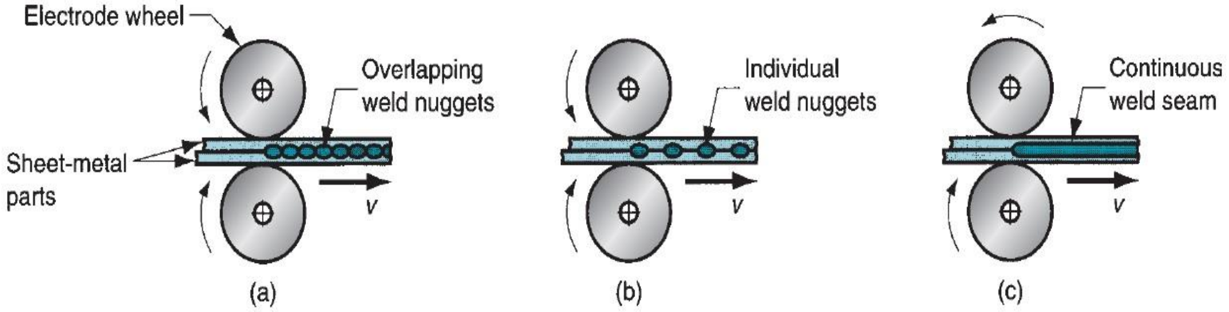


Figure (5-22) (a) conventional RSEW, in which overlapping spots are produced; (b) roll spot welding; and (c) continuous resistance seam.

- Seam-welding machines are similar to press-type spot welders except that electrode wheels are used rather than the usual stick-shaped electrodes.
- Cooling of w.p. and wheels is often necessary in RSEW, and this is accomplished by directing water at the top and underside of w.p. surfaces near the electrode wheels.

(c) Resistance Projection Welding:

- Resistance projection welding (RPW) in which coalescence occurs at one or more relatively small contact points on w.ps.
- These contact points are determined by the design of w.ps. to be joined, and may consist of projections, embossments, or localized intersections of w.ps.
- Figure (5-23) explain this method.
- The w.p. on top has been fabricated with two embossed points to contact the other w.p. at the start of the process.

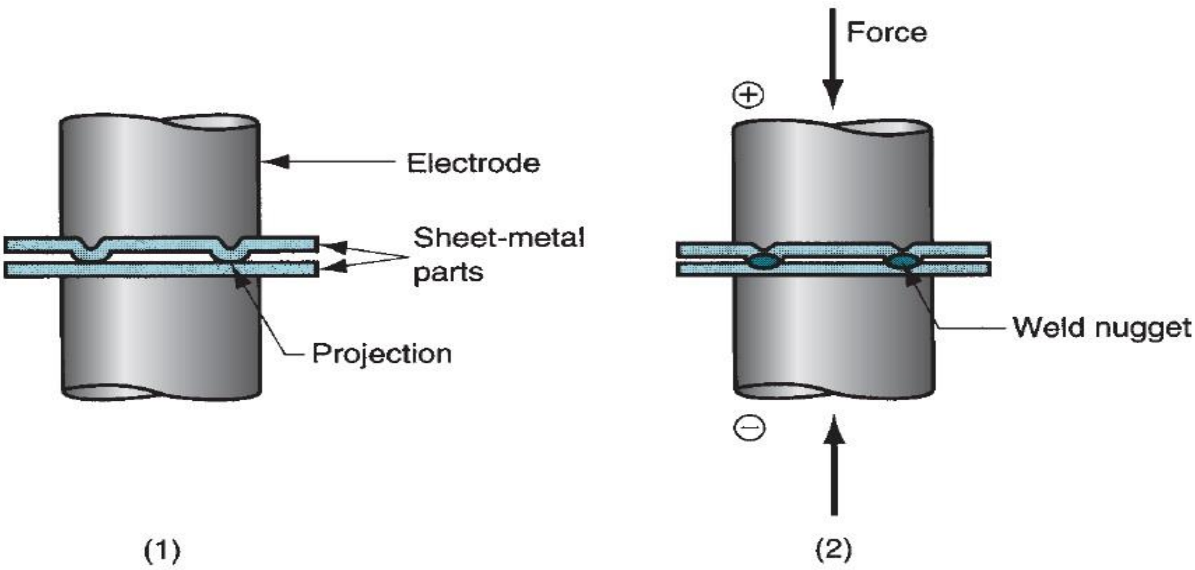


Figure (5-23) Resistance projection welding (RPW): (1) at start of operation, contact between w.ps. is at projections; and (2) when current is applied, weld nuggets similar to those in spot welding are formed at the projections.

- There are variations of resistance projection welding shown in Figure (5-24).
- Figure (5-24a), a fasteners with machined or formed projections can be permanently joined to sheet or plate, facilitating subsequent assembly operations.
- Figure (5-24b), called cross-wire welding, is used to fabricate welded wire products such as wire fence, shopping carts, and stove grills. In this process, the contacting surfaces of the round wires serve as the projections to localize the resistance heat for welding.

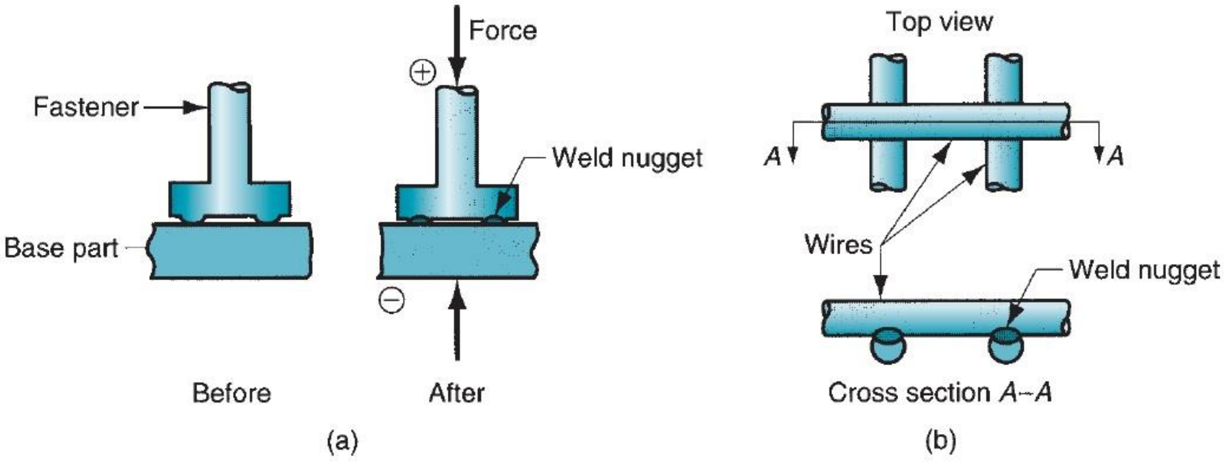


Figure (5-24) Variations of resistance projection welding: (a) welding of a machined or formed fastener onto a sheet-metal part; and (b) cross-wire welding.

Other Resistance-Welding Operations

(a) Flash Welding (FW)

- Normally used for butt joints, the two surfaces to be joined are brought into contact or near contact and electric current is applied to heat the surfaces to the melting point to form the weld.
- The FW process is outlined in Figure (5-25).
- In addition to resistance heating, some arcing occurs (called flashing, hence the name), depending on the extent of contact between the faying surfaces, so flash welding is sometimes classified in the arcwelding group.
- Current is usually stopped during upsetting.
- Some metal, as well as contaminants on the surfaces, is squeezed out of the joint and must be subsequently machined to provide a joint of uniform size.

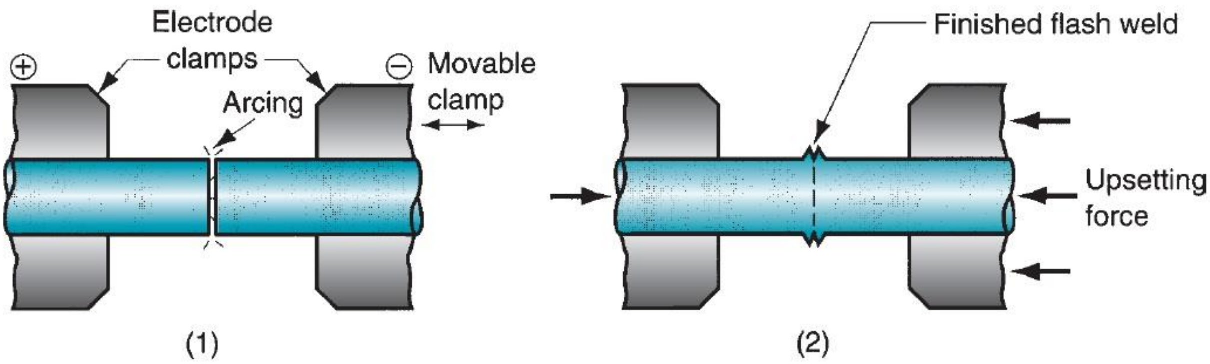


Figure (5-25) Flash welding (FW): (1) heating by electrical resistance; and (2) upsetting—parts are forced together.

- **<u>Applications of FW</u>**:
  (1) butt welding of steel strips in rolling-mill operations,
  (2) joining ends of wire in wire drawing,
  (3) welding of tubular parts.
- The ends to be joined must have the same cross sections.
- For these kinds of high-production applications, flash welding is fast and economical, but the equipment is expensive.

(b) Upset Welding (UW)

- UW is similar to flash welding except that in UW the faying surfaces are pressed together during heating and upsetting.
- In flash welding, the heating and pressing steps are separated during the cycle.
- Heating in UW is accomplished entirely by electrical resistance at the contacting surfaces; no arcing occurs.
- When the faying surfaces have been heated to a suitable temperature below the melting point, the force pressing the parts together is increased to cause upsetting and coalescence in the contact region.
- Thus, **upset welding is not a fusion-welding process** in the same sense as the other welding processes.
- **<u>Applications of UW</u>**:
- Similar to those of flash welding: joining ends of wire, pipes, tubes, and so on.

(c) Percussion Welding (PEW)

- PEW is also similar to flash welding, except that the duration of the weld cycle is extremely short, typically lasting only 1 to 10 ms.
- Fast heating is accomplished by rapid discharge of electrical energy between the two surfaces to be joined, followed immediately by percussion of one part against the other to form the weld.
- The heating is very localized, making this process attractive for electronic applications in which the dimensions are very small and nearby components may be sensitive to heat.

(d)High-Frequency Resistance Welding (HFRW)

- **HFRW** in which a **high-frequency alternating current** is used for heating, followed by the rapid application of an upsetting force to cause coalescence, as in Figure (5-26a).

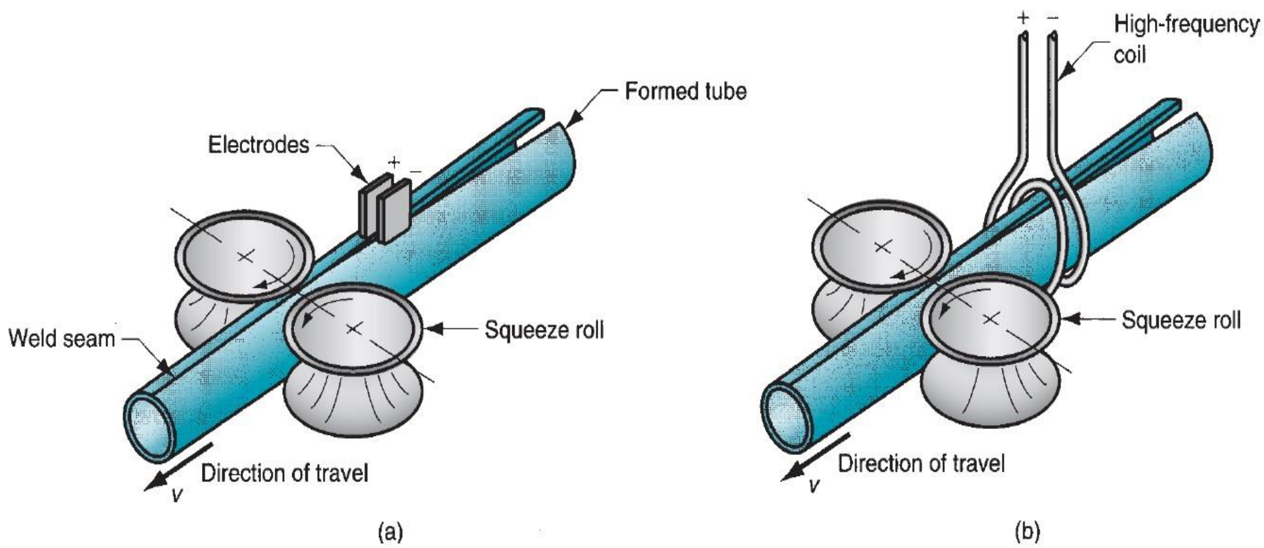


Figure (5-26) Welding of tube seams by: (a) high-frequency resistance welding, and (b) high-frequency induction welding.

- The frequencies are 10 to 500 kHz, and the electrodes make contact with the w.p. in the immediate vicinity of the weld joint.
- In a variation of the process, called **high-frequency induction welding (HFIW)**, the heating current is induced in the w.p. by a high frequency induction coil, as in Figure (5-26b).
- The coil does not make physical contact with the work.
- **<u>Applications of HFRW and HFIW:</u>**
- In continuous butt welding of the longitudinal seams of metal pipes and tubes.