Sub: NCM, 6th sem
CH-03: Unconventional welding process
(part-1: Solid state welding, forge & Friction welding)

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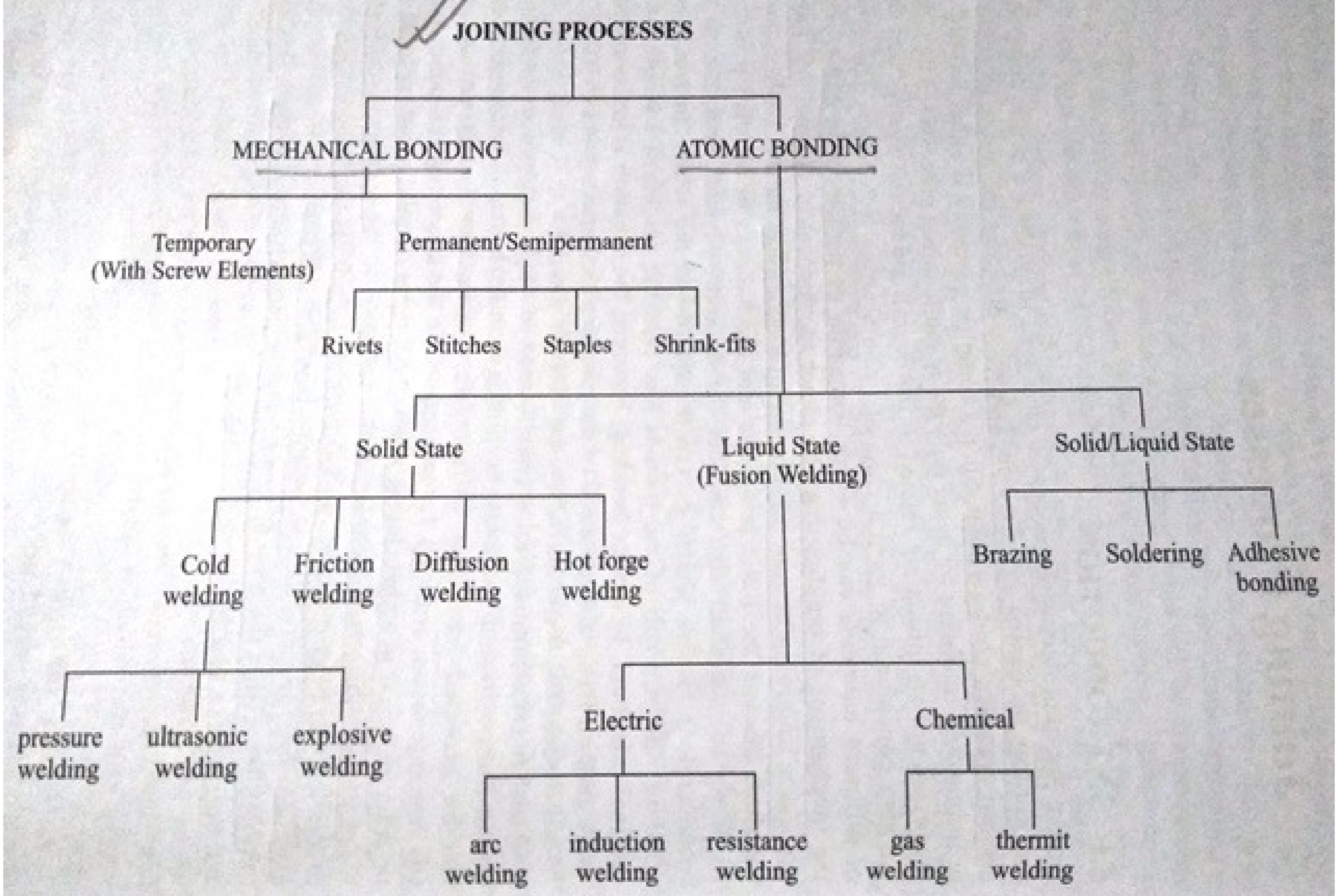
Table 5.1 Classification of joining processes



all joining processes can be grouped into three different categories, namely, (i) autogeneous, (ii) homogeneous, and (iii) heterogeneous. In the processes belonging to (i), no filler material is added during joining. All types of solid phase welding and resistance welding are examples of this category. In the homogeneous joining processes, the filler material used to provide the joint is the same as the parent material. Arc, gas, and thermit welding belong to this category. In the processes of type (iii), a filler material different from the parent material is used. Soldering and brazing are two such joining processes. It may be noted that two materials which are insoluble in each other, such as iron and silver, can be joined by a heterogeneous process. This may be achieved by using a filler material (e.g., copper and tin) which is soluble in both the parent materials (i.e., iron and silver).

Solid-state welding

- Joining takes place without fusion at the interface. In solid-state welding no liquid or molten phase is present in the joint. If two clean surfaces are brought into close contact with each other under sufficient pressure, they form bonds and produce a joint.
- To form a strong bond, it is essential that the interface be free of oxide films, residues, metalworking fluids, other contaminants, and even adsorbed layers of gas.
- Solid-state bonding involves one or more of the following phenomena
  - Diffusion:
  - Pressure:
  - Relative interfacial movements
- This type of welding is preferred, where the metal characteristics must remain unchanged after welding.
- Solid state welding includes the processes like diffusion welding, friction stir welding, explosive welding and electromagnetic welding.

Solid-state bonding involves one or more of the following phenomena:

- **Diffusion:**

➢ *Diffusion* is the movement of atoms across the interfaces which bonded interface and has the same physical & mechanical properties as the base metal

➢ If applying external heat improves the strength of the bond between the two surfaces being joined, as occurs in diffusion bonding.

➢ Heat may be generated internally by friction (as utilized in friction welding), through electrical-resistance heating (as in resistance-welding processes, such as spot welding), and externally by induction heating (as in butt-welding tubes).

- Pressure:

➢ The higher the pressure, the stronger is the interface (as in roll bonding and explosion welding), where plastic deformation also occurs.

➢ Pressure and resistance heating may be combined, as in flash welding, stud welding, and resistance projection welding.

- **Relative interfacial movements:**
- When movements of the contacting surfaces (faying surfaces) occur (as in ultrasonic welding), and generate new, clean surfaces- thus improving the strength of the bond.

Faying surface: Surface that are in contact at a joint

Solid-state welding

- **Hot Forge Welding**
- **Friction Welding**
- **Cold Welding:** Ultrasonic Welding, Explosive Welding

Hot Forge Welding

- Hot Forge welding is a welding process in which the components to be joined are heated to hot working temperatures and then forged together by hammer or other means.
- Considerable skill was required by the craftsmen who practiced it in order to achieve a good weld.
- Forge welding requires the application of pressure by means of either a hammer (hammer welding), rolls (roll welding), or dies (die welding).
- Joint configurations differ depending on whether the joints are to be produced manually or using automatic equipment.

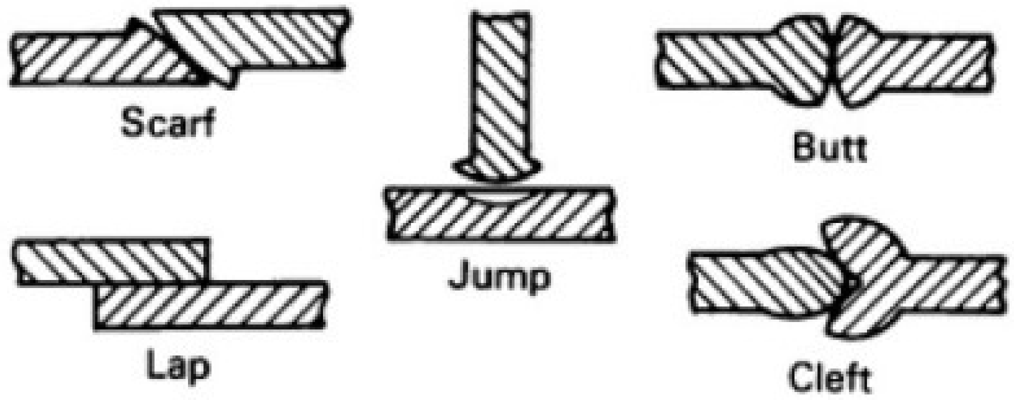


Figure (1) TYPICAL JOINT CONFIGURATIONS USED FOR MANUAL FORGE WELDING APPLICATIONS

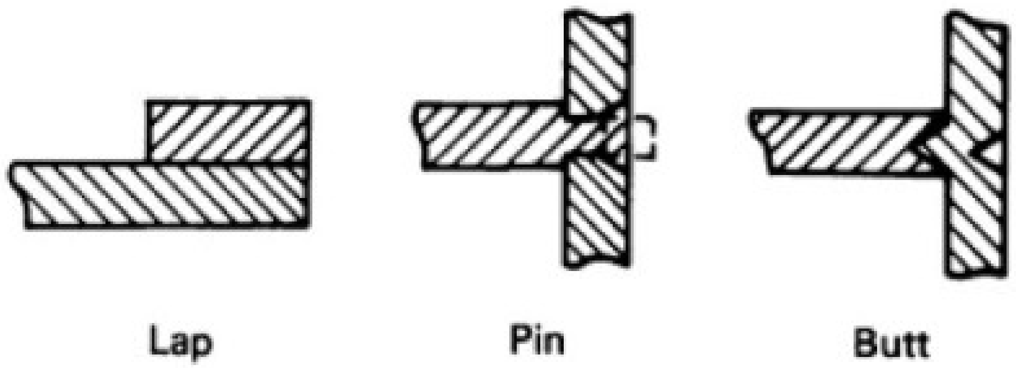
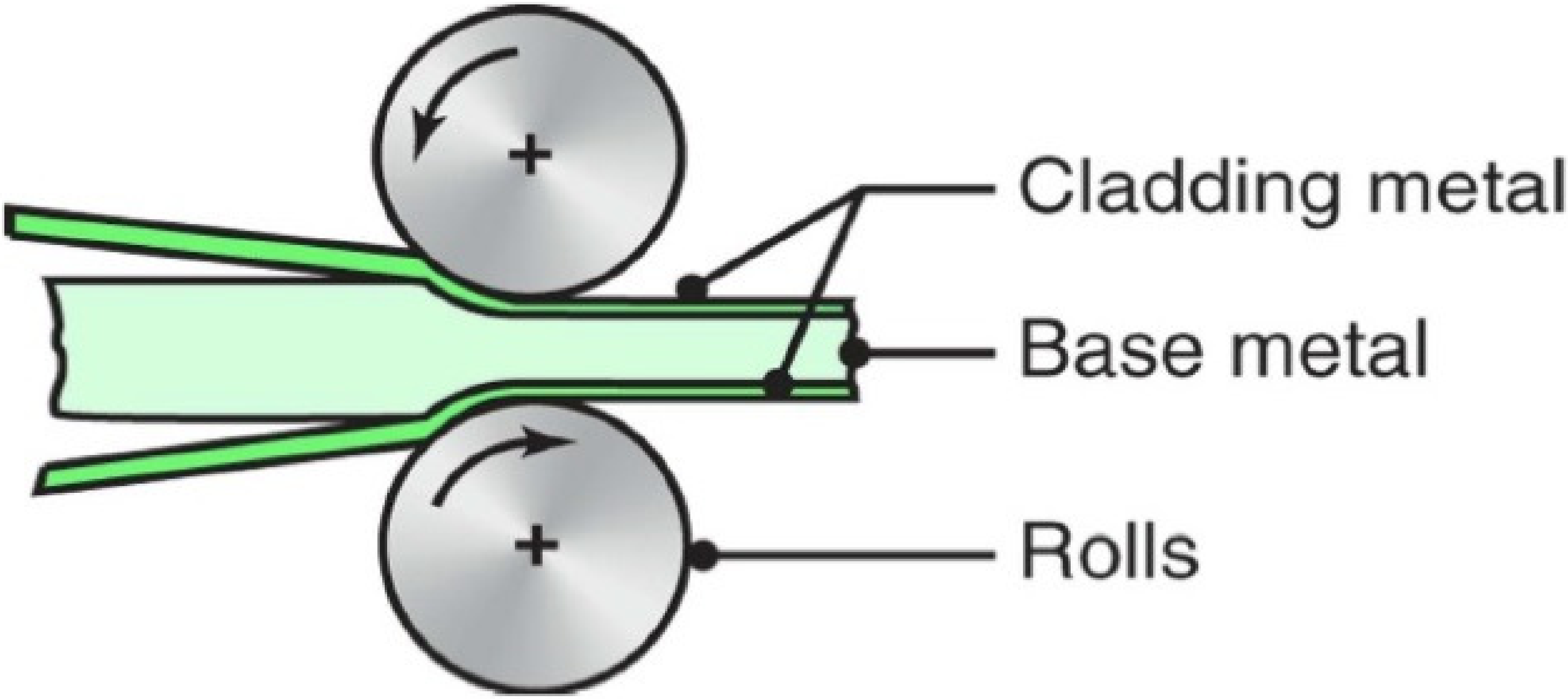


Figure (2) RECOMMENDED JOINT CONFIGURATIONS USED IN AUTOMATIC FORGE WELDING APPLICATIONS

FIGURE 31.1 Schematic illustration of the roll bonding, or cladding, process.



- The normal welding sequence are to:

(1) Apply sufficient pressure to firmly seat the faying surfaces against one another,

(2) Heat the joint to welding temperature.

(3) Rapidly apply additional pressure to upset the weld zone.

- Forge welding is most commonly applied to carbon low carbon - alloy steels, with typical welding temperatures of about 1125 °C (2060 °F). Low-carbon steels can be used in the as-welded condition, but medium-carbon steels
- Applications of this process include welding rods, bars, tubes, rails, aircraft landing gear, chains, and cans.

Friction Welding

- Friction welding is a widely used commercial process, amenable to automated production methods.
- The process was developed in the (former) Soviet Union and introduced into the United States around 1960.
- Friction welding (FRW) is a solid state welding process in which coalescence is achieved by frictional heat combined with pressure. The friction is induced by mechanical rubbing between the two surfaces, usually by rotation of one part relative to the other, to raise the temperature at the joint interface to the hot working range for the metals involved. Then the parts are driven toward each other with sufficient force to form a metallurgical bond.
- The sequence of friction welding shown in figure for welding two cylindrical parts, the typical application.

Coalescence: process of coming or growing together to form one thing or system
Different elements of something join together and become one

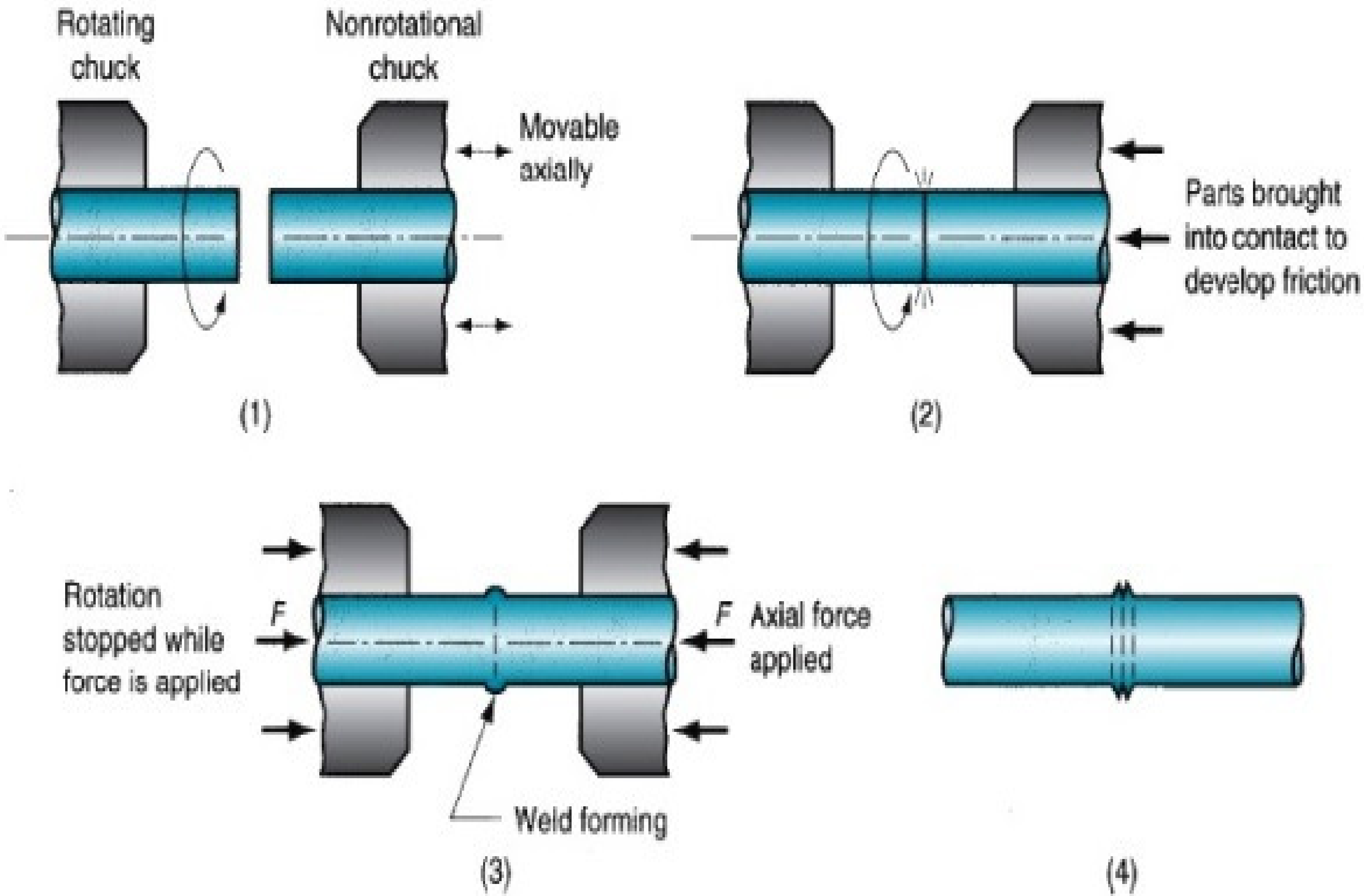
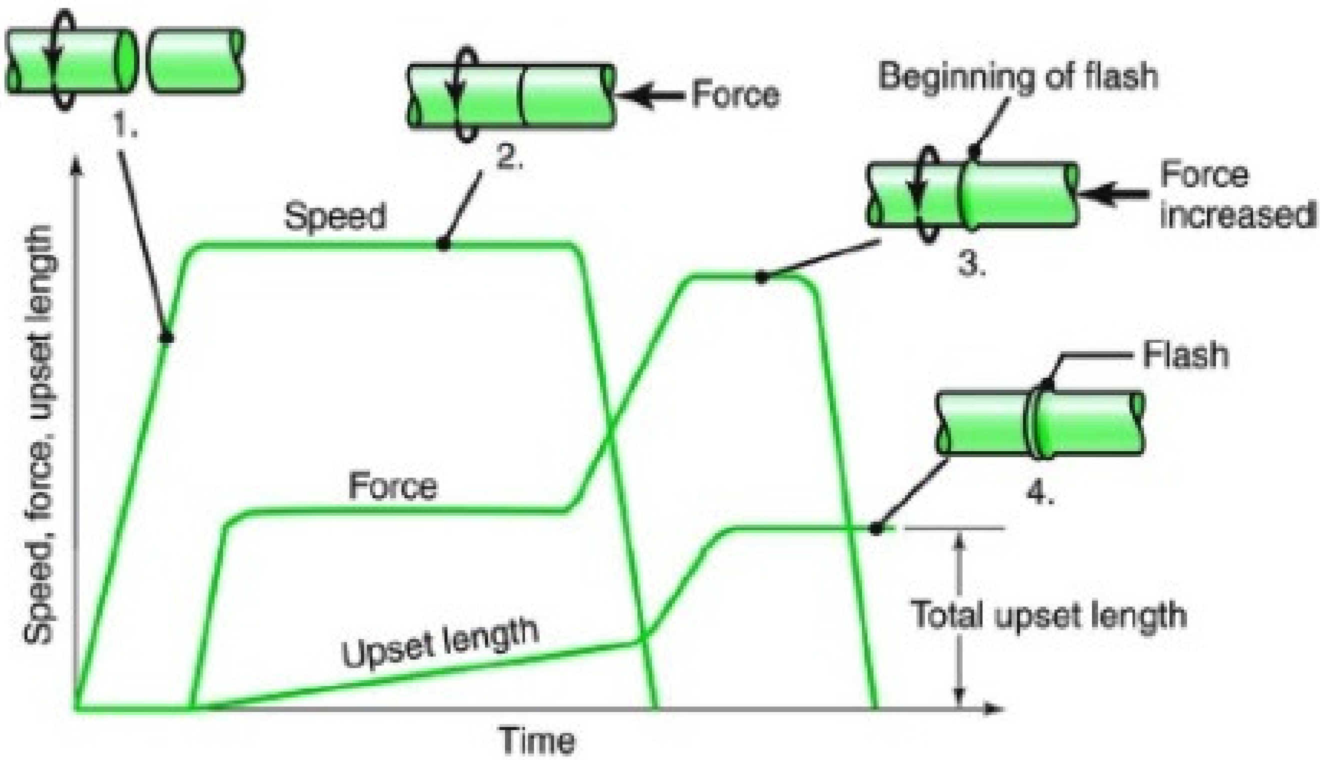


Figure (3) Friction welding (FRW): (1) rotating part, no contact; (2) parts brought into contact to generate friction heat; (3) rotation stopped and axial pressure applied; and (4) weld created.

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.

To generate friction heat



- The axial compression force upsets the parts, and a flash is produced by the material displaced. Any surface films that may have been on the contacting surfaces are expunged during the process. The flash must be subsequently trimmed (e.g., by turning) to provide a smooth surface in the weld region. When properly carried out, no melting occurs at the faying surfaces. No filler metal, flux, or shielding gases are normally used.
- Nearly all FRW operations use rotation to develop the frictional heat for welding.

References:

1. Book: Ghosh A. and Mallik A. K., Manufacturing Science, EWP Pvt. Ltd.

2. https://nptel.ac.in/content/storage2/nptel_data3/html/mhrd/ict/text/112107089/lec1.pdf

3. https://en.wikipedia.org/wiki/List_of_welding_processes

4. https://nptel.ac.in/content/storage2/nptel_data3/html/mhrd/ict/text/112103244/lec8.pdf