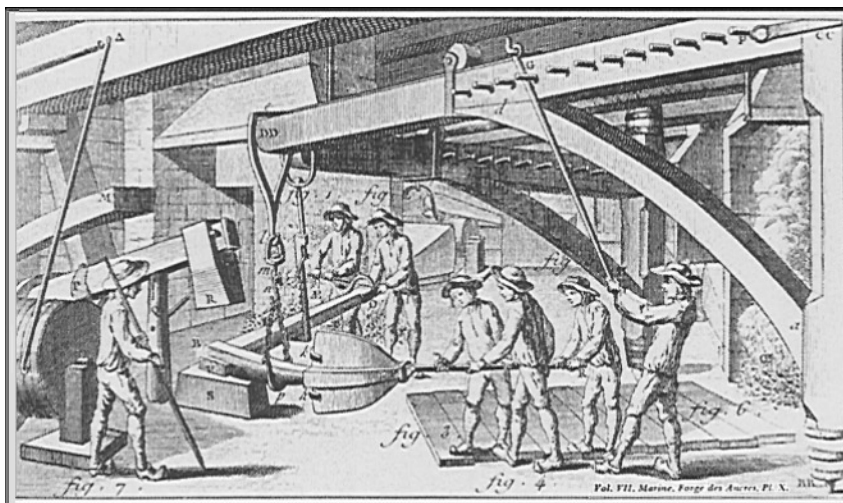


## 8.3 SOLID-STATE WELDING

The solid-state welding group includes the oldest joining process as well as some of the most modern

### *Forge Welding*

*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.

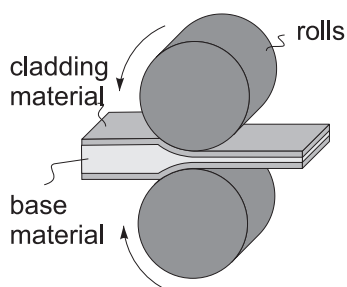


Woodcut showing a large ship's anchor being forged in 18th century France. The arm and the shaft of the anchor are being forge-welded together in this view.

Considerable skill was required by the craftsmen who practiced it to achieve a good weld. The process is of historic significance in the development of manufacturing technology; however, it is of minor commercial importance today.

### *Cold Roll Welding*

Cold roll welding is a solid-state welding process accomplished by applying high pressure by means of rolls between clean contacting surfaces at room temperature:



Cold welding (also cladding) process

Metals to be welded must be very ductile and free of work hardening. Contact surfaces must be exceptionally clean. Metals such as soft aluminum, copper, gold and silver can be readily cold-welded.

For small parts, the forces may be applied by simple hand-operated tools. For heavier work, powered presses are required to exert the necessary force.

Applications of cold welding include cladding stainless steel to mild steel for corrosion resistance, making bimetallic strips for measuring temperature, and producing sandwich strips for coins.

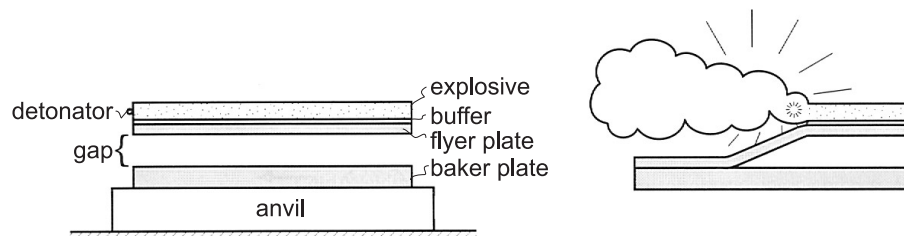
## Diffusion Welding

*Diffusion Welding* is a solid-state welding process that results from the application of heat and pressure, usually in a controlled atmosphere, with sufficient time allowed for solid-state diffusion and coalescence to occur. Temperatures are well below the melting points of the metals, and plastic deformation at the surfaces is only minimal.

Applications of diffusion welding include the joining of high-strength and refractory metals in the aerospace and nuclear industries. The process is used to join both similar and dissimilar metals, and in the latter case a filler layer of a different metal is often sandwiched between the two base metals to promote diffusion. A limitation of the process can be the time required for diffusion to occur between the faying surfaces; this time can range from seconds to hours.

## Explosion welding

*Explosion Welding* is a solid-state welding process in which rapid coalescence of two metallic surfaces is caused by the energy of a detonated explosive. The process for welding one metal plate on another can be described with reference to the figure:



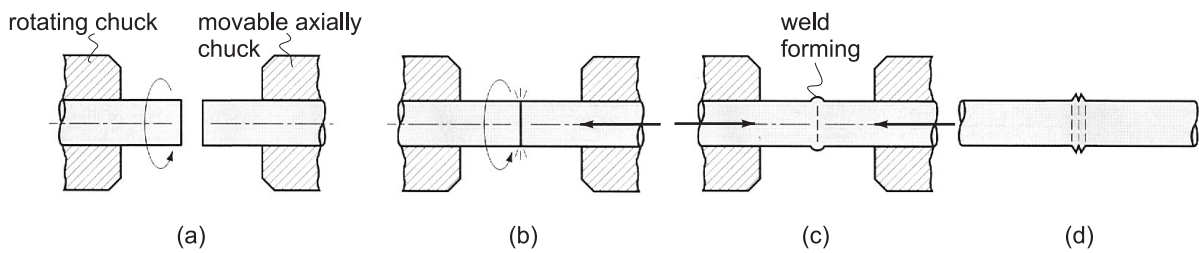
Explosive welding showing the initial setup and the process of explosive welding with the propagating shock wave.

In this setup, the two plates are in a parallel configuration, separated by a certain gap distance, with the explosive charge above the upper plate, called the flyer plate. A buffer layer (for example, rubber or plastic) is often used between the explosive and the flyer plate to protect its surface. The lower plate, called the backer metal, rests on an anvil for support. When detonation is initiated, the explosive charge propagates from one end of the flyer plate to the other. The resulting high-pressure zone propels the flyer plate to collide with the backer metal progressively at high velocity, so it takes on an angular shape as the explosion advances, as illustrated in the sketch.

Explosion welding is commonly used to bond two dissimilar metals, in particular to clad one metal on top of a base metal over large areas. Applications include production of corrosion-resistant sheet and plate stock for making processing equipment in the chemical and petroleum industries. The term *explosion cladding* is used in this context. No filler metal is used in explosion welding, and no external heat is applied.

## Friction welding

*Friction welding* is a solid-state welding process in which coalescence is achieved by frictional heat combined with pressure. The heat is generated by the friction between the two components surfaces, usually by rotation of one part relative to the other. Then the parts are driven toward each other with sufficient force to form a metallurgical bond. The sequence is portrayed in the figure for the typical application of this operation, welding of two cylindrical parts.



Friction welding: (a) no contact, (b) parts brought into contact to generate friction heat, (c) rotation stops and axial pressure applied, (d) final product showing the flash.

The axial compression force upsets the parts, and the material displaced produces a flash. The flash must be subsequently trimmed to provide a smooth surface in the weld region. No filler metal, flux, or shielding gases are required.

Machines used for friction welding have the appearance of an engine lathe. They require a powered spindle to turn one part at high speed and a means of applying an axial force between the rotating part and the non-rotating part.

With its short cycle times, the process is suitable for mass production. It is applied in the welding of various shafts and tubular parts of similar or dissimilar metals. One typical application of friction welding is to coalesce medium-carbon steel shanks to carbide tips in producing twist drills.