Principles:

Friction Welding (FRW) is a solid state welding process which produces welds due to the compressive force contact of workpieces which are either rotating or moving relative to one another. Heat is produced due to the friction which displaces material plastically from the faying surfaces. The basic steps explaining the friction welding process are shown in Fig.4.4.1.

In friction welding the heat required to produce the joint is generated by friction heating at the interface. The components to be joined are first prepared to have smooth, square cut surfaces. One piece is held stationary while the other is mounted in a motor driven chuck or collet and rotated against it at high speed. A low contact pressure may be applied initially to permit cleaning of the surfaces by a burnishing action. This pressure is then increased and contacting friction quickly generates enough heat to raise the abutting surfaces to the welding temperature. As soon as this temperature is reached, rotation is stopped and the pressure is maintained or increased to complete the weld. The softened material is squeezed out to form a flash. A forged structure is formed in the joint. If desired, the flash can be removed by subsequent machining action. Friction welding has been used to join steel bars upto 100 mms in diameter and tubes with outer diameter upto 100 mm.

Inertia welding is a modified form of friction welding, where the moving piece is attached to a rotating flywheel. The flywheel is brought to a specified rotational speed and is then separated...
from the driving motor. The rotating assembly is then pressed against the stationary member and
the kinetic energy of the flywheel is converted into frictional heat. The weld is formed when the
flywheel stops its motion and the pieces remain pressed together. Since the conditions of the
inertia welding are easily duplicated, welds of consistent quality can be produced and the process
can be easily automated. The heat affected zones are usually narrow, since the time period is
very short for heating and cooling. The radial and orbital FRW are as shown in Figs. 4.4.2 and
4.4.3 respectively.

Fig.4.4.1 Basic Steps in Friction welding
Advantages of Friction Welding:

- No filler material, flux or shielding gases are needed.
- It is an environment-friendly process without generation of smoke, fumes or gases.
- No material is melted so the process is in solid state with narrow heat affected zone (HAZ).
- Oxides can be removed after the welding process.
- In most cases, the weld strength is stronger than the weaker of the two materials being joined.
- The process can be easily automated for mass production.
- The process is very efficient and comparatively very rapid welds are made.
- Plant requirements are minimal and wide variety of metals and combinations can be welded.

Limitations of Friction Welding:

- The process is restricted to joining round bars or tubes of same diameter (or bars tubes to flat surfaces), i.e. capable of being rotated about the axis.
- Dry bearing and non-forgeable materials cannot be welded, i.e. one of the component must be ductile when hot, to permit deformations.
• Preparation and alignment of the workpieces may be critical for developing uniform rubbing and heating, particularly for pieces having diameters larger than 50 mm.

• Capital equipment and tooling costs are high and free-machining alloys are difficult to weld.

**Applications of Friction Welding:**

• Friction welded parts in production applications span over wide products for aerospace, agricultural, automotive, defense, marine and oil industries.

• Right from tong holds to critical aircraft engine components are friction welded in production.

• Automotive parts that are friction welded include gears, engine valves, axle tubes, driveline components, strut rods and shock absorbers.

• Hydraulic piston rods, track rollers, gears, bushings, axles and similar parts are commonly friction welded by the manufacturers of agricultural equipment.

• Friction welded aluminum/copper joints are in wide usage in the electrical industry.

• Stainless steels are friction welded to carbon steels in various sizes for use in marine systems and water pumps for home and industrial use.

• Friction welded assemblies are often used to replace expensive casting and forgings.

**FRICTION STIR WELDING (FSW):**

Friction Stir Welding (FSW) is another variant process of friction welding. A schematic of the FSW is shown in Fig. 4.4.4.
The necessity and advent of Friction Stir Welding:

The basic problems with fusion welding of aluminum and its alloys are that they possess:

- Cast brittle dendritic structure,
- Micro porosity,
- Inferior mechanical and fatigue properties,
- Loss of strength in heat affected zone,
- Solidification and liquation cracking,
- Loss of alloying elements from the weld pool.

The following alternate techniques are being used for joining of aluminium and its alloys:

- Electron beam welding (EBW),
- Laser beam welding (LBW),
- Variable polarity plasma arc welding (VPPAW),
- Friction stir welding (FSW).

The basic terminologies and process sequence of FSW process is as shown in Fig. 4.4.5.
Unique advantages of FSW:

- Solid state process.
- Routinely used to join difficult to fusion weld alloys (e.g., 2xxx & 7xxx aluminum alloys).
- Fine grained, re-crystallized microstructure can be obtained.
- No significant alteration of chemical composition.
- Eliminates fusion welding problems.
- Lower power consumption, user friendly and environment friendly process.

![Diagram of FSW process](image)

**Fig. 4.4.5 Basic terminologies and steps in FSW.**

Limitations of FSW:

- Rigid and robust fixtures are required.
- Visible end hole is created.
- Inability to make filler welds.
FSW Typical Applications:

The industrial application of friction stir welding includes following:

- **Aerospace**: Wings, fuselage, cryogenic fuel tanks, aviation fuel tanks, aircraft structure, and external aircraft throw away tanks.

- **Marine**: Deck panes, bulkheads, floors, hull and superstructures, refrigeration plants, internal frameworks, marine and transport structures.

- **Railway**: High speed trains, container bodies, railway tankers, good wagon and underground rolling stocks.

- **Automotive**: Engine and chassis cradles, wheel rims, tailored blanks, armour plate vehicles, motorcycle and bicycle frames, buses and airfield vehicles, fuel tankers, suspension parts, crash boxes.

- **Construction**: Bridges, reactors for power and chemical industries, pipelines, heat exchangers, air conditioners, offshore drilling rigs etc.

- **Other applications include**: Electric motor housing, connectors, busbars, encapsulation of electronics and joining of aluminum to copper, food tins etc.