- It is also used for making hollow containers, automobile fuel tanks, boat fenders, heater ducts and hollow industrial parts like drum.

5.5.3 Thermoforming

It is a series of processes for forming thermoplastic sheet or film over a mould with the application of heat and pressure. It is used in packaging of consumer products and to fabricate large parts like bathtubs, internal door liners, etc. It consists of two main steps viz. heating and forming. Heating is carried out by radiant electric heaters, located on one or both sides of the starting plastic sheet. Time of heating depends on the type of polymer, its thickness and colour. The methods by which forming is carried out are as follows:

- Vacuum forming
- Pressure forming

5.5.3.1 Vacuum forming

- It employs a clamp to grid the plastic sheet having thickness of about 0.125 to 3.2 mm, around its circumference. Refer Figure 5.8 (a).

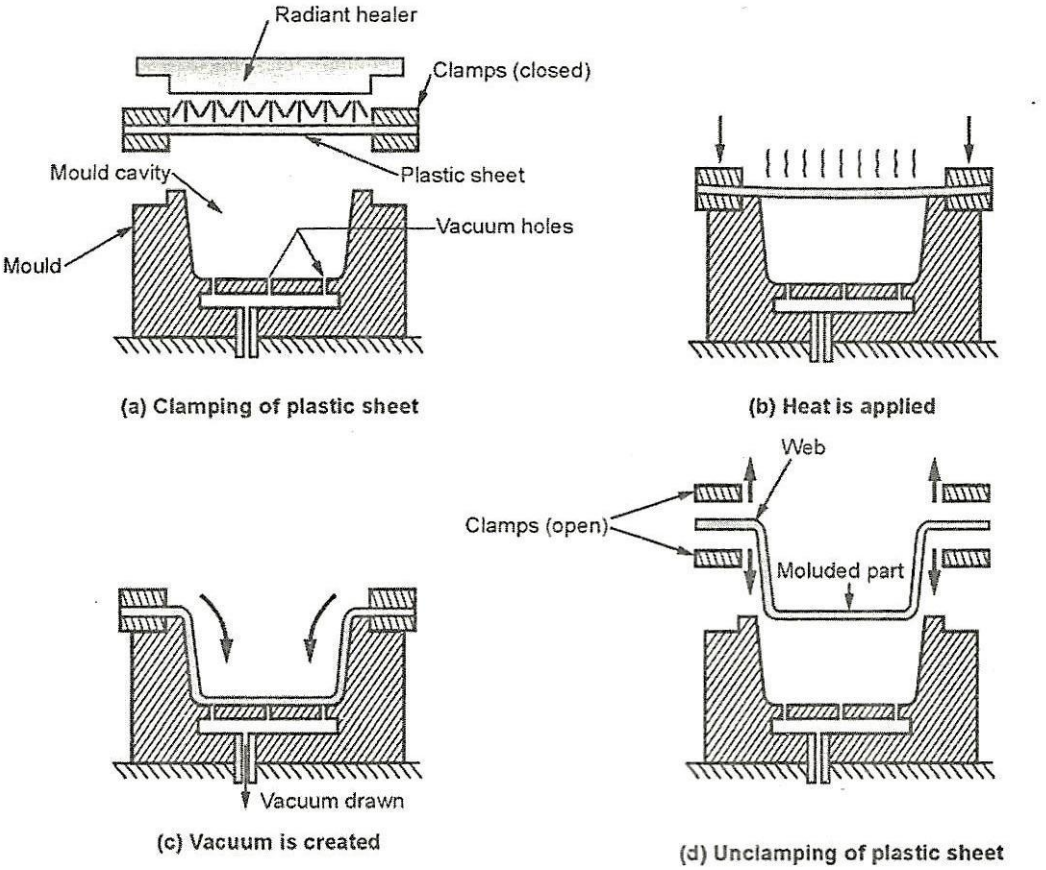

Figure 5.8 Vacuum forming

- A heater is used to bring the polymer to a temperature of about 55°C to 90°C, until it begins to sag.
- Through the small holes in the die, vacuum is applied and the sagging plastic sheet is thus pulled tightly against the mould acquiring the mould shape.

- As the mould is cooler, the polymer is child and stiffened by die contact.
- Figure 5.8 (b) shows that instead of vacuum sometimes hot air is used to drive the plastic sheet into the female mould cavity.

5.5.3.2 Pressure forming

- It involves positive pressure (no vacuum) to force the heated plastic into the mould cavity. It is also called as blow forming**.**
- The main advantage of pressure forming over vacuum forming is that, higher pressures can be developed on the component.
- The process sequenced is similar to vacuum forming, the difference being that the sheet is pressurised from above into the mould cavity.
- Vent holes are provided in the mould to exhaust the trapped air. The forming portion of the sequence is shown in Figure 5.9.

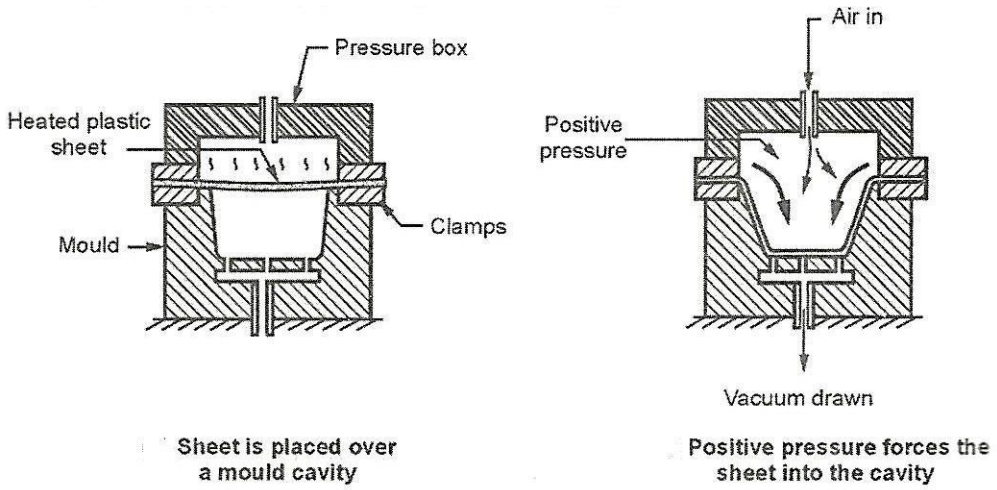

Figure 5.9 Pressure Thermoforming

Advantages of thermoforming

- Initial cost of mould is low.
- Time required for set-up is low.
- Production cost is low.
- During the process less thermal stresses are produced.
- Intricate shapes are easily formed.
- The holes in the mould (to pull a vacuum) are generally less than 0.5 mm hence it will not leave any mark on the formed components.
- Generally moulds are made of aluminium because high strength is not required.
- Cost of tooling is low.

Disadvantages/Limitations of Thermoforming

- Components with openings or holes cannot be produced by this process.
- It is a drawing and stretching operation hence the material should exhibit high uniform elongation, otherwise it will neck and fail.

Applications of Thermoforming

- Thermoforming is used for producing small jelly containers used in restaurants, luggage bags, refrigerator inner panels and containers for packaging.
- Also used for forming of panels for shower stalls and advertising sings.

5.5.4 Extrusion

- Extrusion process is a continuous process in which the hot plastisized material is forced through the die opening of required shape.
- Raw material in the form of thermoplastic pallets, granules or powder is fed through the hopper into a heating cylinder or extruder.
- The extruder is equipped with a screw that blends and conveys the material into a heated die. Refer figure 5.10.

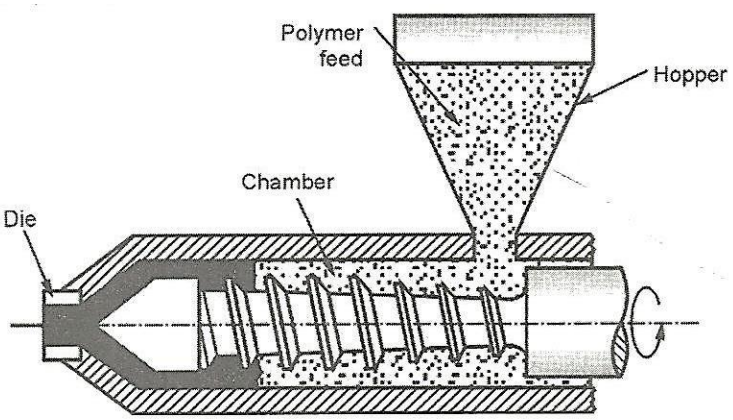

Figure 5.10.Extrusion

- The internal friction due to mechanical action of the screw, along with the heaters around the extruder, heats the material and liquefies it.
- The screw have three different sections which are as follows:
  - Feed section which conveys the material from hopper into the central region of extruder.
  - Transition or melting section where the heat generated from the shearing of the plastic causes melting to begin.
  - Pumping section where additional melting and shearing occurs.
- In the heating chamber the material becomes a thick viscous mass where it is forced through the die.

- When it leaves the die, it is cooled by air or water or by contact with chilled surface and fully hardens.
- To minimise product shrinkage and distortion, control of the rate and uniformity of cooling are important factors.
- Extruded component is then coiled or cut into the required lengths.
- To colour the plastics, dry colour may be added to screw extruder.

Application of Extrusion

- The extrusion moulding process is used for producing solid rods, pipes or tubes of U, J, Y or other sections.
- Also used for extrusion of candy canes, chewing gums, drinking straws, plumbing pipes, door insulation seals, optical fibers, plastic coated wires, cables, window frames, sheets, strips for electrical applications, etc.

5.5.4.1 Extrusion of Film

- Thermoplastic films are produced by a number of processes, one of them important process is extrusion.
- Film refers to thickness below 0.5mm and they are used for packaging applications like product wrapping material, grocery bags, garbage bags, etc.
- A widely used method of making thin polyethylene film for packaging is film blowing.
- It is a complex process which combines the principle of extrusion and blowing to produce an thin film Refer figure 5.11.

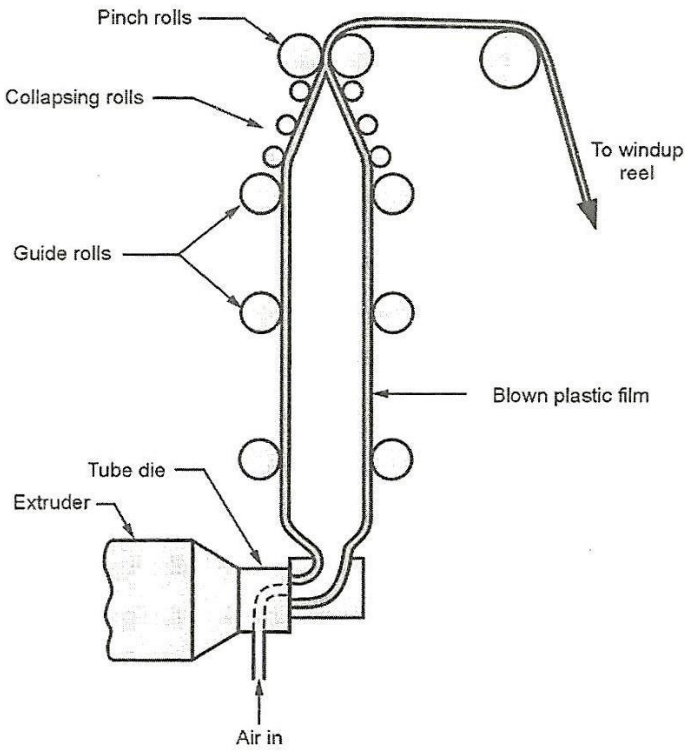

Figure 5.11 Extrusion of Film

- The process starts with the extrusion of a tube which is immediately drawn upward in molten condition and simultaneously expanded in size by blowing air into it through the die mandrel.
- Air pressure in the bubble must be kept constant to maintain uniform thickness and tube diameter.
- Guide rolls and collapsing rolls are used to restrain the blown tube and direct in into the pinch rolls.
- The air contained in the tube is squeezed by pinch rolls and the tube moves forward after it has cooled. Thus the flat tube (film) is then collected into a windup reel.

5.5.4.2 Extrusion of sheet

The term sheet refers to stock with a thickness between 0.5mm to 12.5mm. They are used for products like flat window glazing, stock for thermoforming, etc.

Sheet Forming

- Rubber and some of the thermoplastic sheets are formed by the **Calendering process.**
- In this process the plastic compound composed of resin, plastisizer, filler and colour pigments is heated and passed through the roller.
- The working principle of calendering process is almost similar to rolling process i.e. the material is compressed between rolls and emerges as sheet.
- The main difference between rolling and calendering is that, in calendering there is appreciable thickening after the material has reached minimum thickness at the roll gap and the pre-calendered material is not in the sheet form. Refer figure 5.12.

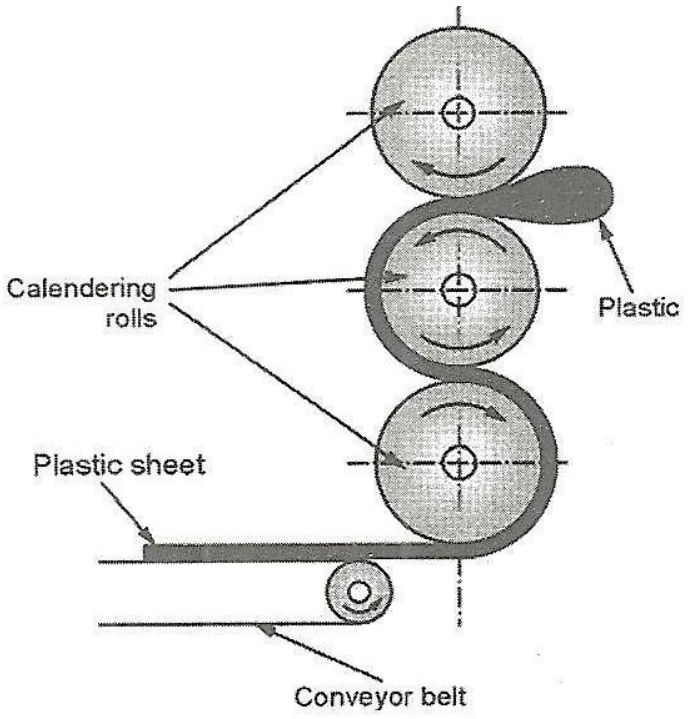

Figure 5.12. Calendering process

- The thickness of the produced sheet depends on the spacing between the rollers.
- During the process, the first roll gap serves as a feeder, the second as a metering device and the third one sets the gauge of the gradually cooling plastic which is then would on a coiler.
- Calendering is high production process and mostly suitable for flexible P.V.C.

Applications of Calendering

- Vinyl, polyethylene, cellulose acetate films, vinyl floor tiles are the products of calendering.
- It is also used for production of rainwear, shower curtains, tapes, trays, ATM cards, laminations and transparent film used for packaging.

5.5.5 Rotational Moulding

Working principle

The rotational moulding process is used to make thin walled hollow parts. In this method, a measured quantity of polymer powder in placed in a thin-walled metal mould. The mould is closed and it is rotated about two mutually perpendicular axes as it is heated.

This rotation will cause the powder to sinter against the mould walls. After heating and sintering, the mould is cooled while it is still rotating. The cooling of mould is done by using water and air. Then the rotation is stopped when the moulded component is removed.

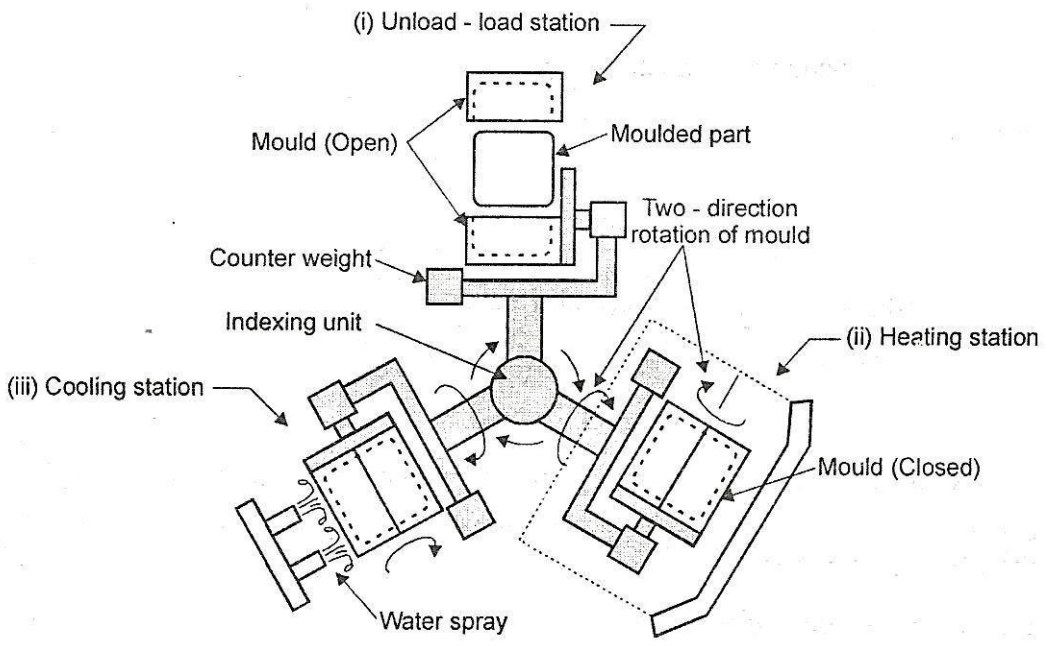

Figure 5.13 Rotational Moulding

In this rotational moulding, thin walled metal mould is made of two pieces and is rotated in perpendicular axis. A measured quantity of powdered plastic material is place inside the mould. Then, the mould is heated and rotated. This action tumbles the powder against the mould where the heating fuses the powder without melting it. Most thermosplastics and some

thermosets can be formed into large hollow parts by rotational moulding. In some parts, chemical agents are added to the powder and cross-linking after the part is formed in the mould by continuous heating.

Rotational molding can also produce parts with complex hollow shapes with wall thickness of 0.4mm minimum. Large size parts as 1.8m×1.8m×3.6m can also be formed by this process. The surface finish of the mould is same as that of surface finish of walls. The temperature-time relationship during the oven cycle is very important.

Applications:

1. It is used to produce toys in P.V.C.
2. It is used to make large containers of polyethylene.
3. It is used to make petrol tanks for motorcars from polyethylene and nylon.
4. Metallic or plastic inserts are moulded by this process.
5. The buckets, housing, boat hulls and trashcans are made by this process.
6. It is used to produce tanks of various sizes, boat hulls and footballs.

5.6 Bonding of Thermosplastics (Laminating Plastics):

- Bonding of thermoplastics is performed by the application of heat and pressure.
- Laminated plastic consists of sheet of paper, fabric, wood, asbestos, cellulose or other similar materials that are coated with resin.
- Lamination process is based on the principle of layers of sheet like metal foil, paper, etc. bonded together in a stack.
- Starting with the top sheet, a properly adjusted laser, cuts each sheet, one at a time in a particular form.
- The unused portions are discarded (wastage) and individual pieces are bonded together.
- The sheet thickness vary from 0.05 mm to 0.12 mm. Lamination process is classified in two categories:
    - High pressure laminates
    - Low pressure laminates

5.6.1 High pressure laminates

- In this method, layers of fibrous reinforcing materials are joined with thermosetting resin binders by the application of heat and pressure.
- The pressure generally ranges form 8 MPa to 24 MPa and the temperature is about 150°C.
- It consists of preparing varnish solution from resins by dissolving them in a suitable solvent, followed by coating fibrous sheets with this varnish.

- These sheets are then dried, cut to size, heated and pressed between metal plates to form the laminated plates. Refer figure 5.14.

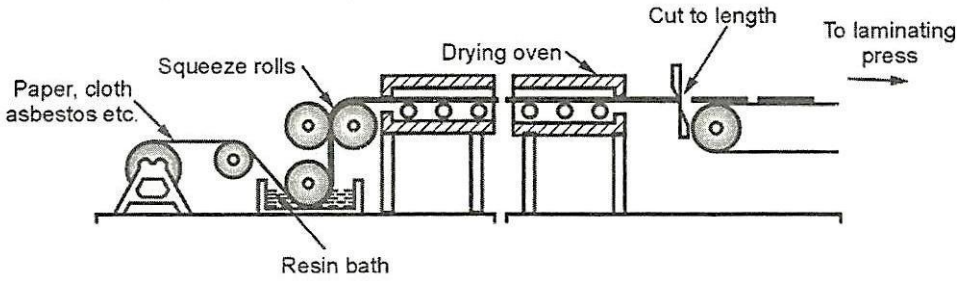

Figure 5.14. Laminating Processes

5.6.2 Low pressure laminates

- In this process, pressure upto 28 MPa are applied.
- Generally thermosetting resins are used in laminating.
- The reinforced materials used are glass, fibre, cotton, nylon, paper and other fibres.
- Commonly used resins are phenolics, polyesters, epoxies and silicones.
- To obtain different colour shades, pigments are added.
- For obtaining better surface finish and better physical properties, fillers like clay, calcium carbonate, asbestos, etc. are added.

Advantages of laminating plastics

- It is a simple method.
- Cost of the process is low.
- There is no restriction of size.
- The process is flexible.
- Minimum equipments are required during the process.

Applications of laminating plastics

- Laminated plastics are used in electrical and electronic components.
- Heavy cloth laminates are used for gear blanks, cams and other industrial purposes.
- For decorative purpose, laminations are widely used in furniture industry.

5.7 Methods of Bonding of Plastics

Different techniques or methods are used for joining or bonding of plastics. The most of the methods have limitations as per the size or type of plastics which they can joint. The different methods of joining of plastics are as follows:

a) Mechanical fastening
b) Solvent bonding
c) Ultrasonic welding
d) Induction welding
e) Vibration welding
f) Hot-platen welding

a) Mechanical fastening

- It is the simplest way to join the plastic components.
- In this method, the fastening elements like hinge, latch or detent is formed into the components to be joined. It is a low cost method.
- As the joint must survive the strain of assembly, service lad and possible repeated use, only the stronger and tougher plastics can be joint.
- Screws, rivets, pins, sheet metal nuts are the commonly used mechanical fasteners.
- They require a plastic which is strong enough to withstand the strain of fastener insertion and subsequent high stress around the fastener.

b) Solvent bonding

- In this technique of bonding, only thermoplastics can be joined by softening them by solvent and then clamping or pressing together.
- Due to this, the plastic molecules intermingle and the components bond together as the solvent evaporates.
- The time of fusion is direct function of solvents evaporation rate and it may be reduced by heating only.
- The pressure to be applied on the component is critical because high pressure may distort the components.

c) Ultrasonic welding

- In this method of joining, two components to be joined are placed together and the ultrasonic pulses are transmitted from a generator to the parts.
- For this purpose resonant vibrating tool called as horn is used which vibrates the component against each other at frequencies around 20,000 Hz.
- Then the parts are heated and fused together.
- It is a fast process and suitable for joining of dissimilar metals also provided that both have same melting temperatures.
- The contact pressure between the two components is critical and it should be just sufficient to cause heating by friction.
- This method is suitable only for thermoplastics except thermosetting resins and teflon.

d) Induction welding

- This method is suitable only for thermoplastics.
- In this method, two components are pressed together with a metal wire or insert in the joint region and the high frequency magnetic field is switched on around it.
- This causes the encased metal to be heated up hence melting the plastic and the compression produces good fusion weld.

- In some cases, metal powder may be added to the original plastic moulding but in that case high frequency is needed to affect the weld.
- The cost of this technique is high.

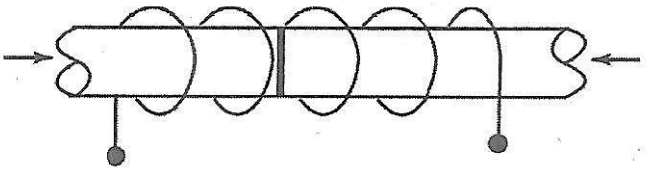

Figure 5.15 Induction welding

e) Vibration welding

- This method produces pressure tight joints in circular, rectangular or irregular shaped components made from thermoplastic materials.
- This method is mainly suitable for hollow container type components having the weld joint in a single plane.
- During the process, the friction heat is developed by pressing two plastic components and vibrating them at 120 cycles/see in the plane of joint.
- After 3-4 second, vibration is stopped at the exact desired relative position of two pieces. The pressure is maintained briefly while the softened plastic cools.

f) Hot-platen welding

In this method, initially the thermoplastic is softened by contacting it with a heated tool and then pressing together. The material is passed through a hot roller with film or sheet. The sticking between the hot tool and material is prevented by coating the tool with the fluorocarbon. This method is used for welding large, irregularly shaped moulded or extruded parts. A heated platen is kept between the components and the edges to be joined are pressed against it. Now the platen is removed and the components with their edges plasticised as pressed together. After some holding and cooling time, the fixture is opened and the welded assembly is removed.

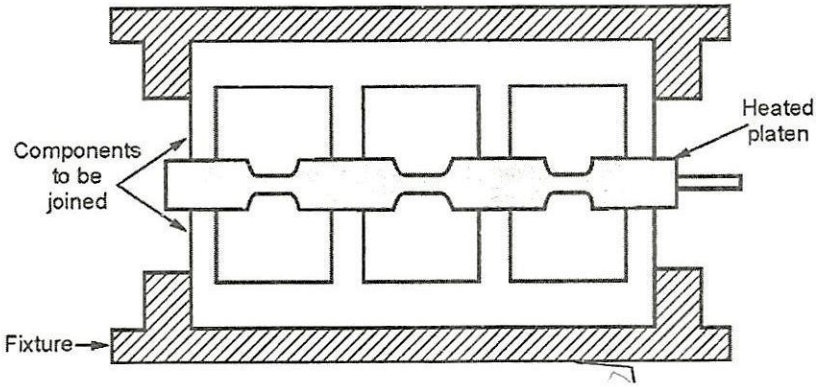

Figure 5.16 Hot-platen welding