**University of Basrah**
**College of Engineering**
**Mechanical Engineering Department**
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# Brazing, Soldering, and Adhesive Bonding

## Introduction

- Brazing and soldering both use filler metals to join and bond two (or more) metal parts to provide a permanent joint.
- It is difficult, although not impossible, to disassemble the parts after a brazed or soldered joint has been made.
- In the spectrum of joining processes, brazing and soldering lie between fusion welding and solid-state welding.
- A filler metal is added in brazing and soldering as in most fusion-welding operations; however, no melting of the base metals occurs, which is similar to solid-state welding.
- Despite these anomalies, brazing and soldering are generally considered to be distinct from welding.
- **Brazing and soldering are attractive compared to welding under circumstances where**:

(1) the metals have poor weldability,
(2) dissimilar metals are to be joined,
(3) the intense heat of welding may damage the components being joined,
(4) the geometry of the joint does not lend itself to any of the welding methods,
(5) high strength is not a requirement.

- **Adhesive bonding shares certain features in common with brazing and soldering:**
- It utilizes the forces of attachment between a filler material and two closely spaced surfaces to bond the parts.
- The differences are that the filler material in adhesive bonding is not metallic, and the joining process is carried out at room temperature or only modestly above.

# Brazing

- Brazing is a joining process in which a filler metal is melted and distributed by capillary action between the faying surfaces of the metal parts being joined.
- No melting of the base metals occurs in brazing; only the filler melts.
- In brazing the filler metal (also called the brazing metal), has a melting temperature (liquidus) that is above 450 °C but below the melting point (solidus) of the base metal(s) to be joined.
- If the joint is properly designed and the brazing operation has been properly performed, the brazed joint will be stronger than the filler metal out of which it has been formed upon solidification.
- This rather remarkable result is due to the small part clearances used in brazing, the metallurgical bonding that occurs between base and filler metals, and the geometric constrictions that are imposed on the joint by the base parts.
- **Brazing Advantages Compared to Welding:**

(1) any metals can be joined, including dissimilar metals;
(2) certain brazing methods can be performed quickly and consistently, thus permitting high cycle rates and automated production;
(3) some methods allow multiple joints to be brazed simultaneously;
(4) brazing can be applied to join thin-walled parts that cannot be welded;
(5) in general, less heat and power are required than in fusion welding;
(6) problems with the heat-affected zone in the base metal near the joint are reduced;
(7) joint areas that are inaccessible by many welding processes can be brazed, since capillary action draws the molten filler metal into the joint.

- **Brazing Disadvantages:**

(1) joint strength is generally less than that of a welded joint;
(2) although strength of a good brazed joint is greater than that of the filler metal, it is likely to be less than that of the base metals;
(3) high service temperatures may weaken a brazed joint;
(4) the color of the metal in the brazed joint may not match the color of the base metal parts, a possible aesthetic disadvantage.

- **Brazing Applications:**
- Brazing as a production process is widely used in a variety of industries, including automotive (e.g., joining tubes and pipes), electrical equipment (e.g., joining wires and cables), cutting tools (e.g., brazing cemented carbide inserts to shanks), and jewelry making.
- In addition, the chemical processing industry and plumbing and heating contractors join metal pipes and tubes by brazing.

- The process is used extensively for repair and maintenance work in nearly all industries.

## Brazed Joints

- Brazed joints are commonly of two types: **butt and lap**.
- The conventional butt joint provides a limited area for brazing, thus jeopardizing the strength of the joint.
- To increase the faying areas in brazed joints, the mating parts are often scarfed or stepped or otherwise altered, as shown in Figure (5-43).

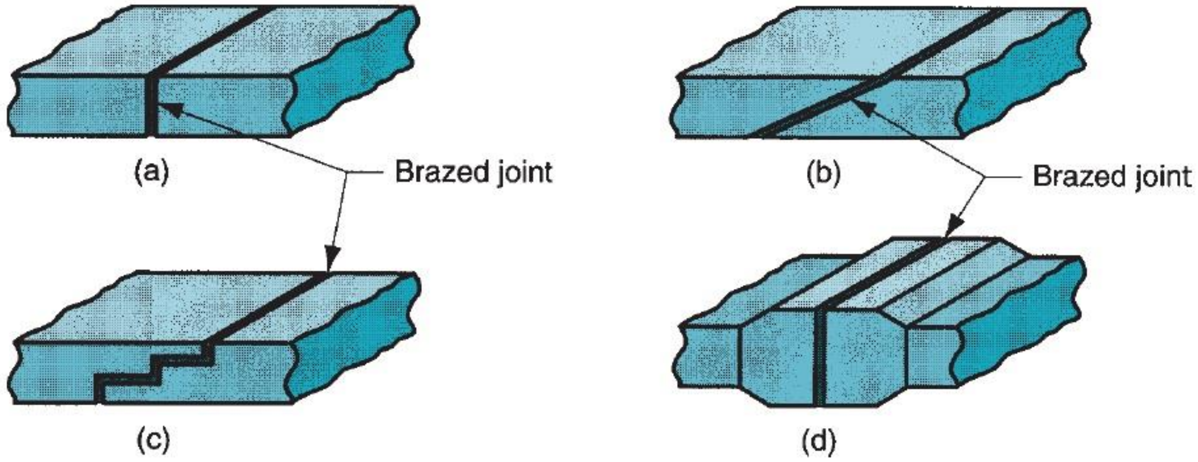

Figure (5-43) (a) Conventional butt joint, and adaptations of the butt joint for brazing: (b) scarf joint, (c) stepped butt joint, (d) increased cross section of the part at the joint.

- One of the particular difficulties associated with a scarfed joint is the problem of maintaining the alignment of the parts before and during brazing.
- Lap joints are more widely used in brazing, since they can provide a relatively large interface area between the parts.
- An overlap of at least three times the thickness of the thinner part is generally considered good design practice.
- Some adaptations of the lap joint for brazing are illustrated in Figure (5-44).
- An advantage of brazing over welding in lap joints is that the filler metal is bonded to the base parts throughout the entire interface area between the parts, rather than only at the edges (as in fillet welds made by arc welding) or at discrete spots (as in resistance spot welding).
- Clearance between mating surfaces of the base parts is important in brazing (must be large enough so as not to restrict molten filler metal from flowing throughout the entire interface).

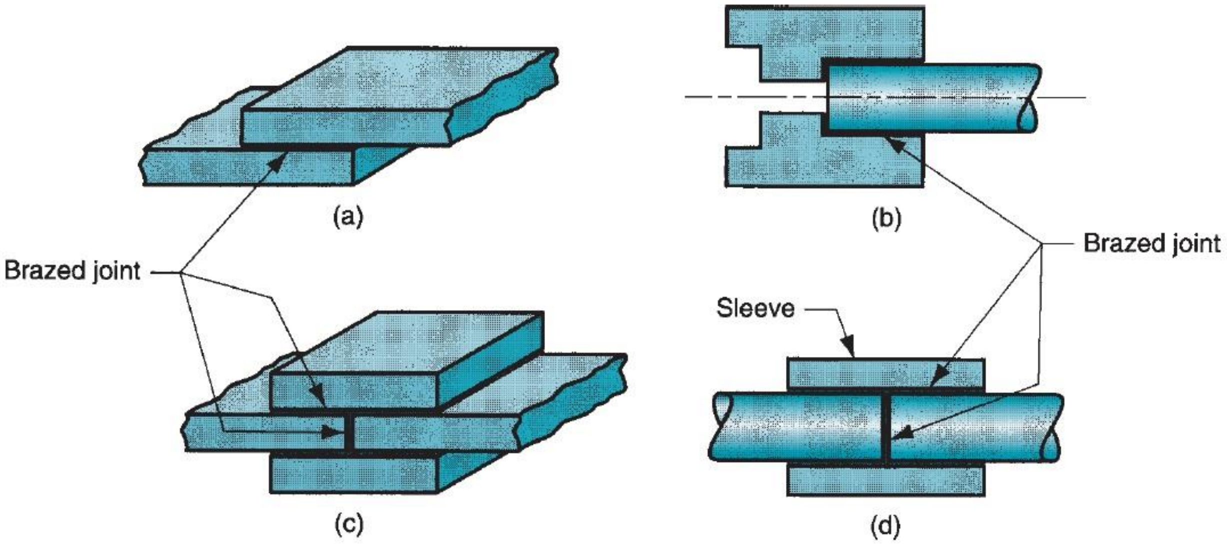

Figure (5-44) (a) Conventional lap joint, and adaptations of the lap joint for brazing: (b) cylindrical parts, (c) sandwiched parts, and (d) use of sleeve to convert butt joint into lap joint.

- Yet if the joint clearance is too great, capillary action will be reduced and there will be areas between the parts where no filler metal is present.
- Joint strength is affected by clearance, as depicted in Figure (5-45).
- There is an optimum clearance value at which joint strength is maximized (typical brazing clearances in practice are 0.025 to 0.25mm).
- These values represent the joint clearance at the brazing temperature, which may be different from room temperature clearance, depending on thermal expansion of the base metal(s).
- The issue is complicated by the fact that the optimum depends on: **(1) base and filler metals, (2) joint configuration, and (3) processing conditions.**
- Cleanliness of the joint surfaces prior to brazing is also important (surfaces must be free of oxides, oils, and other contaminants in order to promote wetting and capillary attraction during the process, as well as bonding across the entire interface).
- Chemical treatments such as solvent cleaning and mechanical treatments such as wire brushing and sand blasting are used to clean the surfaces.
- After cleaning and during the brazing operation, fluxes are used to maintain surface cleanliness and promote wetting for capillary action in the clearance between faying surfaces.

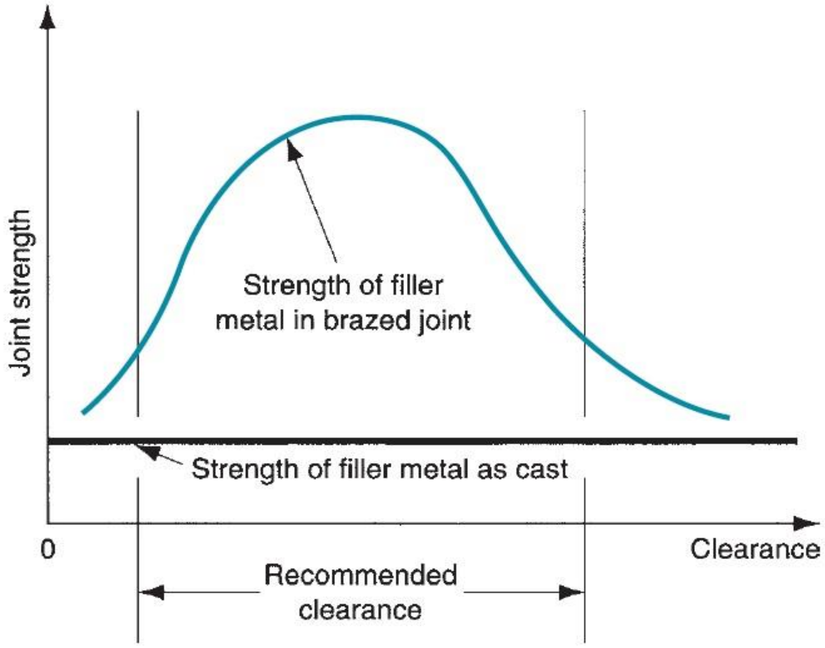

Figure (5-45) Joint strength as a function of joint clearance.

## Filler Metals and Fluxes

- To qualify as a brazing metal, the following characteristics are needed:

(1) melting temperature must be compatible with the base metal,

(2) surface tension in the liquid phase must be low for good wettability,

(3) fluidity of the molten metal must be high for penetration into the interface,

(4) the metal must be capable of being brazed into a joint of adequate strength for the application, and

(5) chemical and physical interactions with base metal (e.g., galvanic reaction) must be avoided.

- Filler metals are applied to the brazing operation in various ways, including wire, rod, sheets and strips, powders, pastes, preformed parts made of braze metal designed to fit a particular joint configuration, and cladding on one of the surfaces to be brazed.
- Several of these techniques are illustrated in Figures (5-46) and (5-47).
- Braze metal pastes, shown in Figure (5-47), consist of filler metal powders mixed with fluid fluxes and binders.
- **Brazing fluxes** serve a similar purpose as in welding; they dissolve, combine with, and otherwise inhibit the formation of oxides and other unwanted byproducts in the brazing process.

- Use of a flux does not substitute for the cleaning steps described above.
- **Flux Characteristics include:**

(1) low melting temperature,
(2) low viscosity so that it can be displaced by the filler metal,
(3) facilitates wetting, and
(4) protects the joint until solidification of the filler metal.
(5) The flux should also be easy to remove after brazing.

- Common ingredients for brazing fluxes include borax, borates, fluorides, and chlorides.
- Wetting agents are also included in the mix to reduce surface tension of the molten filler metal and to improve wettability.
- Forms of flux include powders, pastes, and slurries.
- Alternatives to using a flux are to perform the operation in a vacuum or a reducing atmosphere that inhibits oxide formation.

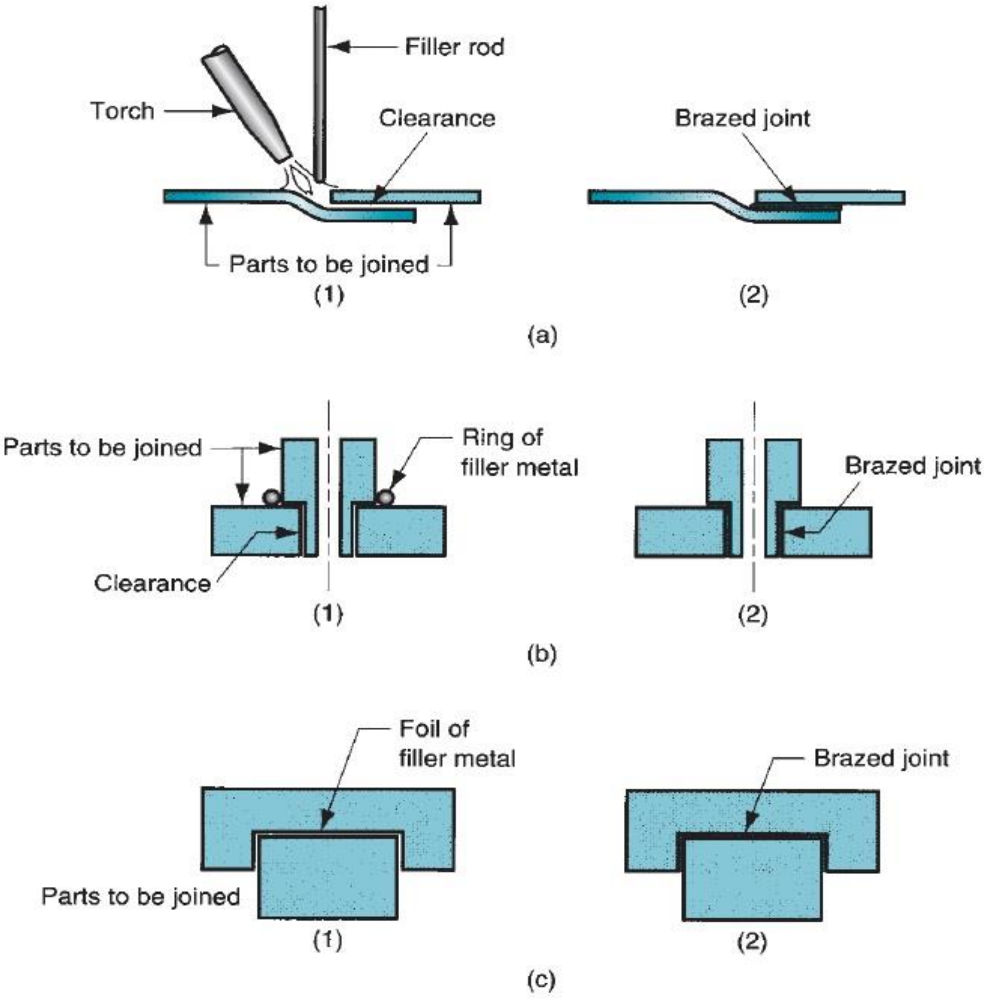

Figure (5-46) Several techniques for applying filler metal in brazing: (a) torch and filler rod; (b) ring of filler metal at Entrance of gap; and (c) foil of filler metal between flat part surfaces. Sequence: (1) before, and (2) after.

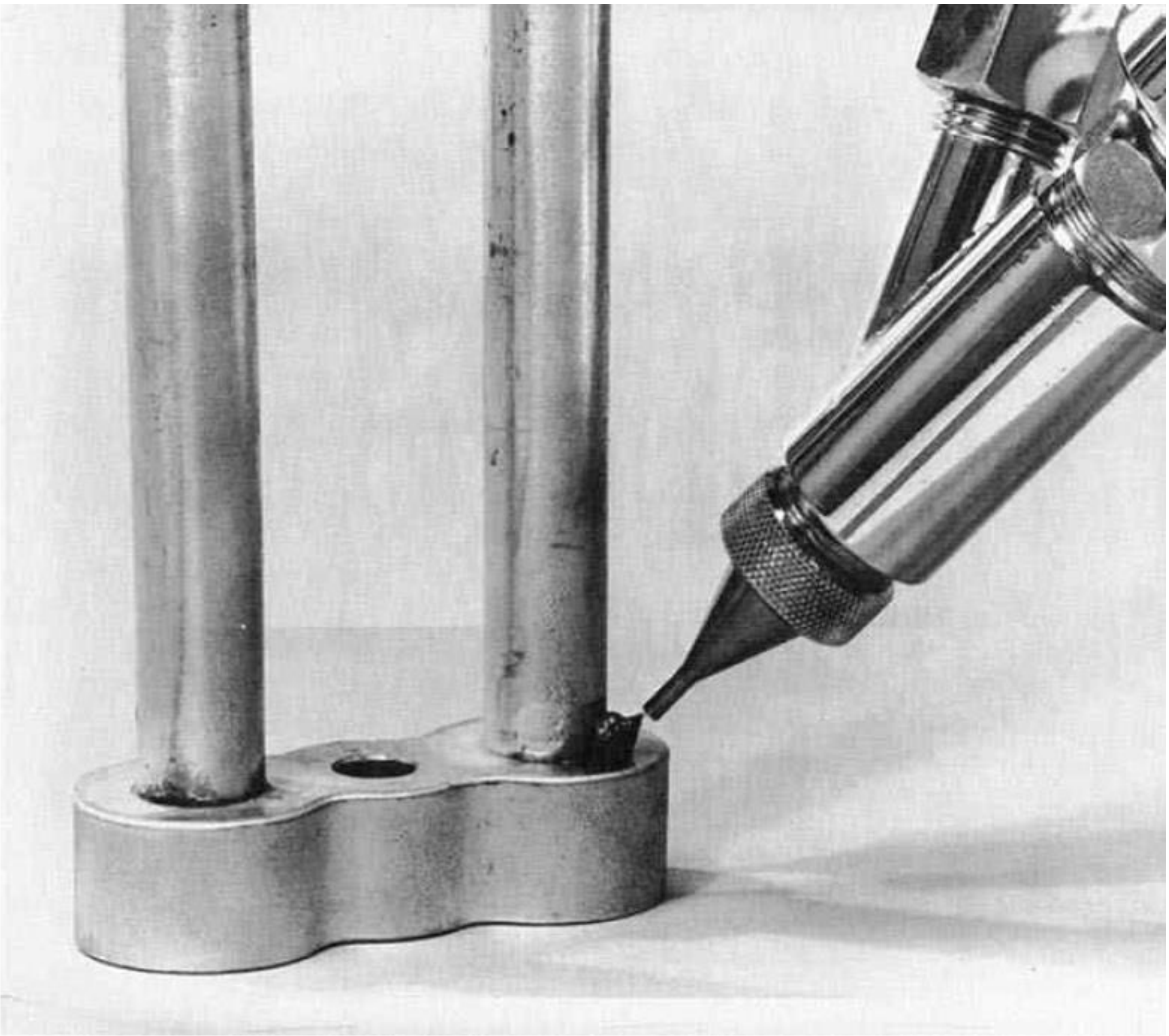

Figure (5-47) Application of brazing paste to joint by dispenser.

## Brazing Methods

There are various methods used in brazing. Referred to as brazing processes, they are differentiated by their heating sources.

### (a) Torch Brazing

- In torch brazing, flux is applied to the part surfaces and a torch is used to direct a flame against the work in the vicinity of the joint.
- A reducing flame is typically used to inhibit oxidation.
- After the w.p. joint areas have been heated to a suitable temperature, filler wire is added to the joint, usually in wire or rod form.
- Fuels used in torch brazing include acetylene, propane, and other gases, with air or oxygen.

- The selection of the mixture depends on heating requirements of the job.
- Torch brazing is often performed manually, and skilled workers must be employed to control the flame, manipulate the hand-held torches, and properly judge the temperatures; repair w.ps. is a common application.
- The method can also be used in mechanized production operations, in which parts and brazing metal are loaded onto a conveyor or indexing table and passed under one or more torches.

### (b) Furnace Brazing

- Furnace brazing uses a furnace to supply heat for brazing and is best suited to medium and high production.
- In medium production, usually in batches, the component parts and brazing metal are loaded into the furnace, heated to brazing temperature, and then cooled and removed.
- High-production operations use flow-through furnaces, in which parts are placed on a conveyor and are transported through the various heating and cooling sections.
- Temperature and atmosphere control are important in furnace brazing; the atmosphere must be neutral or reducing.
- Vacuum furnaces are sometimes used.
- Depending on the atmosphere and metals being brazed, the need for a flux may be eliminated.

### (c) Induction Brazing

- Induction brazing utilizes heat from electrical resistance to a high frequency current induced in the w.p.
- The parts are preloaded with filler metal and placed in a high-frequency AC field—the parts do not directly contact the induction coil.
- Frequencies range from 5 $kH_z$ to 5 $MH_z$.
- High-frequency power sources tend to provide surface heating, while lower frequencies cause deeper heat penetration into the work and are appropriate for heavier sections.
- The process can be used to meet low- to high production requirements.

### (d) Resistance Brazing

- Heat to melt the filler metal in this process is obtained by resistance to flow of electrical current through the parts.
- As distinguished from induction brazing, the parts are directly connected to the electrical circuit in resistance brazing.

- The equipment is similar to that used in resistance welding, except that a lower power level is required for brazing.
- The parts with filler metal preplaced are held between electrodes while pressure and current are applied.
- Both induction and resistance brazing achieve rapid heating cycles and are used for relatively small parts.
- Induction brazing seems to be the more widely used of the two processes.

### (e) Dip Brazing

- In dip brazing, either a molten salt bath or a molten metal bath accomplishes heating.
- In both methods, assembled parts are immersed in the baths contained in a heating pot.
- Solidification occurs when the parts are removed from the bath.
- In the salt bath method, the molten mixture contains fluxing ingredients and the filler metal is preloaded onto the assembly.
- In the metal bath method, the molten filler metal is the heating medium; it is drawn by capillary action into the joint during submersion.
- A flux cover is maintained on the surface of the molten metal bath.
- Dip brazing achieves fast heating cycles and can be used to braze many joints on a single part or on multiple parts simultaneously.

### (f) Infrared Brazing

- This method uses heat from a high-intensity infrared lamp.
- Some IR lamps are capable of generating up to 5000 W of radiant heat energy, which can be directed at the w.ps. for brazing.
- The process is slower than most of the other processes reviewed above, and is generally limited to thin sections.

### (g) Braze Welding

- This process differs from the other brazing processes in the type of joint to which it is applied.
- As pictured in Figure (5-48), braze welding is used for filling a more conventional weld joint, such as the V-joint shown.
- A greater quantity of filler metal is deposited than in brazing, and no capillary action occurs.
- In braze welding, the joint consists entirely of filler metal; the base metal does not melt and is therefore not fused into the joint as in a conventional fusion welding process.

- The principal application of braze welding is repair work.

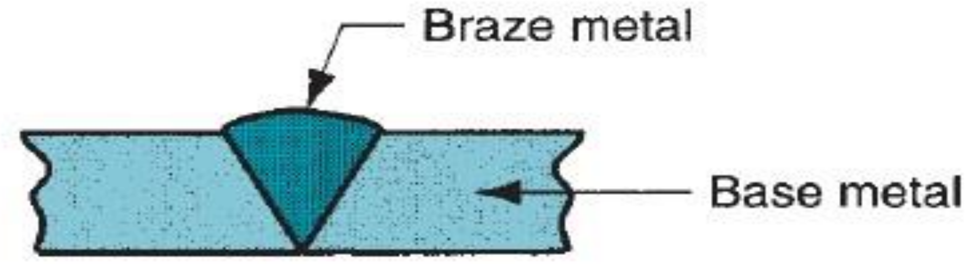

Figure (5-48) Braze welding. The joint consists of braze (filler) metal; no base metal is fused in the joint.