BRAZING, SOLDERING, AND ADHESIVE BONDING

1. Brazing
2. Soldering
3. Adhesive Bonding

Overview of Brazing and Soldering

- Both use filler metals to permanently join metal parts, but there is no melting of base metals
- When to use brazing or soldering instead of fusion welding:
  - Metals have poor weldability
  - Dissimilar metals are to be joined
  - Intense heat of welding may damage components being joined
  - Geometry of joint not suitable for welding
  - High strength is not required

Overview of Adhesive Bonding

- Uses forces of attachment between a filler material and two closely-spaced surfaces to bond the parts
  - Filler material in adhesive bonding is not metallic
  - Joining process can be carried out at room temperature or only modestly above

Brazing

Joining process in which a filler metal is melted and distributed by capillary action between faying surfaces of metal parts being joined

- No melting of base metals occurs
  - Only the filler melts
- Filler metal T_m greater than 450°C (840°F) but less than T_m of base metal(s) to be joined

Strength of Brazed Joint

- If joint is properly designed and brazing operation is properly performed, solidified joint will be stronger than filler metal out of which it was formed
- Why?
  - Small part clearances used in brazing
  - Metallurgical bonding that occurs between base and filler metals
  - Geometric constrictions imposed on joint by base parts

Brazing Compared to Welding

- Any metals can be joined, including dissimilar metals
- Can be performed quickly and consistently, permitting high production rates
- Multiple joints can be brazed simultaneously
- Less heat and power required than FW
- Problems with HAZ in base metal are reduced
- Joint areas that are inaccessible by many welding processes can be brazed; capillary action draws molten filler metal into joint

Disadvantages and Limitations of Brazing

- Joint strength is generally less than a welded joint
- Joint strength is likely to be less than the base metals
- High service temperatures may weaken a brazed joint
- Color of brazing metal may not match color of base metal parts, a possible aesthetic disadvantage

Brazing Applications

- 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)
- Jewelry
- Chemical process industry
- Plumbing and heating contractors join metal pipes and tubes by brazing
- Repair and maintenance work

Brazed Joints

- Butt and lap joints common
  - Geometry of butt joints is usually adapted for brazing
  - Lap joints are more widely used, since they provide larger interface area between parts
- Filler metal in a brazed lap joint is bonded to base parts throughout entire interface area, rather than only at edges

Butt Joints for Brazing

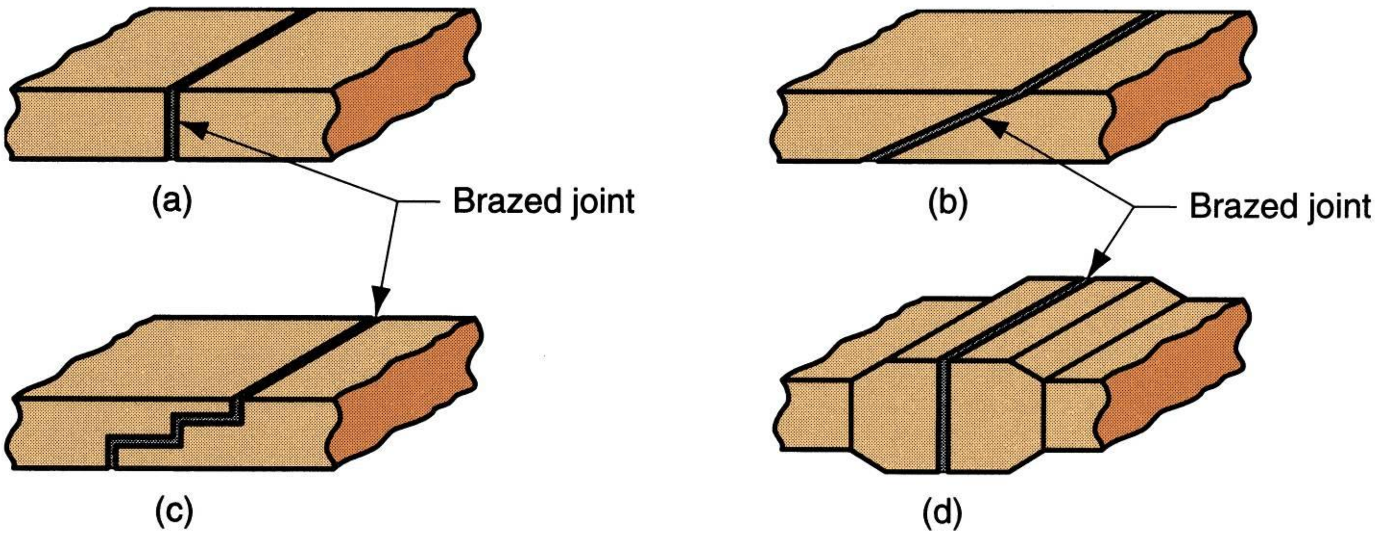


Figure 32.1 (a) Conventional butt joint, and adaptations of the butt joint for brazing: (b) scarf joint, (c) stepped butt joint, (d) increased cross-section of the part at the joint.

Lap Joints for Brazing

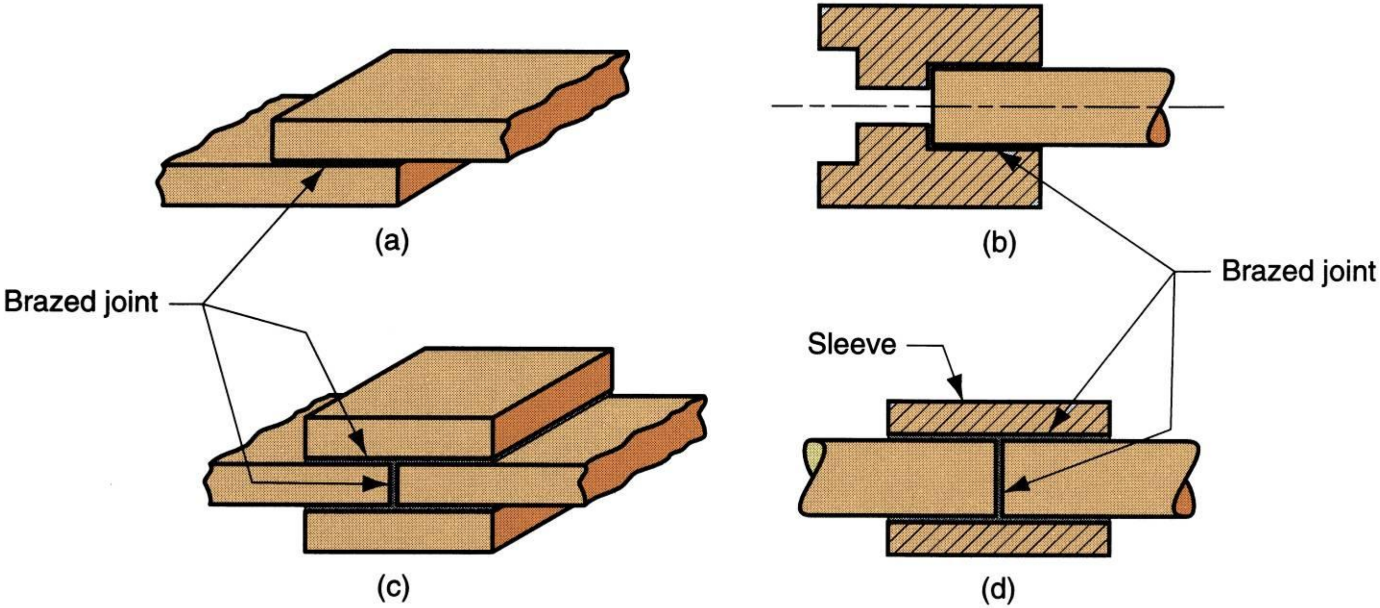


Figure 32.2 (a) Conventional lap joint, and adaptations of the lap joint for brazing: (b) cylindrical parts, (c) sandwiched parts, and (d) use of sleeve to convert butt joint into lap joint.

Some Filler Metals for Brazing

Base metal(s)	Filler metal(s)
Aluminum	Aluminum and silicon
Nickel-copper alloy	Copper
Copper	Copper and phosphorous
Steel, cast iron	Copper and zinc
Stainless steel	Gold and silver

Desirable Brazing Metal Characteristics

- Melting temperature of filler metal is compatible with base metal
- Low surface tension in liquid phase for good wettability
- High fluidity for penetration into interface
- Capable of being brazed into a joint of adequate strength for application
- Avoid chemical and physical interactions with base metal (e.g., galvanic reaction)

Applying Filler Metal

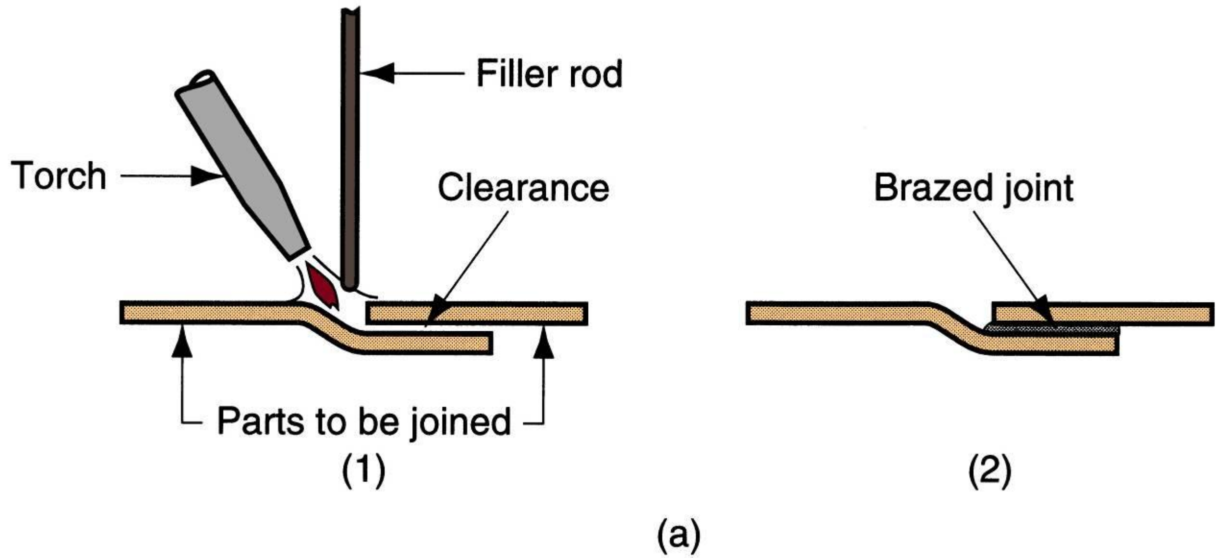


Figure 32.4 Several techniques for applying filler metal in brazing: (a) torch and filler rod. Sequence: (1) before, and (2) after.

Applying Filler Metal

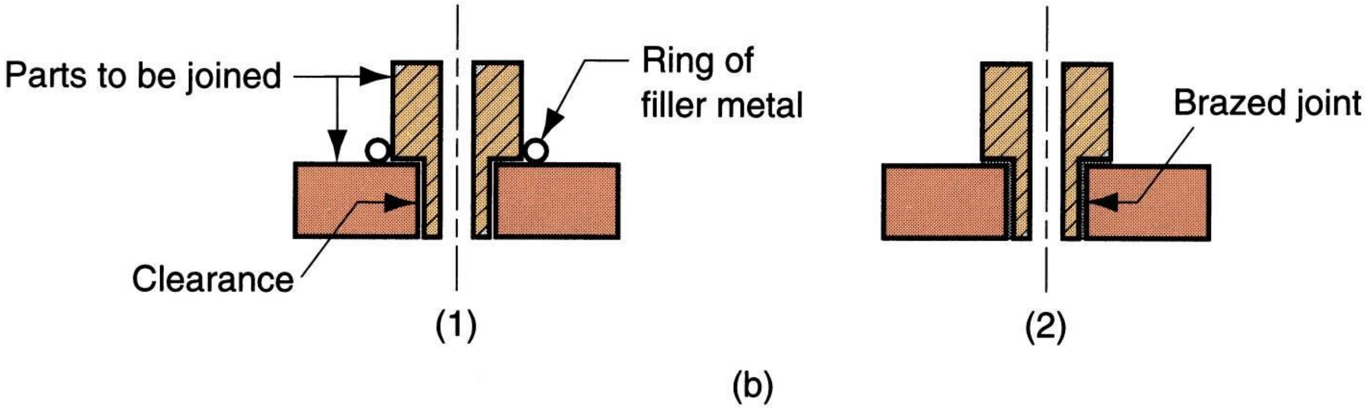


Figure 32.4 Several techniques for applying filler metal in brazing: (b) ring of filler metal at entrance of gap. Sequence: (1) before, and (2) after.

Brazing Fluxes

- Similar purpose as in welding; they dissolve, combine with, and otherwise inhibit formation of oxides and other unwanted byproducts in brazing process
- Characteristics of a good flux include:
  - Low melting temperature
  - Low viscosity so it can be displaced by filler metal
  - Facilitates wetting
  - Protects joint until solidification of filler metal

Heating Methods in Brazing

- Torch Brazing - torch directs flame against work in vicinity of joint
- Furnace Brazing - furnace supplies heat
- Induction Brazing – heating by electrical resistance to high-frequency current in work
- Resistance Brazing - heating by electrical resistance in parts
- Dip Brazing - molten salt or molten metal bath
- Infrared Brazing - uses high-intensity infrared lamp

Soldering

Joining process in which a filler metal with T_m less than or equal to 450C (840F) is melted and distributed by capillary action between faying surfaces of metal parts being joined

- No melting of base metals, but filler metal wets and combines with base metal to form metallurgical bond
- Soldering similar to brazing, and many of the same heating methods are used
- Filler metal called *solder*
- Most closely associated with electrical and electronics assembly (wire soldering)

Soldering Advantages / Disadvantages

Advantages:

- Lower energy than brazing or fusion welding
- Variety of heating methods available
- Good electrical and thermal conductivity in joint
- Easy repair and rework

Disadvantages:

- Low joint strength unless reinforced by mechanically means
- Possible weakening or melting of joint in elevated temperature service

Solders

Usually alloys of tin (Sn) and lead (Pb). Both metals have low T_m

- Lead is poisonous and its percentage is minimized in most solders
- Tin is chemically active at soldering temperatures and promotes wetting action for successful joining
- In soldering copper, copper and tin form intermetallic compounds that strengthen bond
- Silver and antimony also used in soldering alloys

Mechanical Means to Secure Joint

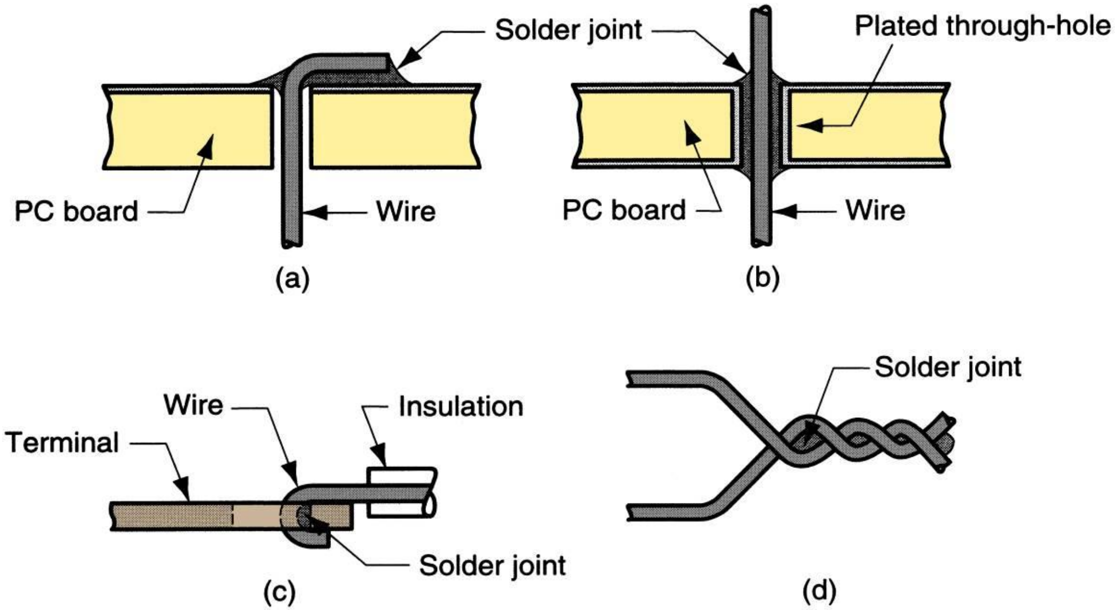


Figure 32.8 Techniques for securing the joint by mechanical means prior to soldering in electrical connections: (a) crimped lead wire on PC board; (b) plated through-hole on PC board to maximize solder contact surface; (c) hooked wire on flat terminal; and (d) twisted wires.

Functions of Soldering Fluxes

- Be molten at soldering temperatures
- Remove oxide films and tarnish from base part surfaces
- Prevent oxidation during heating
- Promote wetting of faying surfaces
- Be readily displaced by molten solder during process
- Leave residue that is non-corrosive and nonconductive

Soldering Methods

- Many soldering methods same as for brazing, except less heat and lower temperatures are required
- Additional methods:
  - Hand soldering – manually operated *soldering gun*
  - Wave soldering – soldering of multiple lead wires in printed circuit cards
  - Reflow soldering –used for surface mount components on printed circuit cards

Wave Soldering

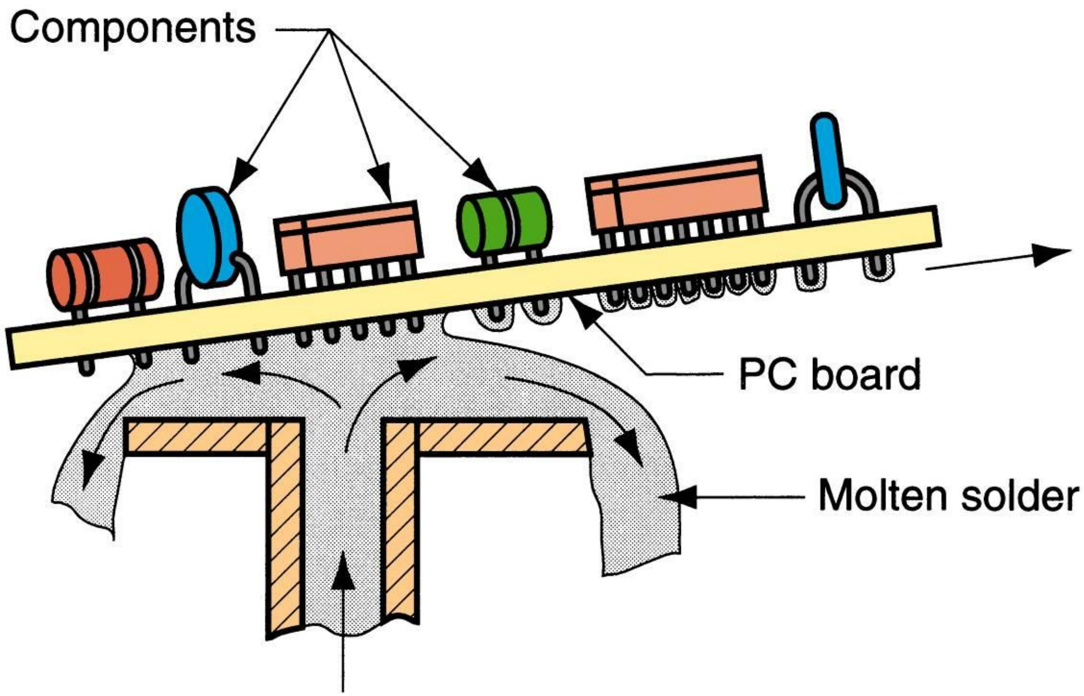


Figure 32.9 Wave soldering, in which molten solder is delivered up through a narrow slot onto the underside of a printed circuit board to connect the component lead wires.

Adhesive Bonding

Joining process in which a filler material is used to hold two (or more) closely-spaced parts together by surface attachment

- Used in a wide range of bonding and sealing applications for joining similar and dissimilar materials such as metals, plastics, ceramics, wood, paper, and cardboard
- Considered a growth area because of opportunities for increased applications

Terminology in Adhesive Bonding

- *Adhesive* = filler material, nonmetallic, usually a polymer
- *Adherends* = parts being joined
- *Structural adhesives* – of greatest interest in engineering, capable of forming strong, permanent joints between strong, rigid adherends

Curing in Adhesive Bonding

Process by which physical properties of the adhesive are changed from liquid to solid, usually by chemical reaction, to accomplish surface attachment of parts

- Curing often aided by heat and/or a catalyst
  - If heat used, temperatures are relatively low
- Curing takes time - a disadvantage in production
- Pressure sometimes applied between parts to activate bonding process

Joint Strength

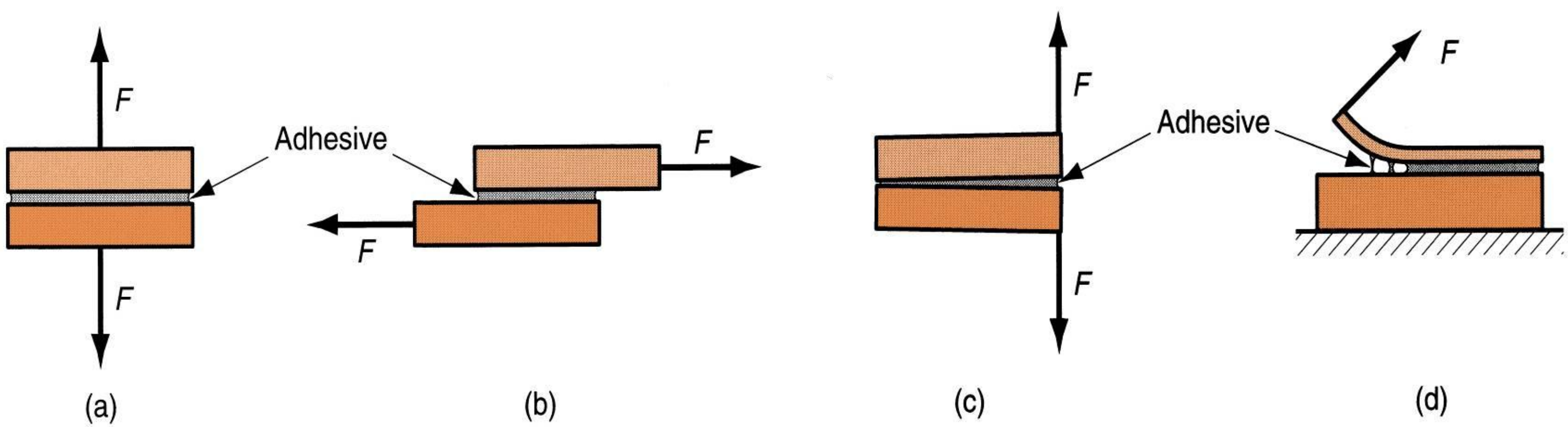
- Depends on strength of:
  - Adhesive
  - Attachment between adhesive and adherends
- Attachment mechanisms:
  - Chemical bonding – adhesive and adherend form primary bond on curing
  - Physical interactions - secondary bonding forces between surface atoms
  - Mechanical interlocking - roughness of adherend causes adhesive to become entangled in surface asperities

Joint Design

- Adhesive joints are not as strong as welded, brazed, or soldered joints
- Joint contact area should be maximized
- Adhesive joints are strongest in shear and tension
  - Joints should be designed so applied stresses are of these types
- Adhesive bonded joints are weakest in *cleavage* or *peeling*
  - Joints should be designed to avoid these types of stresses

Types of Stresses in Adhesive Bonding

Figure 32.10 Types of stresses that must be considered in adhesive bonded joints: (a) tension, (b) shear, (c) cleavage, and (d) peeling.



Joint Designs in Adhesive Bonding

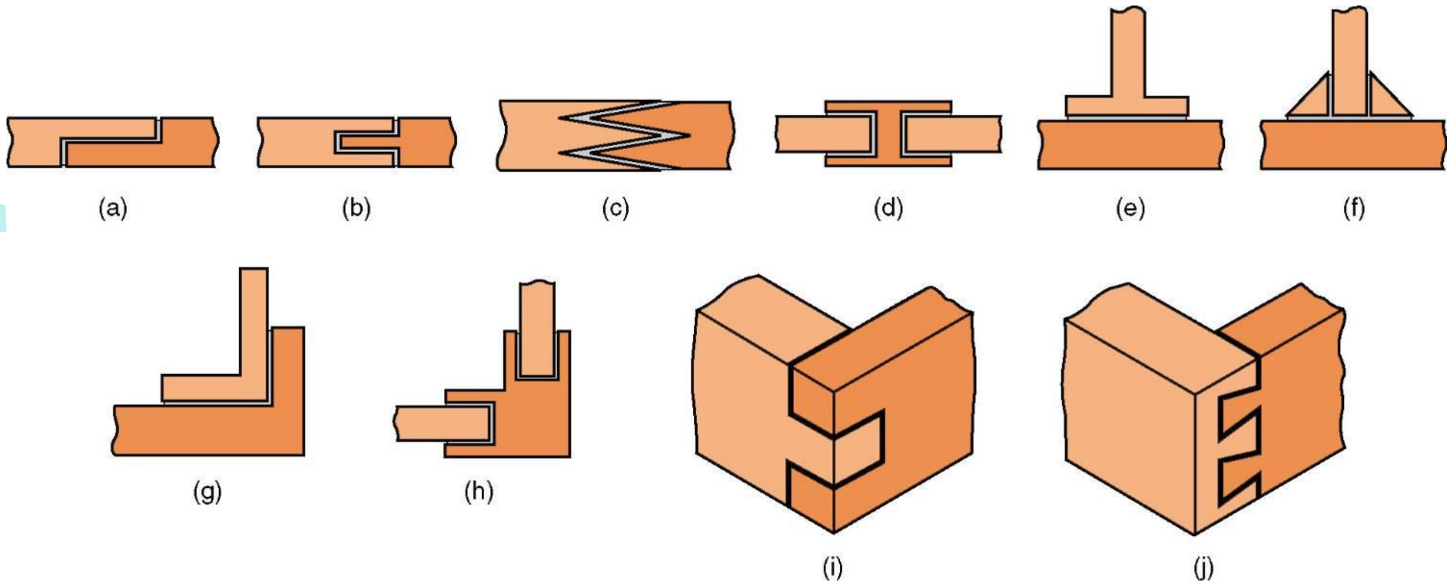


Figure 32.11 Some joint designs for adhesive bonding: (a) through (d) butt joints; (e) through (f) T-joints; (b) and (g) through (j) corner joints.

Adhesive Types

- Natural adhesives - derived from natural sources, including gums, starch, dextrin, soya flour, collagen
  - Low-stress applications: cardboard cartons, furniture, bookbinding, plywood
- Inorganic - based principally on sodium silicate and magnesium oxychloride
  - Low cost, low strength
- Synthetic adhesives - various thermoplastic and thermosetting polymers

Synthetic Adhesives

- Most important category in manufacturing
- Synthetic adhesives cured by various mechanisms:
  - Mixing catalyst or reactive ingredient with polymer prior to applying
  - Heating to initiate chemical reaction
  - Radiation curing, such as UV light
  - Curing by evaporation of water
  - Application as films or pressure-sensitive coatings on surface of adherend

Applications of Adhesives

- Automotive, aircraft, building products, shipbuilding
- Packaging industries
- Footwear
- Furniture
- Bookbinding
- Electrical and electronics

Surface Preparation

- For adhesive bonding to succeed, part surfaces must be extremely clean
- Bond strength depends on degree of adhesion between adhesive and adherend, and this depends on cleanliness of surface
  - For metals, solvent wiping often used for cleaning, and abrading surface by sandblasting improves adhesion
  - For nonmetallic parts, surfaces are sometimes mechanically abraded or chemically etched to increase roughness

Application Methods

- Manual brushing and rolling
- Silk screening
- Flowing, using manually operated dispensers
- Spraying
- Automatic applicators
- Roll coating

Adhesive is dispensed by a manually controlled dispenser to bond parts during assembly (photo courtesy of EFD Inc.).

Advantages of Adhesive Bonding

- Applicable to a wide variety of materials
- Bonding occurs over entire surface area of joint
- Low temperature curing avoids damage to parts being joined
- Sealing as well as bonding
- Joint design is often simplified, e.g., two flat surfaces can be joined without providing special part features such as screw holes

Limitations of Adhesive Bonding

- Joints generally not as strong as other joining methods
- Adhesive must be compatible with materials being joined
- Service temperatures are limited
- Cleanliness and surface preparation prior to application of adhesive are important
- Curing times can limit production rates
- Inspection of bonded joint is difficult