

MSE 440/540: Processing of Metallic Materials

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Lecture 7: Joining Methods

Joining and Assembly

Joining - welding, brazing, soldering, and adhesive bonding

- These processes form a permanent joint between parts

Assembly - mechanical methods (usually) of fastening parts together

- Some of these methods allow for easy disassembly, while others do not

Types of Welding Processes

Welding processes can be divided into two major categories:

Fusion welding

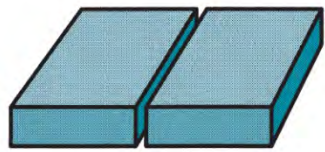
- Arc welding (AW)
- Resistance welding (RW)
- Oxyfuel gas welding (OFW)

Solid state welding: Joining processes using pressure alone or a combination of heat and pressure

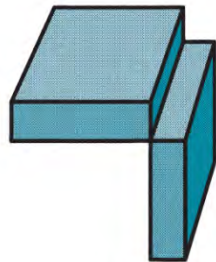
- If heat is used, temperature is below melting point of metals being welded
- No filler metal is added in solid state welding

Five Types of Joints

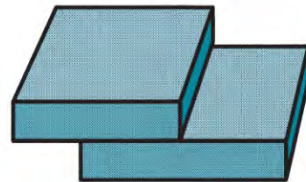
(a) Butt joint, (b) corner joint, (c) lap joint, (d) tee joint, and (e) edge joint



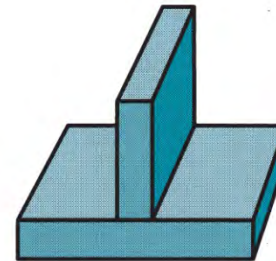
(a)



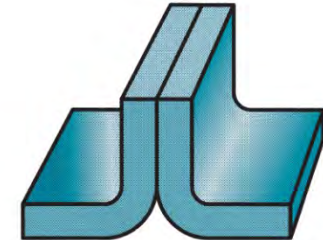
(b)



(c)



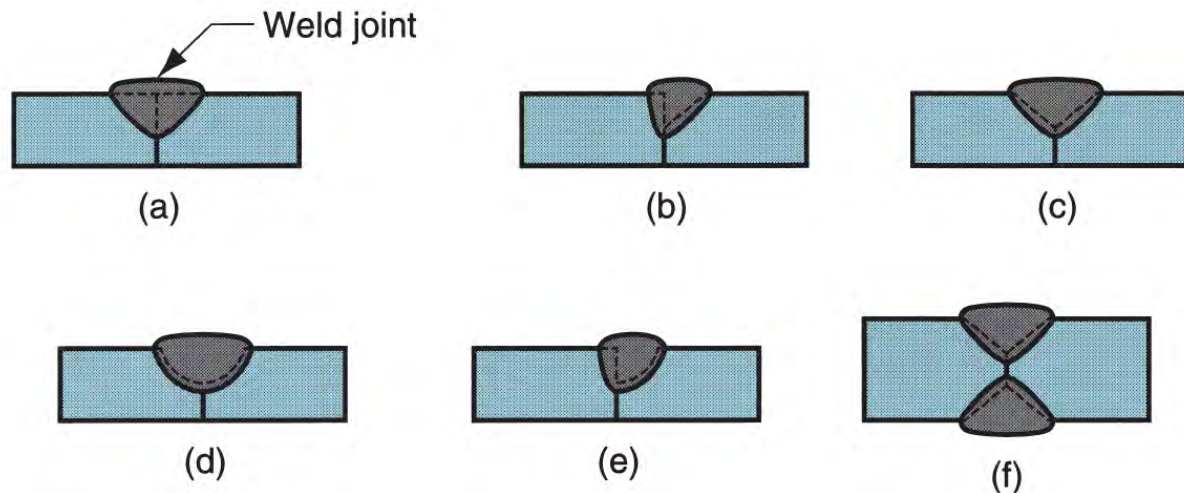
(d)



(e)

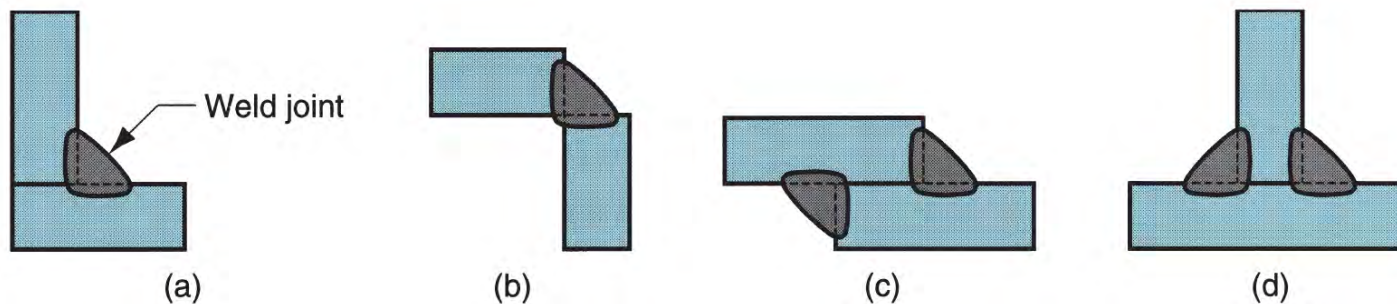
Groove Welds

- (a) Square groove weld, one side; (b) single bevel groove weld; (c) single V-groove weld; (d) single U-groove weld; (e) single J-groove weld; (f) double V-groove weld for thicker sections (dashed lines show original part edges)



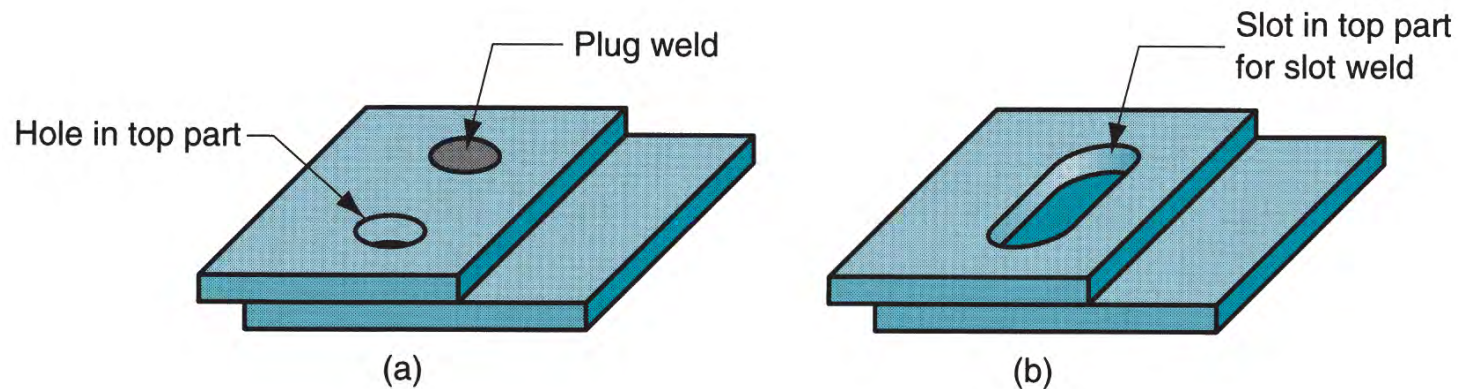
Fillet Welds

- (a) Inside single fillet corner joint; (b) outside single fillet corner joint; (c) double fillet lap joint; (d) double fillet tee joint (dashed lines show the original part edges)



Plug Weld and Slot Weld

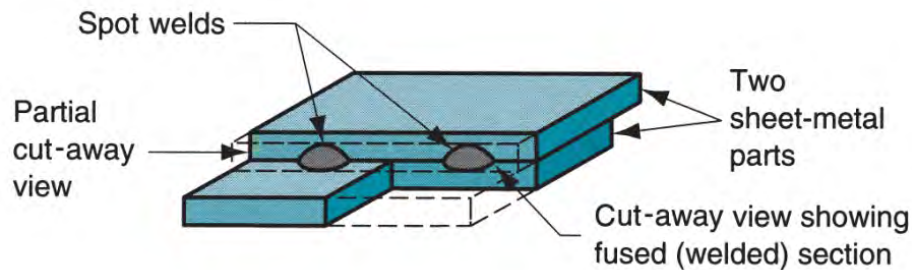
- (a) Plug weld and (b) slot weld



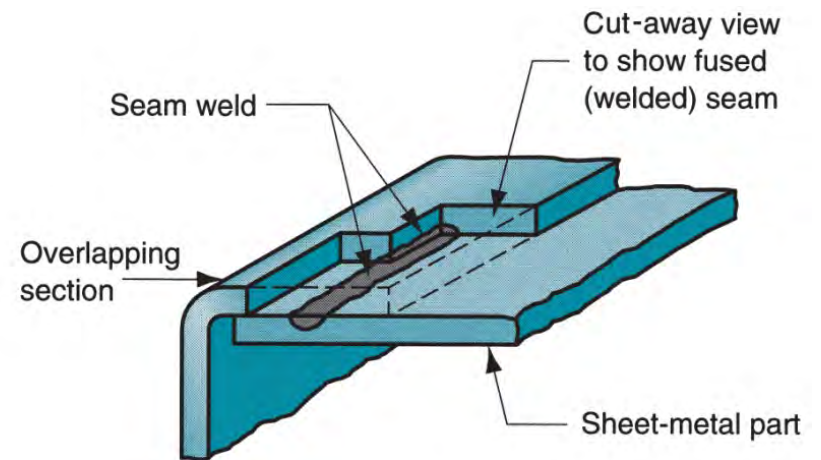
Spot Weld and Seam Weld

Fused section between surfaces of two sheets or plates: (a) spot weld and (b) seam weld

- Used for lap joints
- Closely associated with resistance welding

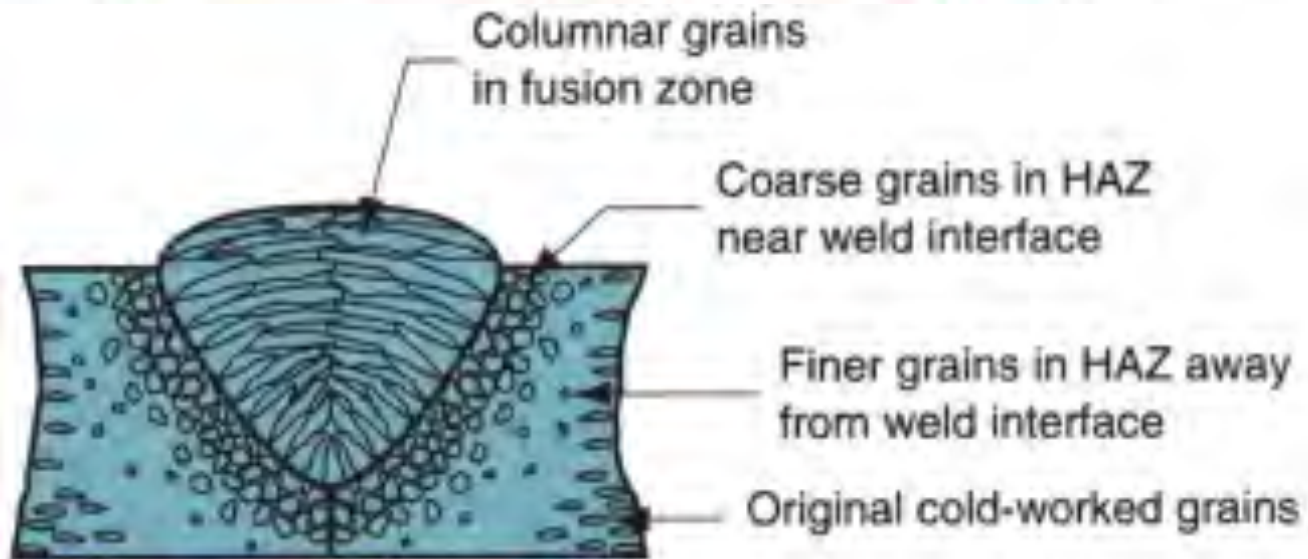
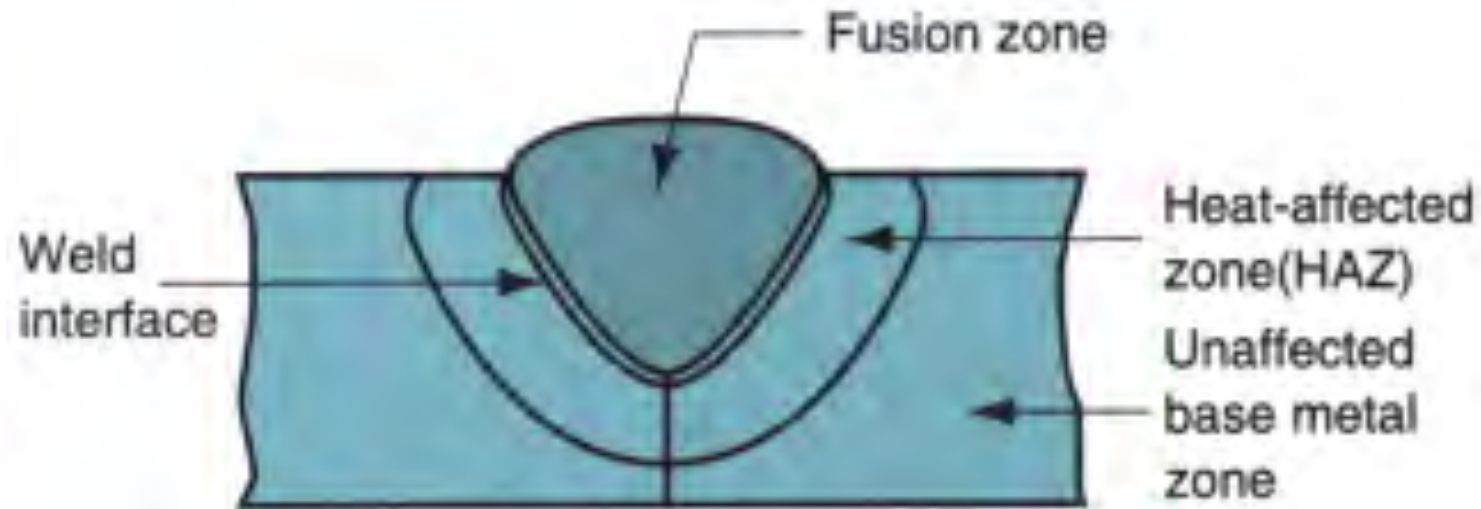


(a)



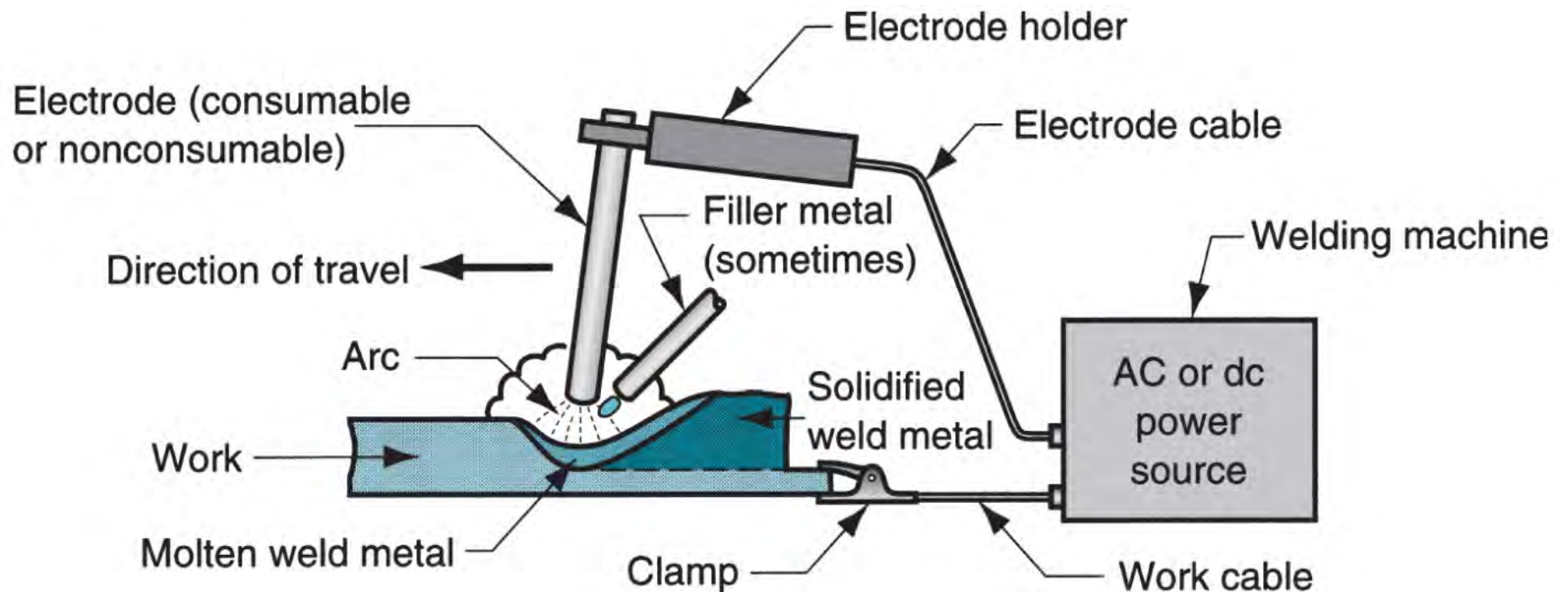
(b)

Typical Fusion Welded Joint



Arc Welding: The most common fusion welding

- A pool of molten metal is formed near electrode tip, and as electrode is moved along joint, molten weld pool solidifies in its wake



<http://www.youtube.com/watch?v=TeBX6cKKHWY>

Two Basic Types of Arc Welding Electrodes

- Consumable – consumed during welding process
 - Source of filler metal in arc welding
- Nonconsumable – not consumed during welding process (e.g. Tungsten)
 - Filler metal must be added separately if it is added

Arc Shielding

- At high temperatures in arc welding, metals are chemically reactive to O_2 , N_2 and H_2 in air
 - Mechanical properties of joint can be degraded by these reactions
 - To protect operation, arc must be shielded from surrounding air in AW processes
- Arc shielding is accomplished by:
 - Shielding gases, e.g., argon, helium, CO_2
 - Flux

Flux

▪ A substance that prevents formation of oxides and other contaminants in welding, or dissolves them and facilitates removal

- Provides protective atmosphere for welding
- Stabilizes arc
- Reduces spattering

▫ **Flux Application**

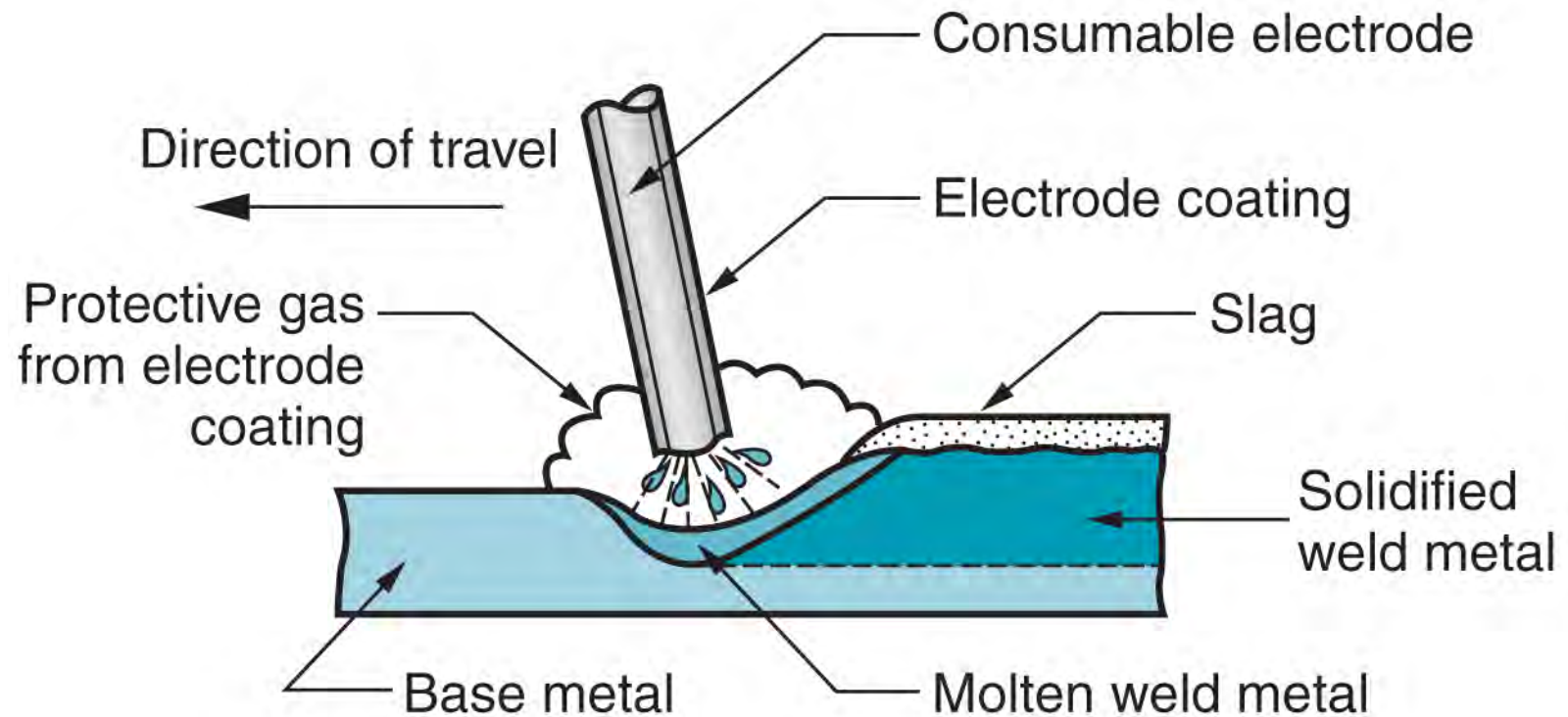
- Pouring granular flux onto welding operation
- Stick electrode coated with flux material that melts during welding to cover operation
- Tubular electrodes in which flux is contained in the core and released as electrode is consumed

Consumable Electrode Arc Welding Processes

- Shielded Metal Arc Welding
- Gas Metal Arc Welding
- Flux-Cored Arc Welding
- Electrode Gas Welding
- Submerged Arc Welding

Shielded Metal Arc Welding (SMAW)

Uses a consumable electrode consisting of a filler metal rod coated with chemicals that provide flux and shielding



Welding Stick in SMAW

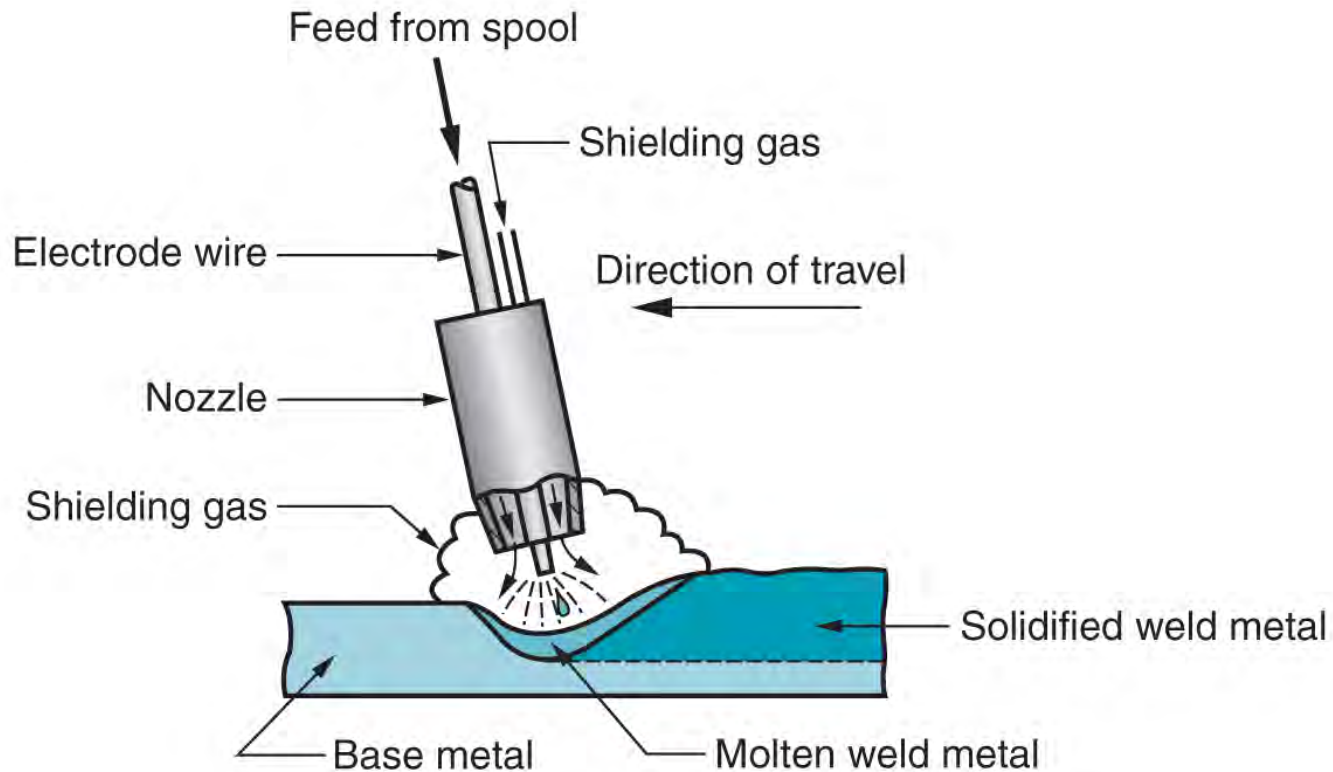
- Composition of filler metal usually close to base metal
- Coating: powdered cellulose mixed with oxides and carbonates, and held together by a silicate binder
- Disadvantages of stick welding:
 - Sticks must be periodically changed
 - High current levels may melt coating prematurely

SMAW Applications

- Used for steels, stainless steels, cast irons, and certain nonferrous alloys
- Not used or rarely used for aluminum and its alloys, copper alloys, and titanium

Gas Metal Arc Welding

Uses a consumable bare metal wire as electrode with shielding by flooding arc with a gas

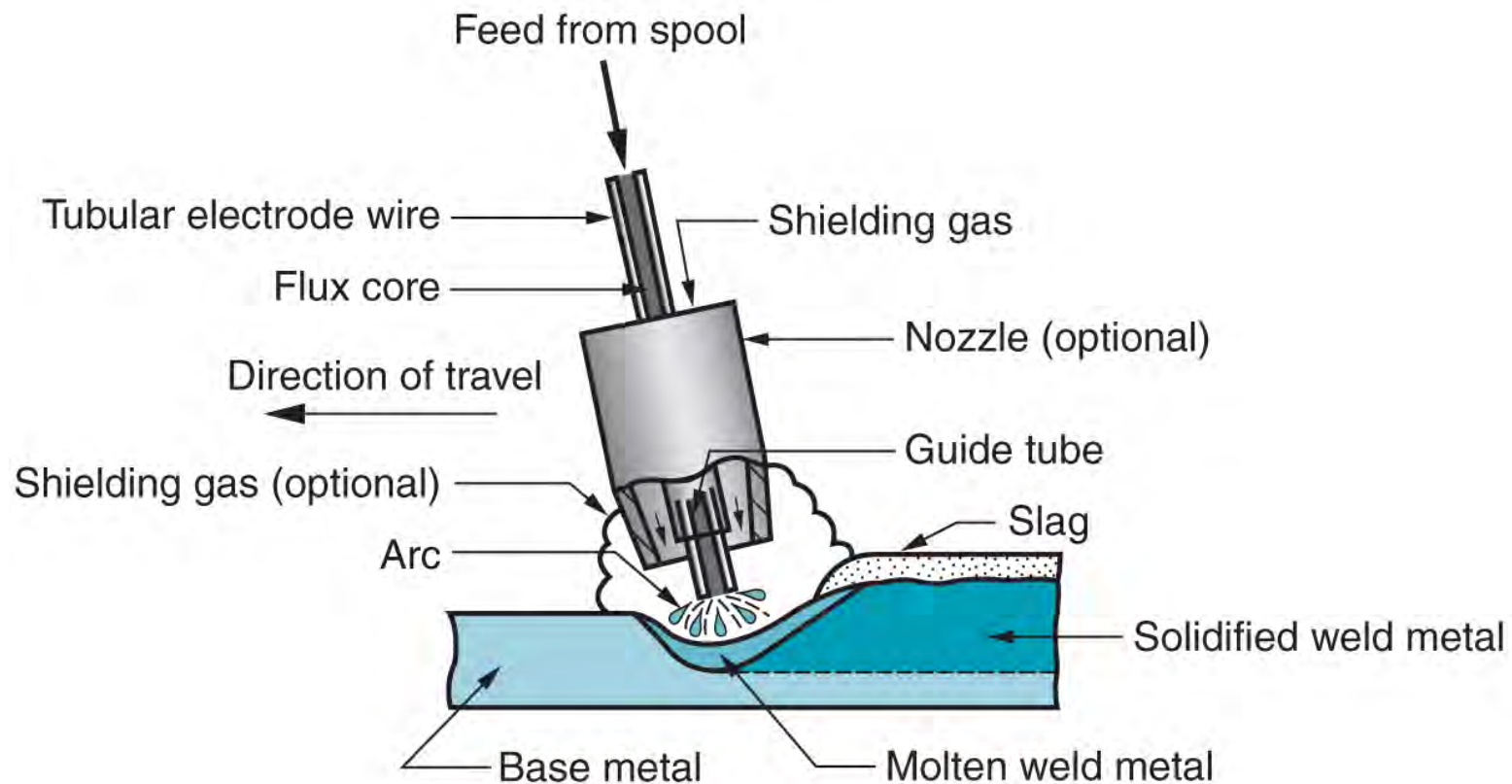


GMAW Advantages over SMAW

- Better arc time because of continuous wire electrode
 - Sticks must be periodically changed in SMAW
- Better use of electrode filler metal than SMAW
 - End of stick cannot be used in SMAW
- Higher deposition rates
- Eliminates problem of slag removal
- Can be readily automated

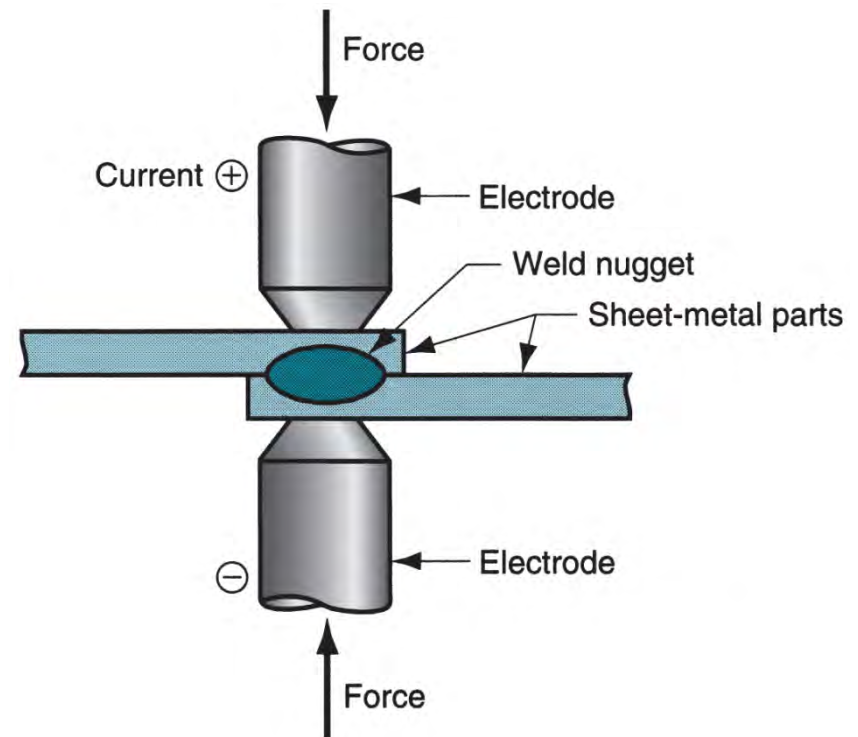
Flux-Cored Arc Welding

Presence or absence of externally supplied shielding gas distinguishes: (1) self-shielded - core provides ingredients for shielding, (2) gas-shielded - uses external shielding gases



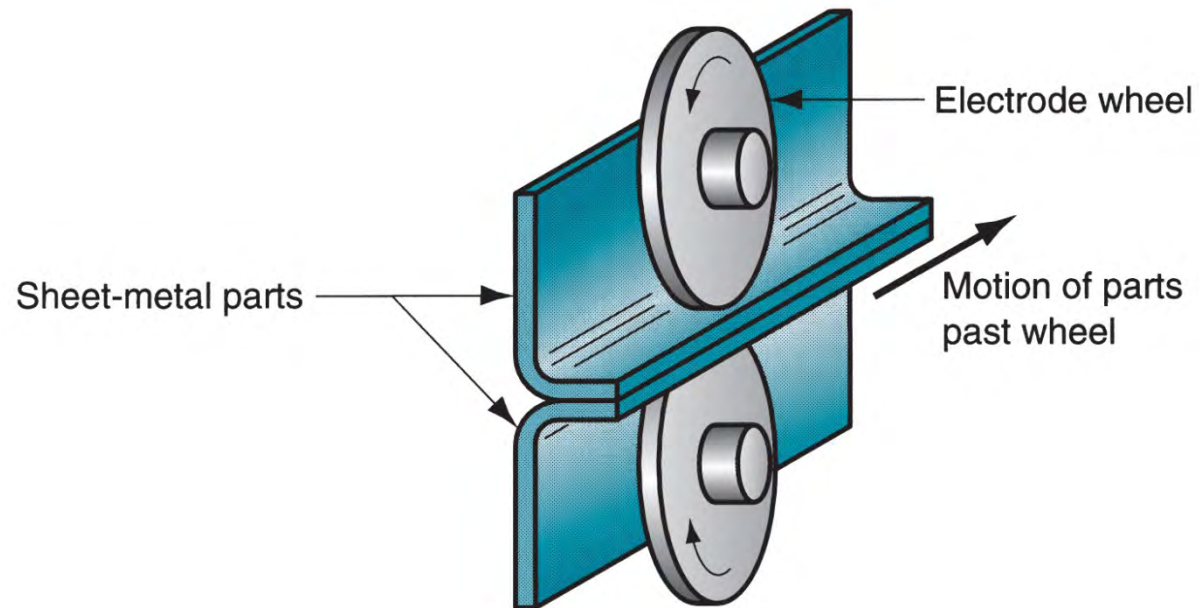
Resistance Welding

- Resistance welding, showing components in spot welding, the main process in the RW group

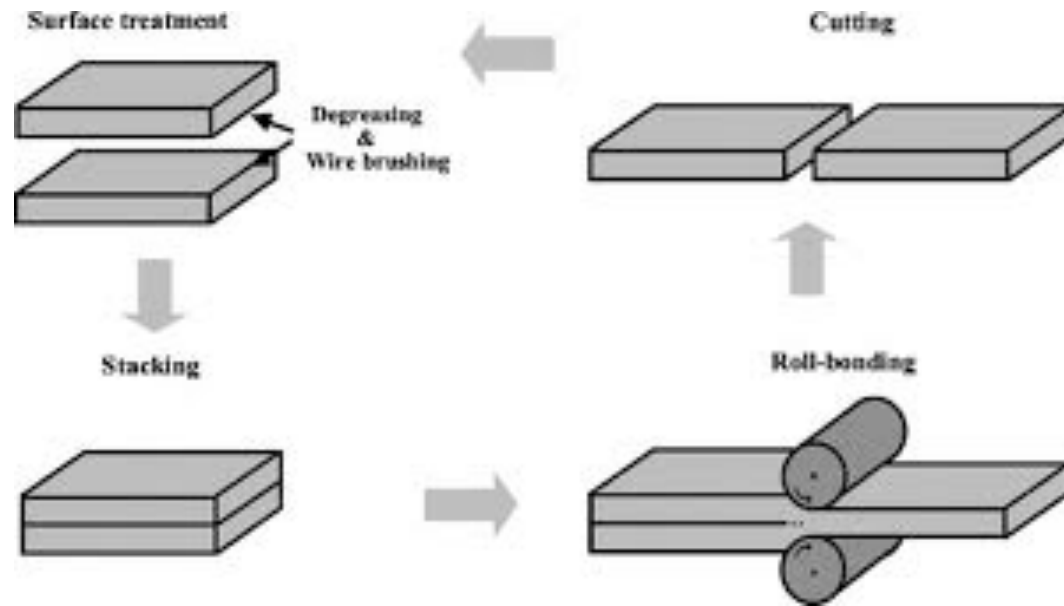
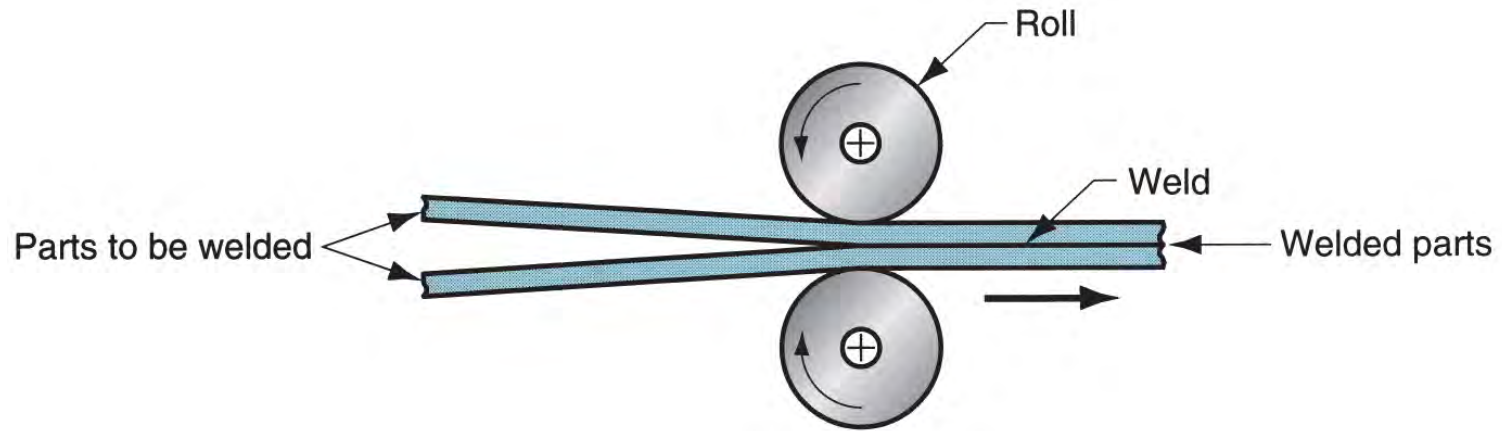


<http://www.youtube.com/watch?v=66-RK0DPXfU>

Resistance Seam Welding

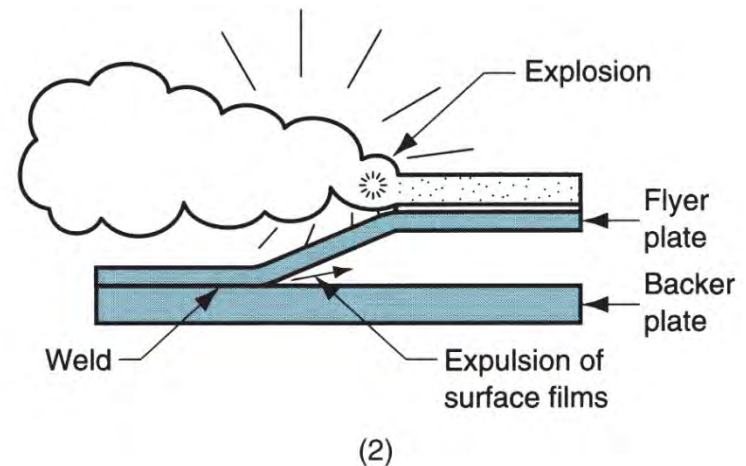
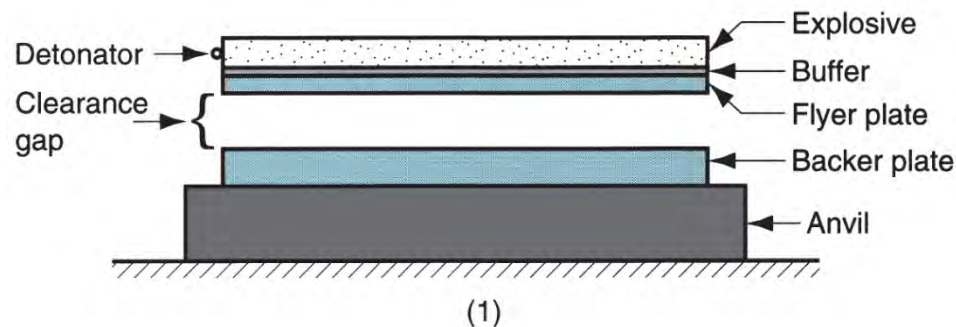


Roll Welding



Explosive Welding

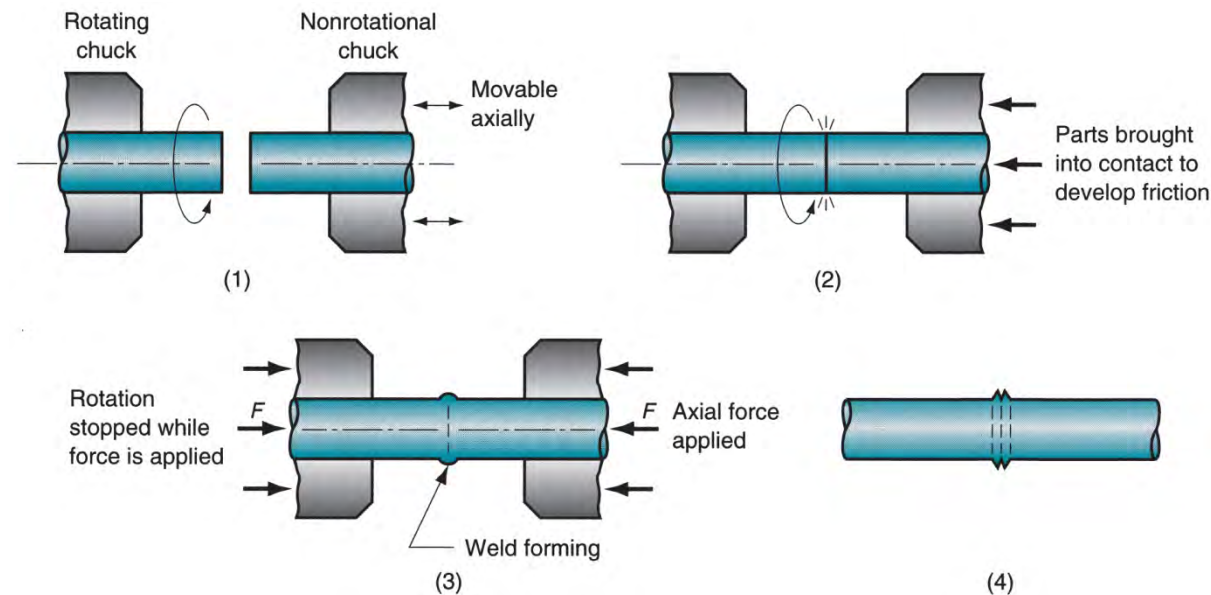
- Commonly used to bond two dissimilar metals, e.g., to clad one metal on top of a base metal over large areas
- (1) Setup in parallel configuration, and (2) during detonation of the explosive charge



http://www.youtube.com/watch?v=HvJee_1w4tA

Friction Welding

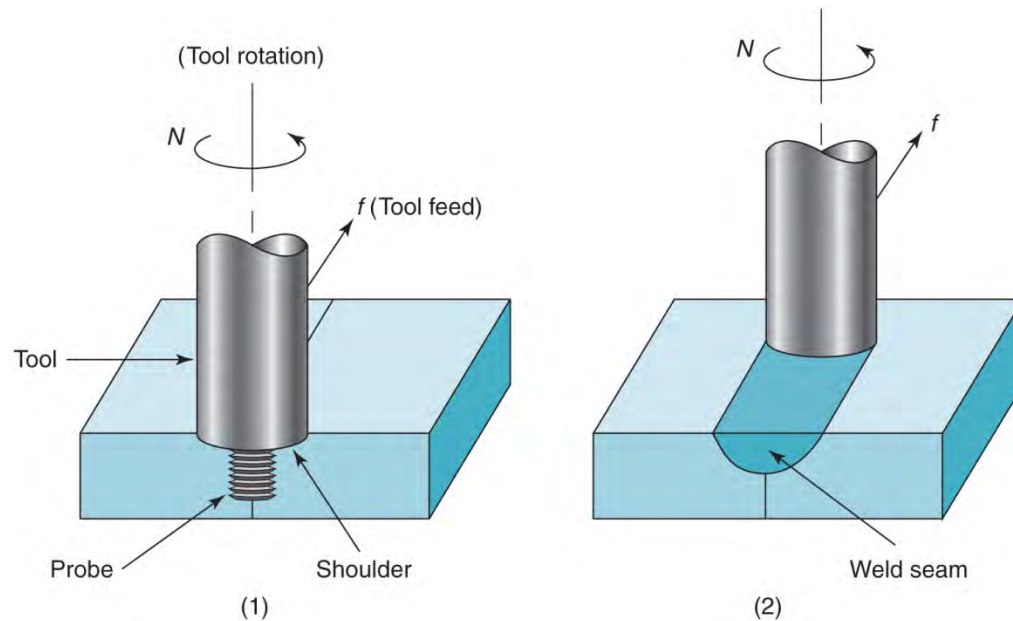
- (1) Rotating part, no contact; (2) parts brought into contact to generate friction heat; (3) rotation stopped and axial pressure applied; and (4) weld created



<http://www.youtube.com/watch?v=5JbnDXw-0pM>

Friction Stir Welding

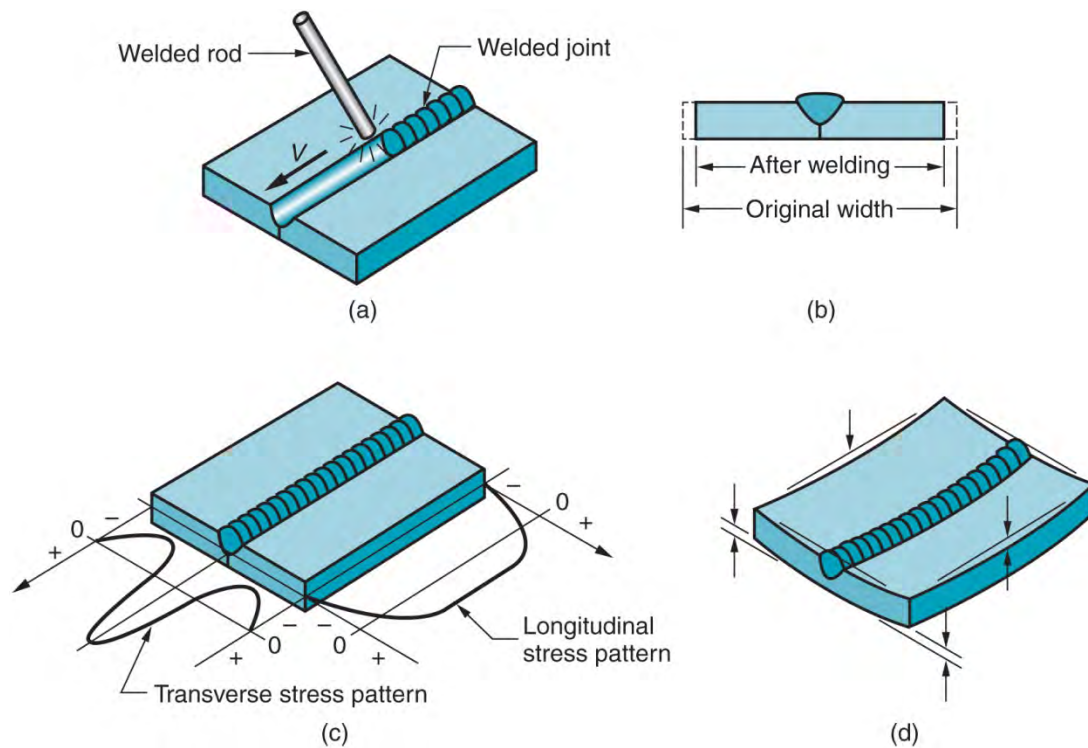
- (1) Rotating tool just before entering work, and (2) partially completed weld seam



<http://www.youtube.com/watch?v=qAOKR6mdTI>

Residual Stresses and Distortion

- (a) Butt welding two plates
- (b) Shrinkage
- (c) Residual stress patterns
- (d) Likely warping of weldment



Techniques to Minimize Warpage

- Welding fixtures to physically restrain parts
- Heat sinks to rapidly remove heat
- Tack welding at multiple points along joint to create a rigid structure prior to seam welding
- Selection of welding conditions (speed, amount of filler metal used, etc.) to reduce warpage
- Preheating base parts
- Stress relief heat treatment of welded assembly
- Proper design of weldment

Welding Defects

- Cracks
- Cavities
- Solid inclusions
- Imperfect shape or unacceptable contour
- Incomplete fusion
- Miscellaneous defects

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 is greater than 450°C (840°F)
 - But less than T_m of base metal(s) to be joined

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 strength of 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

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
- Filler metal called *solder*
- Closely associated with electrical assembly

Soldering Advantages and 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 mechanically
- Joint weakens or melts at elevated temperatures

Solders

Traditionally alloys of tin and lead (both 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

Soldering Fluxes: Functions

- Be molten at soldering temperatures
- Remove oxide films and tarnish from base part surfaces
- Prevent oxidation during heating
- Promote wetting of 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

HW assignment

- Reading assignment: Chapters 12, 13
- Review Questions: 22.2, 22.3, 22.4, 22.8, 22.9, 22.10, 22.15, 23.2, 23.5, 23.6, 23.8, 23.2, 23.20, 23.22, 23.23, 24.1, 24.2, 24.3, 24.2, 24.7, 24.10, 24.11, 24.15,