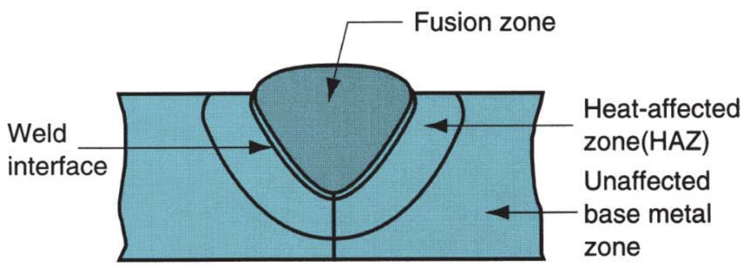
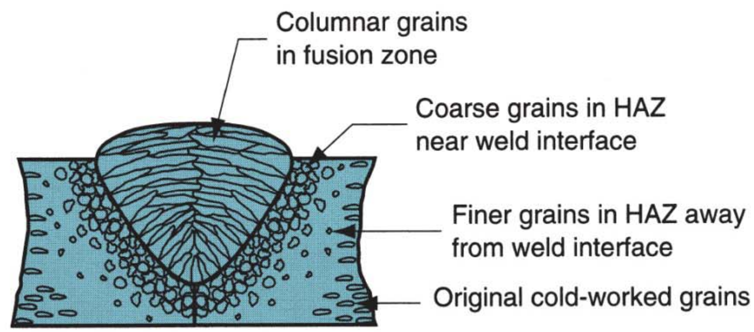
Typical Fusion Welded Joint



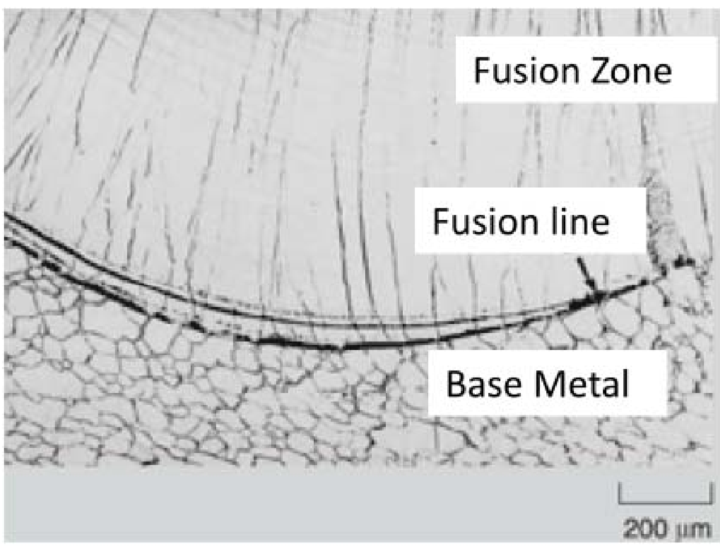
(a)

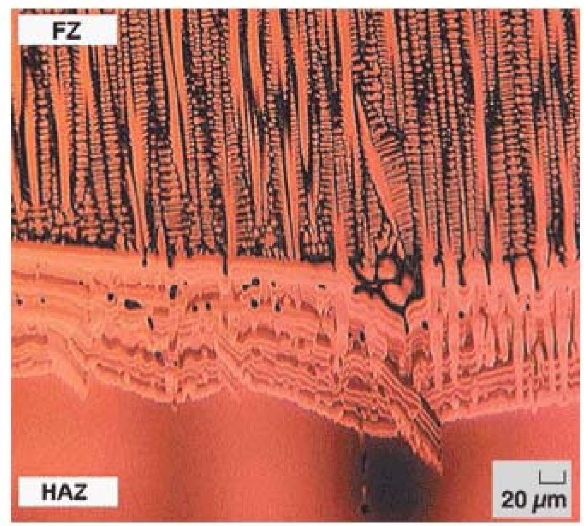


(b)

principal zones in the joint

typical grain structure





Weld characteristics
welding defects

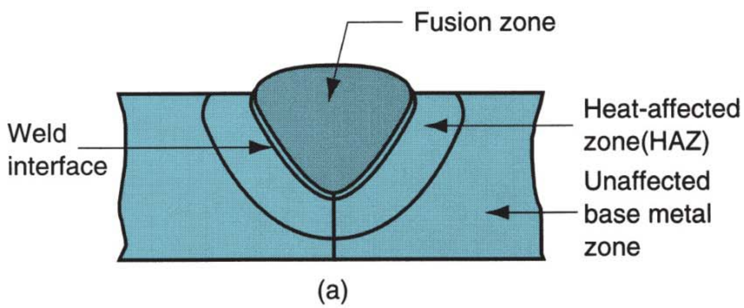
Next class: Causes (relation with heat transfer and fluid flow), and remedies

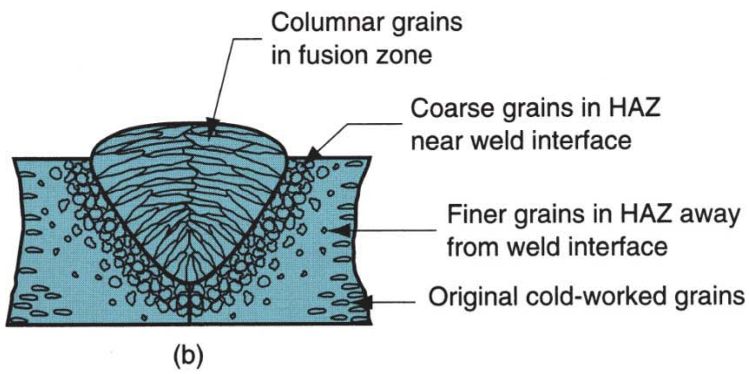
Lecture 16

ME361

Welding defects

Typical Fusion Welded Joint





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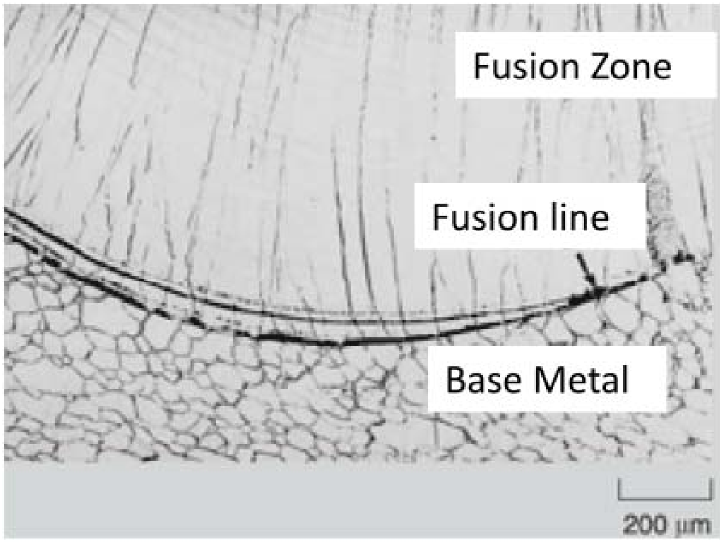
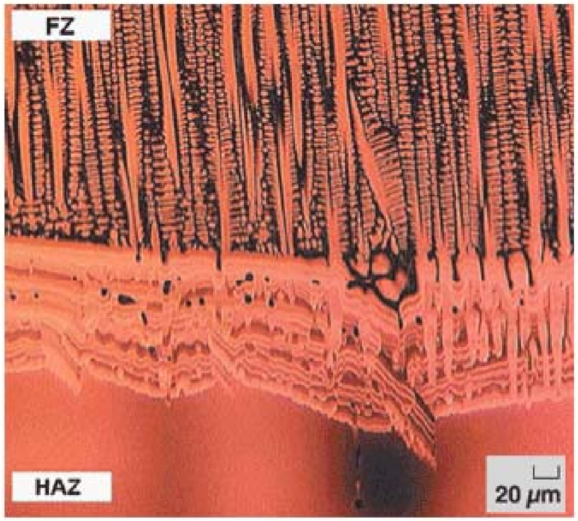
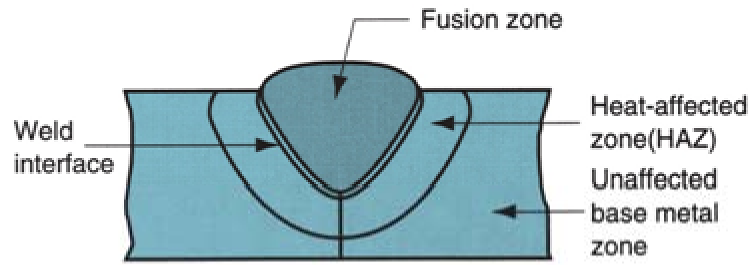




Features of Fusion Welded Joint

Typical fusion weld joint in which filler metal has been added consists of:

- Fusion zone
- Weld interface
- Heat affected zone (HAZ)
- Unaffected base metal zone



Fusion zone (molten):

- mixture of filler and base metal
- mixing of these components is motivated by convention
- similar to casting solidification - Difference is the epitaxial growth in welding
- Epitaxial growth –

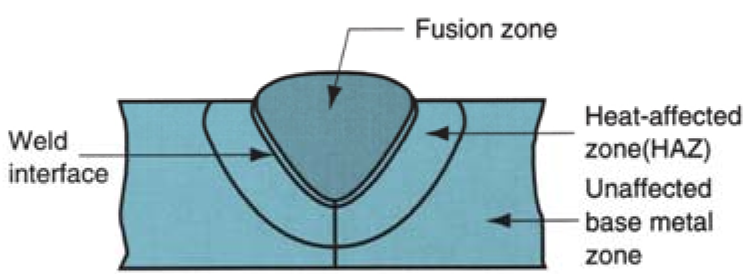
  in which atoms from the molten pool solidify on pre-existing lattices sites of the adjacent solid base metal

Grain orientation developed are perpendicular to the boundaries of the weld interface

Heat Affected Zone (unmolten)

Metal has experienced temperatures below melting point, but high enough to cause microstructural changes in the solid metal

- Chemical composition same as base metal, but this region has been heat treated so that its properties and structure have been altered
  - Effect on mechanical properties in HAZ is usually negative
    - It is here that welding failures often occur



Weldability

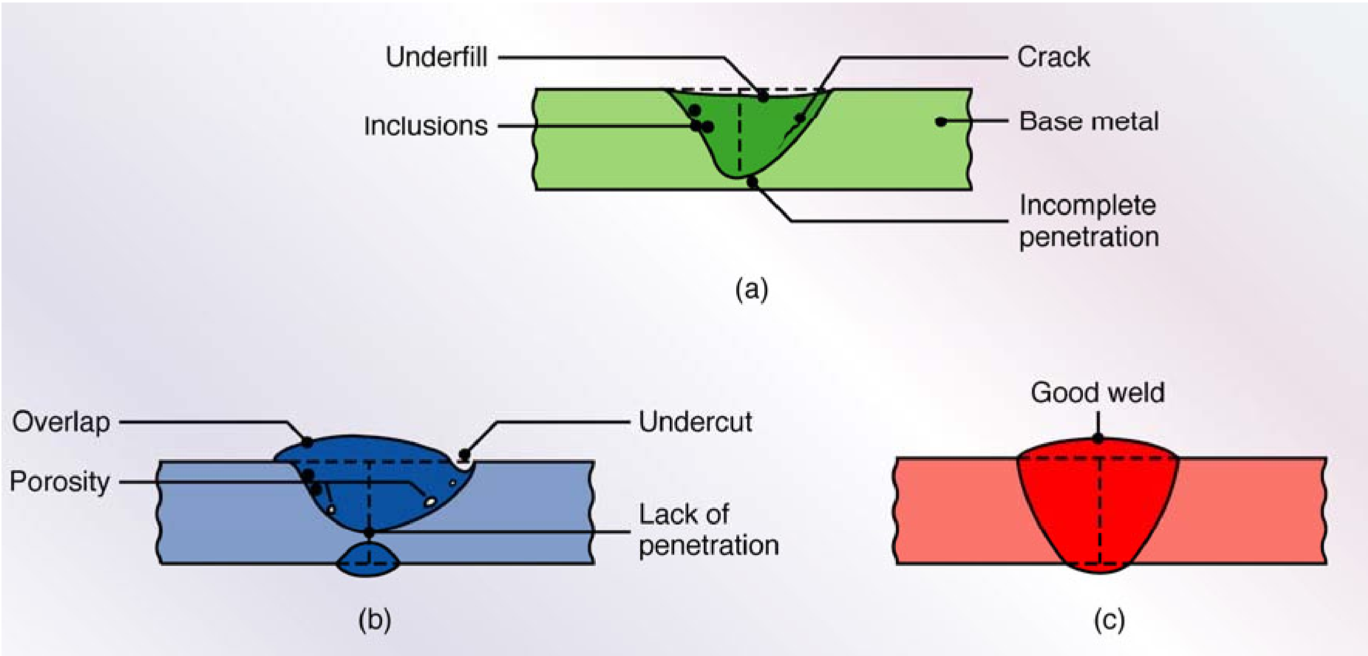
Ability of a metal to get welded easily with absence of weld defects, acceptable strength, ductility and toughness in the welded joint.

Factors that affect weldability:

1. Welding process
2. Base metal properties
3. Filler metal
4. Surface conditions

Welding Defects

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

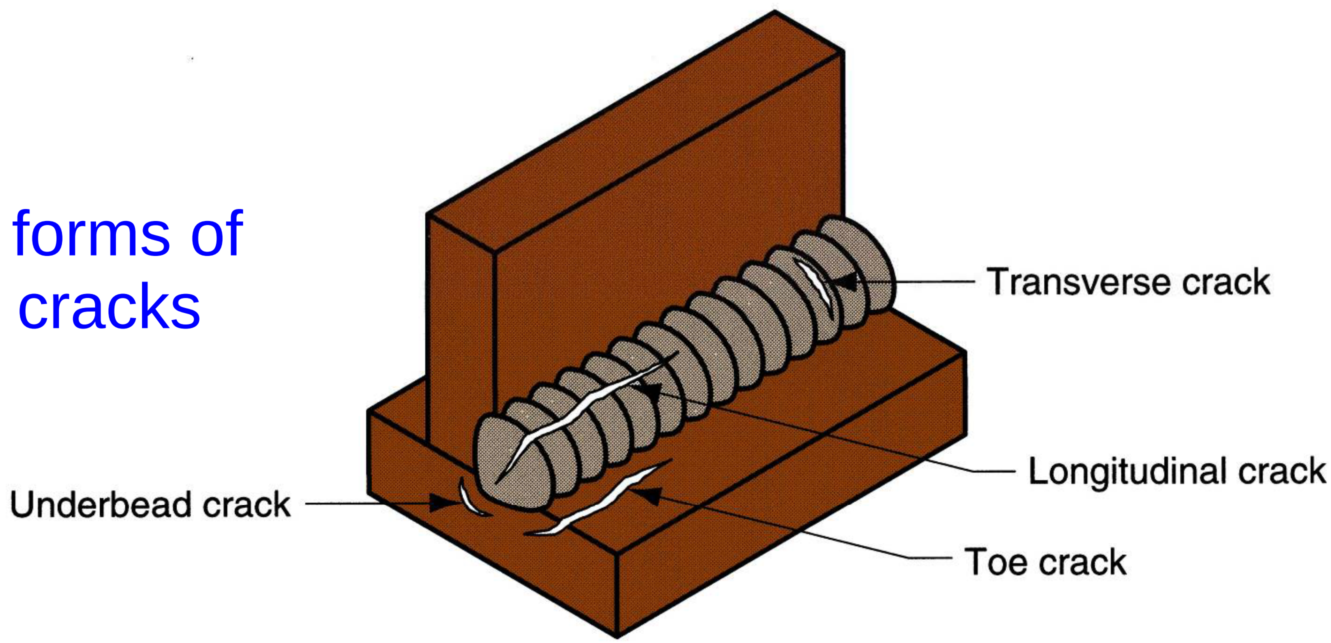


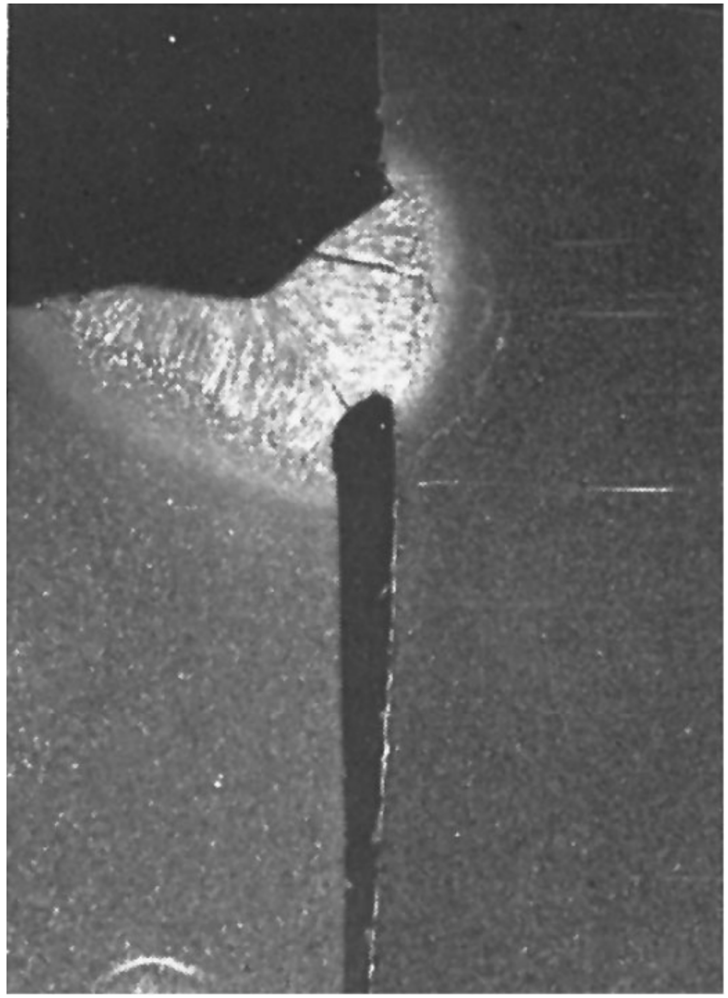
Welding Cracks

Fracture-type interruptions either in weld or in base metal adjacent to weld

- Serious defect because it is a discontinuity in the metal that significantly reduces strength
- Caused by low ductility of weld and/or base metal combined with high restraint during contraction
- In general, this defect must be repaired

Various forms of welding cracks





Crack in a weld bead. The two welded components were not allowed to contract freely after the weld was completed

Cavities

Two defect types, similar to defects found in castings:

1. **Porosity -** small voids in weld metal formed by gases entrapped during solidification
   - Caused by inclusion of atmospheric gases, sulfur in weld metal, or surface contaminants

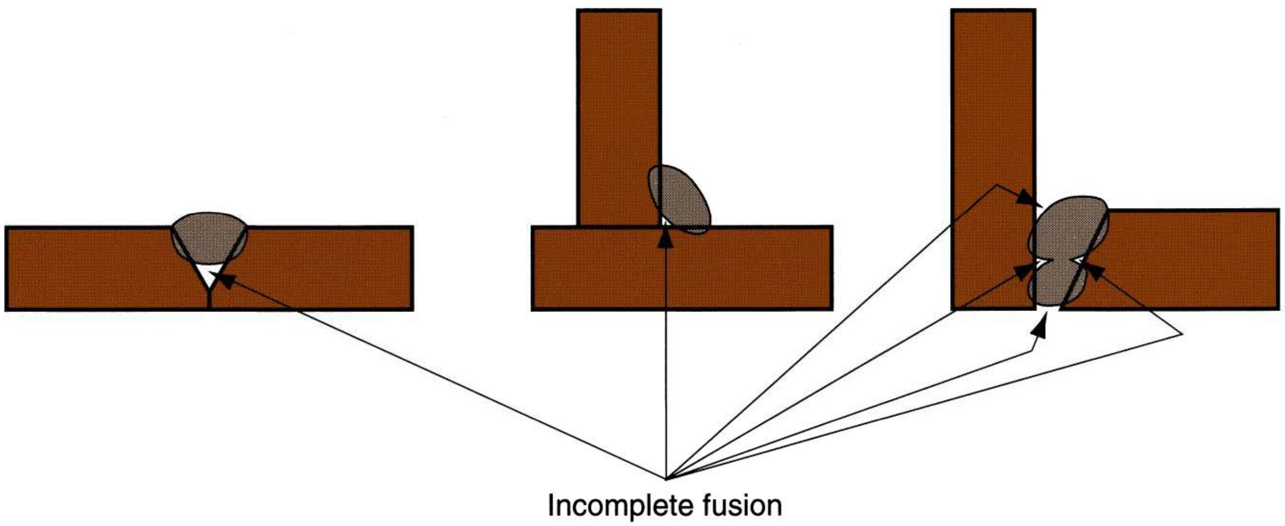
2. **Shrinkage voids -** cavities formed by shrinkage during solidification

Solid Inclusions

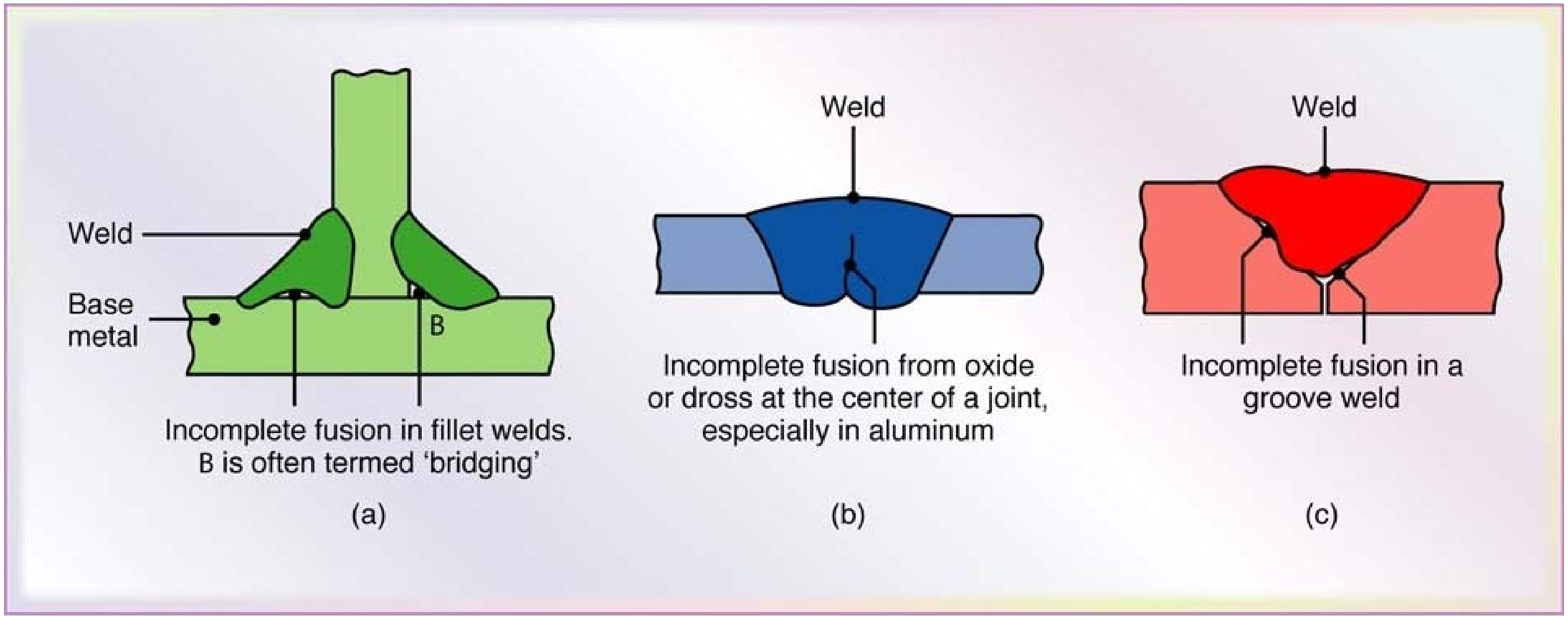
- Solid inclusions - nonmetallic material entrapped in weld metal
- Most common form is slag inclusions generated during arc welding processes that use flux
  - Instead of floating to top of weld pool, globules of slag become encased during solidification
- Metallic oxides that form during welding of certain metals such as aluminum, which normally has a surface coating of Al_2O_3

Incomplete Fusion

Also known as *lack of fusion*, it is simply a weld bead in which fusion has not occurred throughout entire cross section of joint

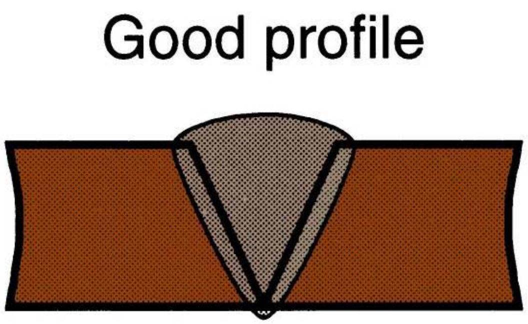


Several forms of incomplete fusion


Weld
Base metal
B
Incomplete fusion in fillet welds. B is often termed 'bridging'
(a)
Weld
Incomplete fusion from oxide or dross at the center of a joint, especially in aluminum
(b)
Weld
Incomplete fusion in a groove weld
(c)

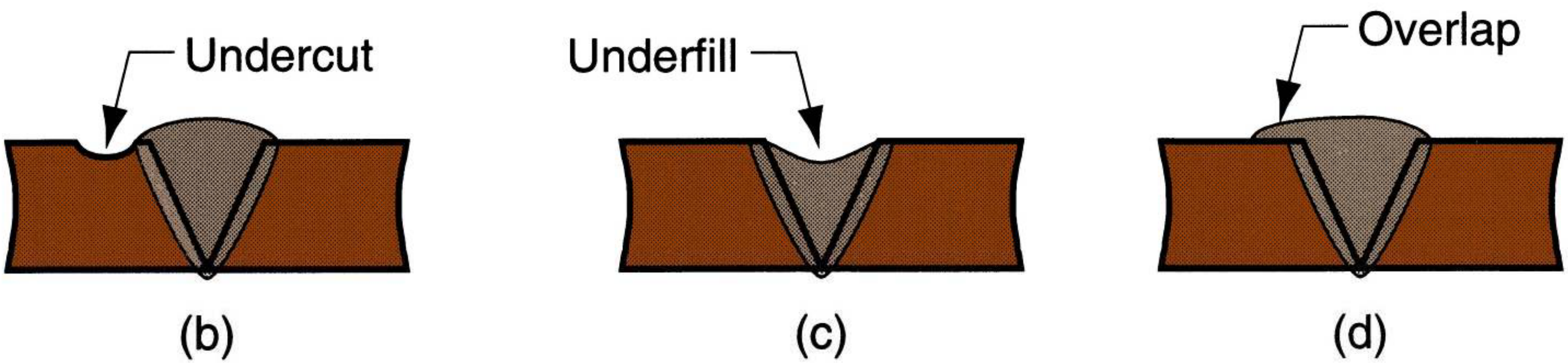
Weld Profile in Arc Welding (AW)

Weld joint should have a certain desired profile to maximize strength and avoid incomplete fusion and lack of penetration



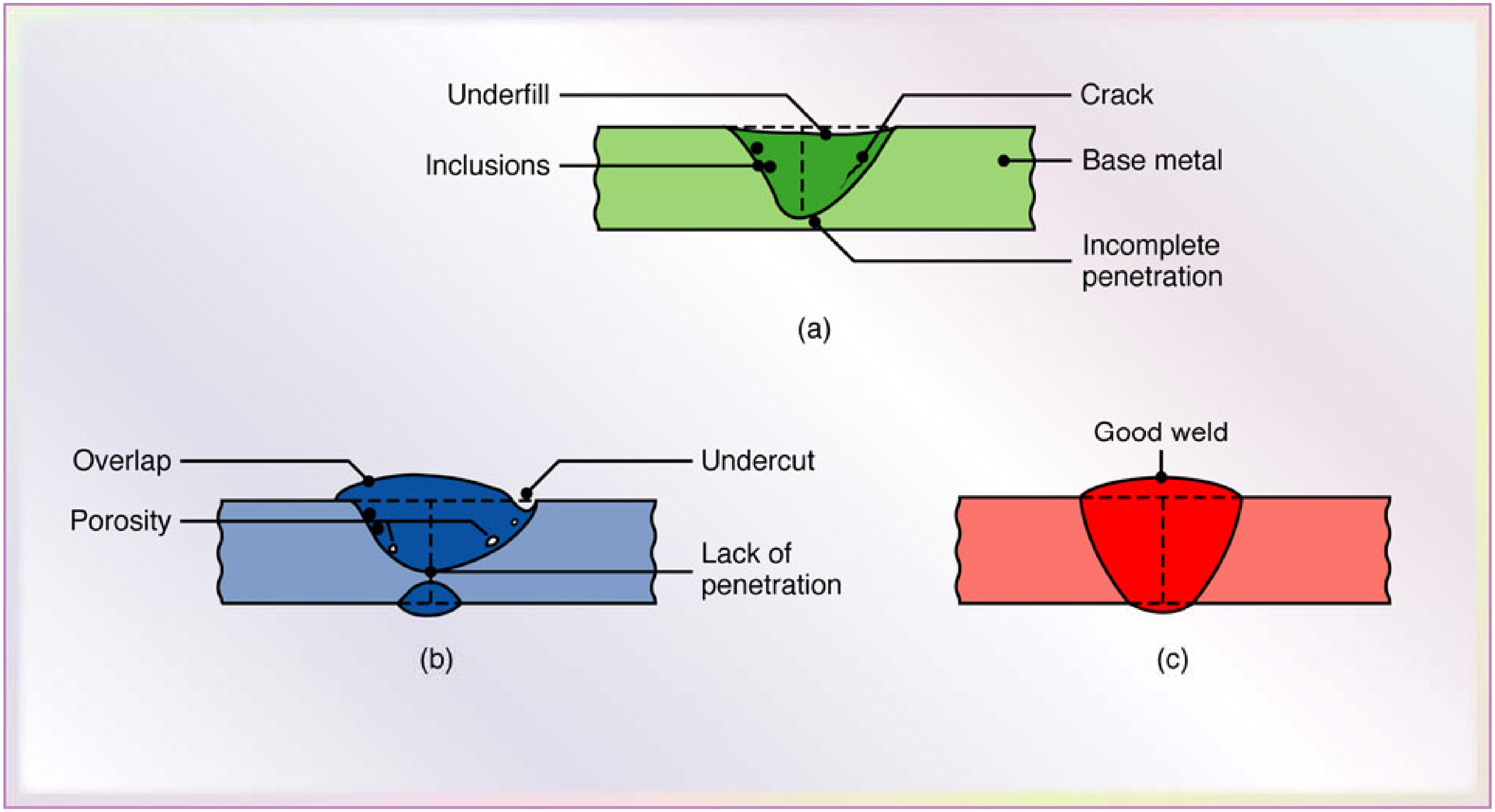
Desired weld profile for single V-groove weld joint

Weld Defects in AW



Same joint but with several weld defects: (b) *undercut*, in which a portion of the base metal part is melted away; (c) *underfill*, a depression in the weld below the level of the adjacent base metal surface; and (d) *overlap*, in which the weld metal spills beyond the joint onto the surface of the base part but no fusion occurs.

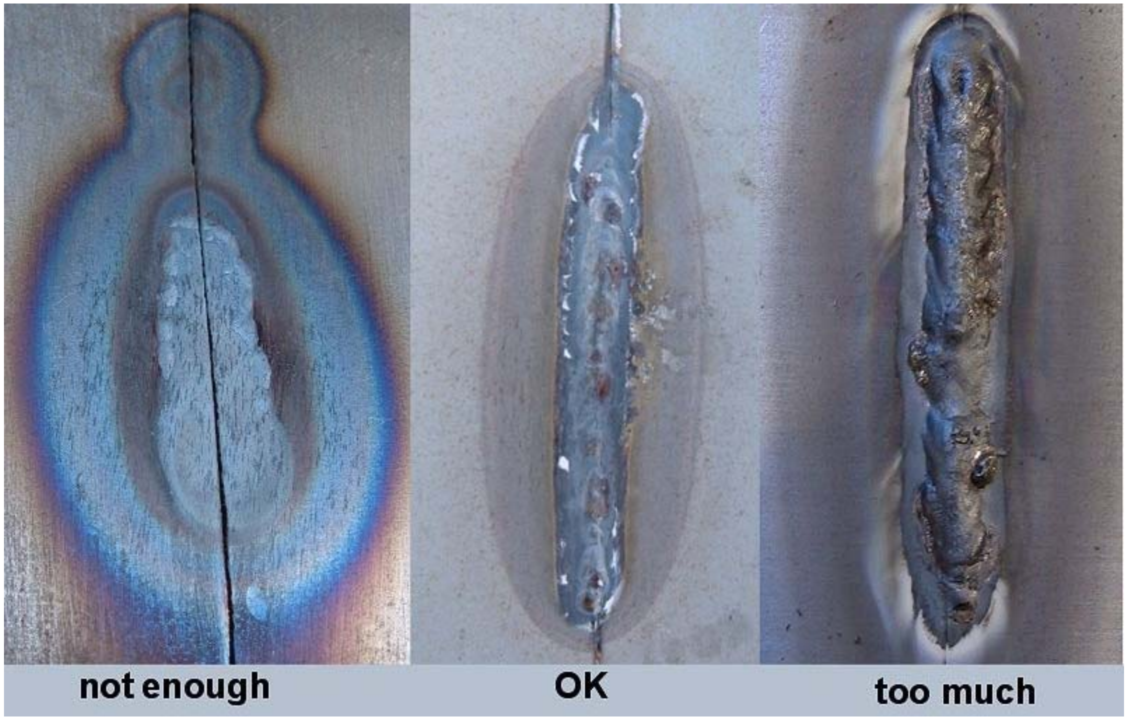
Examples of various defects in fusion welds

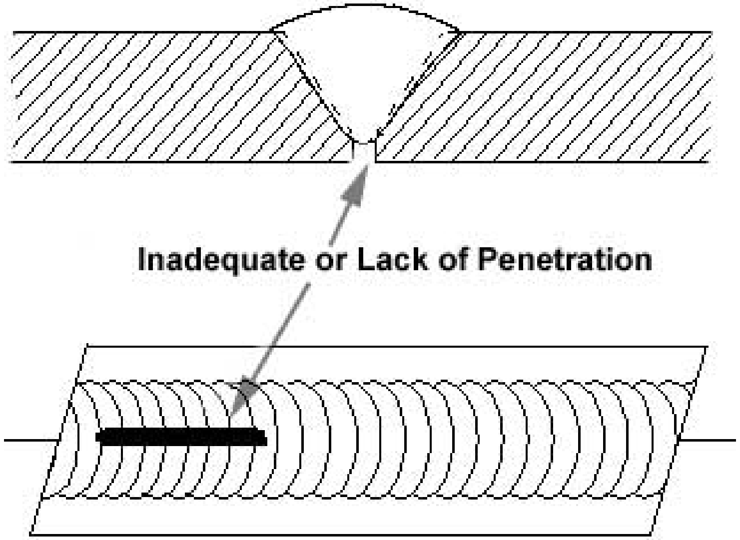


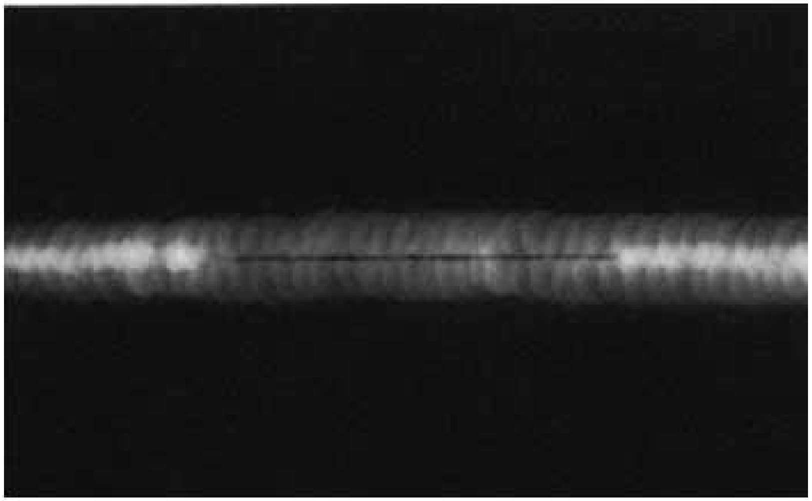
Welding Flaws:

Incomplete Penetration

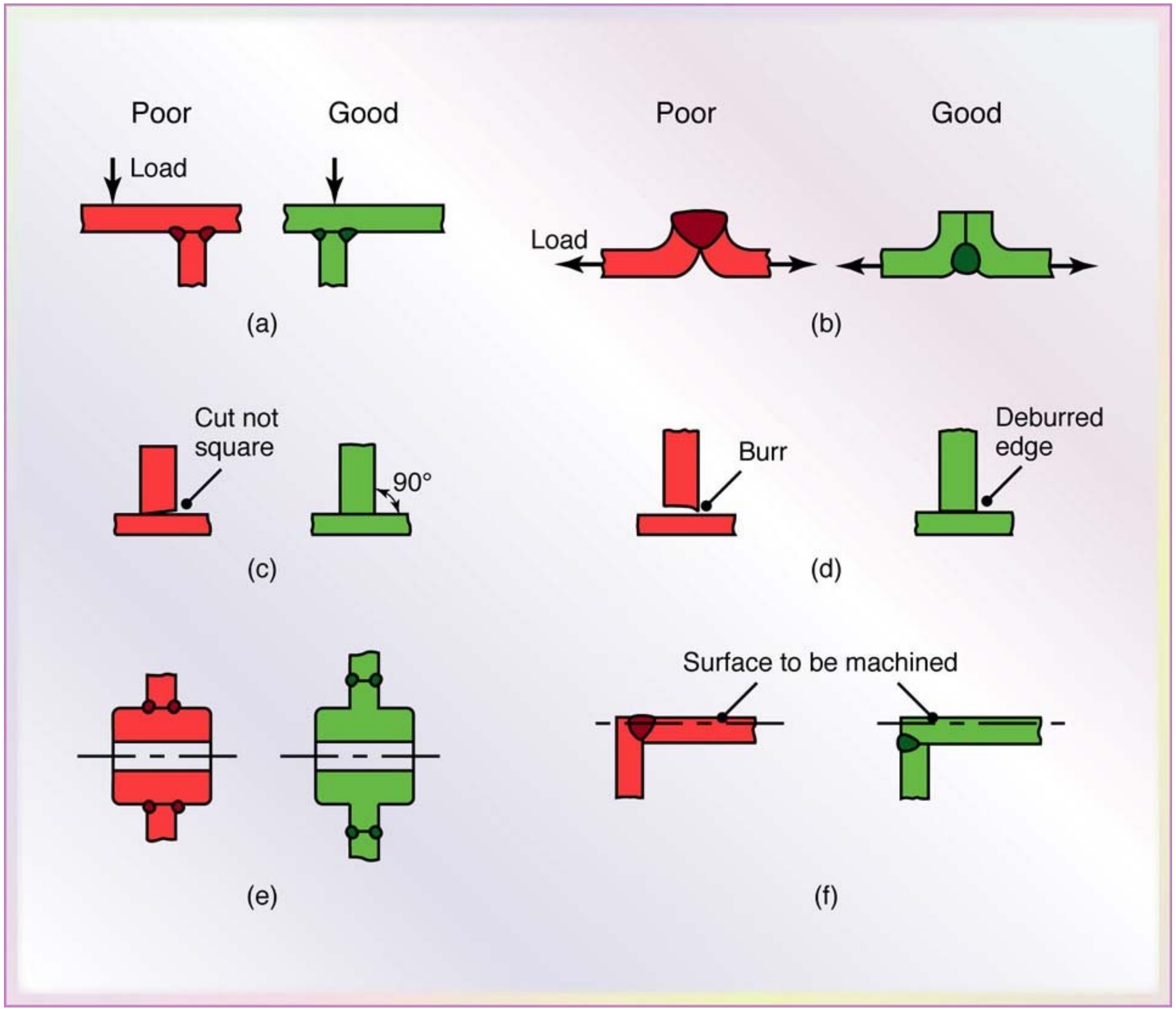
(not enough heat input)







Weld Design



Some examples

Gas metal reaction – important consideration for weld quality

- The **absorption of gas in the weld pool from the arc or the flame.**
- This is due to **reaction between the gas and the liquid metal** in the weld pool, **such reaction are enhanced by the high temperature of the gas and the metal.**
- Two different types of reactions – **1. gas may just get dissolved in the liquid metal**. **2. gas and liquid metal may react chemically to form a stable compound**.

- As **long as the reaction product is soluble, it does not prevent the formation of a weld pool.** However, it may result in an embrittlement of the welded joint.
- An **insoluble reaction product produces either surface scales or slags, and thus physically interferes with the formation of the weld pool**.
- SOLUTION - **either the excess gas to the weld pool is prevented or a flux is used to dissolve and disperse the reaction product**.

Gas metal reaction

Where **gas gets dissolved in the weld pool**

- As the solubility decreases on cooling, degassification starts and, with suitable nuclei the bubbles may form. Porosity formation. If these bubbles are trapped then the quality of the weld is very poor as its porous.

- **Degassification makes the joint very porous (porosity formation)**.

- This **defect is very common in a metal whose oxides are very easily reducible by hydrogen. This can be avoided by the addition of a suitable deoxidant** in the filler metal.

- Another important **gas-metal reaction is the diffusion of the gas into the parent metal from the weld pool.**

- When the temperature of the thermal cycle is high, this diffusion process may be quite fast. The diffusion of hydrogen into the heat affected zone, may again cause an embrittlement of the welded joint.

Cooling of fusion weld

Three important effects intimately connected with the cooling of a fusion weld:

- Contraction - Thermal Stress - Metallurgical phase transformation

All these effects significantly control the quality of the weld.

Thermal stresses or *thermally induced stresses* arise from a material or mechanical structure being acted upon by a temperature gradient or a temperature change (and not simply temperature). There are three principal examples: (1) stresses induced by a volumetric change, either expansion or shrinkage, associated with some chánge of phase in the material of construction; (2) stresses induced by a difference in coefficient of thermal expansion

(3) stresses induced by a temperature gradient resulting in differential rates of expansion (on heating) or contraction (on cooling) within the volume of the material or within the structure.