

Fundamentals of Joining

Chapter 30

30.1 Introduction to Consolidation Processes

- Consolidation Processes consist of
 - Welding
 - Brazing
 - Soldering
 - Fasteners
 - Adhesives
 - Shrink Fits
 - Slots and Tabs
- Each Process has its own advantages and disadvantages

Welding

- Welding is the consolidation of two materials by means of temperature and/or pressure to cause the materials to melt or diffuse at the joint.
- Welding can be done in a wide variety of conditions and methods and is therefore one of the most common consolidation processes.

Welding

- There are two forms of welding
 - Solid State welding where pressure and heat are used to cause the diffusion at the joint, causing the parts to fuse together
 - Fusion welding where heat is applied to create molten material at the joint, which fuses the parts upon solidification
- Both process can cause changes in the structure of the material, and must be considered when selecting a process

30.2 Classification of Welding and Thermal Cutting Processes

- There are numerous Welding and Thermal Cutting Process as shown on the next slide.
- Additional information on specific processes are presented in:
 - Chapter 31 presents gas and arc welding processes
 - Chapter 32 presents resistance and solid state welding
 - Chapter 33 presents other processes including brazing and soldering

Classification of Weld Process

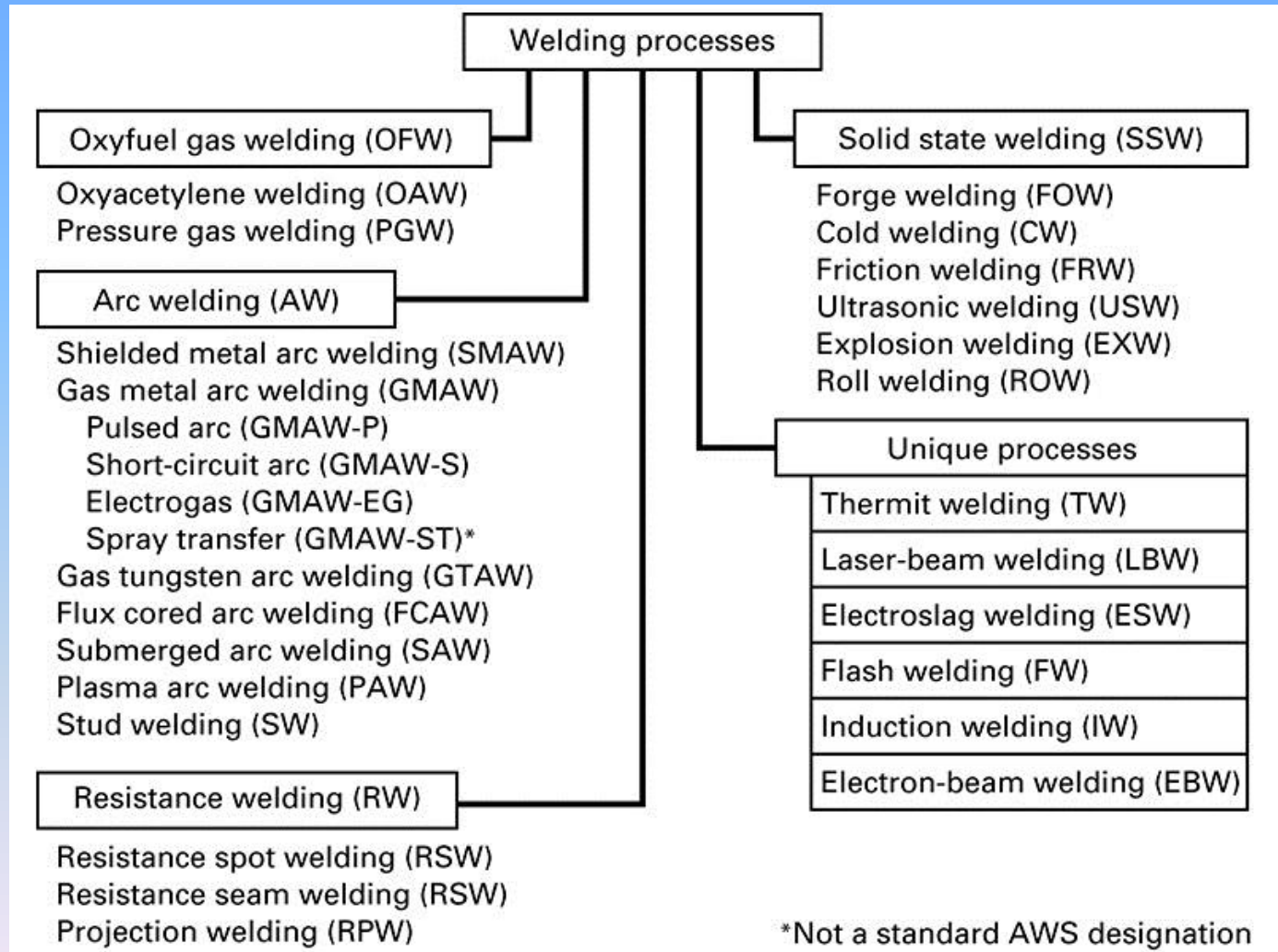


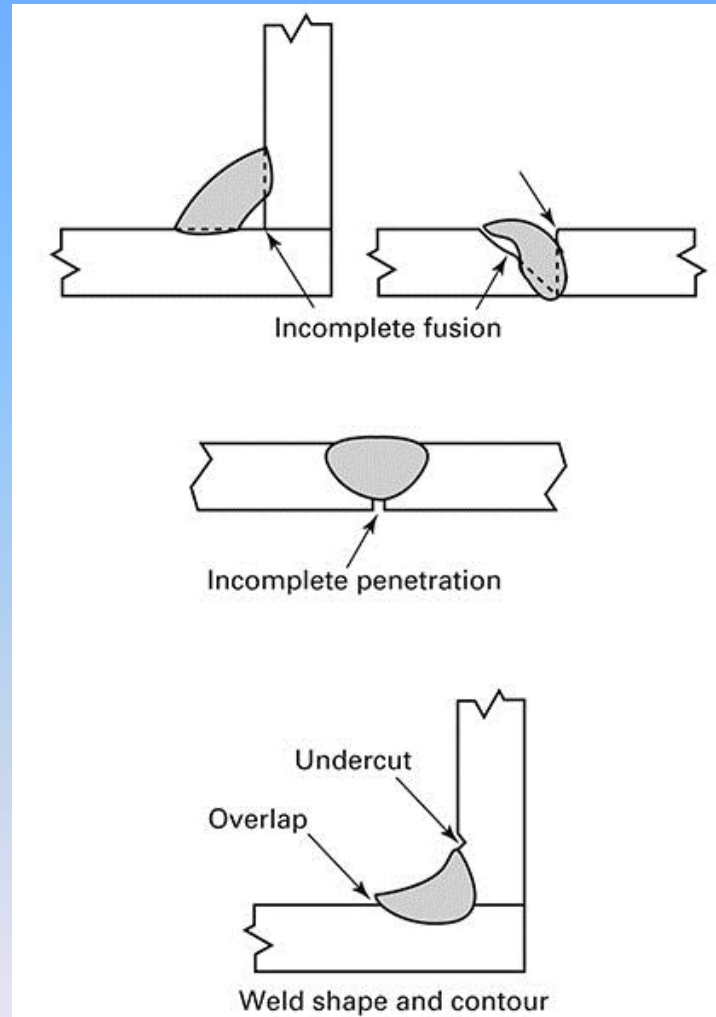
FIGURE 30-1
Classification of common welding processes along with their AWS (American Welding Society) designations.

30.3 Some Common Concerns

- Proper joint design is critical to a successful weld
 - Heating, melting, and resolidification can all produce changes in microstructure of the material and produce residual stress
 - Welding can result in two basic types of defects
 - Cracks
 - Inclusions
 - Incomplete fusion
 - Arc Strikes
 - Metallurgical changes
 - Cavities
 - Unacceptable weld shape
 - Incomplete penetration
 - Spatter
 - Excessive Distortion

Common Weld Defects

FIGURE 30-3 Some common welding defects.



30.4 Types of Fusion Welds and Types of Joints

- Bead welds: Limited penetration so used on thin materials, or surface modifications
- Groove welds: Used on thick materials, requires joint preparation, used for single and multiple passes
- Fillet welds: Use for tee, lap and corner joints
- Plug welds: Used a permanent replacement for rivets or bolts

Basic Fusion Welds

FIGURE 30-4 Four basic types of fusion welds.

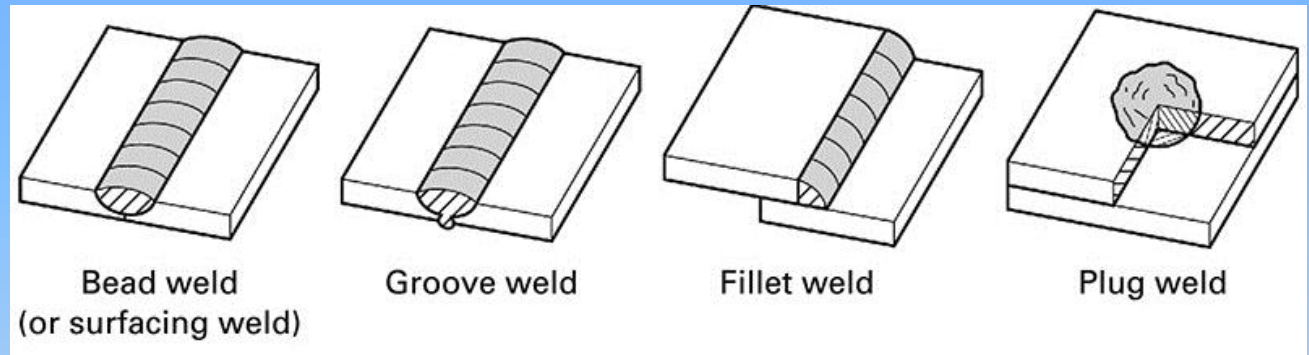
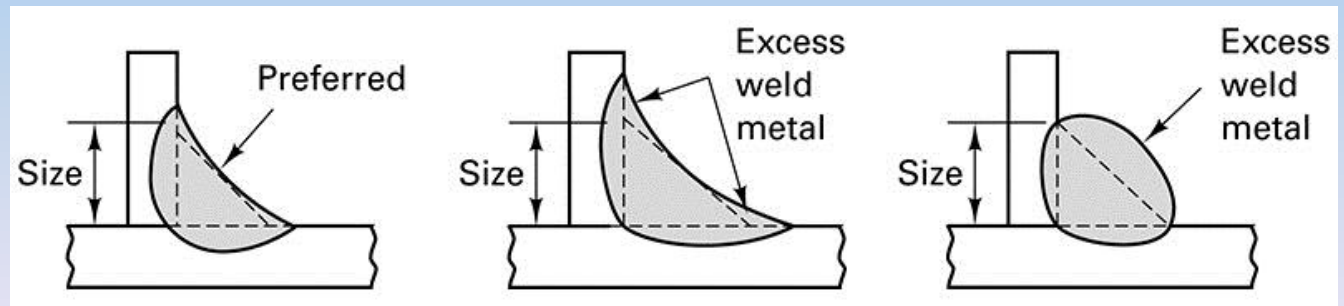
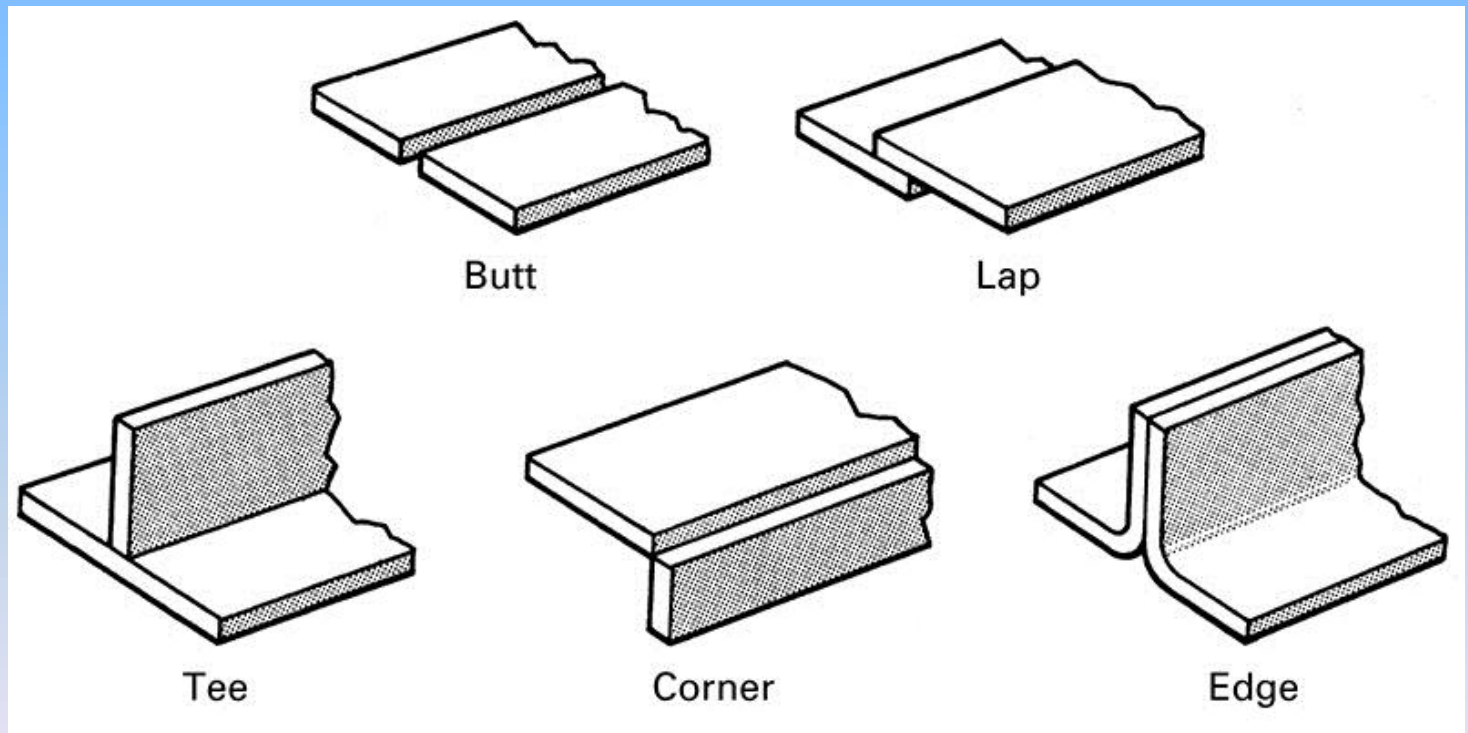


FIGURE 30-6 Preferred shape and the method of measuring the size of fillet welds.



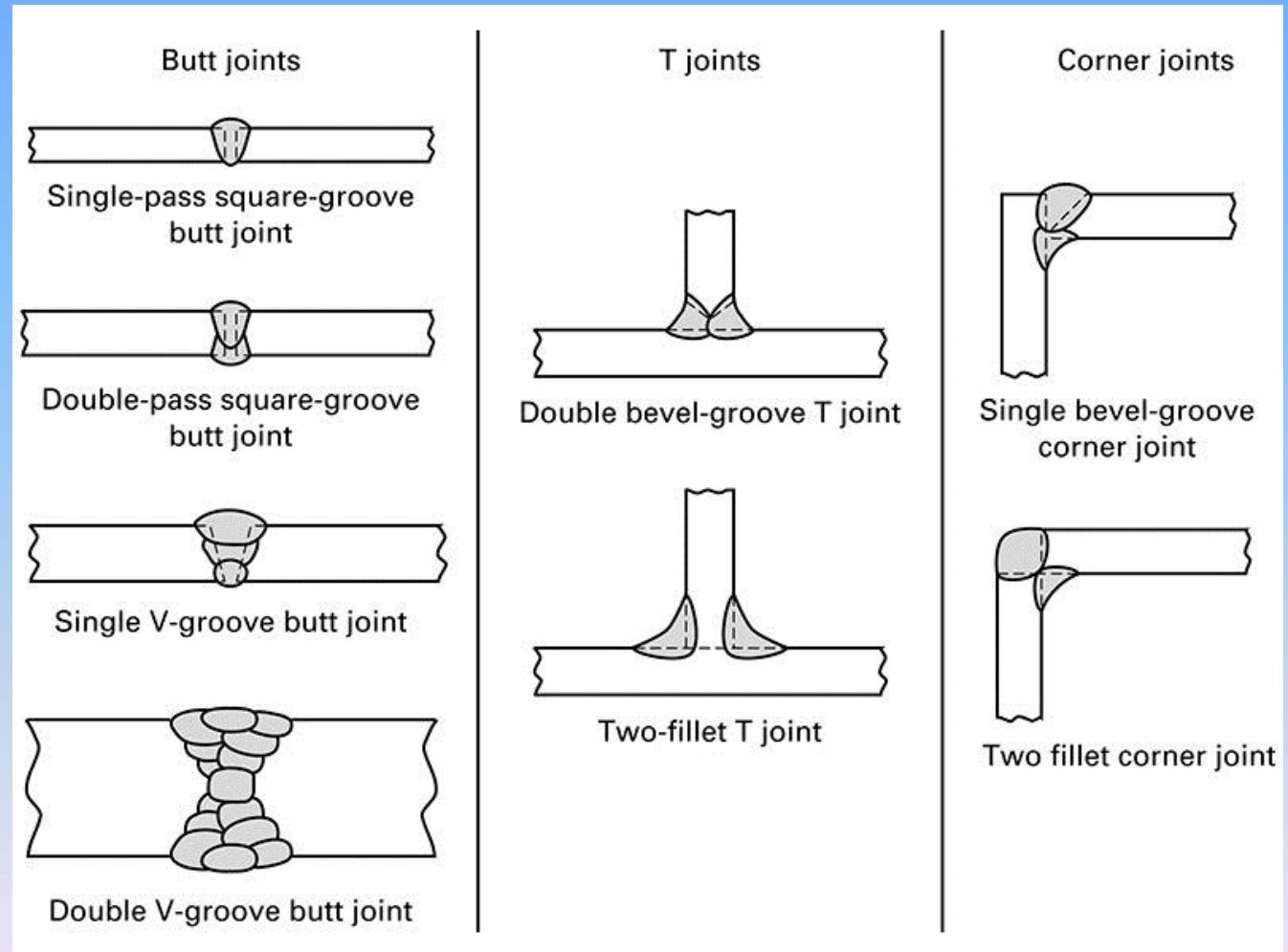
Basic Joint Designs of Fusion Welds

FIGURE 30-7 Five basic joint designs for fusion welding.



Weld Procedures

FIGURE 30-8 Various weld procedures used to produce welded joints. (Courtesy Republic Steel Corporation, Youngstown, OH).



30.5 Design Considerations

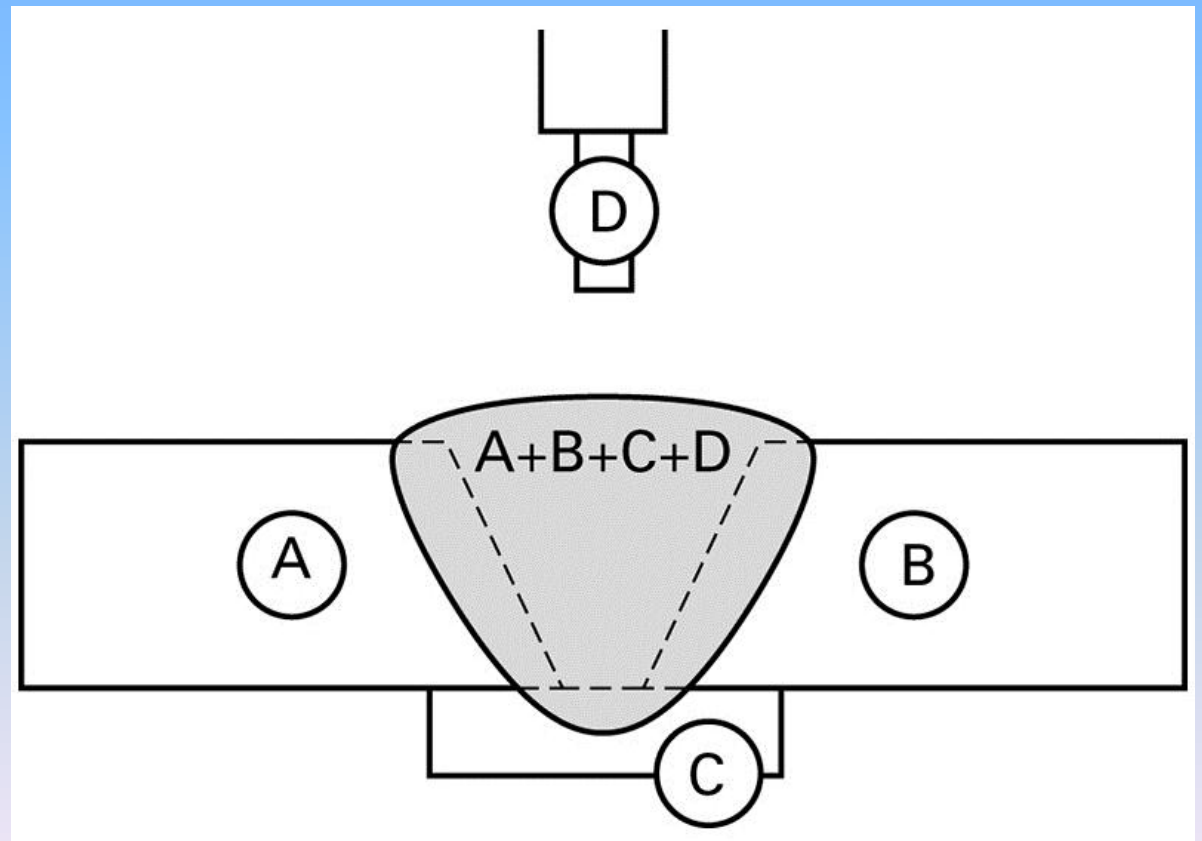
- Welding produces monolithic structures
 - Welded joints do not stop crack propagation, cracks propagation typically does not travel through a bolted joint
 - Vibration stresses are transferred through a weld joint, bolted joints adsorb some of the vibration
- Welded structure are more rigid than bolted assemblies

30.6 Heat Effects

- In fusion welding, the heat melts some of the base material, which is then rapidly cooled, creating changes in the granular structure.
- The pool of metal bonding the base material is a blend of each material, and forms a cast structure in the joint zone.
- Surrounding the pool of metal is the heat affected zone, where metallurgical properties have been changed.

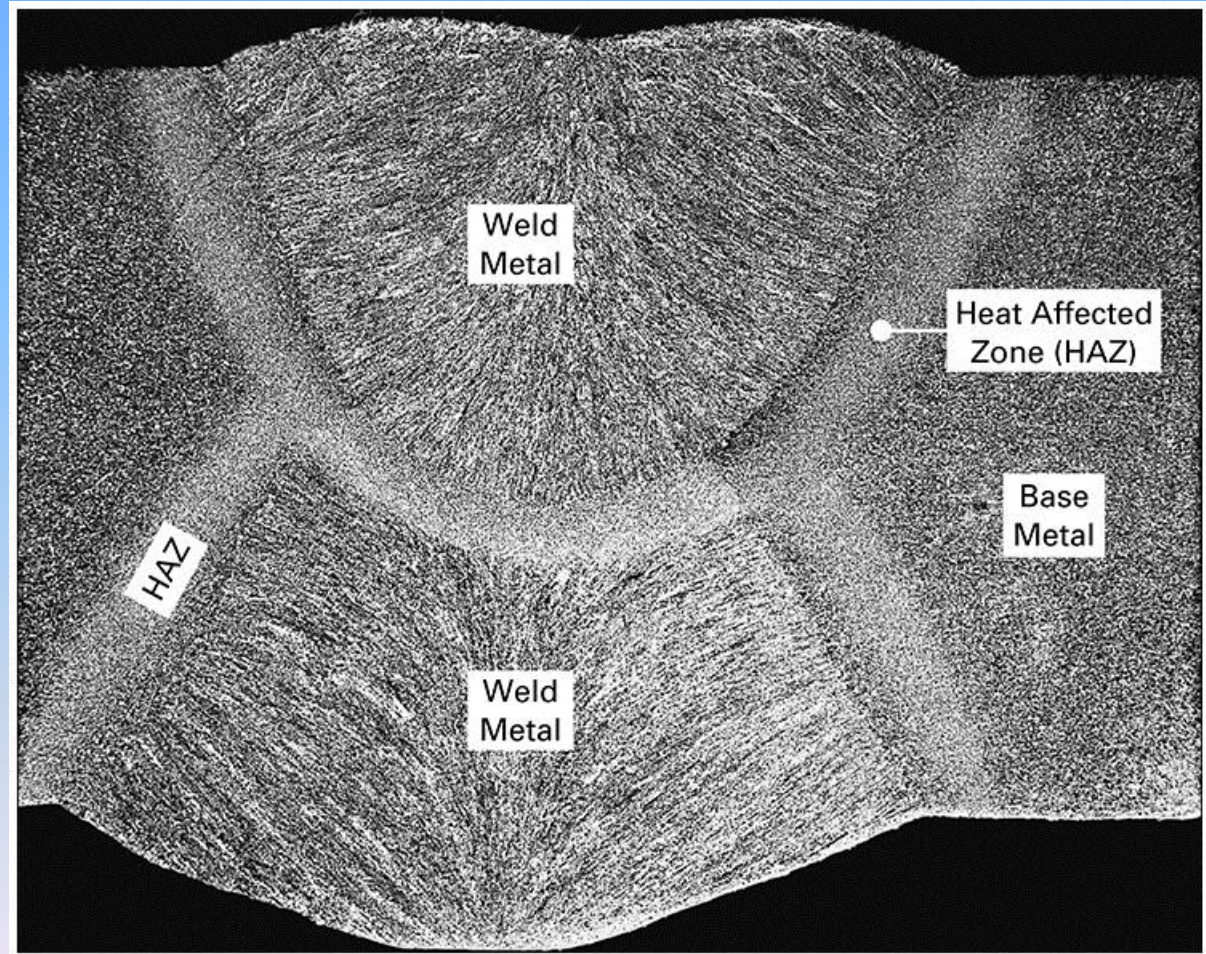
Butt Weld with Backing Plate

FIGURE 30-10 Schematic of a butt weld between a plate of metal A and a plate of metal B, with a backing plate of metal C and filler of metal D. The resulting weld nugget becomes a complex alloy of all four metals.



Microstructure of a Fusion Weld

FIGURE 30-11 Grain structure and various zones in a fusion weld.



Heat Effects cont.

- Deposition materials need as deposited properties equal to the base metal.
- Solidification zone is subject to the all the problems associated with casting.
- Heat affected zone is subjected to enough heat to cause metallurgical changes, leading to phase transformations, embrittlement, precipitation, or cracking.
- The changes in properties are a function of the heat input rate, which are a function of the weld process used.

Zone in a Fusion Weld

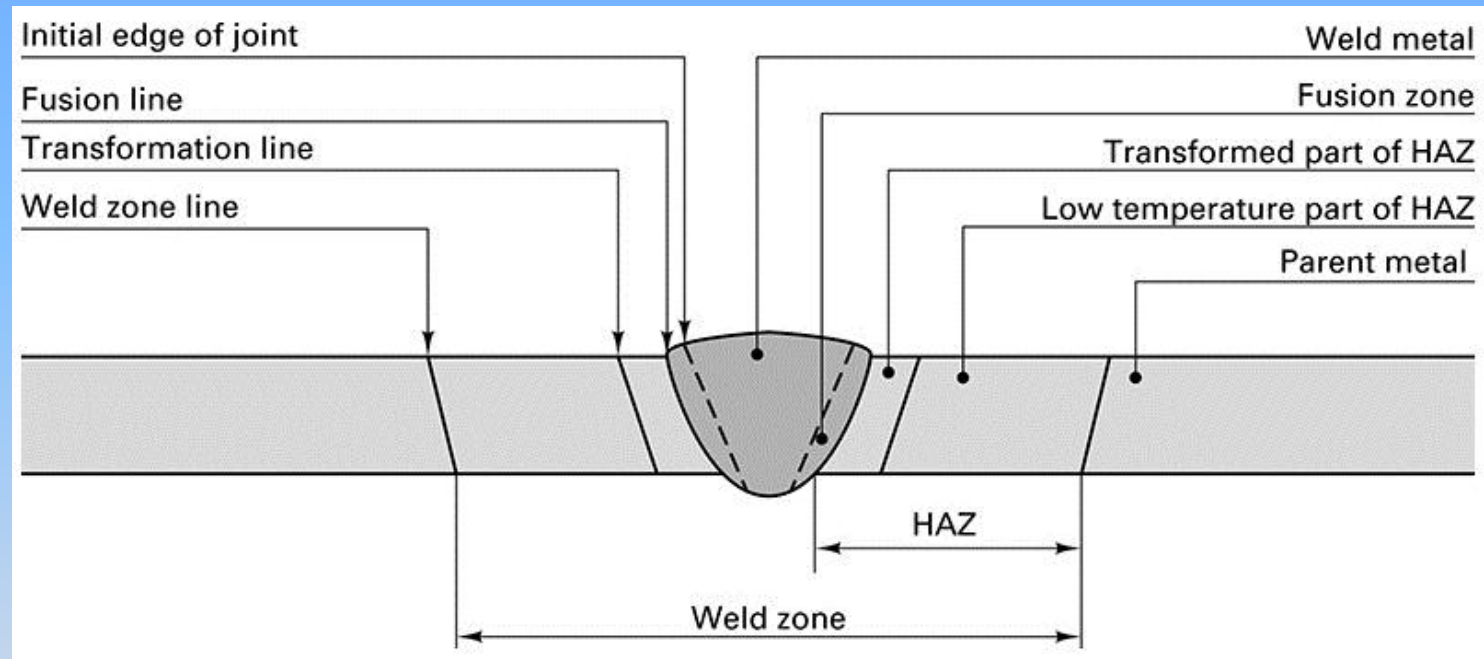


FIGURE 30-13 Schematic of a fusion weld in steel, presenting proper terminology for the various regions and interfaces. Part of the heat-affected zone has been heated above the transformation temperature and will form a new structure upon cooling. The remaining segment of the heat-affected zone experiences heat alteration of the initial structure. (Courtesy Sandvik AB, Sandviken, Sweden)

Heat Rate of Welding Processes

TABLE 30-1 Classification of Common Welding Processes by Rate of Heat Input

Low Rate of Heat Input

Oxyfuel welding (OFW)
Electroslag welding (ESW)
Flash welding (FW)

High Rate of Heat Input

Plasma arc welding (PAW)
Electron-beam welding (EBW)
Laser welding (LBW)
Spot and seam resistance welding (RW)
Percussion welding

Moderate Rate of Heat Input

Shielded metal arc welding (SMAW)
Flux cored arc welding (FCAW)
Gas metal arc welding (GMAW)
Submerged arc welding (SAW)
Gas tungsten arc welding (GTAW)

Heat Effects, cont.

- Post weld heat treatment can be used to reduce the impact of the heat affected zone.
- Welding techniques can be used to reduce the heat distortion in welds
- Preheating the base metal also reduces weld distortion
- Distortion is the result of thermally induced stresses

Stresses in a Weld

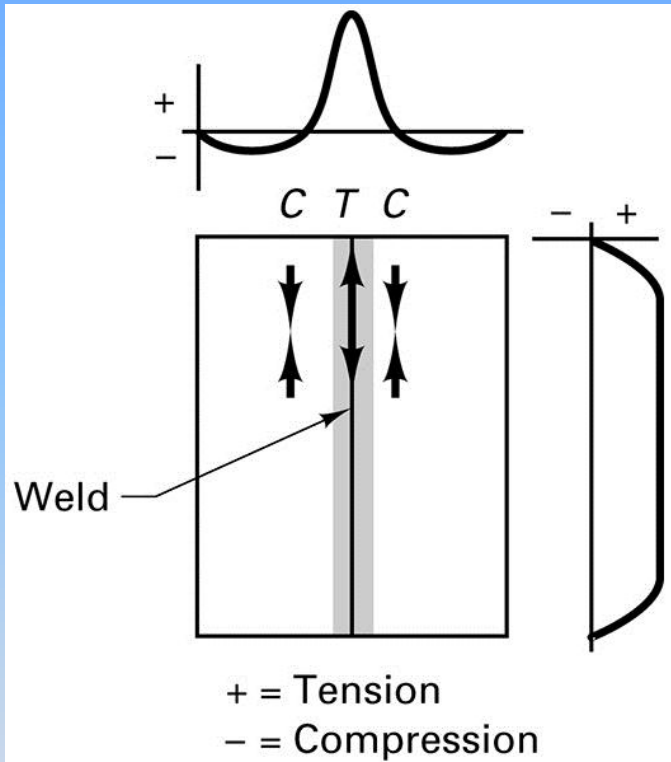


FIGURE 30-14 Schematic of the longitudinal residual stresses in a fusion-welded butt joint.

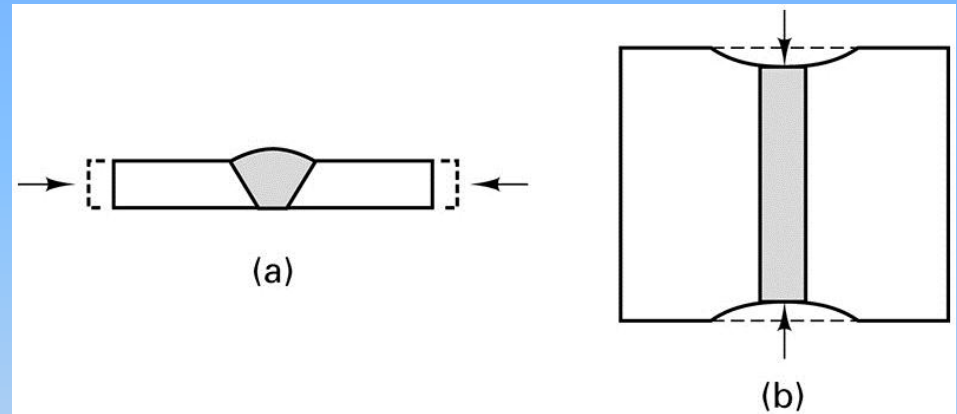


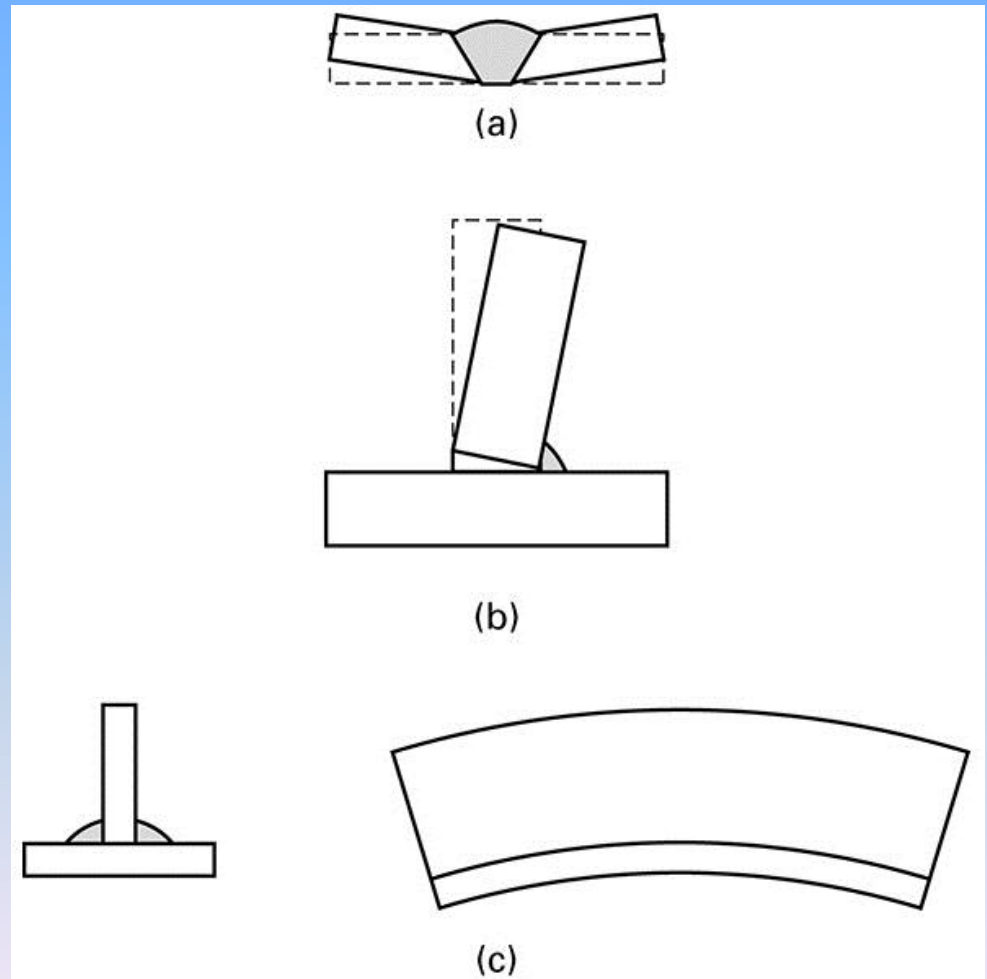
FIGURE 30-15 Shrinkage of a typical butt weld in the transverse (a) and longitudinal (b) directions as the material responds to the induced stresses. Note that restricting transverse motion will place the entire weld in transverse tension.

Thermal Induced Residual Stress

- Thermal induced residual stress is the result of the thermal expansion of the material and the temperature gradient created during the welding process.
- Thermal induced residual stress lead to part distortion and cracking of the welds.
- Distortion can be reduced with the use of restraints, though restraint in one direction is preferred.
- If parts are fully restrained during welding, additional stresses, called reaction stresses are produced

Warpage as a Result of Welding

FIGURE 30-16 Distortions or warpage that may occur as a result of welding operations: (a) V-groove butt weld where the top of the joint contracts more than the bottom; (b) one-side fillet weld in a T-joint; (c) two-fillet weld in a T-joint with a high vertical web.



Cracking as a Result of Welding

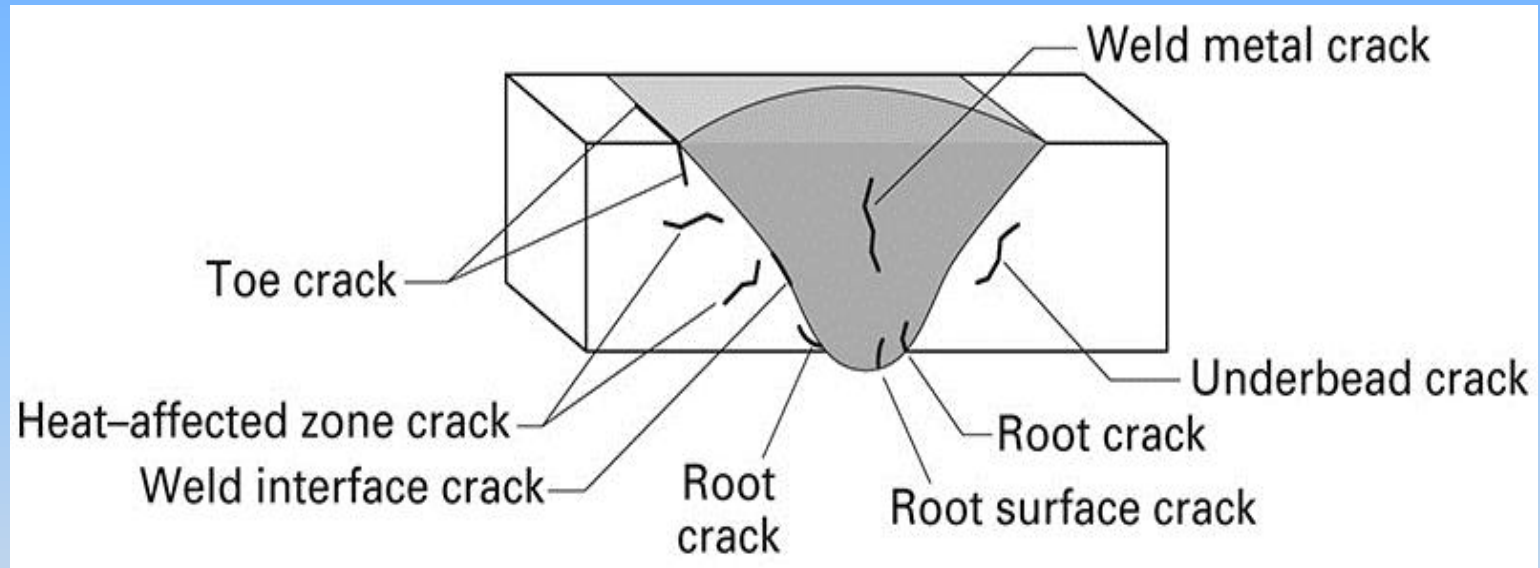


FIGURE 30-17 Various types and locations of cracking that can occur as a result of welding.

30.7 Weldability or Joinability

- The weldability of a material is only relative rating.
- The ability of a material to be welded reliability is dependent upon the process used and the skill of the operator.
- Weldability tables such as 30-2 give general guidelines for a number of materials and processes

AWS Weldability

TABLE 30-2 Weldability or Joinability of Various Engineering Materials^a

Material	Arc Welding	Oxyacetylene Welding	Electron-Beam Welding	Resistance Welding	Brazing	Soldering	Adhesive Bonding
Cast iron	C	R	N	S	D	N	C
Carbon and low-alloy steel	R	R	C	R	R	D	C
Stainless steel	R	C	C	R	R	C	C
Aluminum and magnesium	C	C	C	C	C	S	R
Copper and copper alloys	C	C	C	C	R	R	C
Nickel and nickel alloys	R	C	C	R	R	C	C
Titanium	C	N	C	C	D	S	C
Lead and zinc	C	C	N	D	N	R	R
Thermoplastics	Heated tool R	Hot gas R	N	Induction C	N	N	C
Thermosets	N	N	N	N	N	N	C
Elastomers	N	N	N	N	N	N	R
Ceramics	N	S	C	N	N	N	R
Dissimilar metals	D	D	C	D	D/C	R	R

^aC, commonly performed; R, recommended (easily performed with excellent results); D, difficult; N, not used; S, seldom used.

30.8 Summary

- Proper weld considerations
 - Selection of the process and fillers
 - Design of the Joint
 - Effects of heating and cooling on weld and parent materials
- Parallel considerations apply to brazing and soldering