Introduction to Manufacturing, AGE-1320

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Manufacturing Engineering Technology in SI Units, 6th Edition

Chapter 30: Fusion Welding Processes

Chapter Outline

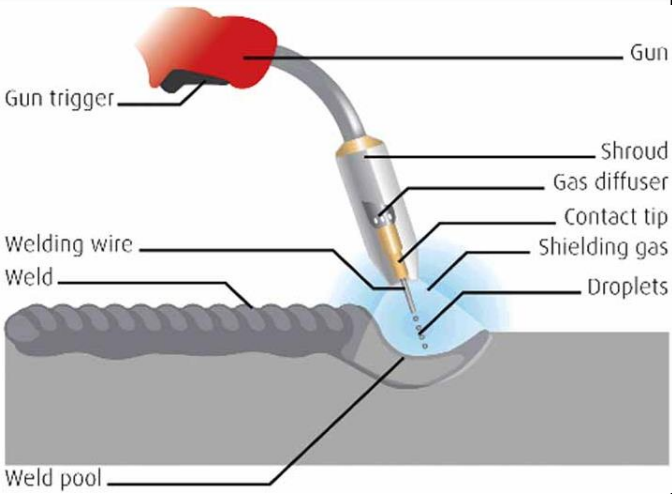
1. **Welding Fundamentals**
2. **Oxyfuel & Arc Welding Basics**
3. **Non-consumable Electrode Processes**
4. **Consumable Electrode Processes**
5. **High-Energy & Cutting Processes**
6. **Defects, Symbols & Safety**

1. Welding Fundamentals

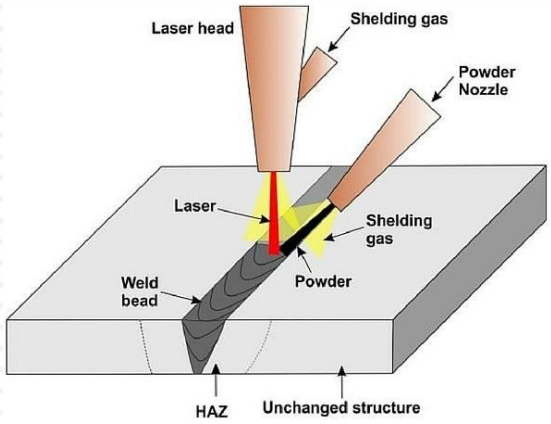
Welding Fundamentals

What Is Fusion Welding?

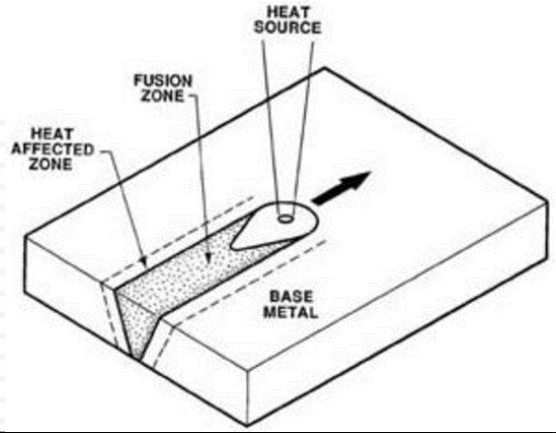
- Joining metals by melting base metal (forms molten weld pool)



- Heat supplied by arc, gas flame, laser, or electron beam



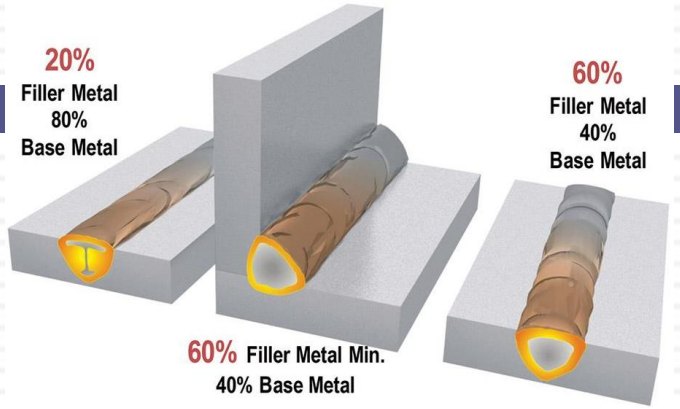
- Fusion Zone + Heat-Affected Zone (HAZ) (HAZ experiences microstructural changes)



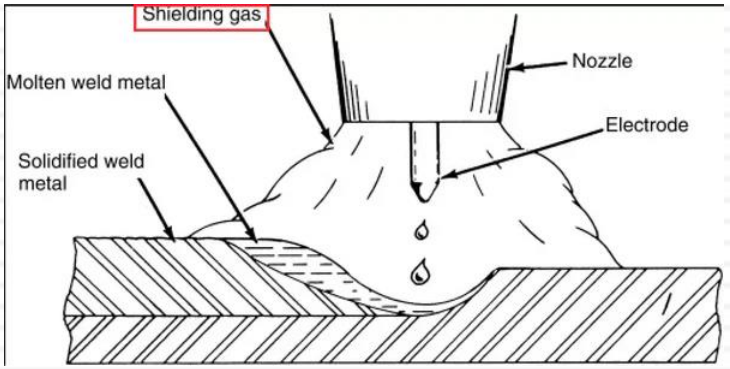
Welding Fundamentals

What Is Fusion Welding? (cont.)

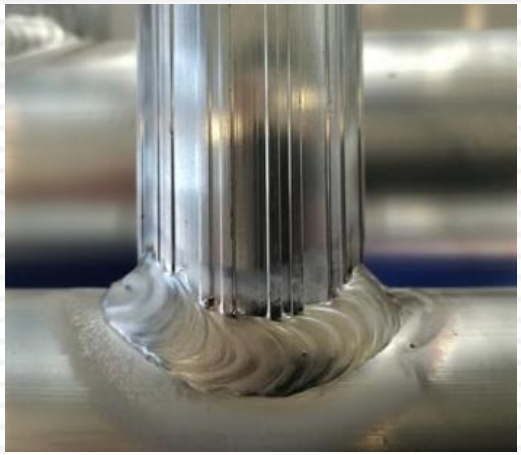
- Filler metal may be added (improves strength and fill)



- Shielding protects molten metal (prevents oxidation and porosity)



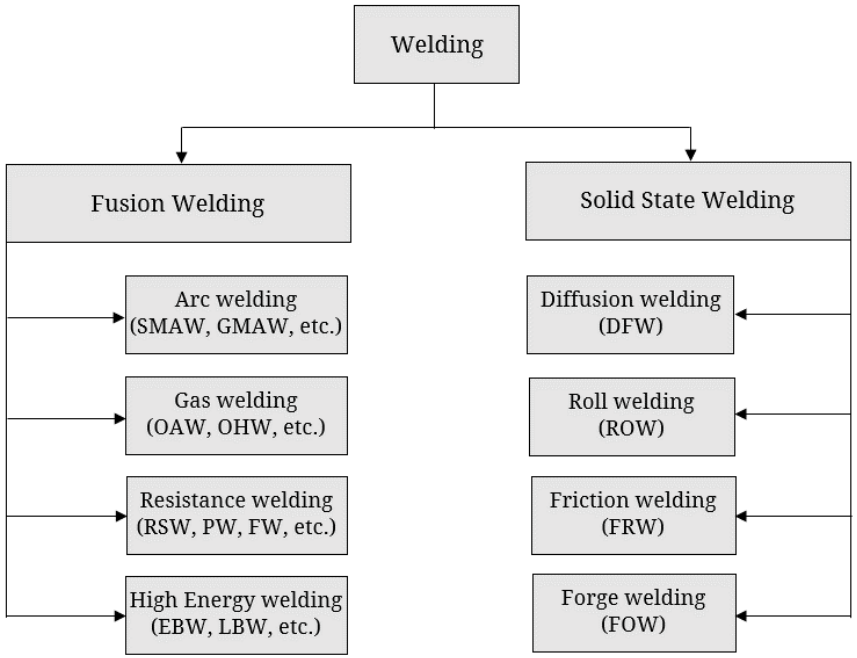
- Used for permanent joints in structural applications



Welding Fundamentals

Classification of Welding Processes

- Arc welding (electric arc generates heat)
- Gas welding (combustion flame melts metal)
- High-energy beam welding (laser, electron beam)
- Consumable vs. Non-consumable electrodes



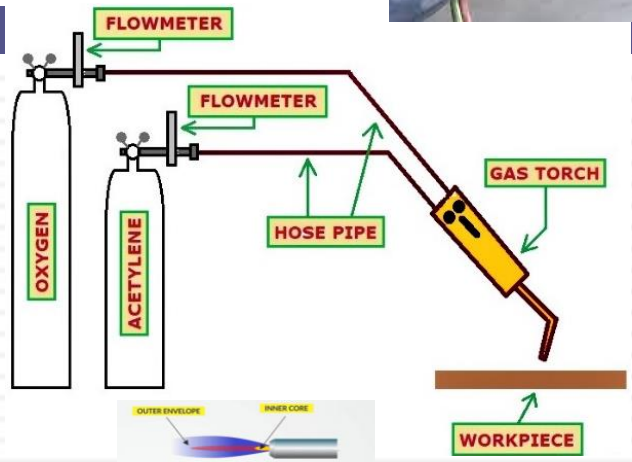
- Manual, semiautomatic, automatic processes
- Selection depends on material, thickness, quality, productivity

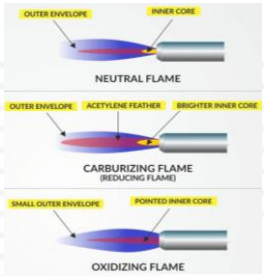
2. Oxyfuel & Arc Welding Basics

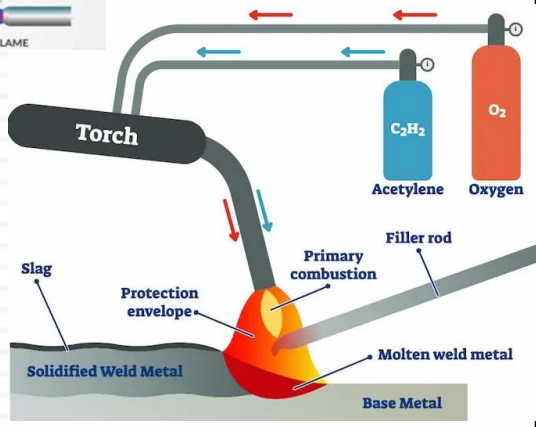
Oxyfuel & Arc Welding Basics

Oxyfuel-Gas Welding (OFW)

- Combustion of fuel gas + oxygen (produces high-temperature flame)
- Common fuel gases: acetylene, propane, hydrogen
- Three flame types: neutral, oxidizing, carburizing (affects chemistry)
- Filler rod may be used (manual feeding)
- Good for repair work and medium-thin sections
- Equipment includes torch, hoses, regulators, cylinders



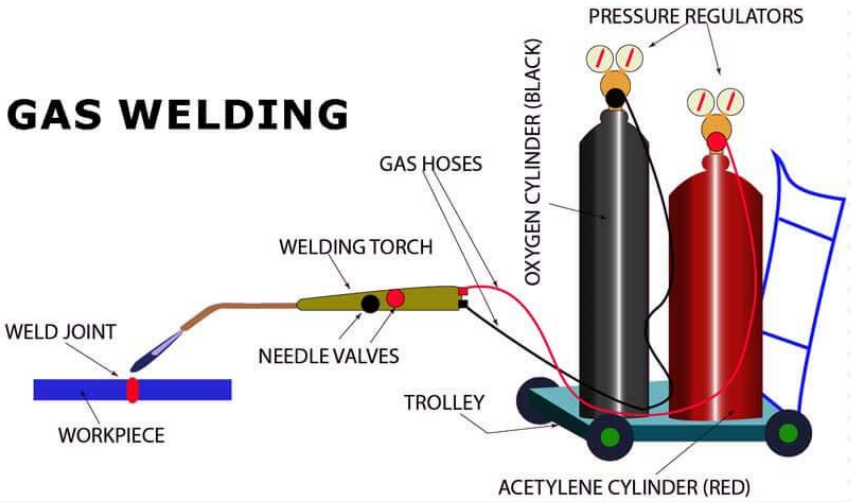


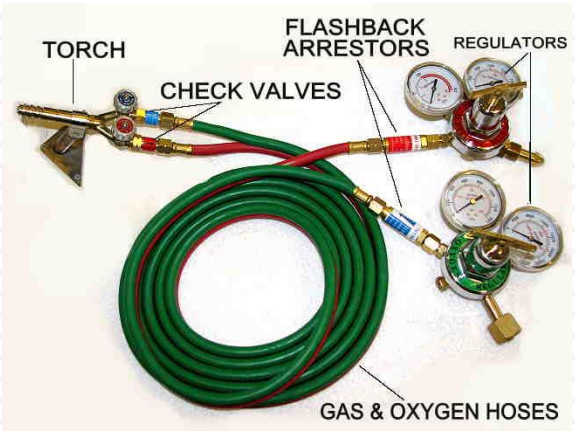


Oxyfuel & Arc Welding Basics

Oxyfuel-Gas Equipment

- Gas cylinders with pressure regulators
- Hoses for oxygen & fuel gas
- Mixer and welding torch (combines gases before ignition)
- Tip size controls flame intensity
- Flashback arrestors prevent flame from entering hose
- Portable, flexible, low-cost equipment

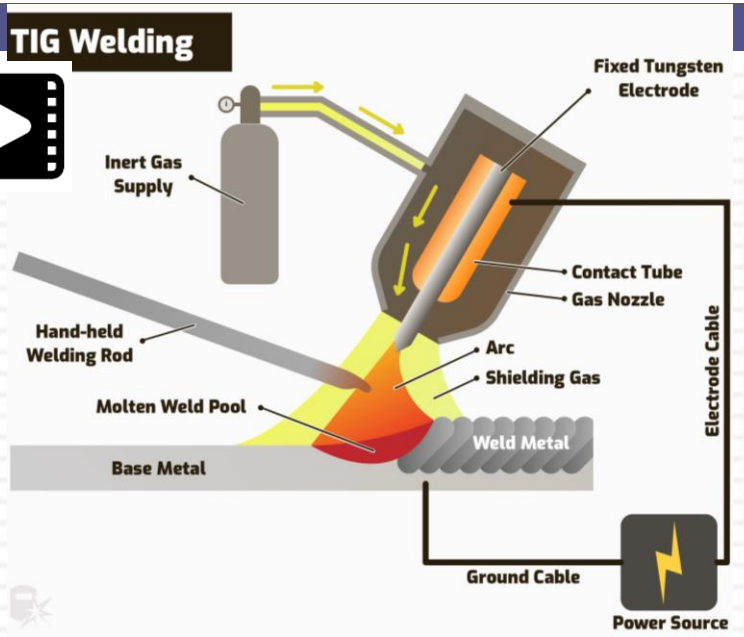




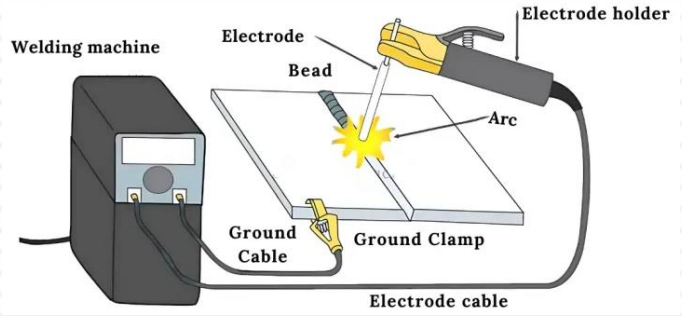
Oxyfuel & Arc Welding Basics

Arc Welding Fundamentals

- Electric arc forms between electrode & workpiece (intense heat ~6,000°C)
- Arc melts base metal and filler (if consumable electrode used)
- Power supply may be AC or DC
- Shielding prevents contamination (gas or flux coating)
- Weld pool solidifies to form joint
- Applicable to wide range of thicknesses



Gas tungsten-arc welding (aka TIG)

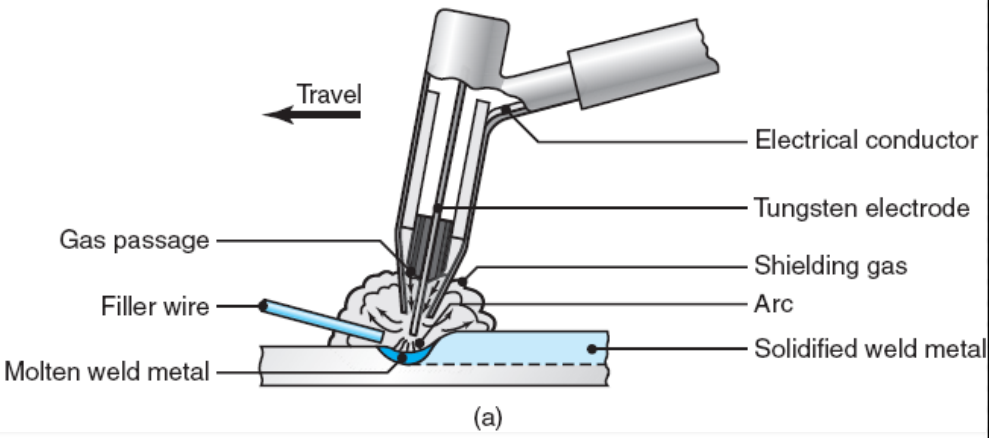


3. Non-consumable Electrode Processes

Non-consumable Electrode Processes

GTAW (Gas Tungsten Arc Welding / TIG)

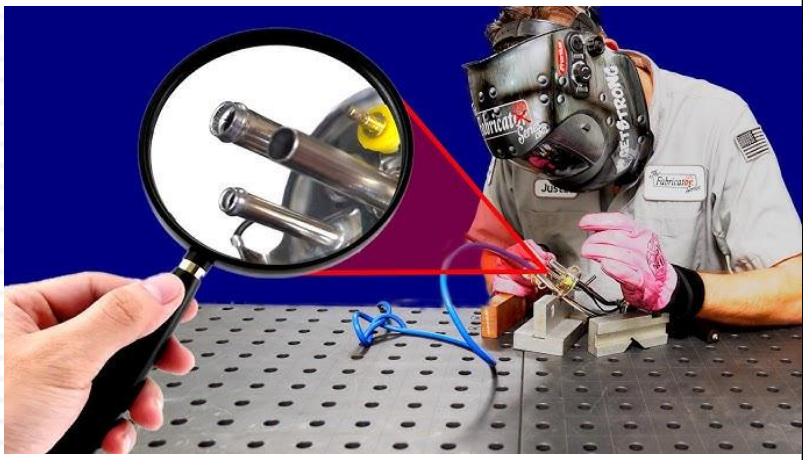
- Uses non-consumable tungsten electrode (has very high melting point)
- Filler rod optional (added manually)
- Shielding gas: Ar or He (protects weld pool)



- Produces clean, high-quality welds (no slag)
- Suitable for thin sections and reactive metals (Al, Mg, Ti)
- Lower deposition rate compared to consumable processes

Non-consumable Electrode Processes

Advantages & Limitations of GTAW



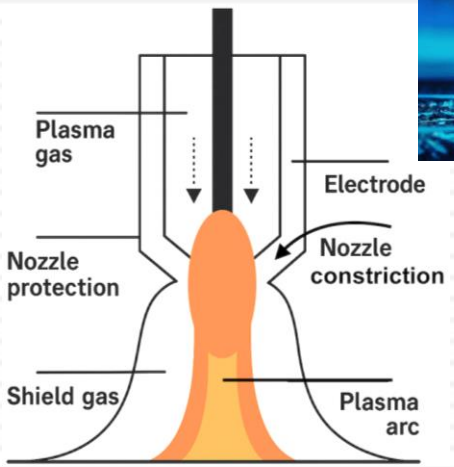
- Advantages:
  - High-quality, precise welds
  - No spatter or slag
  - Excellent control over heat input
  - Suitable for thin materials →

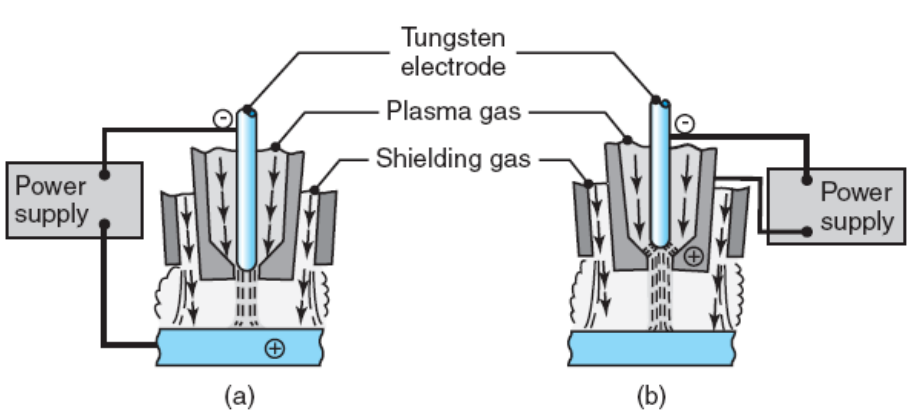
- Limitations:
  - Lower productivity (slow process)
  - Requires high operator skill
  - Expensive equipment compared to SMAW

Non-consumable Electrode Processes

Plasma Arc Welding (PAW)

- Similar to GTAW, but arc constricted through nozzle (higher energy density)
- Produces narrow, deep welds
- Can cut or weld various thicknesses
- Non-transferred and transferred arc modes
- Higher productivity than GTAW (but more expensive)





a) transferred-arc

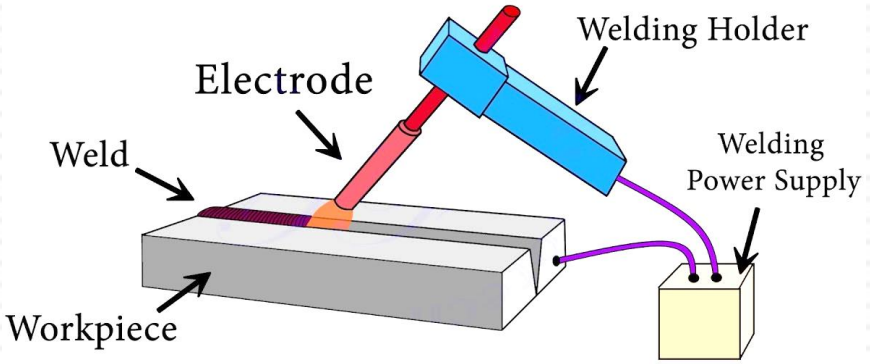
b) non-transferred arc

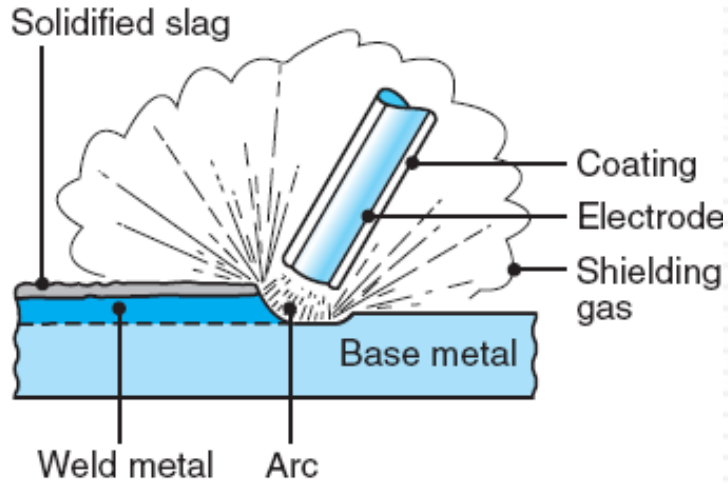
4. Consumable Electrode Processes

Consumable Electrode Processes

SMAW (Shielded Metal Arc Welding)

- Consumable electrode with flux coating (flux melts → forms protective slag)
- Most widely used manual welding process
- Simple and portable equipment
- Works for steel, cast iron, stainless steel,
- Good penetration & versatility
- Slag must be removed after welding

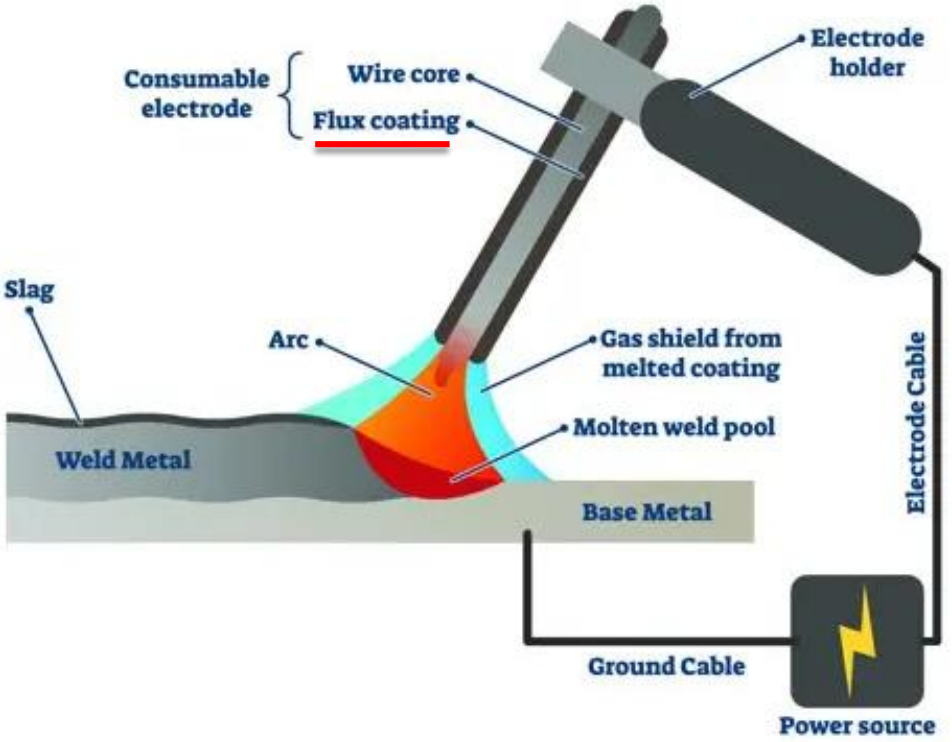




Consumable Electrode Processes

Electrode Coatings (for SMAW)

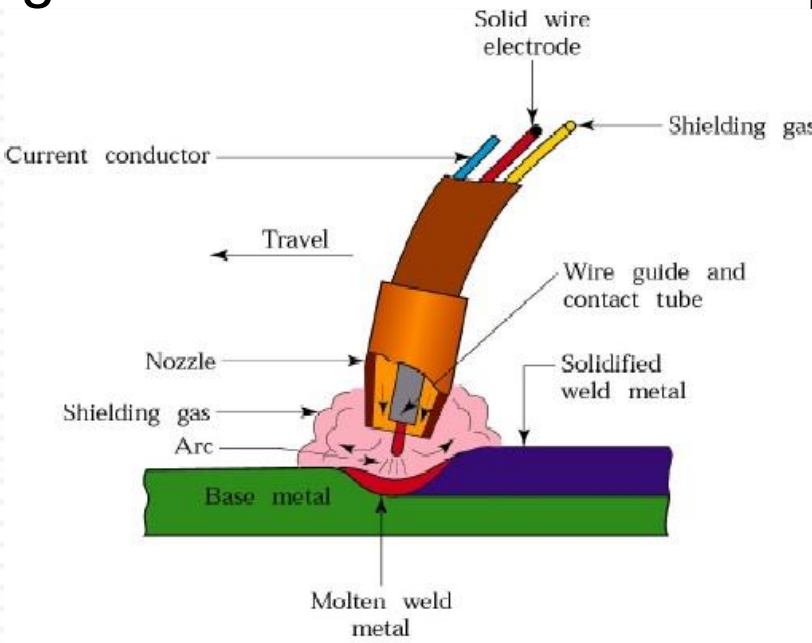
- Flux coating generates shielding gas (prevents oxidation)
- Forms slag (protects cooling weld metal)
- Adds alloying elements (improves mechanical properties)
- Provides arc stability
- Different coatings for different applications



Consumable Electrode Processes

GMAW (Gas Metal Arc Welding)

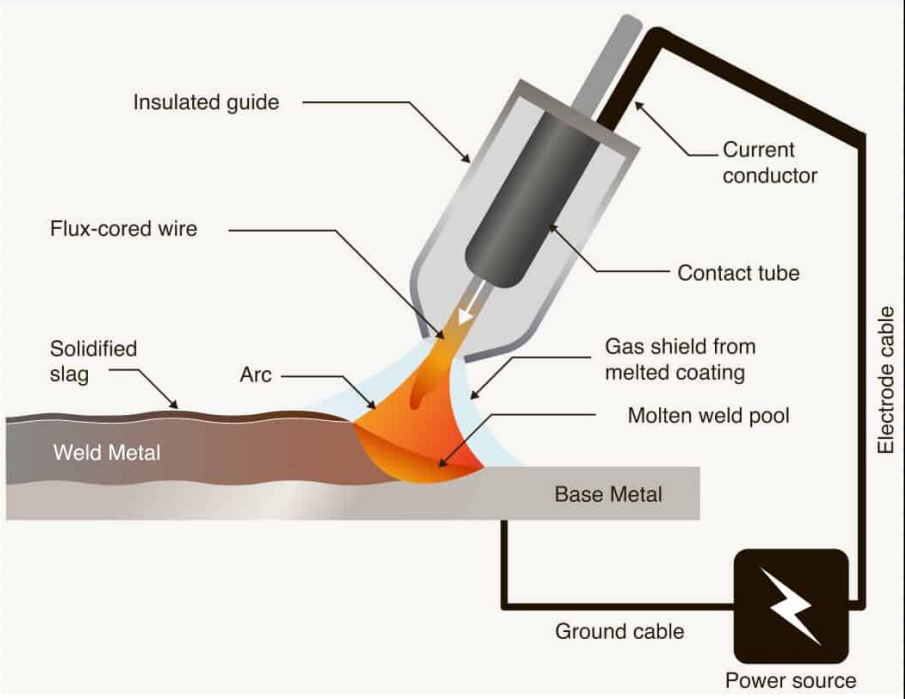
- aka MIG (Metal Inert Gas) or MAG (Metal Active Gas) welding
- Consumable wire electrode fed continuously
- Shielding gas supplied externally (CO_2, Ar, mixtures)
- High productivity & long welds
- Less operator skill required (compared to SMAW)
- Good for thin-to-medium thicknesses
- Minimal post-weld cleanup (no slag)



Consumable Electrode Processes

FCAW (Flux-Cored Arc Welding)

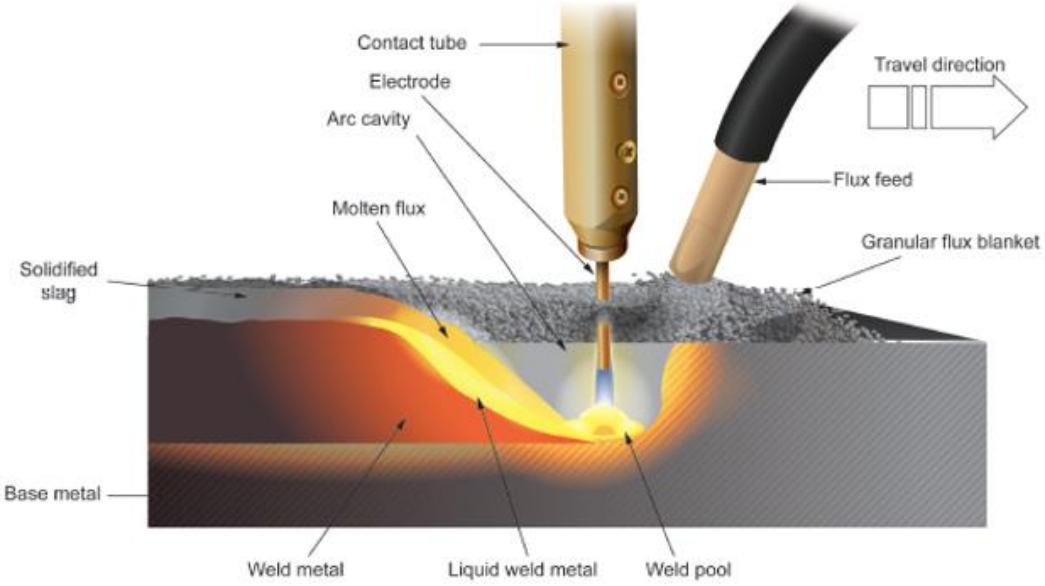
- Tubular consumable wire with flux inside
- Two types: self-shielded (outdoor) and gas-shielded
- High deposition rate (faster than SMAW and GMAW)
- Good for structural steel fabrication
- Produces more spatter than GMAW
- Suitable for thick materials



Consumable Electrode Processes

SAW (Submerged Arc Welding)

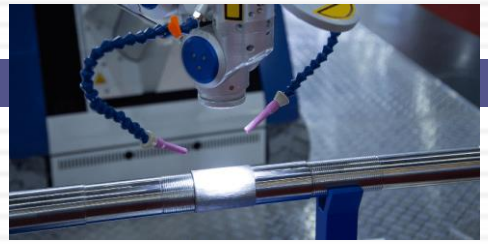
- Arc submerged under granular flux (no visible arc)
- Very high deposition rate
- Good for thick plates and long welds
- Minimal spatter, deep penetration



- Automated process (used in shipbuilding, pipes)
- Requires flat or horizontal positions

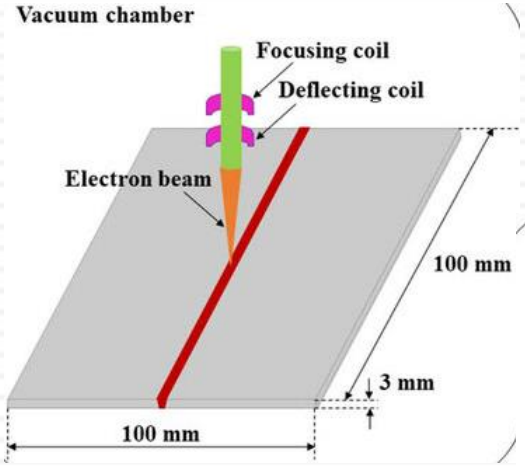
5. High-Energy & Cutting Processes

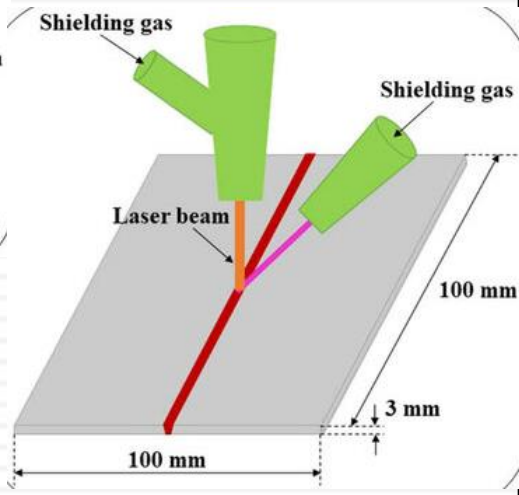
High-Energy & Cutting Processes

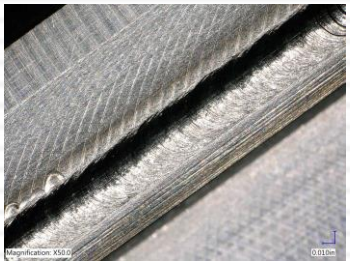


High-Energy Beam Welding (EBW & LBW)

- Electron-beam welding (vacuum chamber, deep penetration)
- Laser-beam welding (precise, high speed)
- Very small HAZ
- High quality & minimal distortion
- Excellent for aerospace, micro-welding
- Expensive and specialized equipment



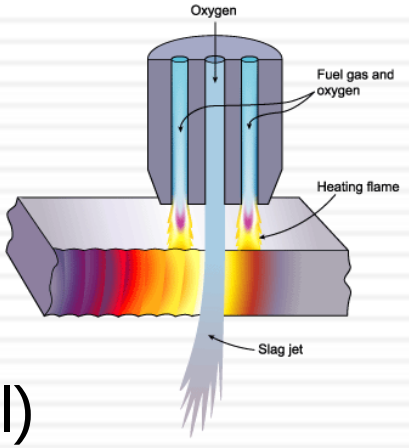


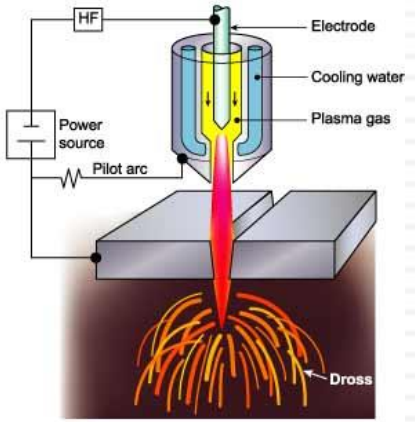


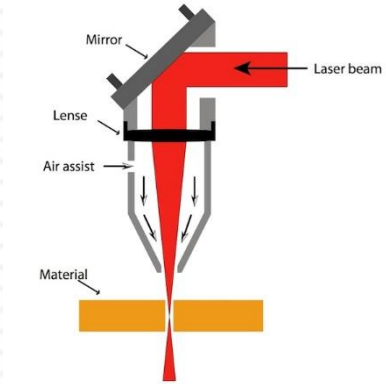
High-Energy & Cutting Processes

Cutting Processes

- Oxyfuel cutting
  (oxidation process for steels)
- Plasma arc cutting
  (ionized gas jet melts material)
- Laser cutting
  (high precision, minimal HAZ)
- Cutting often integrated
  with welding operations
- Choice depends on
  material and thickness
- Good complement to welding preparation



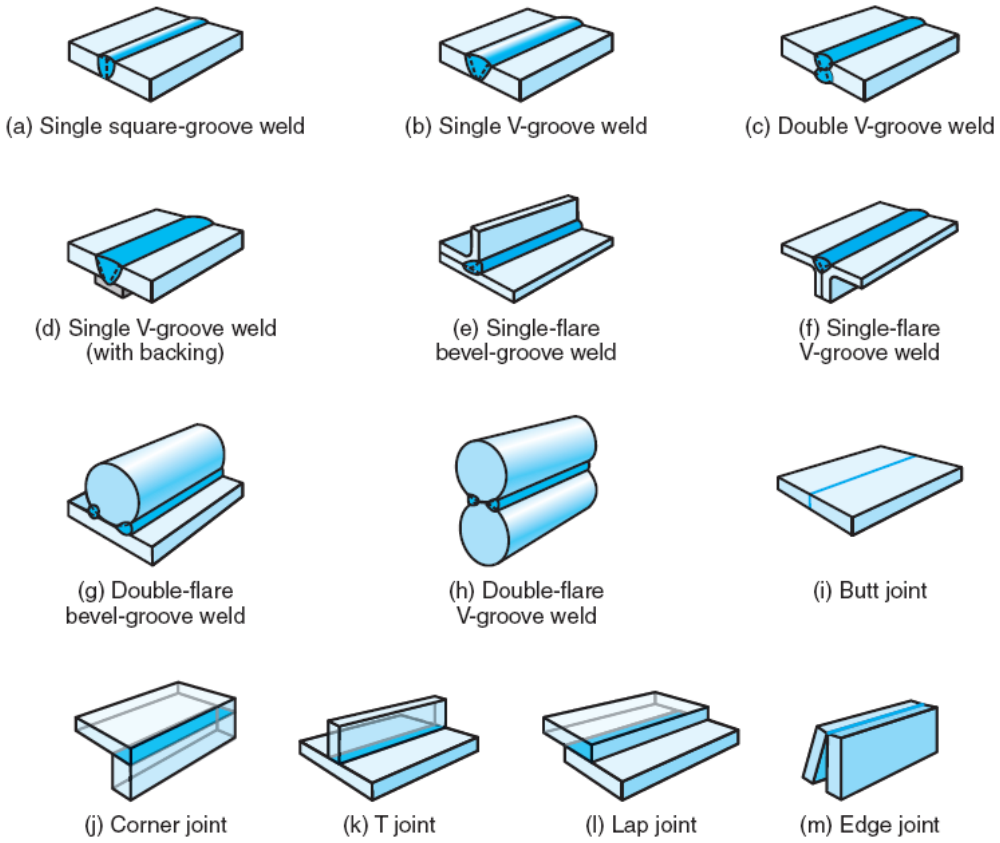


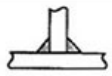
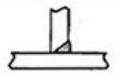


High-Energy & Cutting Processes

Joint Design in Welding

- Butt joints, lap joints, T-joints, corner joints
- Groove types: square, V, bevel, U, J
- Fillet welds vs groove welds
- Access and welding position influence design
- Joint preparation essential for quality
- Over-welding increases cost and distortion



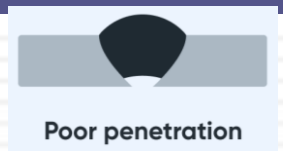
LINCOLN ELECTRIC THE WELDING EXPERTS		Weld Type	
		Fillet	Groove
Joint Type	Butt	N.A.	
	T		

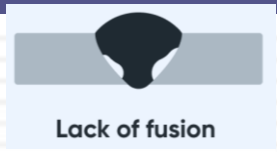
6. Defects, Symbols & Safety

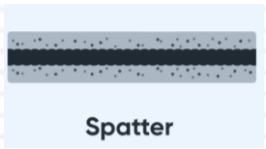
Defects, Symbols & Safety

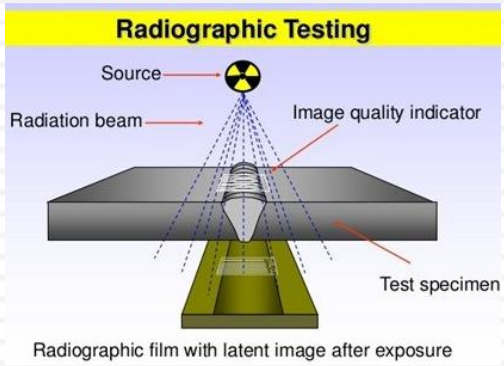
Welding Defects, Quality, & Testing

- Weld discontinuities: porosity, slag inclusions, underfill
- Cracks: hot cracking, cold cracking (HAZ-related)
- Surface irregularities: spatter, undercut, overlap
- Visual inspection (first step)
- NDT methods: radiography, ultrasonics, magnetic particle
- Mechanical tests: bend test, tensile test





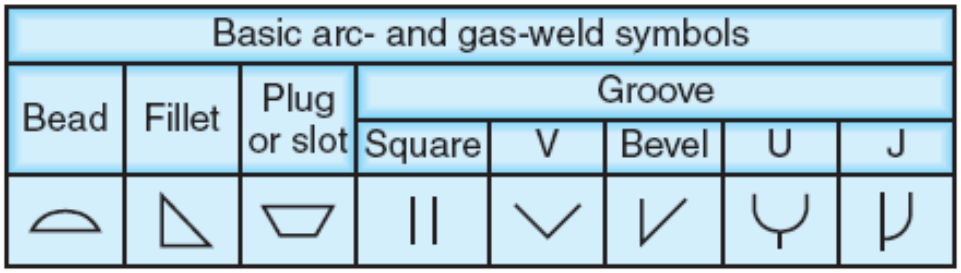


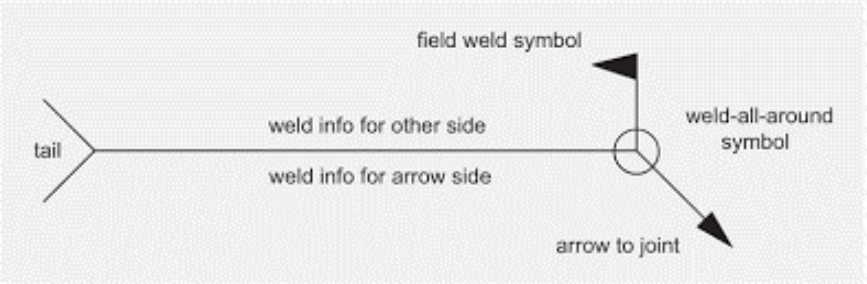


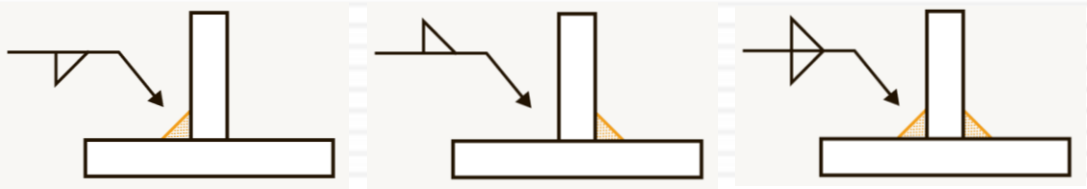
Defects, Symbols & Safety

Welding Symbols (AWS Standard)

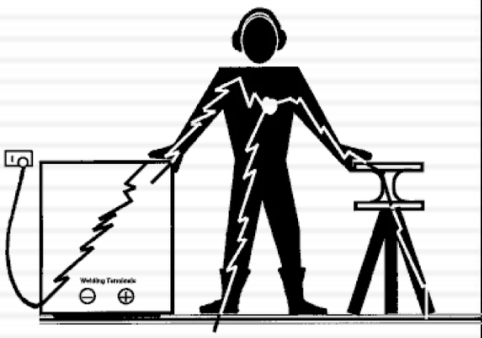
- Reference line & arrow (indicate location)
- Weld symbol placed on reference line
- Fillet weld symbol (triangle)
- Groove weld symbols (V, U, J, etc.)
- Additional info: size, length, pitch
- Tail may include process or notes







Defects, Symbols & Safety



Welding Safety

- UV radiation (requires helmet and PPE)
- Sparks and spatter (protective clothing)
- Electric shock risk (proper grounding and insulation)
- Welding fumes (ventilation required)
- Hot surfaces and burns (handled with gloves)
- Oxygen cylinder hazards (for OFW and cutting)