

Module 5

Joining Processes

Classification of welding processes

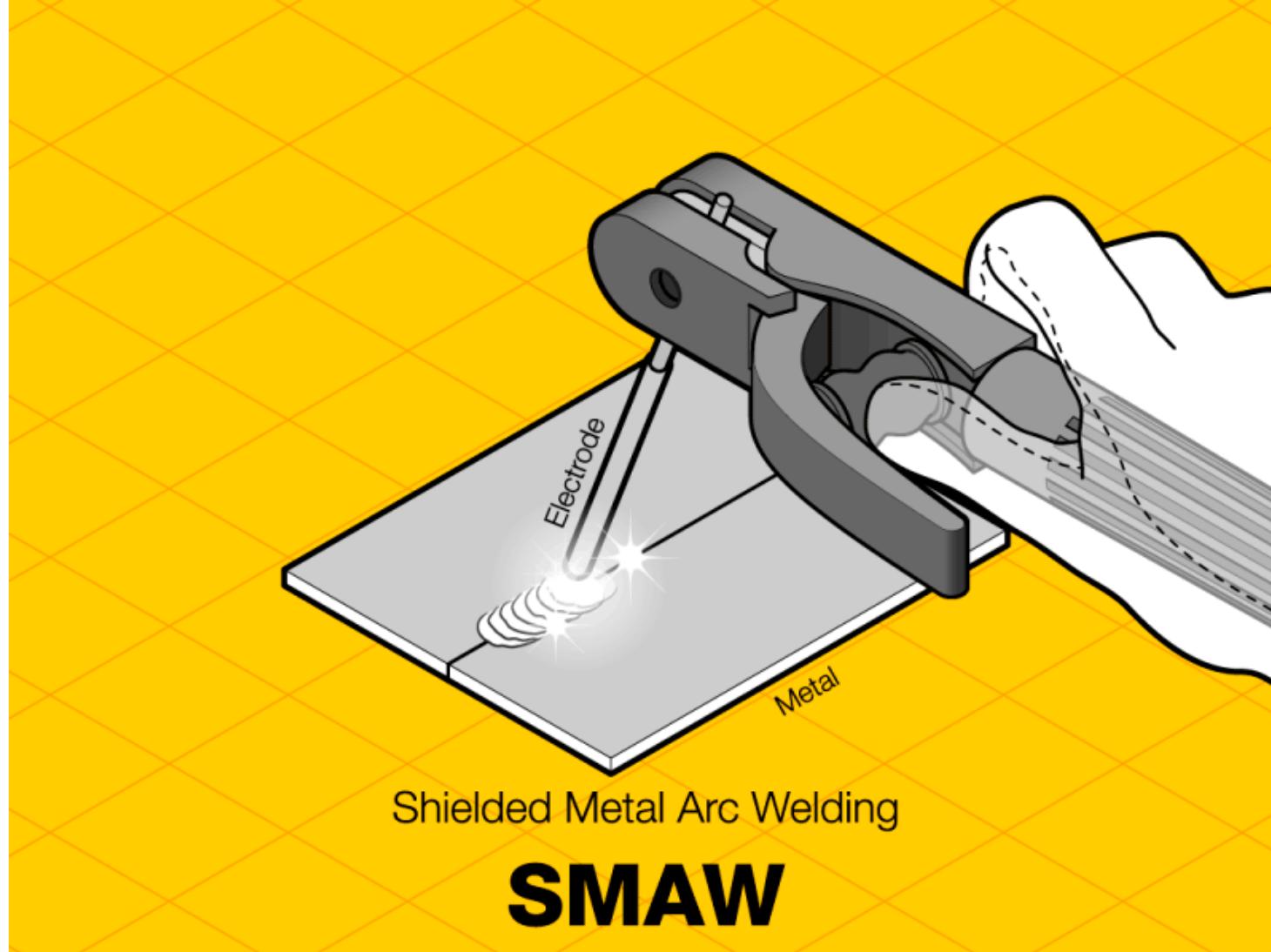
Fusion welding: Oxy fuel gas welding -types of flames and uses, Arc welding: power sources - methods of arc initiation and maintenance, arc stability, duty cycle, metal transfer. Non-consumable electrode - GTAW, PAW, AHW. Consumable electrode - SMAW, SAW, GMAW, FCAW, EGW, ESW. Electrodes and its coatings. Beam welding (EBW & LBW).

Solid State welding:

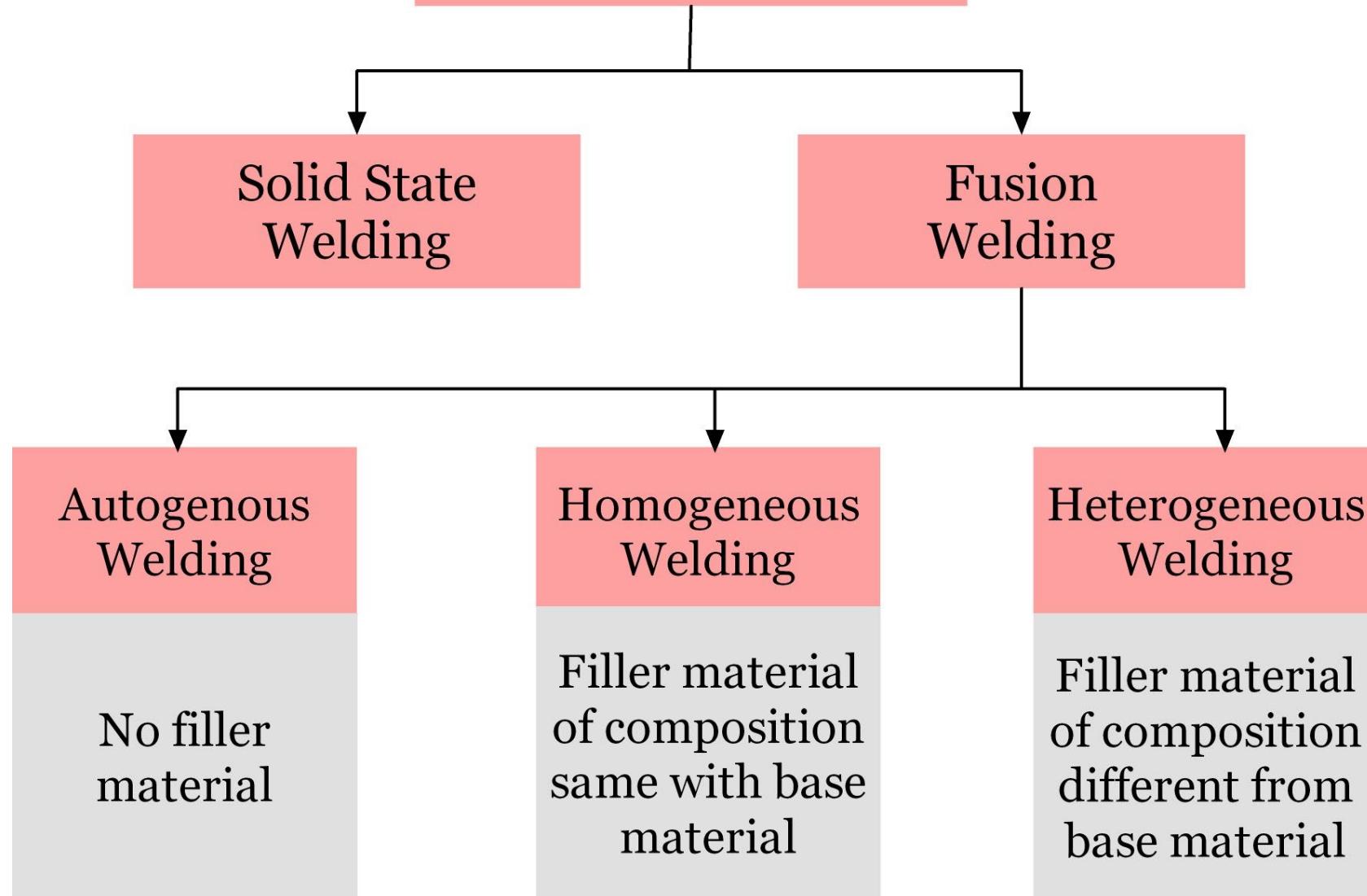
Cold welding and roll bonding, Ultrasonic welding, Friction welding, Friction stir welding, Resistance welding, Explosion welding, Diffusion welding, Thermit welding.

Brazing, Soldering and adhesive bonding: Principle of Operation, advantages, Limitations and application.

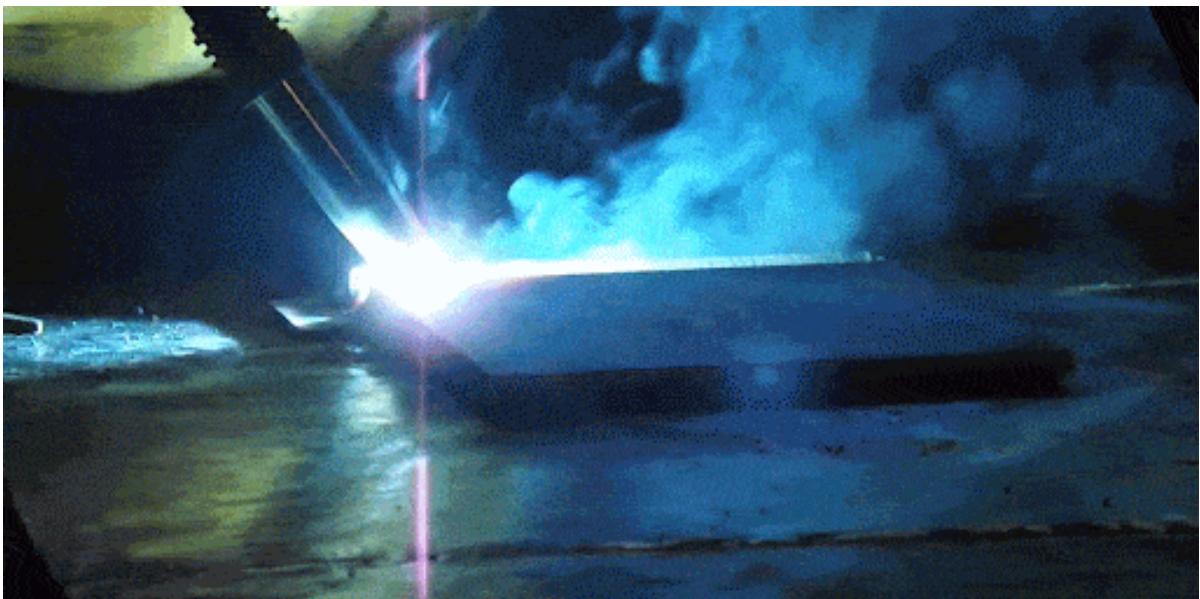
Welding



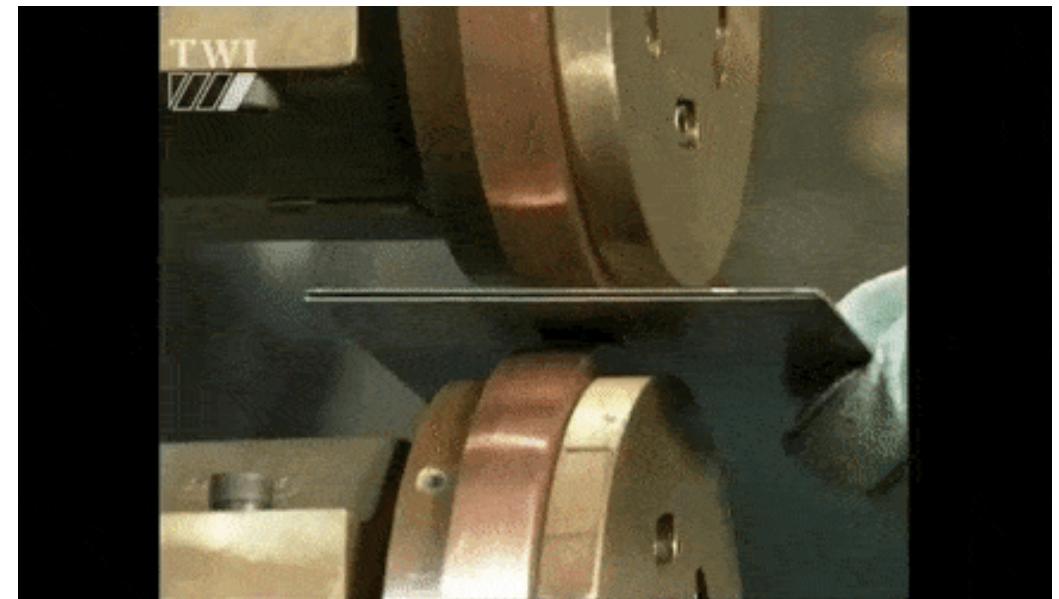
Welding



Types of Welding

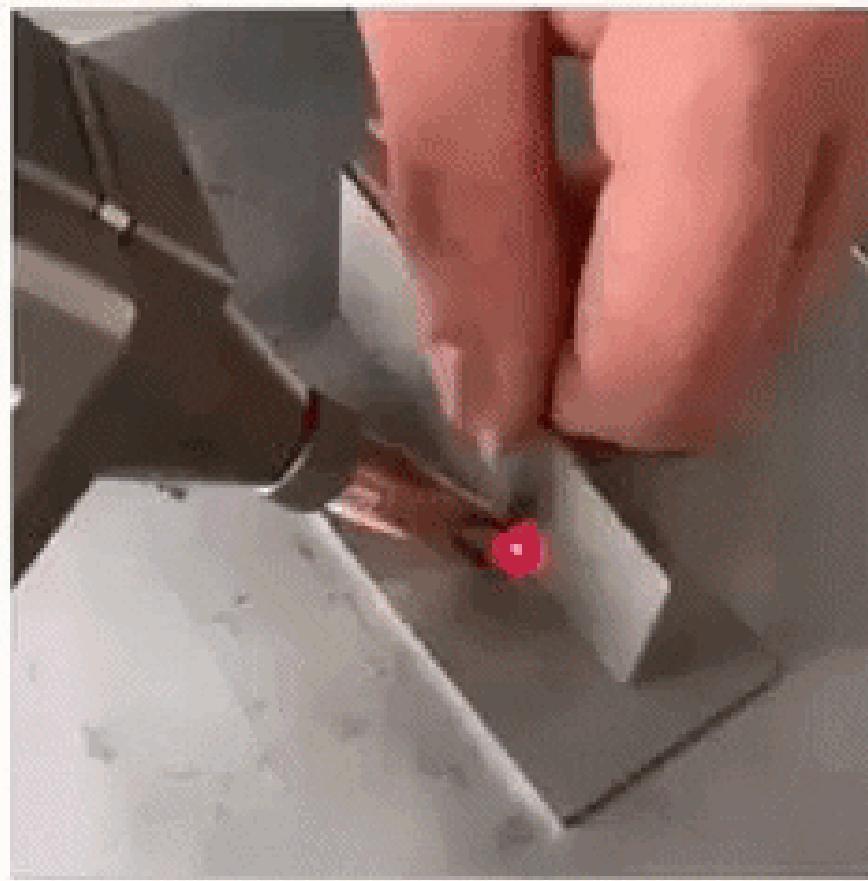
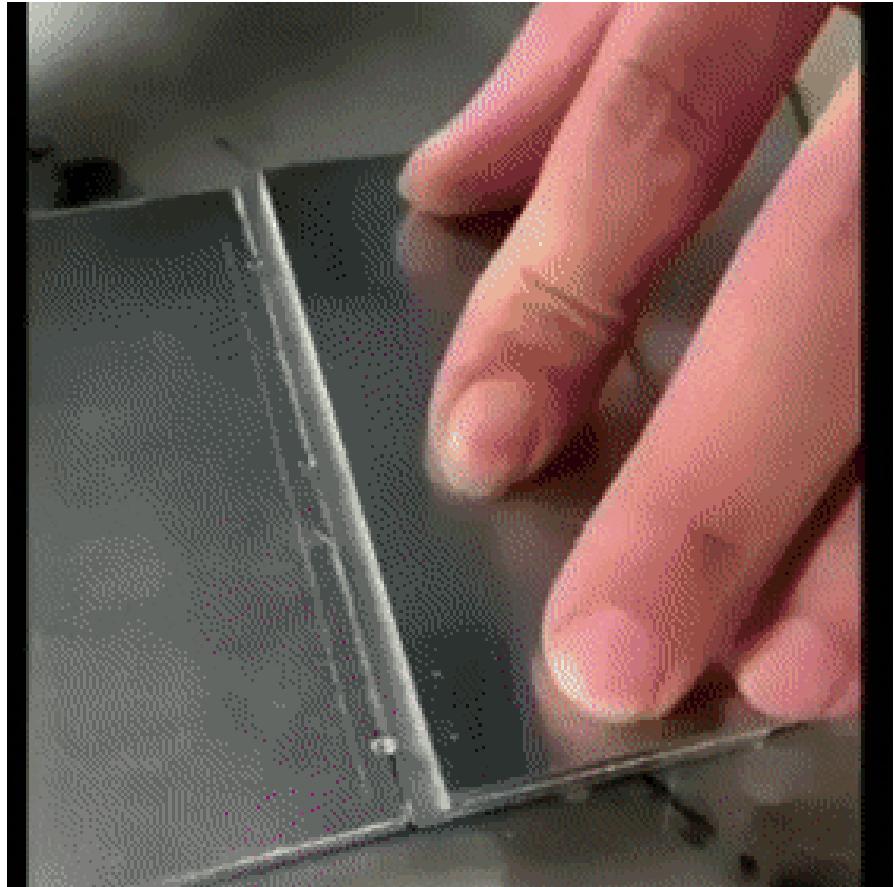


Fusion Welding



Solid state Welding

Radiant energy welding



Laser welding



Applications



Space shuttle being prepared for launch
Notice the large welded support structure

Source: Courtesy of NASA



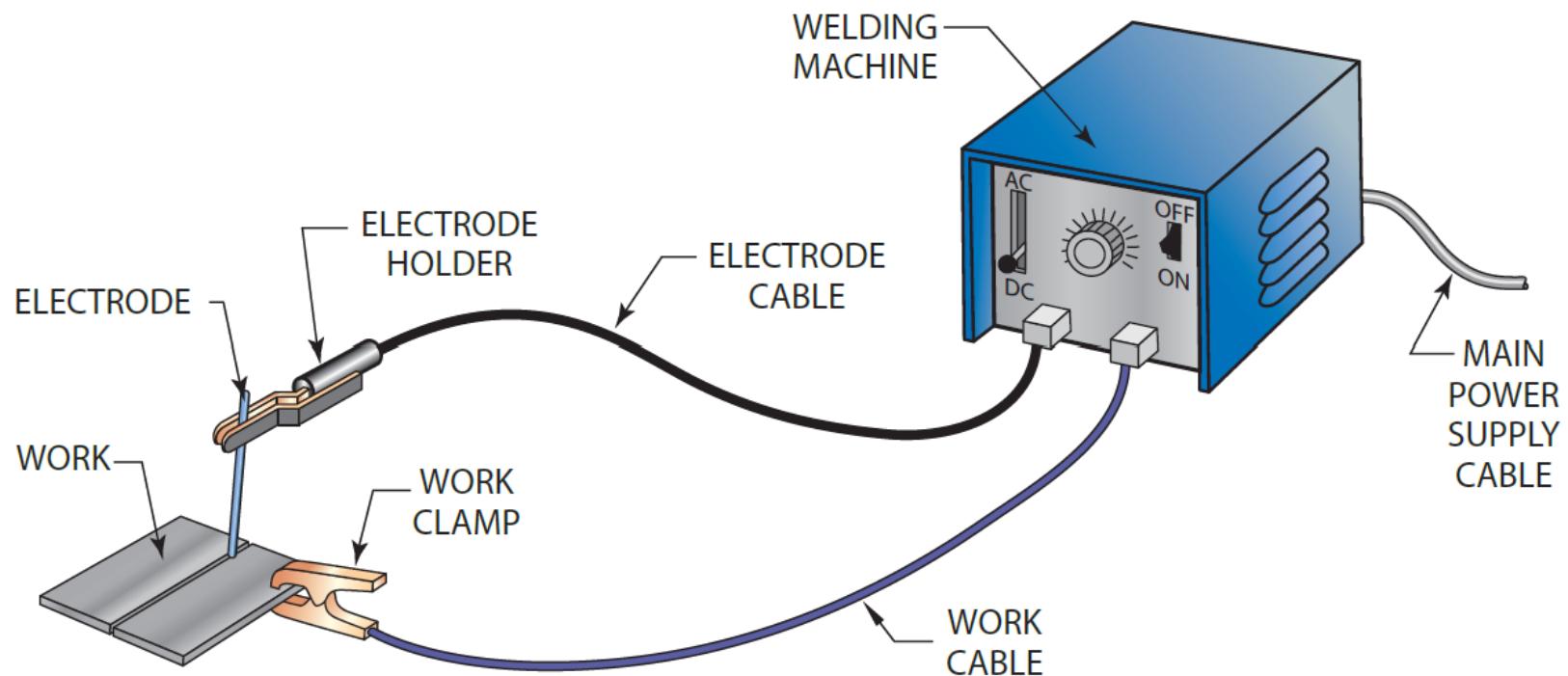
Spiral staircase

Ship



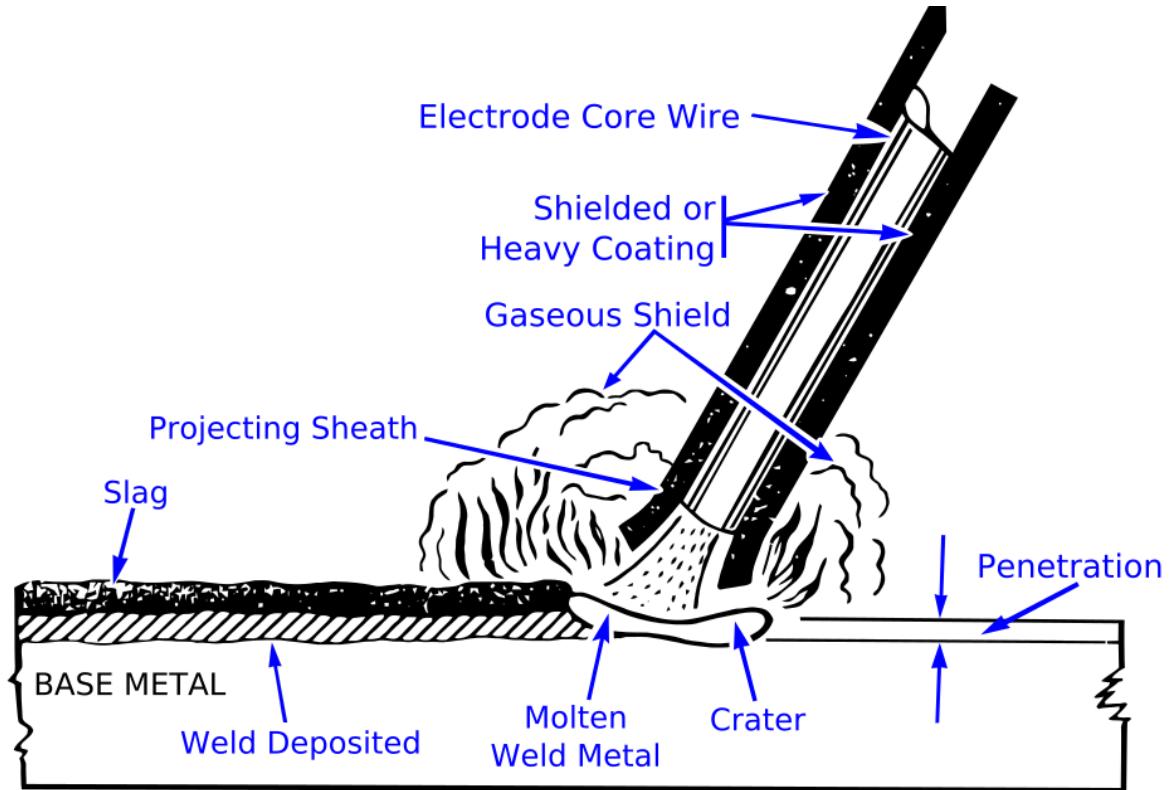
Roller coaster

Arc welding

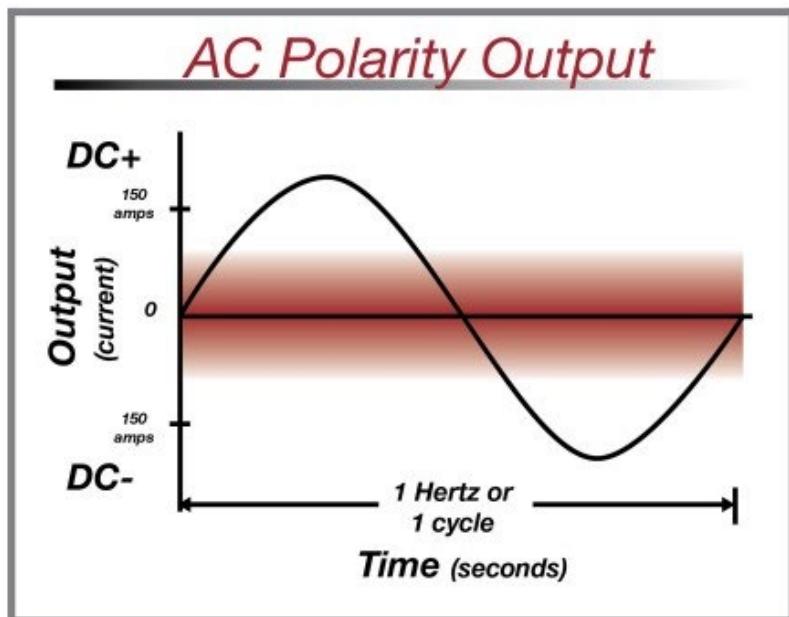
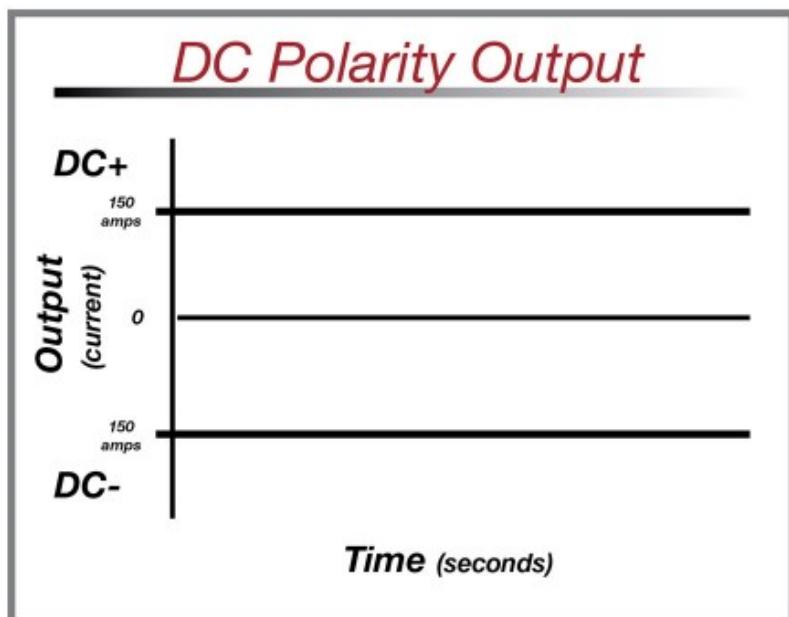


Principle of Arc

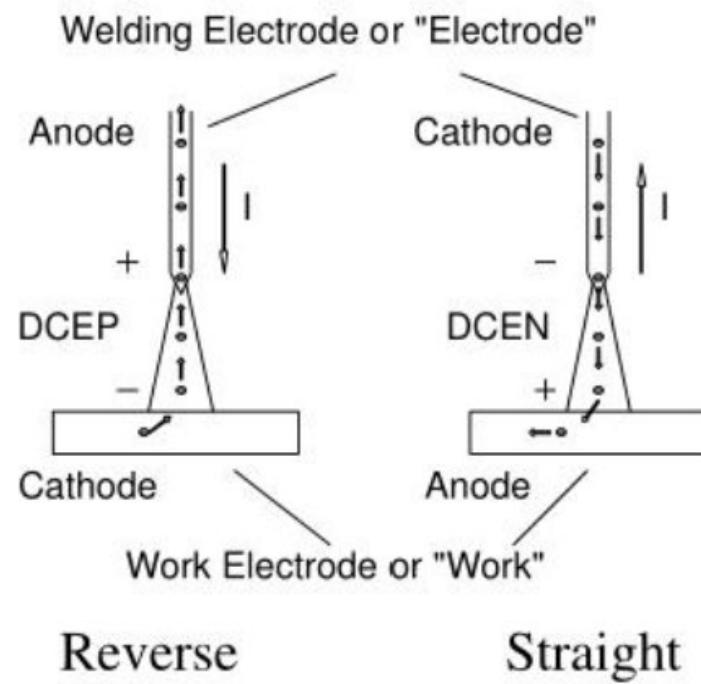
- A suitable gap is kept between the work and electrode
- A high current is passed through the circuit.
- The electric energy is converted into heat energy, producing a temperature of 3000°C to 4000°C .
- This heat melts the edges to be welded and molten pool is formed.
- On solidification the welding joint is obtained



Physics of arc welding /Welding Science



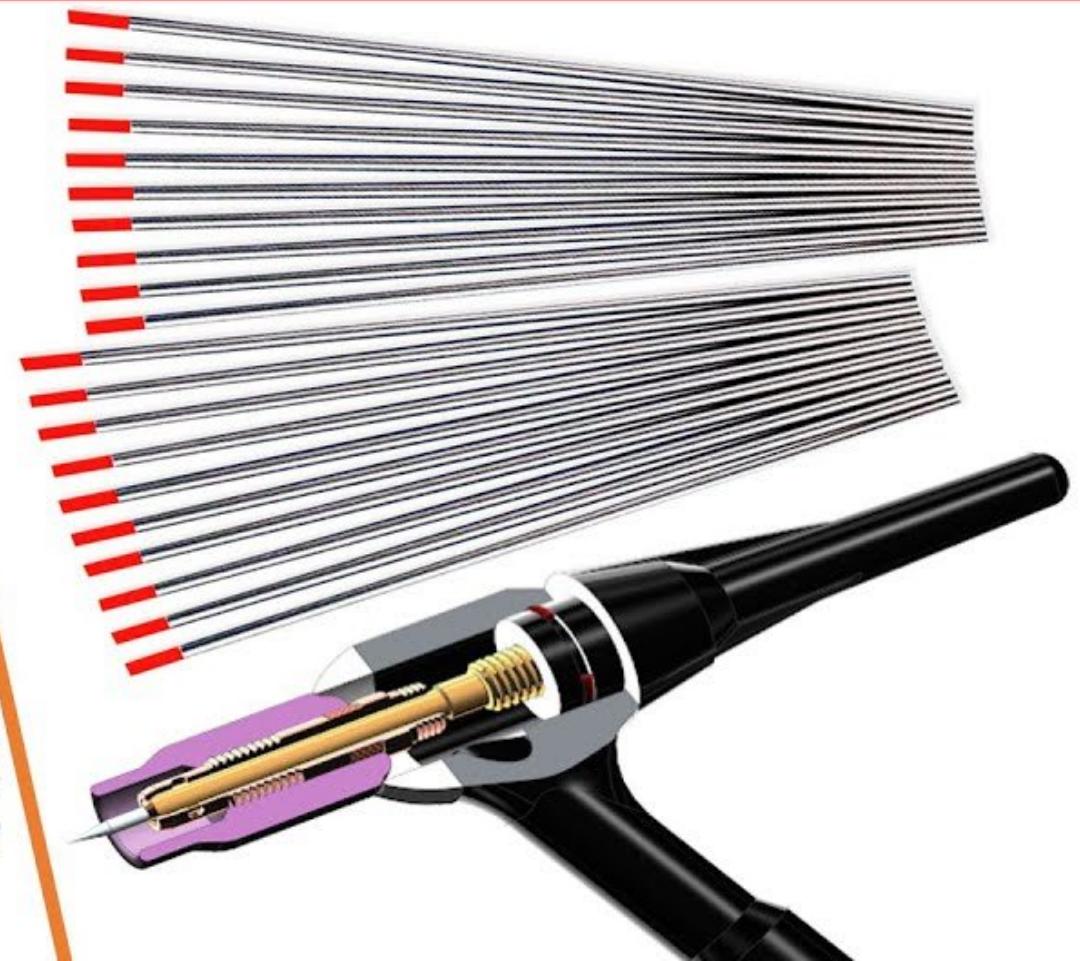
Polarity and Current Flow



Reverse and Straight polarity

DCEP (Reverse polarity)	DCEN (Straight polarity)
Electrode positive	Electrode negative
Less heat flows to workpiece	More heat flows to workpiece
Shallow penetration of weld	Deeper penetration of weld
Preferably used for welding low melting point metals/alloys	Preferably used for welding high melting point metals/alloys
Thin metals can be weld	Thicker metals can be weld

Consumable Electrode Non-Consumable Electrode



Stick electrode



Wire electrode



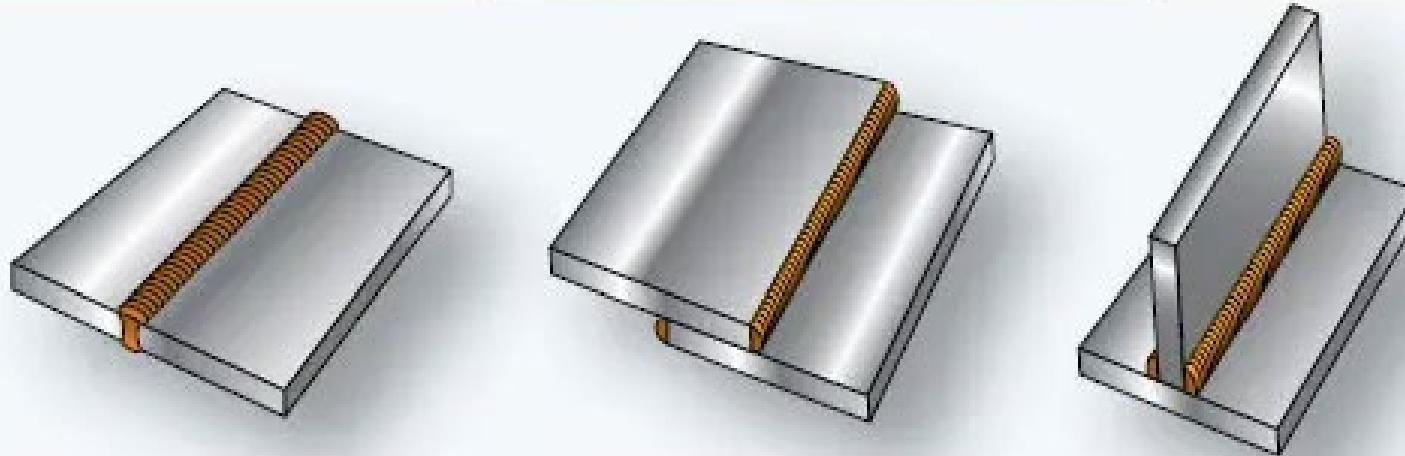


Coated Electrodes

The electrode is coated in a metal mixture called flux, which gives off gases as it decomposes to prevent

1. Weld contamination
2. Introduces deoxidizers to purify the weld
3. Causes weld-protecting slag to form
4. Improves the arc stability, and
5. Provides alloying elements to improve the weld quality.

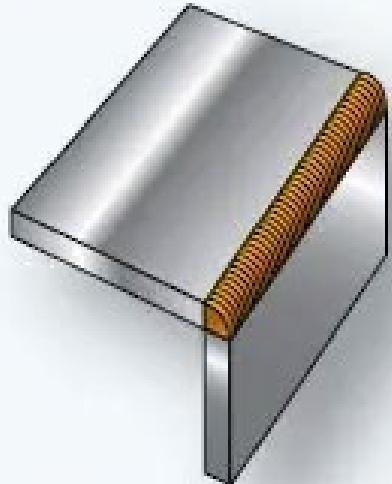
Weld Joints



Butt joint

Lap joint

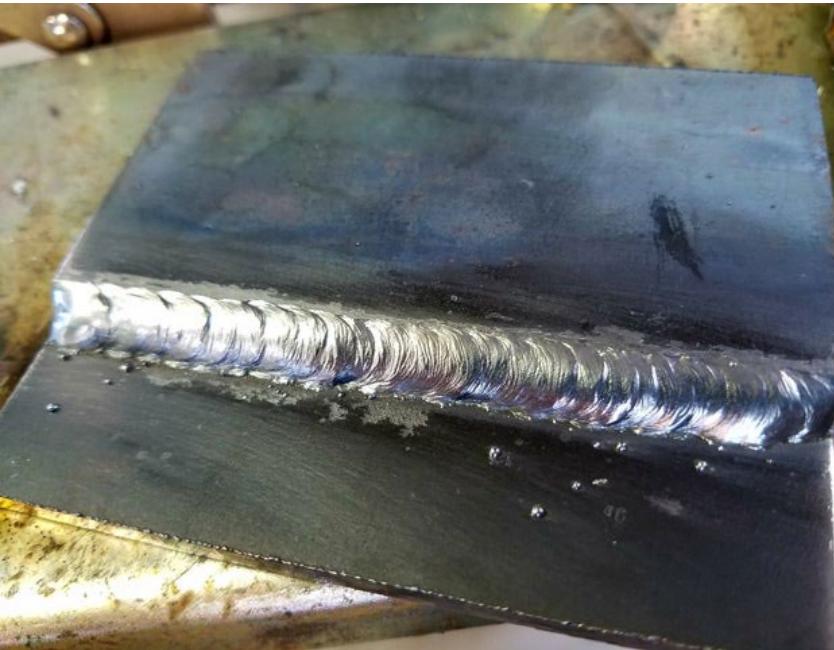
Tee joint



Corner joint



Edge joint



mig-welding.co.uk



GOOD WELD

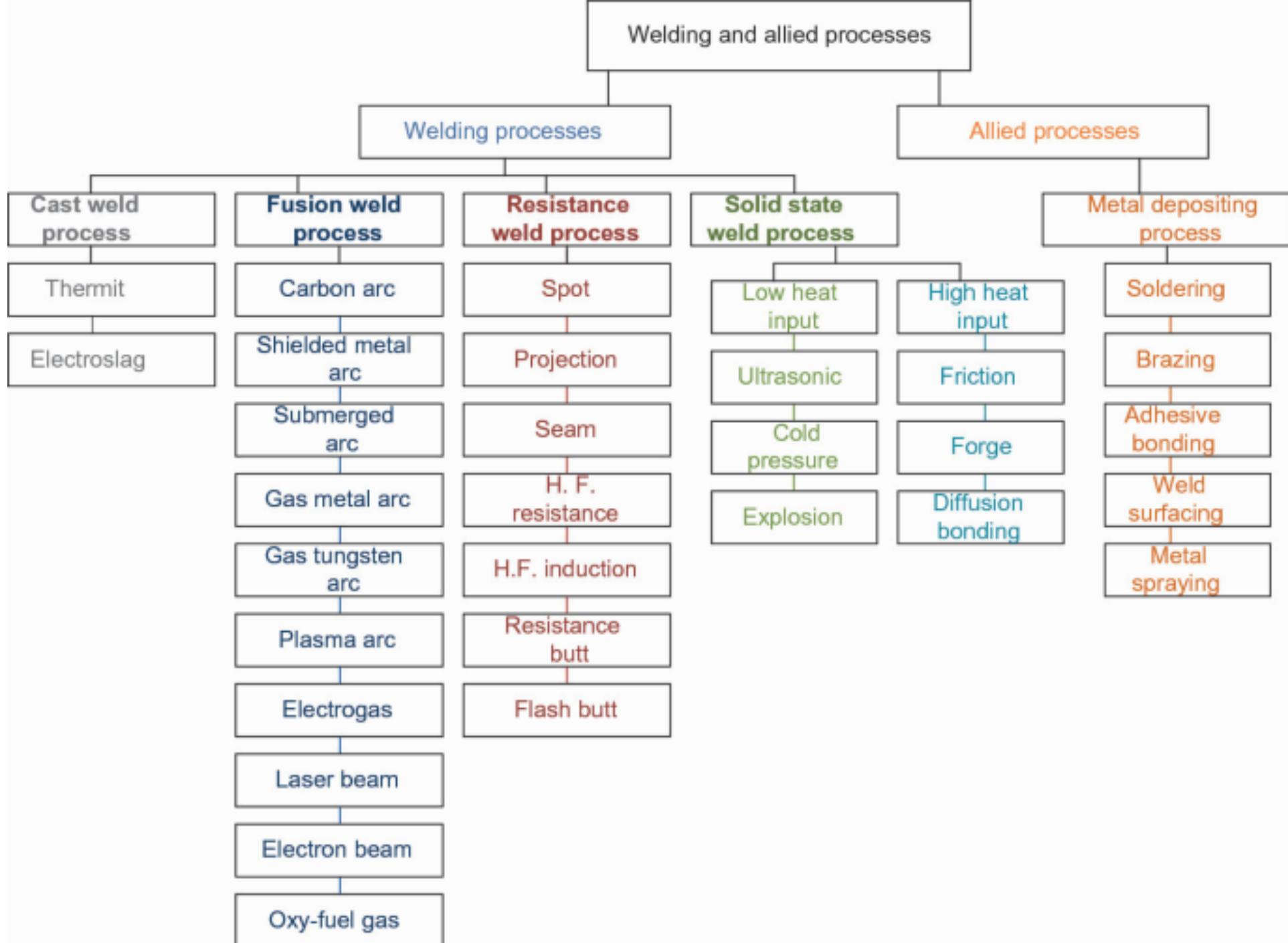


MARGINAL WELD



2.0 mm

BAD WELD



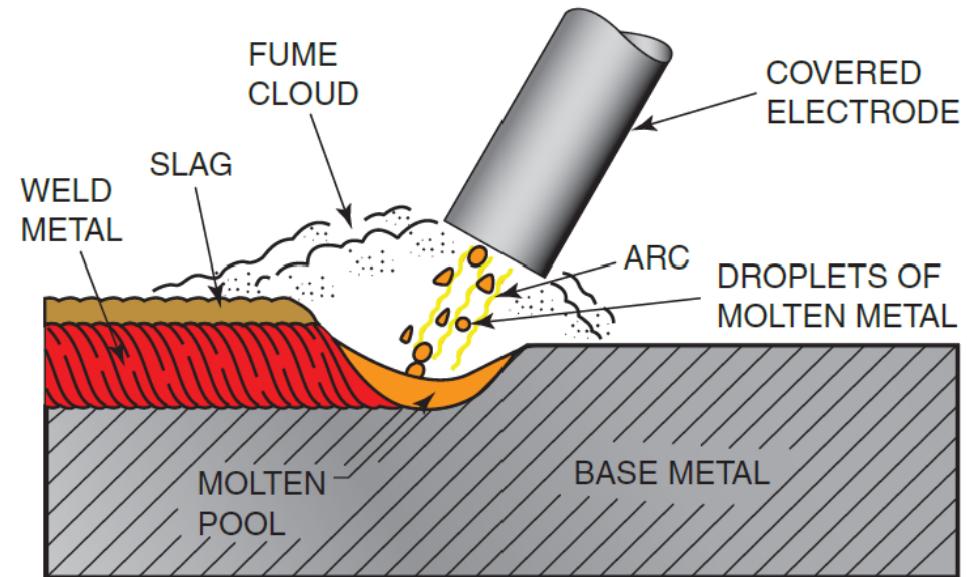
Welding Processes

Electrode : Consumable

SMAW – Shielded Metal Arc Welding

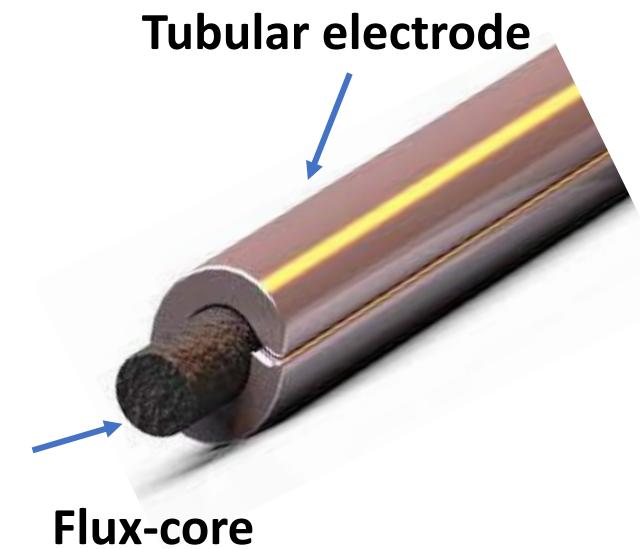
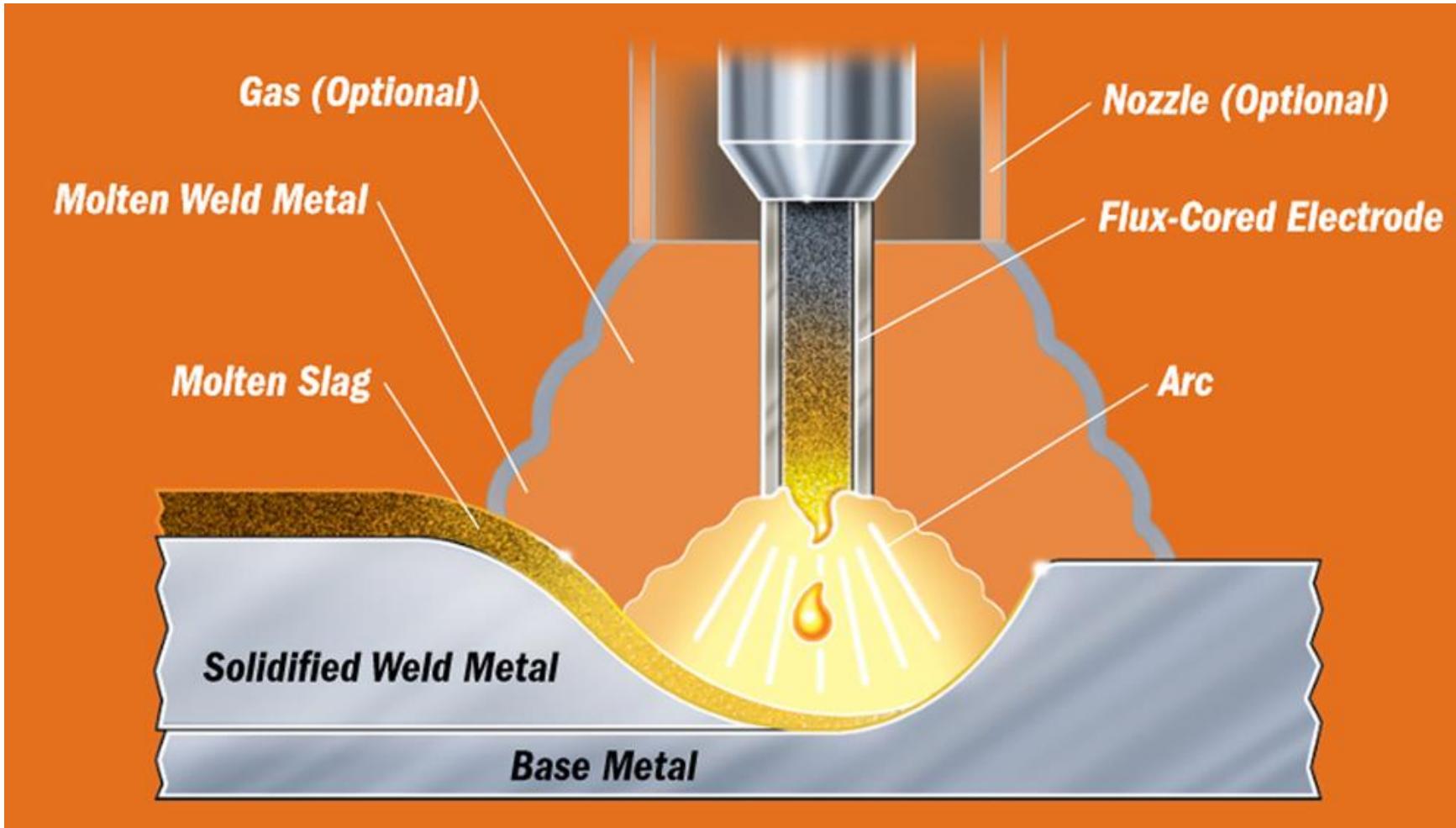


Courtesy of Lincoln Electric Company

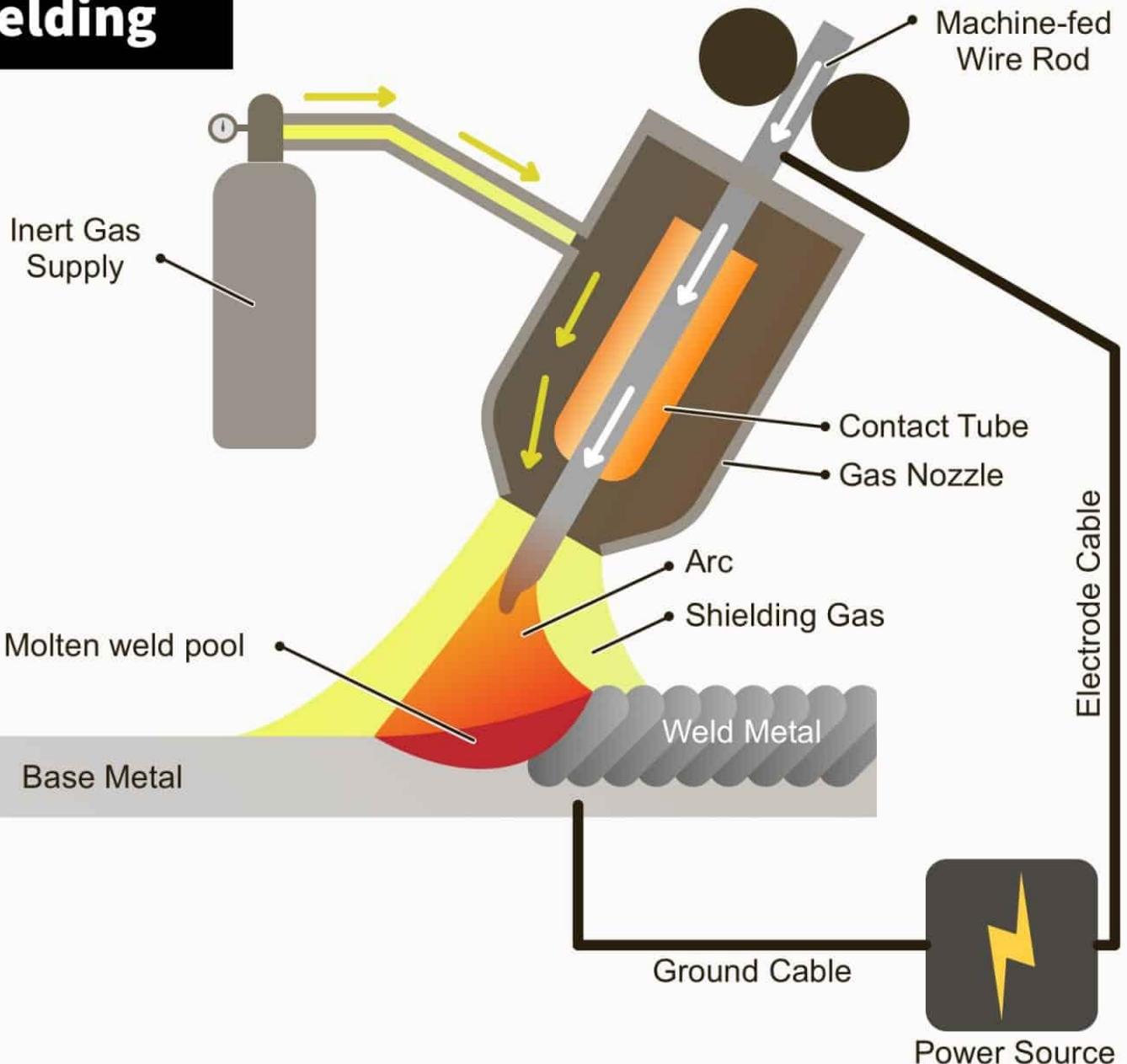
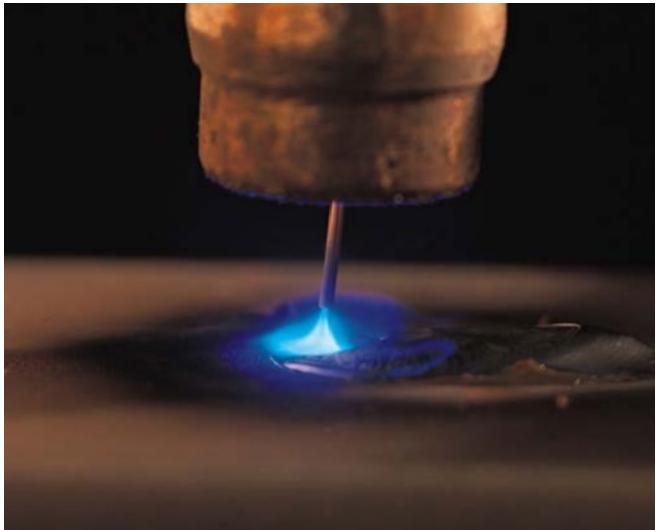


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Flux cored arc welding



MIG Welding



MIG (Metal inert gas)/GMAW (Gas Metal arc) welding

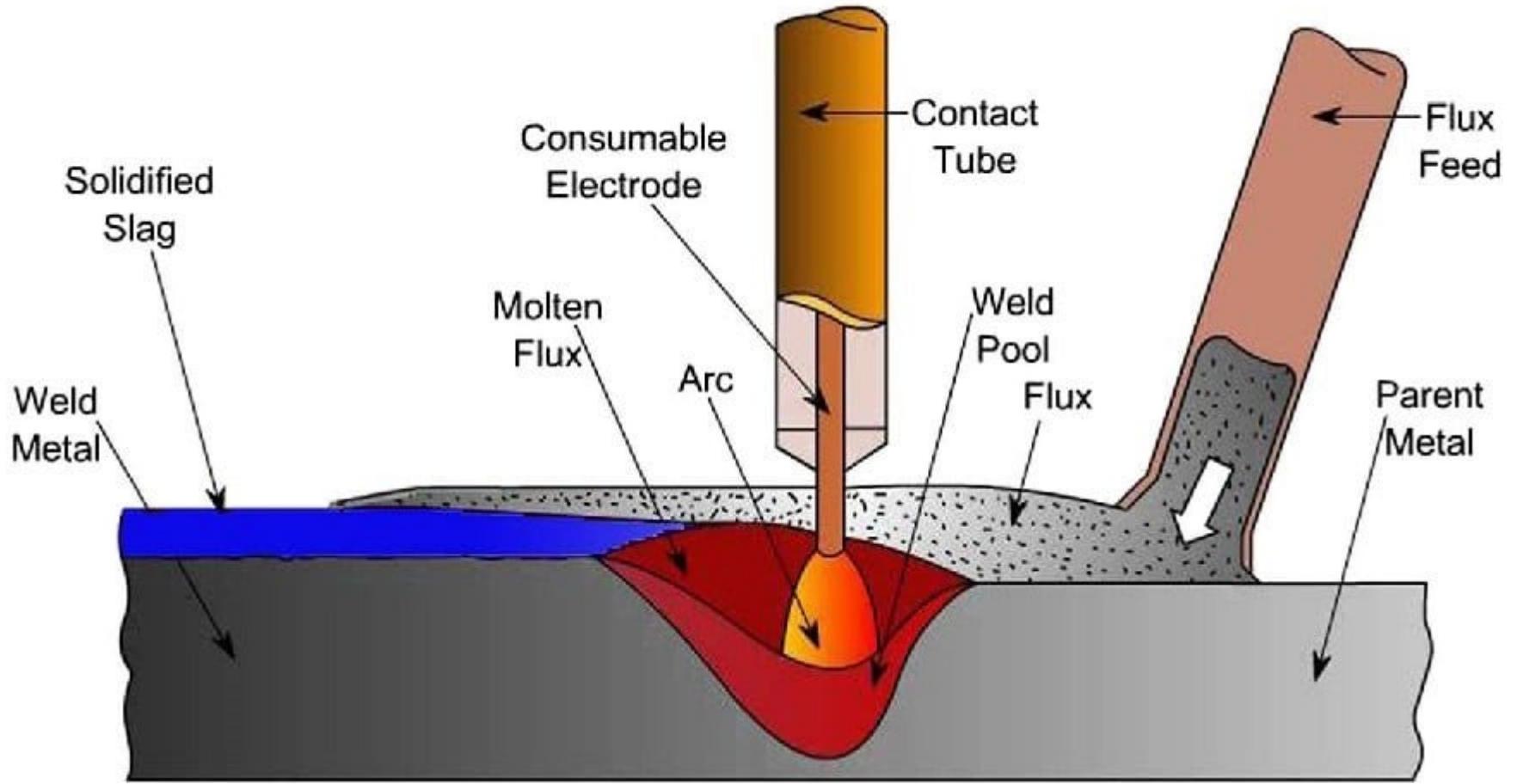
- DCEP/DCEN
- Constant Voltage/constant current power supply
- Shielding gases that are commonly used in MIG welding are argon, carbon dioxide, and a special mixture of gases with helium.

Steels - common gases used include mixture of 5-25% carbon dioxide and remaining argon

Non-ferrous metals - argon and a mixture of helium and argon are commonly used.

- wire diameter (usually between 0.6 and 1.6mm)
- All types of metals can be welded
- Ease in maintenance and higher productivity
- Workpieces of thickness <= 6 mm can easily weld

Submerged Arc Welding (SAW)





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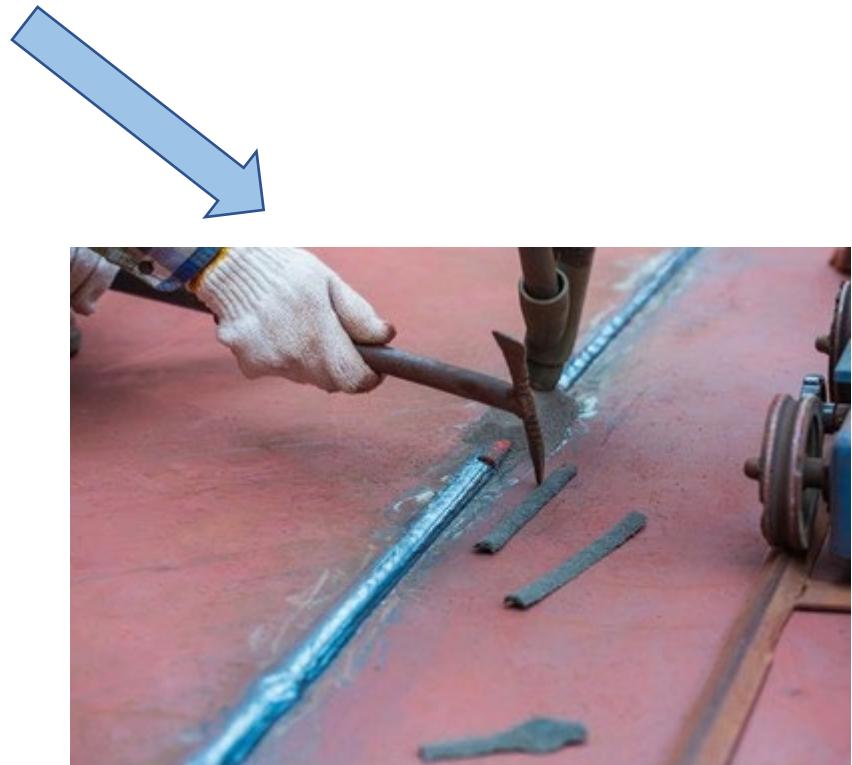




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SAW Process



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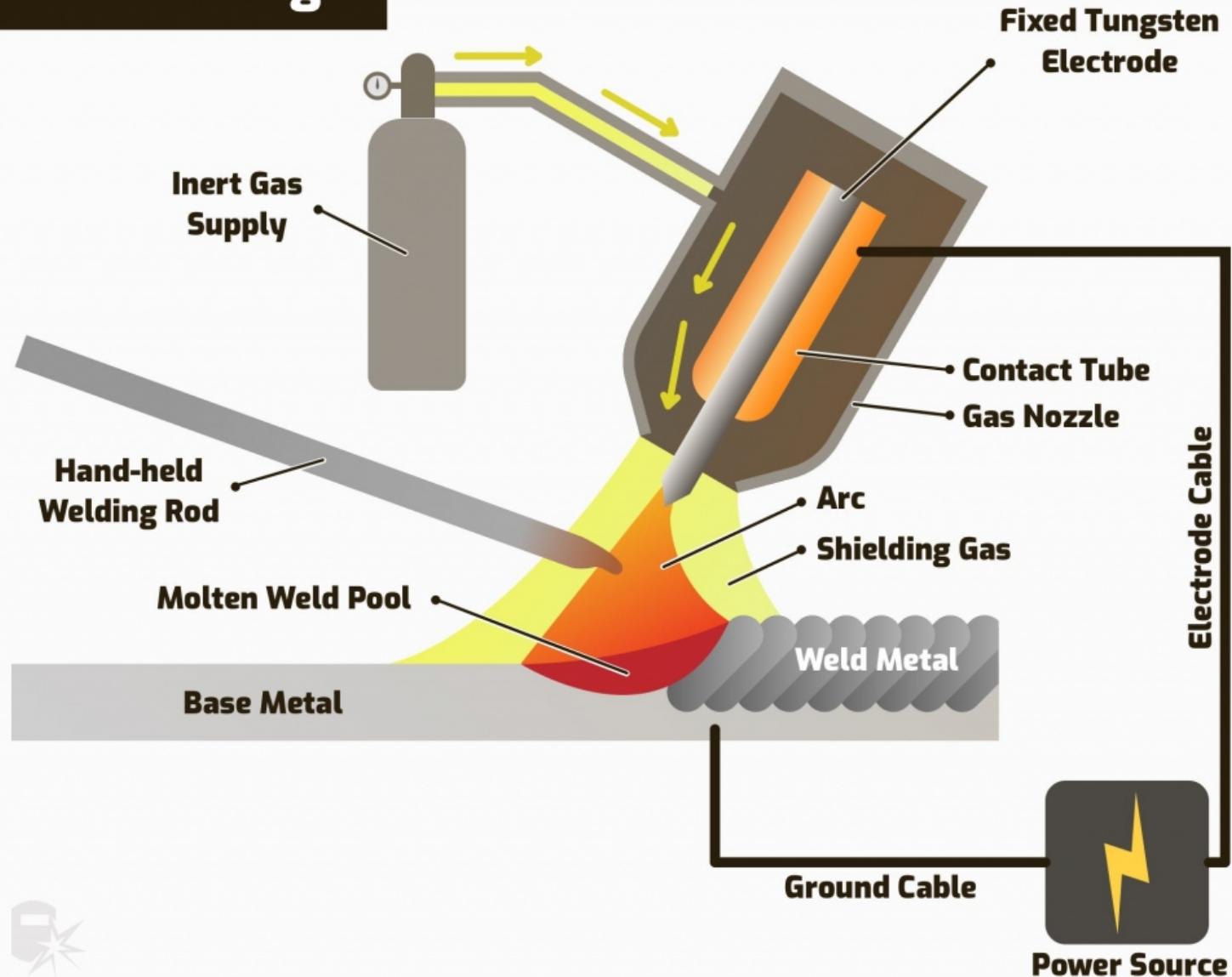
Aspects of SAW process

- DC/AC with 100% duty cycle, Current – 300 to 1500 A
- Continuous process and the length of one weld may go up to 10 minutes.
- Process is quick
- Fumes, UV and spatter free
- High deposition rate
- Removal of slag
- Thicker sections of metals can be easily weld
- Linear or circular sections of the workpieces can be weld easily

Welding Processes

Electrode : Non-Consumable

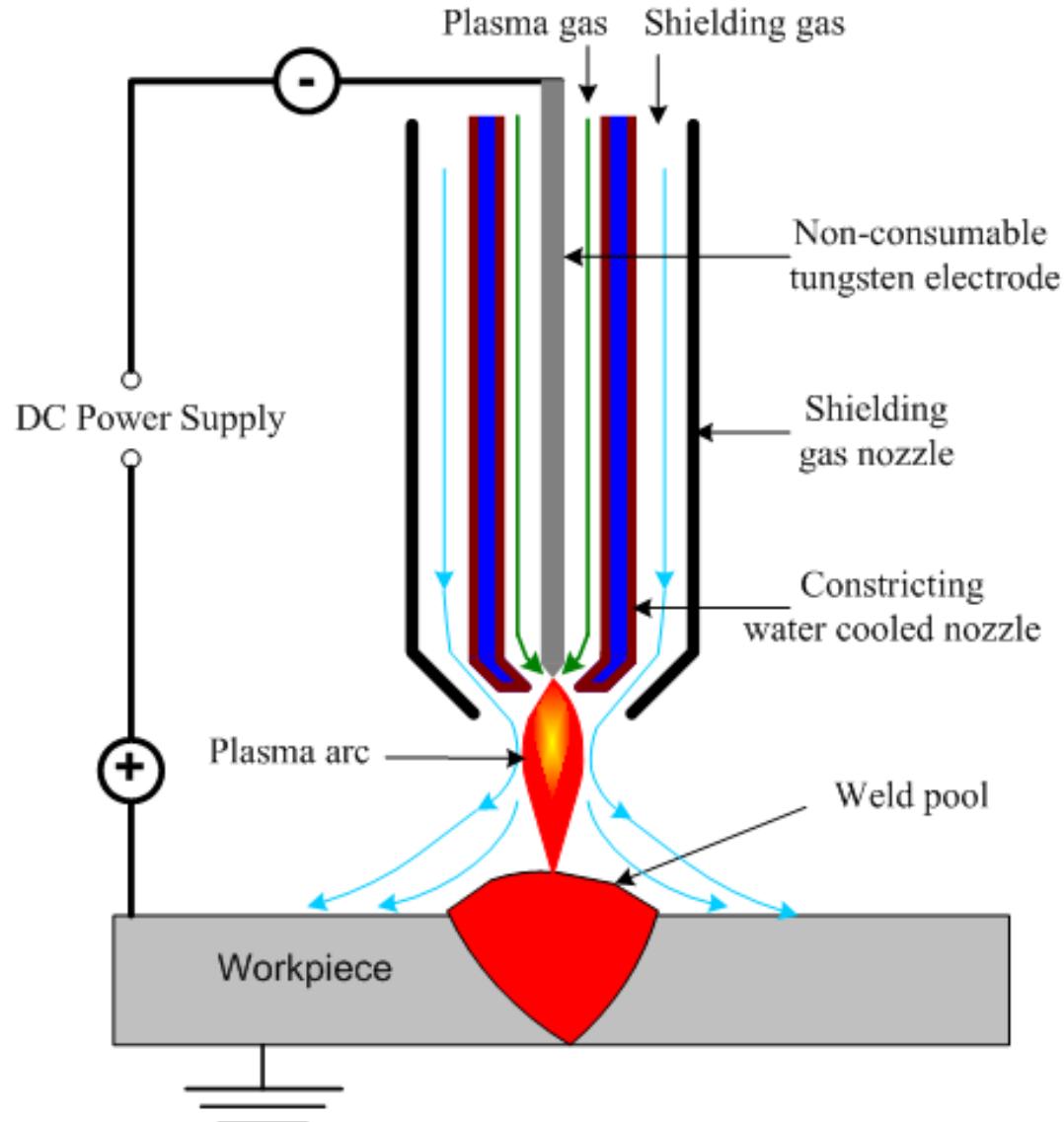
TIG Welding



Aspects of TIG welding

- DC/AC power source
- No contact between electrode and workpiece
- Non-consumable electrode
- Clean and stable arc
- Pleasing welds
- Filler metal may/may not be used : Touching the tungsten electrode with the filler metal contaminates the electrode, requiring you to stop and reground the tungsten tip. So, adding the filler metal is tricky because the tungsten tip and the filler wire tip have to be close and move in the same direction without touching.
- Shielding gases : Argon and helium. Argon is almost perfect and gets the job done in 99% of the cases.
- Gas tungsten arc welding is typically used for precision welds and joining exotic metals like stainless steel, aluminum, Chromoly, nickel alloys, and magnesium.

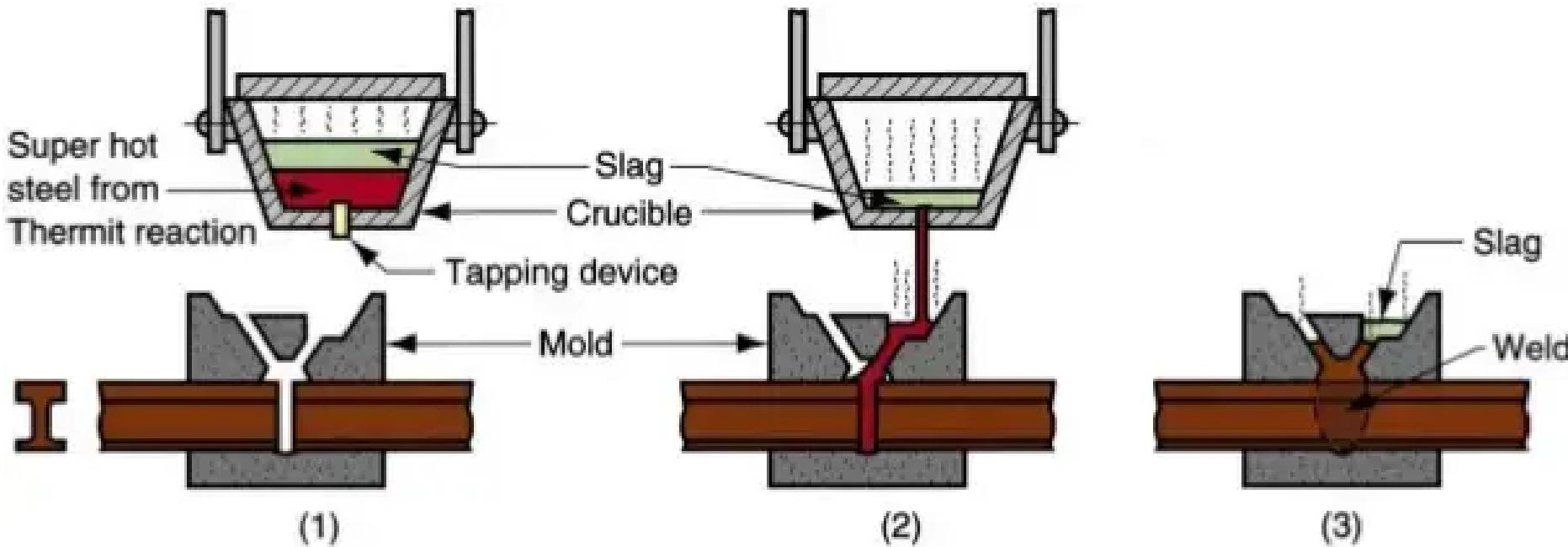
Plasma Arc Welding (PAW)



Types

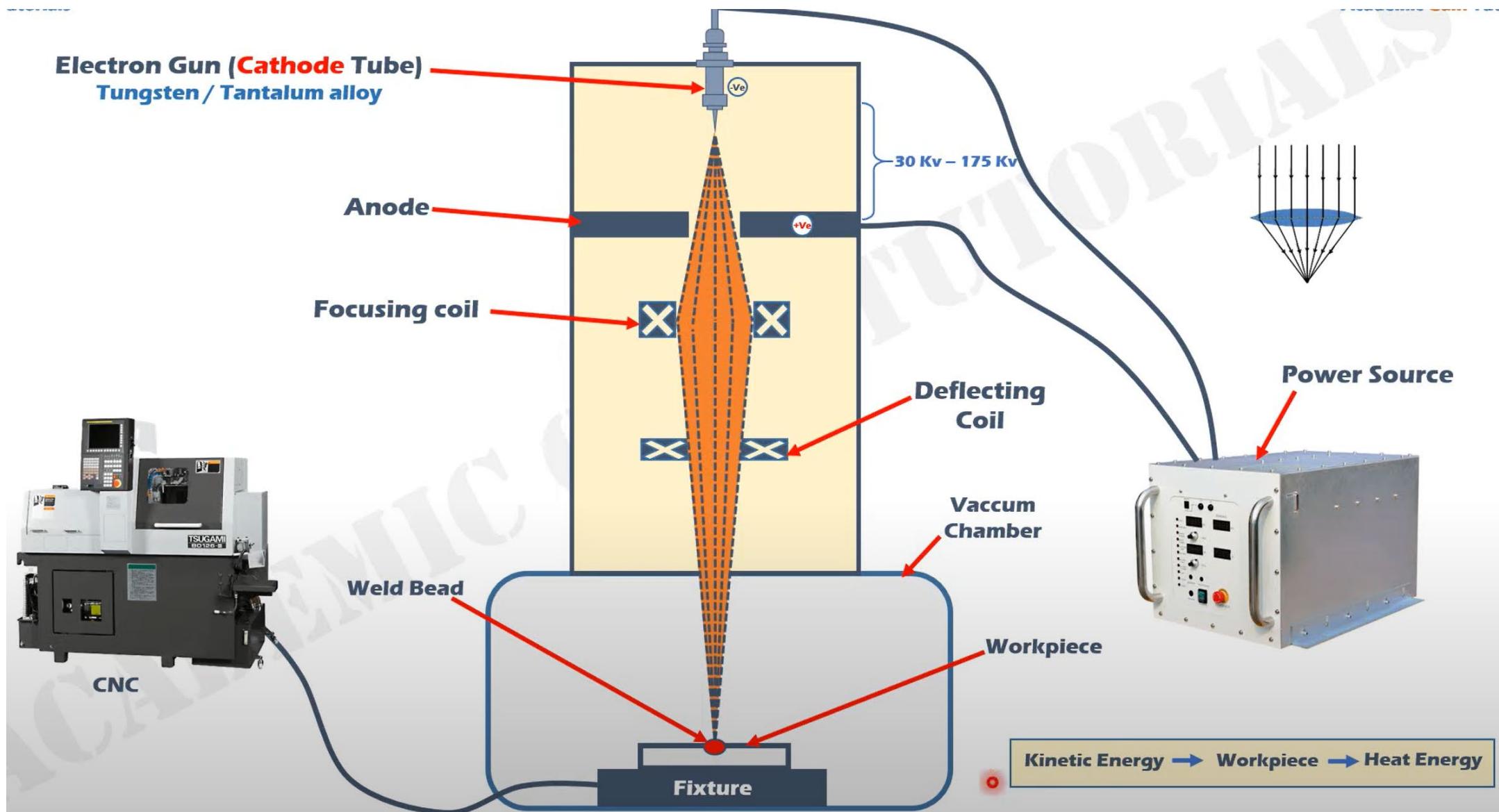
Transferred plasma arc welding

Non-transferred plasma arc welding

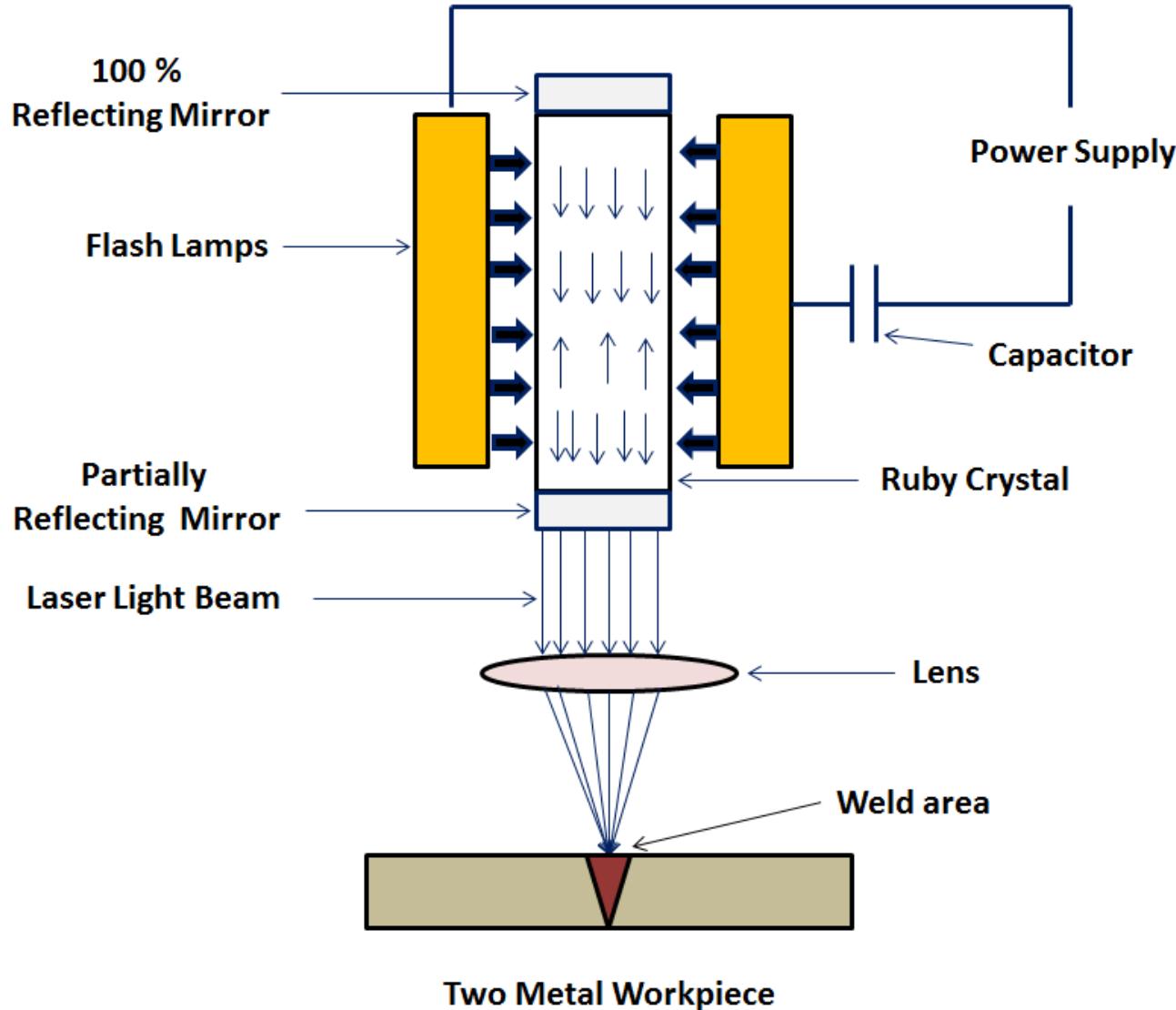


Thermit welding: (1) Thermit ignited; (2) crucible tapped, superheated metal flows into mold; (3) metal solidifies to produce weld joint.

Electron Beam Welding (EBW)

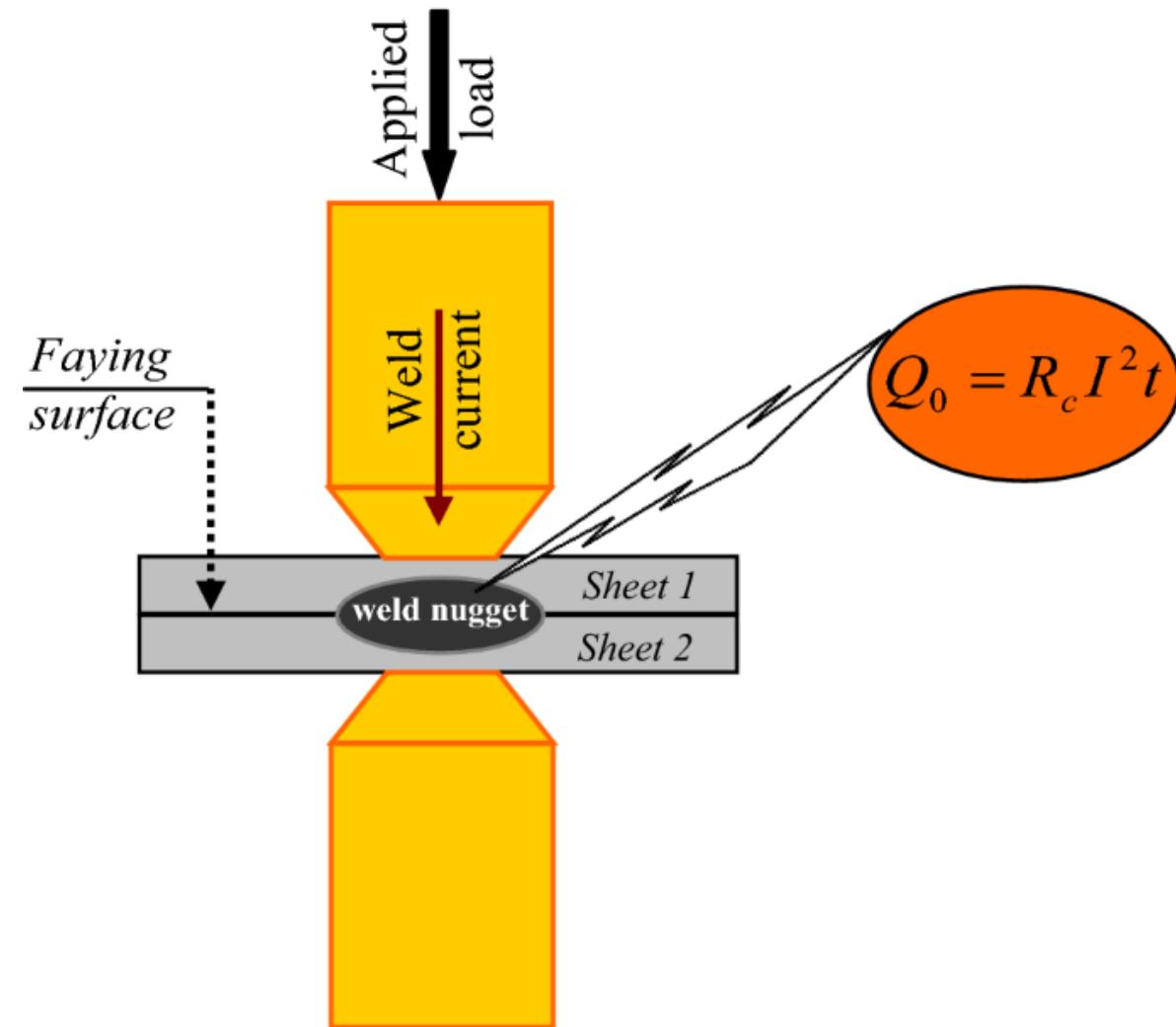


Laser Beam Welding (LBW)

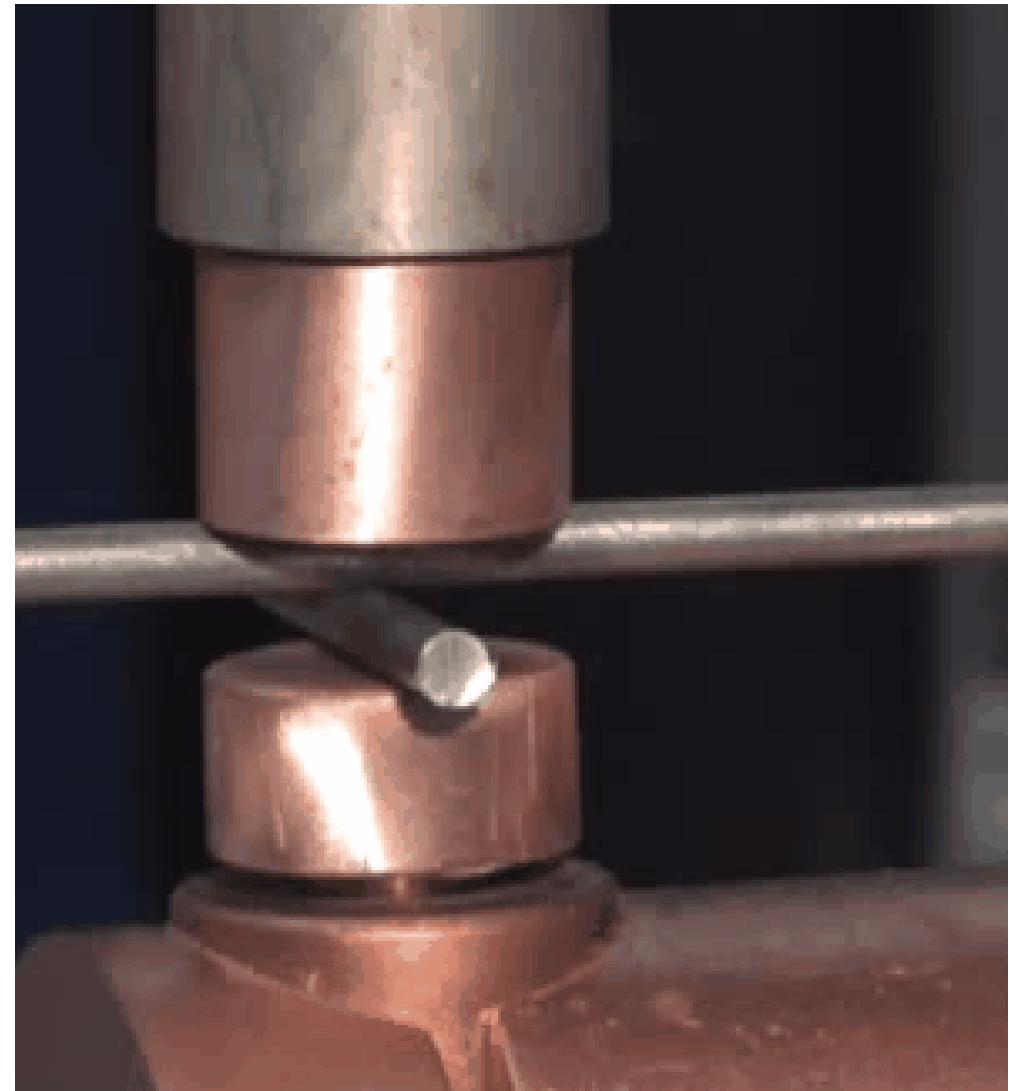
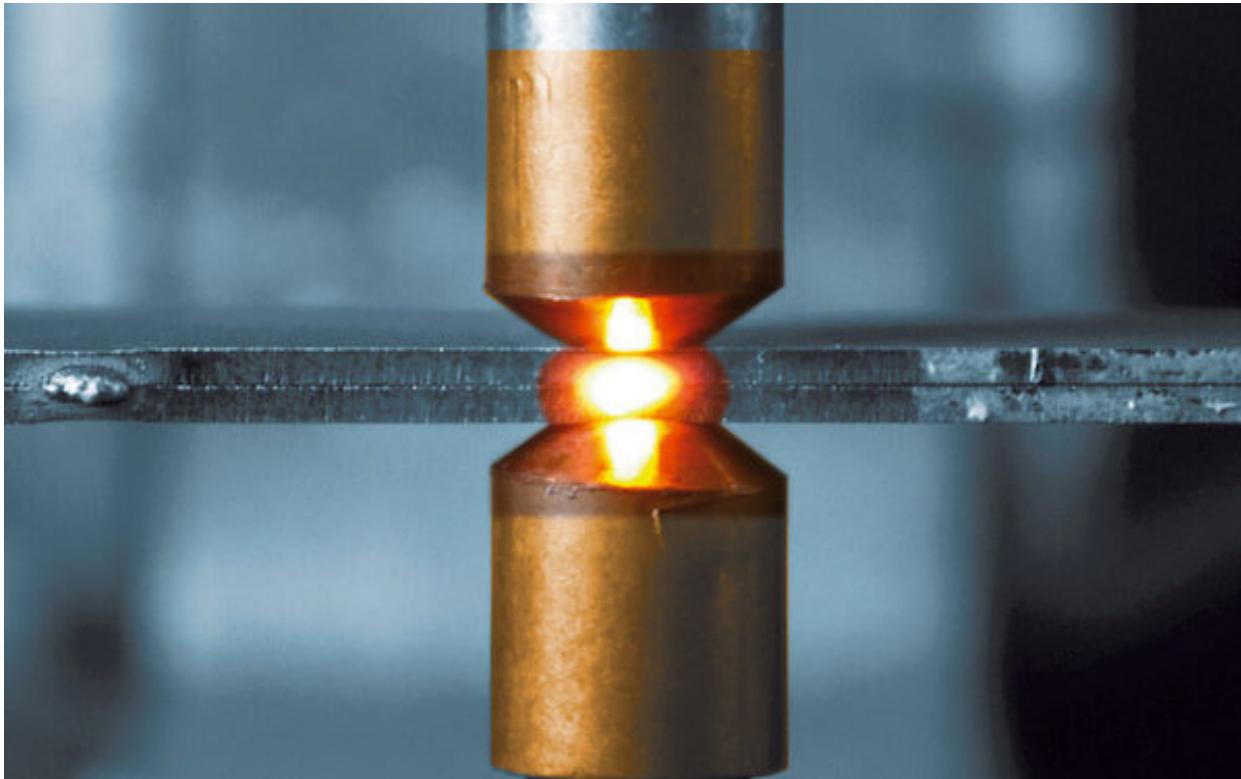


Solid State Welding Processes

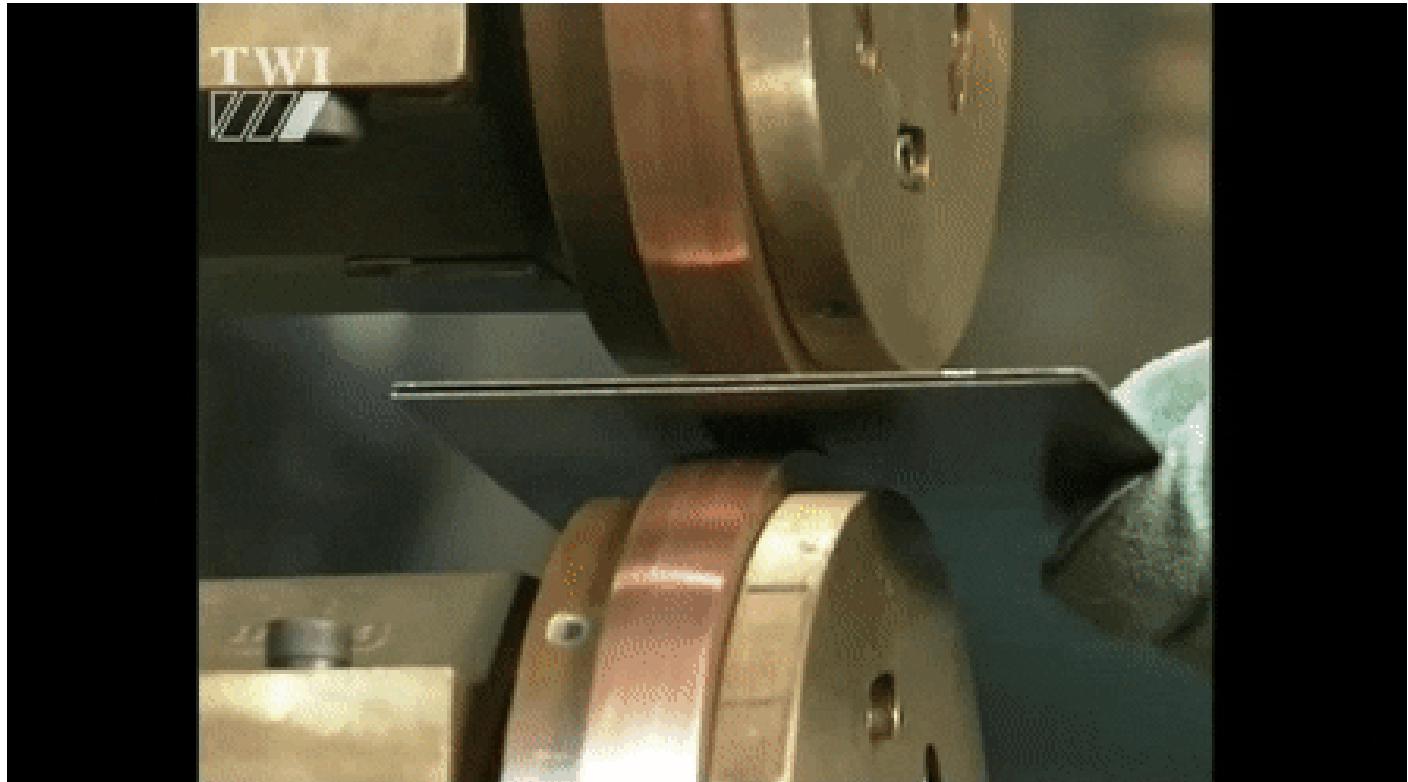
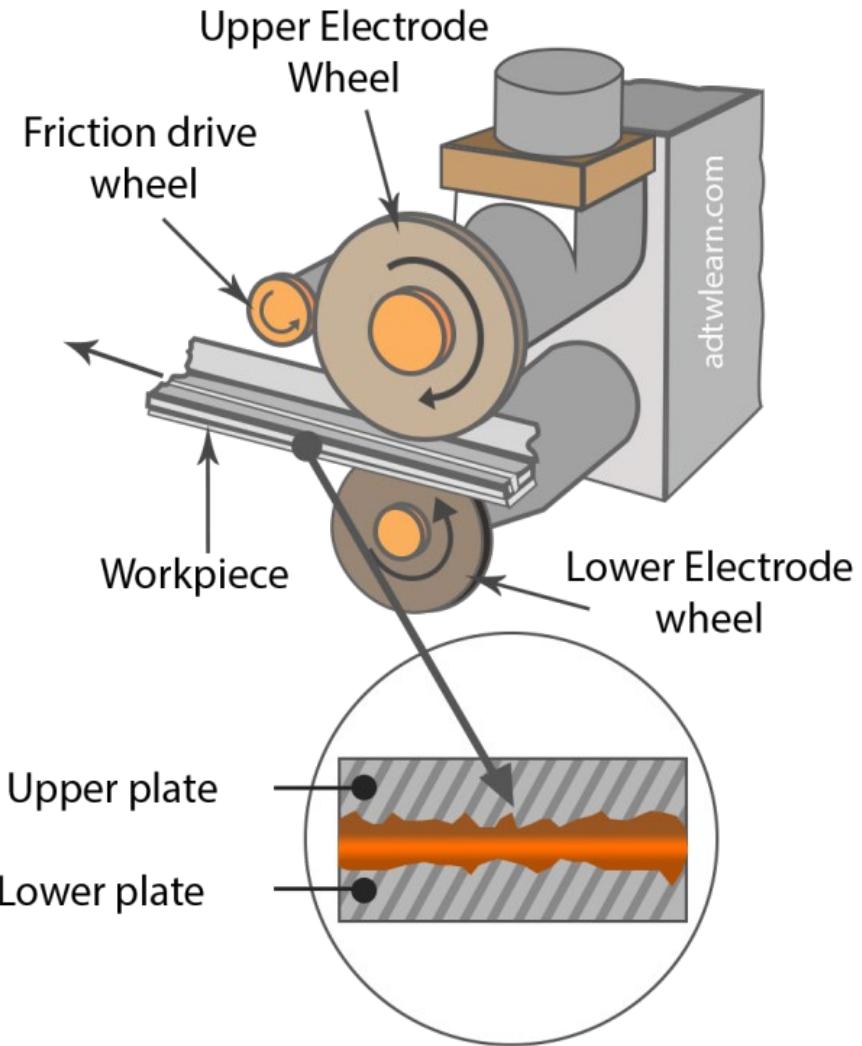
Resistance Welding (RW)



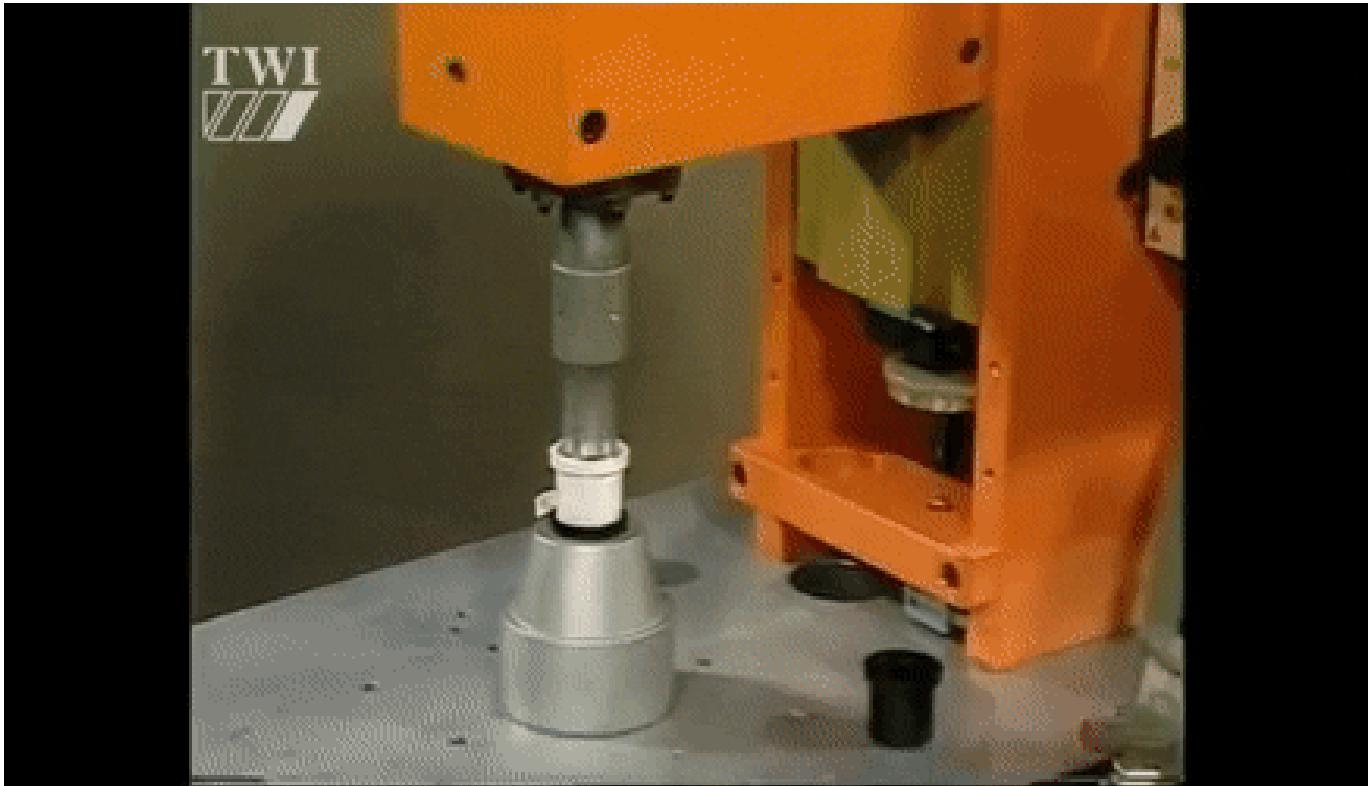
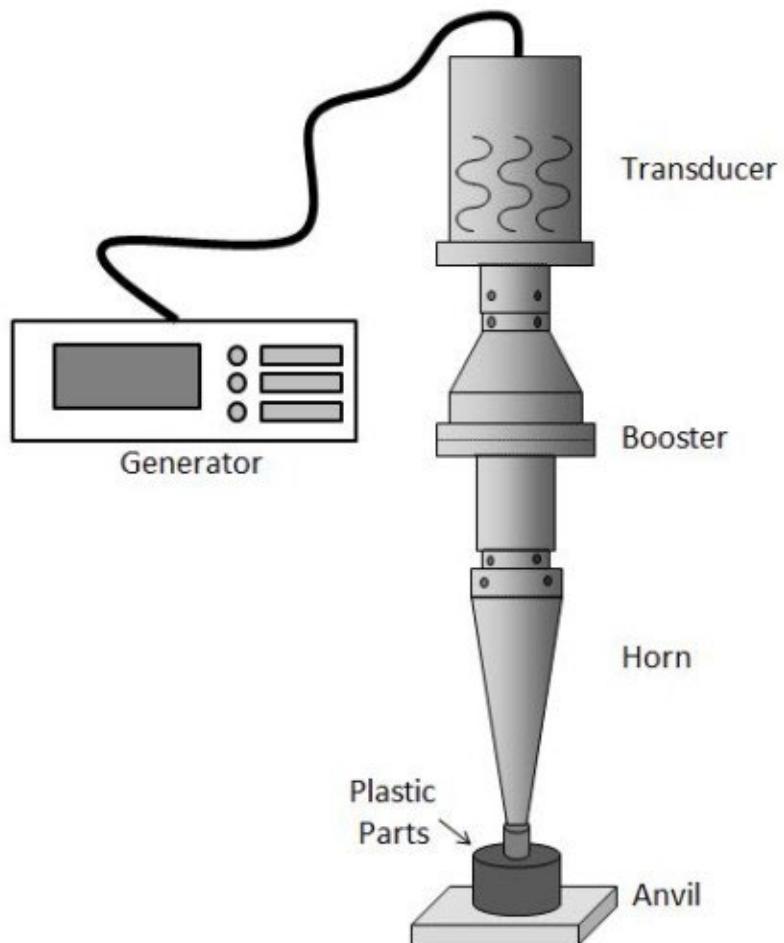
Resistance Spot welding



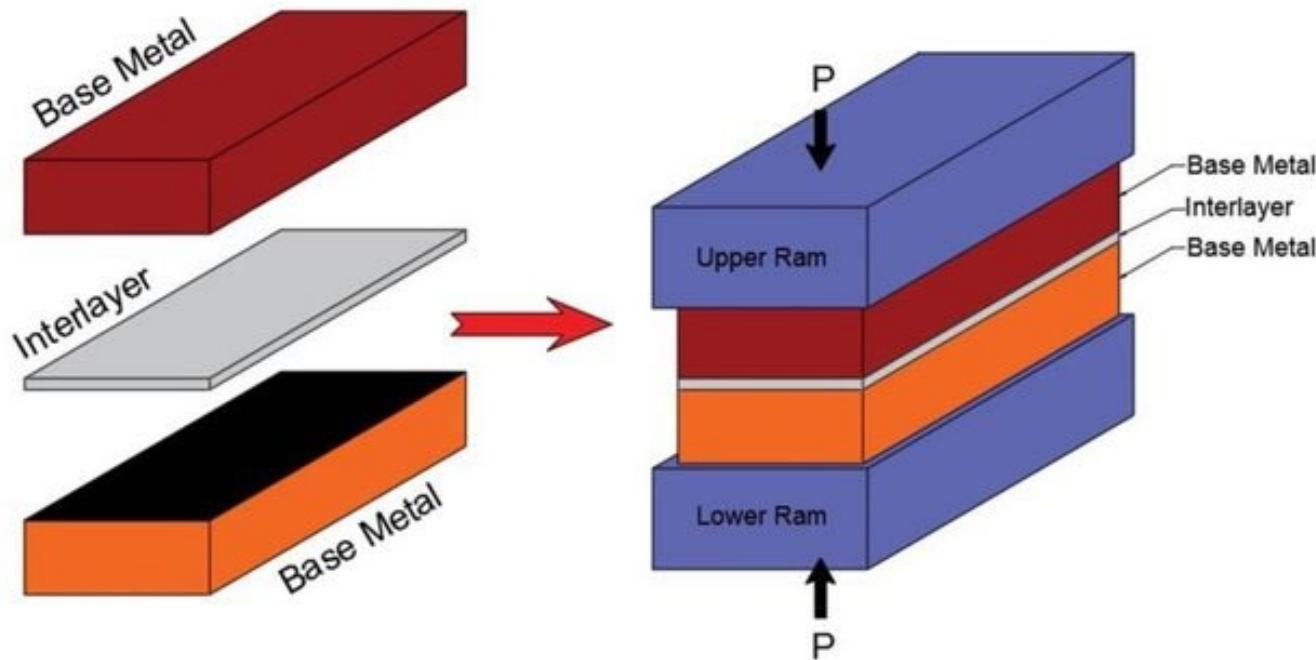
Resistance Seam welding



Ultrasonic Welding



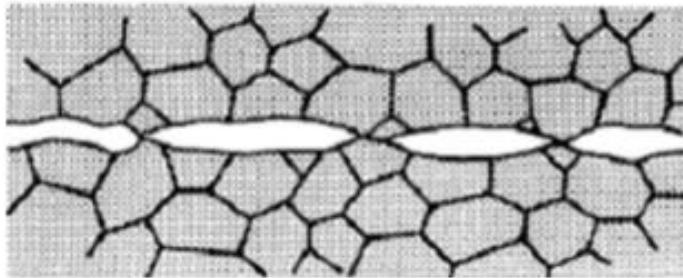
Diffusion Welding



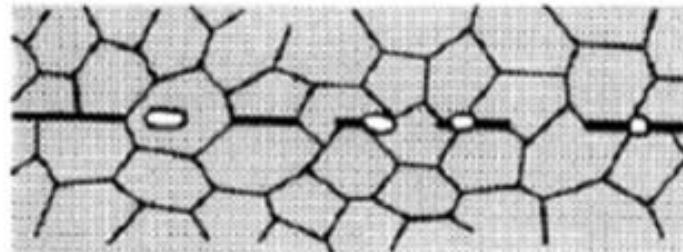
Metal 1	Metal 2	Interlayer	Temperature (°C)	Pressure (N/mm ²)	Time (minutes)
Copper	Molybdenum	-	900	7.35	10
Copper	Steel	-	900	04.9	10
Copper	Nickel	-	900	14.7	20
Copper	Copper	-	800-850	4.9-6.9	15-20
Titanium	Nickel	-	800	09.8	10
Titanium	Copper	Molybdenum	950	04.9	30
Titanium	Copper	Niobium	950	04.9	30

Stages of diffusion bonding

Asperities contact

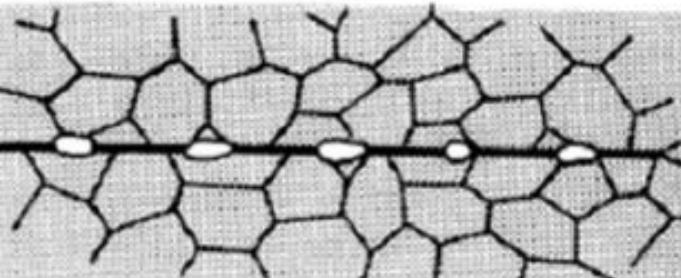


(a)

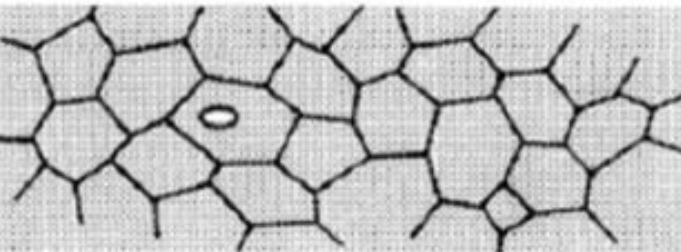


(c)

Stage II: Grain boundary migration & Pore formation

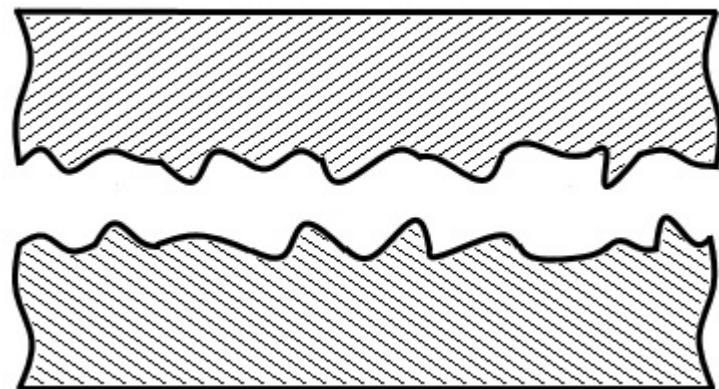


(b)

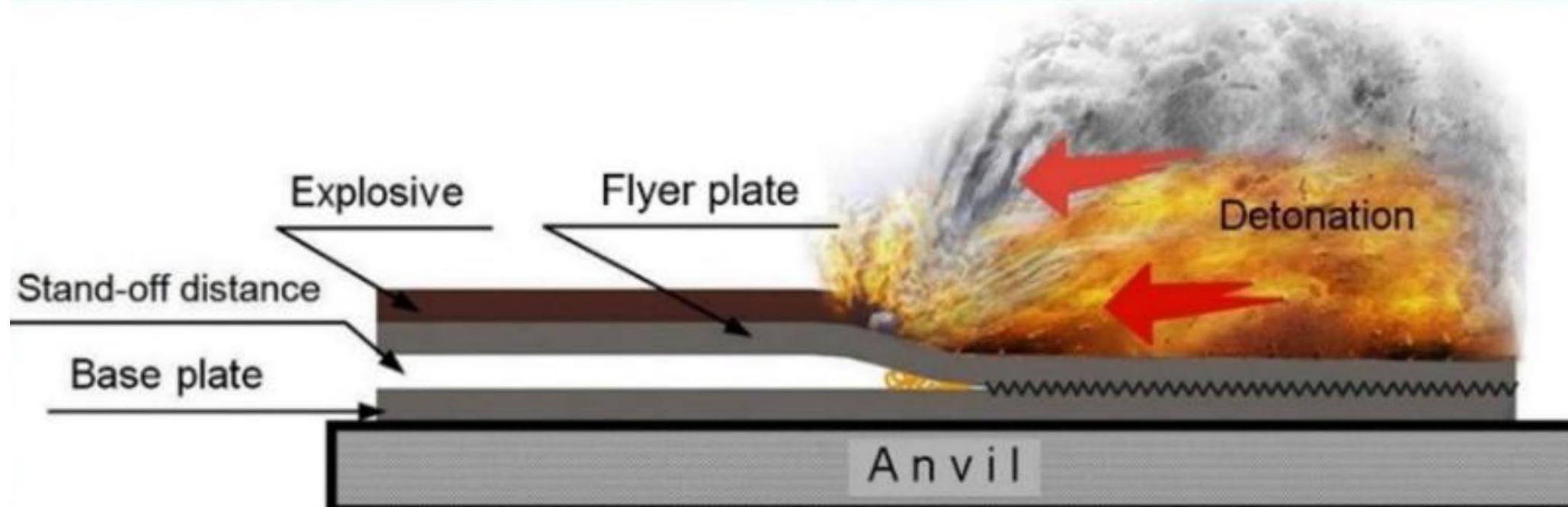


(d)

Stage III : Volume diffusion & Pore elimination

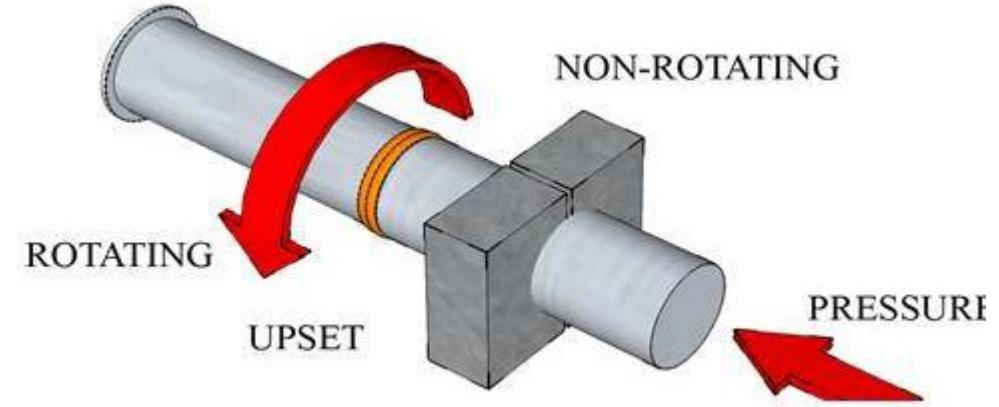
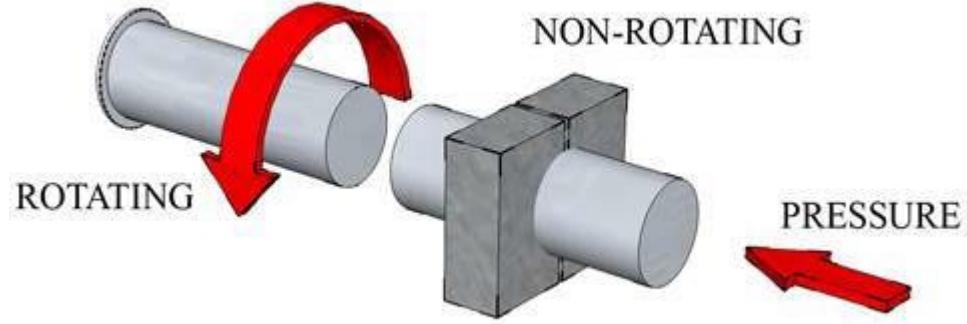


Explosion welding



copper	duplex steel	titanium	zirconium	nickel alloys
copper alloys		nickel		
	tantalum		aluminum	stainless steel
carbon steel				copper
alloy steel		stainless steel		
	aluminium			

Friction Welding



Friction Stir Welding

