TA201A
Manufacturing Processes

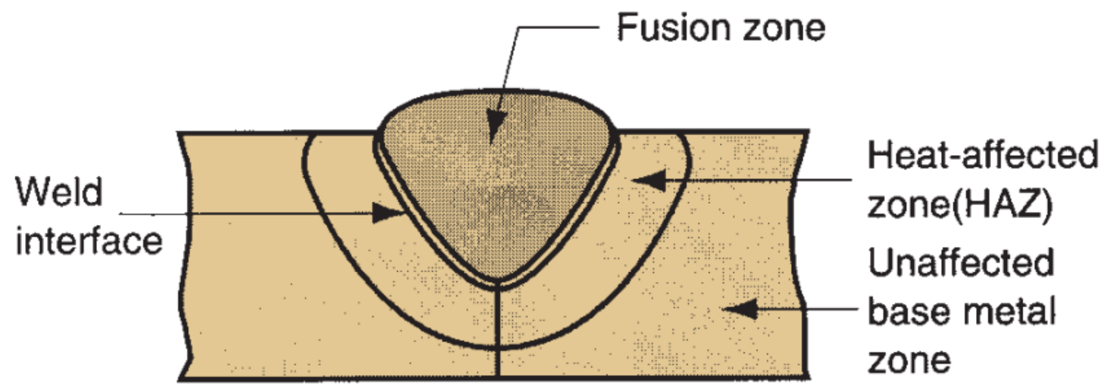
Week-8

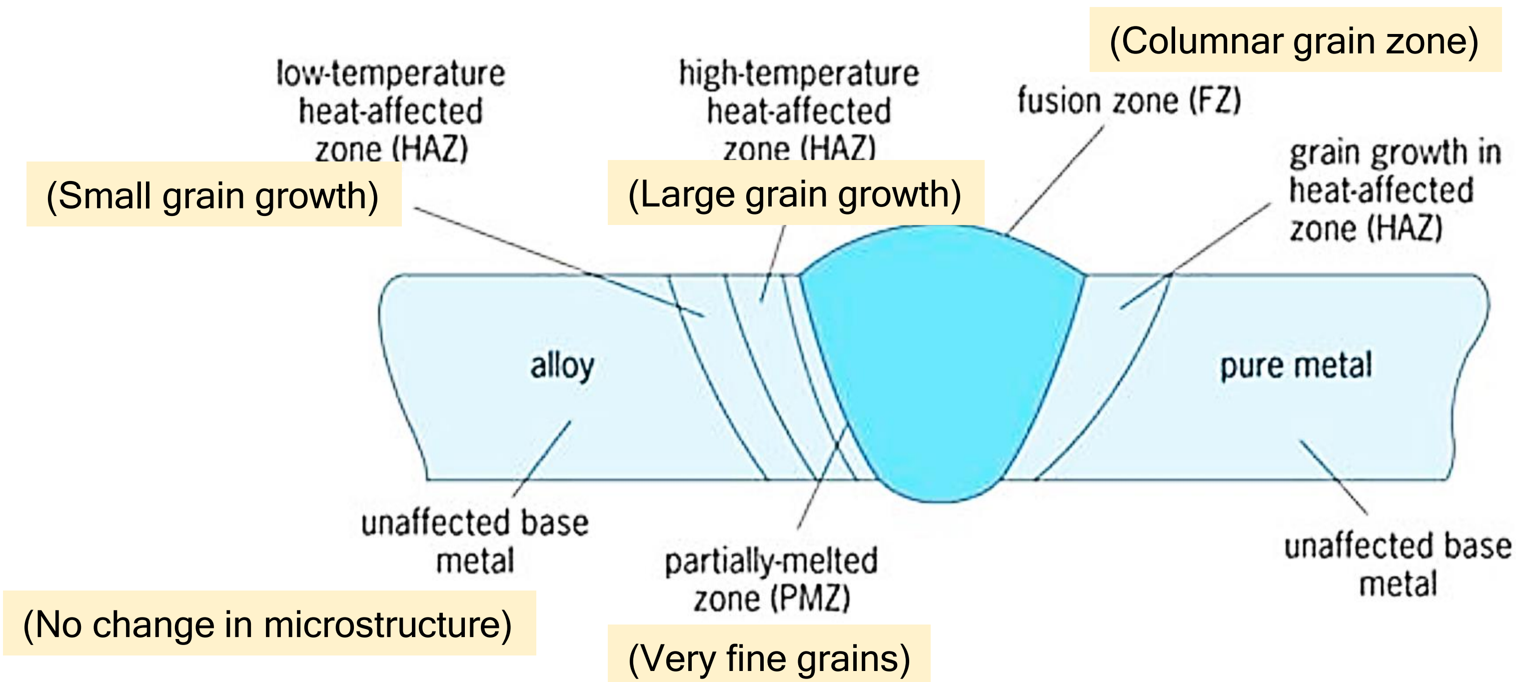
11 Oct, 2022

2022-2023 Semester-I

Lecture 8

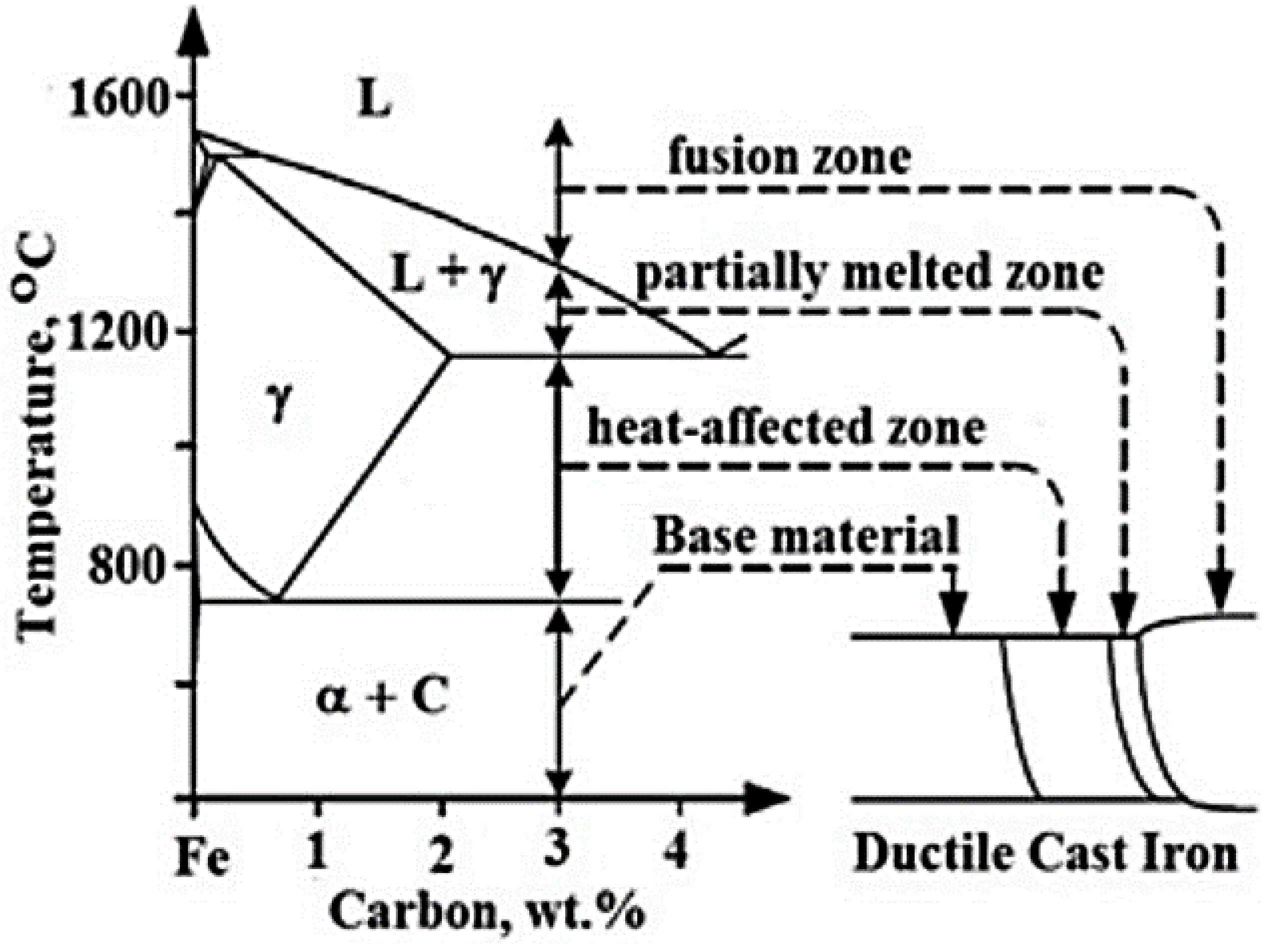
Cross section of Fusion weld

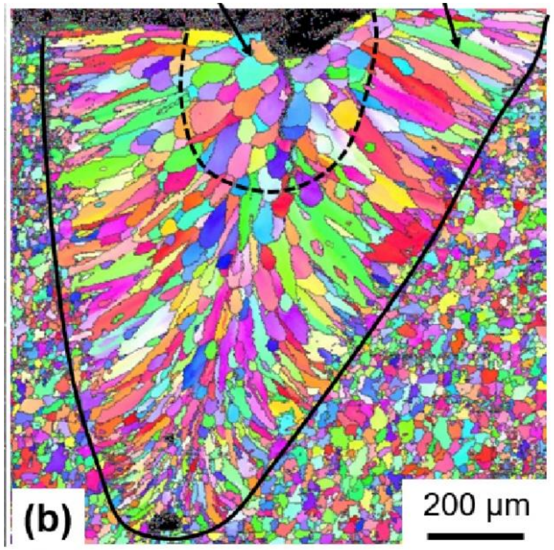




Microstructures in different zones

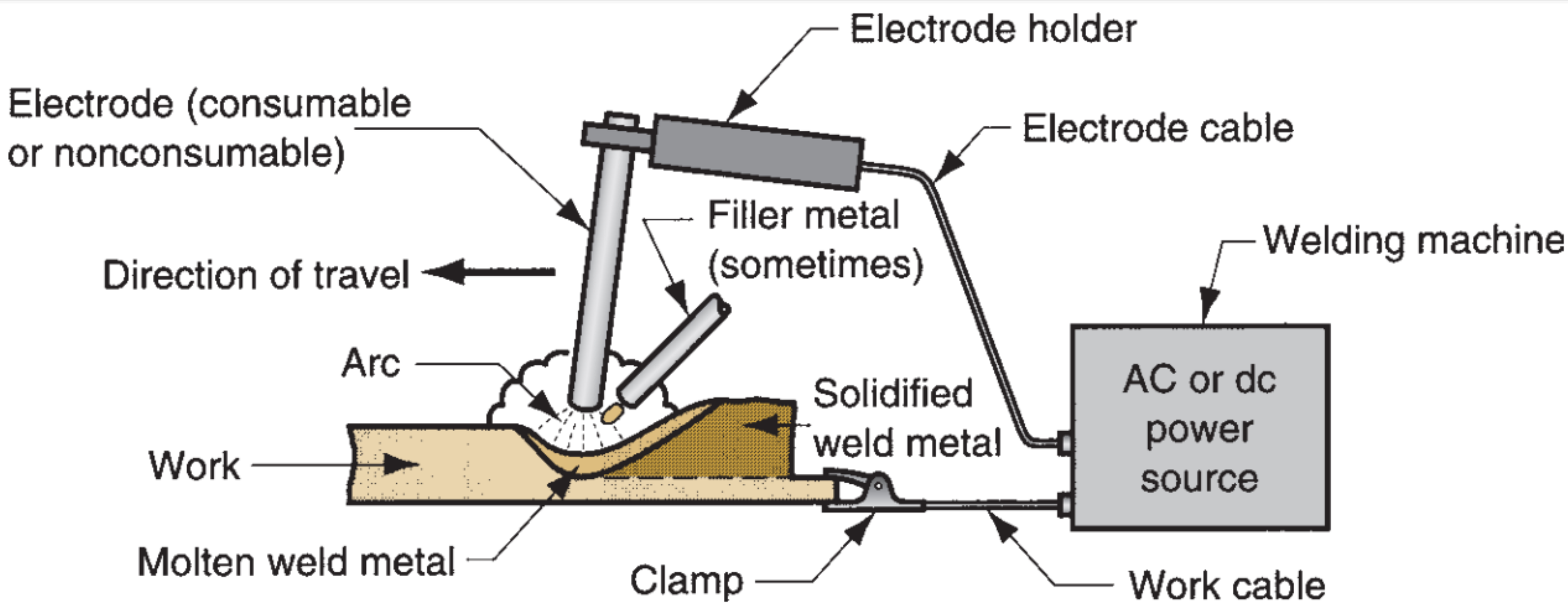
Microstructures in different zones





https://www.researchgate.net/publication/321388116_Some_Aspects_on_the_Welding_Characteristics_and_Formation_of_Microstructures_in_a_Newly_Developed_Coated_Electrode_for_Austempered_Ductile_Iron_ADI/figures?lo=
http://38.95.177.60/oe/fulltext.cfm?uri=oe-26-18-22626&id=3963161

Arc Welding

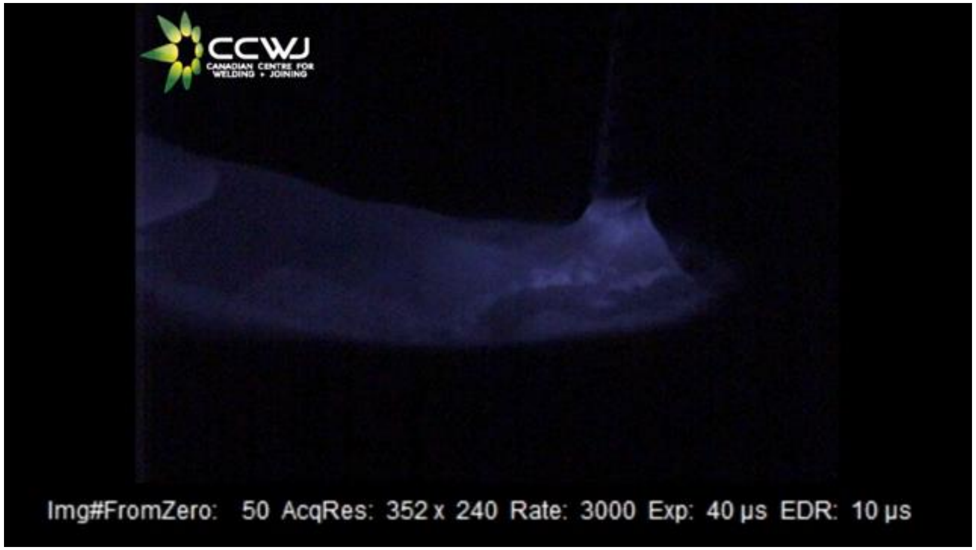


- ❑ Coalescence of the metals is achieved by the heat from an electric arc between the tip of an electrode and the workpiece to be welded
- ❑ Electric arc: Discharge of electric current across a gap in a circuit
- ❑ Touch it and separate it and maintain the distance
- ❑ Temperature ~ 5500°C
- ❑ Filler metal is added to increase the strength and volume of the weld metal

Electrode nature

- Consumable : Filler metal acts as electrode
- Non-consumable : W (tungsten rod)

  Separate filler metal is needed



Wire electrode (Consumable)

Non-consumable electrode (separate Filler metal)

https://www.youtube.com/watch?v=kVyi5PQbhX0
https://www.youtube.com/watch?v=tpXFGpSXONY&t=35s

Different Arc Welding Techniques

Abbreviations	Welding Process	Electrodes
GMAW (MIG, MAG)	Gas Metal Arc Welding (Metal Inert Gas, Metal active gas)	Consumable
GTAW (TIG, WIG)	Gas tungsten arc welding (Tungsten inert gas, W inert gas)	Non consumable
SMAW (MMAW, MMA)	Shielded Metal Arc Welding (Manual metal arc welding, manual metal arc)	Consumable
FCAW	Flux-Cored Arc Welding	Consumable
SAW	Submerged Arc Welding	Consumable

Arc Shielding

Need: To avoid chemical interaction between molten metal with O_2, H_2 and N_2.

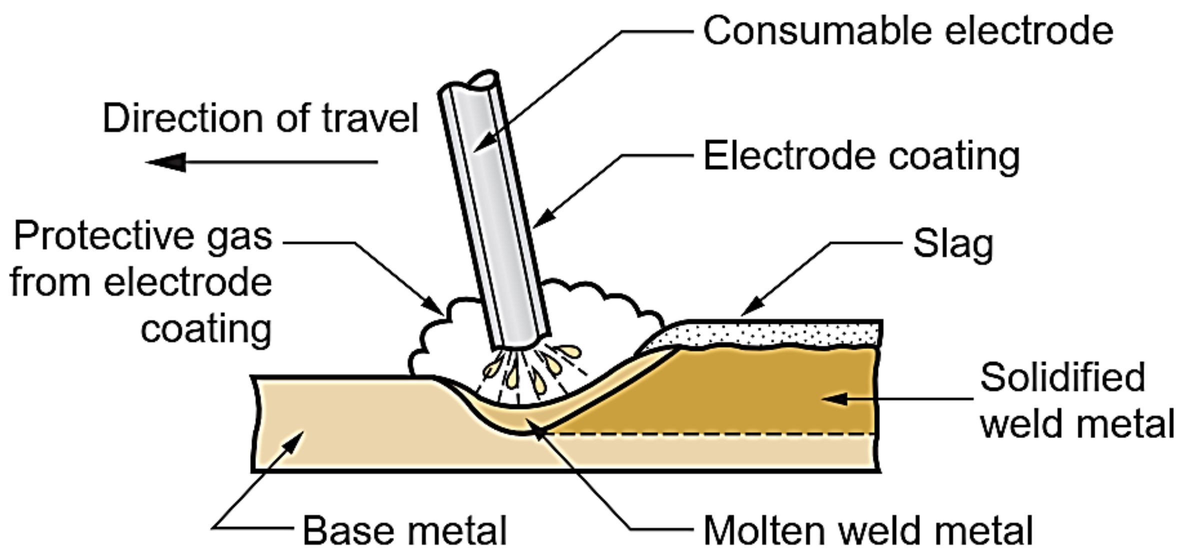
- Provides protective atmosphere for welding
- Stabilizing arc
- Reducing spattering

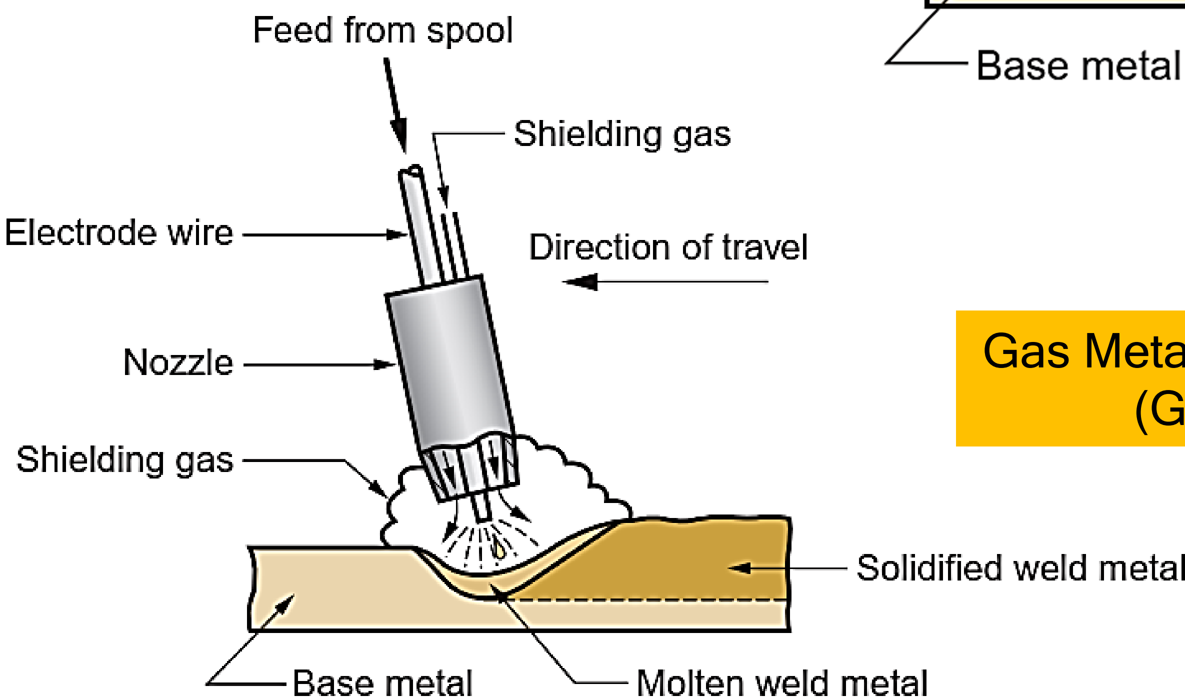
Shields: Gas blanket or flux or both

1. Gas (as in GMAW/ MAG/ TIG) : Argon, Helium or Mixture of Ar + CO_2
2. Flux: Flux forms slag which is to be removed
   A. Using a stick coated with flux material (SMAW/ MMAW)
   B. Flux can be delivered by pouring granular flux onto the welding operation (submerged AW)
   C. Using tubular electrode in which flux is contained in the core (as in the case of Flux-cored AW)

Arc Shielding

Shielded Metal Arc Welding (SMAW)





Gas Metal Arc Welding (GMAW)

Power source and analysis

Both AC and DC arc are used

f_1 : Heat transfer factor: Ratio of the actual heat received by the workpiece and the total heat generated at the source)

f_2 : Melting factor: Fraction of heat received by the workpiece available for melting (This is due to the conduction of heat away from weld zone)

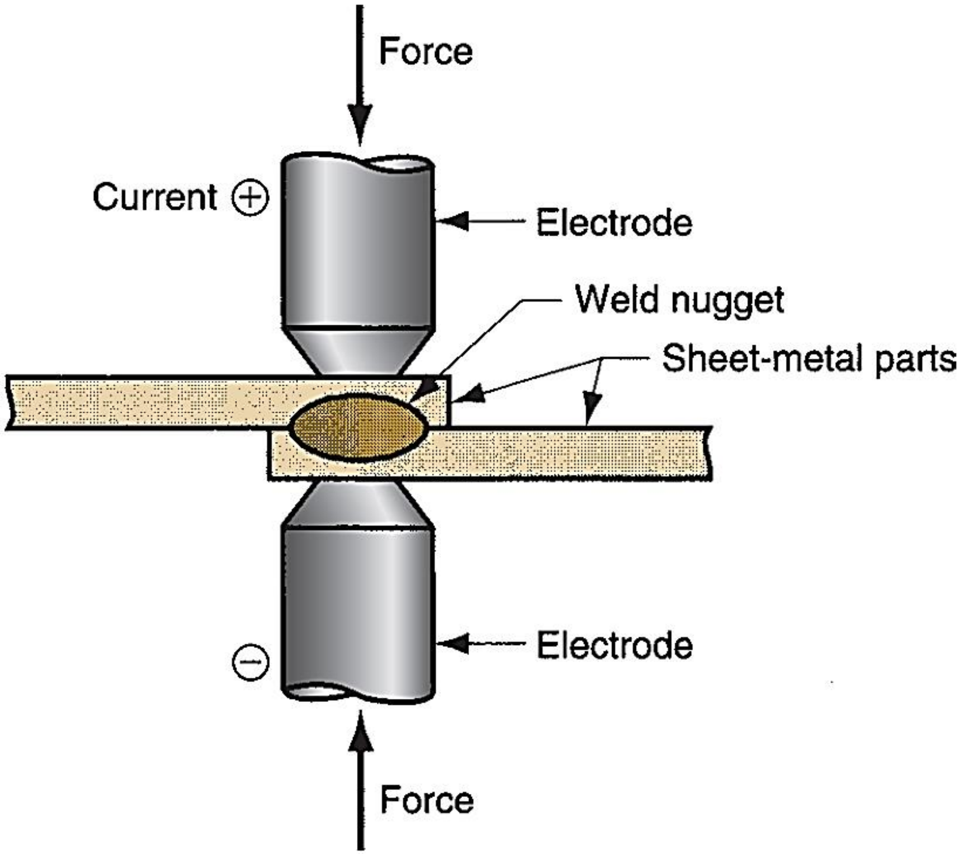
R_{Hw}: Rate of heat energy delivered to the weld (J/s)

$$R_{Hw} = U_m \times A_w v = f_1 f_2 R_H = f_1 f_2 (V \times I)$$

V : Voltage (V)

I : Current (Amp)

Resistance Welding



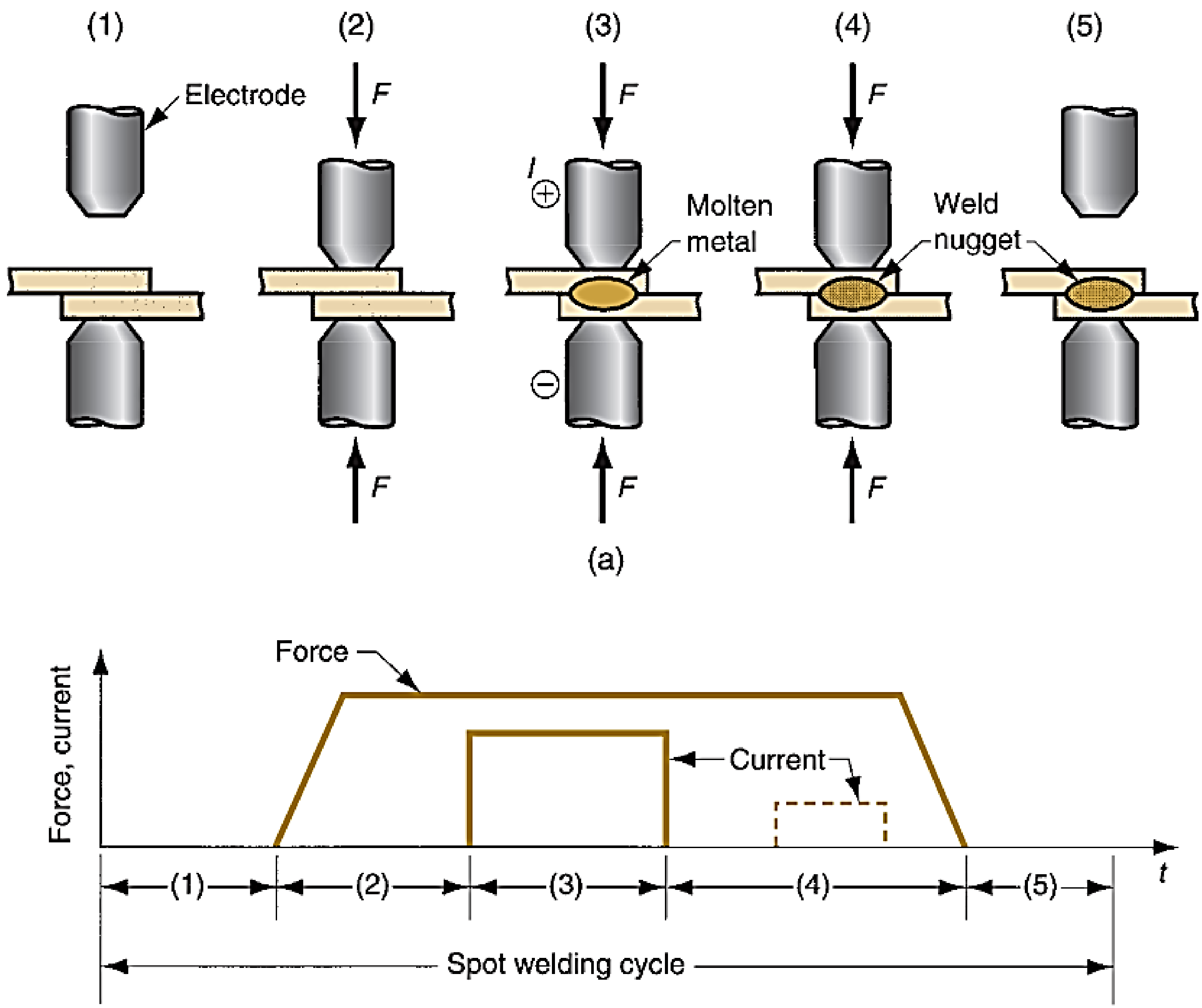
$$H = I^2Rt$$

H : Heat generated
I : Current
R : Resistance
T : Time

Heat + Pressure :

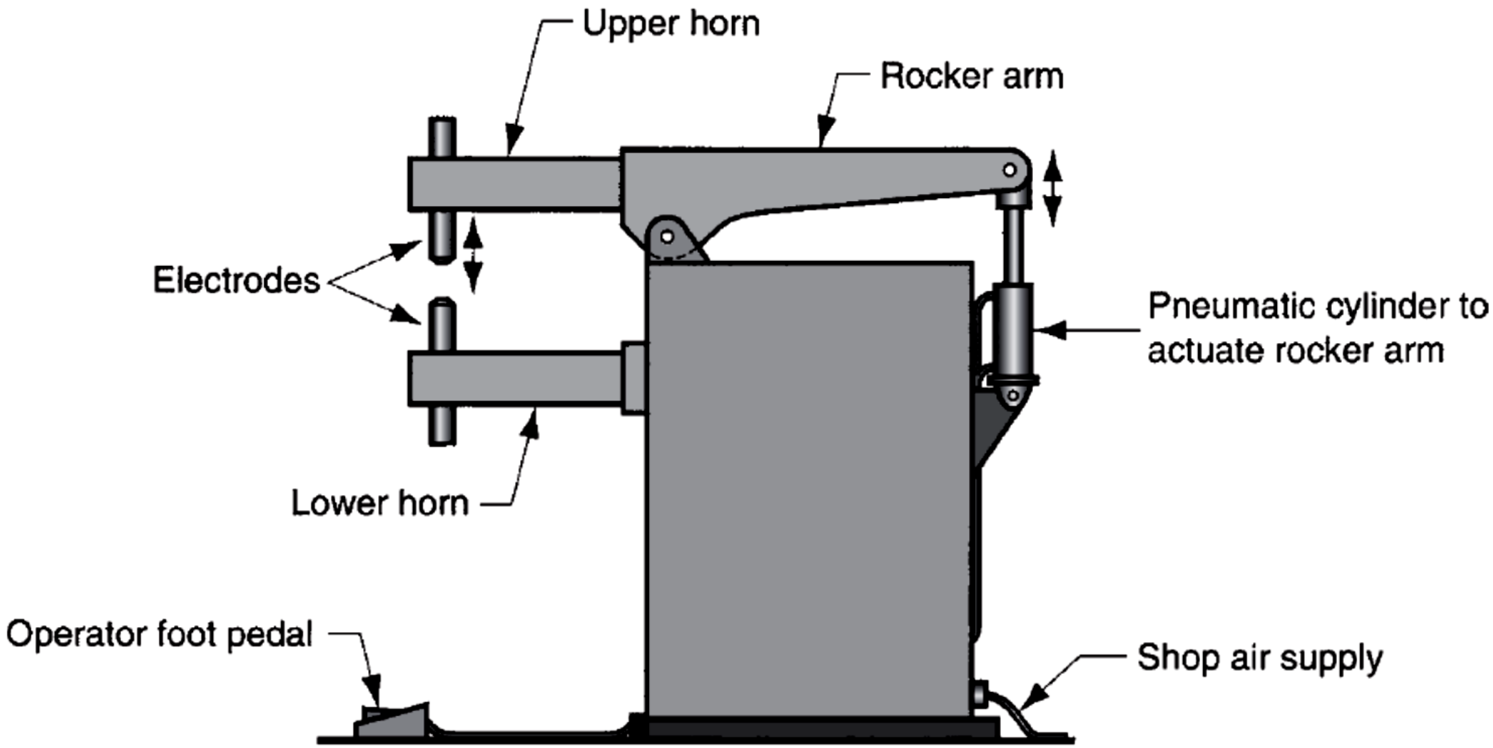
Joining by fusion due to electrical resistance to the current flow at the junction to be welded

Spot Welding



Resistance Welding

Rocker-arm spot-welding machine



Advantages:

1. No filler metal
2. No shielding gases or flux
3. High production rate
4. Good repeatability and reliability

Disadvantages:

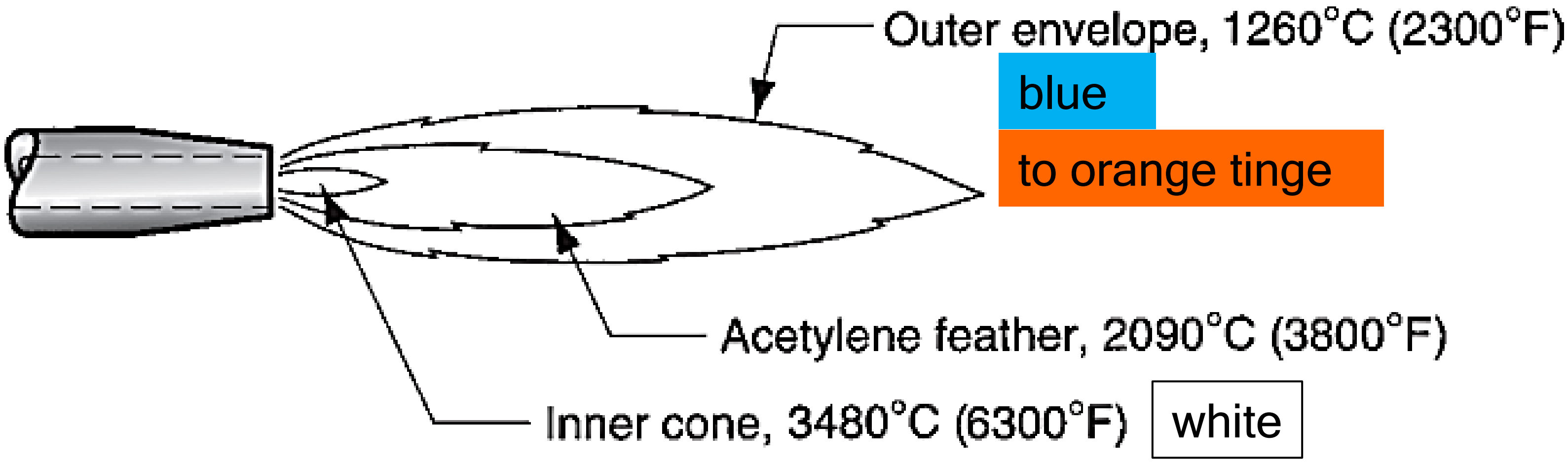
1. High cost

Oxyfuel Gas Welding

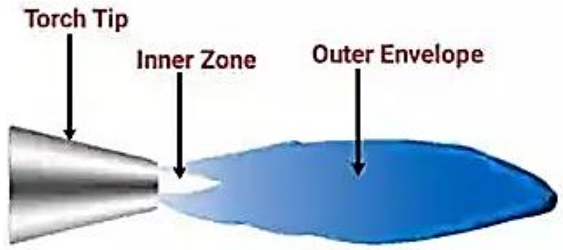
Acetylene is the fuel and
Combustion of C_2H_2 by O_2 generates heat,
and temperature can reach upto 3500˚C.

$C_2H_2 + O_2$	$\rightarrow$	$2CO + H_2$ + Heat	(inner core)
$CO + H_2 + ½\ O_2$	$\rightarrow$	$2CO_2 + H_2O$ + Heat	(outer envelope)
			shields as well as heat loss

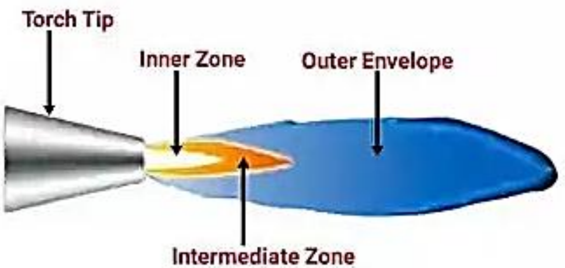
- **Total heat generated is 55×10^6 J/m^3**



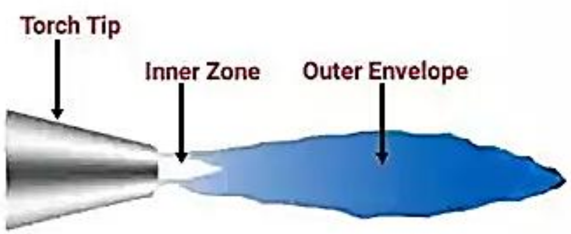
Types of flames



Neutral Flame



Carburizing Flame



Oxidizing Flame

$(O_2/C_2\,H_2)$ ratio	Used for	Not used for
1	Low C steel, Mild steel, Medium C steel	Brass
< 1	High C steel, and Grey cast iron	Ferrous Materials
> 1	Brass	Al

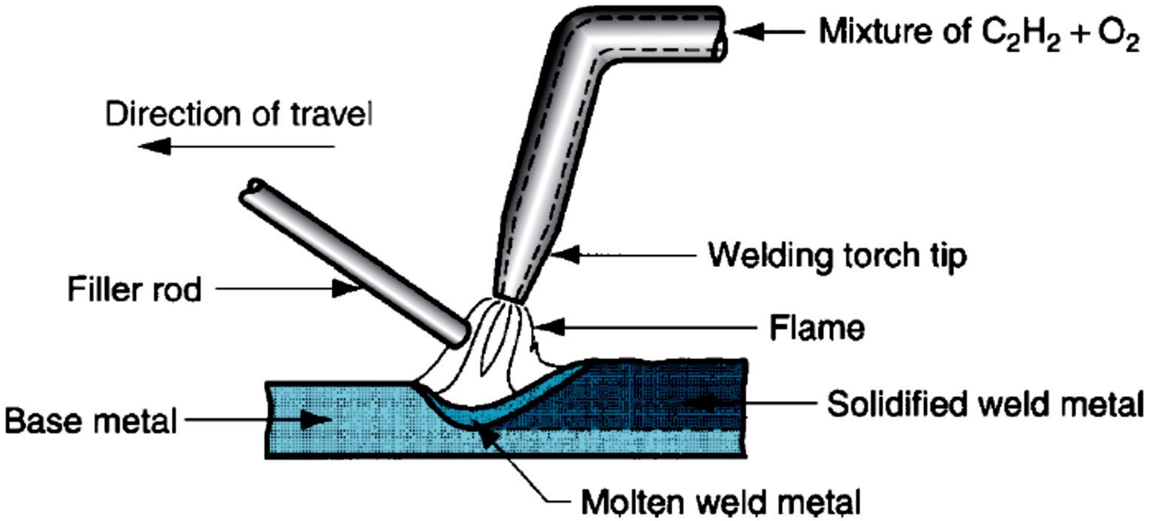
https://www.mechical.com/2021/08/types-of-gas-welding-flame.html

OxyAcetylene Welding (OAW)

- It can be used for structural sheet metal fabrication, automotive bodies, repair work
- f_1 is relatively low because of large spread of flame (0.1 to 0.3)

https://www.youtube.com/watch?v=c8qjgmJzNI8

OxyAcetylene Welding (OAW)



Advantages:

- Inexpensive
- Portable
- Economical and versatile process
- Well suited for low quality production and repair job

Disadvantages:

- Longer time for welding
- Larger HAZ
- Problem with stainless steel welding
- Not suitable for thicker plate (> 6.5 mm)

TABLE • 29.2 Gases used in oxyfuel welding and/or cutting, with flame temperatures and heats of combustion.

Fuel	Temperature[a] °C	Temperature[a] °F	Heat of Combustion MJ/m3	Heat of Combustion Btu/ft³
Acetylene (C_2H_2)	3087	5589	54.8	1470
MAPP[b] (C_3H_4)	2927	5301	91.7	2460
Hydrogen (H_2)	2660	4820	12.1	325
Propylene[c] (C_3H_6)	2900	5250	89.4	2400
Propane (C_3H_8)	2526	4579	93.1	2498
Natural gas[d]	2538	4600	37.3	1000

Refer solved problem in Groover for the calculation of
- The rate of heat generated and transferred to the work piece
- Powder density

Radiation: Electron Beam Welding (EBW)

It is a fusion welding process in which heat for welding is provided by a highly focused and high-intensity stream of electrons impinging against the work surface

- The electron source operates at high voltage (10 - 150 kV) to accelerate the electrons
- The power in EBW is not exceptional, but it has high power density
- Most metals and certain refractory and difficult-to-weld metals can also be welded

Disadvantages

- It is operated in the vacuum chamber to minimize the disruption of the electron beam by air molecules
- High cost
- Need for precision in preparation and alignment

Watch this video: https://www.youtube.com/watch?v=xYi2x0o--34

Radiation: Laser Beam Welding

It is a fusion welding process in which coalescence is achieved by an energy of a highly concentrated, coherent light beam focused on the joint to be welded

- Focuses energy onto a small area
- Produce weld of high quality, deep penetration, and narrow HAZ
- Low heat input produces low distortion
- No filler metal required
- Materials need not be conductive
- Normally performed with shielding gases

Comparison with EBW

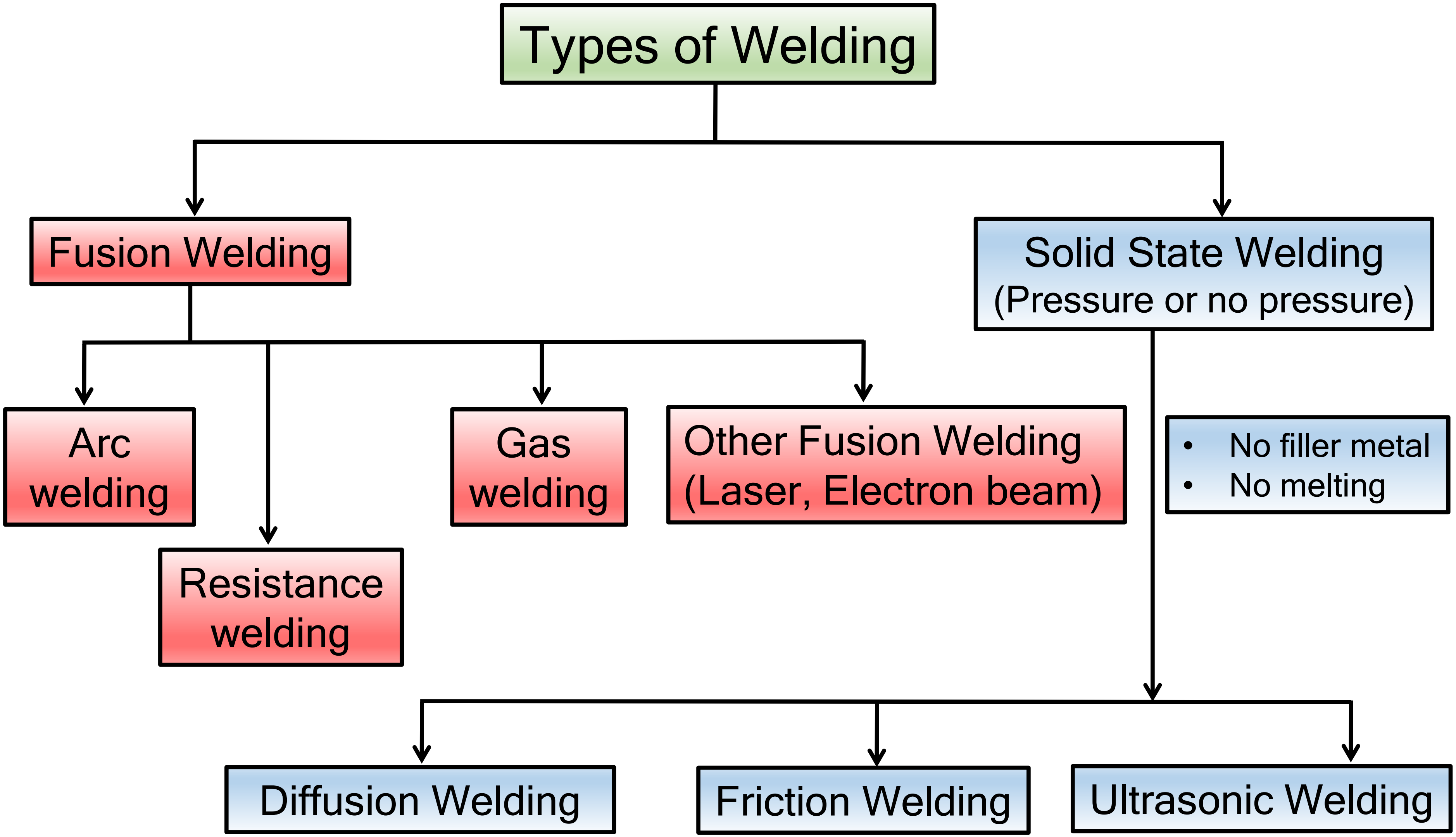
No vacuum required

No x-rays are emitted

Maximum depth of LBW is 0.75 in where for EBW, it is 2.0 in

https://www.azom.com/article.aspx?ArticleID=18916

Revisit: Types of Welding



Solid State Welding

- Application of Heat or Pressure or only Pressure leads to welding
- Localized melting is possible or melting may not even occur (but its not fusion)
- Filler metal is not used
- Metallurgical bond is created with almost no melting

Advantages:

- Welding with no melting
- Metallurgical purity is maintained
- No HAZ
- Dissimilar metals can be bonded
- Whole surface is bonded

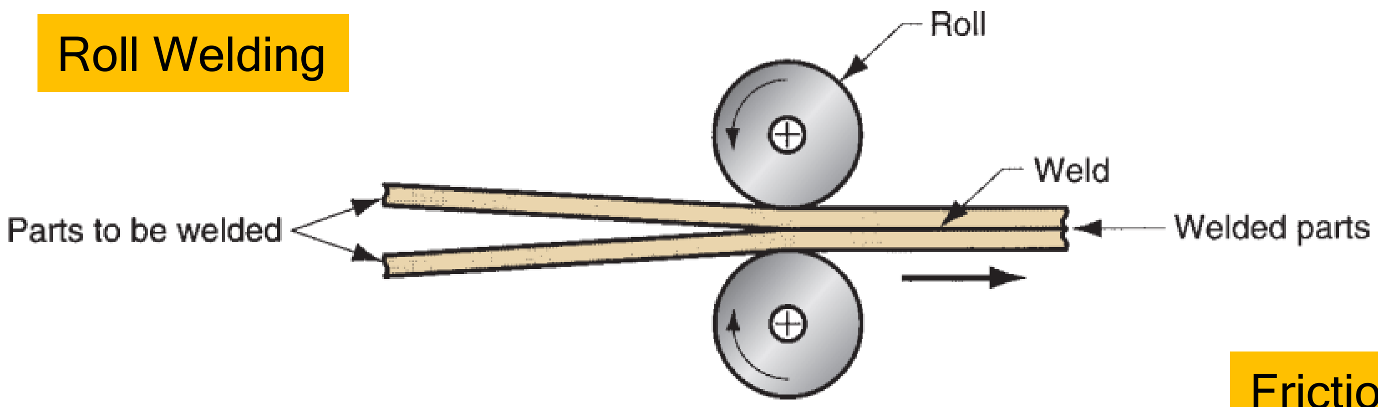
Disadvantages:

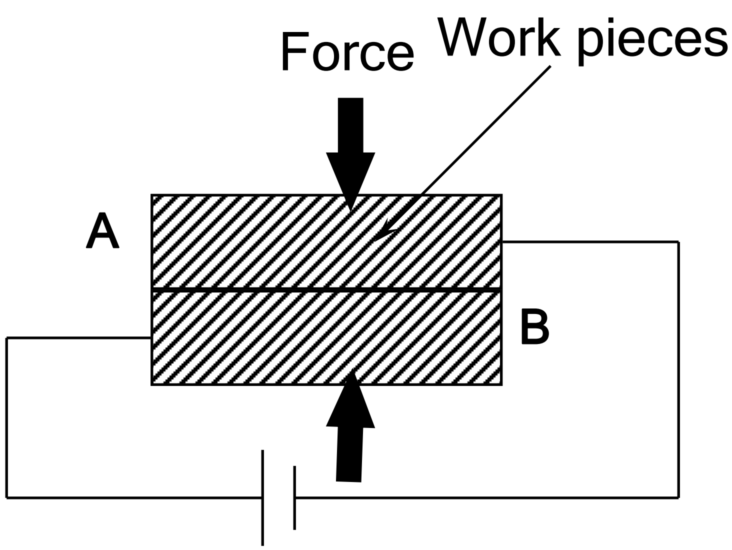
- Films and other contaminants must be removed
- Thorough cleaning of surface is needed

Examples: Forge welding, Roll welding, Cold welding, Diffusion welding, Explosion welding (Cladding)

Solid State Welding: Different techniques

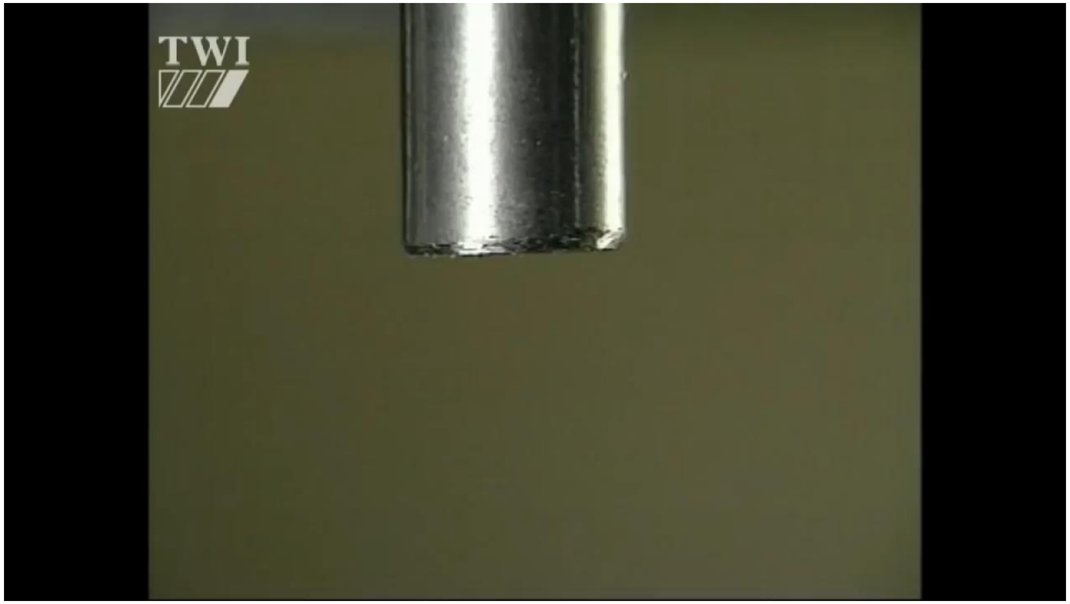
Roll Welding





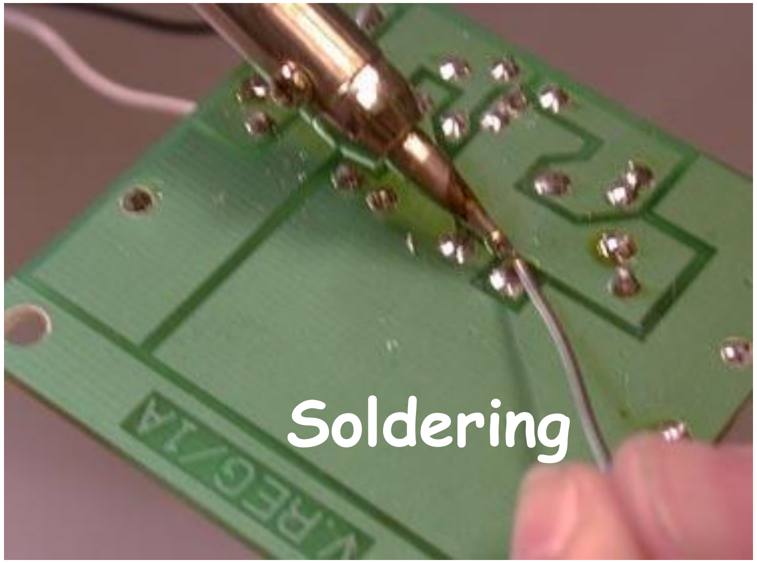
Schematic representation of Diffusion Welding using electrical resistance for heating

Friction Welding



https://www.youtube.com/watch?v=MIYJnd2X9eU

Brazing, Soldering and Adhesive joining



Adhesive bonding

Brazing and Soldering

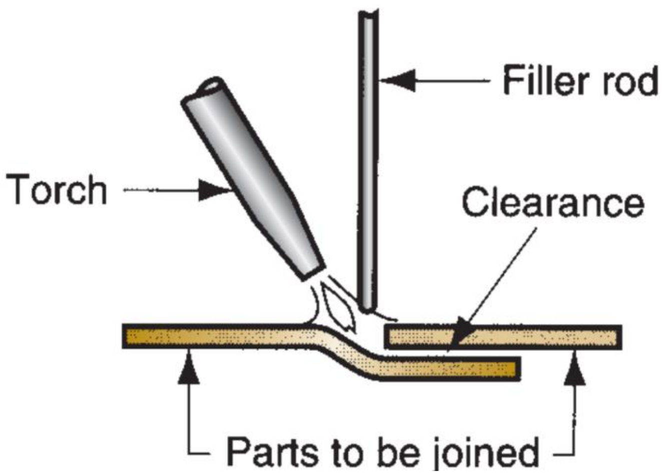
They have lots of similarities between them

- ❖ Filler metal melts but base metal does not melt
- ❖ Filler metal used for joining, fills the gap by capillary action

Advantages over Welding

- ❖ Metals with poor weldability can be joined
- ❖ Dissimilar metals can be joined
- ❖ Useful when geometry of the joints does not support other welding processes
- ❖ High strength is not a requirement

Brazing Process



Brazing Processes

- Torch Brazing
- Furnace Brazing
- Induction Brazing
- Resistance Brazing

Shape of the Filler metal:
Wire, Rod, Strips

https://www.youtube.com/watch?v=SvULvkvaVhI

Brazing

- Filler metal melts and gets distributed due to capillary force between the facing surfaces
- Filler metal melts but base metal does not
- Melting temperature of filler metal > 450˚C but must be below the melting point of base metal

Advantages of Brazing:

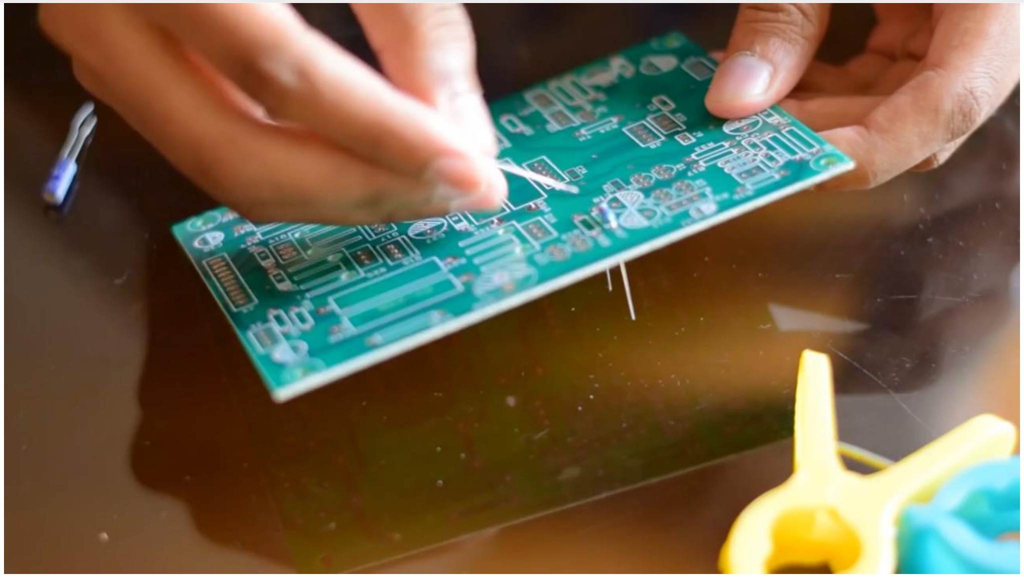
- ✓ Any metals can be joined even dissimilar metals
- ✓ Quick and consistent
- ✓ Joining thin walled part
- ✓ Less heat and power requirement (less HAZ problem)
- ✓ Difficult to access parts can be joined (because of Capillary force)

Filler Metals

1. Melting temperature must be compatible with base metal
2. Surface tension of the liquid must be low to increase the wettability
3. Fluidity for penetration must be high
4. Should impart adequate strength
5. Avoidance of chemical interaction. No galvanic effect should be there.

Filler Metal	Typical Composition	Approximate Brazing Temperature °C	Approximate Brazing Temperature °F	Base Metals
Aluminum and silicon	90 Al, 10 Si	600	1100	Aluminum
Copper	99.9 Cu	1120	2050	Nickel copper
Copper and phosphorous	95 Cu, 5 P	850	1550	Copper
Copper and zinc	60 Cu, 40 Zn	925	1700	Steels, cast irons, nickel
Gold and silver	80 Au, 20 Ag	950	1750	Stainless steel, nickel alloys
Nickel alloys	Ni, Cr, others	1120	2050	Stainless steel, nickel alloys
Silver alloys	Ag, Cu, Zn, Cd	730	1350	Titanium, Monel, Inconel, tool steel, nickel

Soldering



1. Similar to Brazing
2. Melting point of filler metal is greater than 180°C and less than 450°C
3. Capillary action distributes the molten filler metals
4. No melting of the base metal
5. Filler melts, wets and combine with base metal to give strength because of metallurgical bond.

https://www.youtube.com/watch?v=6D5nylyWTK0

Solder alloys

1. Cleaning of the surfaces are necessary to increase the wettability.
2. Filler metal is called *Solder*
3. Electronic industry finds great use of soldering.
4. Most Solders are alloys of *tin* and *lead*, since both metals have low melting points.

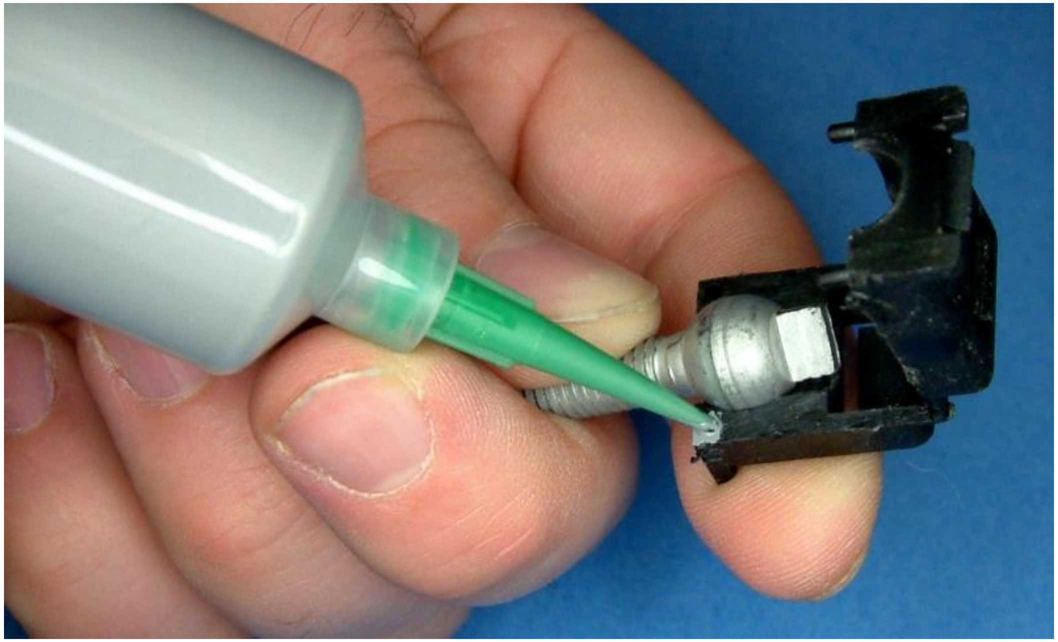
Filler Metal	Approximate Composition	Approximate Melting Temperature °C	Approximate Melting Temperature °F	Principal Applications
Lead-silver	96 Pb, 4 Ag	305	580	Elevated temperature joints
Tin-antimony	95 Sn, 5 Sb	238	460	Plumbing and heating
Tin-lead	63 Sn, 37 Pb	183[a]	361[a]	Electrical/electronics
	60 Sn, 40 Pb	188	370	Electrical/electronics
	50 Sn, 50 Pb	199	390	General purpose
	40 Sn, 60 Pb	207	405	Automobile radiators
Tin-silver	96 Sn, 4 Ag	221	430	Food containers
Tin-zinc	91 Sn, 9 Zn	199	390	Aluminum joining
Tin-silver-copper	95.5 Sn, 3.9 Ag, 0.6 Cu	217	423	Electronics: surface mount technology

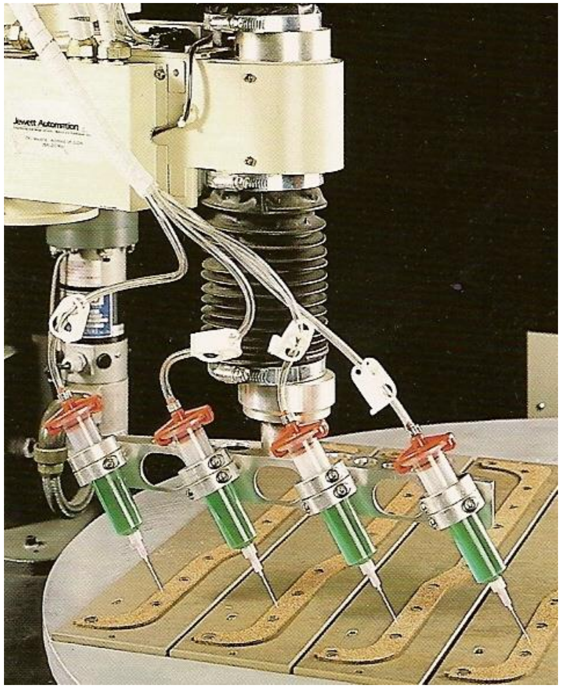
Compiled from [2], [3], [4], and [13].
Eutectic composition—lowest melting point of tin–lead compositions.

Adhesive Bonding

Adhesive bonding is a joining process in which a filler material is used to hold two (or more) closely spaced parts together by surface attachment.

Filler material is called Adhesive (Generally nonmetallic substance- Polymer). Parts to be joined are called Adherands





Courtesy: Google Images

Adhesive bonding

https://www.youtube.com/watch?v=MspylAy8xWw

Curing

Process by which adhesive's physical properties change usually by chemical reaction to accomplish surface attachment of the parts

Strength of the attachments can be attributed to one of the following mechanisms:

1. **Chemical bonding**: adhesives unite with the adherands by forming primary chemical bonding, upon hardening
2. **Physical Interaction**: Secondary bonding results between atoms of opposite surfaces
3. **Mechanical interlocking**: in which the surface roughness of the adherand causes the hardened adhesive to become entangled or trapped in its microscopic surface asperities

Major Applications

1. Aerospace
2. Automotive
3. Packaging industry

Adhesive bonding

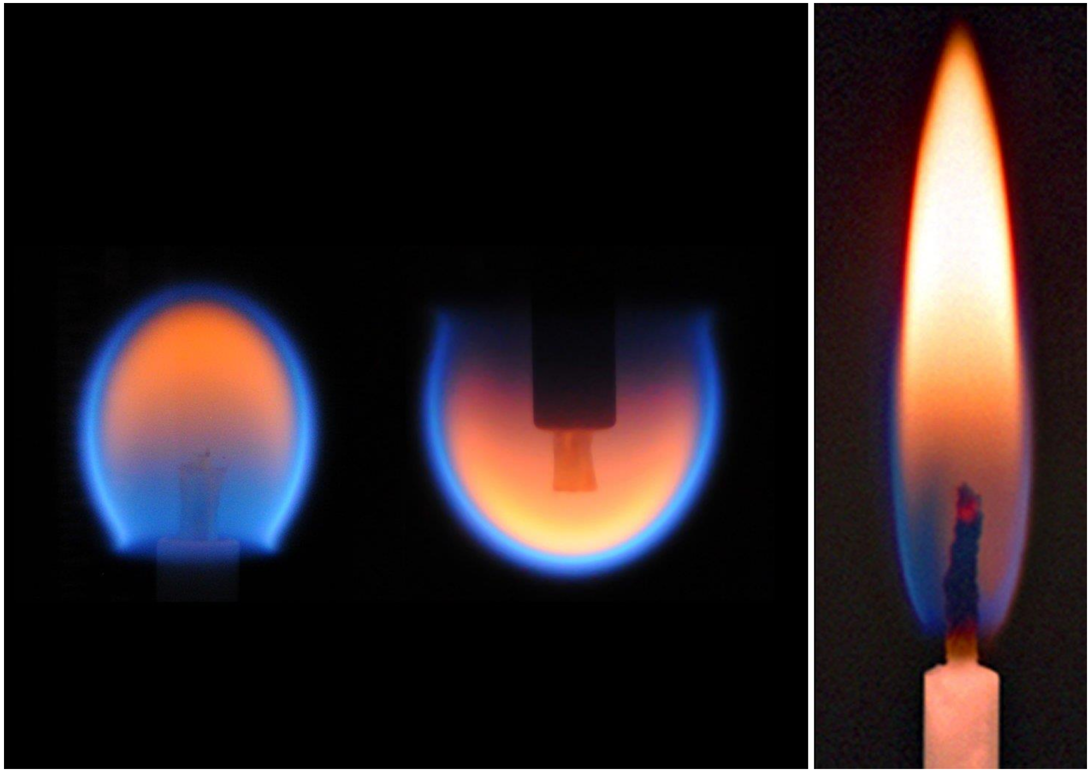
Advantages:

1. This process is applicable to a wide variety of materials
2. Parts of different sizes and cross sections can be joined
3. Bonding occurs over the entire surface area of the joint
4. Low temperature curing avoids damage to parts being joined
5. Sealing as well as bonding can be achieved
6. Simplified joint design

Limitations:

1. Joining is not as strong as other joining methods
2. Adhesive must be compatible with adherends
3. Service temperature is limited
4. Cleanliness and surface preparation is very crucial
5. Curing time imposes production rate

Fun Fact… Flame in Space



https://www.nasa.gov/mission_pages/station/research/news/bassII