TA201A
Manufacturing Processes

Week-7

27 Sept, 2022

2022-2023 Semester-I

Lecture 7

Joining [Chapters - 30, 31, 32 & 33: Groover]

- Welding
  - Fusion Welding
  - Physics of fusion welding
  - Examples: Arc Welding, Resistance Welding, Gas Welding
  - Solid state Welding
  - Weld Quality and Weldability
- Brazing
- Soldering
- Adhesive Bonding

History of welding…

1000 BCE, the Egyptians

Delhi Iron Pillar

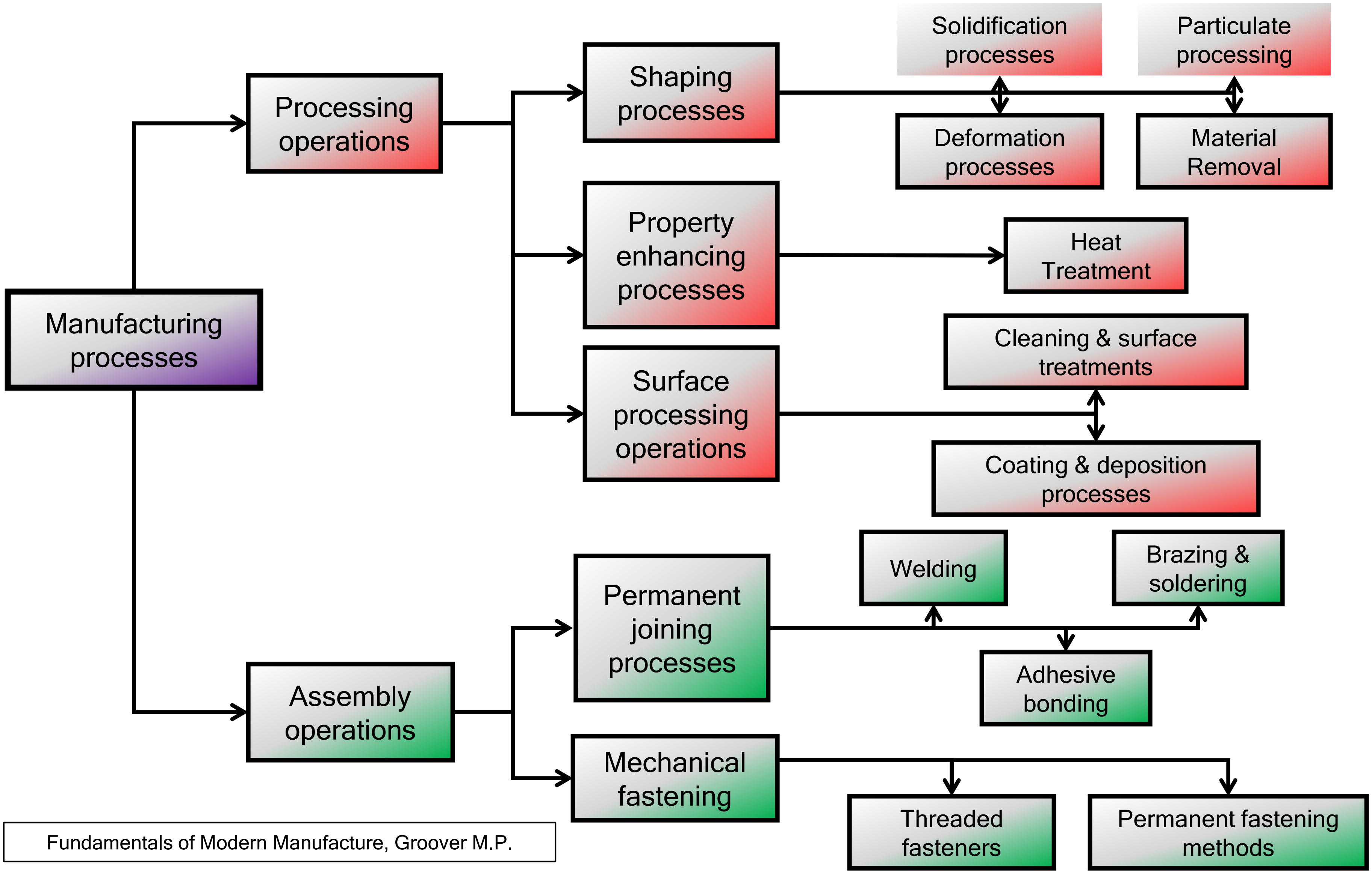
Forge welding

In 1800s: Sir Humphrey Davy: (1) the electric arc, and (2) acetylene gas

Three welding processes – Arc welding, Resistance welding, and Oxyfuel gas welding

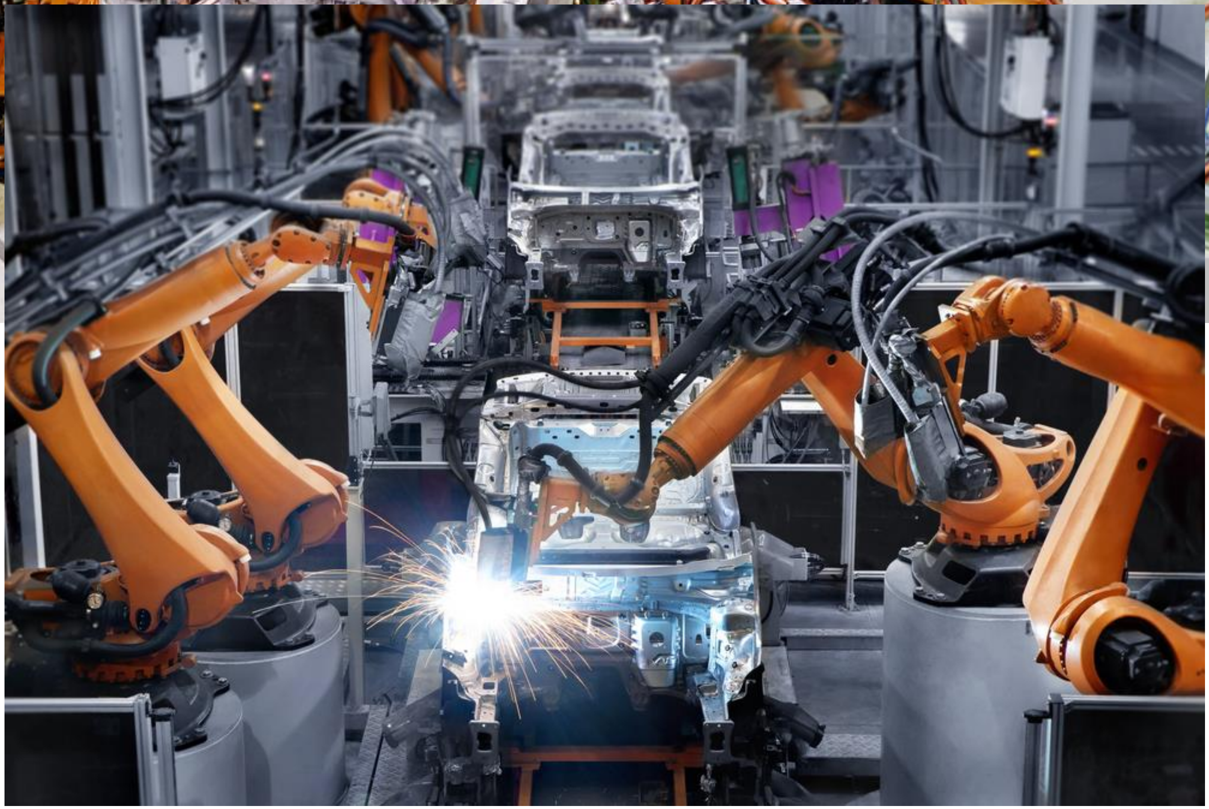
Courtesy: Google Image

Classification of Manufacturing Processes



Fundamentals of Modern Manufacture, Groover M.P.

Joining in Automotive Industry

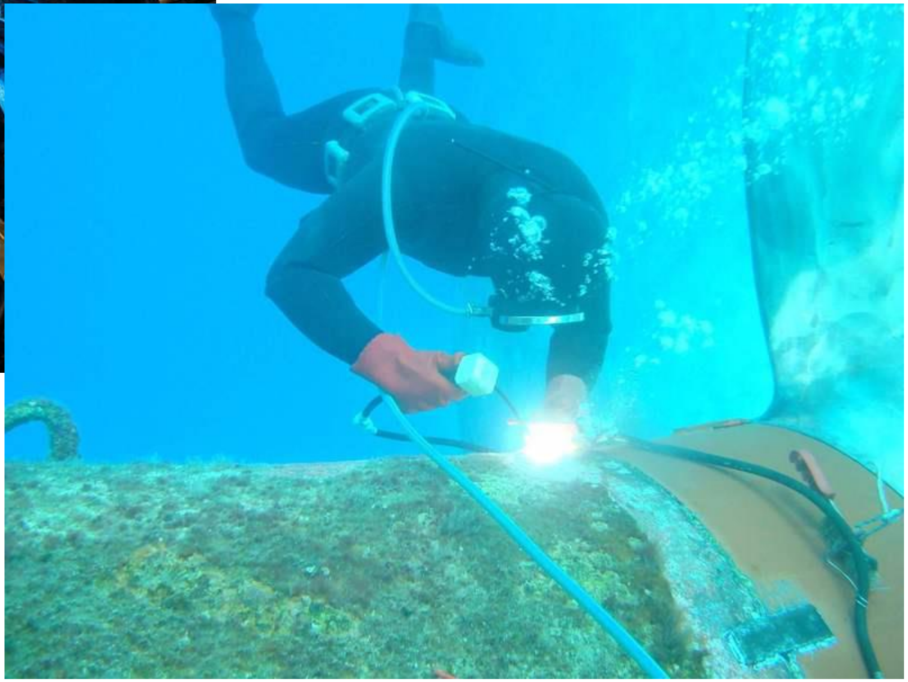


https://www.simufact.com/joining-body-in-white.html
https://www.toyotaofseattle.com/

Joining processes

Aerospace industry

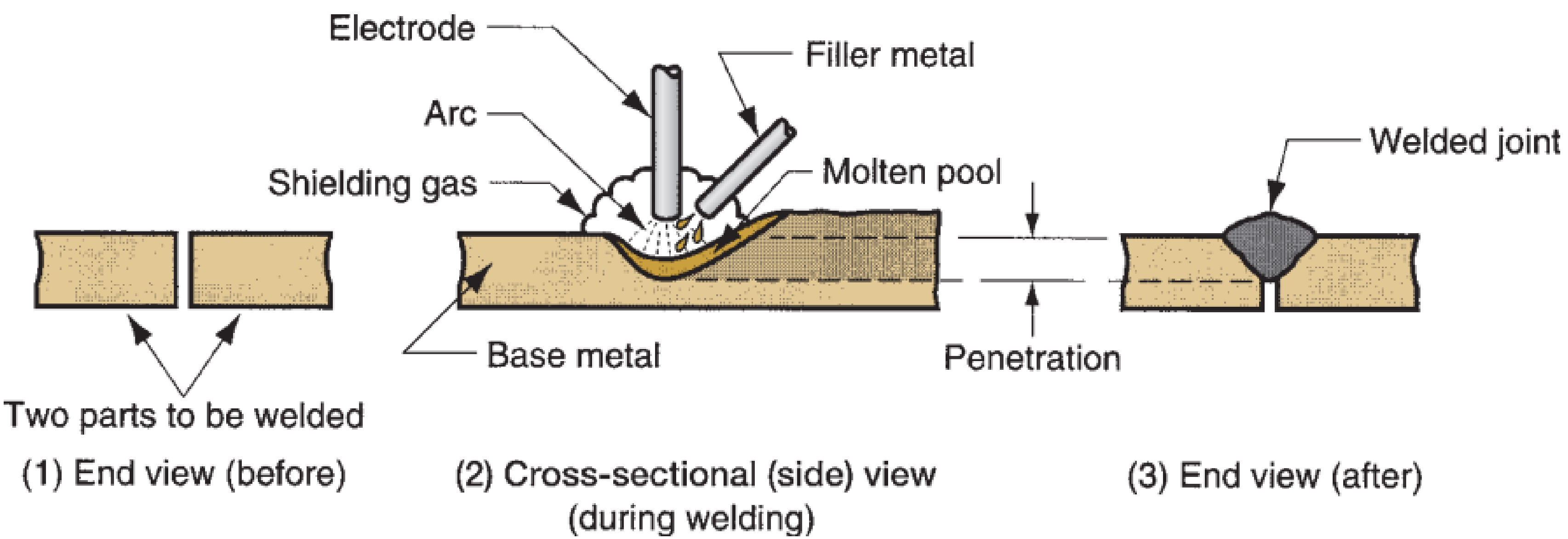
Under water welding



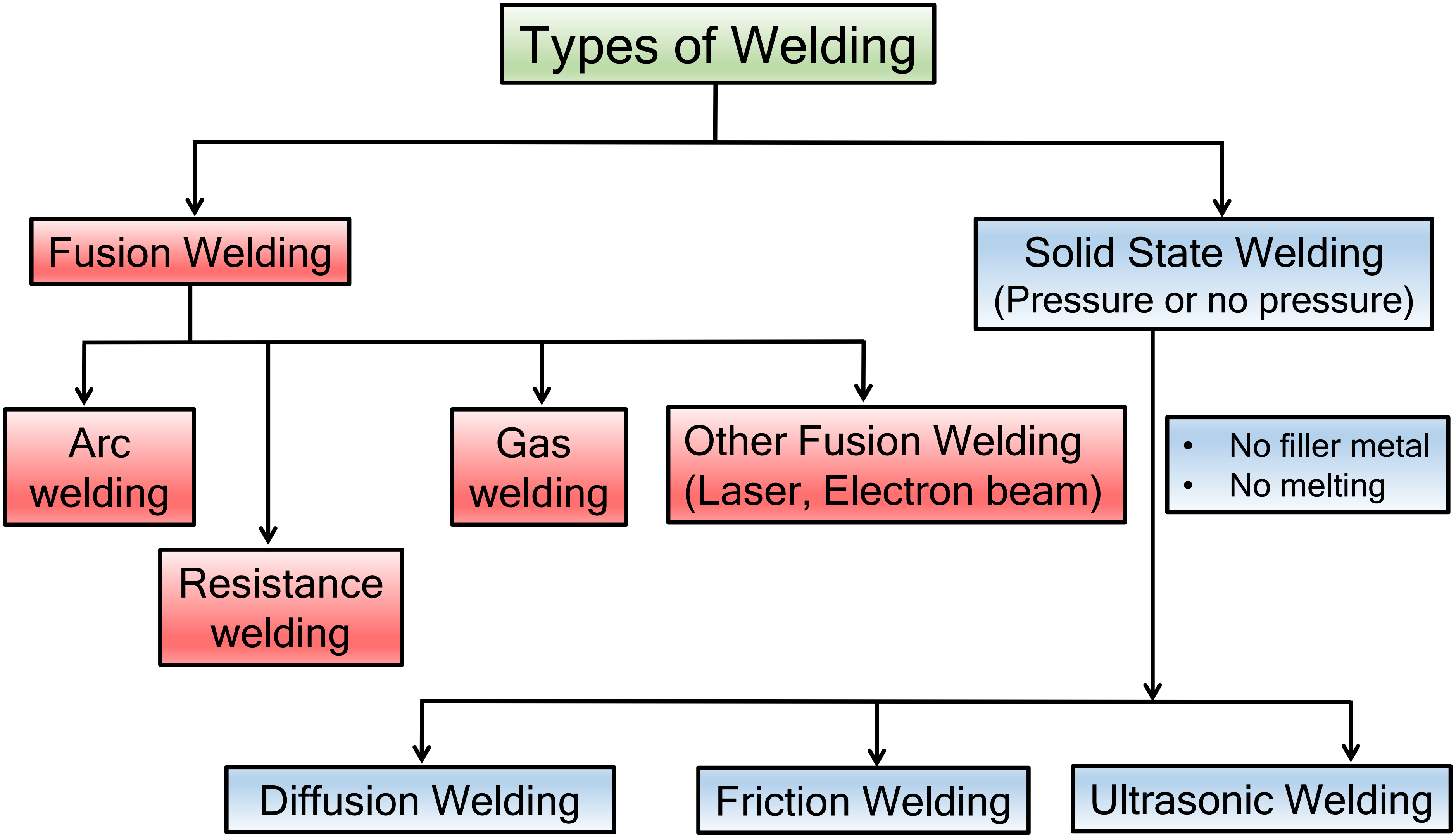
Courtesy: Google Image

Welding

- Welding involves localized **coalescence** of two metallic parts at their faying surface
- The **faying surfaces** are the part surface in contact or close proximity that are to be joined
- Welding is usually performed on parts made of the **same metal** but some welding operations can also be used to join dissimilar metals



Types of Welding



Fusion Welding

Melting base metal and coalescing two work pieces using heat is called Fusion Welding

It involves:

- Melting of localized regions
- Solidification of molten pool when the heat is extracted
- Source of heating is usually in moving condition

Heat source:

- Chemical, as in gas welding
- Electrical, as in arc welding, Resistance welding
- Electron & Laser beam welding

Fusion Welding

Advantages

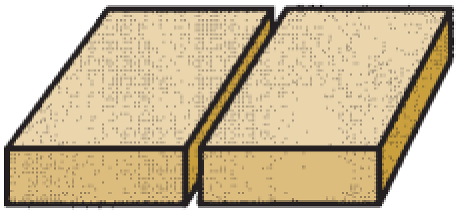
- ✓ It provides a permanent joint
- ✓ Joint can be stronger than the parent materials if the strength of filler metal is more than that of the parent metals and proper welding techniques are used
- ✓ Most economical way of joining
- ✓ Not restricted to factory environment

Disadvantages

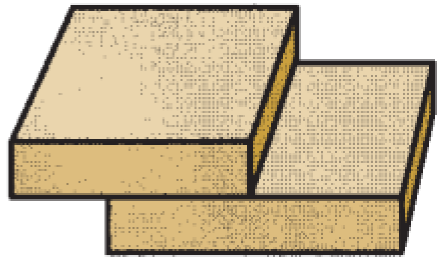
- ➢ Manual welding requires skilled trade
- ➢ High energy requirement
- ➢ Difficult to dismantle if required
- ➢ Possibility of defect formation

Types of weld Joints

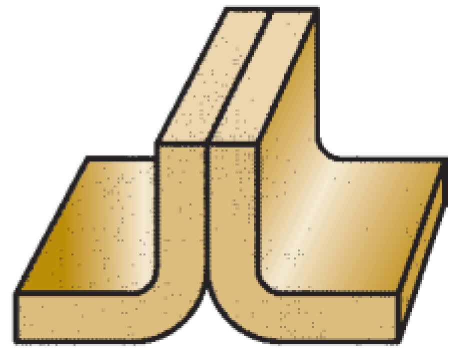
(a) Butt Joint



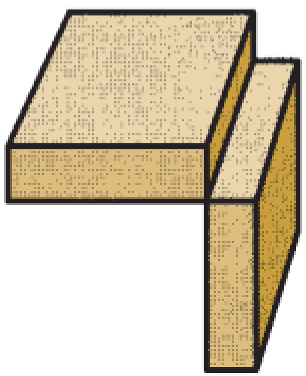
(c) Lap Joint



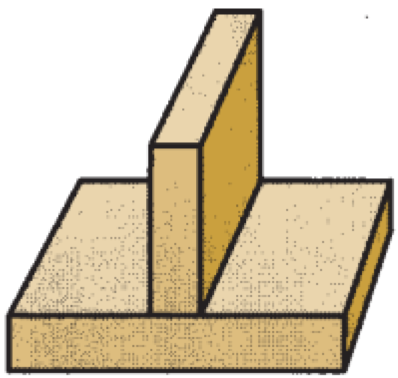
(e) Edge Joint



(b) Corner Joint

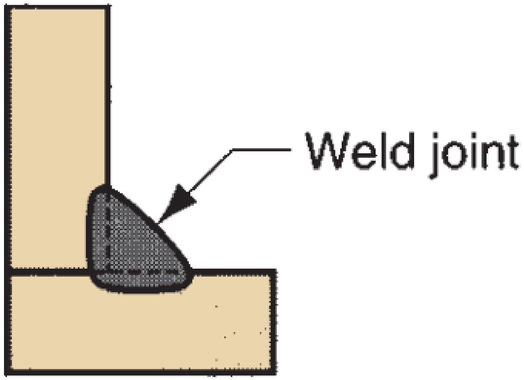


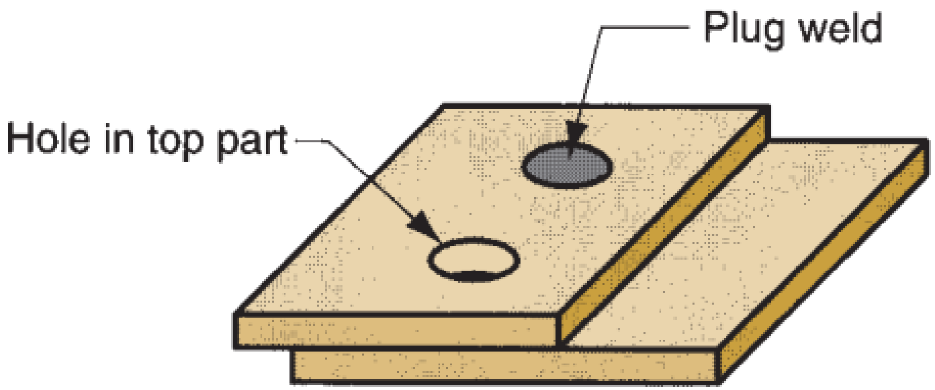
(d) Tee Joint



Types of weld

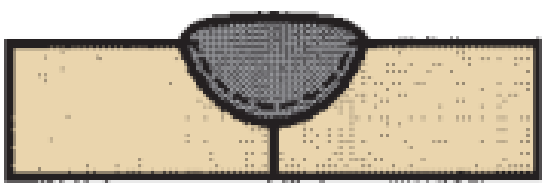
Fillet weld

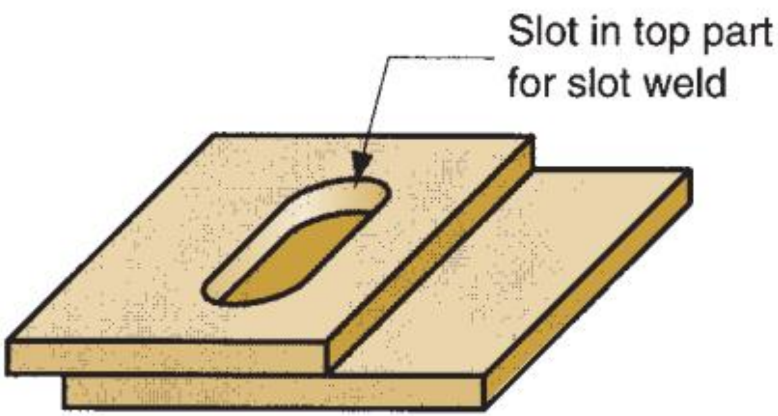




Plug welds and slot welds

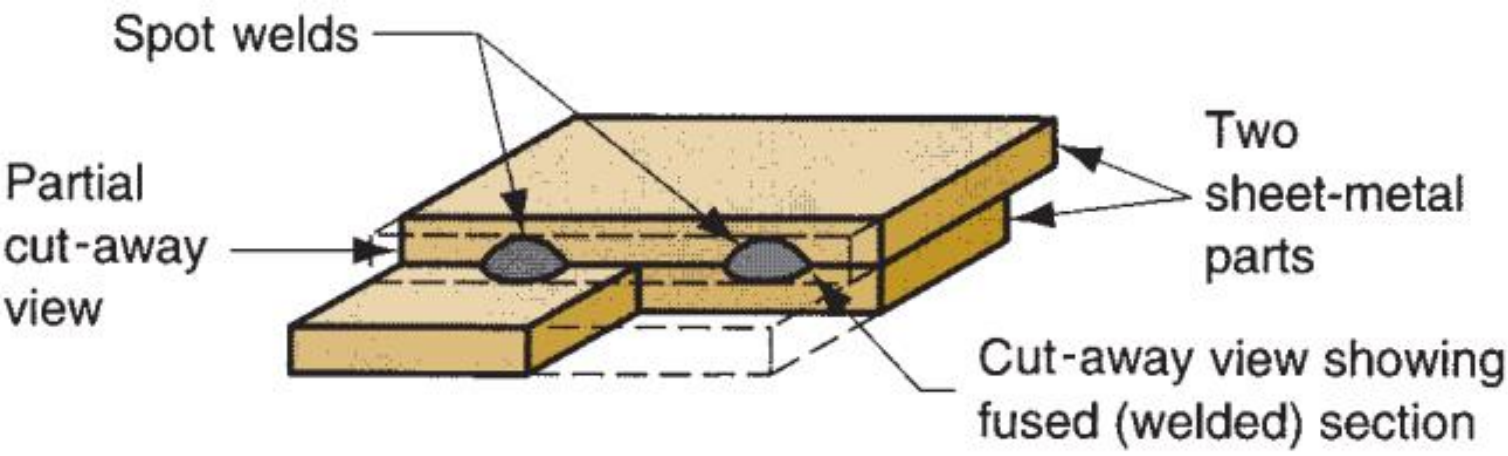
Groove welds



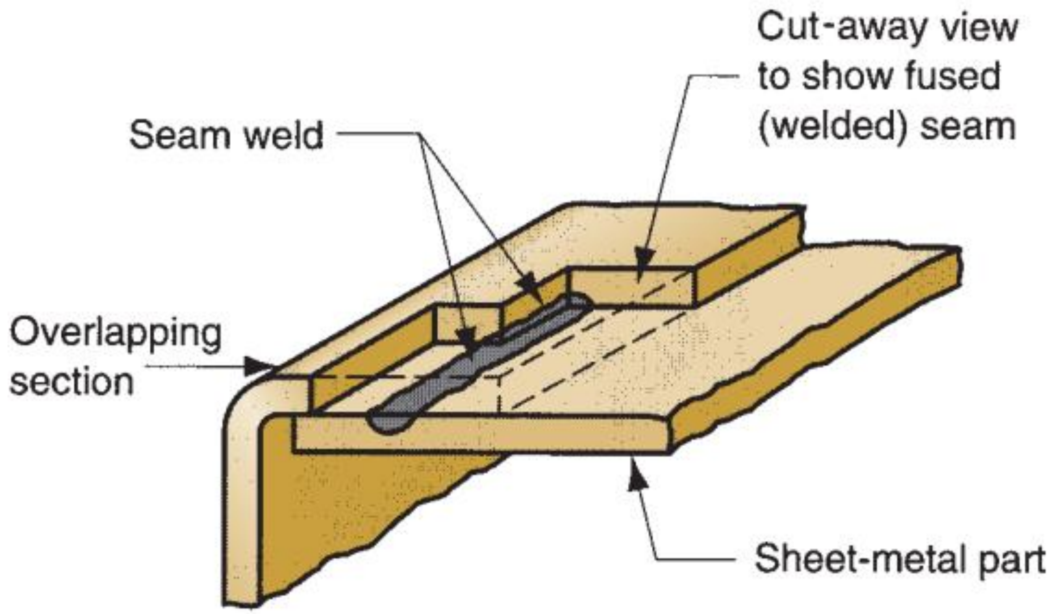


Types of weld

Spot weld



Seam weld

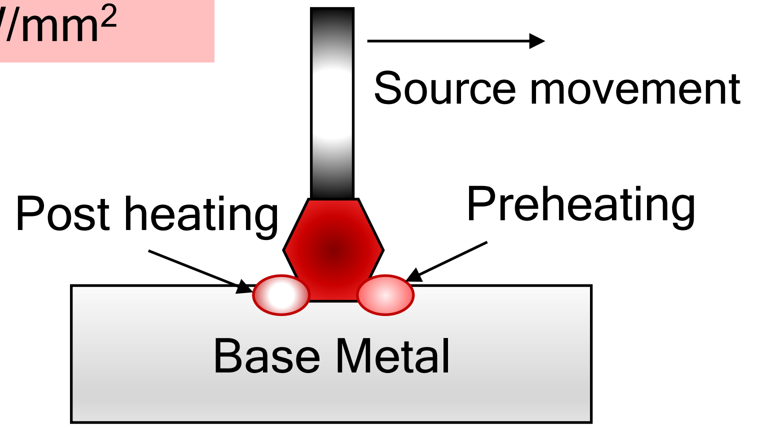


Physics of Fusion Welding

Heat density or power density can be defined as the power transferred to the work per unit surface area, W/mm^2

Power Density (PD) = P/A

P = Power entering the surface (Watt)
A = Surface area over which energy is entering



- Minimum power density required to melt most metals in welding is about $10\ W/mm^2$
- If power density is higher than $10^5\ W/mm^2$, then it can vaporize metals

Complications:

- PD is not uniform across the cross section
- Because of moving heat source
- Preheating and post-heating of base metal

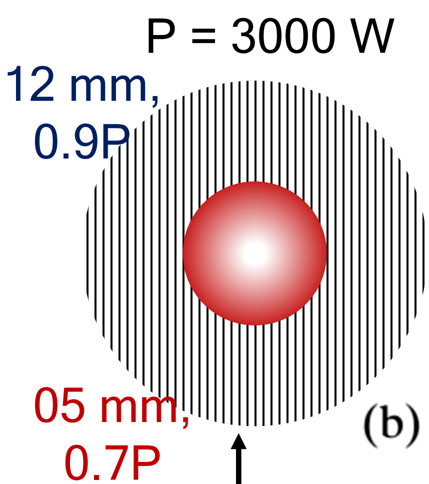
Power density in welding

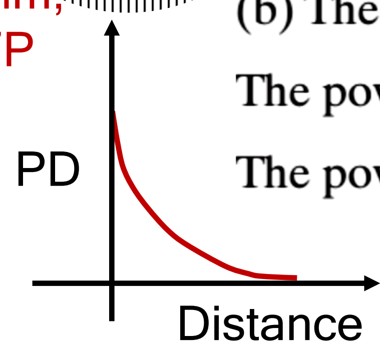
A heat source transfers 3000 W to the surface of a metal part. The heat impinges the surface in a circular area, with intensities varying inside the circle. The distribution is as follows: 70% of the power is transferred within a circle of diameter 5 mm, and 90% is transferred within a concentric circle of diameter 12 mm.

What are the power densities in

(a) the 5-mm-diameter inner circle and

(b) the 12-mm-diameter ring that lies around the inner circle?





Solution: (a) The inner circle has an area $A = \dfrac{\pi(5)^2}{4} = 19.63\ \text{mm}^2$

The power inside this area $P = 0.70 \times 3000 = 2100$ W

Thus the power density $PD = \dfrac{2100}{19.63} = \mathbf{107\ W/mm^2}$

(b) The area of the ring outside the inner circle is $A = \dfrac{\pi(12^2 - 5^2)}{4} = 93.4\ \text{mm}^2$

The power in this region $P = 0.9\,(3000) - 2100 = 600$ W.

The power density is therefore PD$\dfrac{600}{93.4} = \mathbf{6.4\ W/mm^2}$

Importance: Power density

High power density and low energy are preferable because

- Quick melting of base metal or filler metal is crucial
- To avoid metallurgical damage (Defects)

What are the defects that can arise because of prolong heating?

Defects:
(a) Grain size can change for the base metals
(b) Distortion

Welding Process	**W/mm^2**
Oxyfuel welding	10
Arc welding	50
Resistance welding	1000
Laser beam welding	9000
Electron beam welding	10,000

Physics of Welding

Quantity of heat required to melt a given volume of metal is the sum of

1. Heat to reach melting point
2. Latent heat of fusion

To a reasonable approximation

Quantity of heat (U_m) required for melting

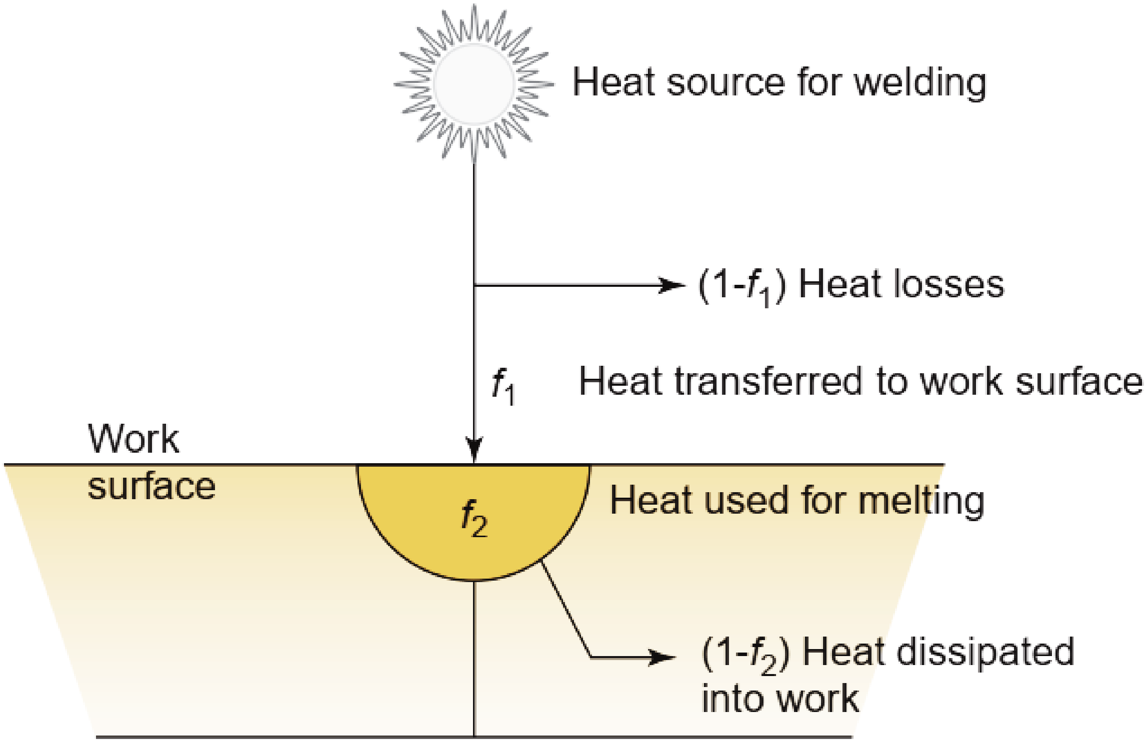
$$U_m = K\, T_m^2$$

K = Constant (3.33×10^{-6}) when Kelvin scale is used

U_m = Heat required (Joules/mm^3)

T_m = Melting temperature

Physics of Welding



f_1, f_2 are in the range of 0 to 1

f_1: Heat transfer factor: defined as the ratio of the actual heat received by the workpiece divided by 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)

- f_1 is determined largely by process to effectively utilize the energy into usable heat (Arc welding are efficient and oxy-fuel are not so efficient)
- f_2 is determined by thermal properties of material, configuration and work thickness.

Physics of Welding

Total heat (amount = H)

$\downarrow f_1H$

Heat received by workpiece (amount = f_1H)

$\downarrow f_2f_1H$

Heat for melting (amount = $f_1f_2H = H_w$)

$$H_w = f_1f_2H$$

H_w : net heat available for welding (Joule)

For Aluminium, f_2 is very small and welding becomes difficult…why?

In aluminum, heat is spread all around and effective melting zone becomes large. Solution is to utilize high PD process

Energy Balance in Welding

Quantity of heat (U_m) required for melting $U_m = K\,T_m^{\,2}$ (Joules/mm^3)

Volume of the metal to be melted (mm^3) = V

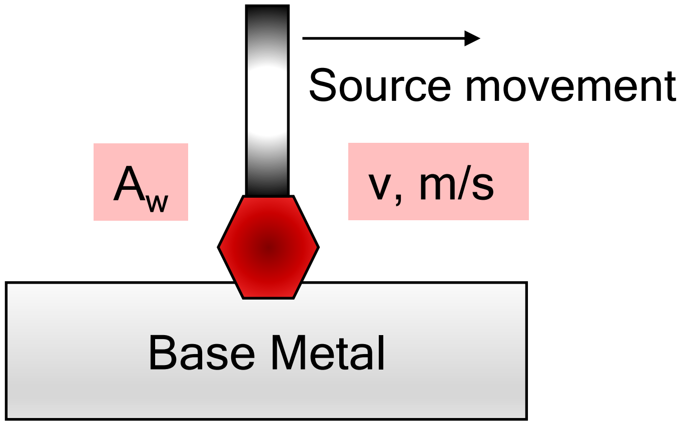
U_mV = Energy needed for welding

Heat input for welding (Hw) = f_1f_2H

Energy Balance in Welding

$$U_mV = f_1f_2H$$

Rate Balance in Welding



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

R_H :Heat generated at the source per unit time

Volume rate of metal welded

$R_{Wv} = A_w v$

$f_1 f_2 R_H$ = Net Heat available for welding per unit time

Quantity of Heat required for welding per unit time

= U_m, Heat required (Joules/mm^3) × Volume rate of metal welded (mm^3/s)

Rate Balance in Welding $U_m R_{Wv} = f_1 f_2 R_H$

$$U_m A_w v = f_1 f_2 R_H$$

Fun Fact…. Welding in Space

Gemini iv mission and cold welding

Astronaut: Ed White

- “Flat surfaces of similar metal would strongly adhere if brought into contact under vacuum”
- Newly discovered micro- and nano-scale cold welding has already shown great potential in the latest nanofabrication processes

https://www.mentalfloss.com/article/88068/cold-welding-metal-space-video
Richard Feynman, The Feynman Lectures, 12-2 Friction