Casting, Forming & **Welding**
(ME31007)

Jinu Paul
Dept. of Mechanical Engineering

CFW- Welding marks distribution

CFW Total Marks = 100
Casting =33, Forming = 33, Welding =33

End semester exam – 50 %
Mid semester exam – 30 %
Class test 1 (Before midsem) – 7 %
Class test 2 (After midsem) – 7 %
Attendance + Assignments - 6 %

Course details: Welding

	Topic	Hours	
1.	Introduction to welding science & technology	3	
2	Welding Processes	4	
3	Welding Energy sources & characteristics	2	
4	Welding fluxes and coatings	1	
5	Physics of Welding Arc	3	
6	Heat flow in welding	2	
7	Design of weld joints	1	
8	Defects, Testing and inspection of weld joints	2	
9	Metallurgical characteristics of welded joints, Weldability, Brazing, soldering, adhesive joining	2	
	Total	20	

References

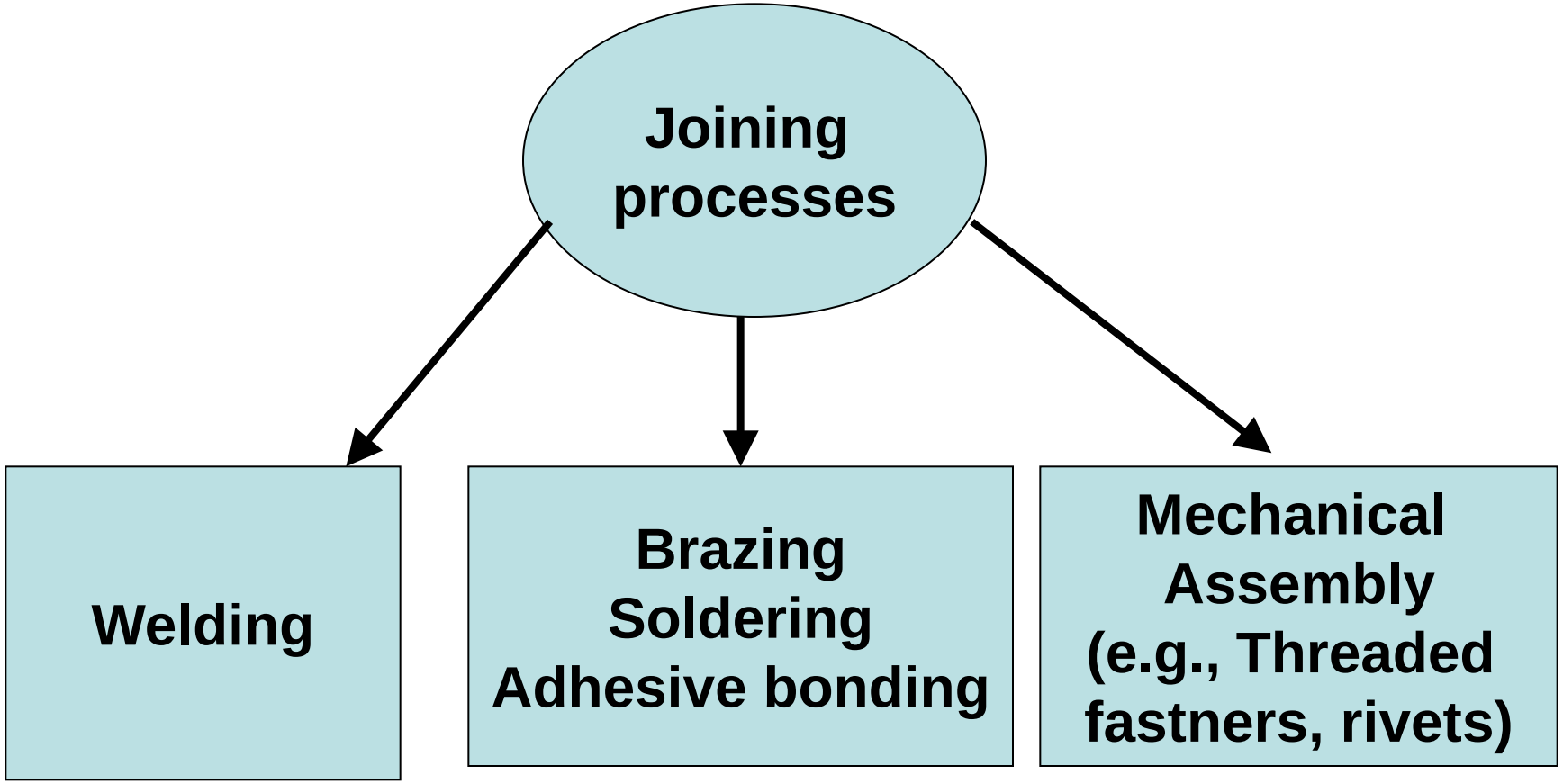
- Principles of Welding, Robert W Messler
- Metallurgy of Welding, J.F. Lancaster
- Welding Science and Technology, Md. Ibrahim Khan
- Welding Technology-O.P. Khanna
- Manufacturing Engineering and Technology, S. Kalpakjian

Lectures 1-2

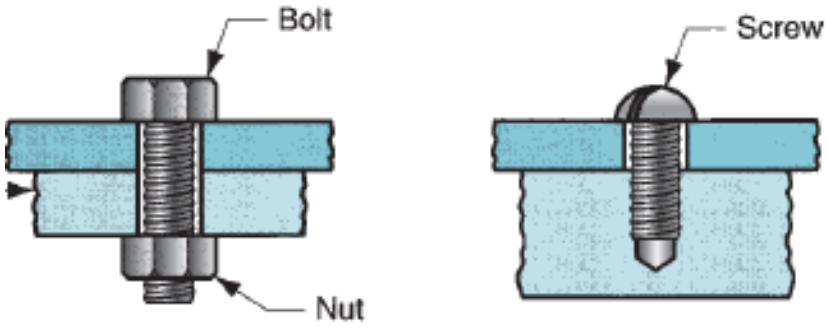
19 July 2016, Tuesday, 10.00 am -12.00 noon

Introduction to welding

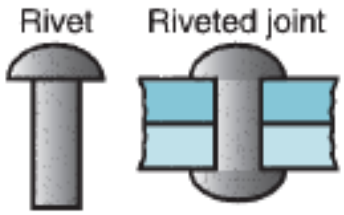
Overview of Joining processes



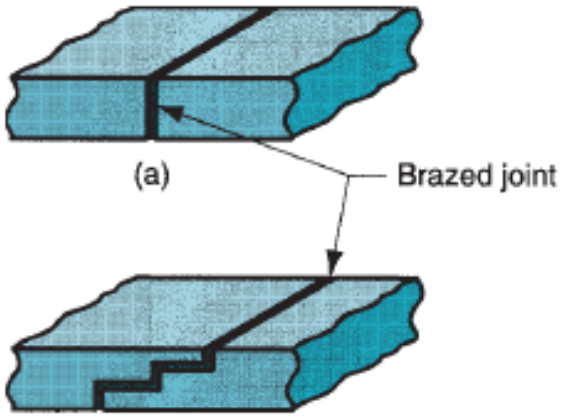
Joining processes-overview



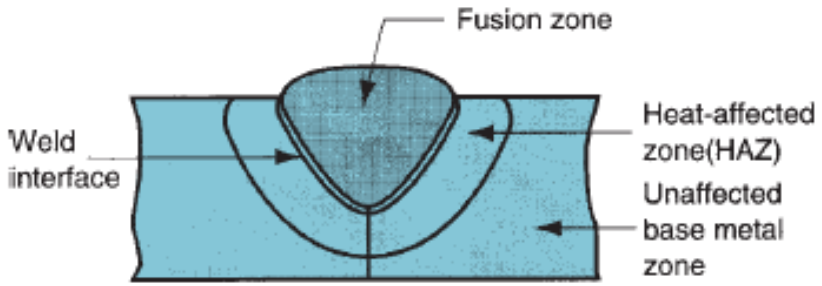
Threaded fastner



Riveted Joint



Brazed Joint



Welded Joint

What are the joints that were used in the Eiffel Tower?

Some application areas of welding

Aircraft industry

Ship building

Automotive industry

Welding: Application areas

- Applications in Air, Underwater & Space
- Automobile industry, aircraft industry, ships and submarines
- Buildings, bridges, pressure vessels, girders, pipelines, machine tools, offshore structures, nuclear power plants, etc.
- House hold products, farm, mining, oil industry, jigs & fixtures, boilers, furnaces, railways etc.

Welding process-Features

- Permanent joining of two materials through localized coalescence resulting from a suitable combination of Temperature & Pressure
- Formation of Common metallic crystals at the joints/interface
- With or Without filler material

Welding process-Features

- Continuity: absence of any physical disruption on an atomic scale
- Not necessarily homogeneous but same in atomic structure, thereby allowing the formation of chemical bonds

Material (similar/dissimilar)	Metals	Ceramic	Polymer
Type of bond	Metallic	Ionic/covalent	Hydrogen, van der Waals, or other dipolar bonds

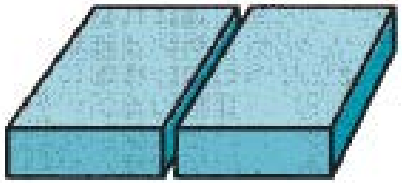
Welding Process: Advantages

- Exceptional structural integrity, continuity, fluid tightness, portable equipments
- Strength of joints can approach or exceed the strength of the base material(s)
- Wide range of processes & approaches
- Can be performed manually, semi automatically or completely automatically
- Can be performed remotely in hazardous environments (e.g., underwater, areas of radiation, outer space) using robots

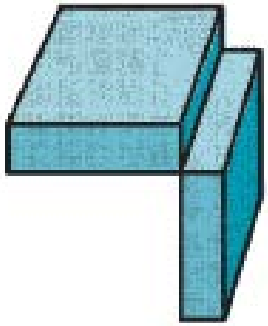
Welding Process: Disadvantages

- Precludes disassembly
- Requirement for heat in producing many welds can disrupt the base material microstructure and degrade properties; may induce residual stresses
- Requires considerable operator skill
- Capital equipment can be expensive (e.g., laser beam, vacuum chambers etc.)

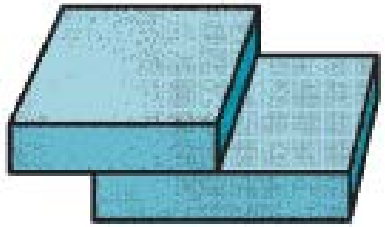
Types of joints in welding



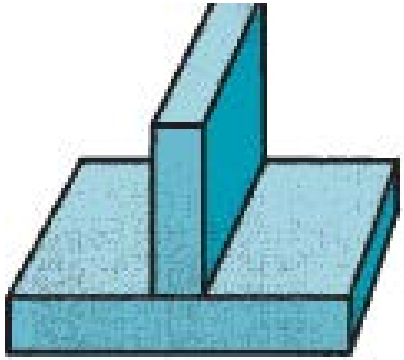
Butt joint



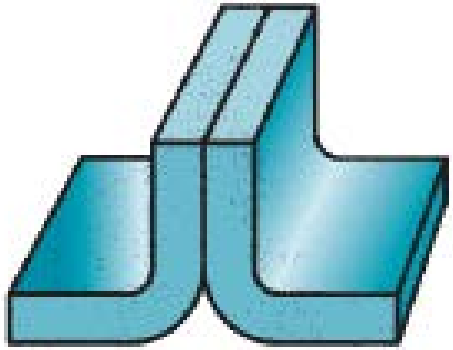
Corner joint



Lap joint



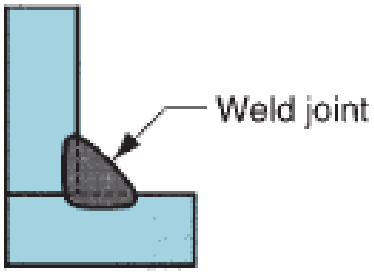
Tee joint



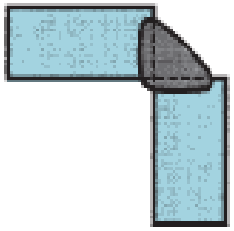
Edge joint

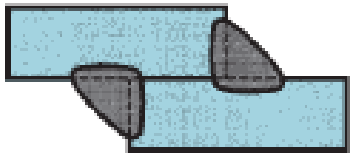
Types of welds

1) Fillet weld

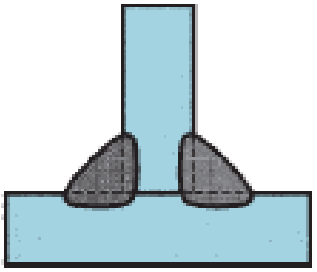


Fillet weld on corner joint





Fillet weld
on lap joint

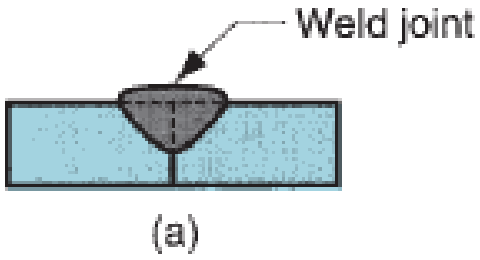


Fillet weld
on T-joint

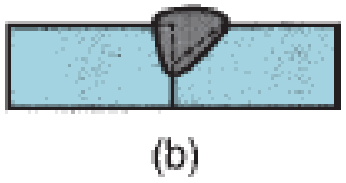
Types of welds

2) Groove weld

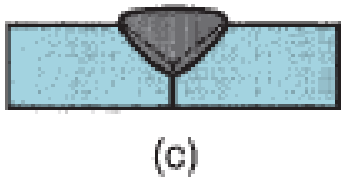
(a) square groove weld,

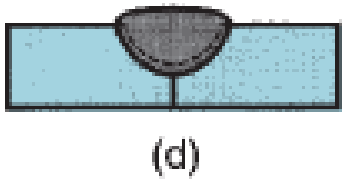


(b) single bevel groove weld

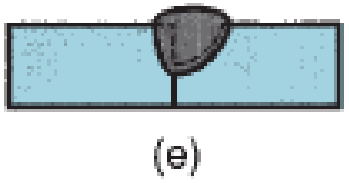


(c) single V-groove weld

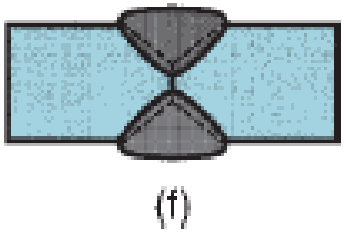




(d) single U-groove weld



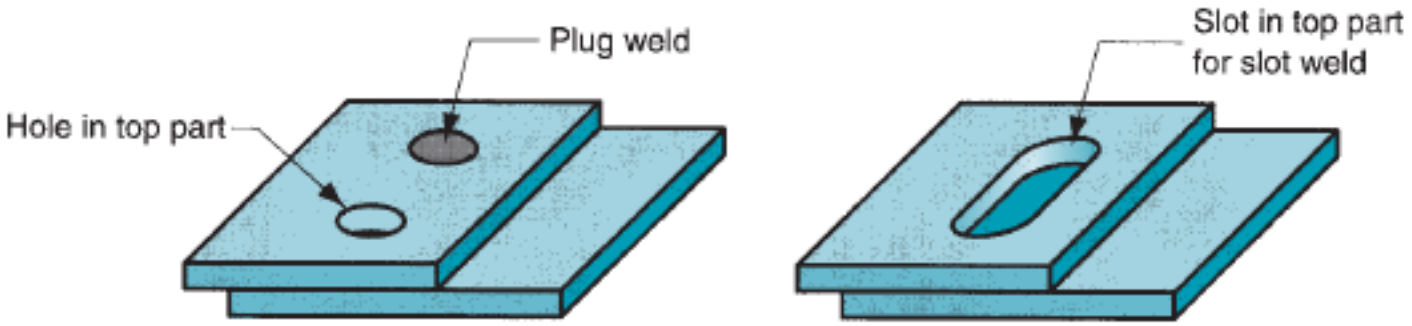
(e) single J-groove weld



(f) Double V- groove weld for thicker sections

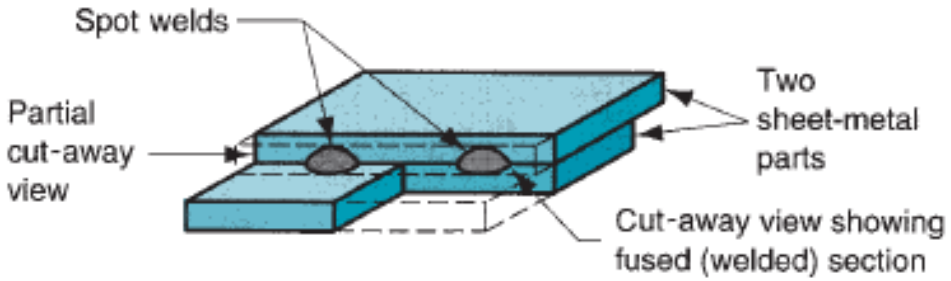
Types of welds

3) Plug & slot weld

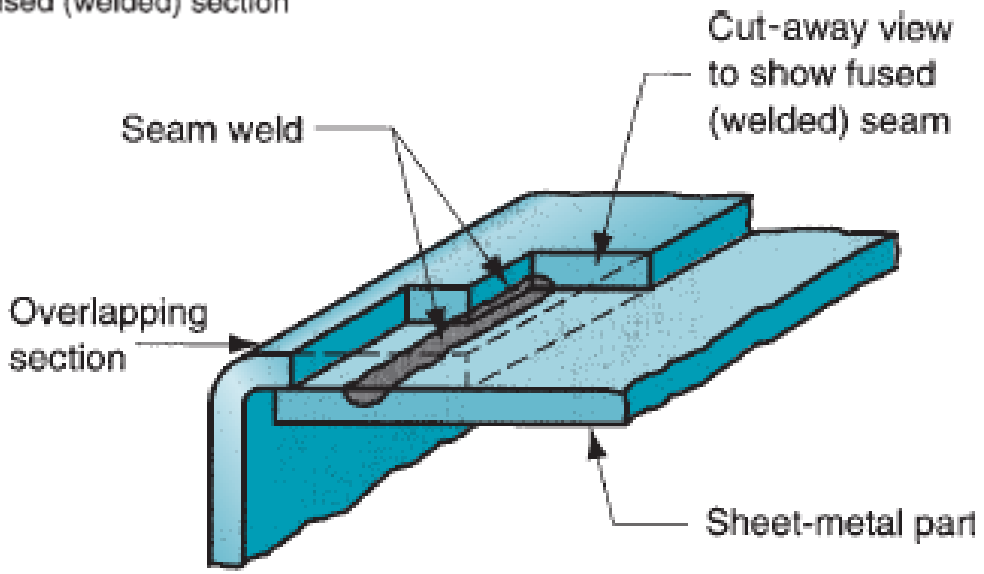


- Drill hole/slot on the top plate only
- Hole/slot is filled with filler metal

Types of welds



4) Spot weld

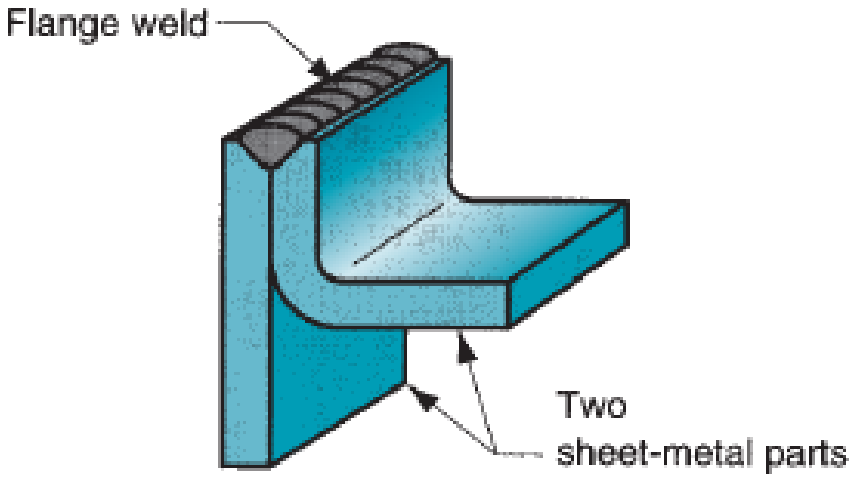


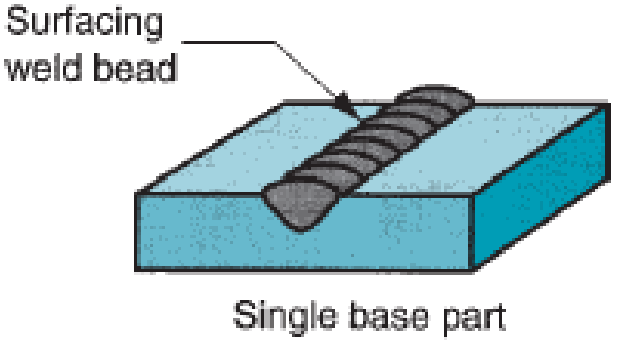
5) Seam weld

- Fused section between the surfaces of two sheets
- Mostly associated with resistance welding

Types of welds

6) Flange weld & Surfacing weld





- Surfacing weld is not for joining parts
- The purpose is to increase the thickness of the plate or to provide a protective coating on the surface.

Weld symbols


Fillet weld


Square Butt


Single V Butt


Double V Butt


Single U


Single Bevel Butt

Flush/Flat contour


Convex contour

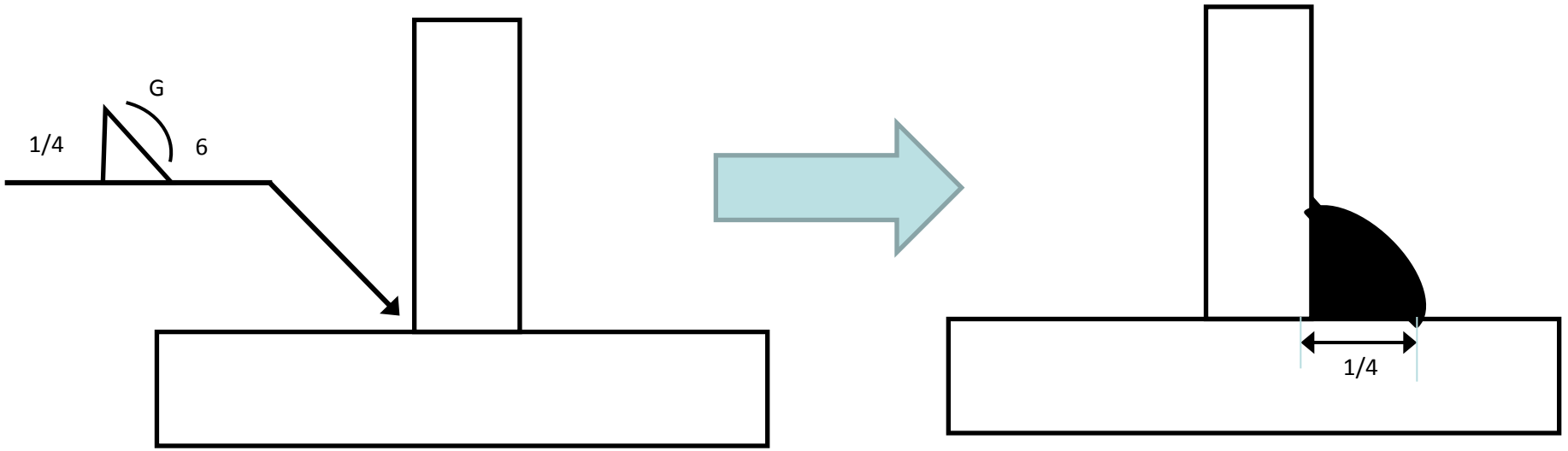

Concave contour

G Grinding Finish

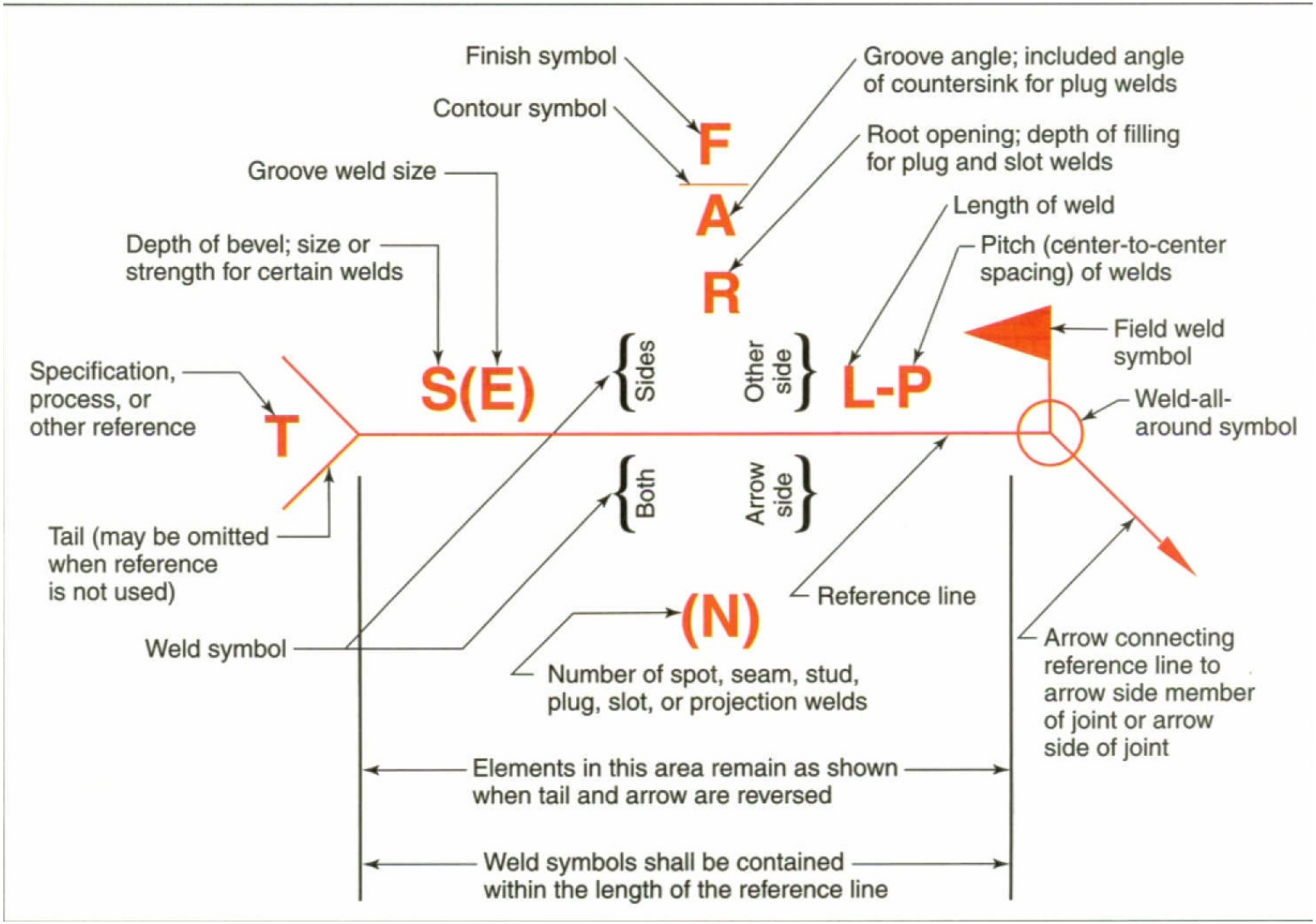
M Machining Finish

C Chipping Finish

Weld Specification-Example



Weld Specification



Basic elements of a welding setup

1. Energy source to create union by pressure/heat
2. Method to remove surface contaminants
3. Protect metal from atmospheric contamination
4. Control of weld metallurgy

1. Energy source

Classification of Fusion welding based on energy source

Energy source	Types of welding
Chemical	Oxy fuel gas welding, Exothermic welding/ Thermite welding, Reaction brazing/Liquid phase bonding
Radiant energy	Laser beam welding, Electron beam, Infrared welding/ brazing, Imaging arc welding, Microwave welding,
Electric-Perm. electrode arc	Gas tungsten arc welding, plasma arc welding, Carbon arc welding, atomic hydrogen welding, Stud arc welding
Electric-Consumable electrode	Gas metal arc welding, Shielded metal arc welding, Submerged arc welding, Electrogas welding, Electroslag welding, Flux cored arc welding
Electric-Resistance	Resistance spot, resistance seam, projection welding, flash/ upset welding, Percussion, Induction welding

1. Energy source

Classification of solid state welding based on energy source

Energy source	Types of welding
Mechanical	Cold welding, Hot pressure welding, Forge welding, Roll welding, Friction welding, Ultrasonic welding, Friction stir welding, Explosion welding, Deformation diffusion welding, Creep isostatic pressure welding, Super plastic forming
Chemical + Mechanical	Pressure gas welding, Exothermic pressure welding, Pressure thermit forge welding
Electrical + Mechanical	Stud arc welding, Magnetically impelled arc butt welding, resistance spot welding, resistance seam welding, projection welding, flash welding, upset welding, percussion welding, resistance diffusion welding

2. Removal of Surface contaminants

- Surface contaminants may be organic films, absorbed gases or chemical compounds of the base metals (usually oxides)
- Heat when used as source of energy removes organic films and absorbed gases
- Fluxes are used to clean oxide films and other contaminants to form slag
- Slag floats and solidifies above weld bead protecting the weld from further oxidation

3. Protection from atmospheric contamination

- Shielding gases are used to protect molten weld pool from atmospheric contaminants like O_2 & N_2 present in air
- Shielding gases could be Ar, He,CO_2
- Alternatively, welding could be carried out in an inert atmosphere.

4. Control of weld metallurgy

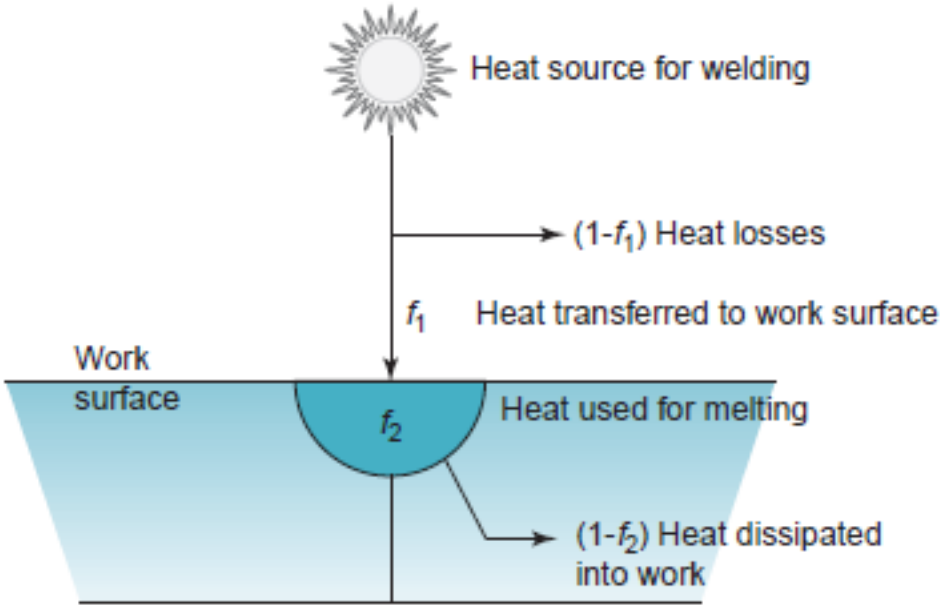
- Microstructures formed in the weld and HAZ determines the properties of the weld
- Depends on heating, cooling rates (power, weld travel speed)
- Can be controlled by preheating/ post heat treatment
- De-oxidants, alloying elements etc. added to control weld metal properties

Power density

- Defined as the power transferred to work per unit surface area (W/mm^2)
- Time to melt the metal is inversely proportional to power density

Welding Process	Approx. Power density (W/mm^2)
Oxy-fuel welding	10
Arc welding	50
Resistance welding	1000
Laser beam welding	9000
Electron beam welding	10,000

Heat transfer mechanisms in Fusion Welding



Heat transf. factor f_1= Heat transf. to work / Heat gen. by source

Melting Factor f_2 = Heat used for melting / Heat tranf. to work

Useful heat or energy = $f_1.f_2$

Example No: 1

The power source in a particular welding setup generates 3500 W that can be transferred to the work surface with a heat transfer factor $f_1 = 0.70$. The metal to be welded is low carbon steel, whose melting temperature is 1760K. The melting factor in the operation is 0.50. A continuous fillet weld is to be made with a cross-sectional area of 20 mm^2. Determine the travel speed at which the welding operation can be accomplished?

Heat capacity of low carbon steel (C_p)=480 J/Kg.K

Latent heat of melting L_m =247 kJ/Kg

Density ρ = 7860 kg/m^3

Initial sample temperature T_0 = 300 K

Example 1-Solution

Rate of heat input to the weld bead = $3500 \times f_1 \times f_2$

$= 3500 \times 0.7 \times 0.5 = 1225$ J/s

Heat input = Energy used for heating to T_m + Energy used for melting

$1225 = [C_p(T_m - T_0) + L_m] \rho \times A \times v$

$1225 = [480(1760-300) + 247 \times 10^3] \times 7860 \times 20 \times 10^{-6} \times v$

Travel speed v = 0.0082 m/s = **<u>8.2 mm/s</u>**