K. K. College of Engineering and Management

At:-Nairo, Bagsuma, Govindpur, Dhanbad

Course code :-

Course Objectives :--

The main **objective** of this **course** is to emphasize the importance **manufacturing** sciences in the day-to-day life, and to study the basic **manufacturing processes** and tools used.
The **course** is delineated particularly to understand the conventional **manufacturing processes** like casting, metal forming, and welding **process**.

Subject :Manufacturing Technology

Course Contents :-

1. Welding (07 hrs)
1.1. Define and classification of various welding processes.
1.2. Gas& Arc welding-Principle, Equipment, applications and types of Flames.
1.3. Electrode specifications, current setting & use of flux in welding
1.4 Advance welding process- TIG, MIG, Thermit Welding, Submerge Arc Welding, Plasma Arc Welding, Laser Welding, Ultrasonic Welding, Forge Welding, Explosive Welding & Cold Pressure Welding.
1.5. Resistance welding-Spot welding, Seam welding, Projection welding
1.6. Welding defects, non destructive testing.
1.7. Brazing and soldering: Types, Principles, Applications

2. Casting (08 hrs)
2.1 Introduction and history
2.2 Patterns-Material used, types, Patterns allowances, Cores, Core allowances.
2.3 Moulding Sand – Types, characteristics and properties of sand.
2.4 Moulds-Mould materials, Types, Moulding processes
2.5 Process and steps in Sand Moulding
2.6 Mould making
a. Runner and Gating System
b. Core, Chaplets and Chills.
c. Parts of Mould

2.7 Melting practice. Types of furnaces with specific application Cupola furnace, Electric arc furnace.
2.8 Special casting processes. Viz die-casting, centrifugal casting, Investment casting, Continuous casting

2.9 Casting defects and its remedies

3. Forging (06 hrs)
3.1 Introduction, Hot & Cold forging.
3.2 Press and hammer (Concept only)
3.3 Explain different forging tools, specification and uses
3.4 Describe various forging processes-Drop forging, Upset forging, stamping, Die forging, press forging.
3.5 Types of dies-Open Die, Closed Die (Single Impression and Multi-impression)
3.6 Closed die Forging operations- Fullering, Edging, Bending, Blocking, Finishing
3.7 Forging defects and their remedies.

4. Rolling and Extrusion (04 hrs)
4.1 Principles of rolling and extrusion.

4.2 Hot and cold rolling.
4.3 Introduction to various rolling mills.
4.4 Methods of extrusion–Direct, Indirect, backward & impact Extrusion, Hot & Cold extrusion processes - applications.

5. Press working (05 hrs)
5.1 Types of presses and their specifications.
5.2 Die set components. –punch and die shoe, guide pin, bolster plate, stripper, stock guide, feed stock, pilot.
5.3 Punch and die clearances for blanking and piercing, effect of clearance.
5.4 Press working operations- cutting, bending, drawing, punching, blanking, notching, l ancing

6. Lathe (04 hrs)
6.1 Principle, types and specification of Lathes
6.2 Functions of basic parts and tools.
6.3 Operations–grooving, Turning, parting off, Knurling, facing, Boring, Drilling, threading, step turning, taper turning.

7. Drilling, Boring & Reaming (04 hrs)
7.1 Drilling
7.1.1 Introduction, classification of drilling machine& their parts
7.1.2 Drilling accessories
7.1.3 Nomenclature of twist drill
7.1.4 Cutting parameters
7.2 Reaming
7.2.1 Introduction.
7.2.2 Nomenclature of reaming tool
7.3 Boring
7.3.1 Introduction, classification of boring machine and their parts
7.3.2 Counter boring and counter sinking operations

8. Maintenance & Maintenance Planning (4 hrs)
8.1 Introduction

8.2 Objective of maintenance
8.3 Types – planned and unplanned maintenance
8.4 Repair cycle and repair complexity.
8.5 Equipment history card, work order.

Course Outcome :-

The main **objective** of this **course** is to emphasize the importance **manufacturing** sciences in the day-to-day life, and to study the basic **manufacturing processes** and tools used.
The **course** is delineated particularly to understand the conventional **manufacturing processes** like casting, metal forming, and welding **process**.

WELDING

Welding is the process of joining two metallic pieces together in permanent manner. Heat and/or pressure is applied to get the joint.

- Gas welding
- Arc welding
- Resistance welding
- Solid state welding

HISTORY OF WELDING…..

- Began when people found they could shape rocks by chipping them with other rocks

- Copper probably first metal to be worked

    - Ductile (easily hammered, bent or drawn)
    - In Egypt as early as 4000 B.C. and USA before 2000 B.C.

- Welding began more than 3000 years ago

- Bronze developed between 3000 and 2000 B.C.

- Iron became known to Europe about 1000 B.C.

- Working of metals followed one another in great ancient civilizations
  Copper, bronze, silver, gold, and iron

- Chinese developed ability to make steel from wrought iron in 589 A.D.

- Belgians responsible for progress with steel in Europe

- Japan manufactured steel by repeated welding and forging and controlling amount of carbon by use of fluxes

- Industrial Revolution in the middle of the eighteenth century brought many improvements

- Working of dies and molds became commonplace by beginning of nineteenth century

Early Developments in Welding

- Edmund Davy discovered acetylene at beginning of nineteenth century

- Sir Humphrey Davy discovered the electric arc in 1801

- Workable electrical generating devices invented and developed on practical basis by 1850

Bare Metal Electrode Welding

- ✓ Introduced in 1888 by N. G. Slavianoff (Russian)
- ✓ Discovery first recognized in western Europe in 1892
- ✓ C. L. Coffin was pioneer of welding industry in United States
- ✓ 1889 received patent on equipment and process for flash-butt welding
- ✓ 1890 received additional patents for spot welding
- ✓ In 1908, Benardos patented *electroslag* process of welding thick plates in one pass

Welding Associations

- American National Standards Institute (ANSI)
- American Petroleum Institute (API)
- American Society of Mechanical Engineers (ASME)
- American Welding Society (AWS)
- American Bureau of Shipping (ABS)

Welding is joining two pieces of metal by:

- Heating to temperature high enough to cause softening or melting
- With or without application of pressure
- With or without use of filler metal

ELEMENTS OF WELDING PROCESS

- **FILLER MATERIAL**

- Filler materials are used **to fill the space between the welded joint.**
- Filler material is melted and added to the joint during the welding process.
- It **adds strength to the joint.**

FLUXES-

is a **cleaning agent** used to avoid the contamination of welded joint by impurities like oxides, by oxygen combined with metal during welding.

Flux dissolve oxide, trapped gases and slag(impurities) from base metal.

<u>WELD POOL</u> -

dime-sized workable portion of a weld where the base metal has reached its melting point and is ready to be infused with filler material.

Weld pool is central to the success of the welding process.

Weld pool solidifies to become weld beed.

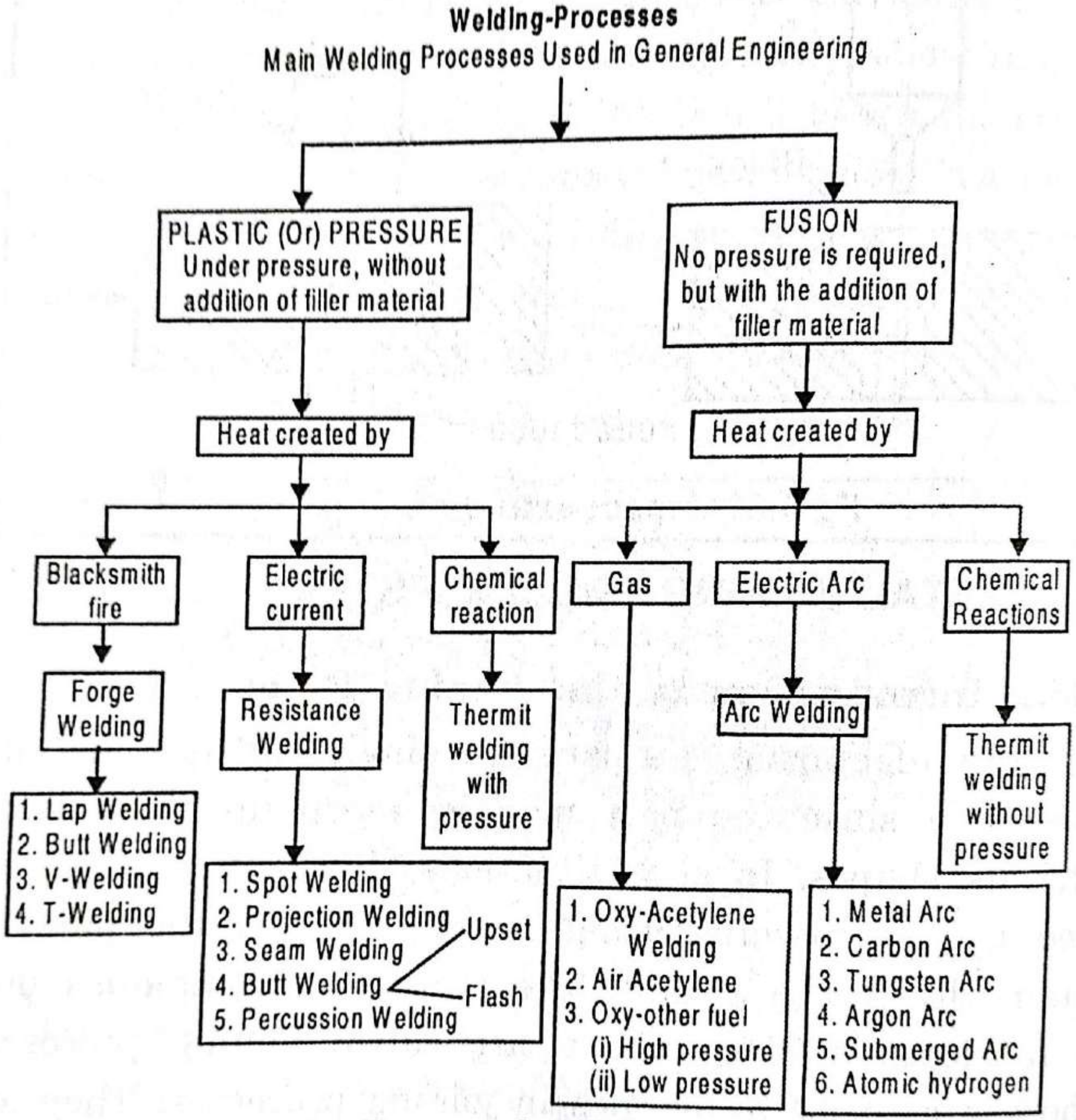


Fig. 5.61 Types of welding processes

WELDING

Classification of welding processes:

(i). Arc welding

- Carbon arc
- Metal arc
- Metal inert gas
- Tungsten inert gas
- Plasma arc
- Submerged arc
- Electro-slag

(ii). Gas Welding

- Oxy-acetylene
- Air-acetylene
- Oxy-hydrogen

(iii). Resistance Welding

- Butt
- Spot
- Seam
- Projection
- Percussion

(iv)Thermit Welding

(v)Solid State Welding

Friction
Ultrasonic
Diffusion
Explosive

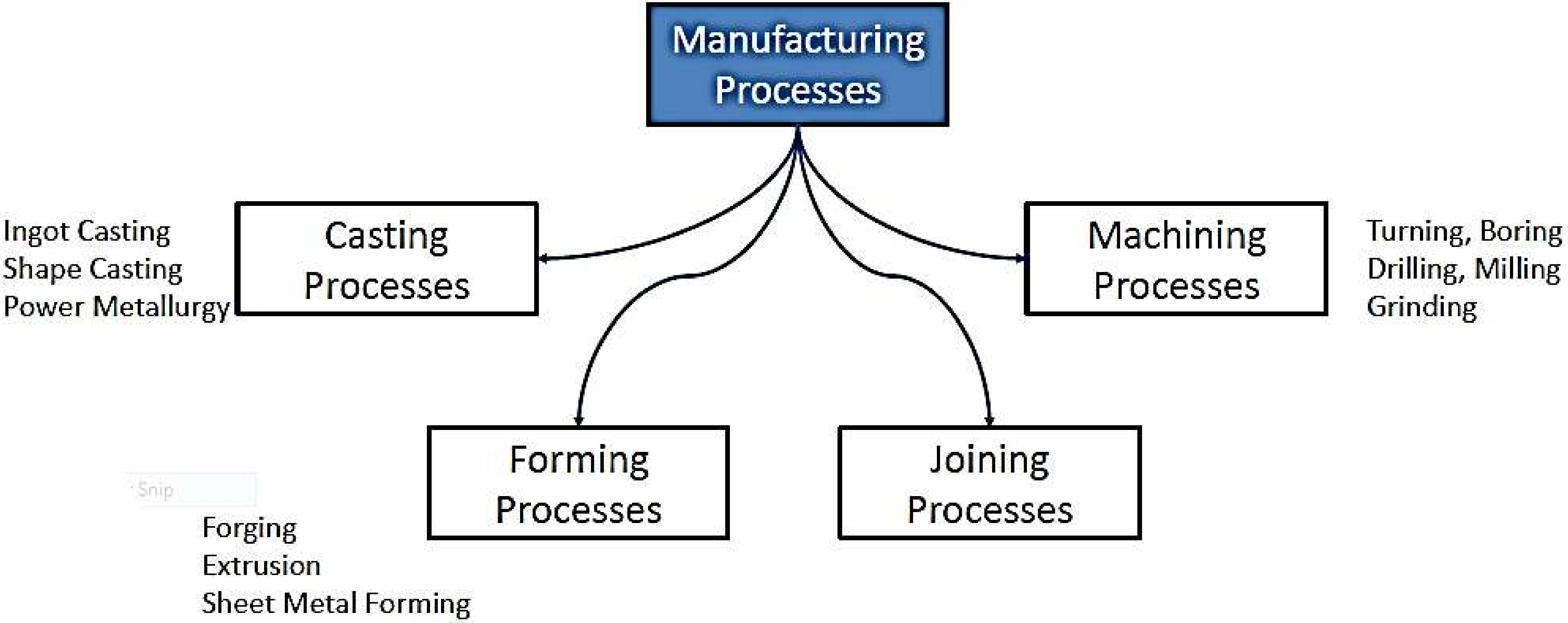
(vi)Newer Welding

Electron-beam
Laser

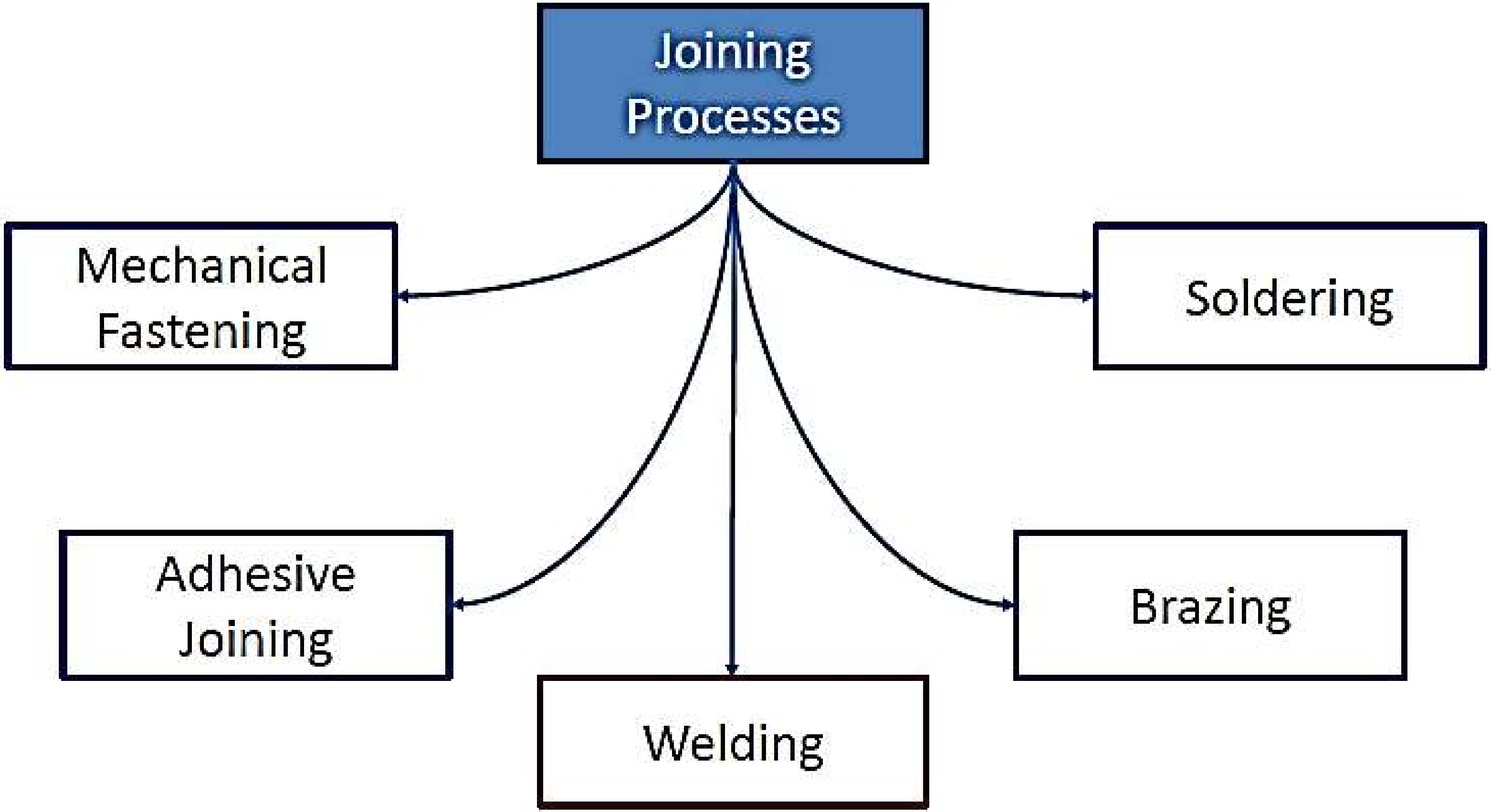
(vii)Related Process

Oxy-acetylene cutting
Arc cutting
Hard facing
Brazing
Soldering

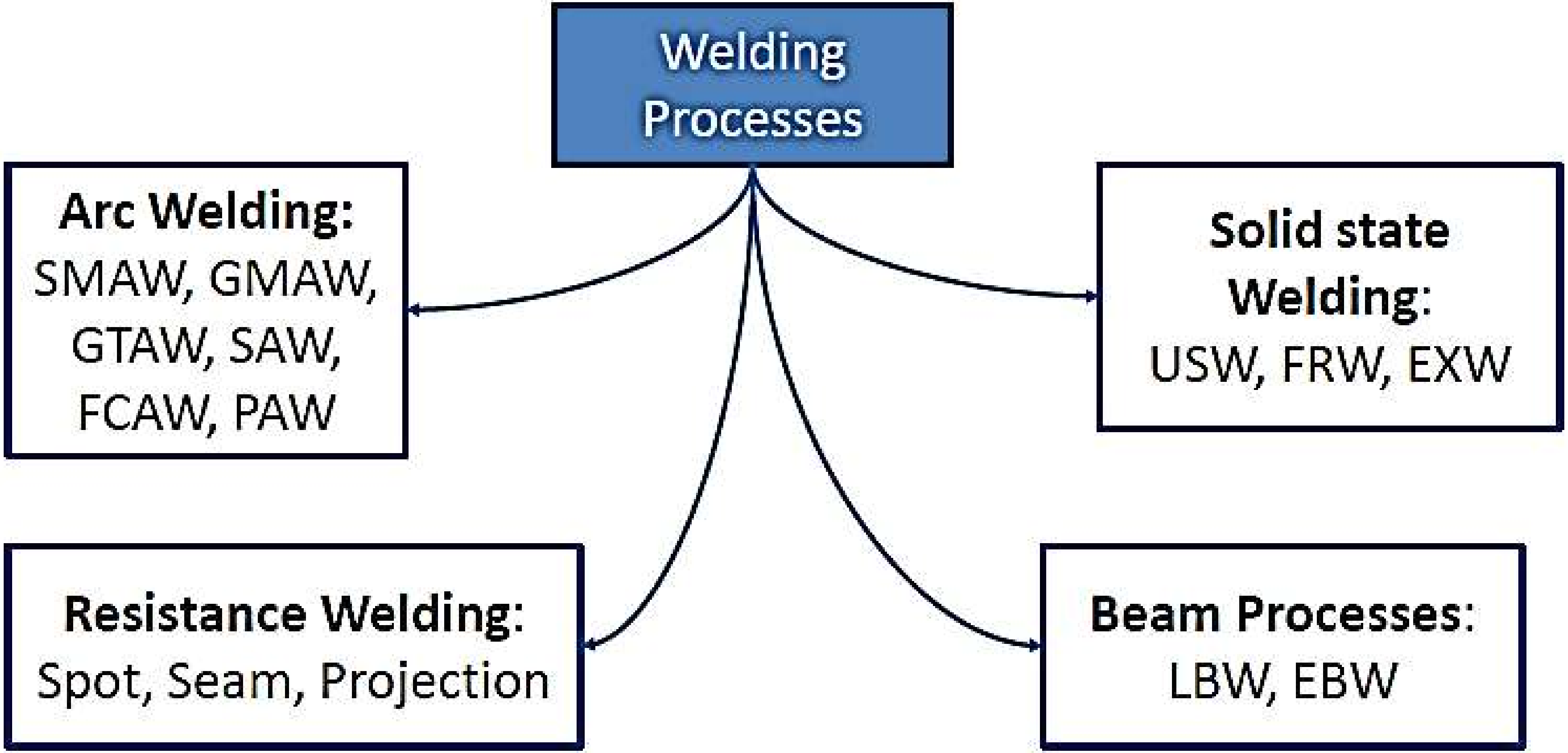
Classification of Manufacturing Processes



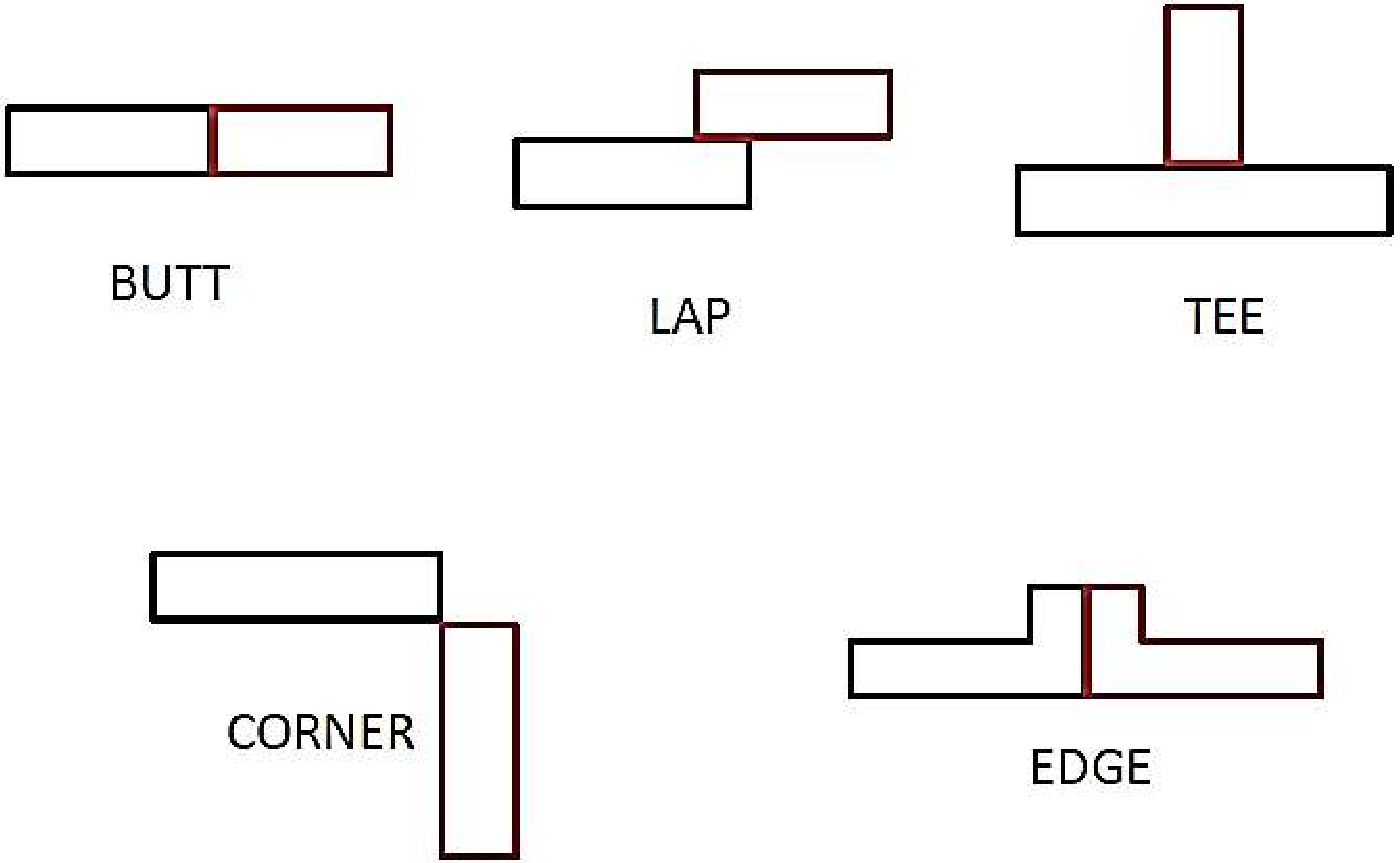
Classification of Joining Processes



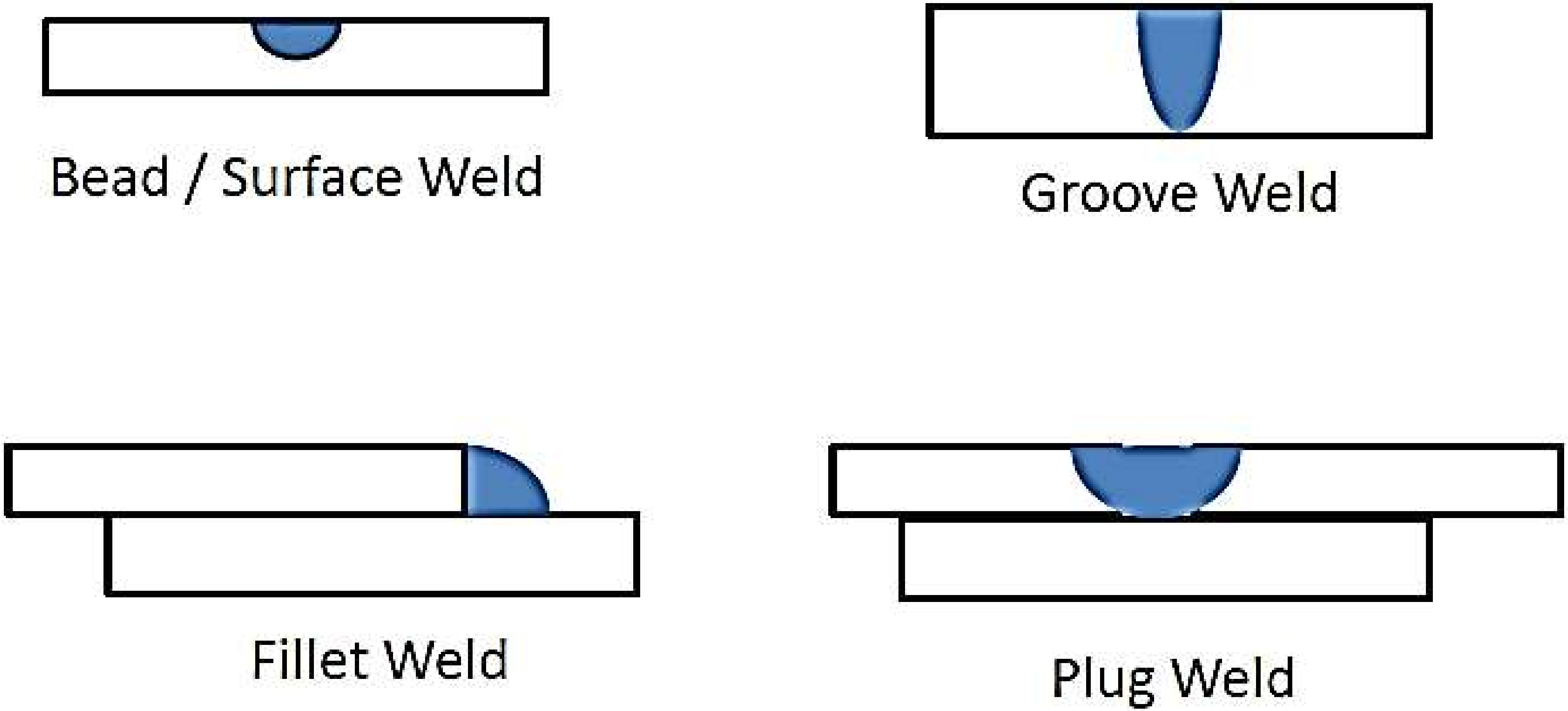
Different Welding Processes



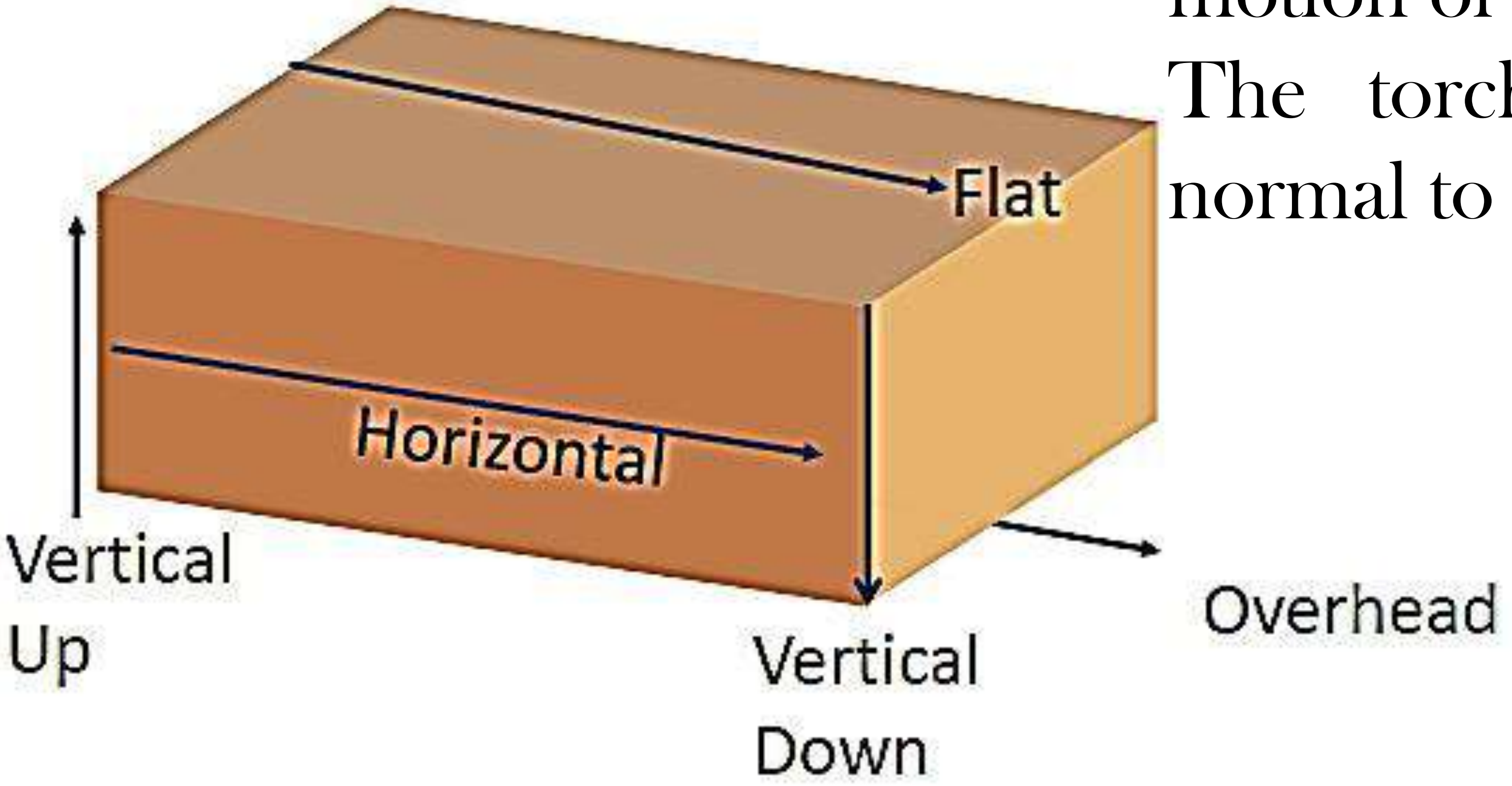
Five basic joint designs



Four basic types of fusion welds

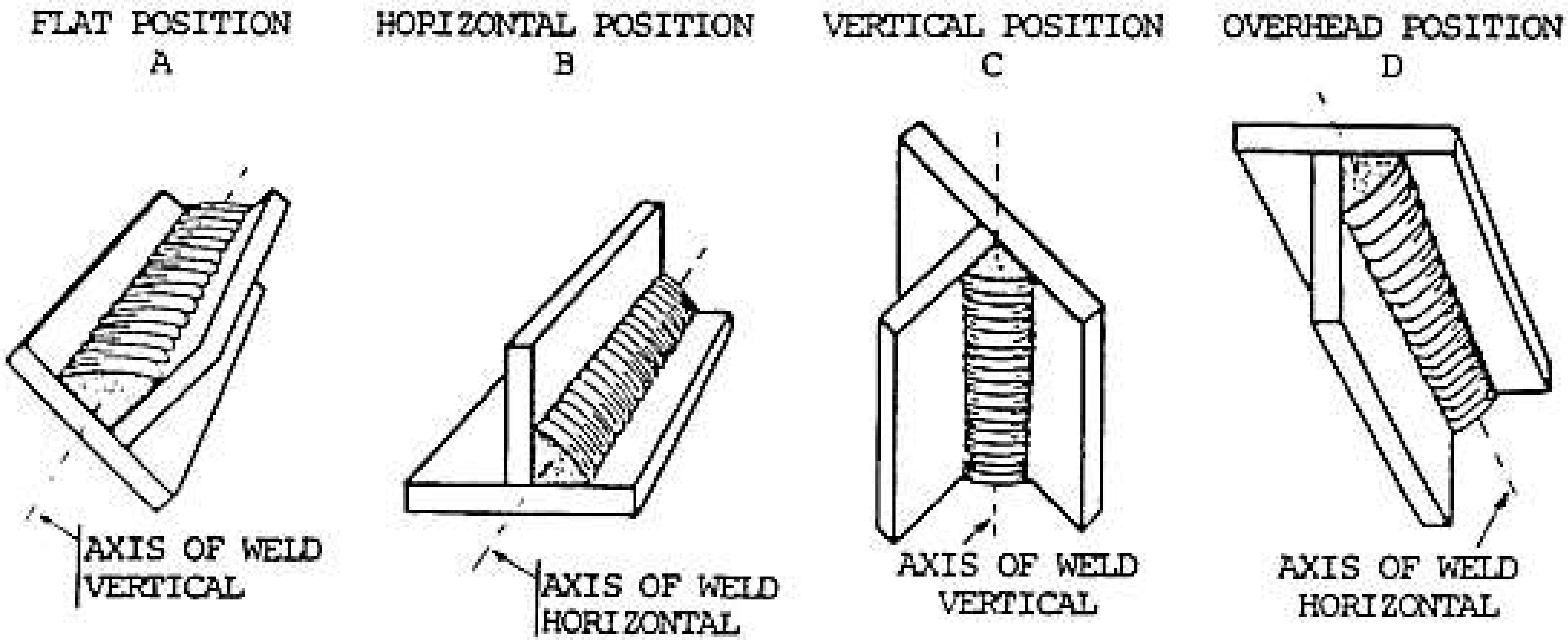


Five Welding Positions



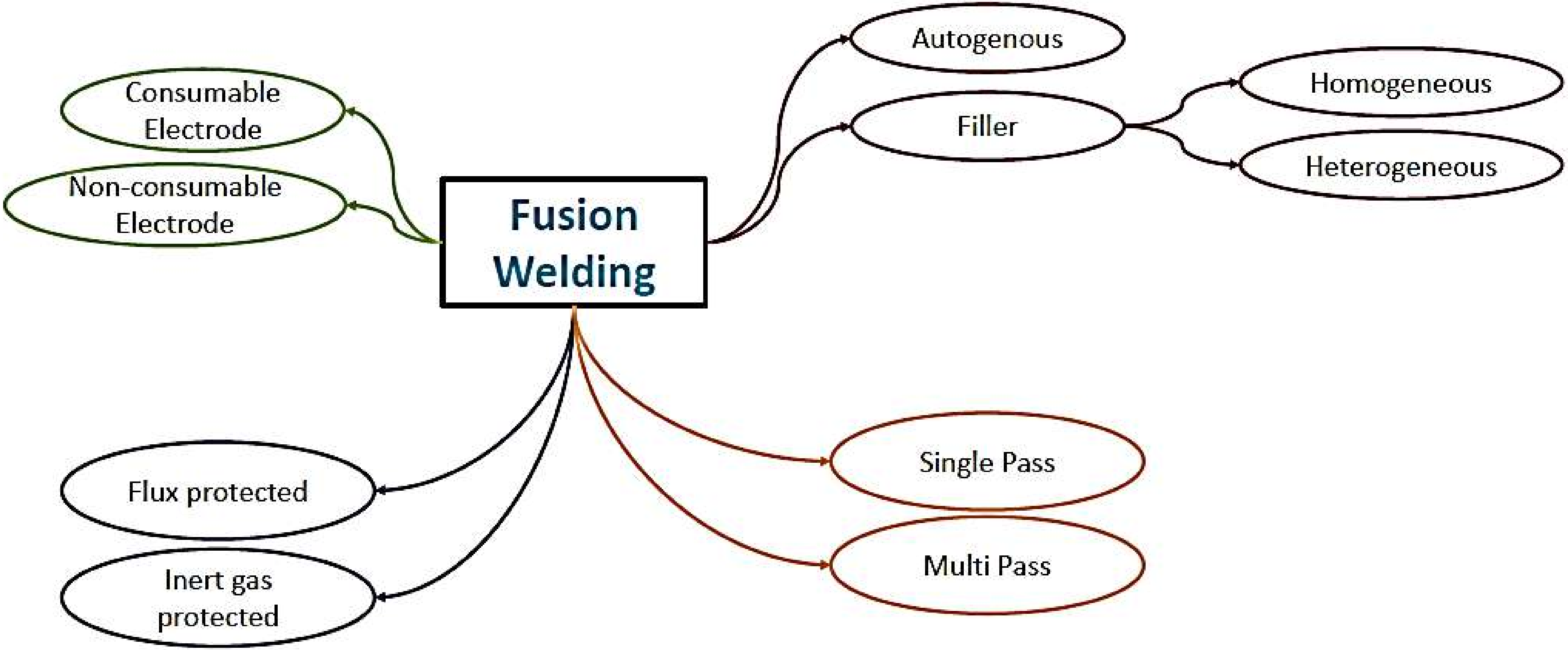
Arrow shows the direction of motion of the electrode / torch.

The torch is held approximately normal to this direction.



Welding positions--fillet welds--plate.

Classification of Welding



Terminology in welding

- Traverse rate : velocity of the welding source : m/s
- Heat Input : ratio of power to velocity : J/m
- Rate of heat input or heat intensity : W/m^2
- Heat intensity distribution

Arc Welding (AW)

- A fusion welding process in which coalescence of the metals is achieved by the heat from an electric arc between an electrode and the work

- Energy from the arc produces temperatures ~ 10,000 °F (5500° C), hot enough to melt any metal

- Most AW processes add filler metal to increase volume and strength of weld joint

ELECTRIC ARC ?

- ✓ An electric arc is a discharge of electric current across a gap in a circuit
- ✓ It is sustained by an ionized column of gas (*plasma*) through which the current flows
- ✓ To initiate the arc in AW, electrode is brought into contact with work and then quickly separated from it by a short distance

Two Basic Types of AW Electrodes

- **Consumable**
  - consumed during welding process
  - Source of filler metal in arc welding

- **Nonconsumable**
  - not consumed during welding process
  - Filler metal must be added separately if it is added

Arc Shielding

- At high temperatures in AW, metals are chemically reactive to oxygen, nitrogen, and hydrogen in air
  - Mechanical properties of joint can be degraded by these reactions
  - To protect operation, arc must be shielded from surrounding air in AW processes
- Arc shielding is accomplished by:
  - Shielding gases, e.g., argon, helium, CO_2
  - Flux

Flux

- A substance that prevents formation of oxides and other contaminants in welding, or dissolves them and facilitates removal

  - Provides protective atmosphere for welding

  - Stabilizes arc

  - Reduces spattering

Various Flux Application Methods

- Pouring granular flux onto welding operation
- Stick electrode coated with flux material that melts during welding to cover operation
- Tubular electrodes in which flux is contained in the core and released as electrode is consumed

Power Source in Arc Welding

Direct current (DC) vs. Alternating current (AC)

- AC machines less expensive to purchase and operate, but generally restricted to ferrous metals

- DC equipment can be used on all metals and is generally noted for better arc control

Direct current (D.C.) always flows from:

- The positive (higher potential) terminal to the negative (lower potential) terminal, as per the conventional theory.
- Negative terminal to positive terminal as per electronic theory.

In the latest machines a polarity switch is used to change the polarity.

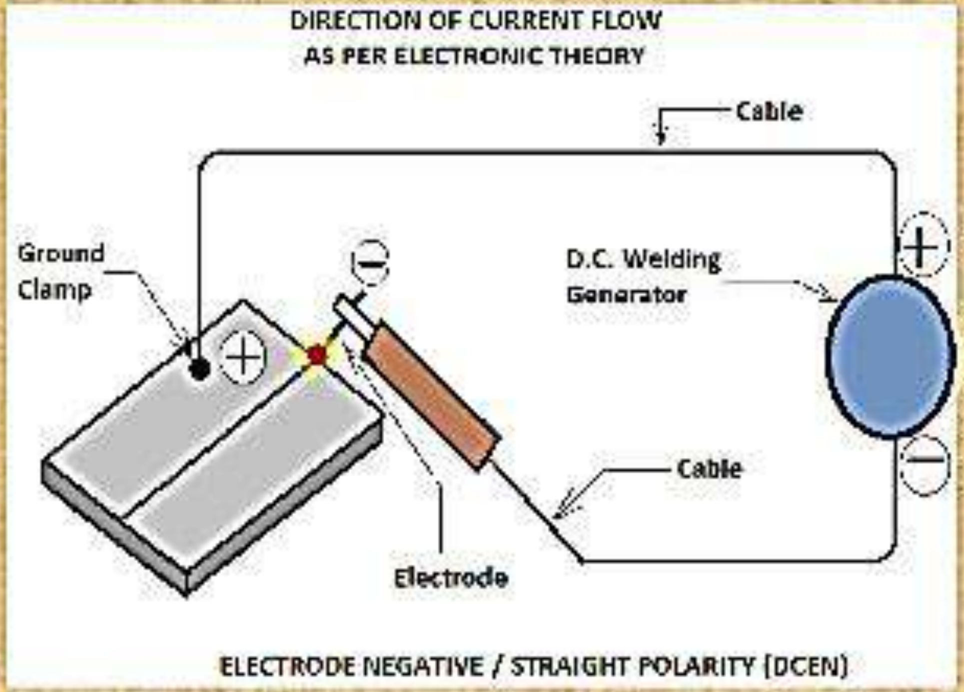
Kinds of polarity

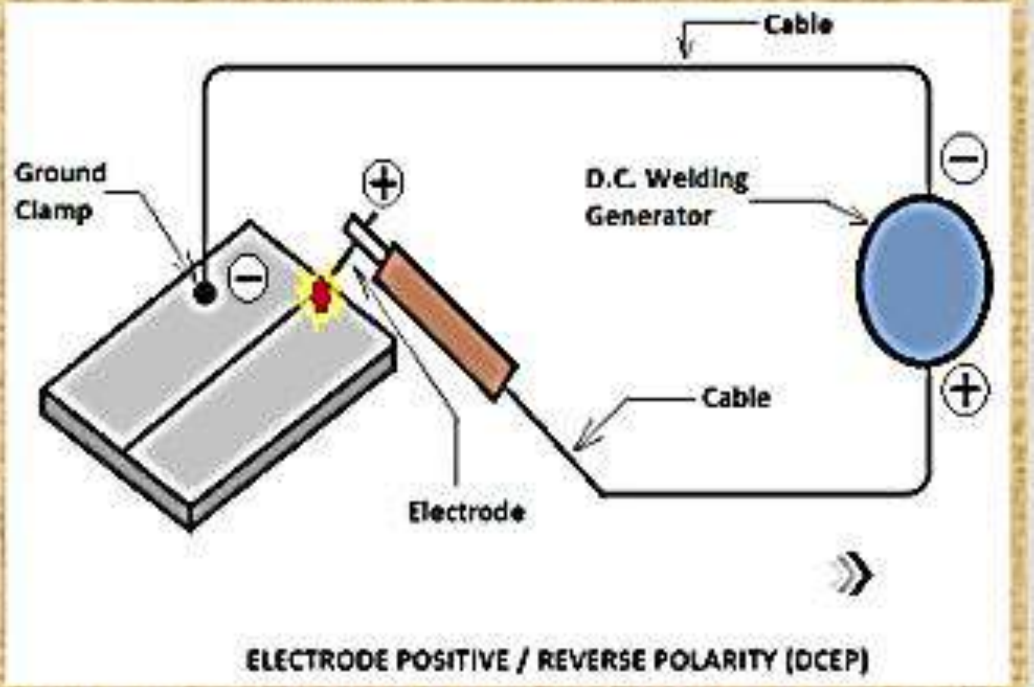
Straight polarity / electrode negative (DCEN):

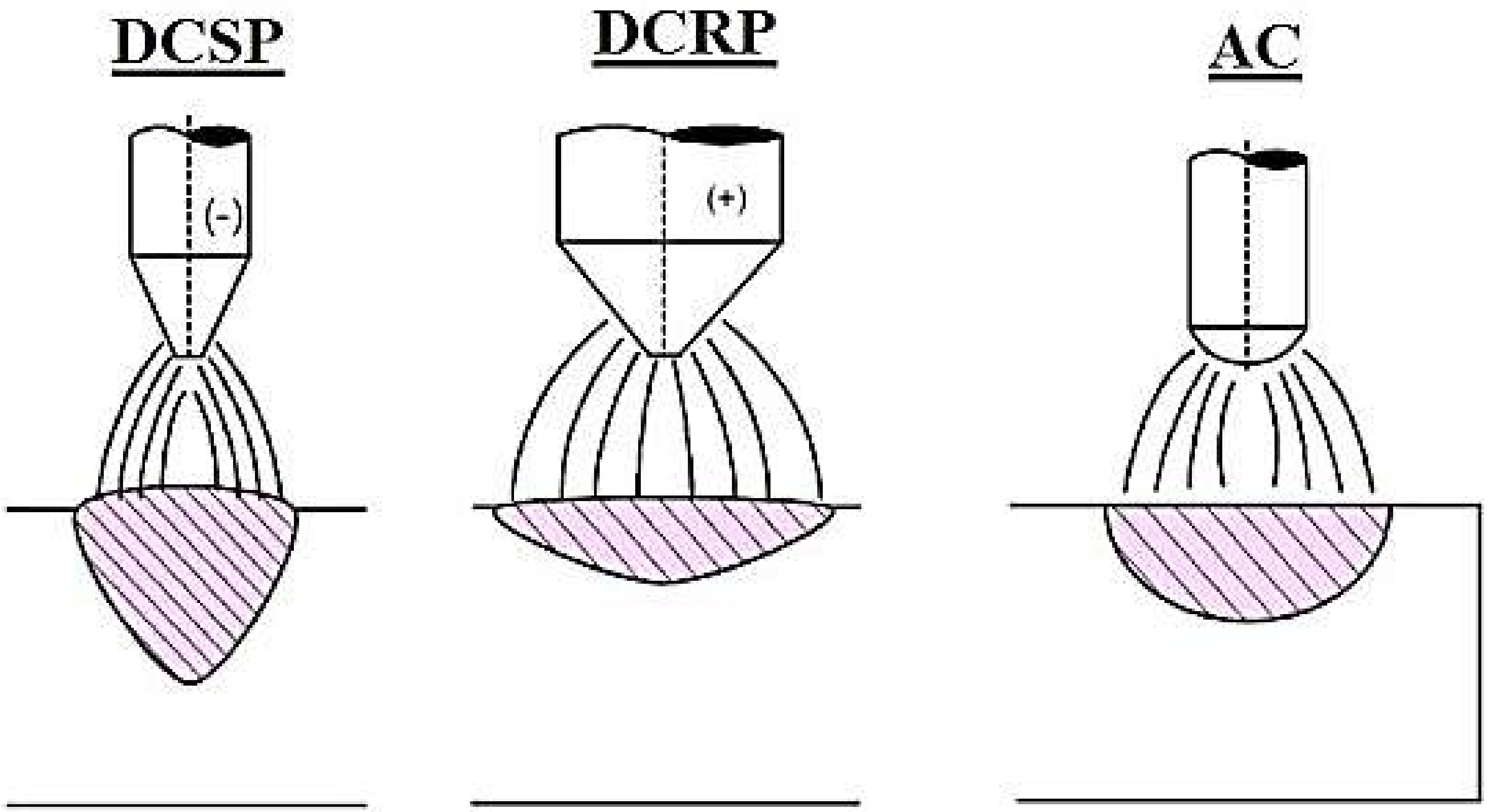
In straight polarity the electrode is connected to the negative and the work to the positive terminal of the power source.

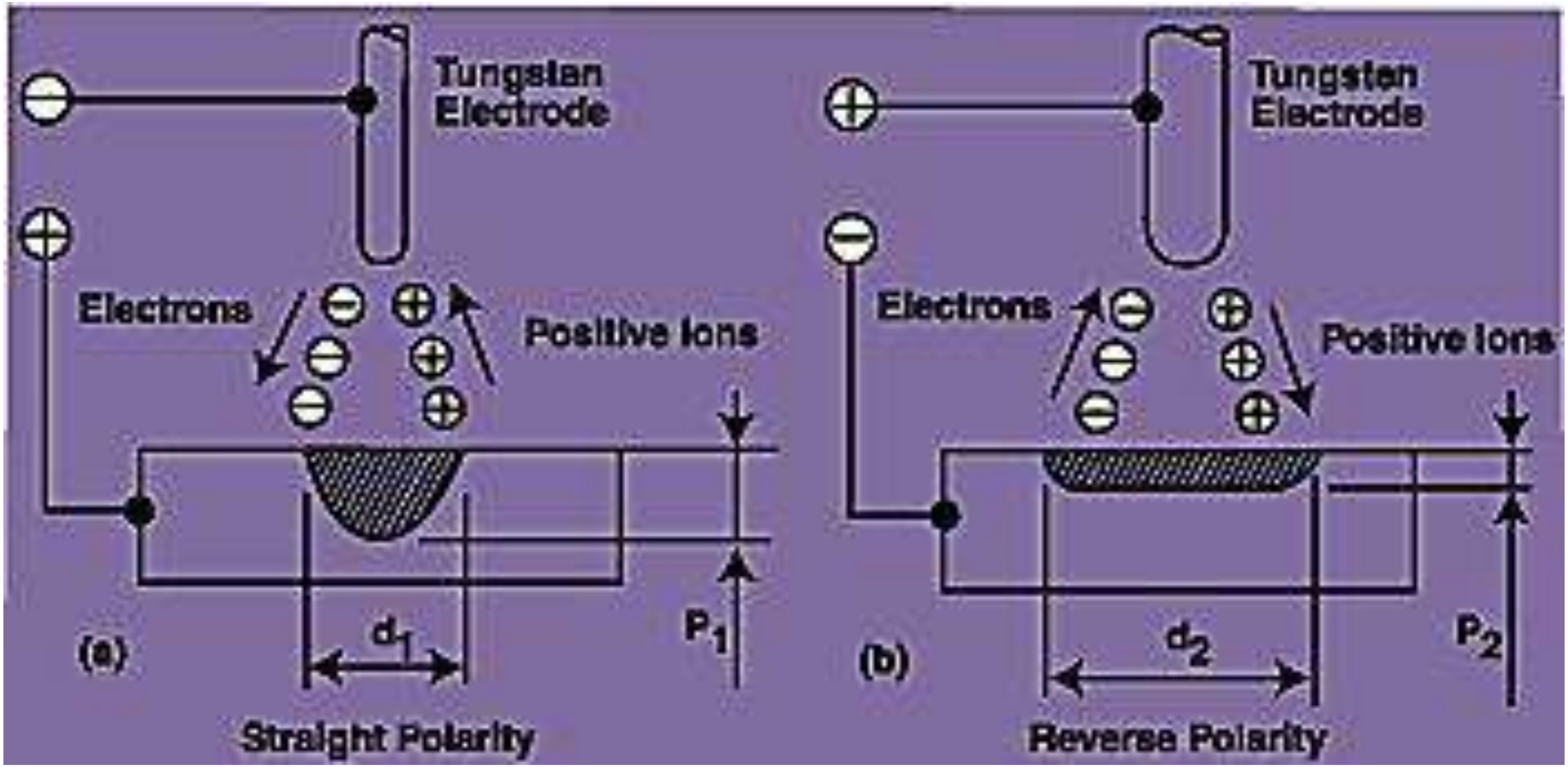
Reverse polarity / electrode positive (DCEP):

In reverse polarity the electrode is connected to the positive and the work to the negative terminal of the power source.






DCSP
(-)
DCRP
(+)
AC



Tungsten Electrode
Electrons
Positive Ions
(a)
d_1
P_1
Straight Polarity
Tungsten Electrode
Electrons
Positive Ions
(b)
d_2
P_2
Reverse Polarity

Application of polarity

Straight polarity is used for:

- Welding with bare light coated and medium coated electrodes.
- Welding the thicker sections in down hand position to obtain more base metal fusion and penetration.

Reverse polarity is used for:

- Welding of non-ferrous metals.
- Welding of cast iron.
- Welding with heavy and super heavy coated electrodes.
- Positional welding.
- Sheet metal welding.

Consumable Electrode

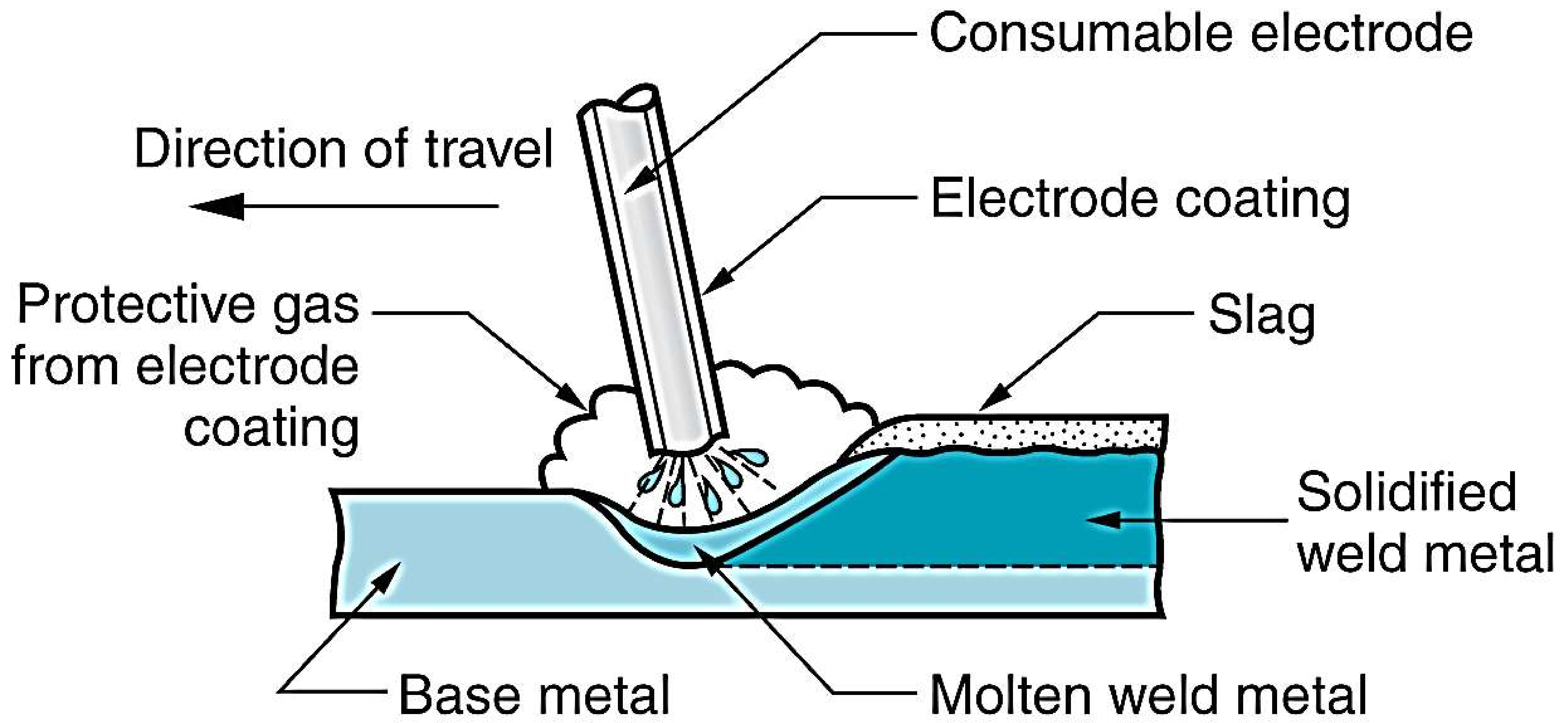
AW Processes

- Shielded Metal Arc Welding (SMAW)
- Gas Metal Arc Welding (GMAW)
- Flux-Cored Arc Welding (FCAW)
- Electrogas Welding
- Submerged Arc Welding (SAW)

Shielded Metal Arc Welding (SMAW)

Uses a consumable electrode consisting of a filler metal rod coated with chemicals that provide flux and shielding

Sometimes called "stick welding"



Consumable electrode
Direction of travel
Electrode coating
Protective gas from electrode coating
Slag
Solidified weld metal
Base metal
Molten weld metal

SMAW

Welding Stick in SMAW

• Composition of filler metal usually close to base metal

• Coating: powdered cellulose mixed with oxides and carbonates, and held together by a silicate binder

• Welding stick is clamped in electrode holder connected to power source

Disadvantages of stick welding:

- Sticks must be periodically changed
- High current levels may melt coating prematurely

SMAW Applications

- Used for steels, stainless steels, cast irons, and certain nonferrous alloys

- Not used or rarely used for aluminum and its alloys, copper alloys, and titanium

Gas Metal Arc Welding (GMAW) or MIG

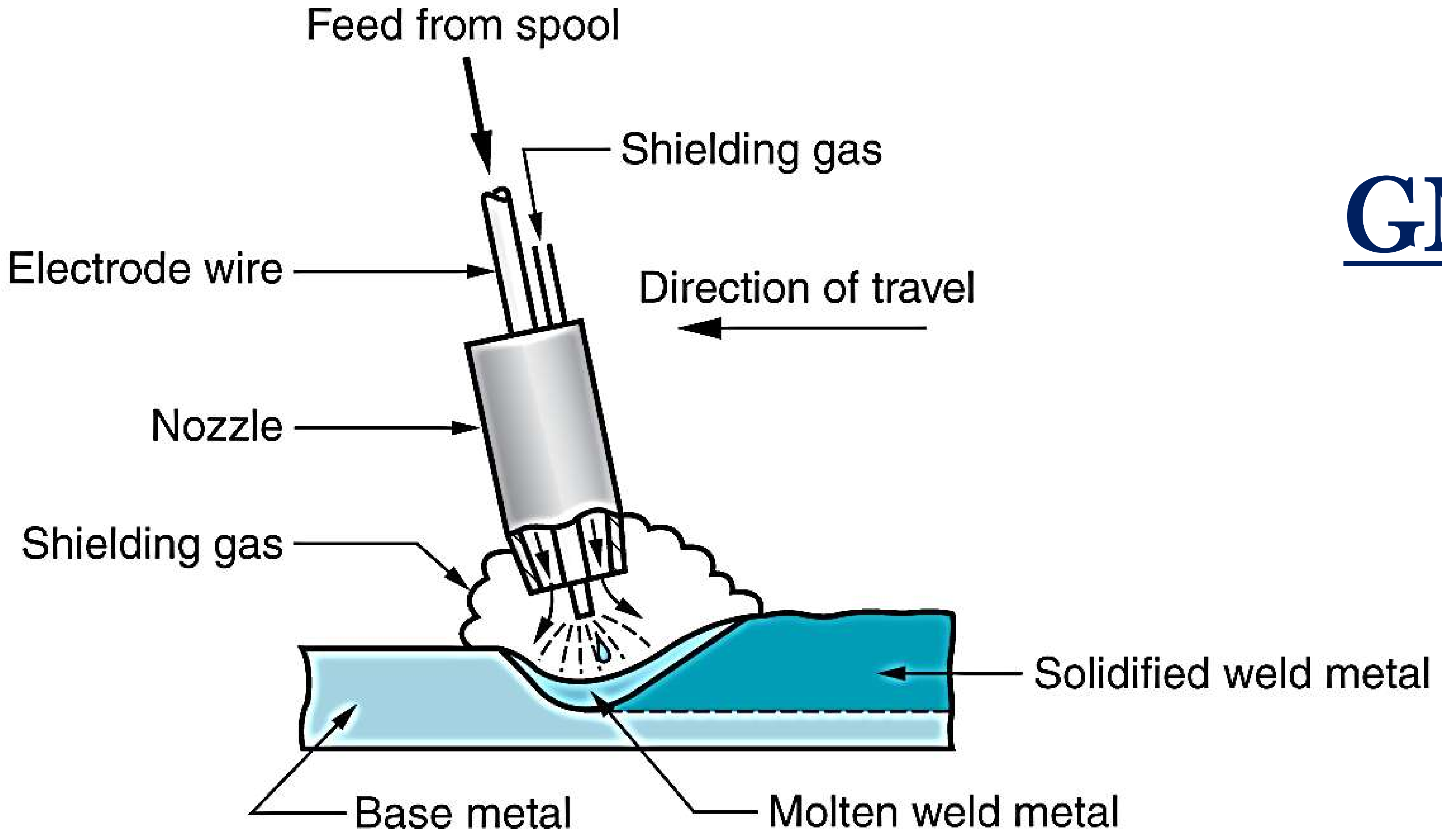
- Uses a consumable bare metal wire as electrode with shielding by flooding arc with a gas

- Wire is fed continuously and automatically from a spool through the welding gun

- Shielding gases include argon and helium for aluminum welding, and CO_2 for steel welding

- Bare electrode wire plus shielding gases eliminate slag on weld bead

GMAW



Feed from spool
Shielding gas
Electrode wire
Direction of travel
Nozzle
Shielding gas
Solidified weld metal
Base metal
Molten weld metal

GMAW Advantages over SMAW

- Better arc time because of continuous wire electrode
- Sticks must be periodically changed in SMAW
- Better use of electrode filler metal than SMAW
- End of stick cannot be used in SMAW
- Higher deposition rates
- Eliminates problem of slag removal
- Can be readily automated

Flux-Cored Arc Welding (FCAW)

- Adaptation of shielded metal arc welding, to overcome limitations of stick electrodes - two versions

  Self-shielded FCAW - core includes compounds that produce shielding gases

  Gas-shielded FCAW - uses externally applied shielding gases

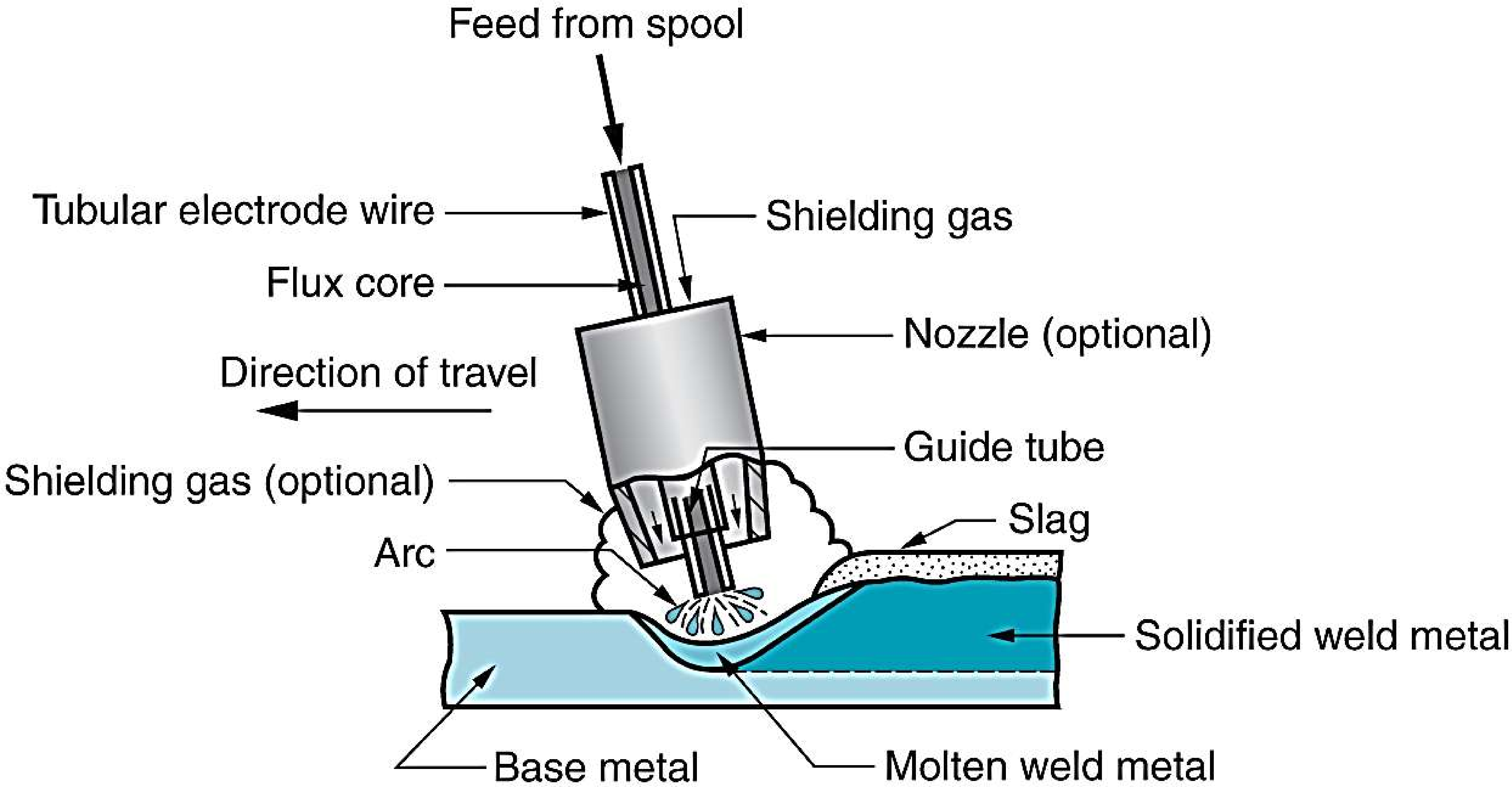
- Electrode is a continuous consumable tubing (in coils) containing flux and other ingredients (e.g., alloying elements) in its core

Flux-Cored Arc Welding

Presence or absence of externally supplied shielding gas distinguishes:

(1) self-shielded - core provides ingredients for shielding,

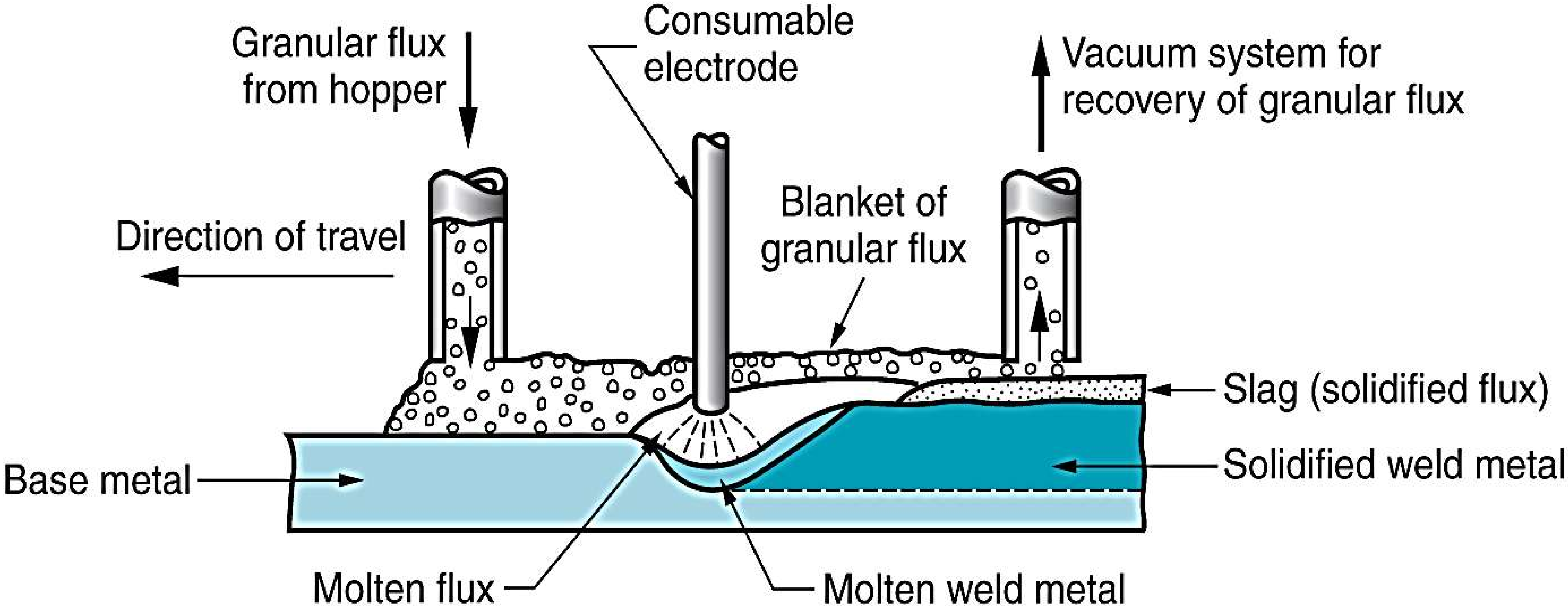
(2) gas-shielded - uses external shielding gases


Feed from spool
Tubular electrode wire
Shielding gas
Flux core
Nozzle (optional)
Direction of travel
Guide tube
Shielding gas (optional)
Slag
Arc
Solidified weld metal
Base metal
Molten weld metal

FCAW

Submerged Arc Welding (SAW)

- Uses a continuous, consumable bare wire electrode, with arc shielding by a cover of granular flux
- Electrode wire is fed automatically from a coil
- Flux introduced into joint slightly ahead of arc by gravity from a hopper
- Completely submerges operation, preventing sparks, spatter, and radiation


Granular flux
from hopper
Consumable
electrode
Vacuum system for
recovery of granular flux
Direction of travel
Blanket of
granular flux
Slag (solidified flux)
Base metal
Solidified weld metal
Molten flux
Molten weld metal

SAW

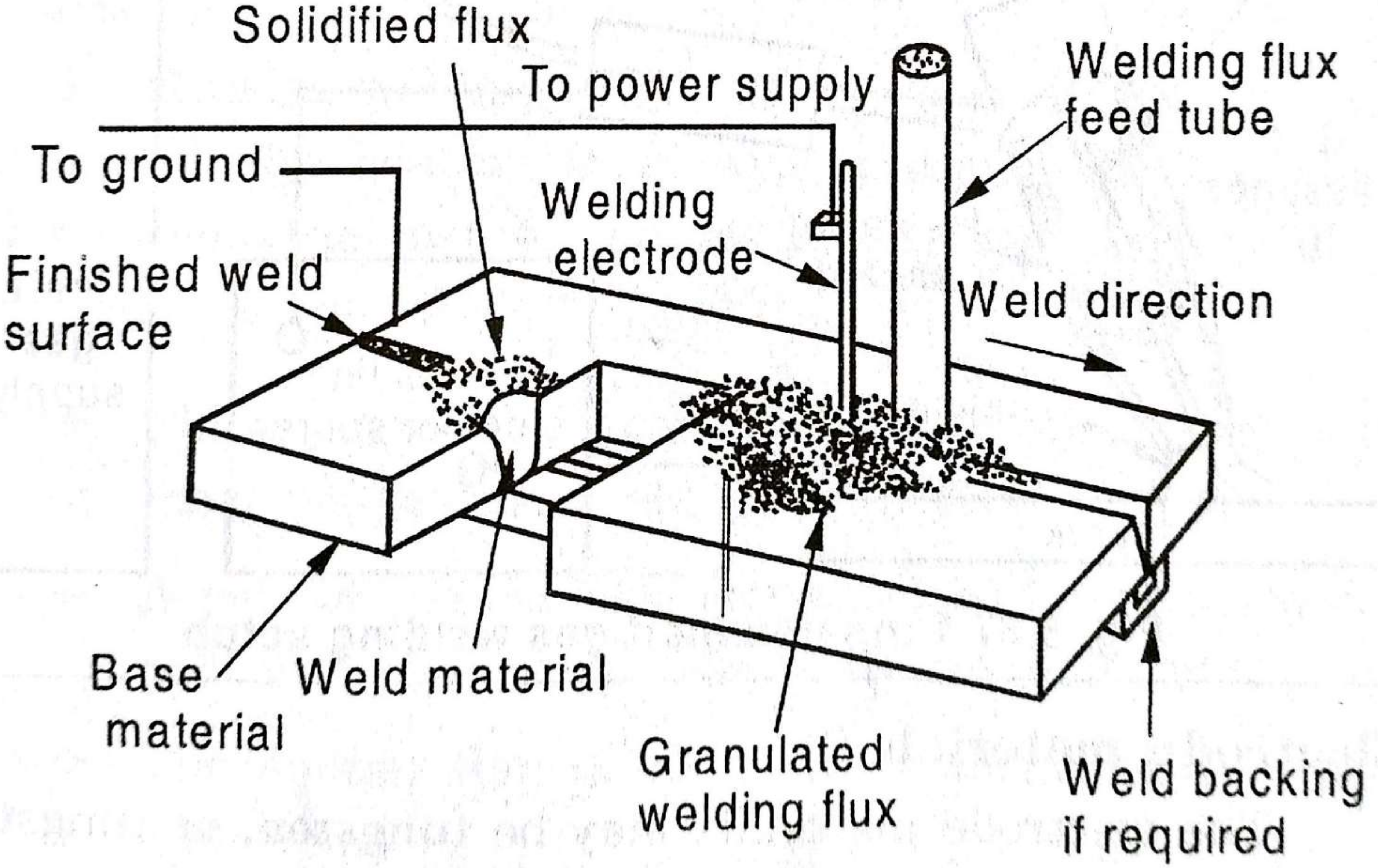
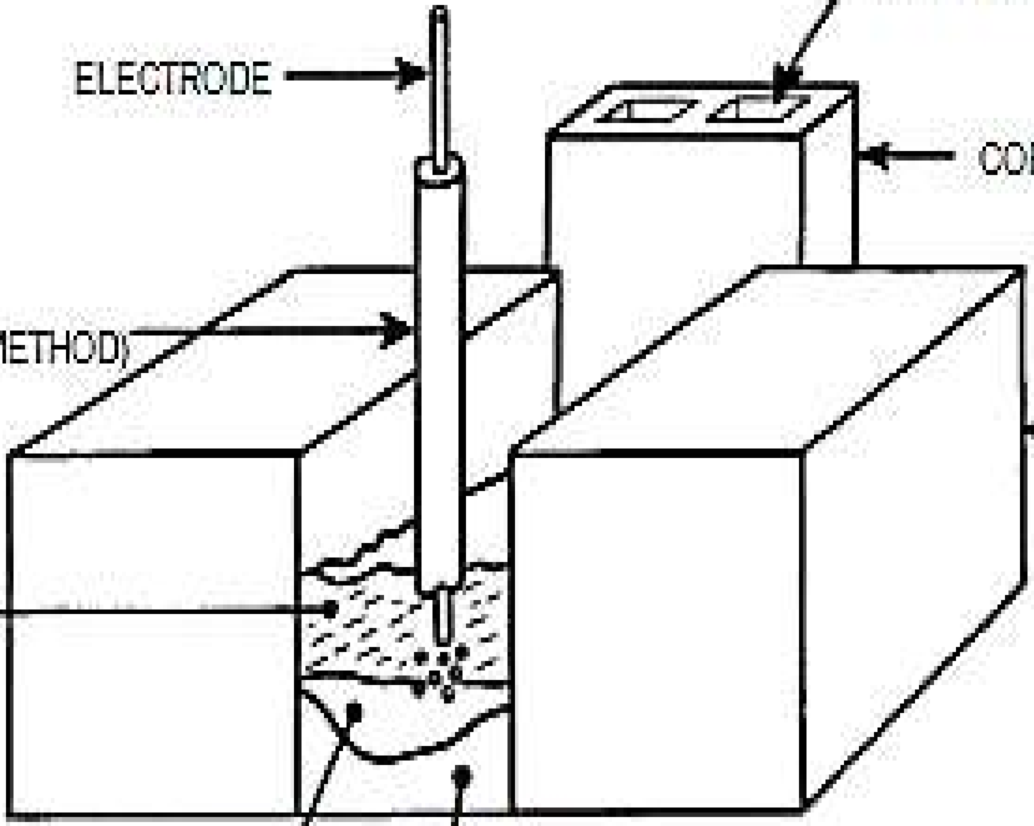


Fig. 5.66 Schematic submerged arc welding process

SAW Applications

- Steel fabrication of structural shapes (e.g., I-beams)
- Seams for large diameter pipes, tanks, and pressure vessels
- Welded components for heavy machinery
- Most steels (except hi C steel)
- Not good for nonferrous metals

ELECTROSLAG WELDING



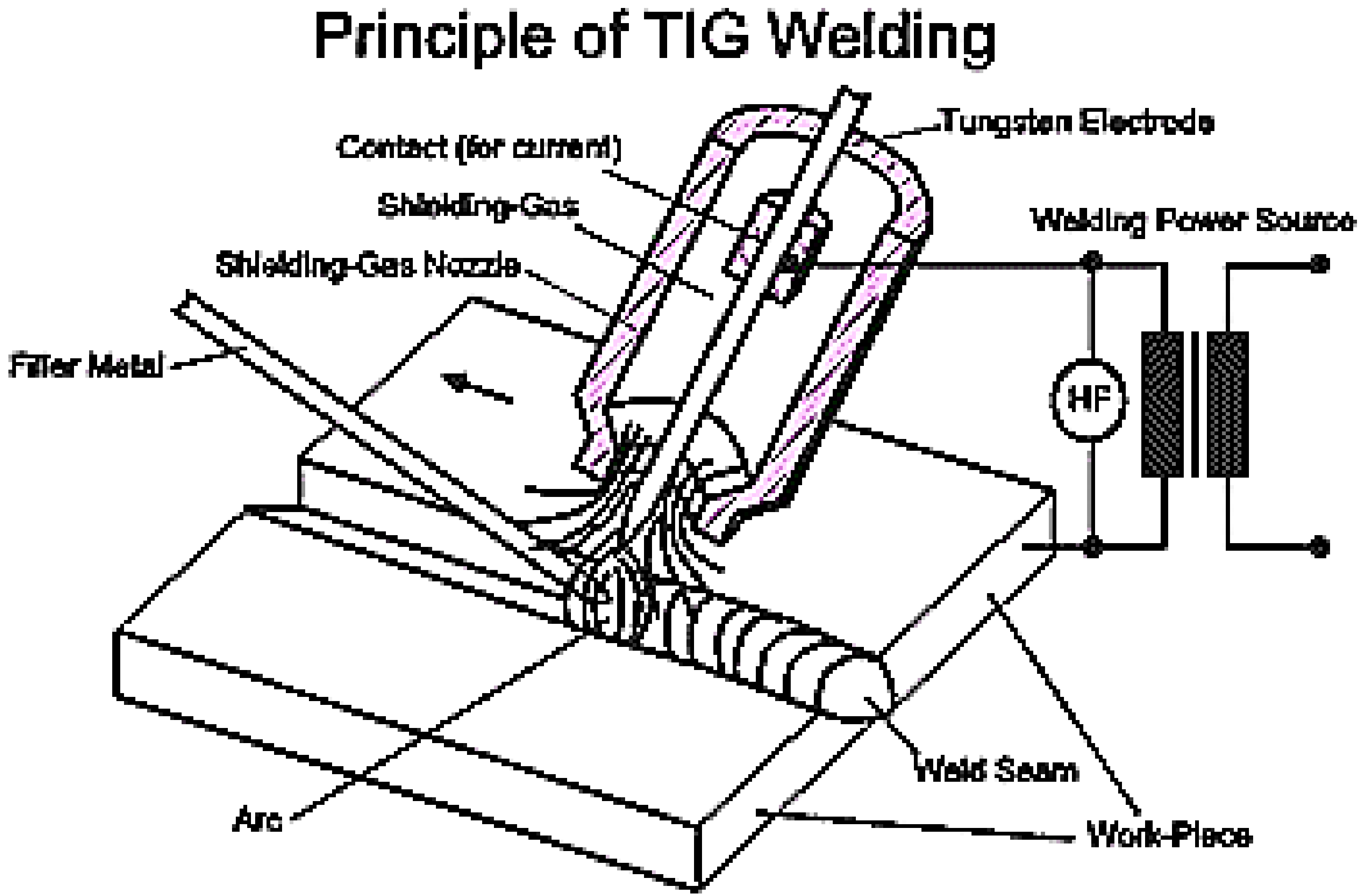
ELECTROSLAG WELDING

This initial charge heats a layer of loose flux that becomes molten and extinguishes the arc.

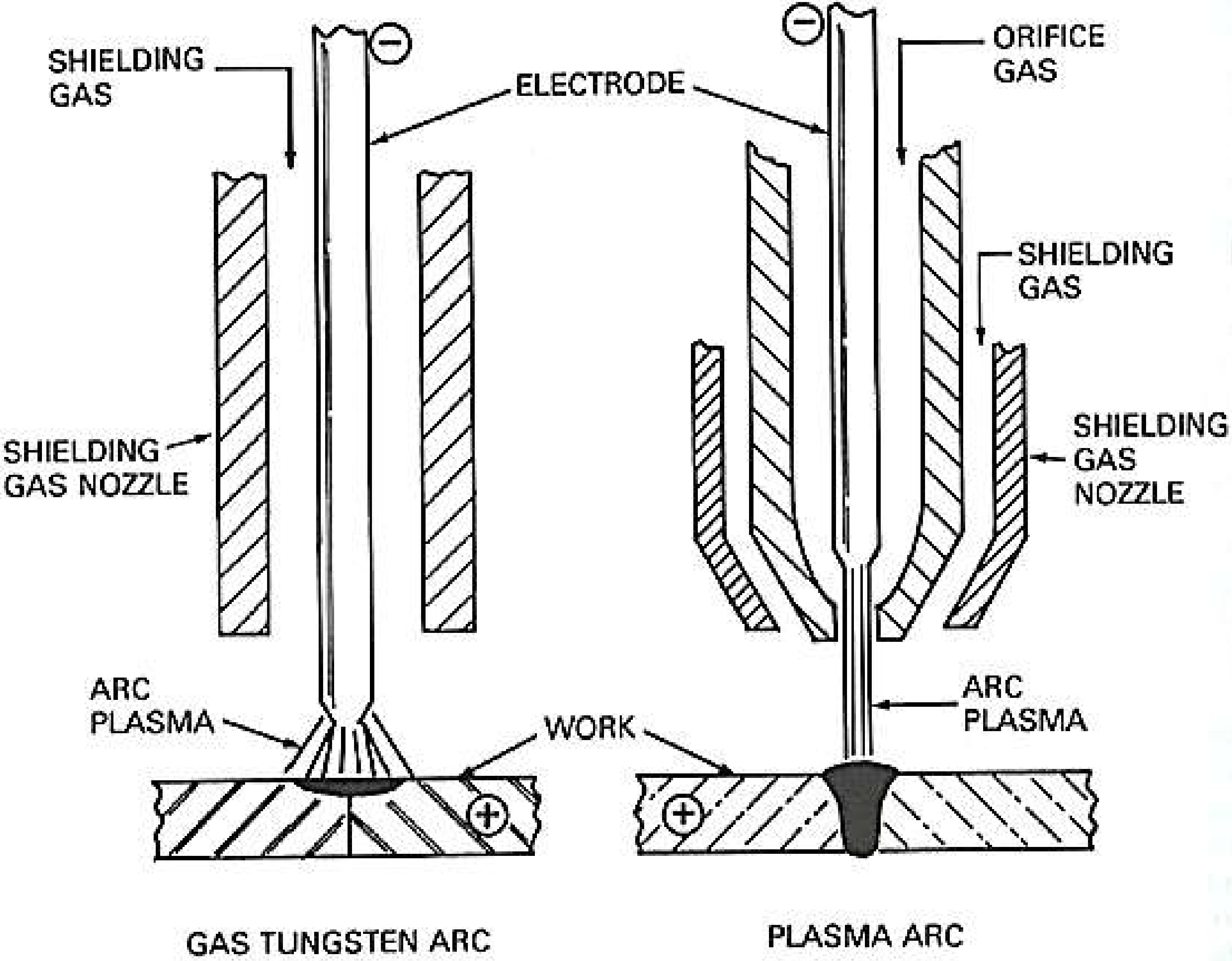
ARC WELDING – NONCONSUMABLE ELECTRODES

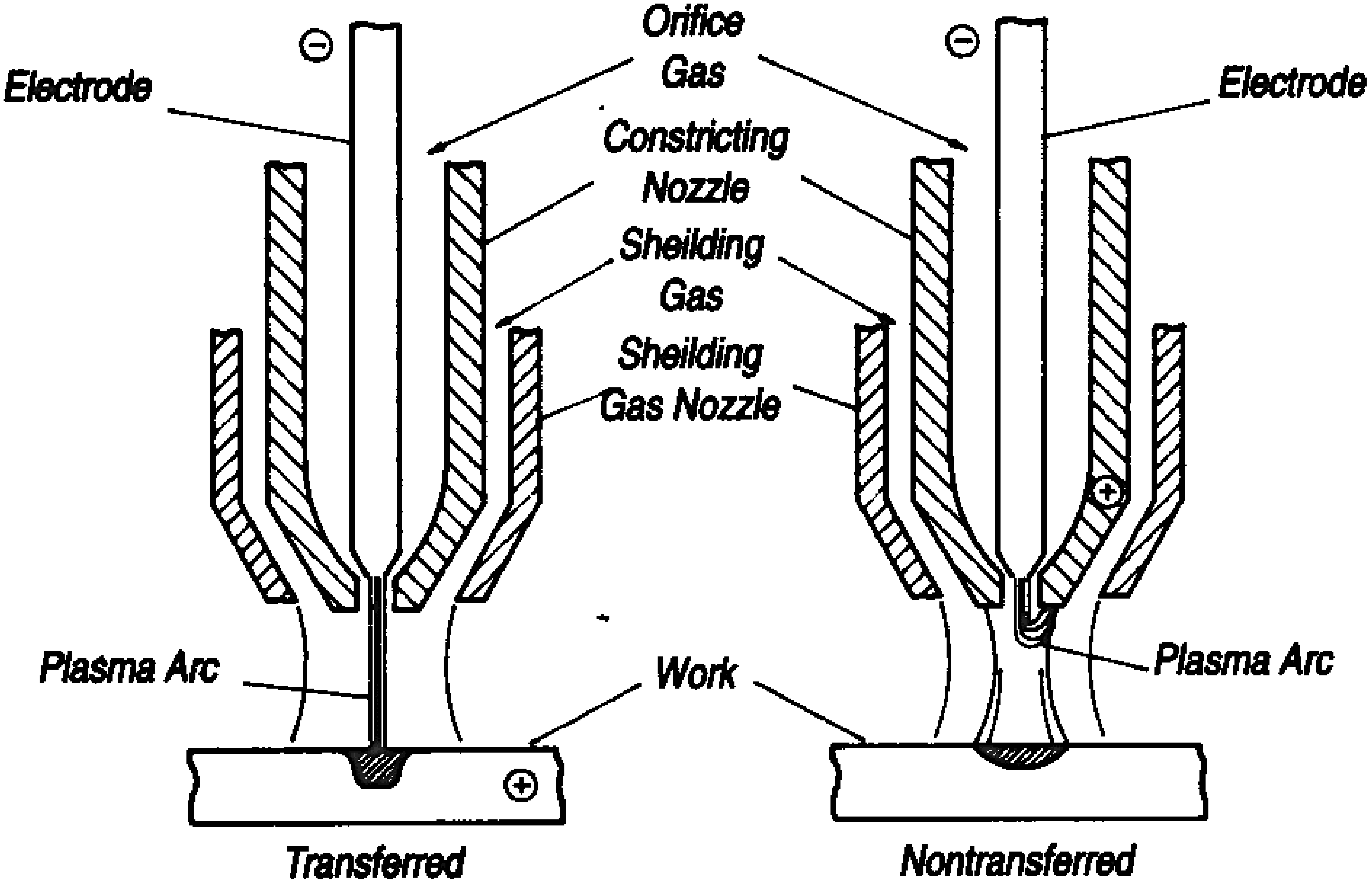
- GTAW (Gas tungsten arc welding) or TIG welding
- Plasma arc welding

TIG WELDING or GTAW



Typical flow rate of shielding inert gas may vary from 5-50 liters/min.


SHIELDING GAS
ELECTRODE
SHIELDING GAS NOZZLE
ARC PLASMA
WORK
GAS TUNGSTEN ARC
ORIFICE GAS
SHIELDING GAS
SHIELDING GAS NOZZLE
ARC PLASMA
PLASMA ARC


Orifice
Gas
Constricting
Nozzle
Sheilding
Gas
Sheilding
Gas Nozzle
Electrode
Electrode
Plasma Arc
Plasma Arc
Work
Transferred
Nontransferred

Transferred plasma arc welding process	Non-transferred plasma arc welding process
Arc is established between electrode and workpiece	Arc is established between electrode and nozzle.
The work piece is part of the electrical circuit and heat is obtained from the anode spot and the plasma jet. Therefore, higher amount of energy is transferred to work. This is useful for welding.	The work piece is not part of the electrical circuit and heat is obtained from the plasma jet. Therefore, less energy is transferred to work. This is useful in cutting.
Higher penetration is obtained, so thicker sheets can be welded.	Less penetration is obtained, so thin sheets can be welded.
Higher process efficiency.	Less process efficiency.

Merits and Demerits of Arc Welding

Advantages	Disadvantages
• Simple welding equipment	• Not clean enough for reactive metals such as aluminium and titanium.
• Portable	
• Inexpensive - Lowest cost joining method.	• The deposition rate is limited because the electrode covering tends to overtheat and fall off.
• Used for maintenance, repair, and field construction	
• Most efficient way to join metals	• The electrode length is ~ 35 mm and requires electrode changing → lower the overall production rate.
• Affords lighter weight through better utilization of materials.	
• Joins all commercial metals.	• Manually applied, Therefore high labor cost.
• Provides design flexibility.	• Need high energy, hence causing danger
	• Not convenient for disassembly.
	• Defects are hard to detect at joints.

PROPERTIES OF ELECTRODES, SHIELDING GAS AND FLUX

- ***Consumable electrodes*** *materials are selected such that finished weld metal should have* ***similar mechanical properties*** *that of base metal with no defects,*

  Consumable Electrodes *contains* ***de-oxidising metals (Si, Mn, Ti, Al) and de-nitriding metals (zirconium)*** *in small percentages to prevent entrapment of oxygen and nitrogen in the weld,* ***reducing the porosity*** *and giving continuous weld.*

- ***Shielding gas*** *is necessary to* ***protect weld area*** *from atmospheric gases, thereby reducing porosity and cracking.*

  EG. argon, helium, carbon dioxide etc

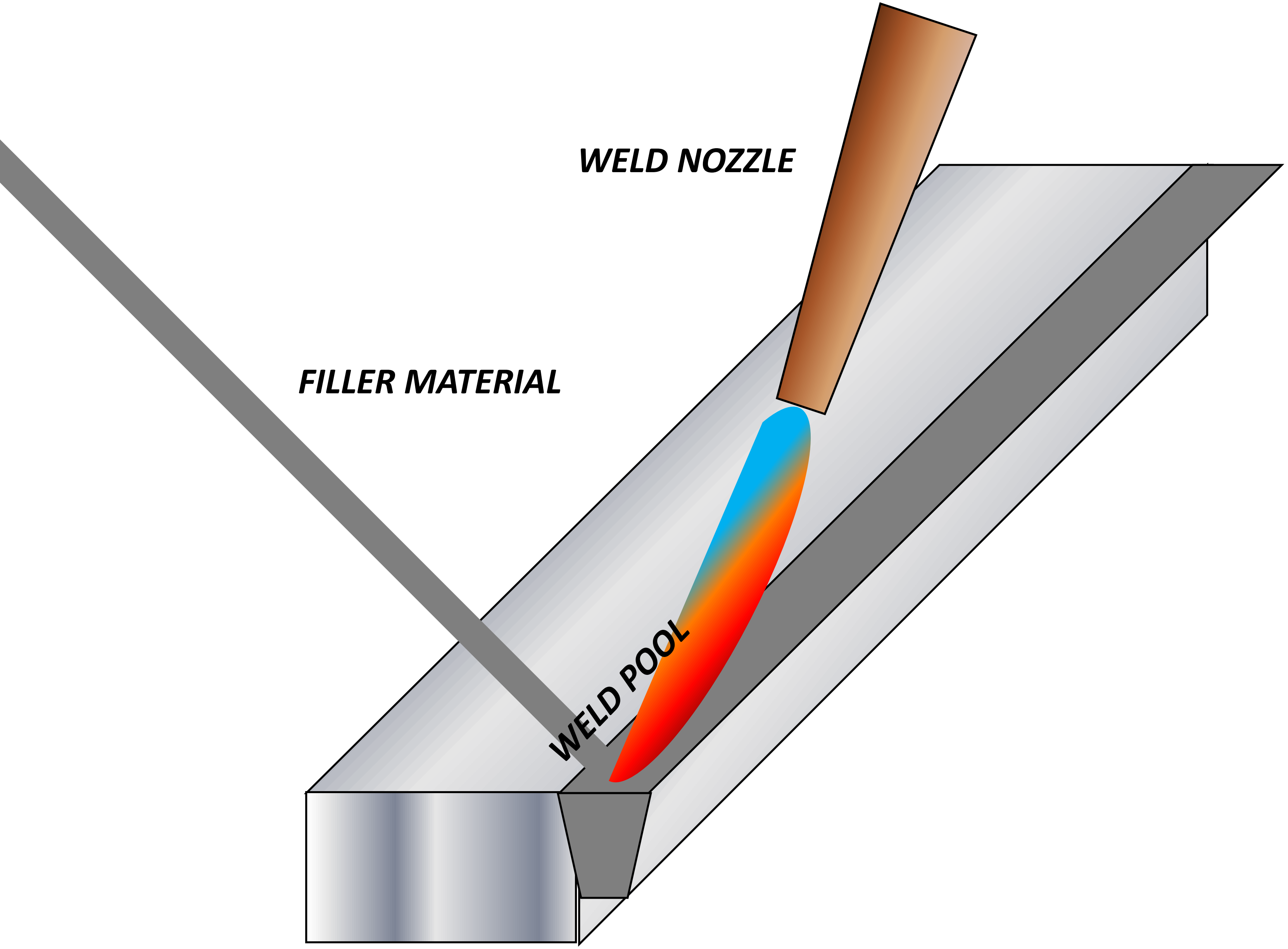
- ***Flux*** *when melted by the arc, mixes with the impurities in the weld pool and* ***forms slag and covers the weld pool from contamination.***

  E.G. lime, silica, manganese dioxide, calcium flouride etc

  flux is either ***coated on the electrode surface****, or* ***inside the electrode****, or* ***provided additionally(non-consumable electrodes)****.*

GAS WELDING

OXY – ACETELYNE GAS WELDING



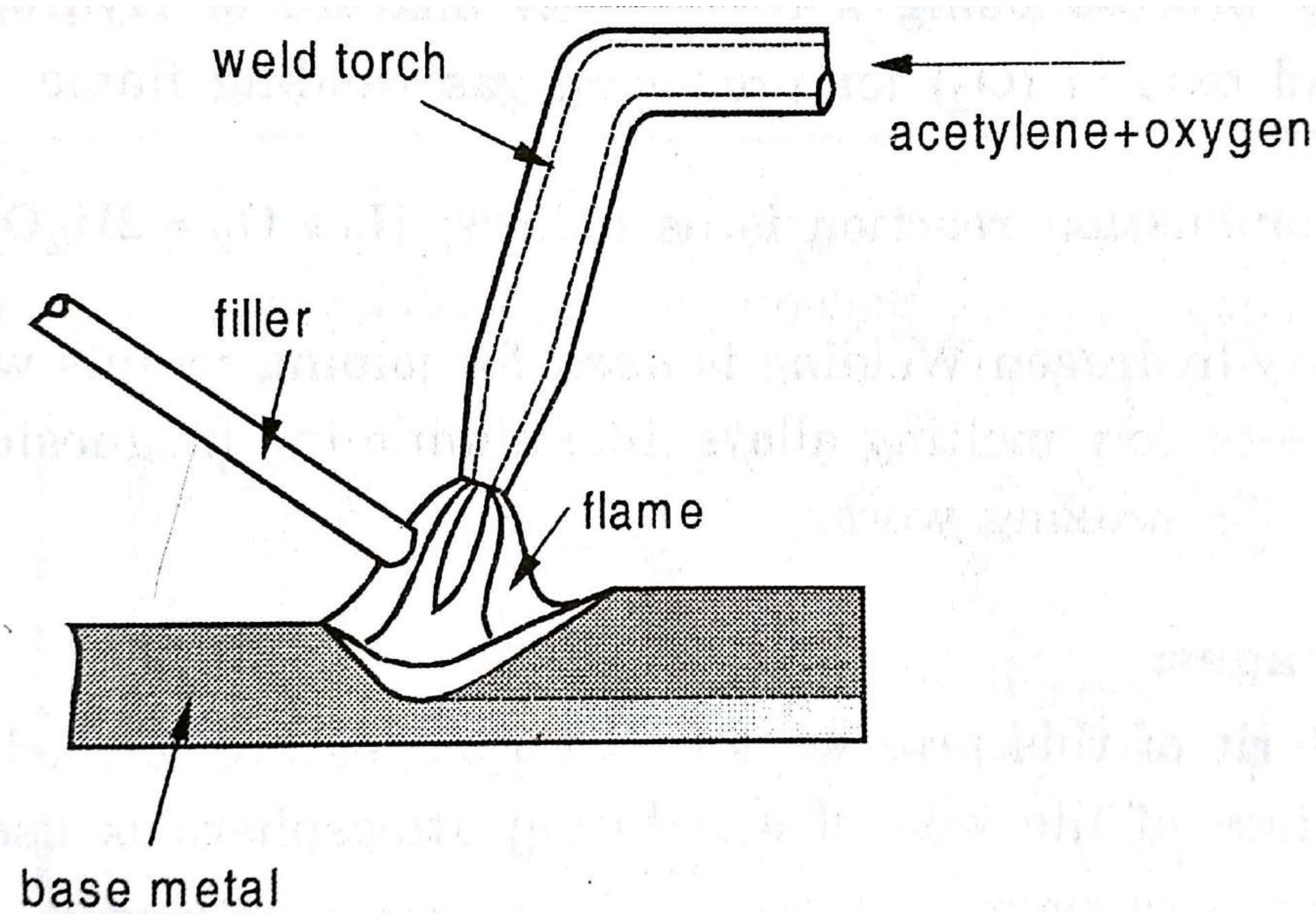
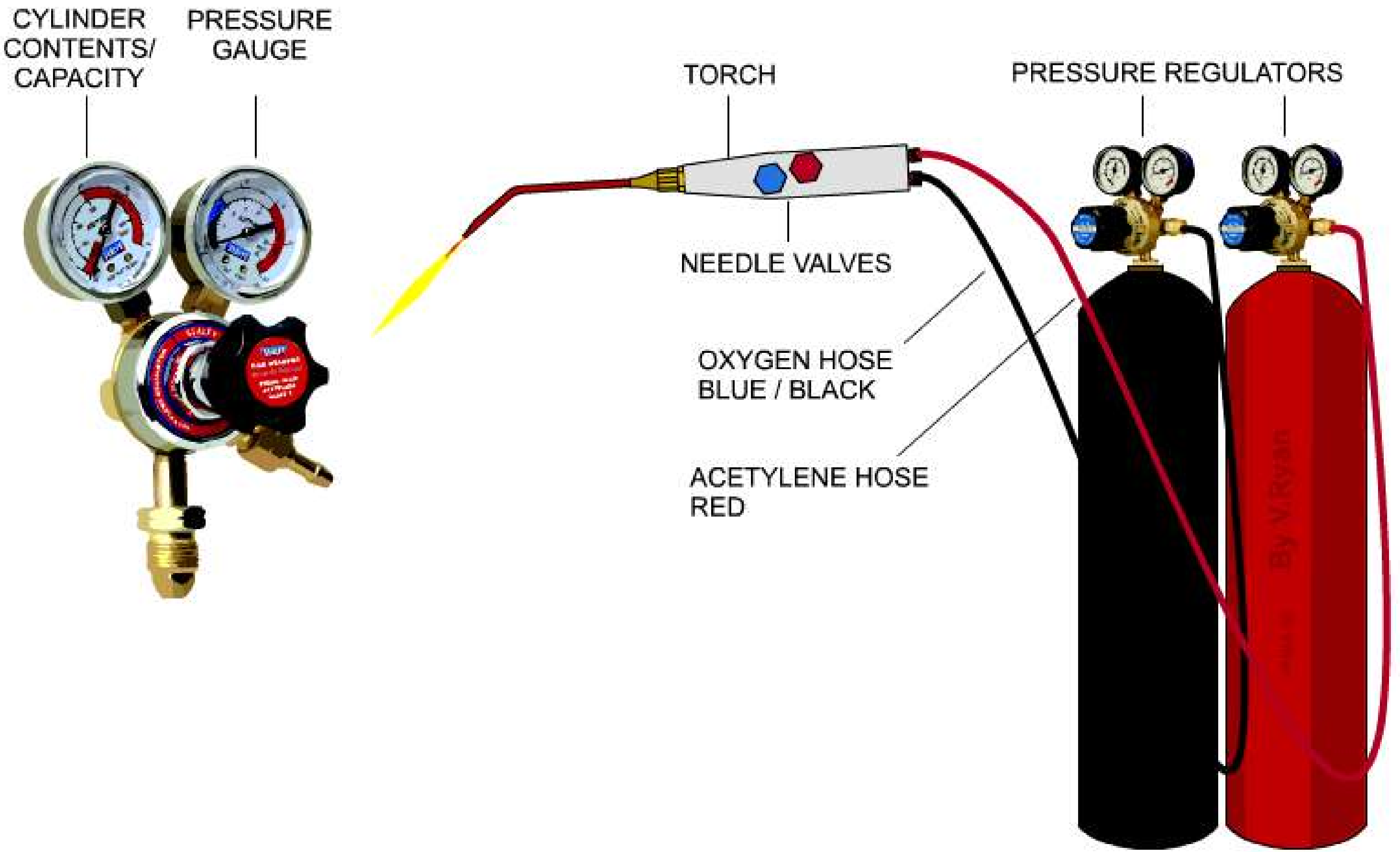


Fig. 5.62. Typical Oxy- Acetylene gas welding process.

OXY-ACETELYNE GAS WELDING SETUP



- Gas welding is a fusion welding process.
- Acetylene burned in oxygen is used as source of heat. This heat is used to fuse the metal joints.

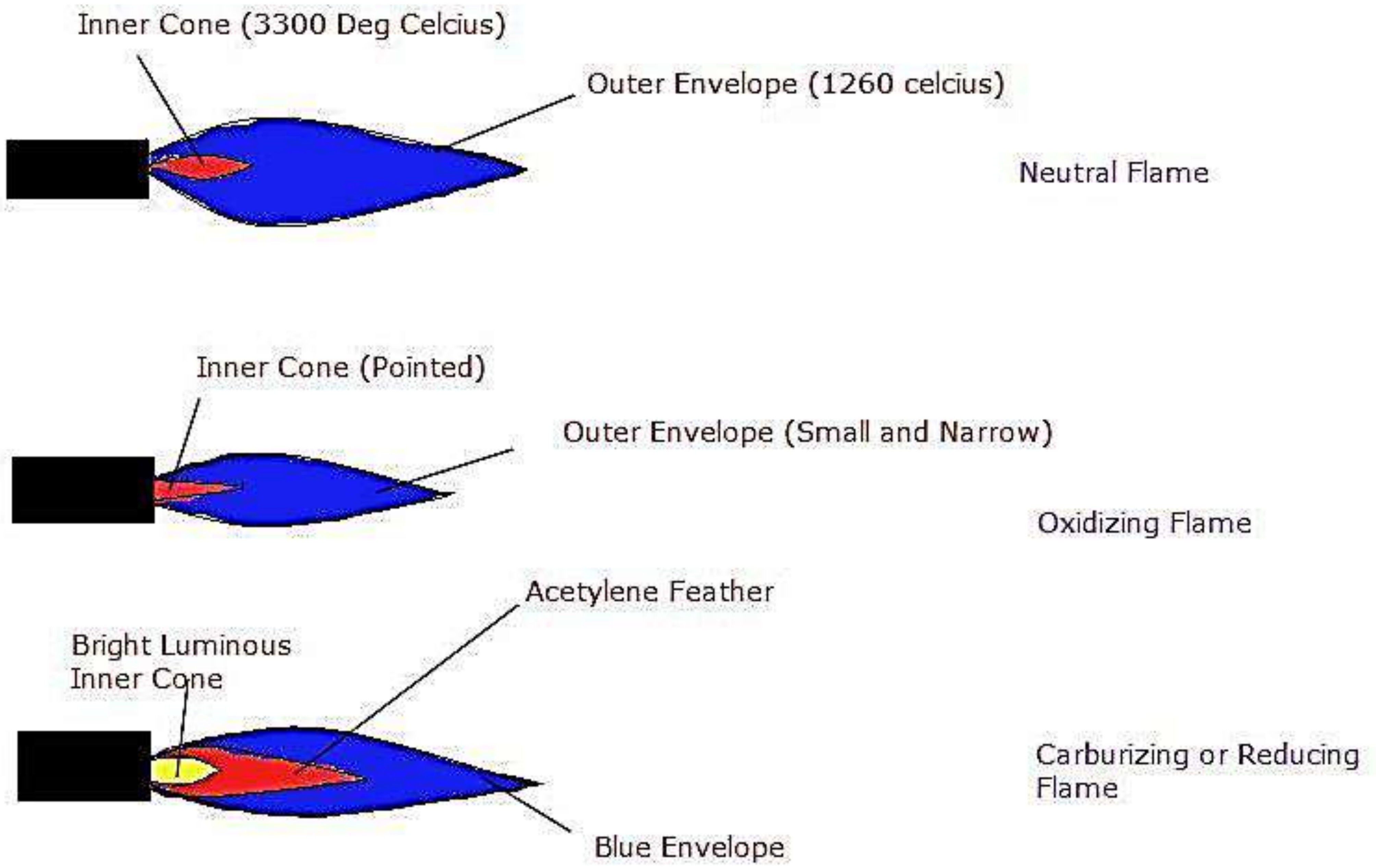
ADVANTAGES

1. Simple
2. Portable
3. Easy maintenance

DISADVANTAGES

1. Very low welding speed,
2. Large amount of heat is required, **some amount of heat is wasted, since heat is distributed over a large area.**
3. large **heat affected zones**.
4. Should not be used with reactive metals like **Titanium and Zirconium.**

TYPES OF FLAMES



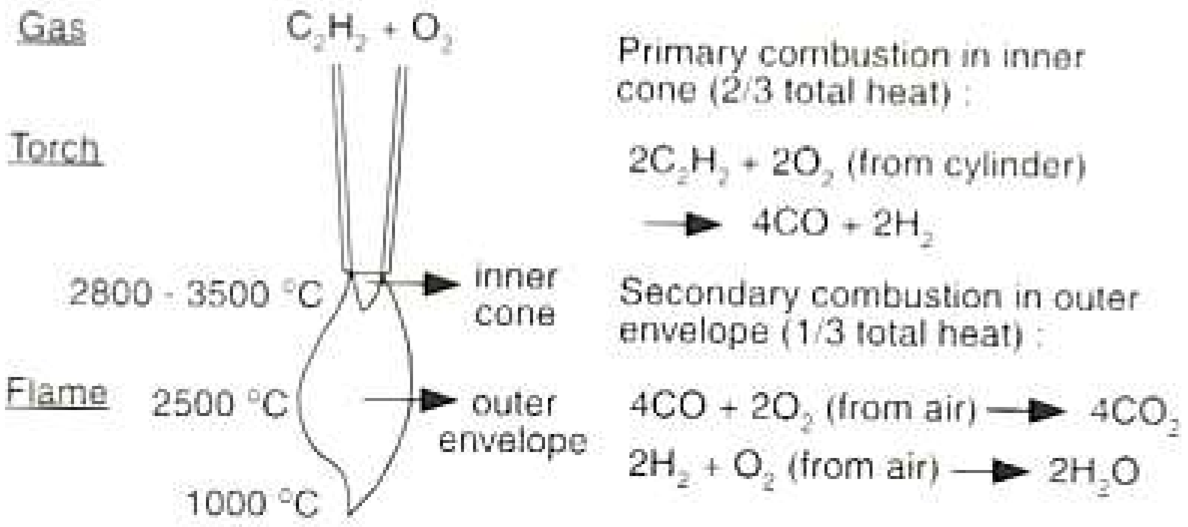
Gas Welding

- **Oxy-acetylene Welding:**

$$CaC_2 + 2H_2O = Ca\,(OH)_2 + C_2H_2$$

$$C_2H_2 + 2.5O_2 = 2CO_2 + H_2O_{(vapour)} + 306.800\ \text{cal/mol}$$

Chemical reactions and temperature distribution in a neutral oxyacetylene



The secondary combustion is also called the protection envelope since CO and H_2 here consume the O_2 entering from surrounding air, thereby protecting the weld from oxidation.

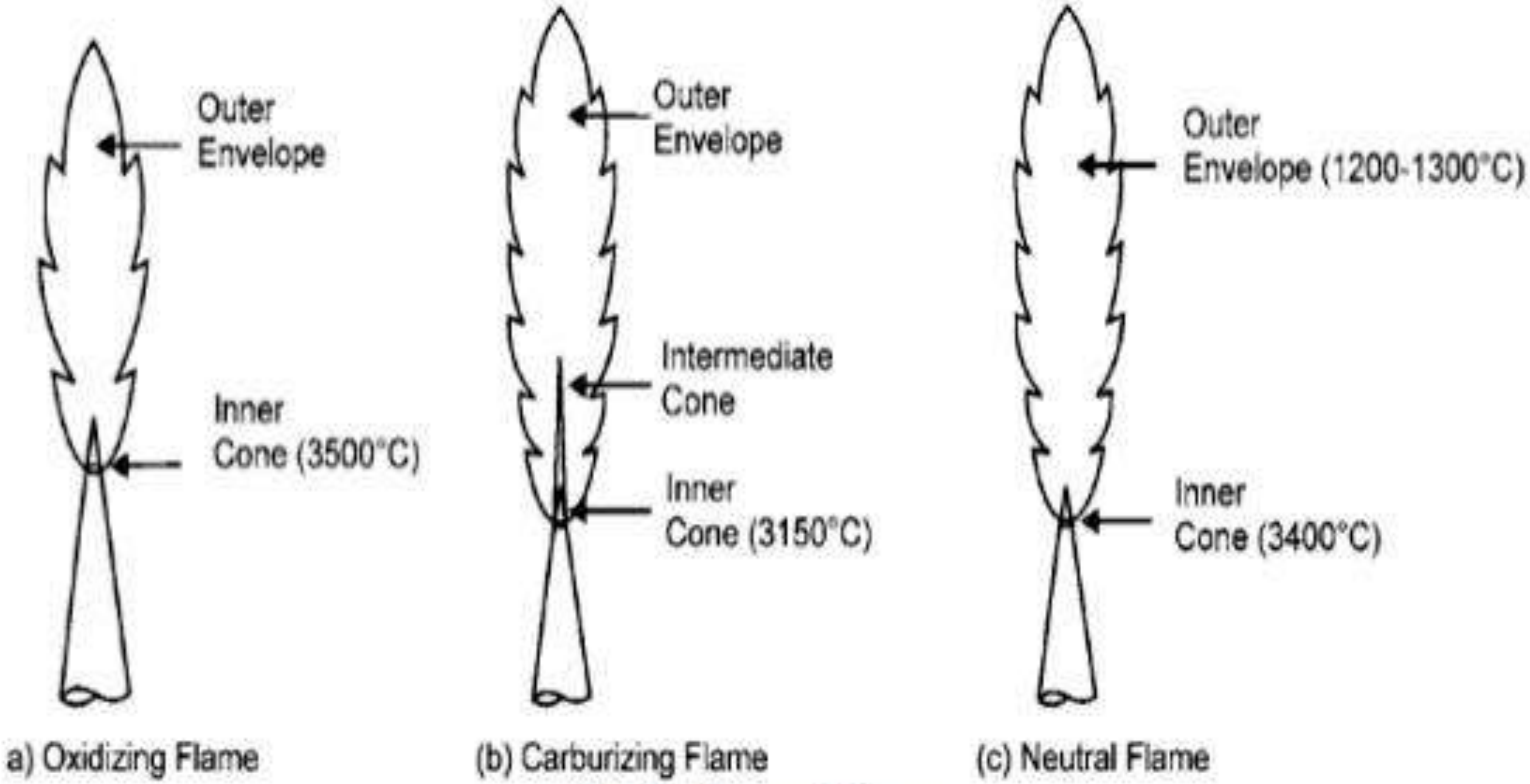
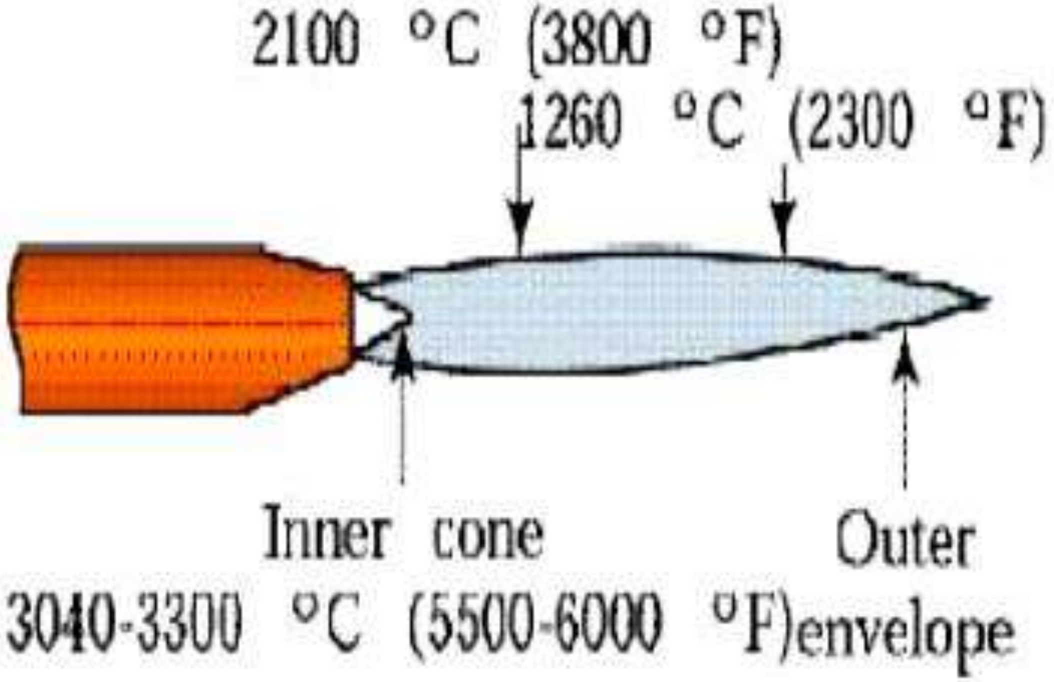
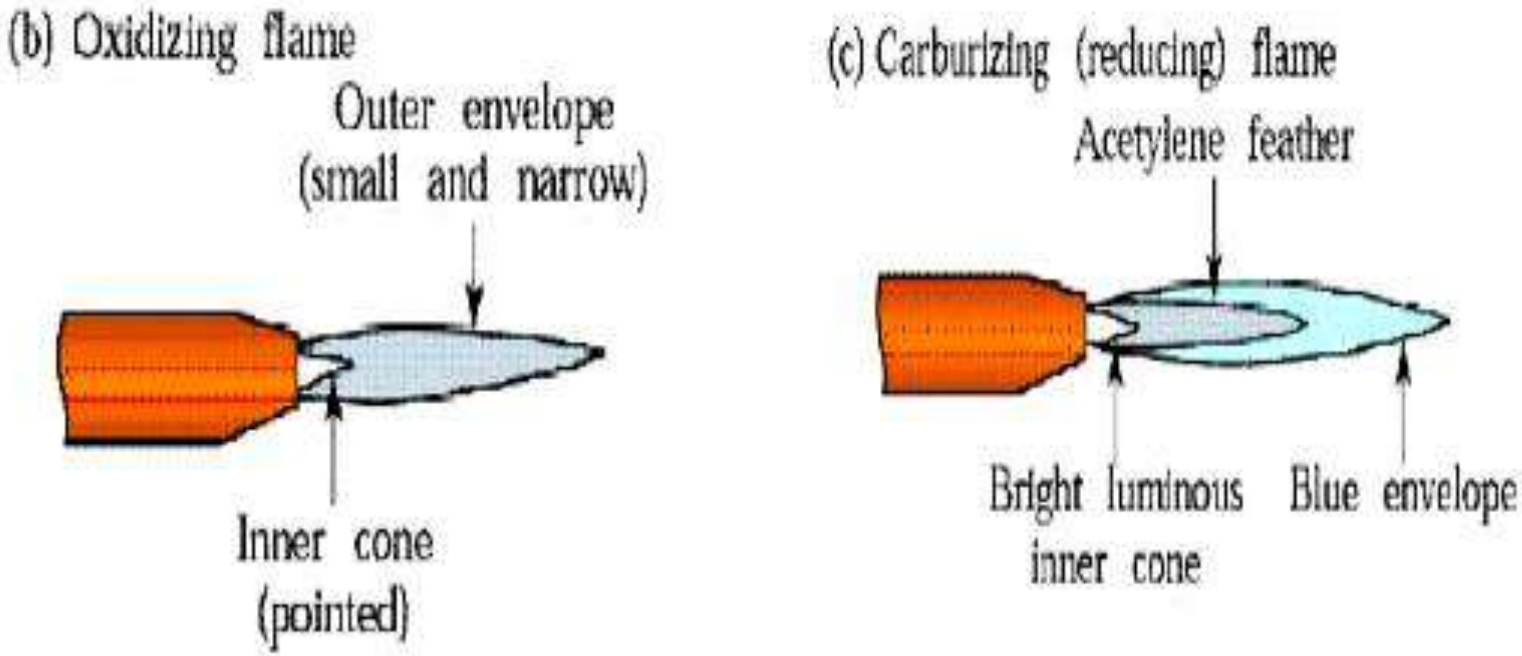


Fig. 7.3: Types of Flames

(a) Neutral flame



Three basic types of oxyacetylene flames used in oxyfuel-gas welding and cutting operations: (a) neutral flame; (b) oxidizing flame; (c) carburizing, or reducing flame.



Three basic types of oxyacetylene flames used in oxyfuel-gas welding and cutting operations:
(a) neutral flame; (b) oxidizing flame; (c) carburizing, or reducing flame.

Types of Gas Welding

- 1. Leftward Welding
- 2. Rightward Welding

Gas welding two types

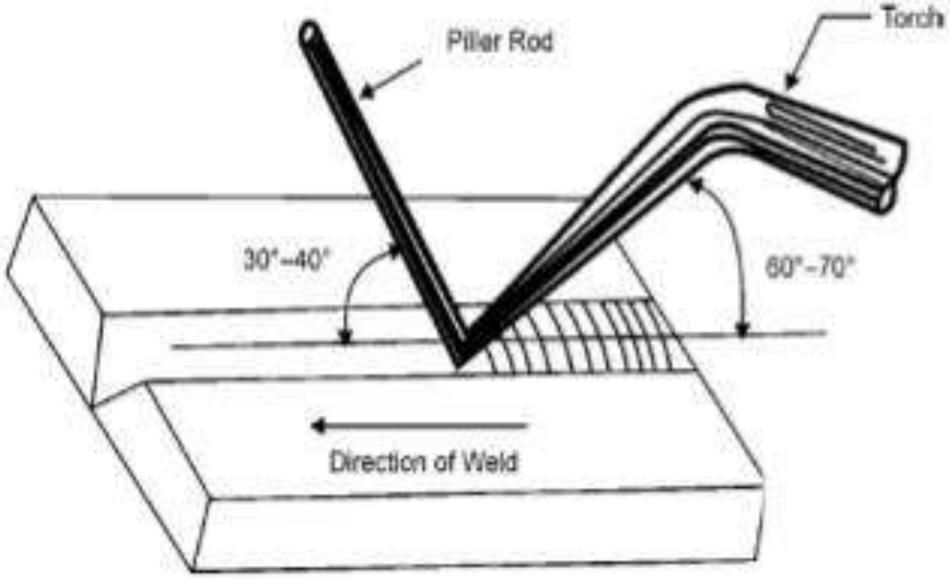


Fig. 7.4: Leftward Welding

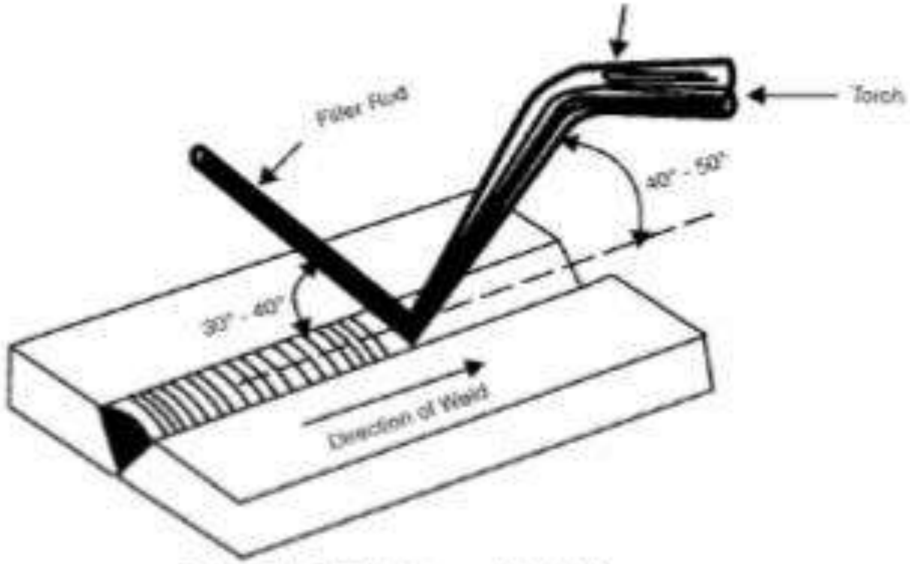


Fig. 7.5: Rightward Welding

GAS WELDING EQUIPMENTS

1. Gas Cylinders

    Pressure

        Oxygen – 125 kg/cm2

        Acetylene – 16 kg/cm2

2. Regulators

        Working pressure of oxygen 1 kg/cm2

        Working pressure of acetylene 0.15 kg/cm2

        Working pressure varies depending upon the thickness of the work pieces welded.

3. Pressure Gauges
4. Hoses
5. Welding torch
6. Check valve
7. Non return valve

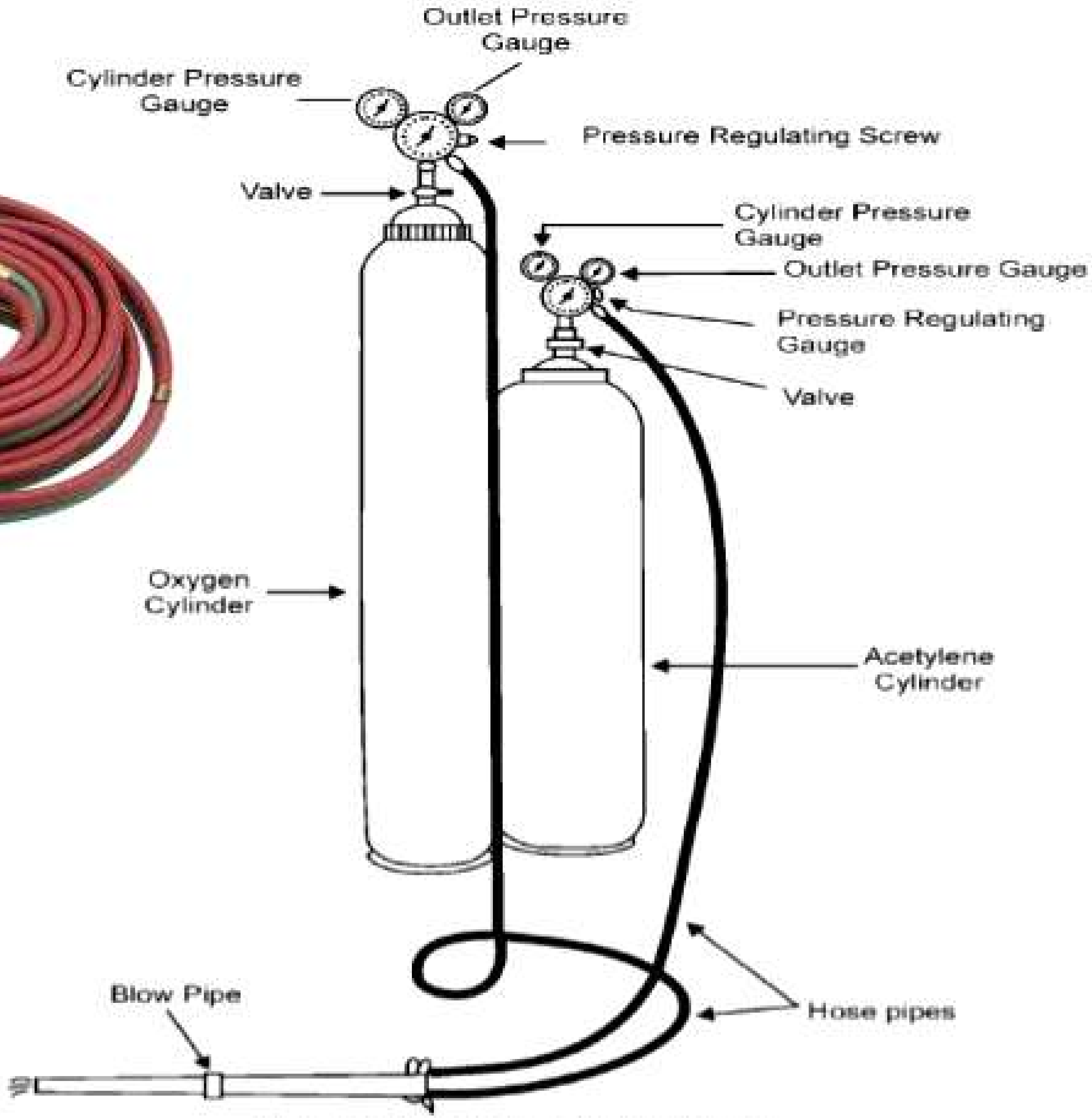


Fig. 7.2: Apparatus for Gas Welding

Gas welding Apparatus

1. Oxygen cylinder
2. Acetylene cylinder
3. Pressure gauges
4. Valves
5. Hose pipes
6. Torch
7. Welding tip
8. Pressure regulators
9. Lighter
10. Goggles

Gas welding torch

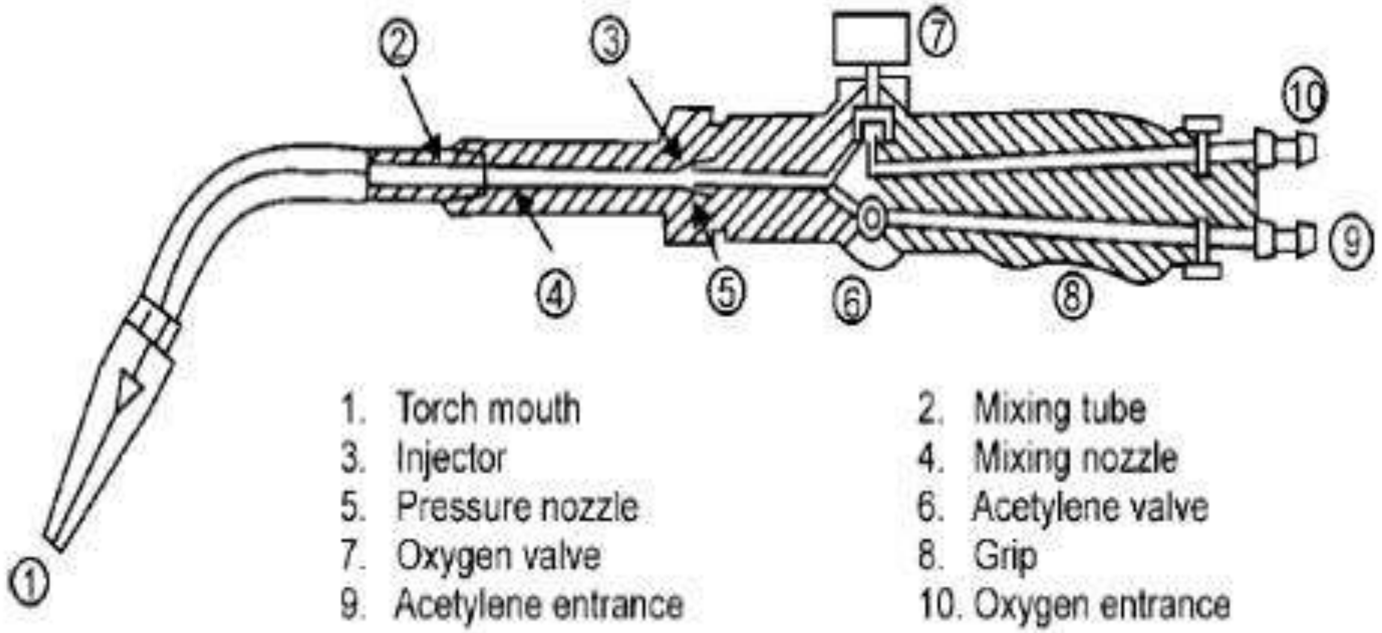


Fig. 7.9: Welding Torch

Gas Welding - Advantages

- Simple equipment
- Portable
- Inexpensive
- Easy for maintenance and repair

Gas Welding - Disadvantages

- Limited power density
- Very low welding speed
- High total heat input per unit length
- Large heat affected zone
- Severe distortion
- Not recommended for welding reactive metals such as titanium and zirconium.

WELD DEFECTS

- ***WELD SPATTER-***

  *Caused by a **long arc length**, **very high current**, or a phenomenon called **arc blow (electric arc being deflected away from the weld pool by magnetic forces).***

  Damages appearance of the weld and increases cleaning cost.

- ***POROSITY-***

  *Caused due to **arc blow***

- ***POOR FUSION-***

  Caused by low current, contaminated joint surface, improper electrode

- ***SHALLOW PENETRATION –***

  Caused by decreased melting of electrodes. This can be prevented by decreasing weld speed, increasing the current , using smaller electrodes

- ***CRACKING-***

  High carbon content, high allow content, high sulphur content and Excessive restraining of base metal which causes internal stress inside the weld, which leads to cracking when cools down or contracts.

TYPES OF WELD JOINTS

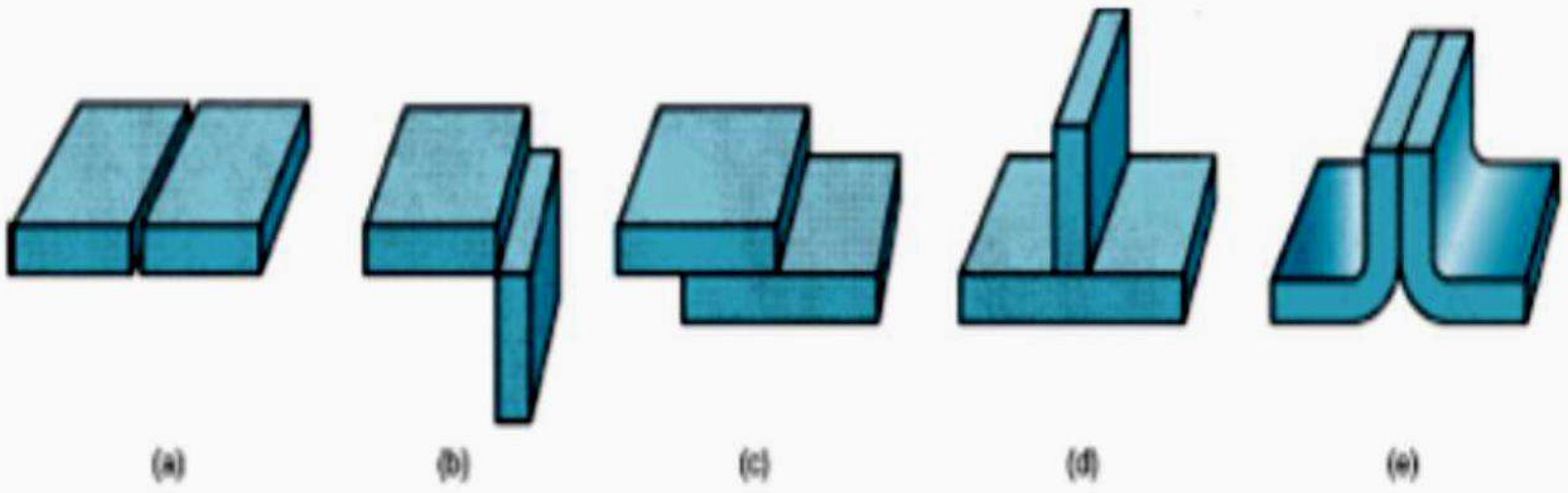
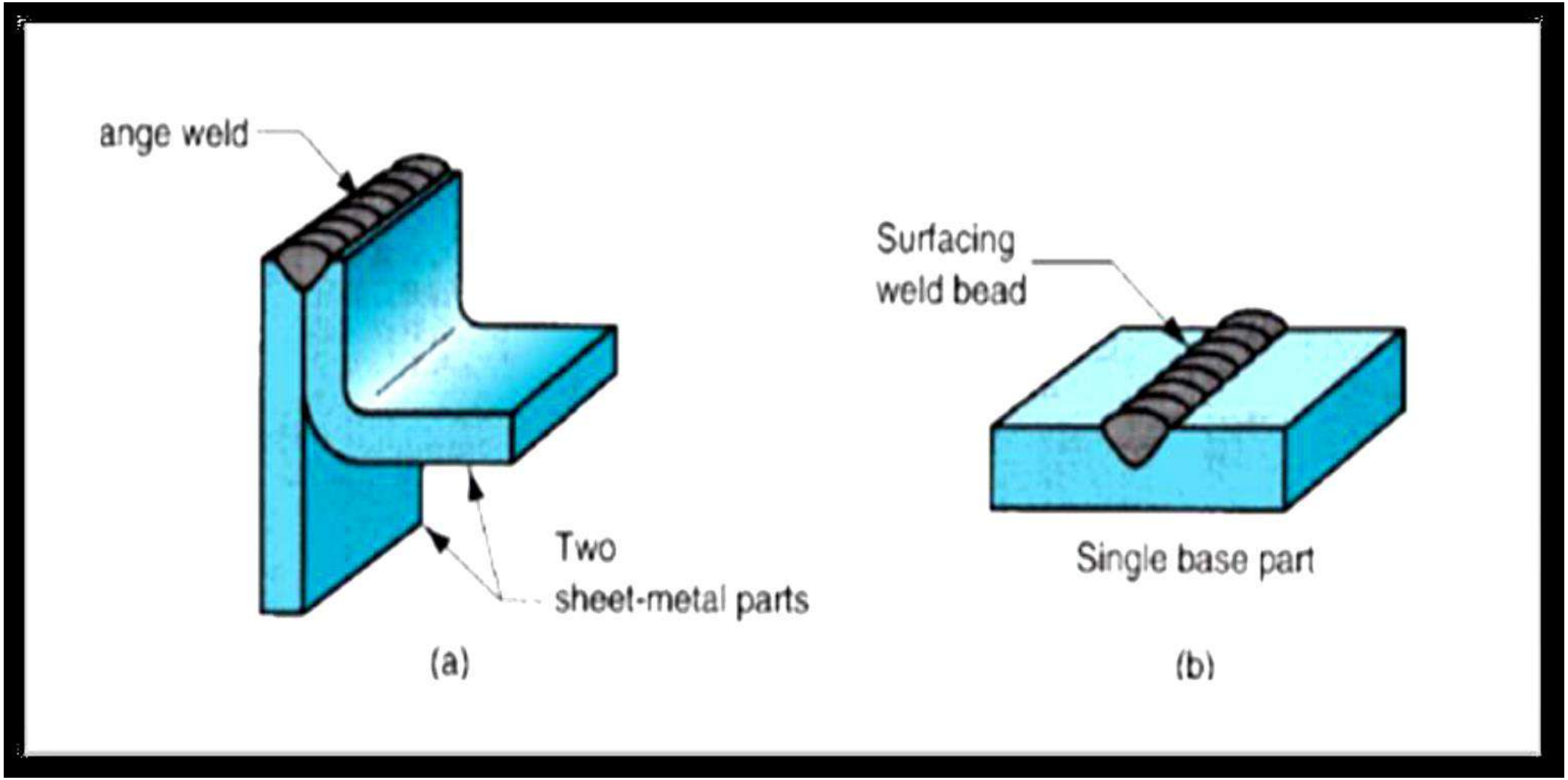


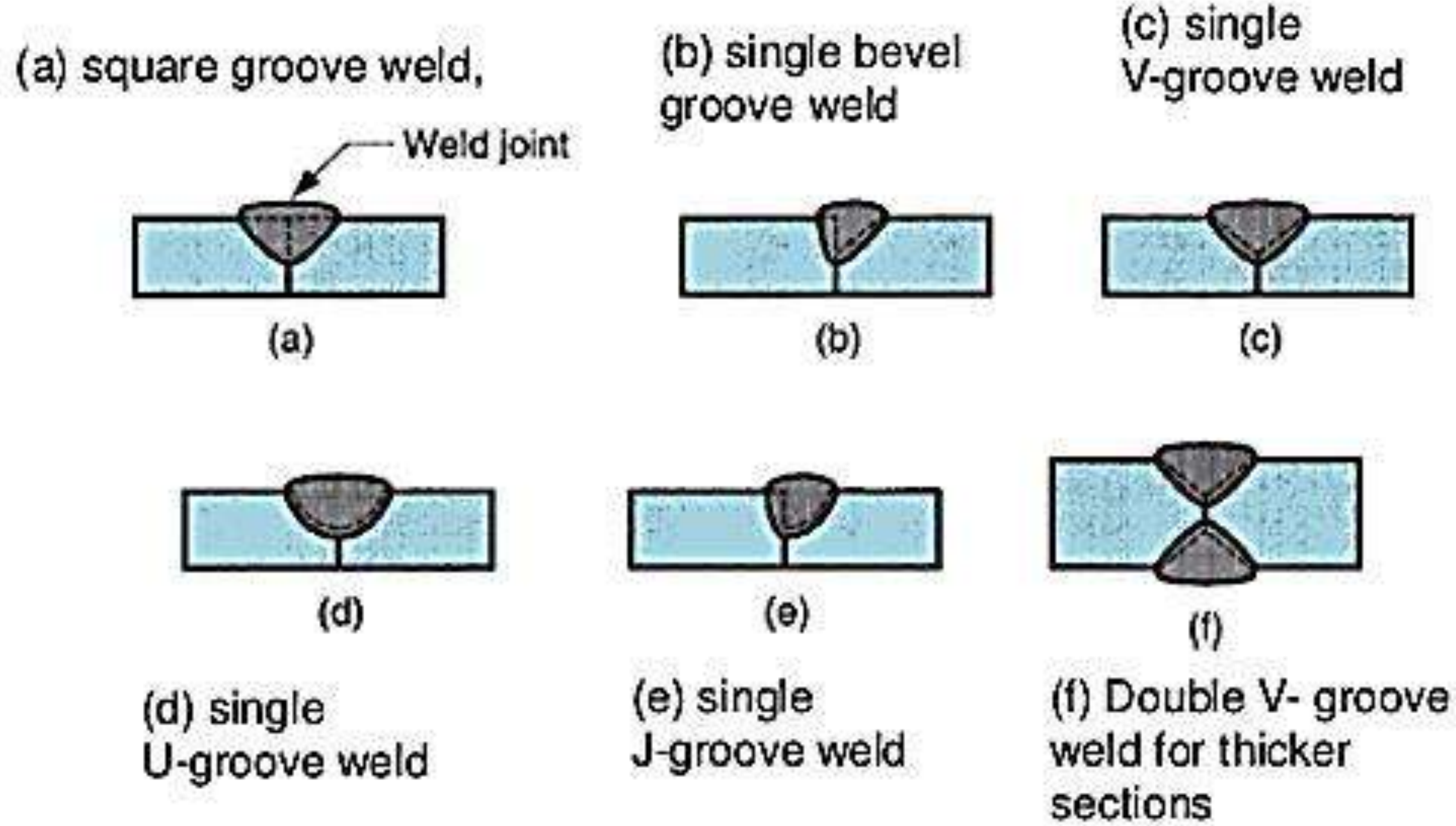
FIGURE 29.2 Five basic types of joints: (a) butt, (b) corner, (c) lap, (d) tee, and (e) edge.

BUTT JOINT, CORNER JOINT, LAP JOINT, TEE JOINT, EDGE JOINT

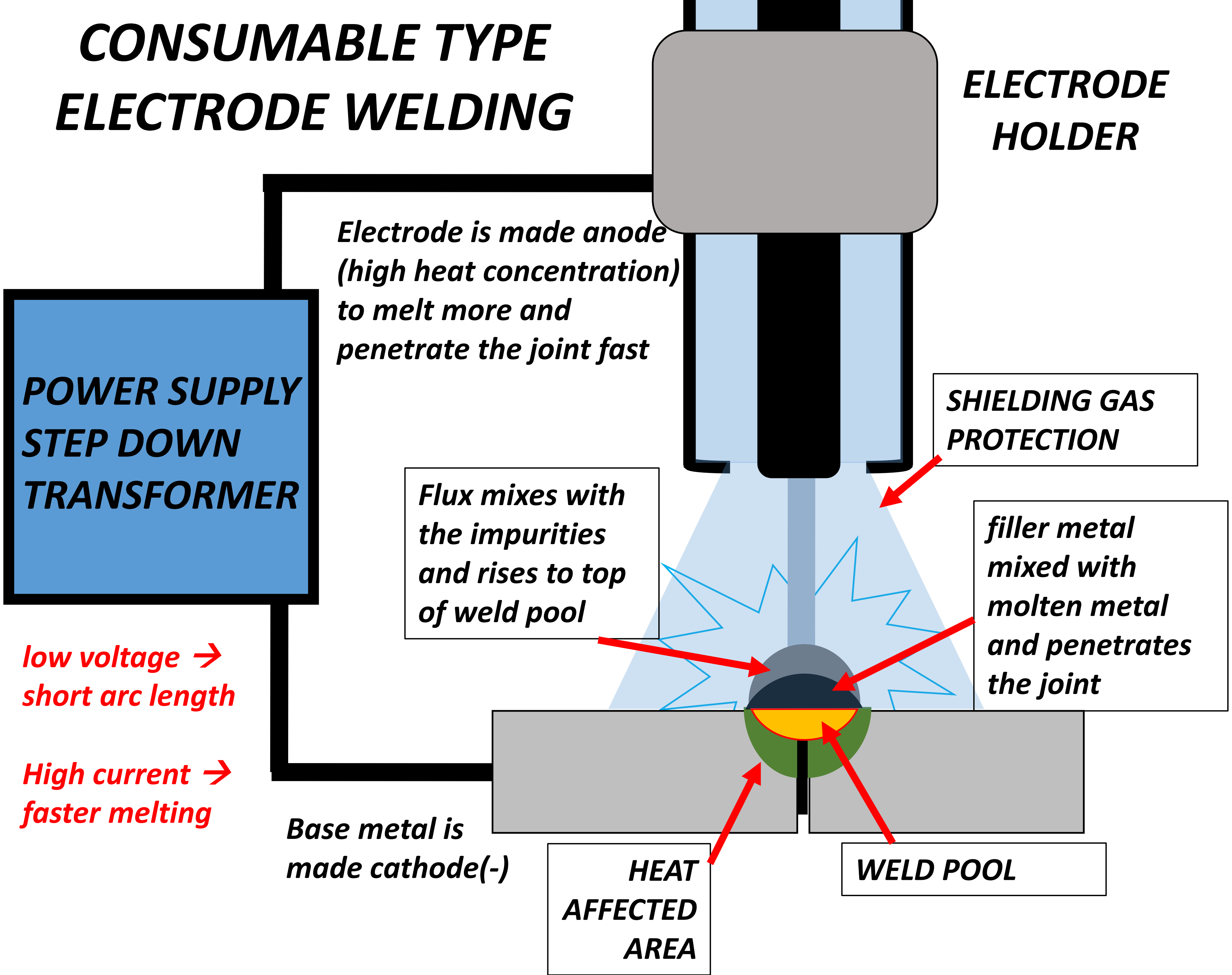


FLANGE WELDS AND SURFACING WELDS

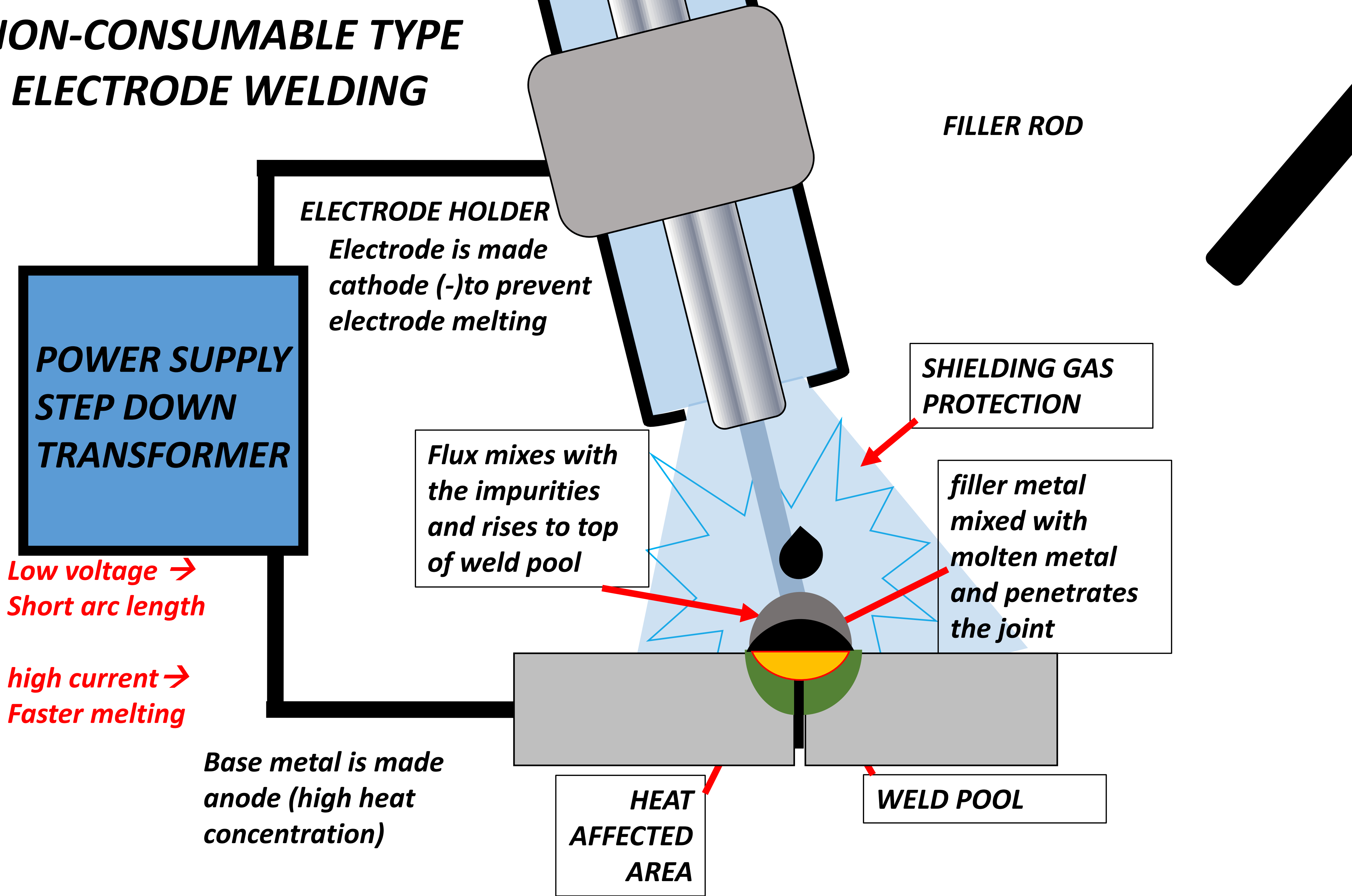
GROOVE WELDS



CONSUMABLE TYPE ELECTRODE WELDING



NON-CONSUMABLE TYPE ELECTRODE WELDING



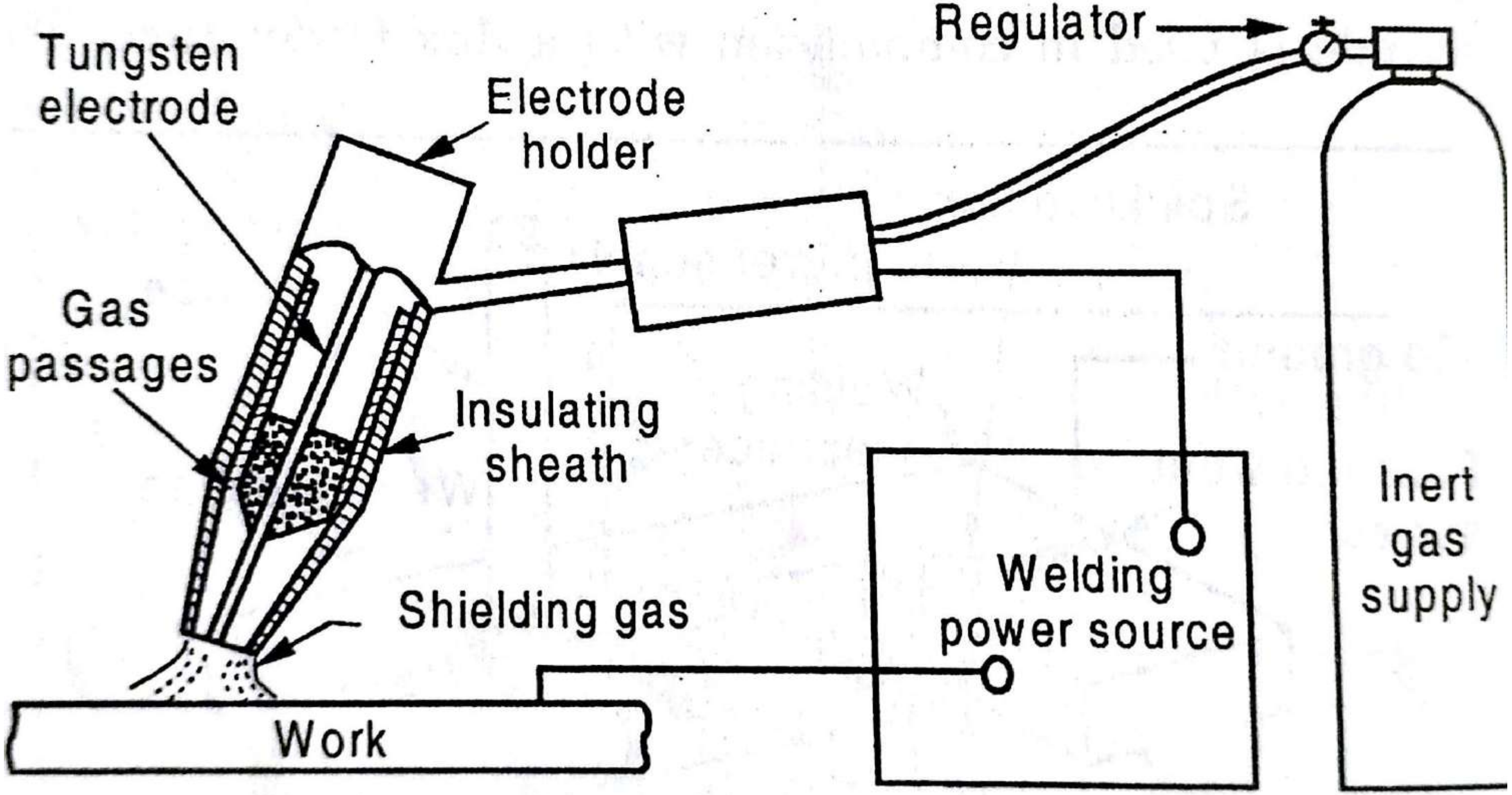


Fig. 5.67 Tungsten inert gas welding setup

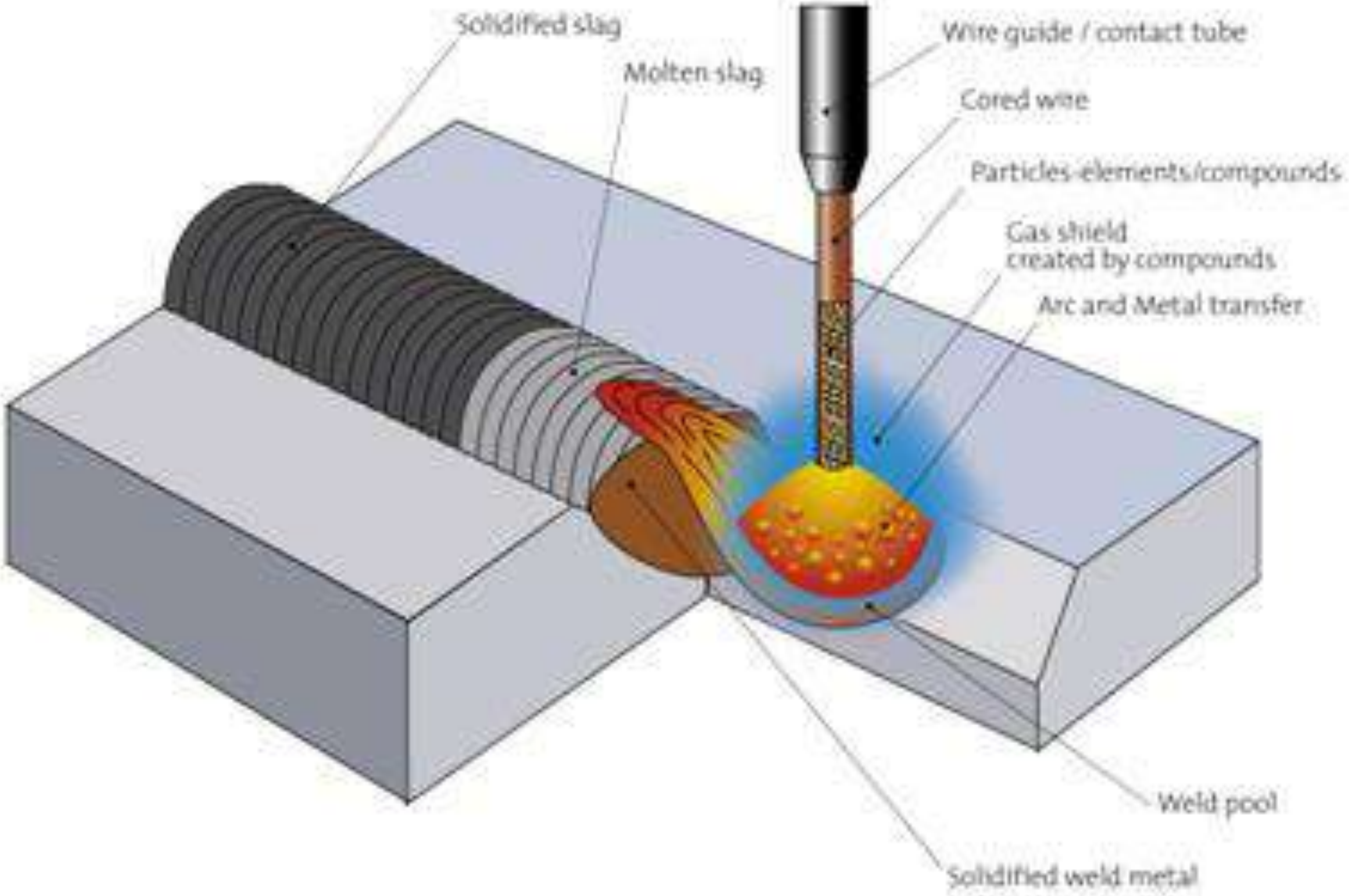
	GAS WELDING	ARC WELDING
1.	Heat is produced by the gas flame	Heat is produced by electric arc
2.	The flame temperature is about 3200°C	In arc welding, the temperature of arc is about 4000°C
3.	Separate filler rod introduced	Arc producing as well as filler rod material is the electrode
4.	Suggested for thin materials	Suggested for medium and thick materials
5.	Gas welded parts do not have much strength	Arc welded parts have very high strength.
6.	Filler metal may not be the same parent metal.	Filler metal must be same or an alloy of the parent metal.
7.	Brazing and Soldering are done using gas.	Brazing and Soldering can't be carried out by electric arc.

METAL INERT GAS WELDING

ADVANTAGES	DISADVANTAGES	METALS	APPLICATIONS
1. Speed due to continuously fed filler electrodes	*1. cannot be used in **areas of high air movement**, Because of the need to maintain a stable shroud of shielding gas* ***2. Pority of the welded** joints because solidification of the weld pool takes place before the escape of entrapped gas.* *3. Forms Solid impure **Aluminium dross** floating on the weld pool* ***4. complicated** equipment*	*1. welding metals with high thermal conductivities like **aluminium** and other **non-ferrous, steels**.*	*automobile industries.*

FLUX-CORED ARC WELDING

- ***Flux-cored arc welding*** *(**FCAW** or **FCA**) is a semi-automatic or automatic arc welding process.*
- ***Tubular consumable electrode containing a flux*** *which provides necessary protection from the atmosphere and metal impurities, is continuously-fed to weld point.*
- *constant-voltage or, less commonly, a constant-current welding power supply.*
- *An externally supplied shielding gas is sometimes used*


Solidified slag
Molten slag
Wire guide / contact tube
Cored wire
Particles-elements/compounds
Gas shield
created by compounds
Arc and Metal transfer
Weld pool
Solidified weld metal

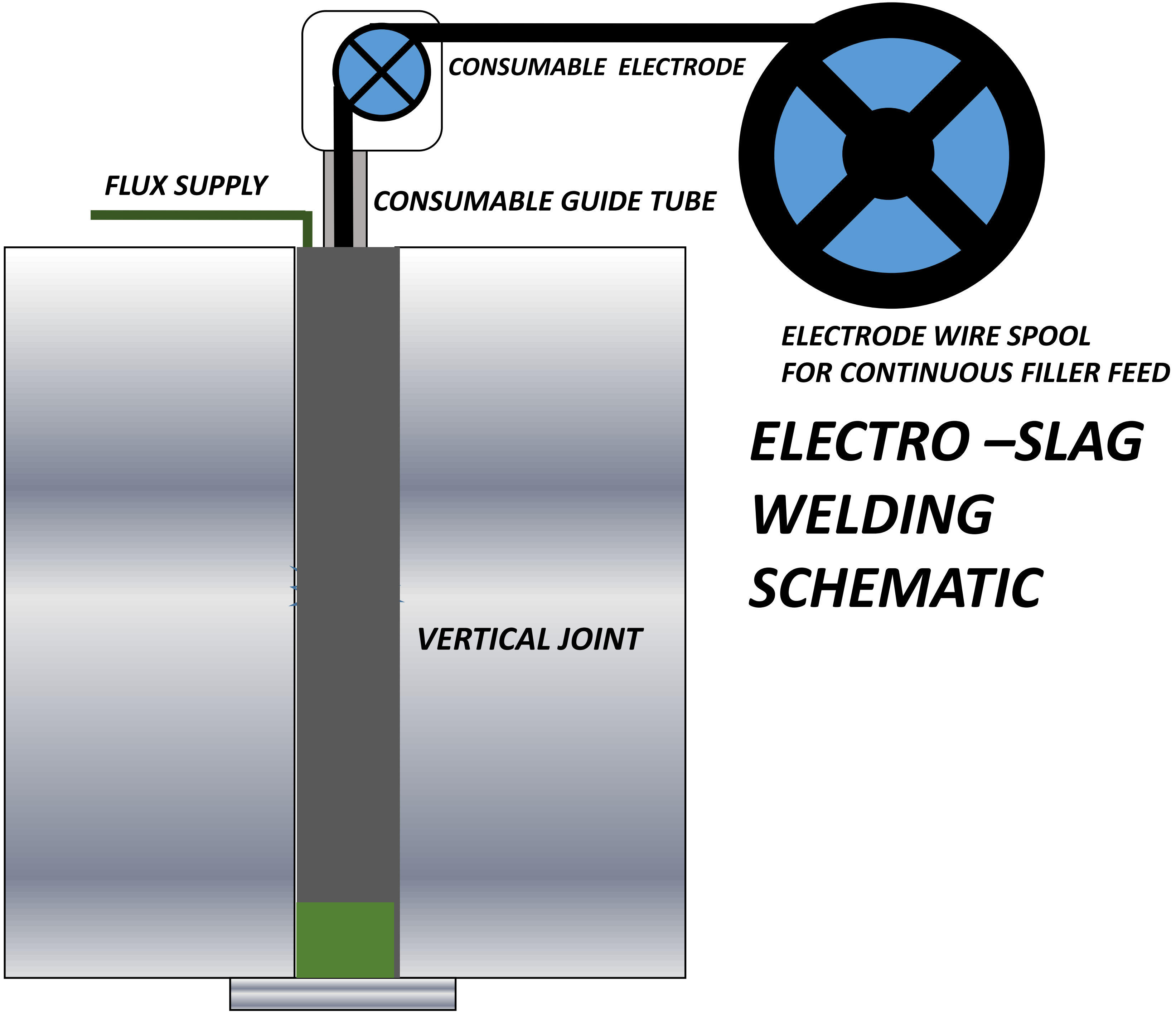
ADVANTAGES	DISADVANTAGES	METALS	APPLICATIONS
1. All position welding 2. high welding speed 3. Portability 4. thicker and out-of-position metals 5. higher production rate 6. fewer weld defects 7. slag is also easy to remove	1. cannot be used in a windy environment 2. excessive, noxious smoke (making it difficult to see the weld pool) 3. Skilled operation 4. Contact tip melting, preventing flux flow. 5. Costly electrode 6. Irregular wire feed	1. Alloy steels 2. Nickel alloys	1. Construction 2. Automotive industries

SUBMERGED ARC WELDING

ADVANTAGES	*DISADVANTAGES*	*METALS*	*APPLICATIONS*
1. *No weld spatters* 2. *No fumes* 3. *No visible spark* 4. *High welding speed* 5. *Deep weld penetration for thick plates* 6. *Suitable for indoor and outdoor work* 7. *Minimal weld defect*	1. *Limited to flat horizontal surfaces* 2. *Non visibility of process.*	1. *Steels* 2. *Nickel alloys*	1. *Structural and ship/barge constructions*

TUNGSTEN INERT GAS WELDING

ADVANTAGES	DISADVANTAGES	METALS	APPLICATIONS
1.Great control over weld area 2. Strong high quality welds. 3. Filler metal is not in direct contact with the arc, so no filller metal is wasted by vaporization	1. Complex 2. More operator skill 3. Slower process 4. Manual filler metal feed 5. Difficult to maintain short arc length 6. Ultra-violet radiation 7. Formation of ozone due to arc plasma 8. If current exceeds, tungsten inclusion may take place in the base metal.	1. Stainless steel 2. Aluminium 3. magnesium 4. Zinc and alloys	1. Aerospace industry 2. Space vehicles 3. Bycycle industry 4. Naval aplications

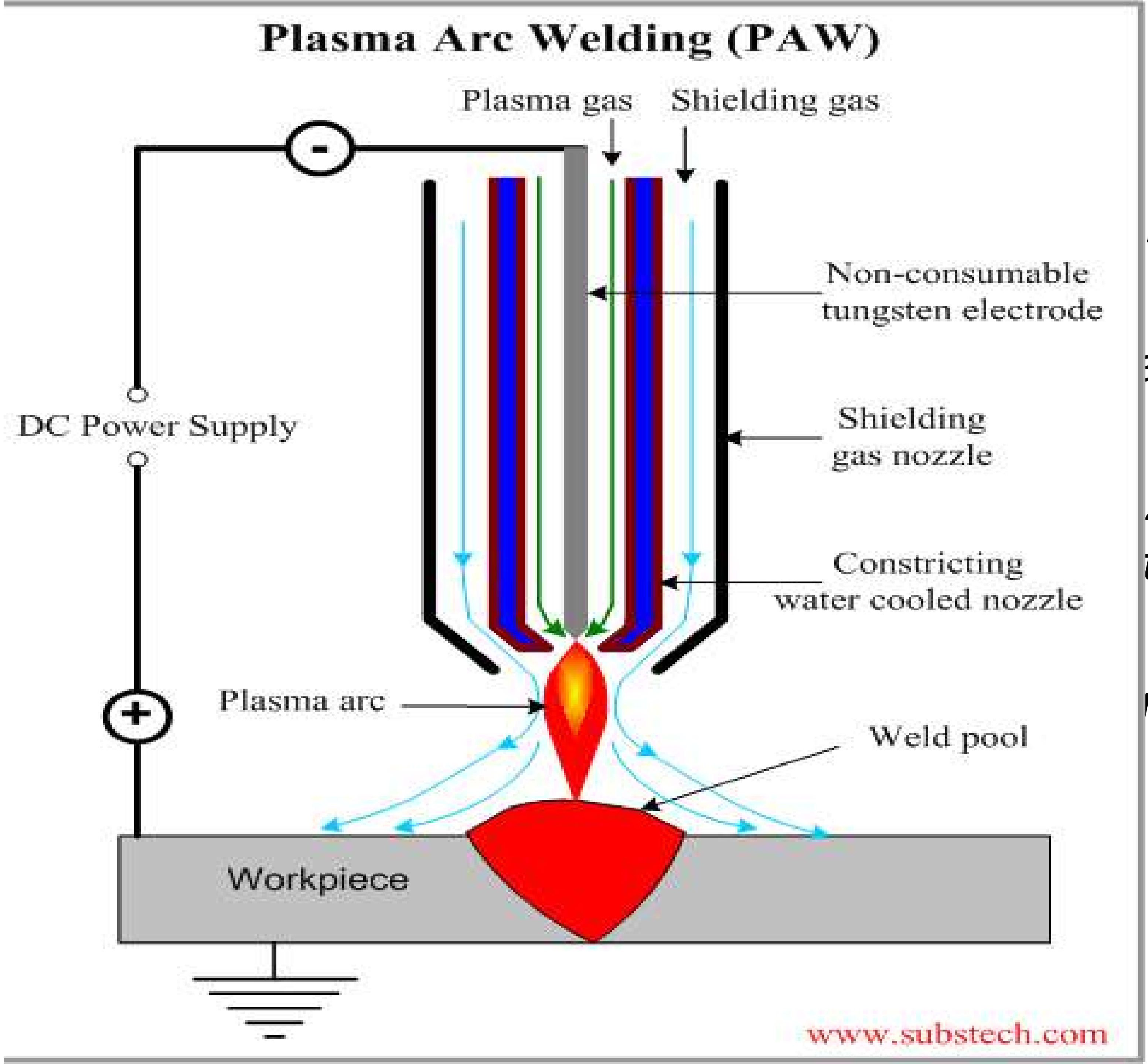


ELECTRO –SLAG WELDING SCHEMATIC

EL

Electroslag Welding

ADVANTAGES	DISADVANTAGES	METALS	APPLICATIONS
1. Single pass is sufficient 2. Thick materials 3. High filler metal utilization 4. No weld spatter, because no arc 5. Skilled operators not required 6. Minimum joint preparation and cleaning	1. Restricted to vertical position 2. High heat input leads to poor weld quality.	1. Cast iron 2. Aluminium 3. Magnesium 4. Copper 5. titanium	1. Ship building 2. Building Construction 3. Machine frames 4. Heavy pressure vessels 5. Joining turbine casting



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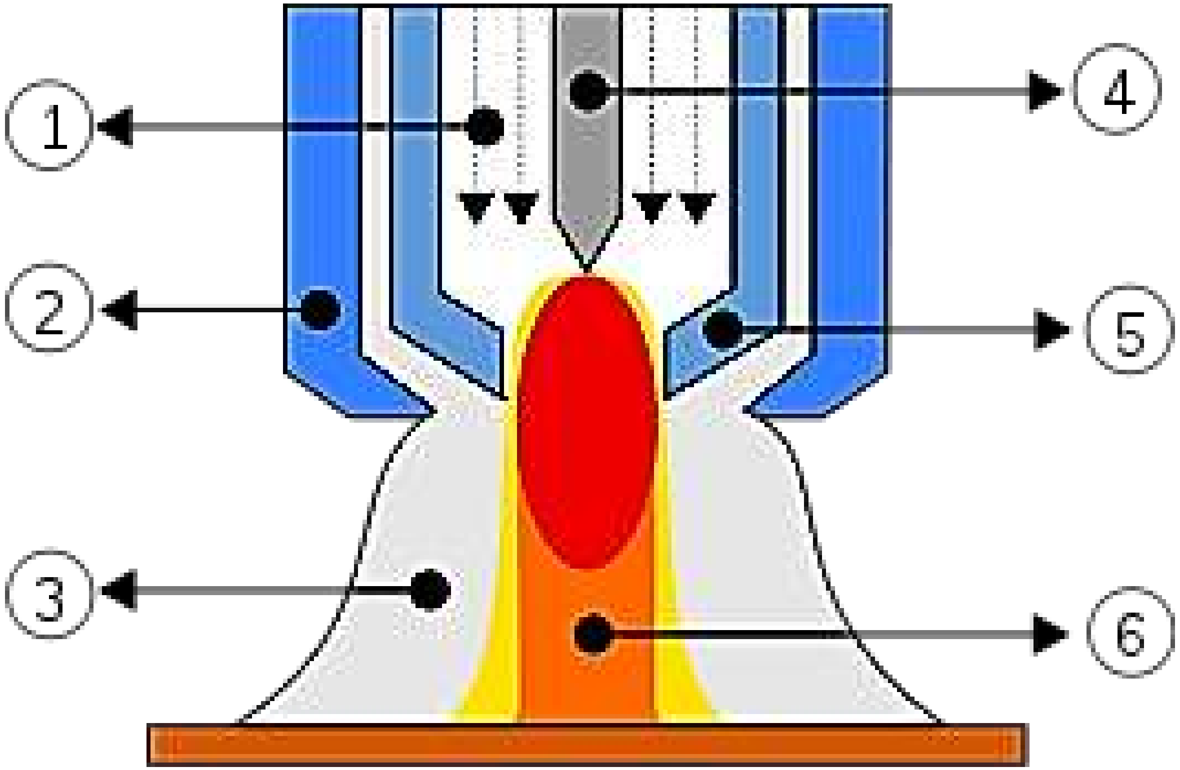


1. Gas plasma, 2. Nozzle protection, 3. Shield Gas, 4. Electrode, 5. Nozzle constriction, 6. Electric arc

STEP 3:

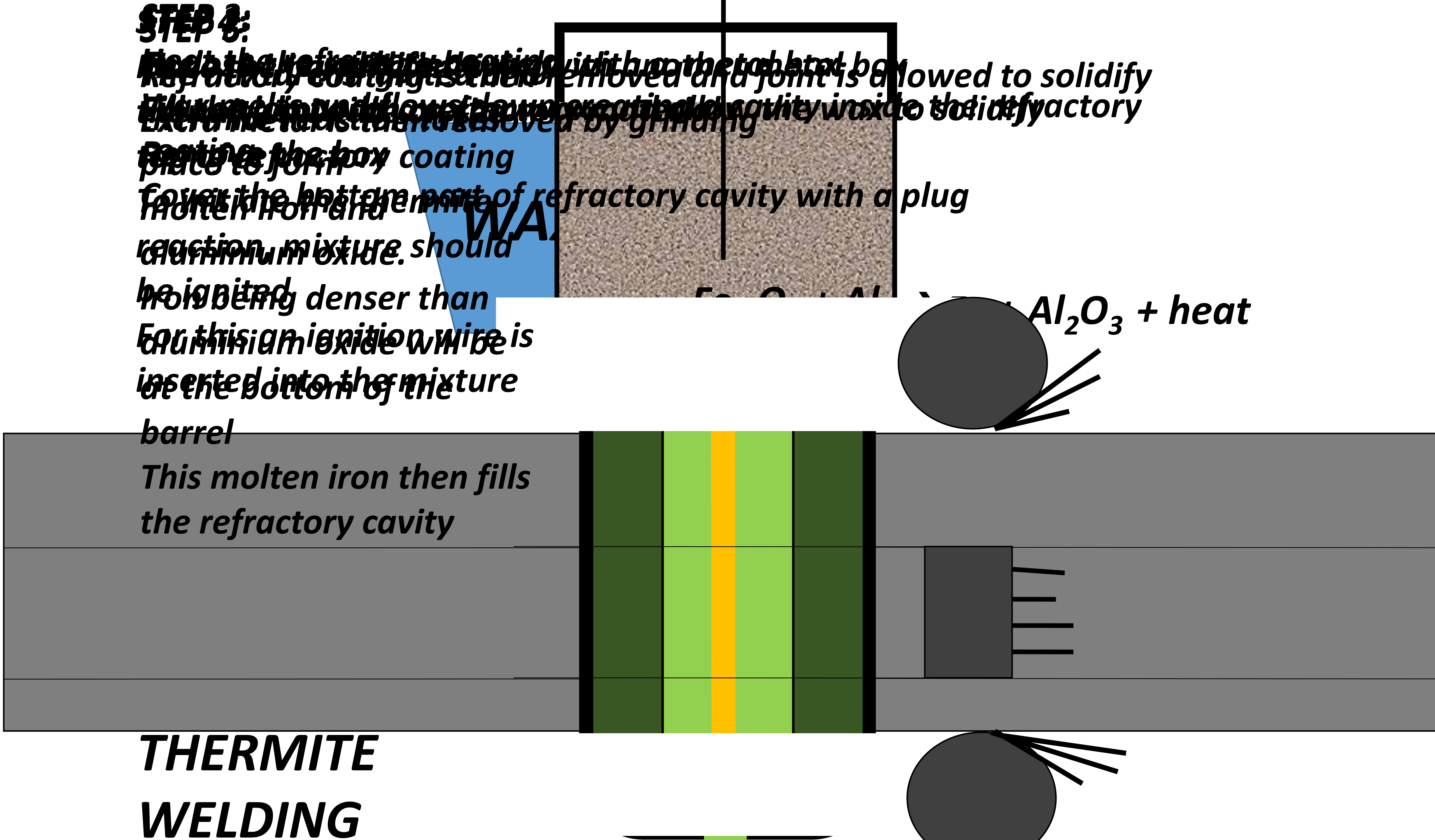
Refractory coating is then removed and joint is allowed to solidify

Extra metal is then removed by grinding

Cover the bottom part of refractory cavity with a plug

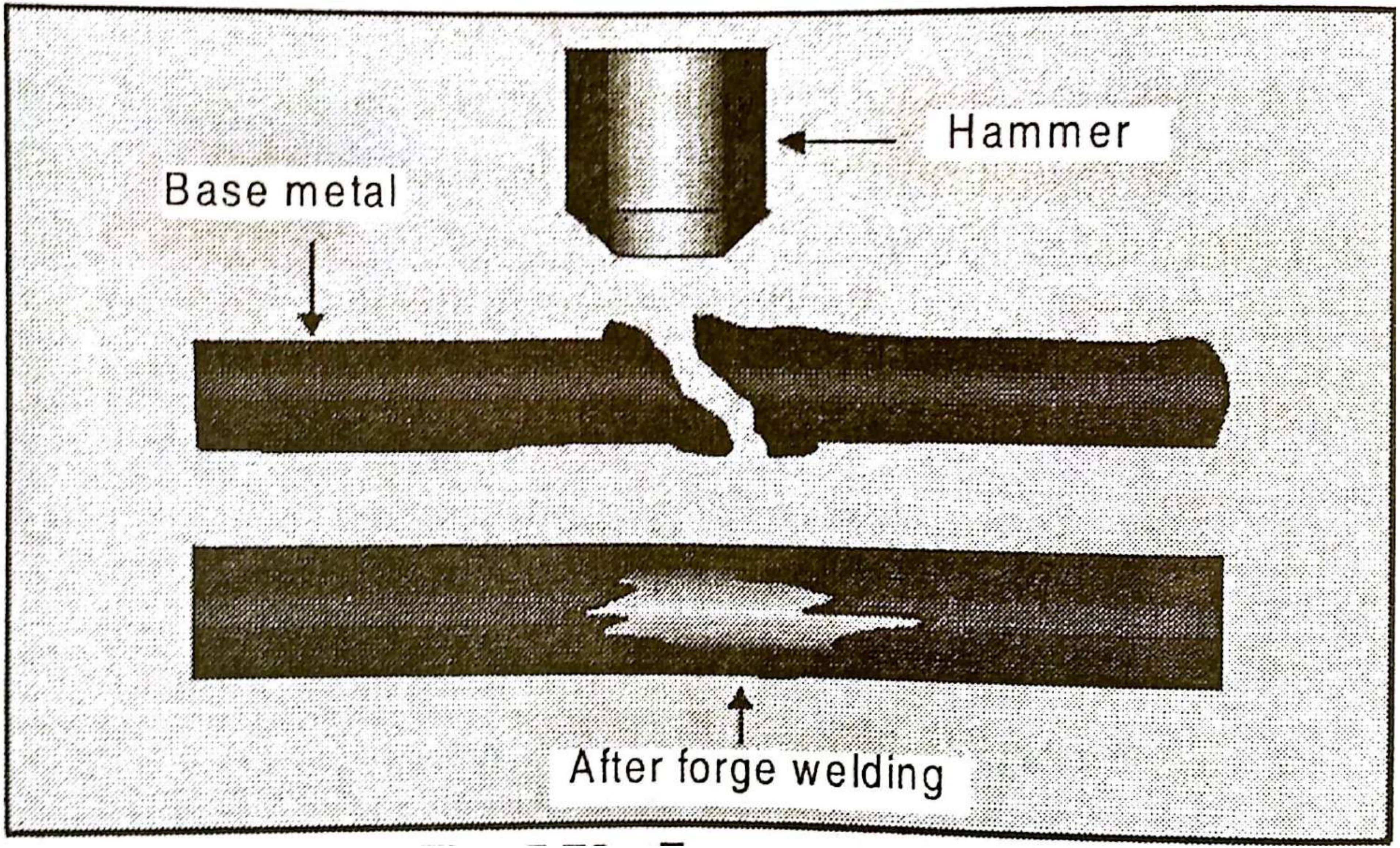
$Fe_2O_3 + Al \rightarrow Fe + Al_2O_3 + \text{heat}$

This molten iron then fills the refractory cavity

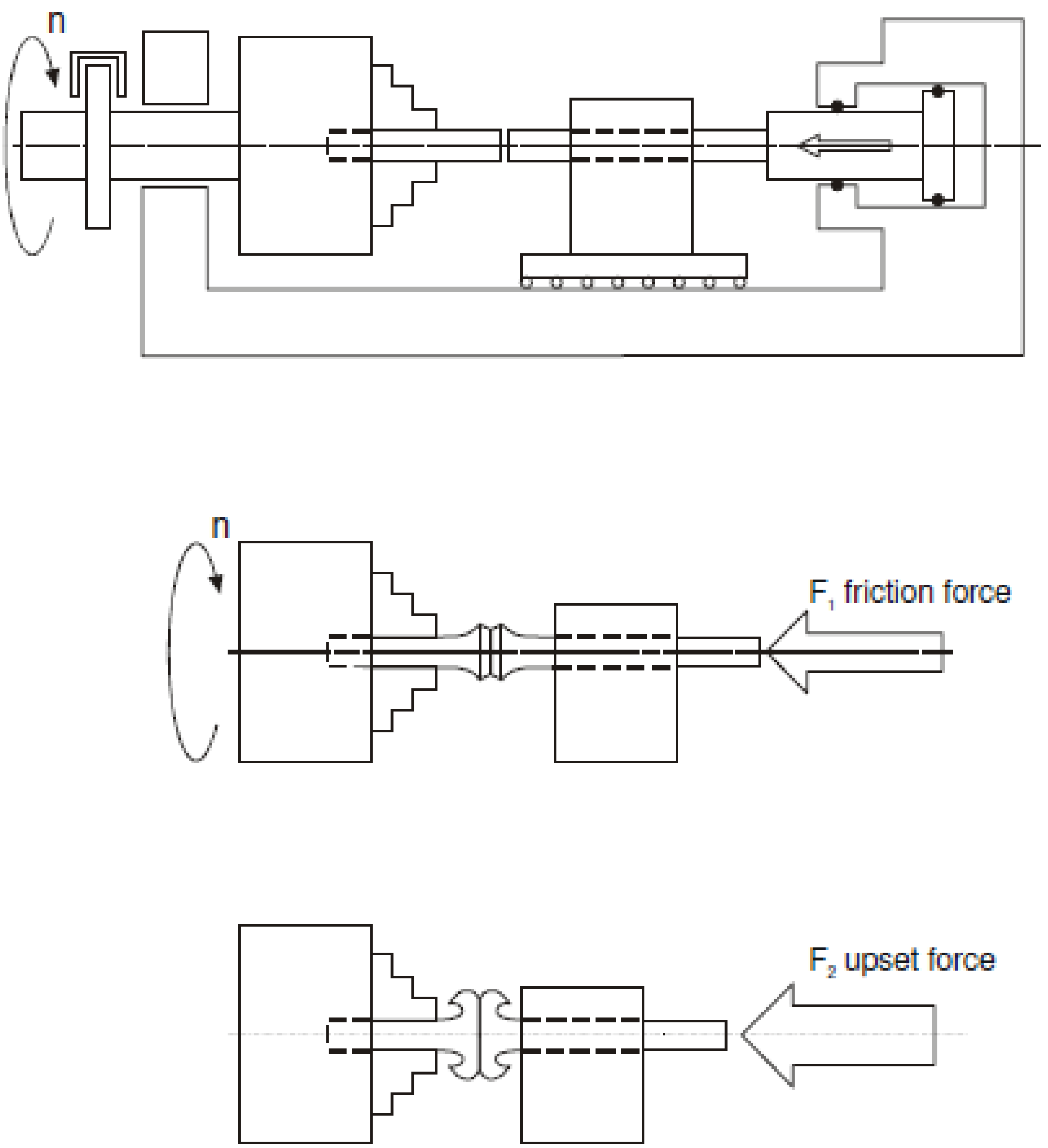


THERMITE WELDING

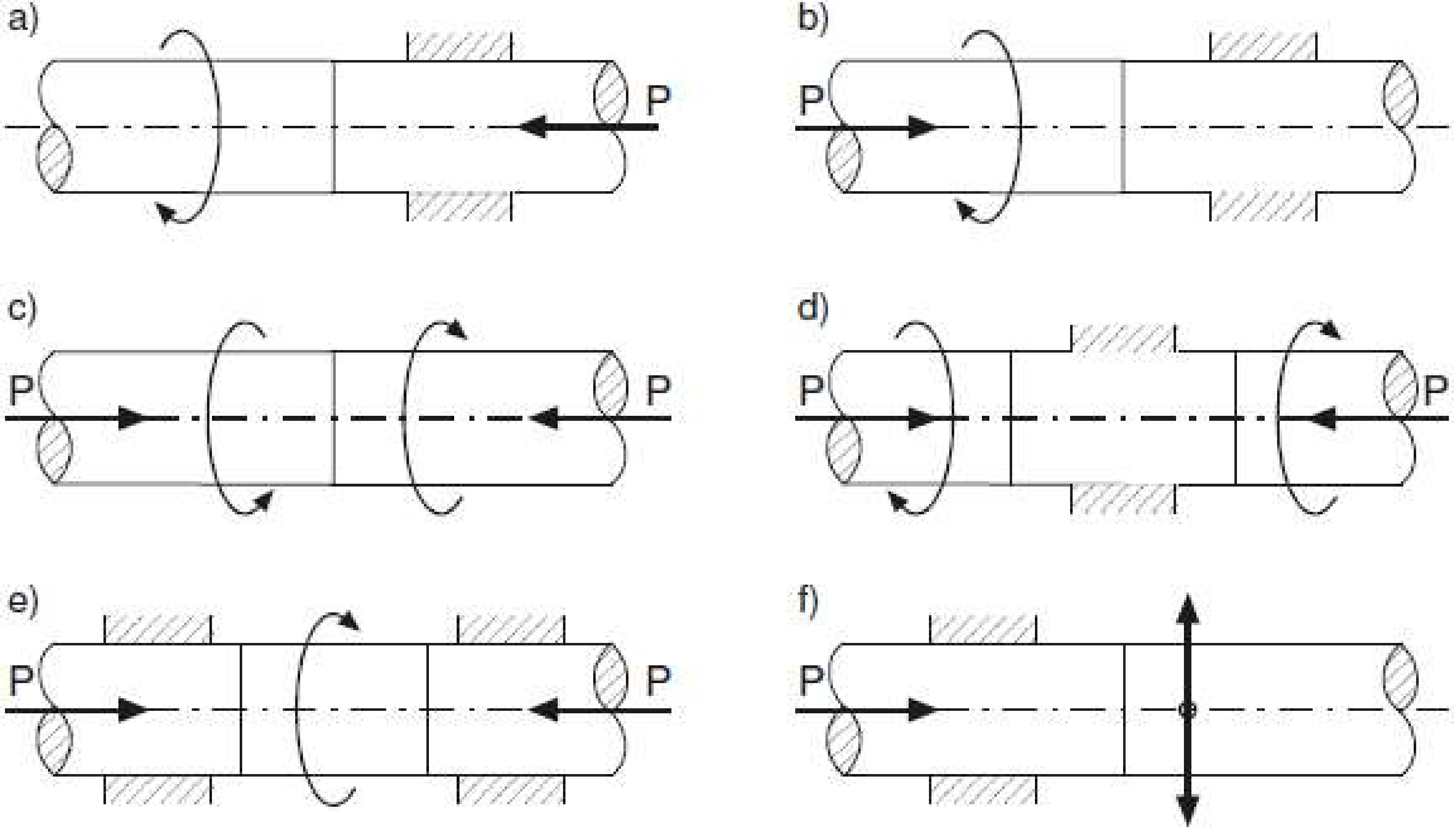
PRESSURE WELDING METHODS



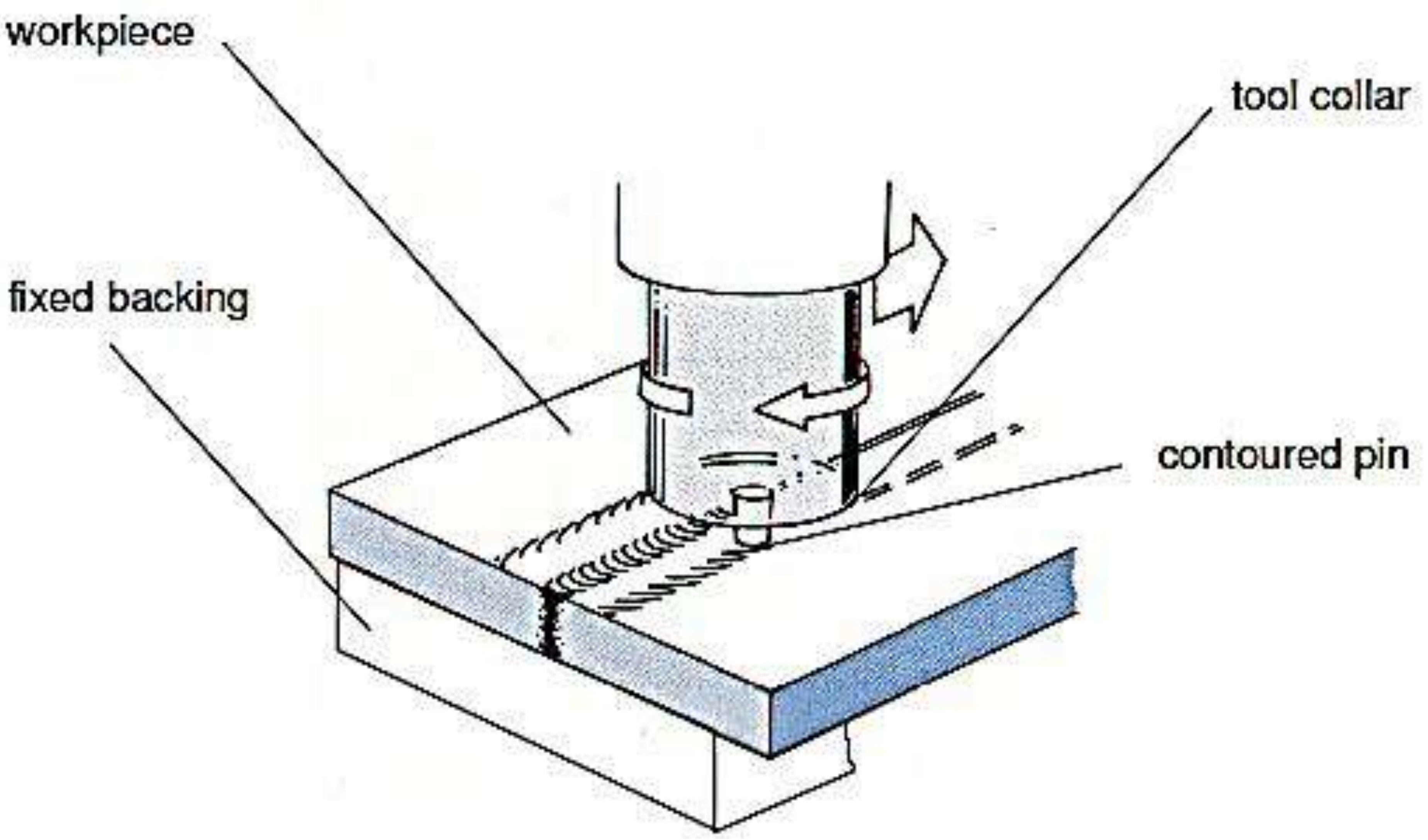
FRICTION WELDING

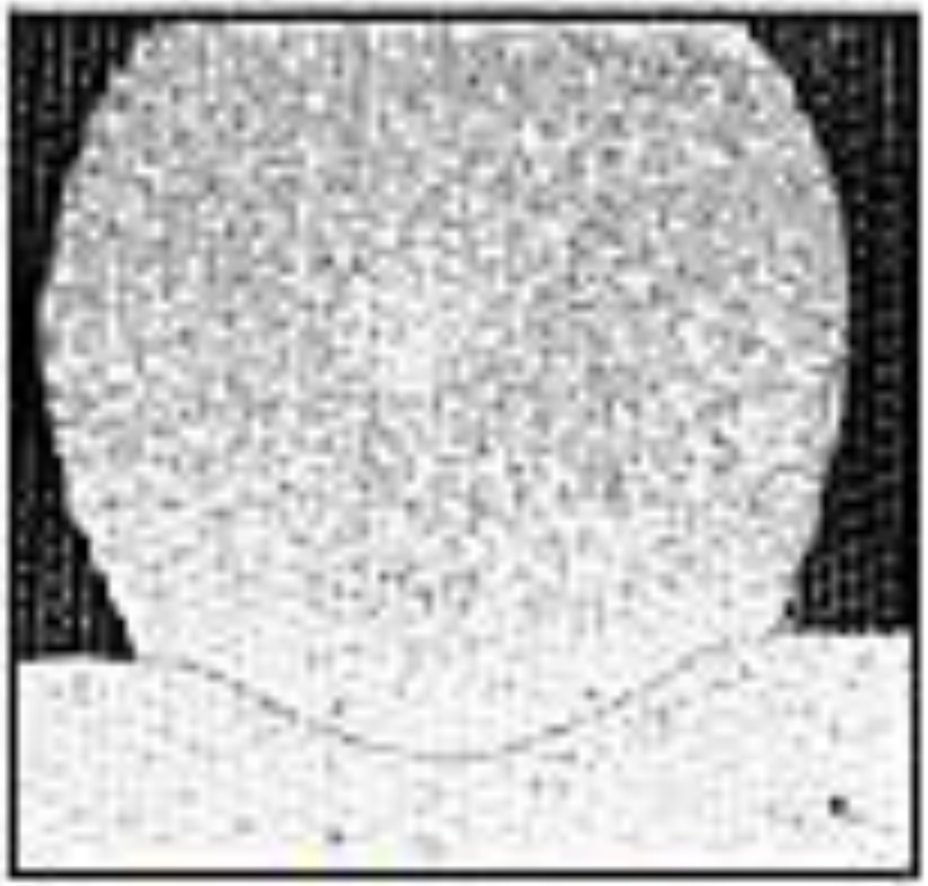


TYPES OF FRICTION WELDING PROCESSES

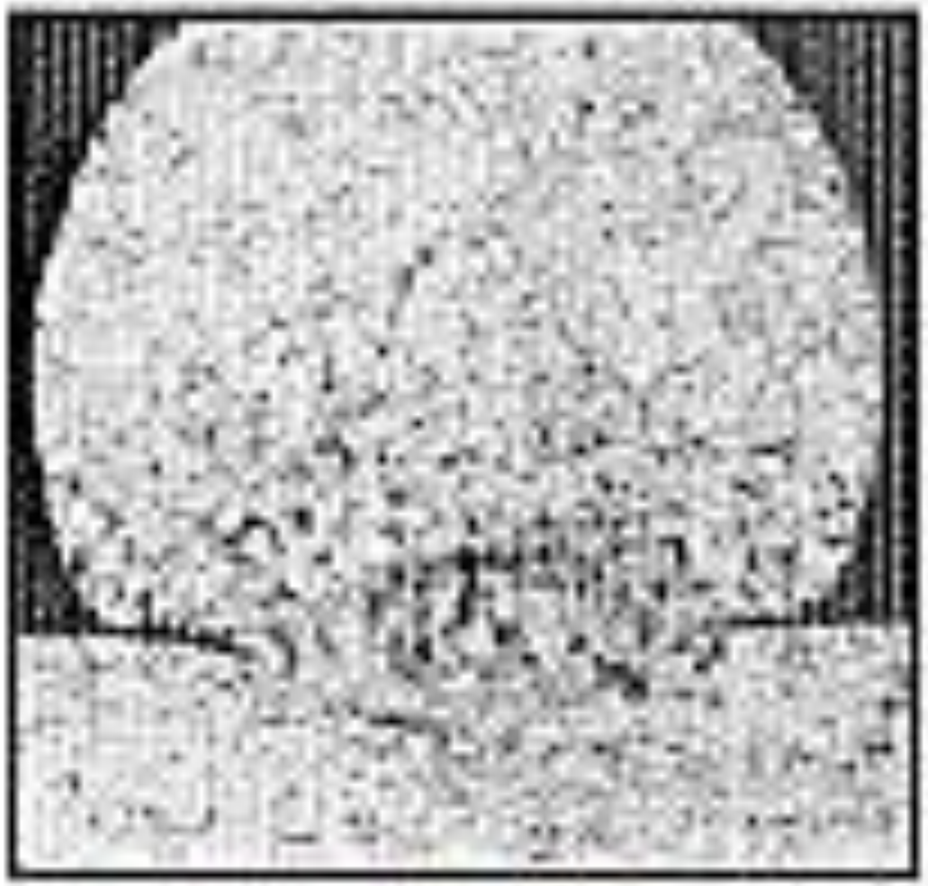


FRICTION STIR WELDING





Solid State Bond



Fusion Bond

RESISTANCE WELDING

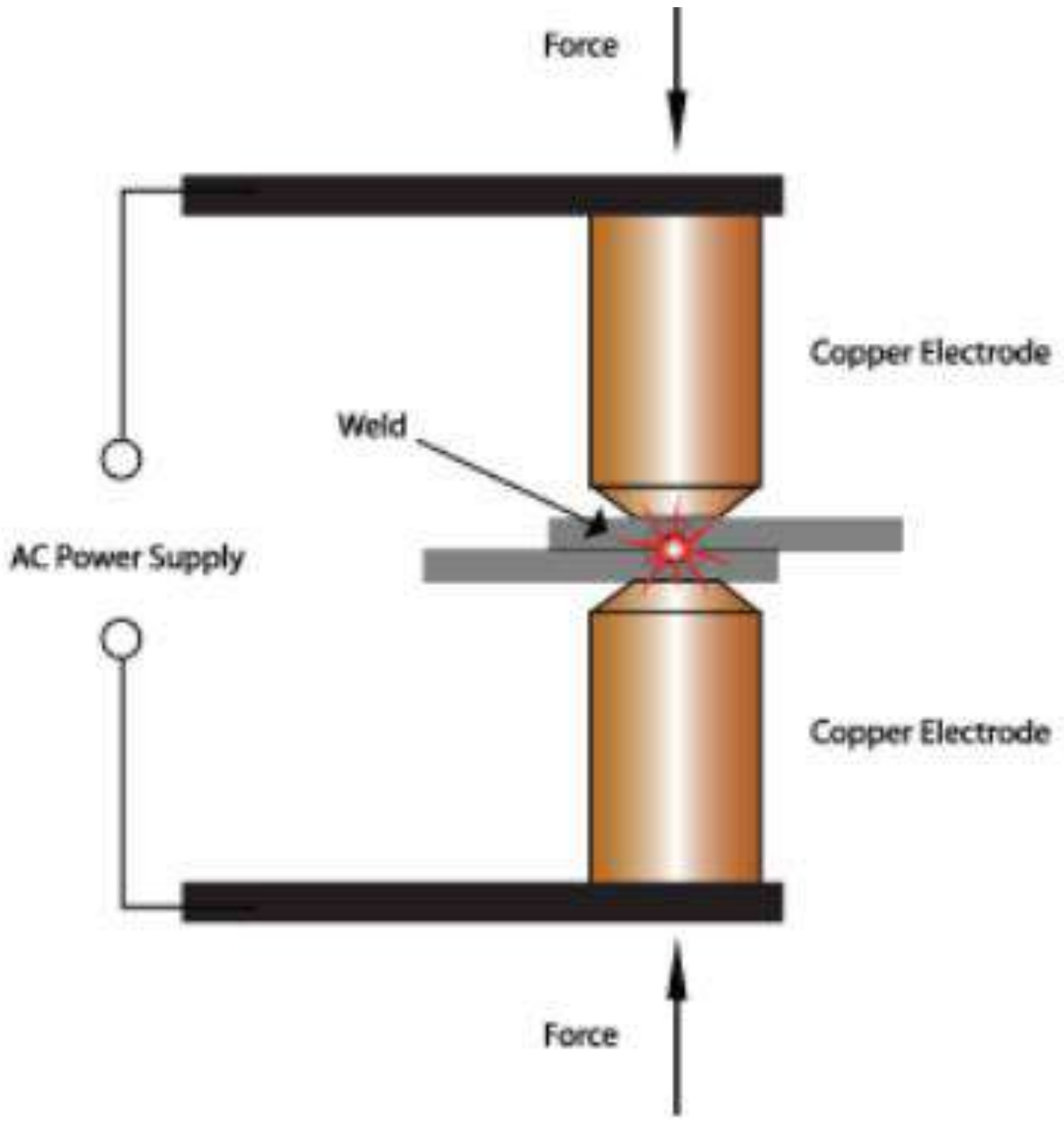
Resistance welding process makes use of the electrical resistance for generating heat required for melting the workpiece. It is generally used for joining thin plates and structures. It has different variants such as Seam welding, Projection welding and Spot welding.

general heat generation formula for resistance welding is:

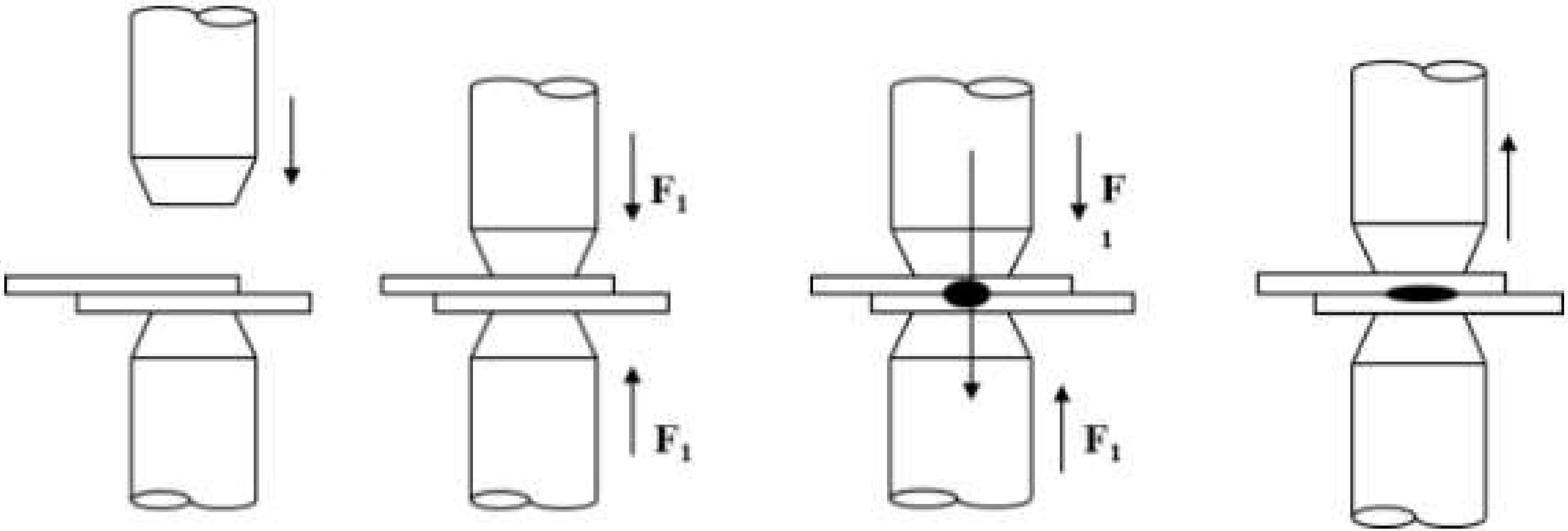
$$\textbf{Heat} = I^2 \times R \times t,$$

Primary functions of Electrode

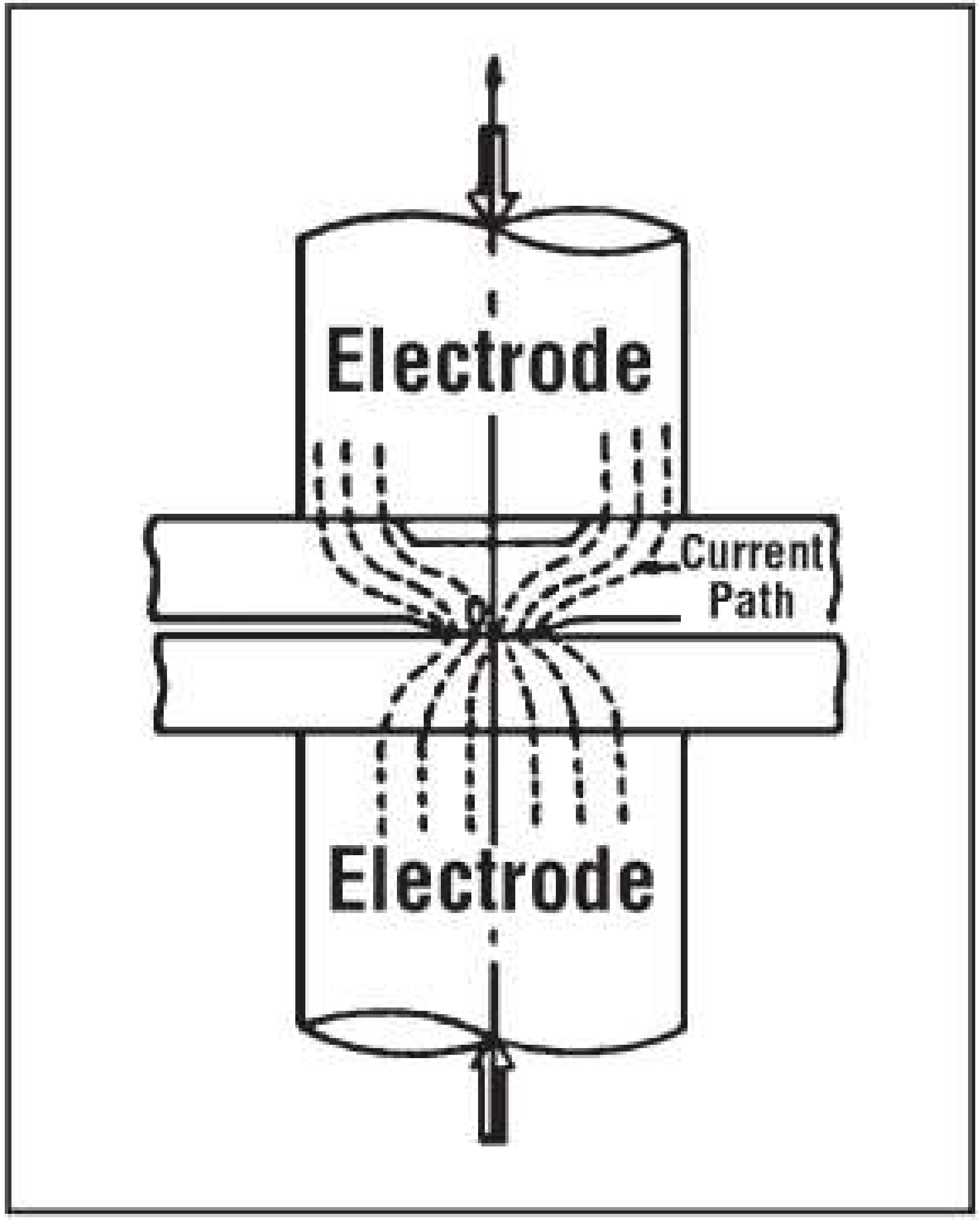
- Conduct the required heat to the weld zone
- Transmit the necessary force to the weld area
- Help the dissipate the heat from the weld zone



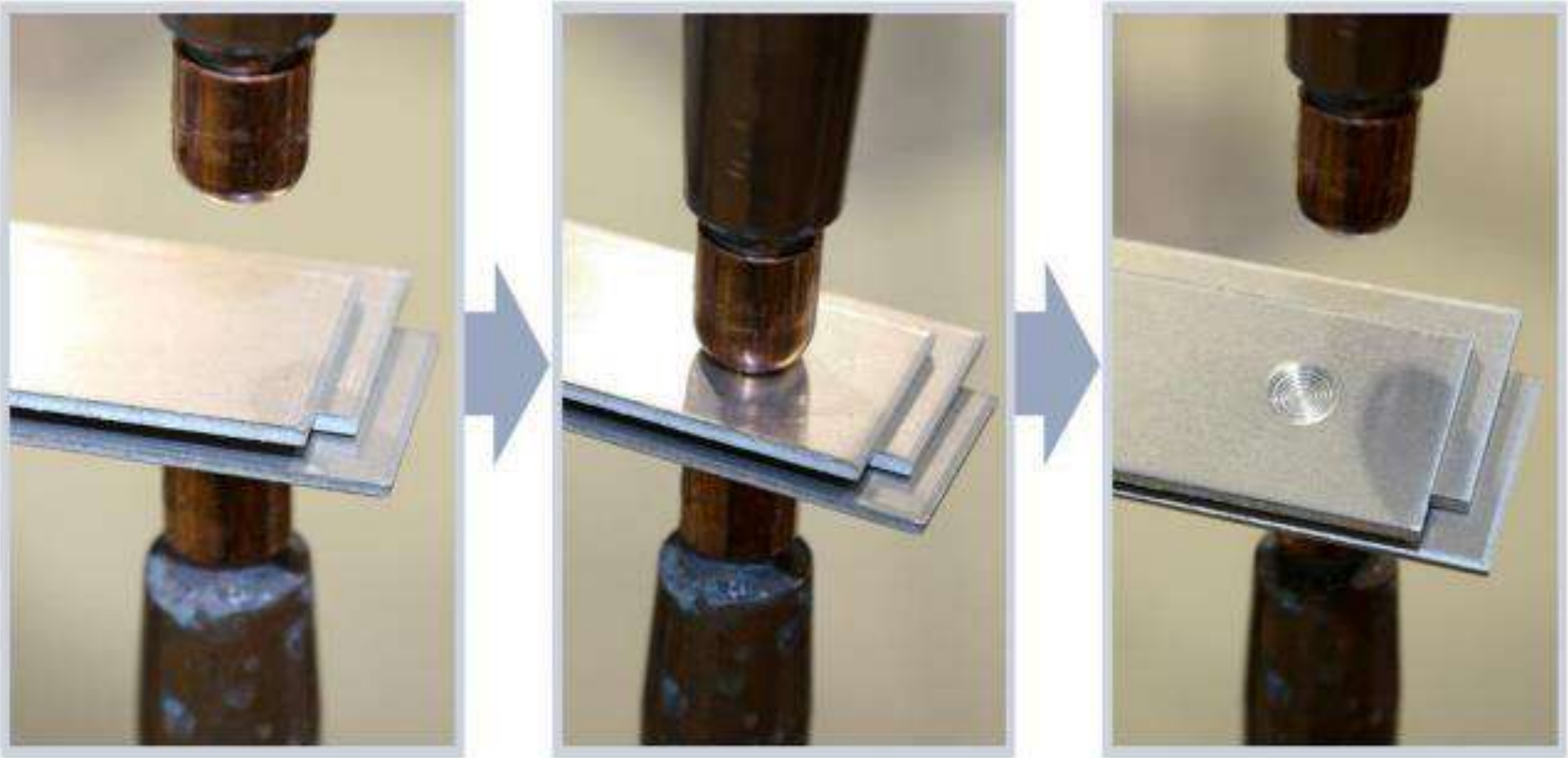
Schematic of resistance spot welding process



Typical steps in producing a resistance spot weld


Electrode
Current Path
Electrode


ELEKTRON



ADVANTAGES OF RESISTANCE WELDING

- They are very rapid in operation.
- The equipment can be fully automated.
- They conserve materials as no filler material, shielding gas or flux is required.
- Skilled operators are not required.
- Dissimilar metals can be easily joined.
- A high degree of reliability and reproducibility can be achieved.

DISADVANTAGES OF RESISTANCE WELDING

- The equipment has a high initial cost.
- There are limitations to the type of joints that can be made (mostly suitable for lap joints).
- Skilled maintenance persons are required to service the control equipment.
- Some materials require special surface preparations prior to welding.

RESISTANCE SEAM WELDING

Seam consists of a series of overlapping spot welds.

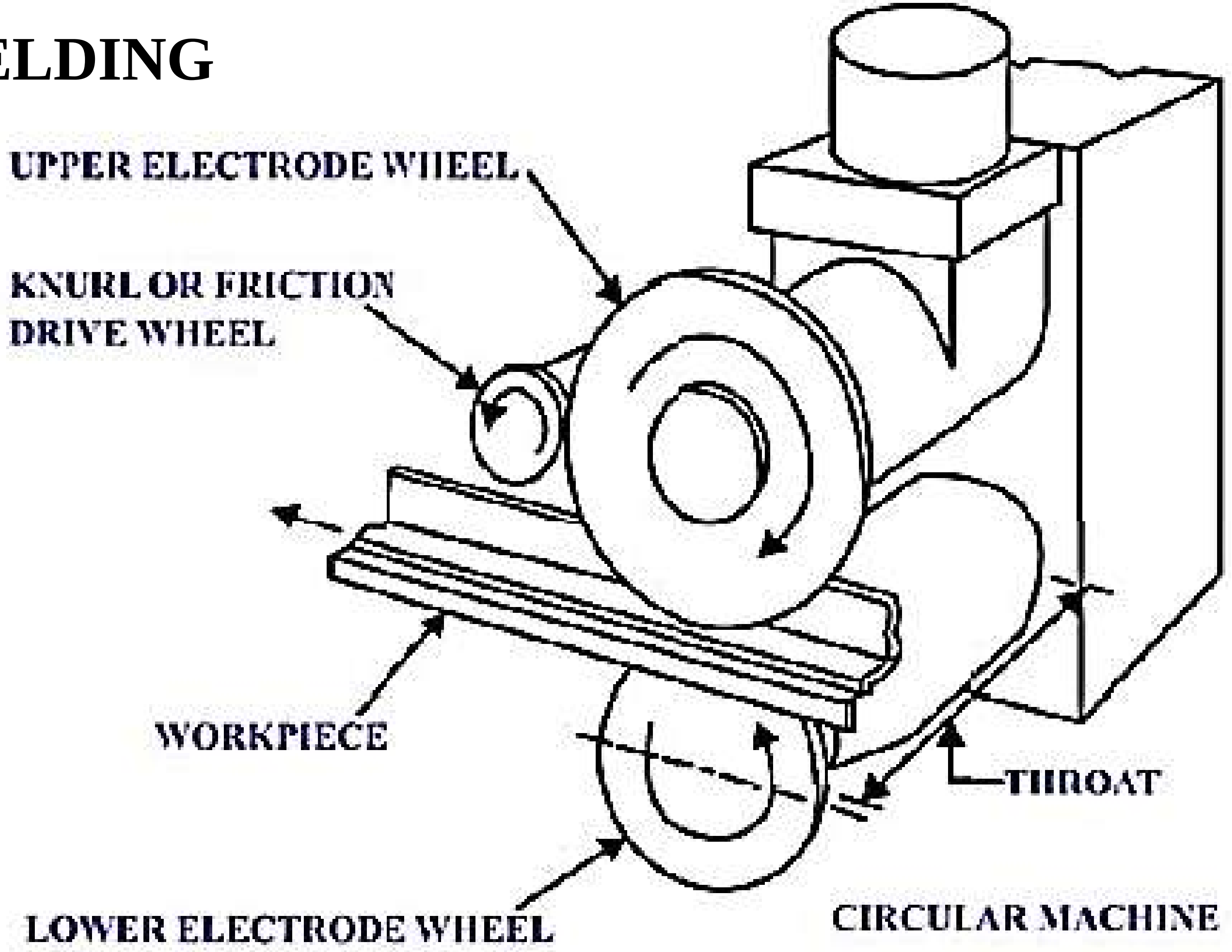
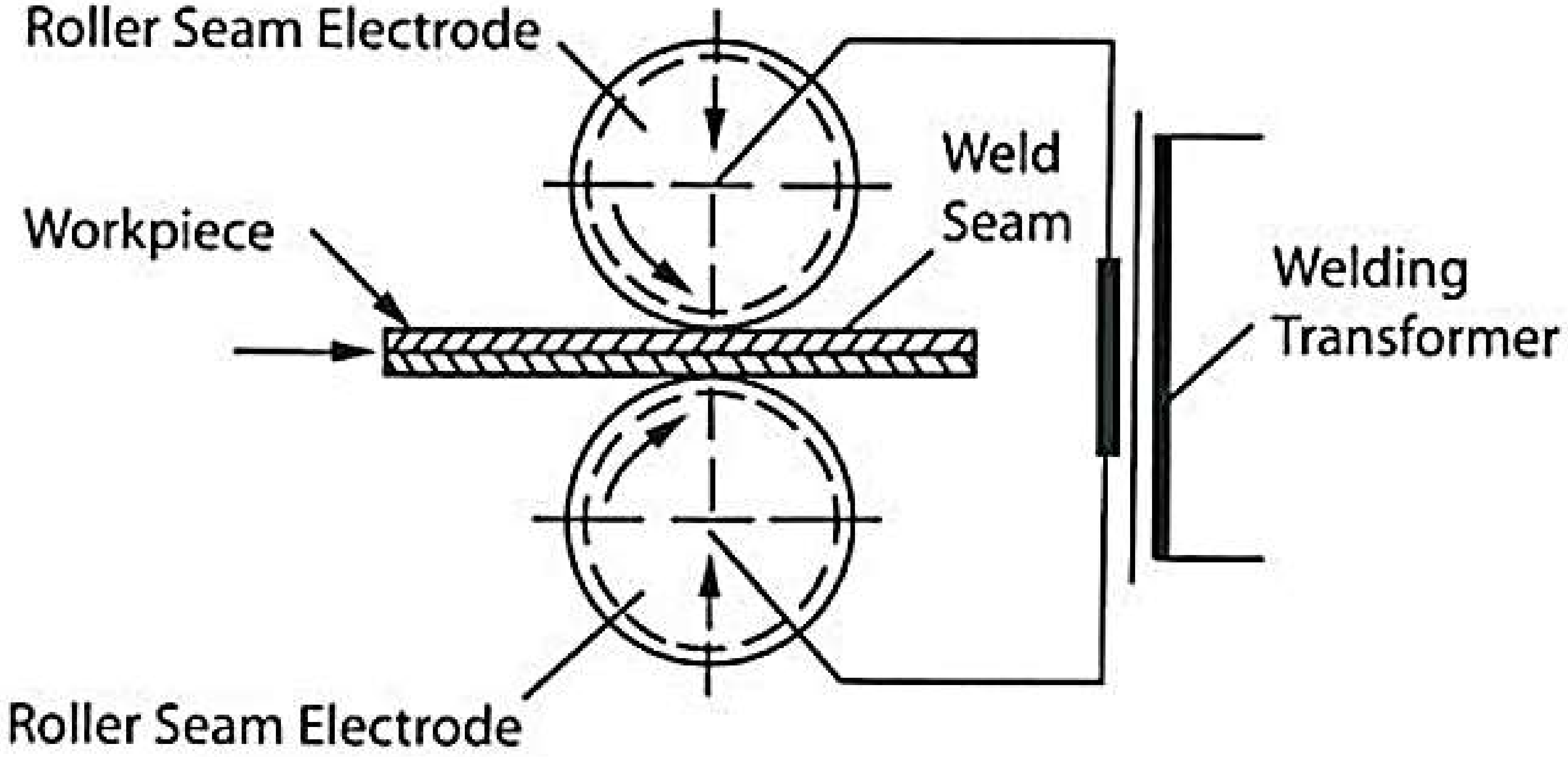
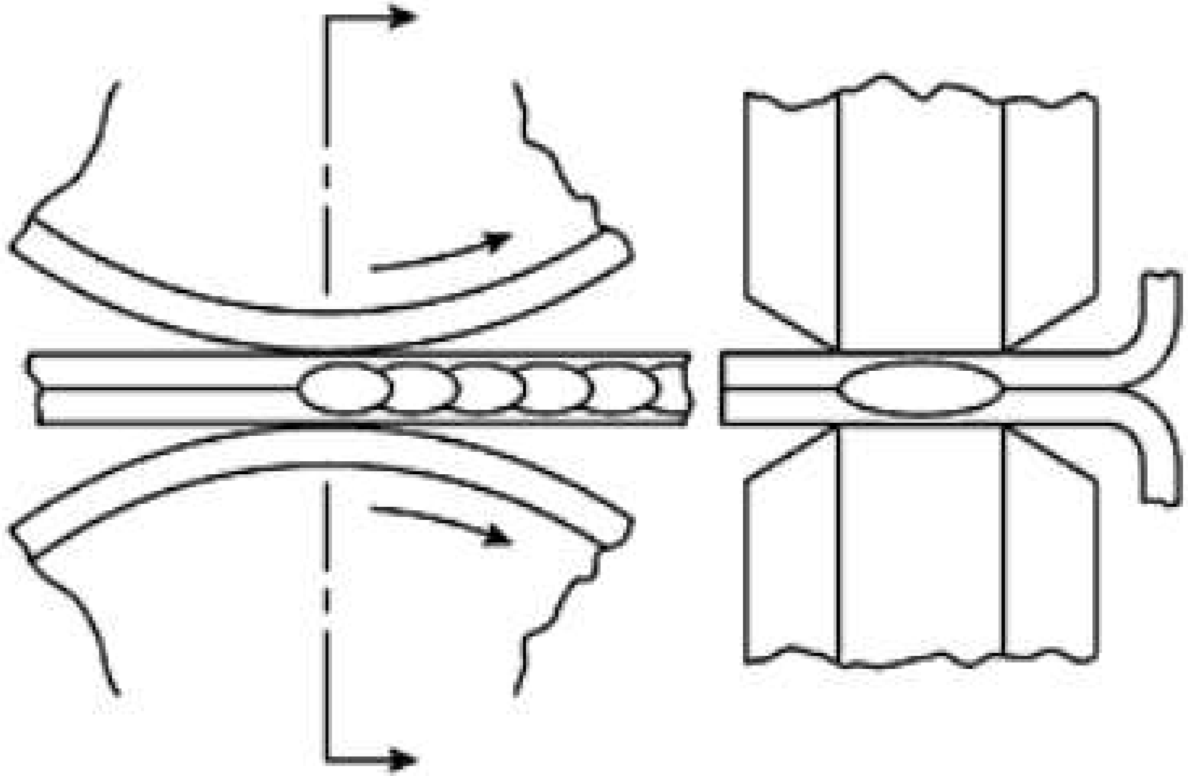
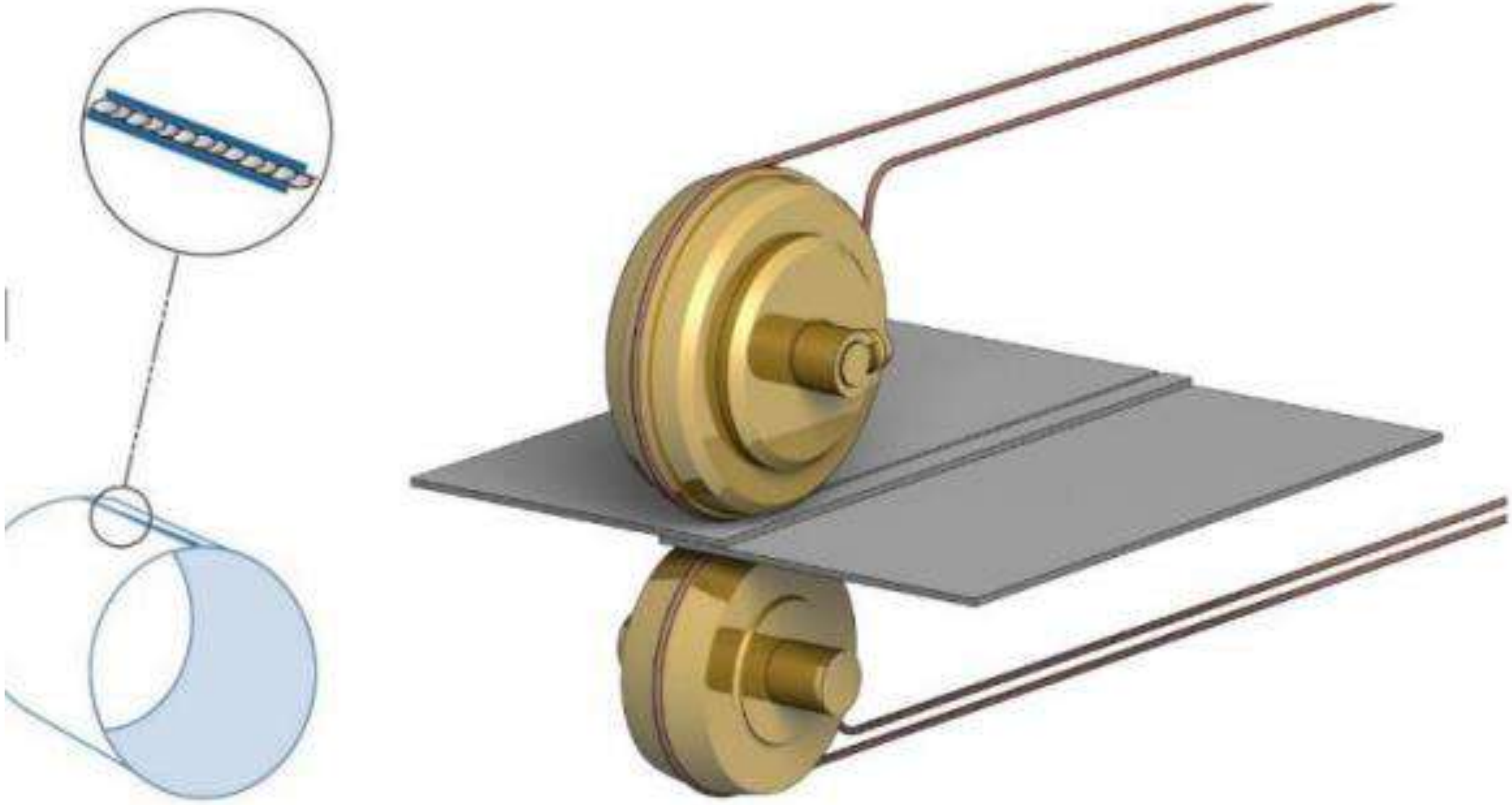


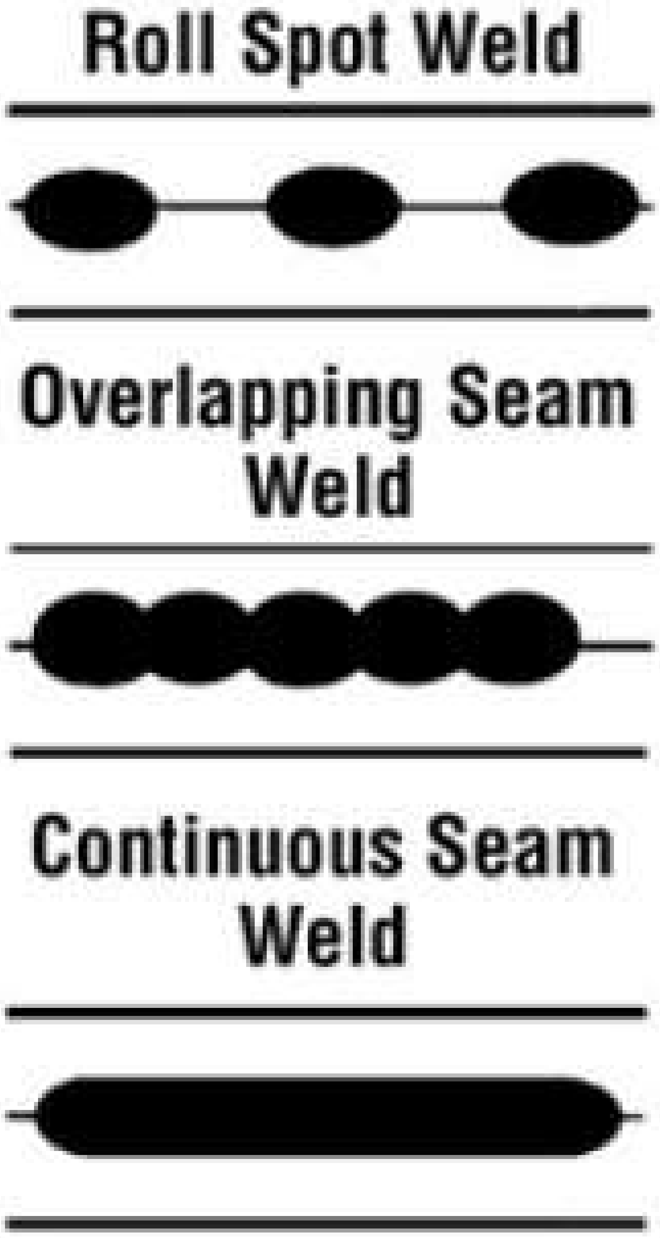
Fig. 4.2.1 Schematic of the Resistance Seam welding process

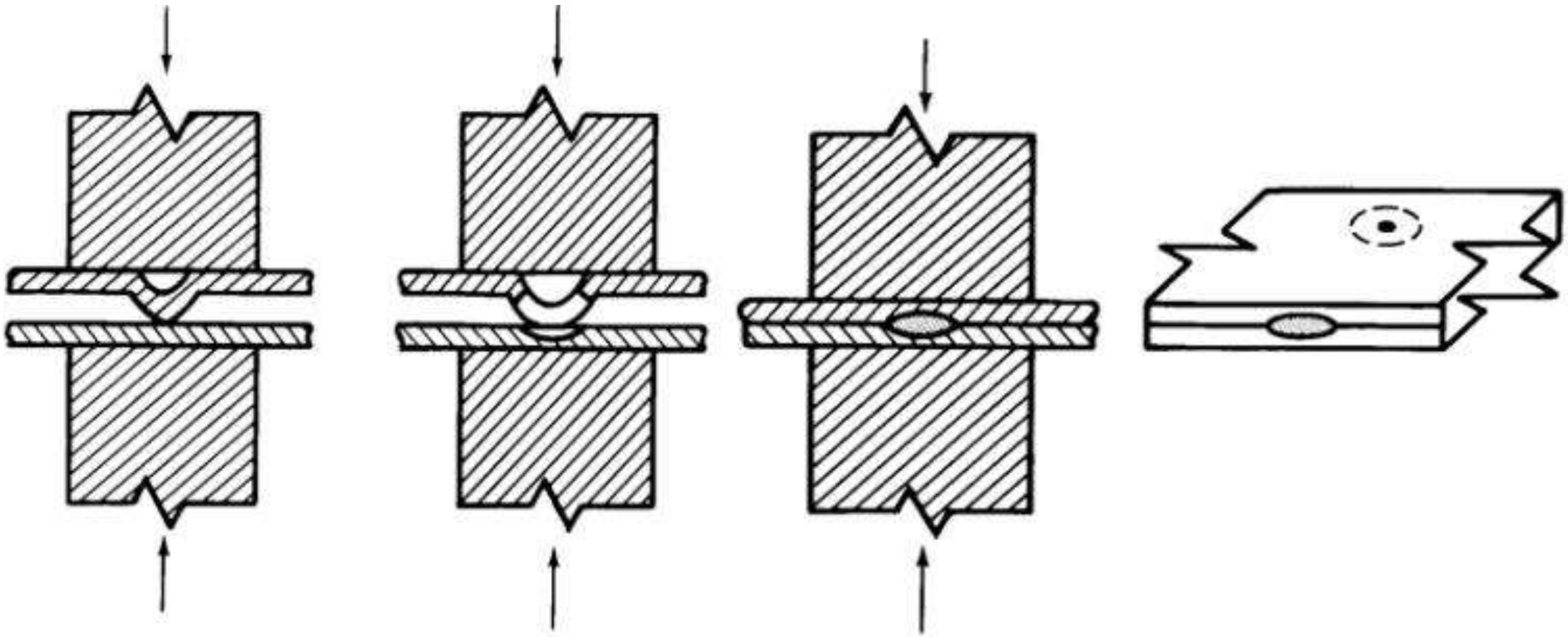


Resistance seam welding process

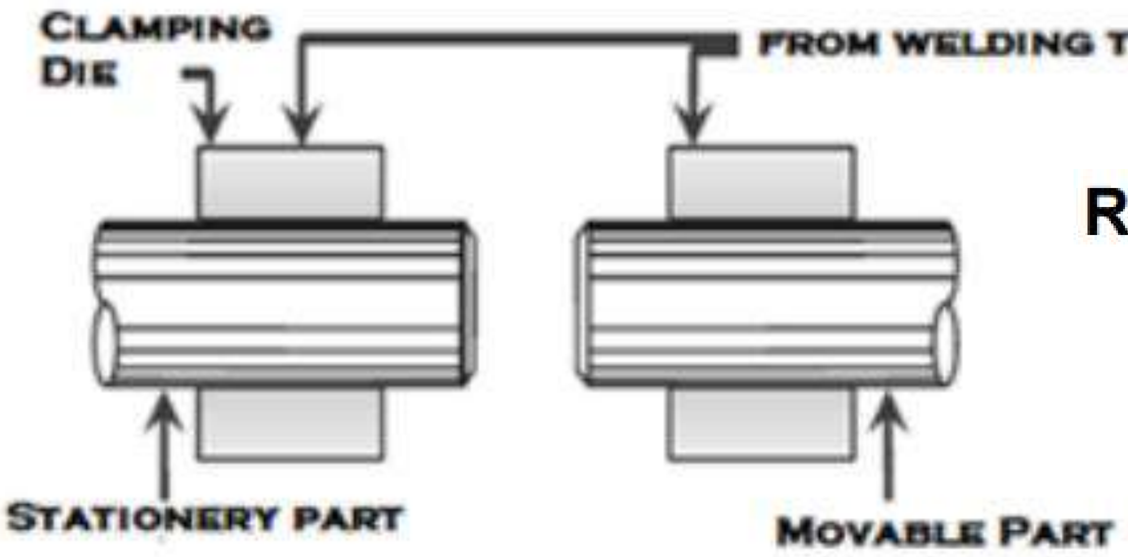


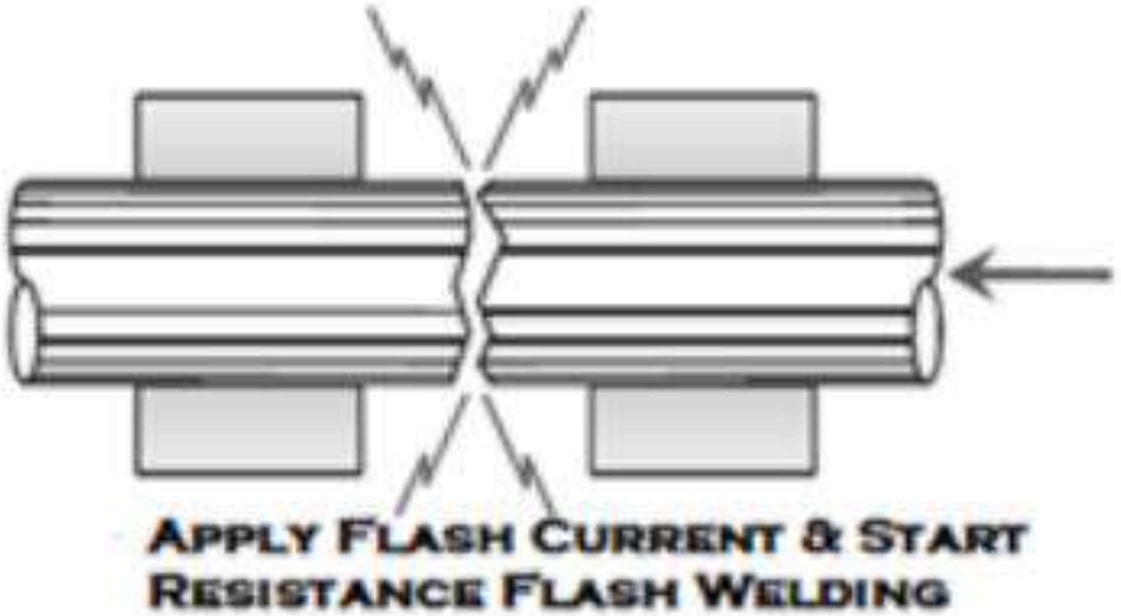

Roll Spot Weld
Overlapping Seam Weld
Continuous Seam Weld

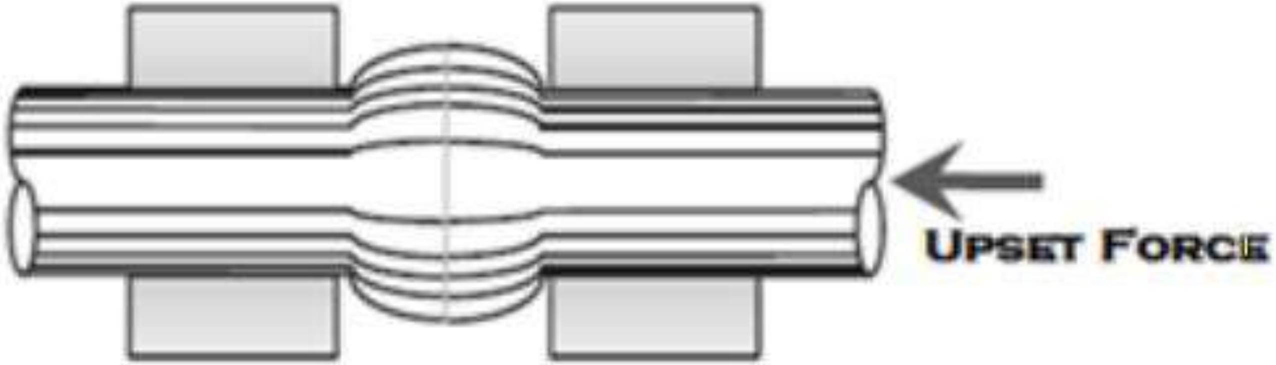


Process sequence of resistance projection welding

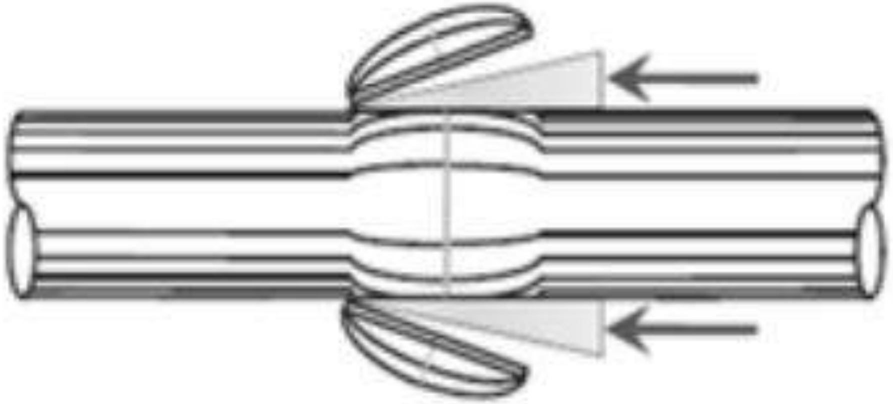
Resistance butt welding (flash welding)







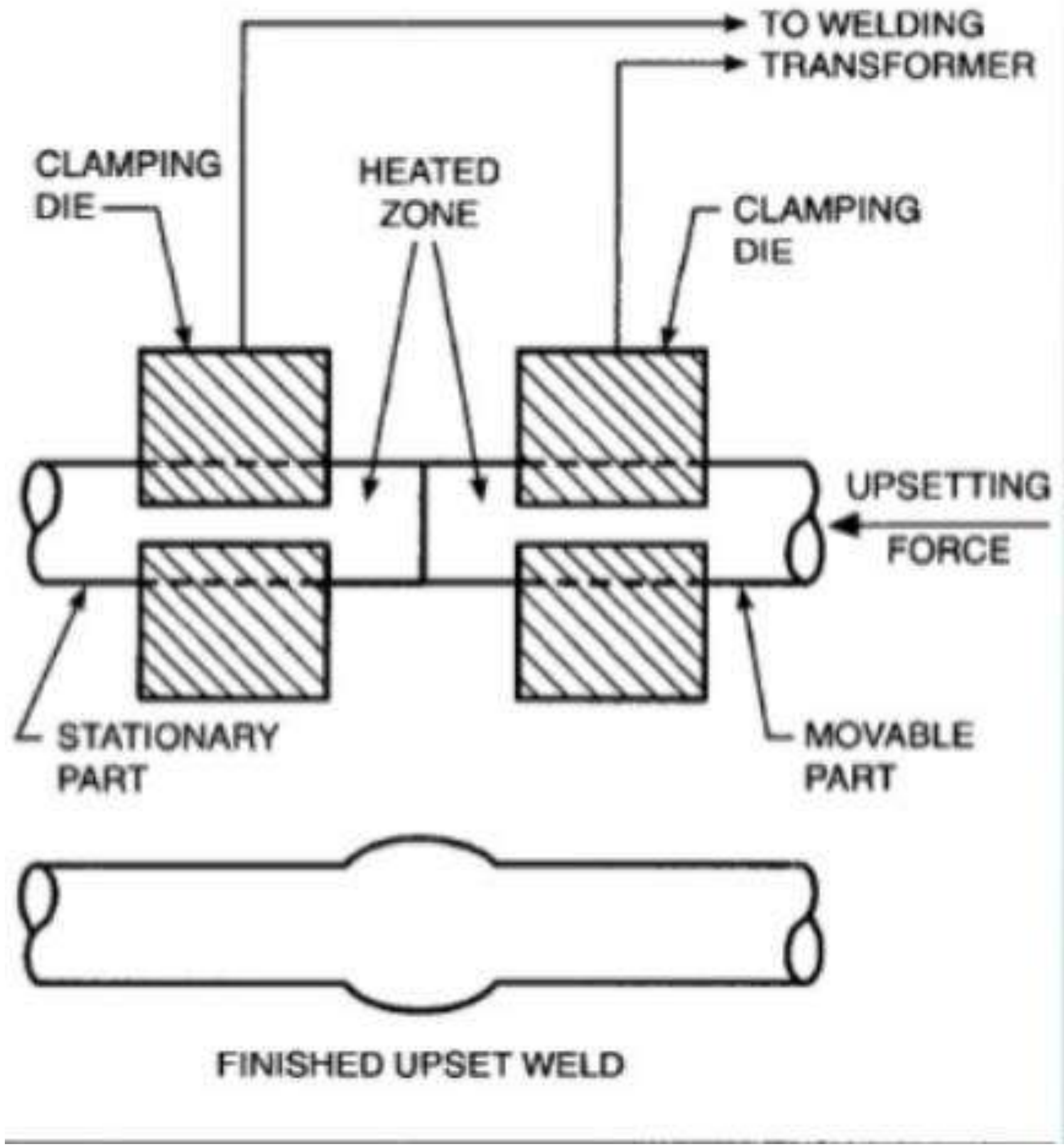
Upset & Terminate Current



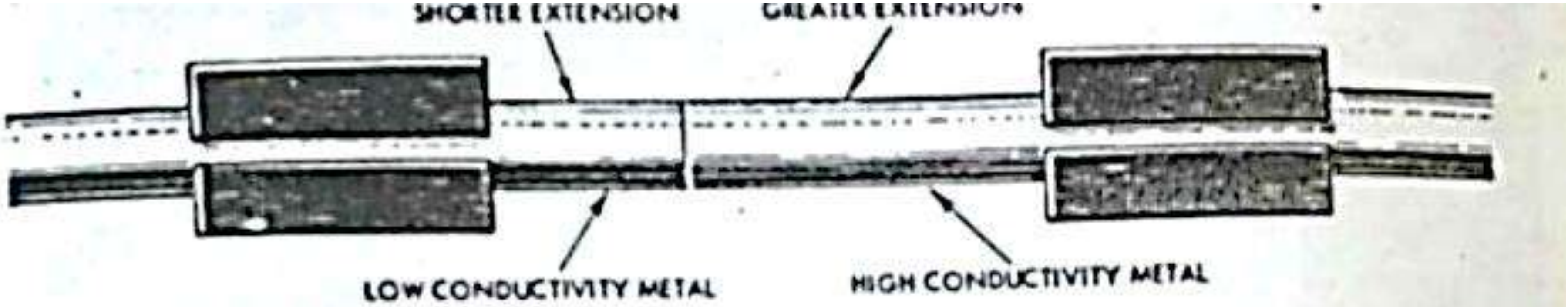
Trimming

Flash butt welding process sequence

UPSET WELDING/BUTT WELDING



HOW TO ACHIEVE HEAT BALANCE



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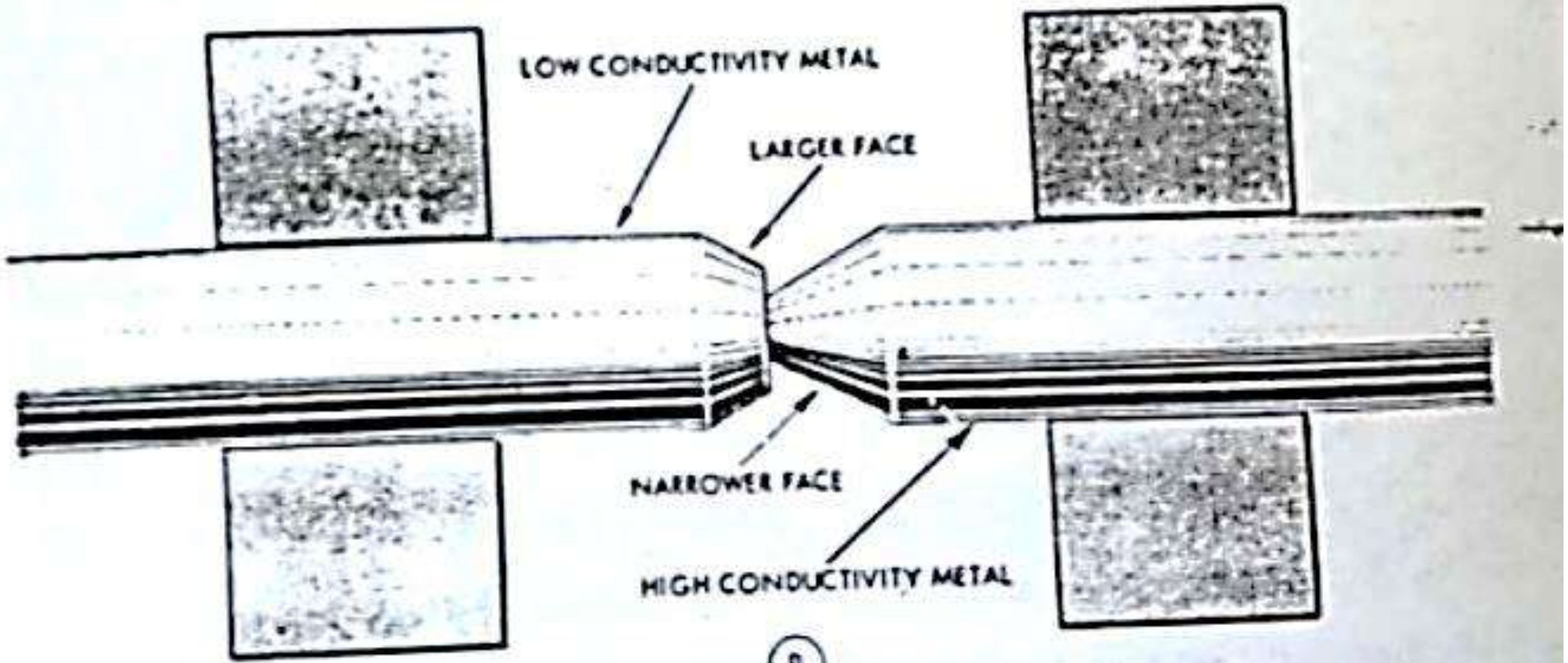
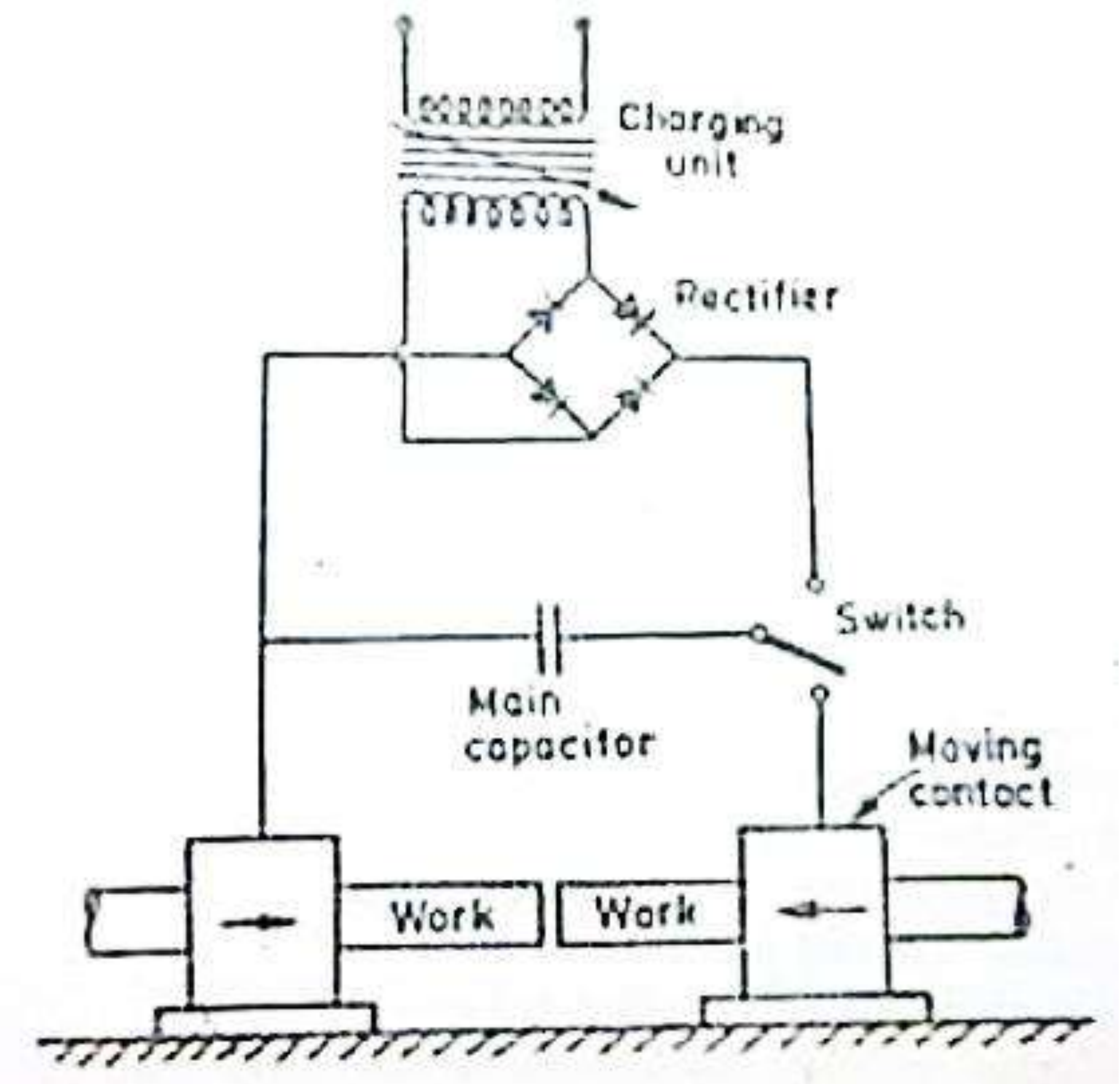


B

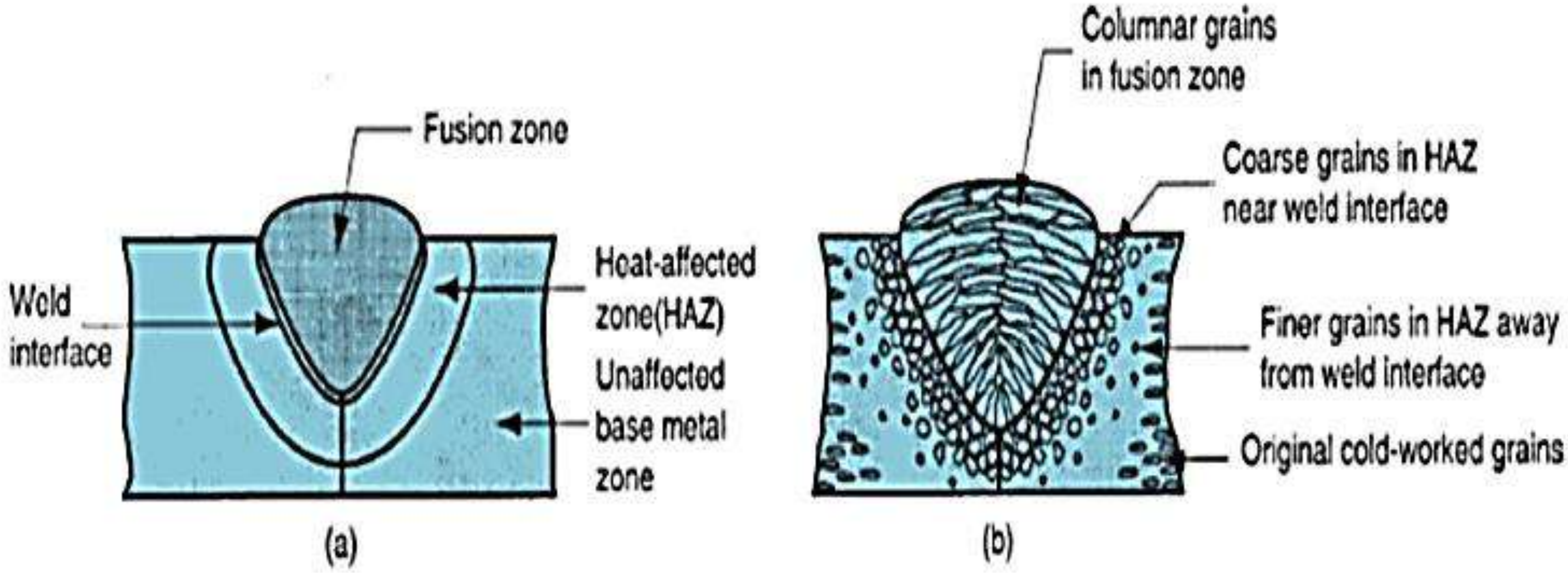
PERCUSSION WELDING



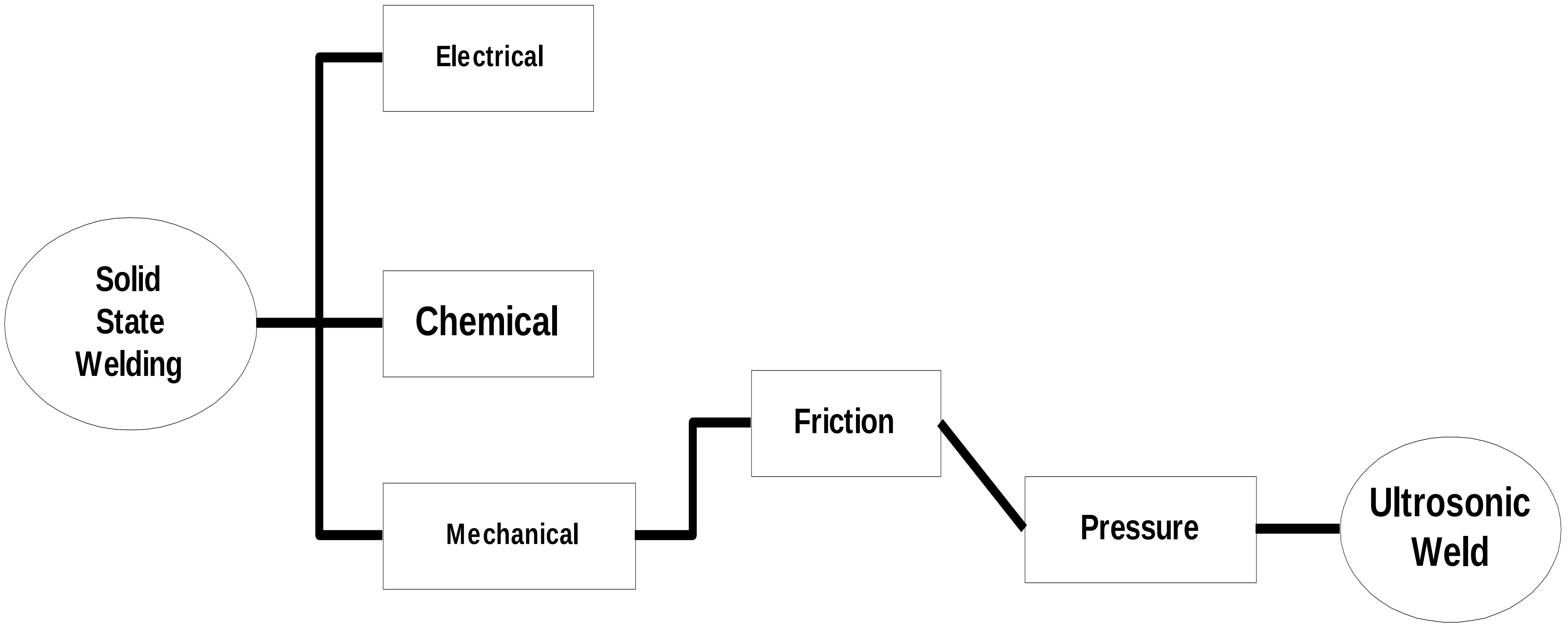
PERCUSSION WELDING

PROCESS IN WHICH HEAT IS PRODUCED FROM AN ARC THAT IS GENERATED BY THE RAPID DISCHARGE OF ELECTRICAL ENERGY BETWEEN THE WORKPIECES AND FOLLOWED BY IMMEDIATELY BY AN IMPACTING FORCE WHICH WELD THE PIECES TOGETHER

CROSS SECTION OF A TYPICAL FUSION WELDED JOINT



The fusion zone consists of a mixture of filler metal and base metal that have completely melted.



Solid State Welding
Electrical
Chemical
Mechanical
Friction
Pressure
Ultrosonic Weld

Ultrasonic welding (USW)

Moderate pressure is applied between the two parts and an oscillating motion at ultrasonic frequencies is used in a direction parallel to the contacting surfaces. The combination of normal and vibratory forces results in shear stresses that remove surface films and achieve atomic bonding of the surfaces.

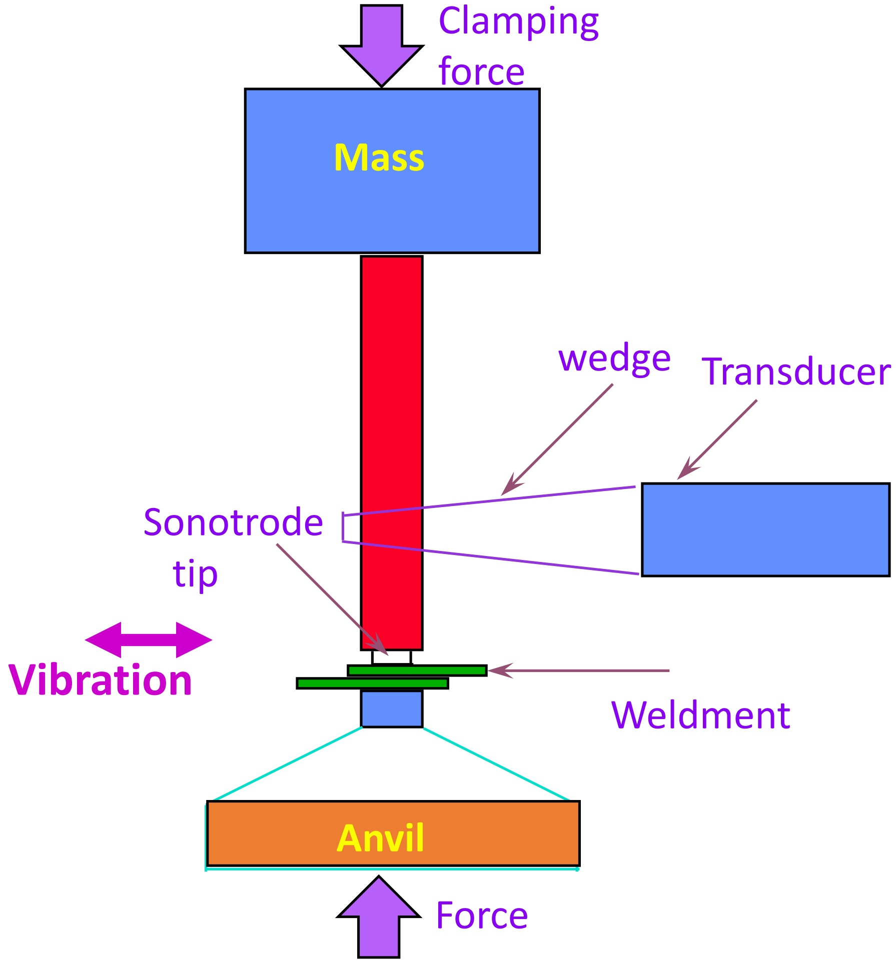
Definition of Ultrasonic Welding

A solid state welding process in which coalescence is produced at the faying surfaces by the application of high frequency vibratory energy while the work pieces are held together under moderately low static pressure.

Ultrasonic Welding Process

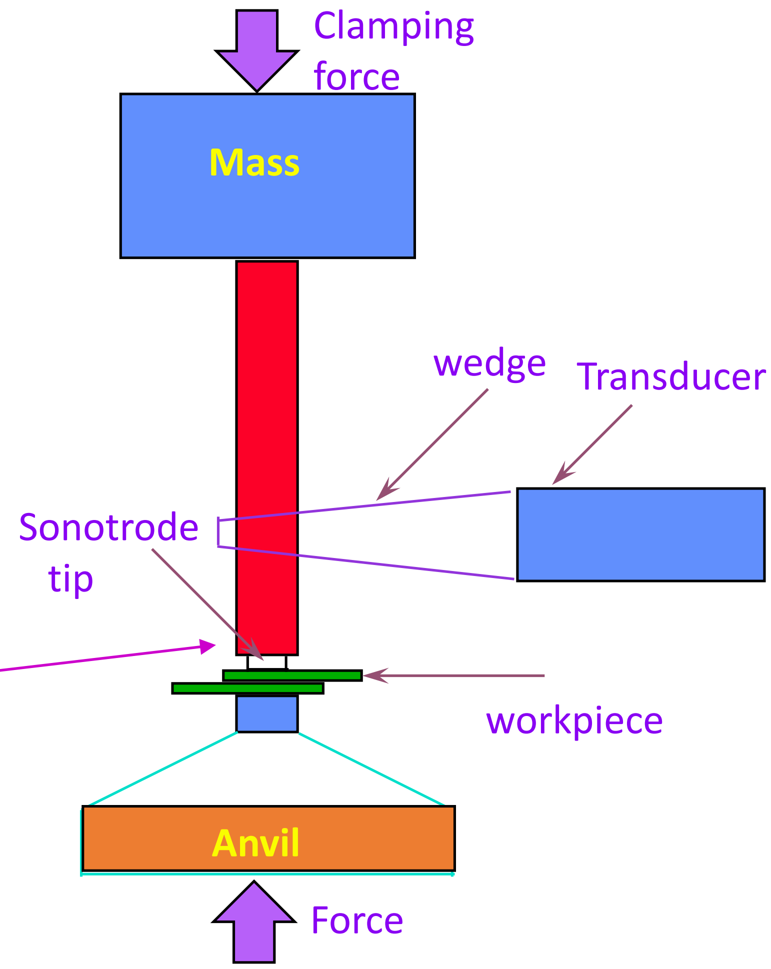
Process Description:

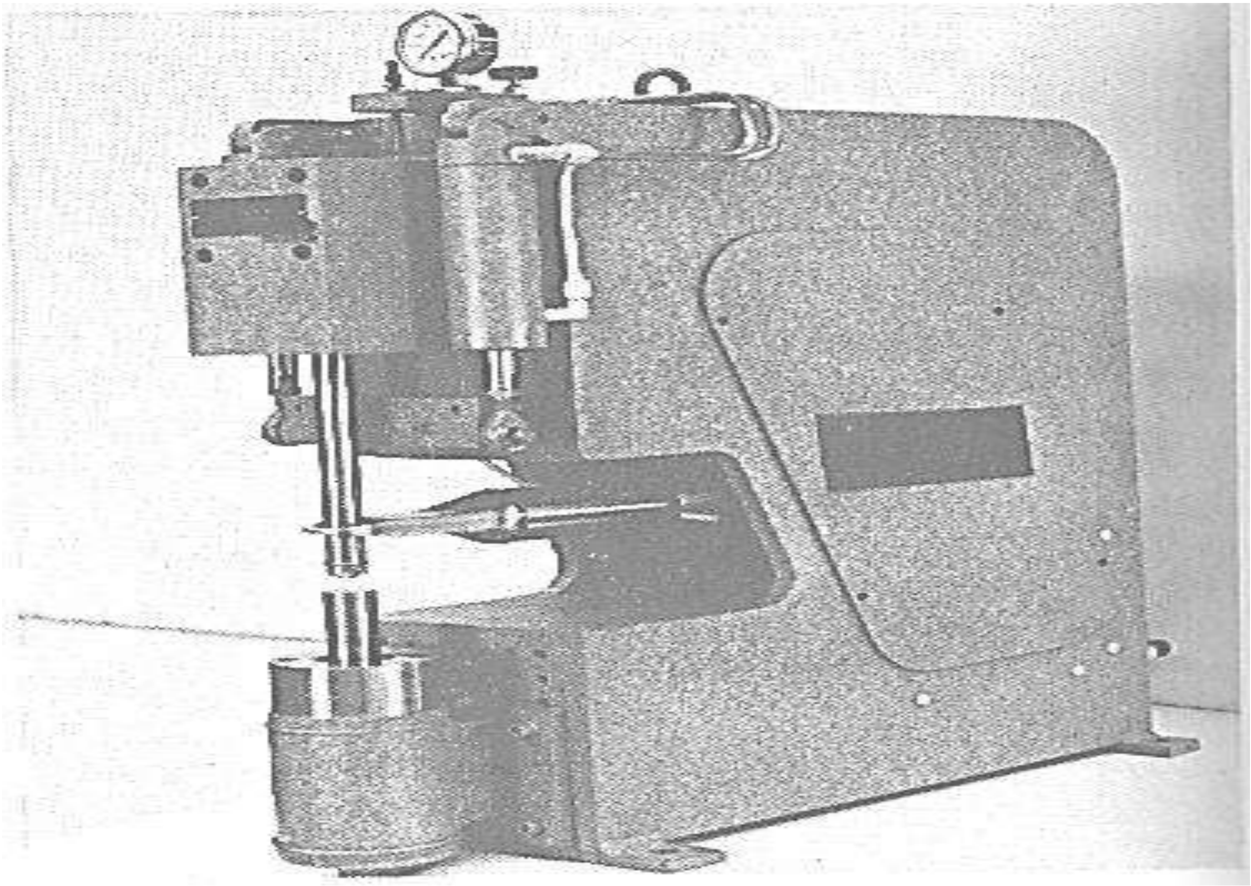
- Components of ultrasonic welding system include:
  - Transducer
  - Sonotrode
  - Anvil



Ultrasonic Welding Mechanism

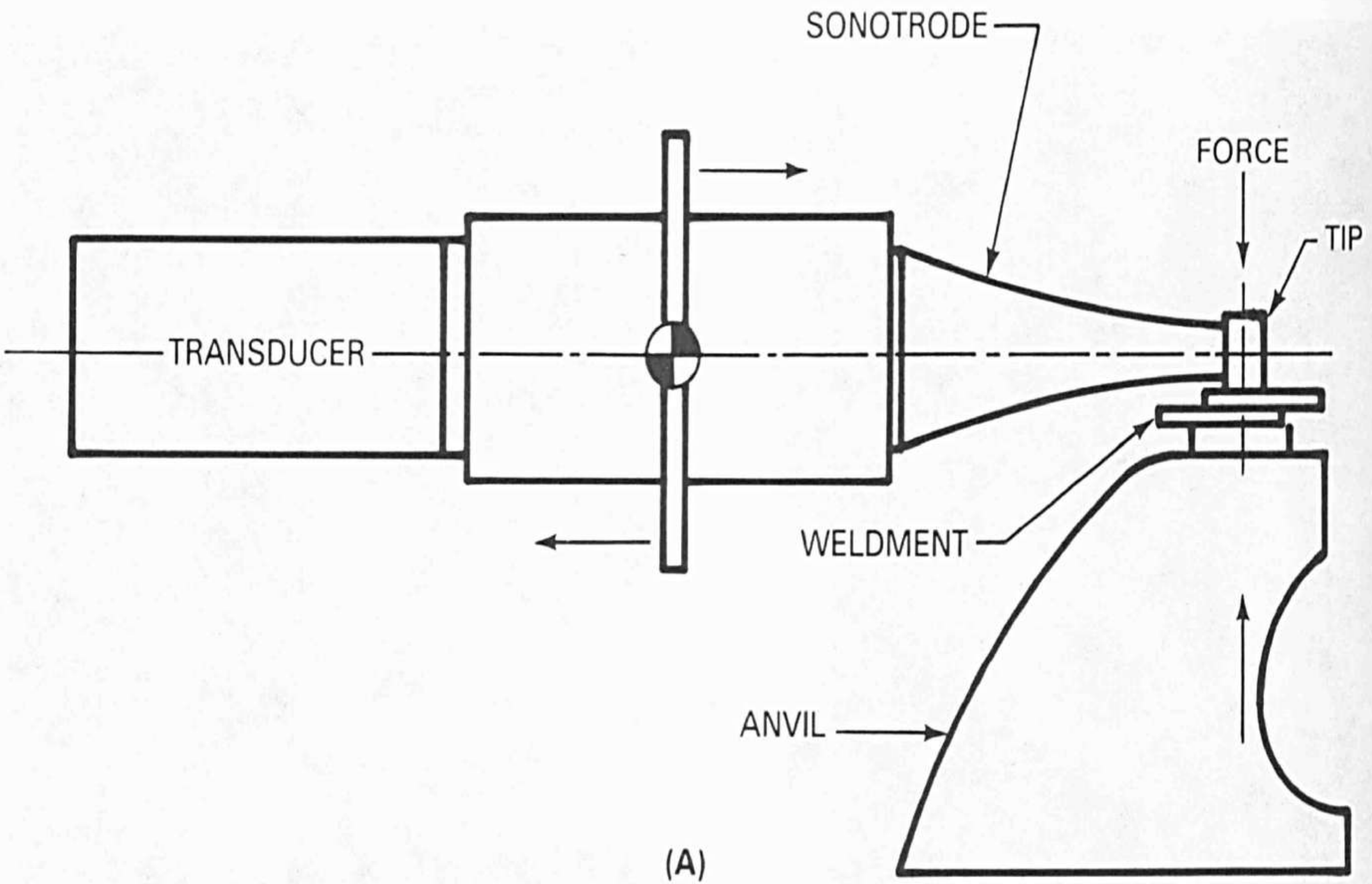
- A static clamping force is applied perpendicular to the interface between the work pieces.
- The contacting sonotrode oscillates parallel to the interface.
- Combined effect of static and oscillating force produces deformation which promotes welding.





ultrasonic
spot-type welding machine

Courtesy AWS handbook



(A)

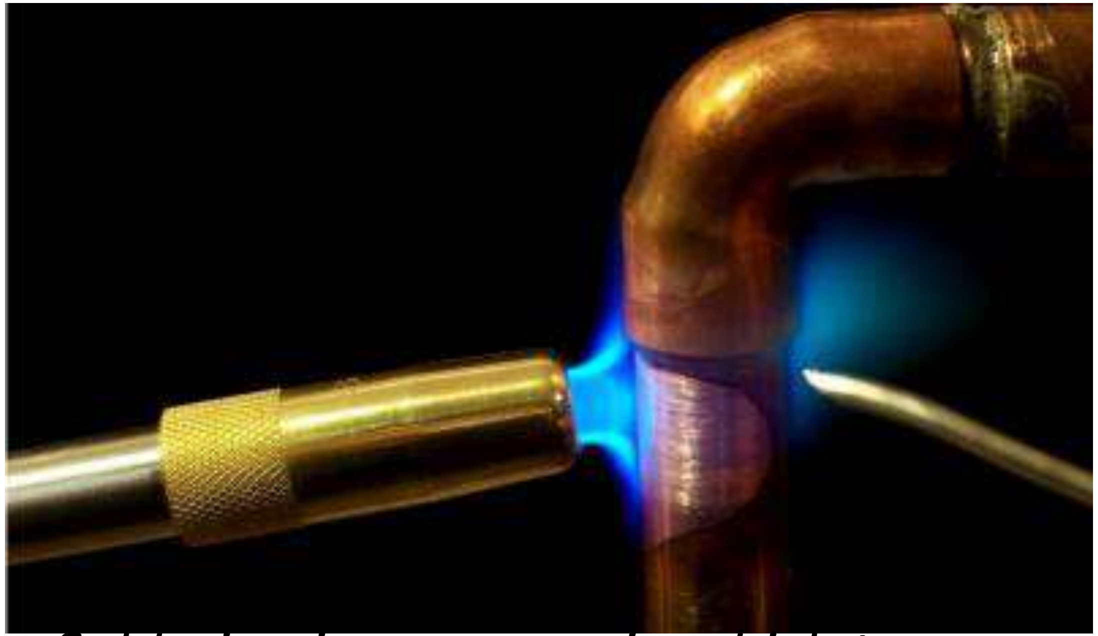
Advantages of Ultrasonic Welding

- No heat is applied and no melting occurs.
- Permits welding of thin to thick sections.
- Welding can be made through some surface coatings.
- Pressures used are lower, welding times are shorter, and the thickness of deformed regions are thinner than for cold welding.

Limitations of Ultrasonic Welding

- The thickness of the component adjacent to the sonotrode tip must not exceed relatively thin gages because of power limitations of the equipment.
- Process is limited to lap joints.
- Butt welds can not be made because there is no means of supporting the workpieces and applying clamping force.

SOLDERING



- *Soldering is a process in which two or more metal items are joined together by melting and flowing a filler metal (solder) into the joint*
- *the* ***filler metal having a lower melting point than the adjoining metal.***
- *Soldering differs from welding in that* ***soldering does not involve melting the work pieces.***
- *In brazing, the filler metal melts at a higher temperature, but in* ***soldering filler alloy melts at lower temperature than brazing****.*
- *Used for* ***low strength applications*** *like electronics and plumbing*

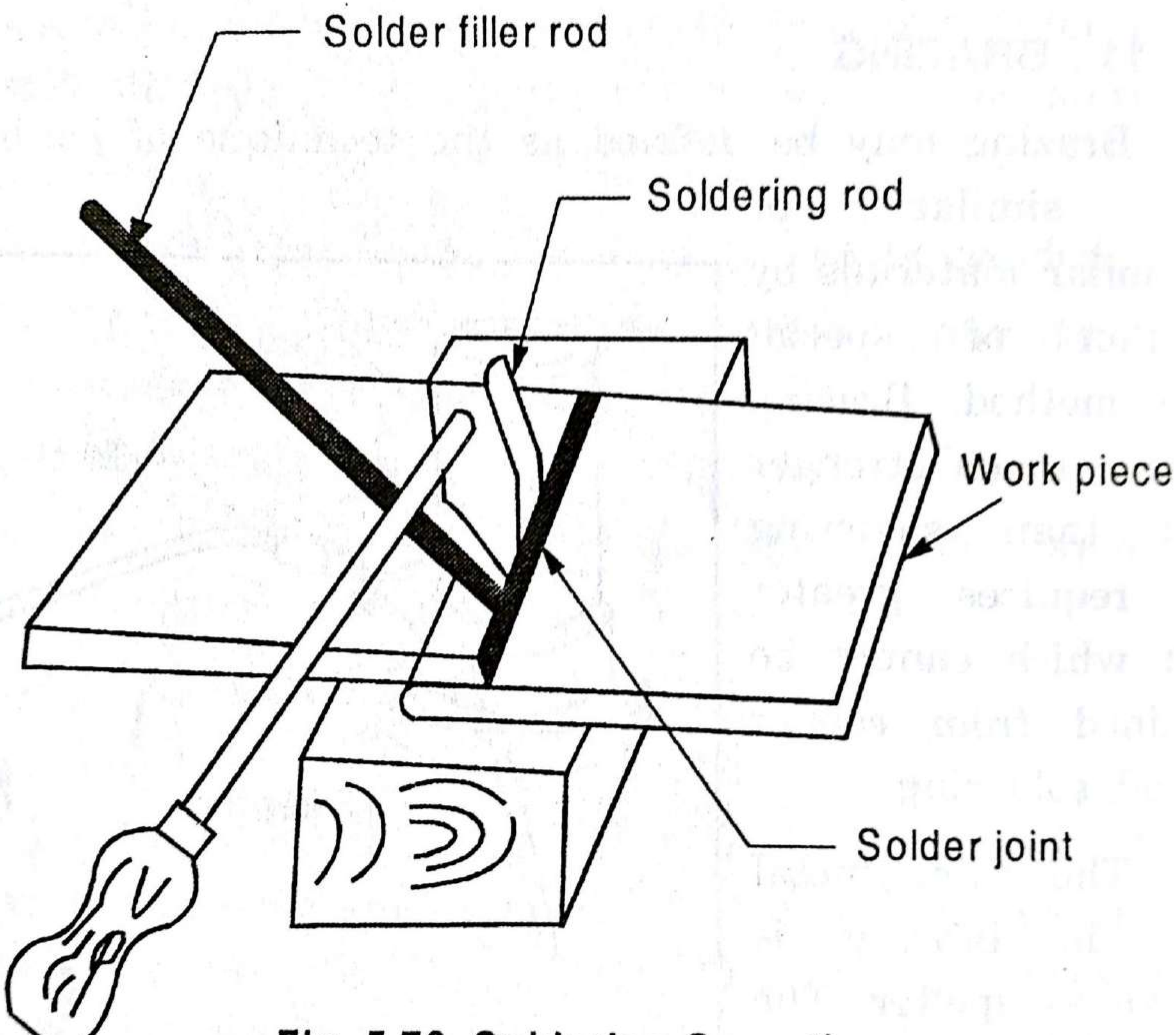


Fig. 5.73. Soldering Operation

TYPES OF SOLDERS

- Tin Lead solders
- 60% Tin and 40% lead
- 50% Tin and 50% lead
- Tin-Antimony-Lead solders
- Lead Silver solders
- Cadmium Silver Solders

FLUXES USED FOR SOLDERING

1. INORGANIC ACIDS

2. NON CORROSIVE RESIN BASED FLUXES

TYPES OF SOLDERING METHODS

1. SOLDERING IRON METHOD

2. DIP AND WAVE METHOD

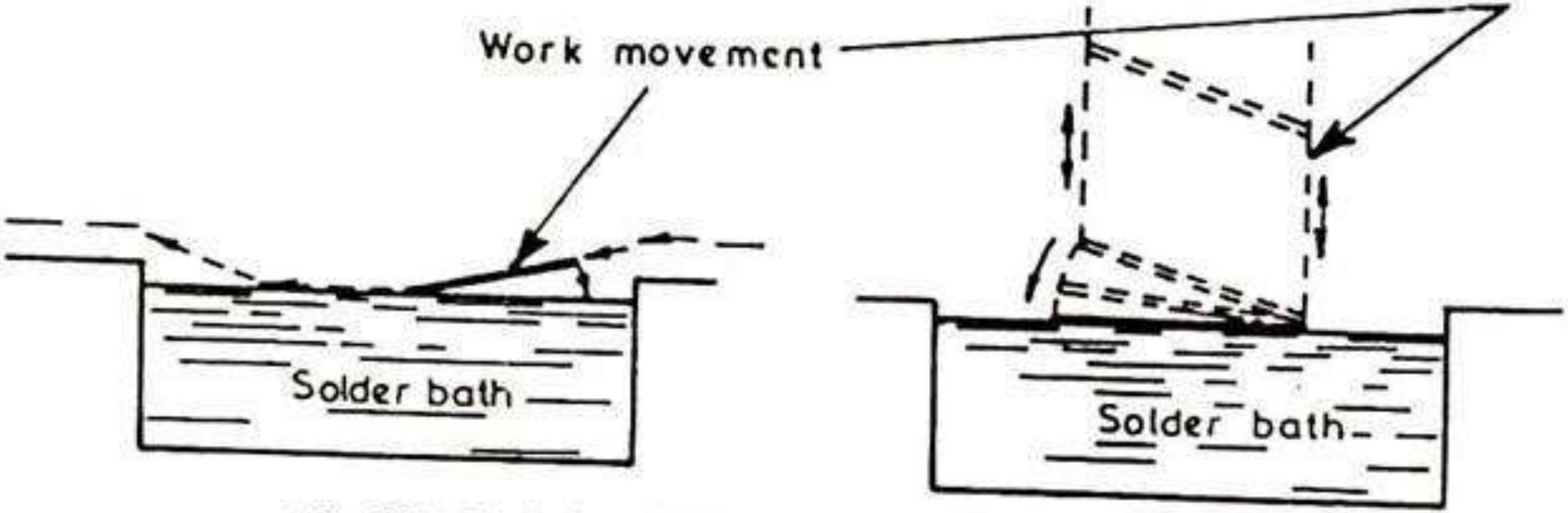
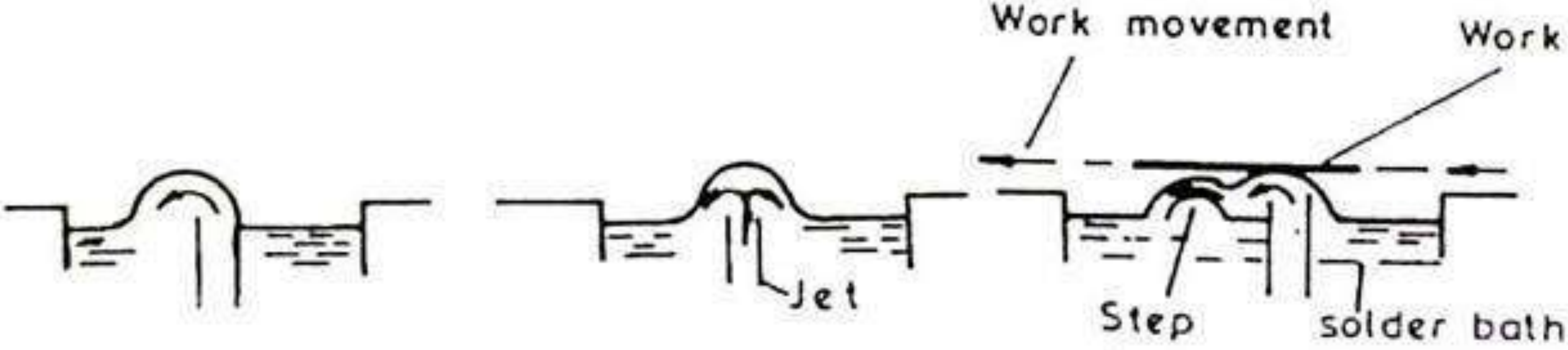


Fig. 17·4 Typical workpiece movements in dip soldering.



(a) Single wave (b) Double wave (c) Series wave

Fig. 17·5 Wave soldering techniques.

BRAZING

Aluminum or copper alloys are used as filler materials

Brazing *is a metal-joining process in which two or more metal items are joined together by melting and flowing a filler metal into the joint,* ***the filler metal having a lower melting point than the adjoining metal.***

Brazing differs from welding in that it ***does not involve melting the work pieces*** *and from soldering in using higher temperatures for a similar process.*

It is similar to soldering, except the ***temperatures used to melt the filler metal are higher for brazing than soldering****.*

A major advantage of brazing is the ability to ***join the same or different metals with considerable strength****.*

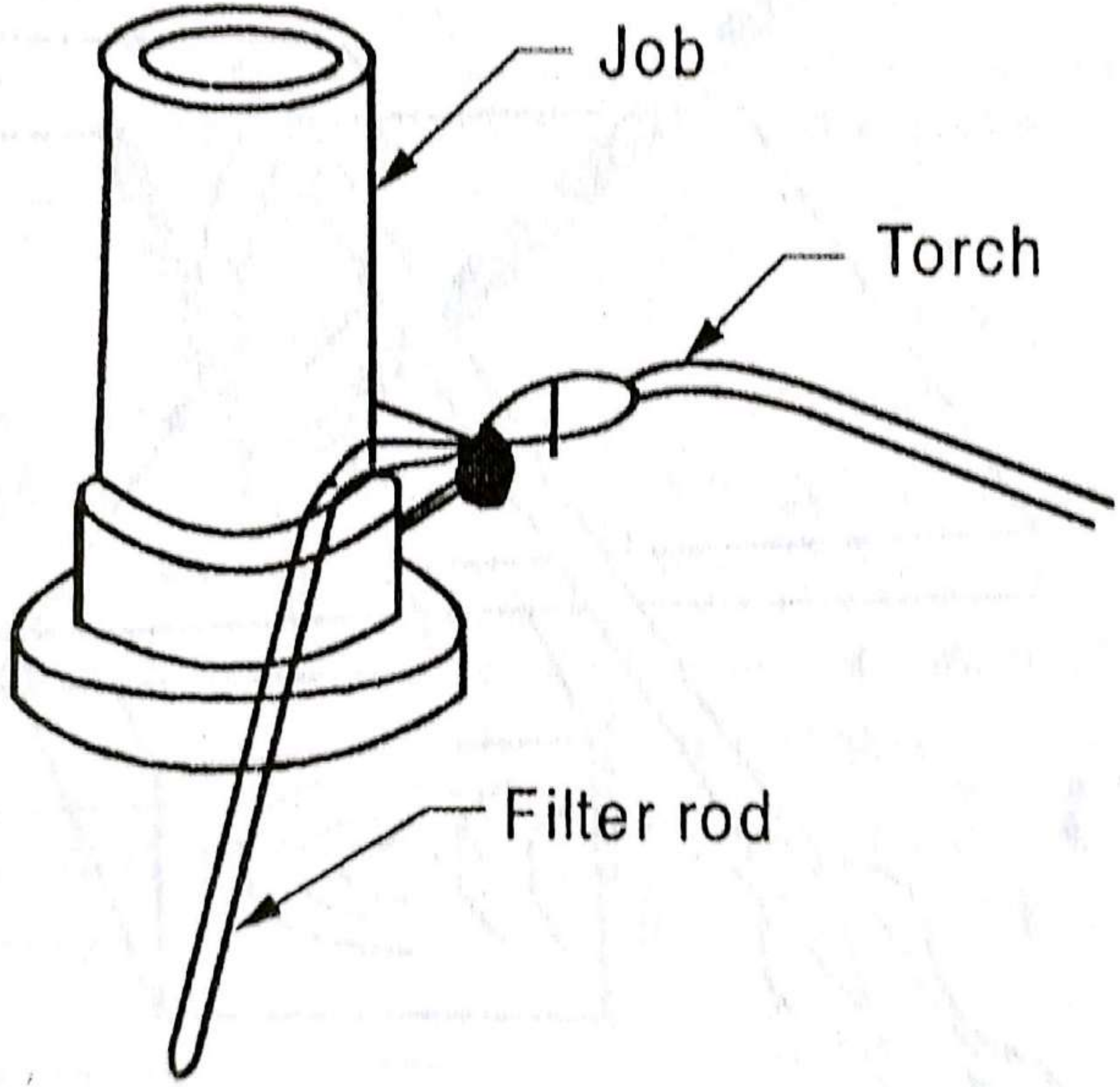


Fig. 5.72 Brazing Operation

FILLER METALS IN BRAZING

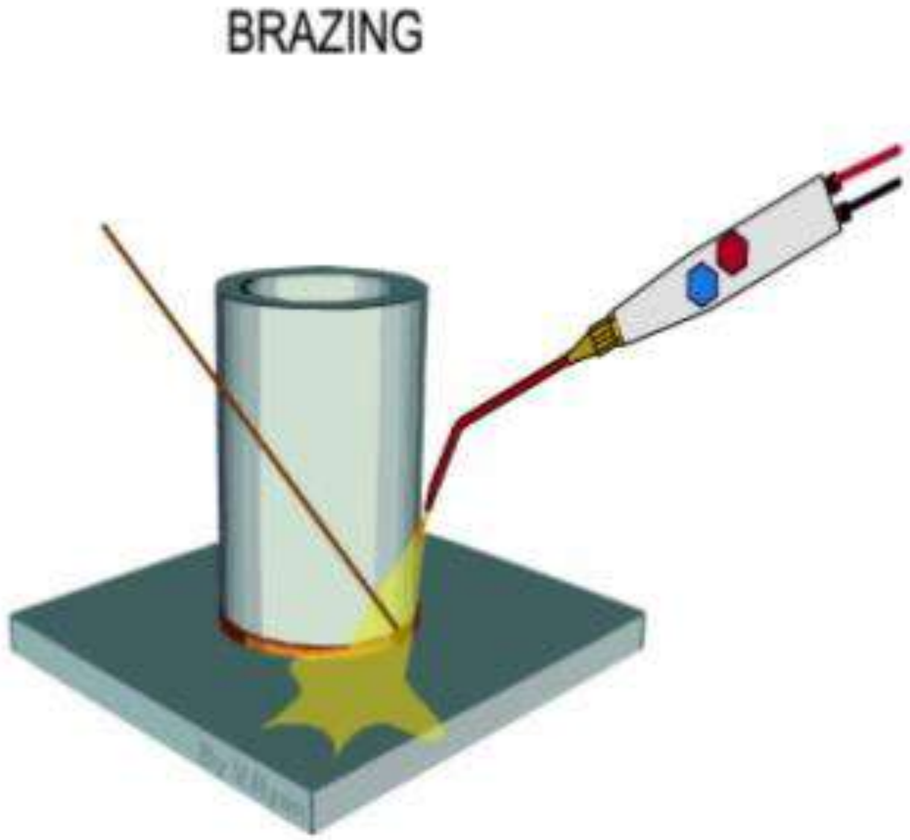
1. ALUMINIUM & SILICON
2. COPPER & PHOSPHEROUS
3. COPPER & ZINC

BRAZING PROCESSES

1. TORCH BRAZING
2. VACUUM BRAZING

Brazing Methods:

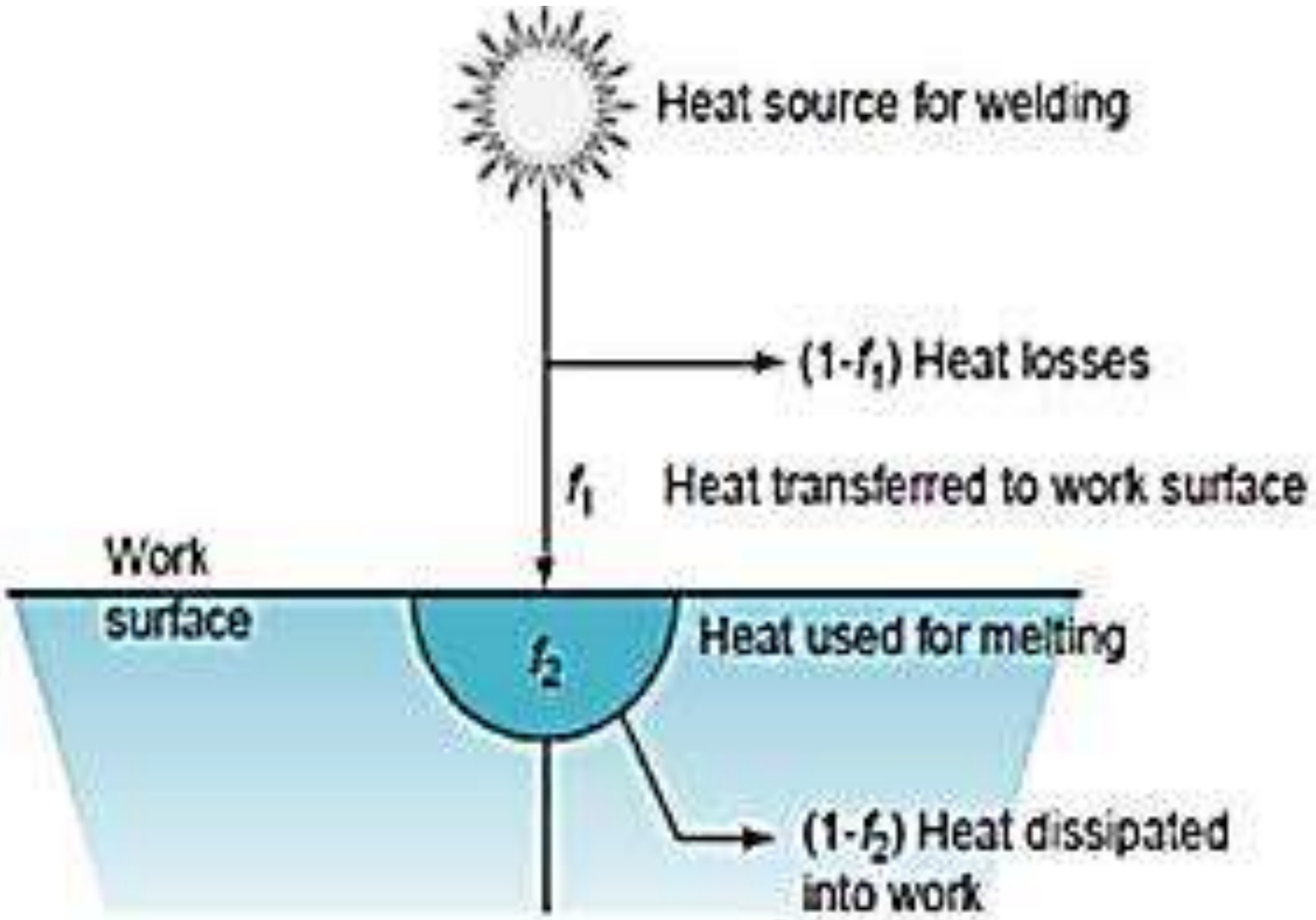
- **Torch Brazing:-** flux is applied to the part surfaces and a torch is used to focus flame against the work at the joint. A reducing flame is used to prevent the oxidation.



- .

	Soldering	Brazing	Welding
1	These are weakest joint out of three. Not meant to bear the load. Use to make electrical contacts generally.	These are stronger than soldering but weaker than welding. These can be used to bear the load upto some extent.	These are the strongest joints used to bear the load. Strength of a welded joint may be more than the strength of base metal.
2	Temperature requirement is upto 450°C.	It may go to 600°C in brazing.	Temperature required is upto 3800°C of welding zone.
3	No need to heat the workpieces.	Workpieces are heated but below their melting point.	Workpiece to be joined need to be heated till their melting point.

	Soldering	Brazing	Welding
4	No change in mechanical properties after joining.	May change in mechanical properties of joint but it is almost negligible.	Mechanical properties of base metal may change at the joint due to heating and cooling.
5	Cost involved and skill requirements are very low.	Cost involved and skill required are in between the other two.	High cost is involved and high skill level is required.
6	No heat treatment is required.	No heat treatment is required after brazing.	Heat treatment is generally required to eliminate undesirable effects of welding.
7	Preheating of workpieces before soldering is good for making good quality joint.	Preheating is desirable to make strong joint as brazing is carried out at relatively low temperature.	No preheating of workpiece is required before welding as it is carried out at high temperature.


Heat source for welding
(1-f_1) Heat losses
f_1
Heat transferred to work surface
Work surface
f_2
Heat used for melting
(1-f_2) Heat dissipated into work

TYPES OF FLAMES

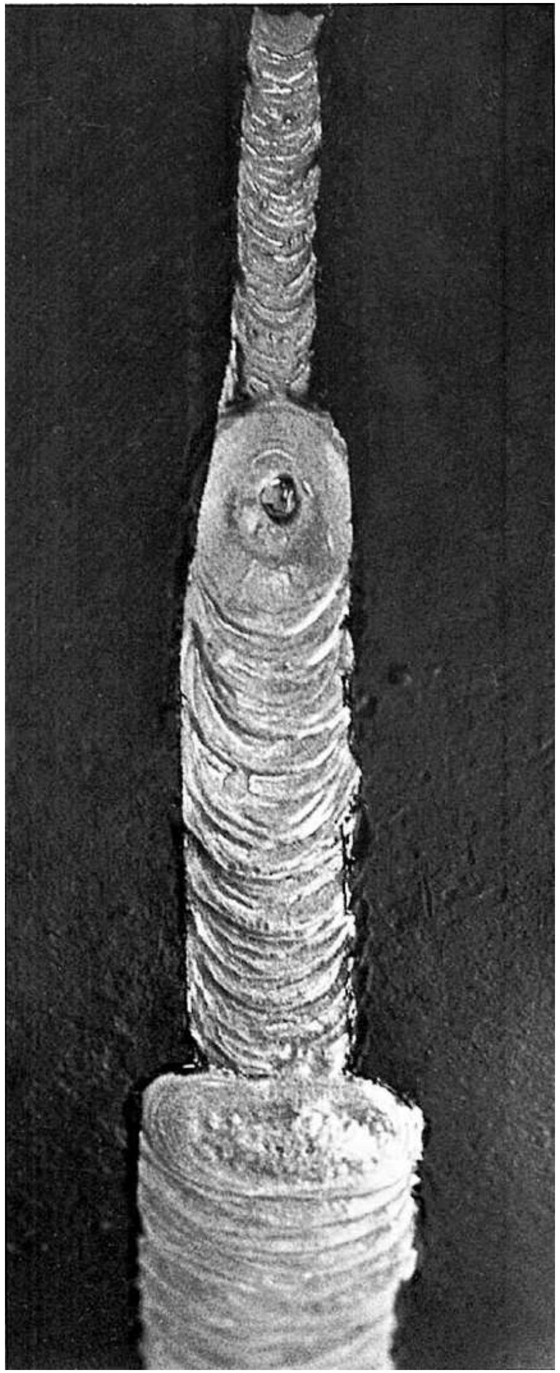
- Oxygen is turned on, flame immediately changes into a long white inner area (Feather) surrounded by a transparent blue envelope is called **Carburizing flame** (3000^0c)

- Addition of little more oxygen give a bright whitish cone surrounded by the transparent blue envelope is called **Neutral flame** (It has a balance of fuel gas and oxygen) (3200^0c)
- Used for welding steels, aluminium, copper and cast iron

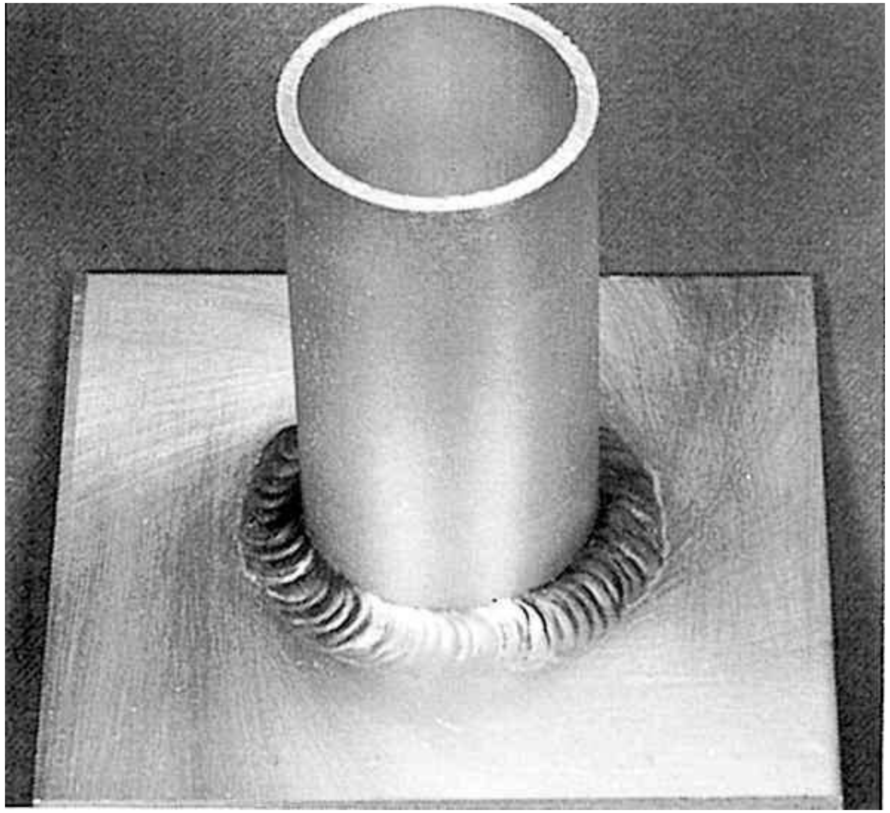
- If more oxygen is added, the cone becomes darker and more pointed, while the envelope becomes shorter and more fierce is called **Oxidizing flame**
- Has the highest temperature about 3400^0c
- Used for welding brass and brazing operation

Multipass Welds

Ability to make multipass welds such as this one, on plate and pipe, led to growth of industry. Welds are sound and have uniform appearance.



- Patent issued in 1930 to Hobart and Devers for use of electric arc within inert gas atmosphere
- Tungsten electrode replace magnesium procedure Patent issue in 1942
- Linde Company developed gas tungsten arc welding (GTAW)
  - Also called tungsten inert gas (TIG) process or HELIARC



An aluminum weld made using the TIG process. The welding of aluminum is no longer a problem and can be done with the same ease as that of steel.

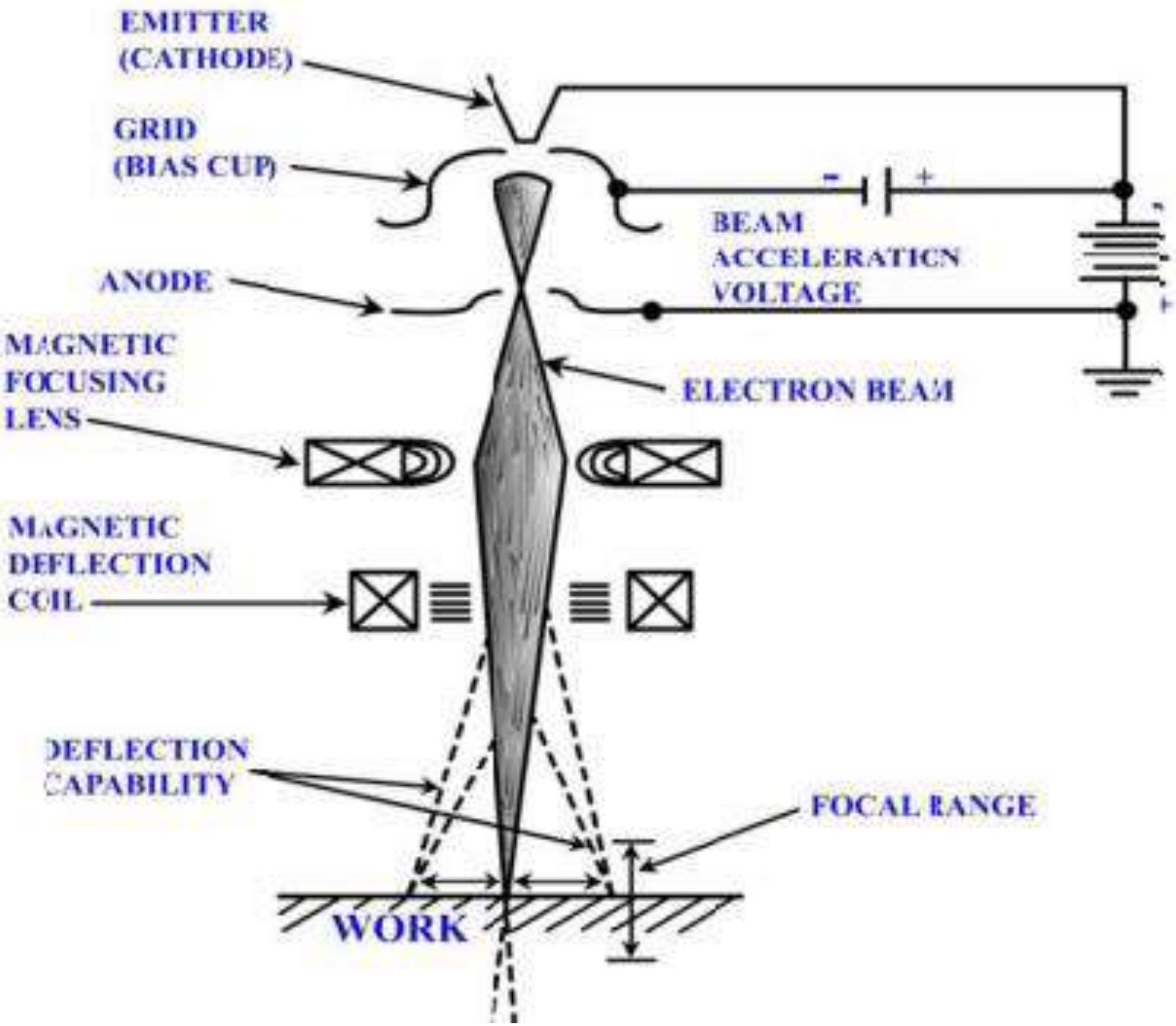
HIGH ENERGY BEAM WELDING

- ELECTRON BEAM WELDING
- LASER BEAM WELDING

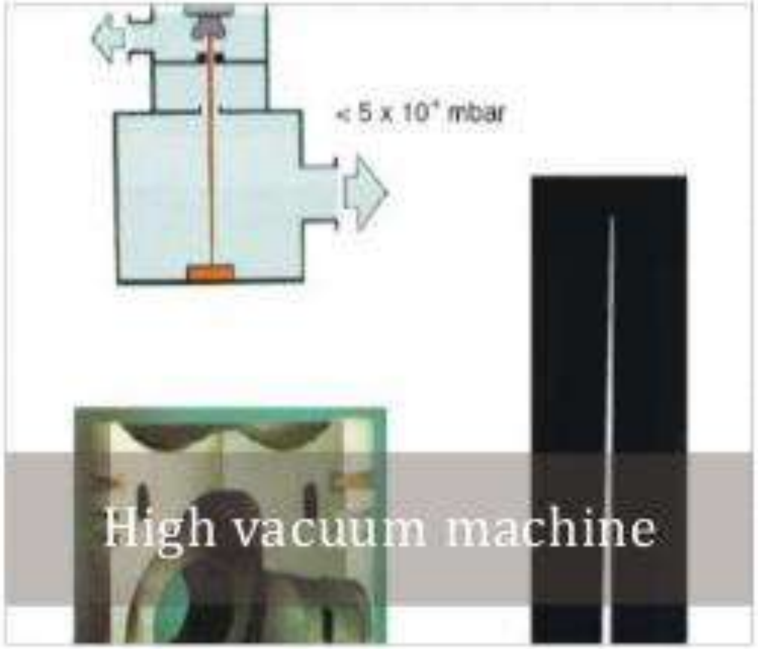
ELECTRON BEAM WELDING

EBW set up

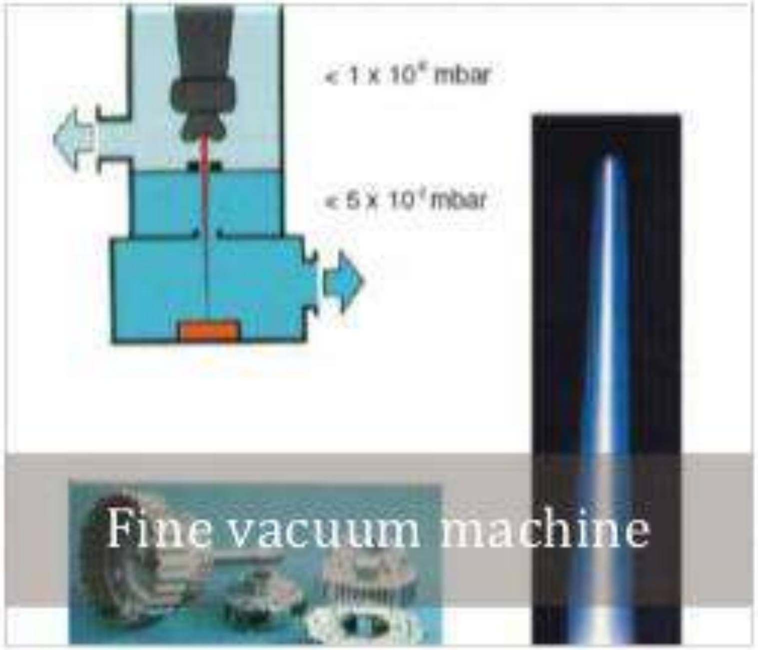
a) Electron gun,
b) Power supply,
c) Vacuum Chamber,
d) Work piece handling device



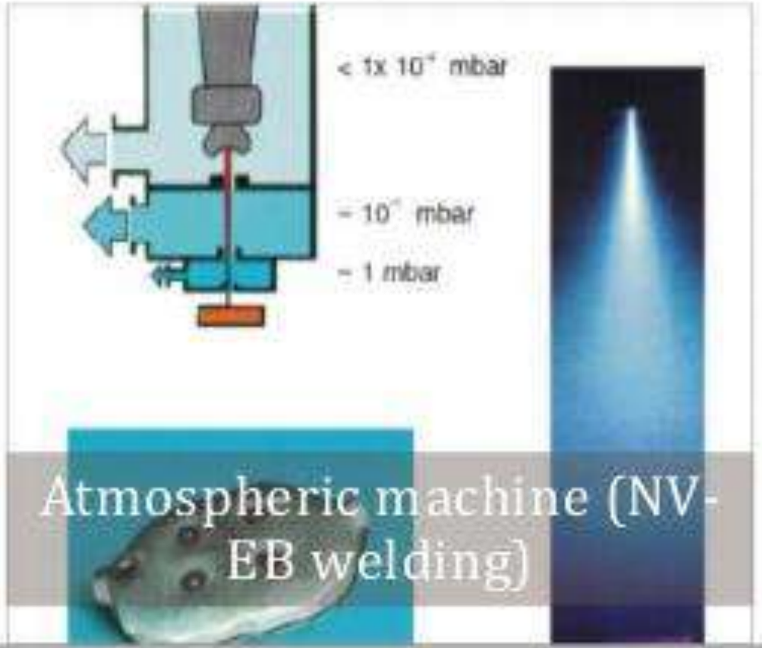
EMITTER
(CATHODE)
GRID
(BIAS CUP)
BEAM
ACCELERATION
VOLTAGE
ANODE
MAGNETIC
FOCUSING
LENS
ELECTRON BEAM
MAGNETIC
DEFLECTION
COIL
DEFLECTION
CAPABILITY
FOCAL RANGE
WORK



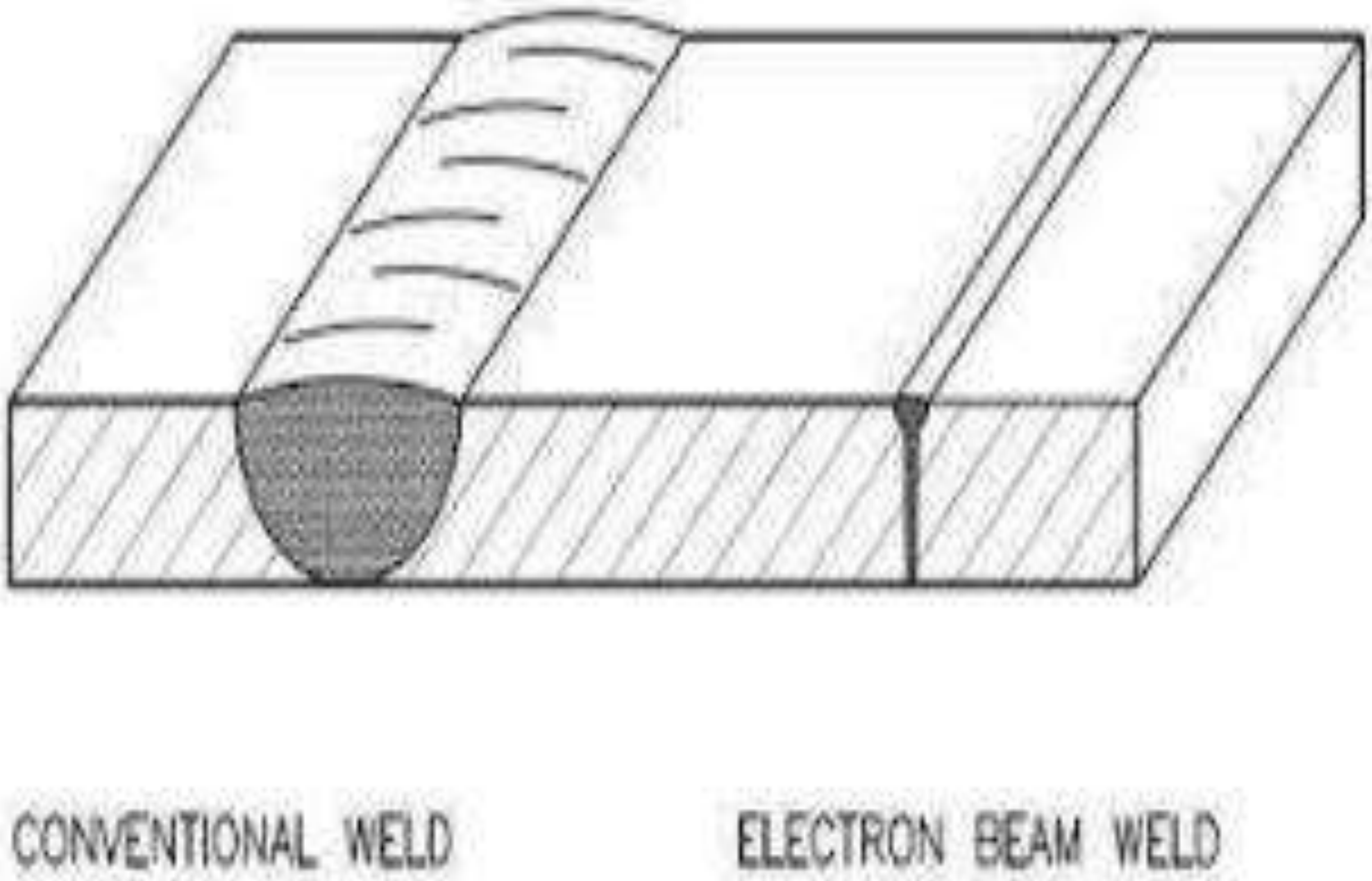
High vacuum machine



Fine vacuum machine

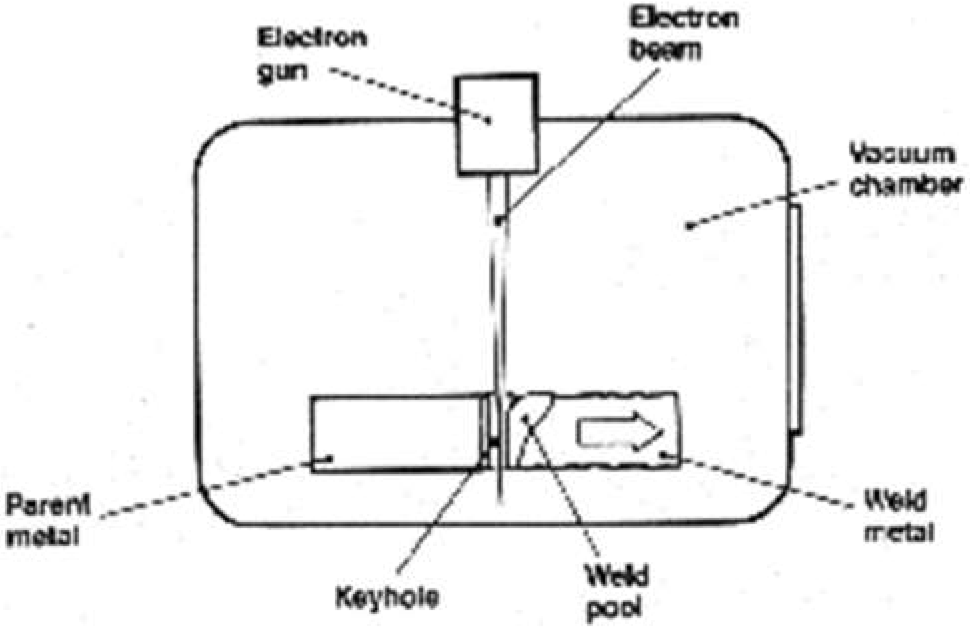


Atmospheric machine (NV-EB welding)

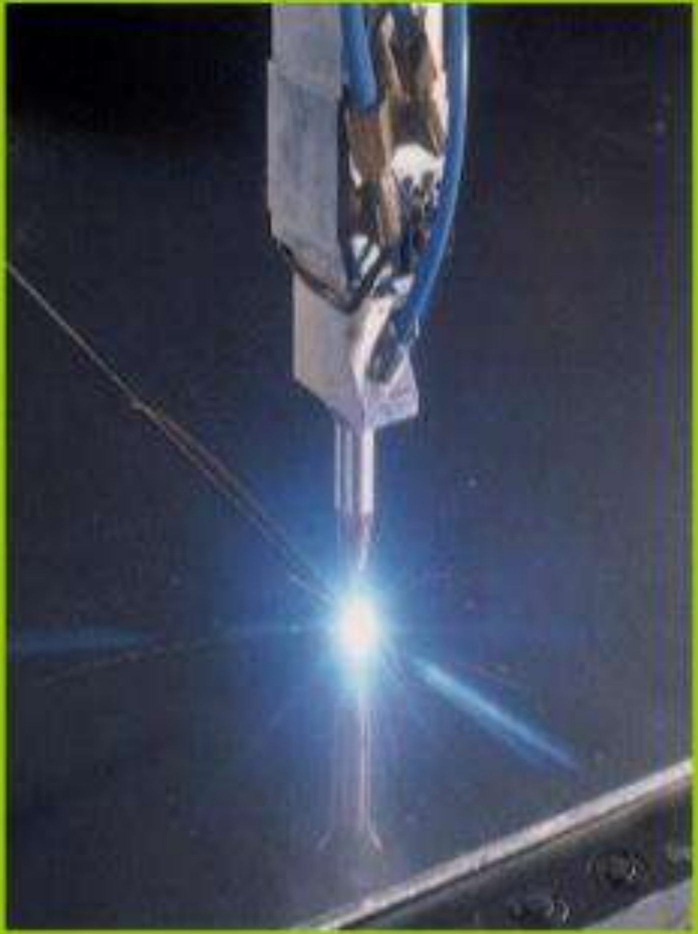

CONVENTIONAL WELD
ELECTRON BEAM WELD

Electron Beam Welding

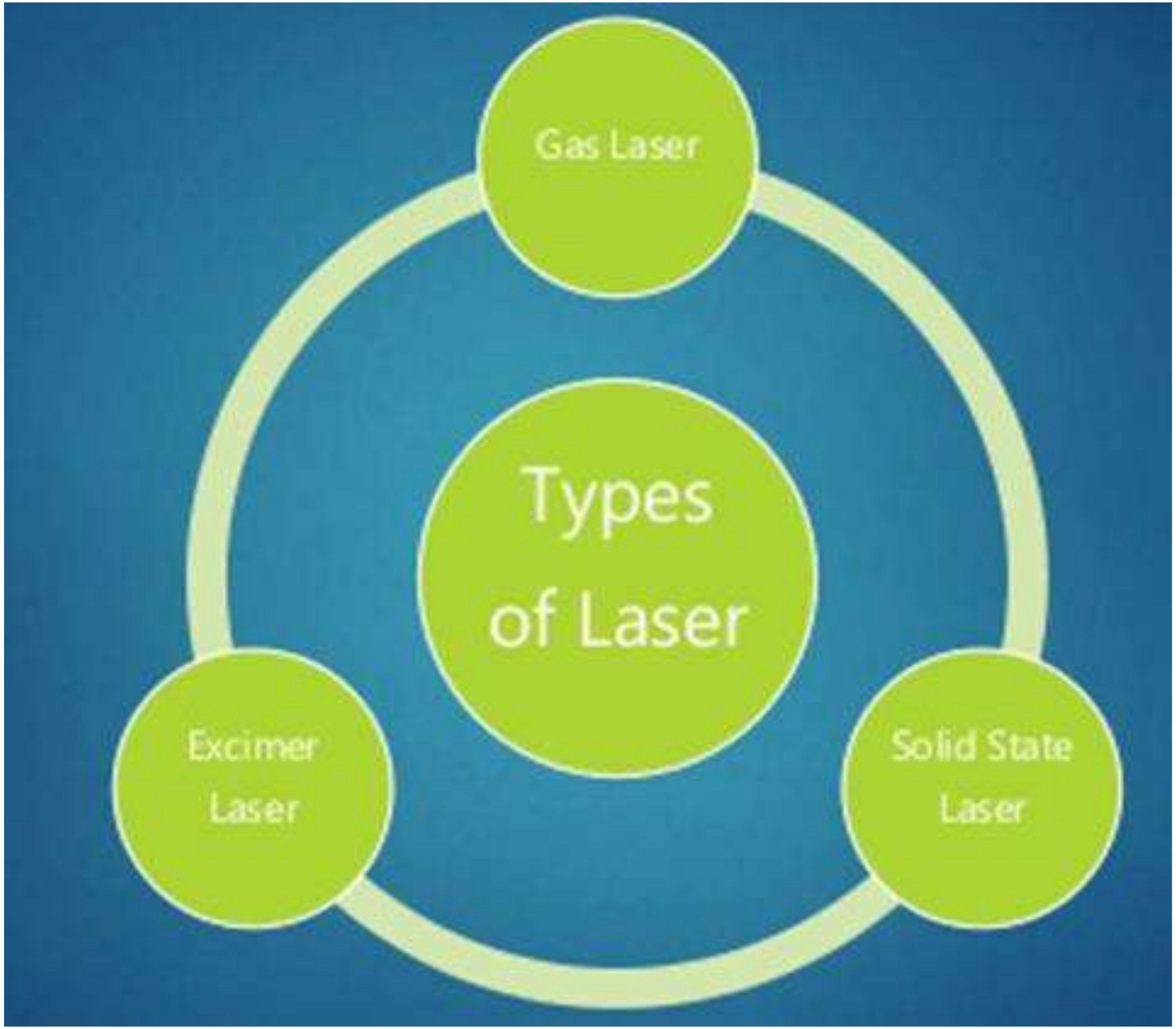
- Heat source
  - concentrated beam of high energy electrons
  - 30-200kV
  - 0.1mA to 1A
- System requires a vacuum chamber
  - electron range in air is normally only a few mm



Laser welding



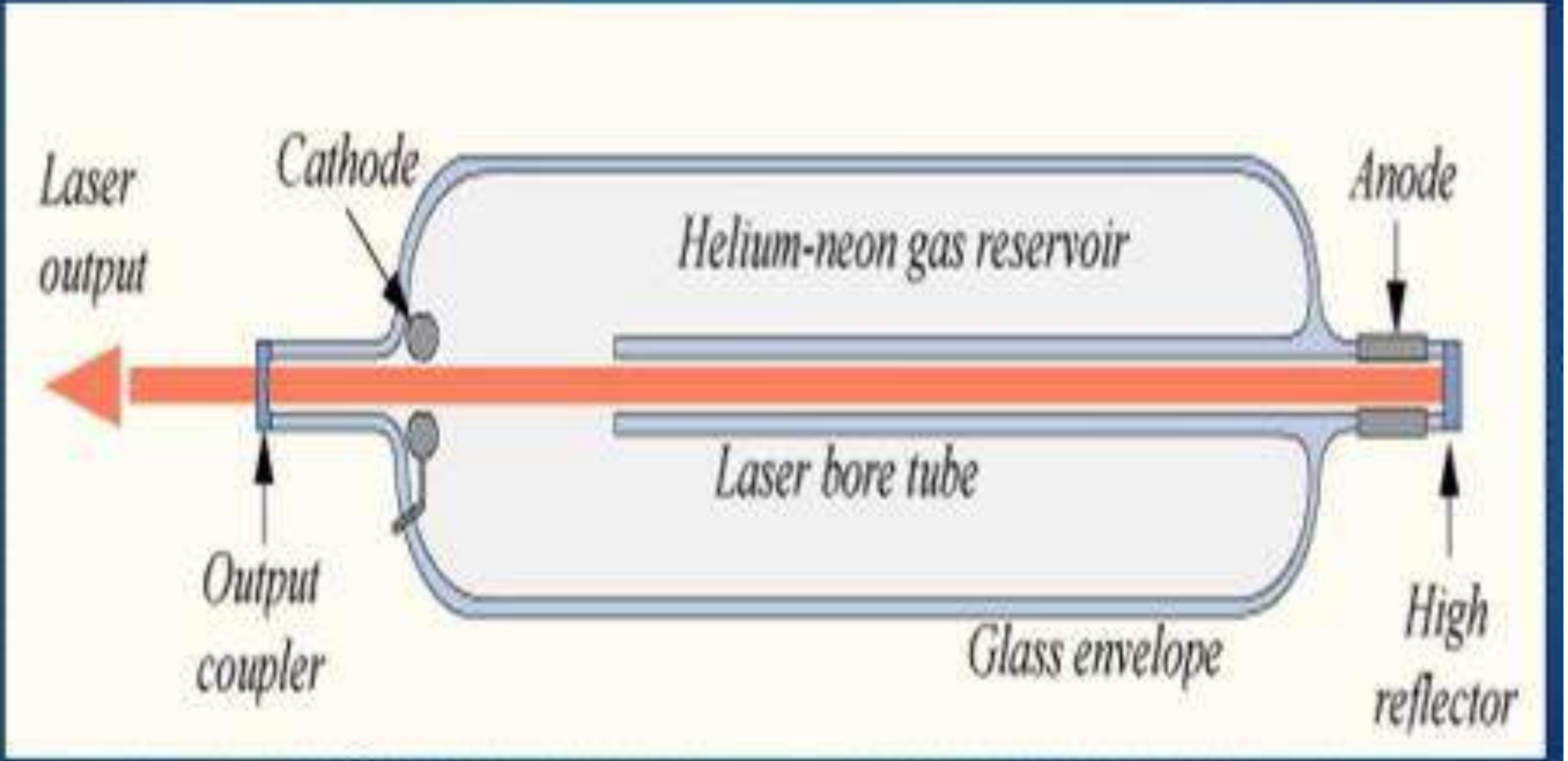
- Laser welding is a commercial process used to weld a wide range of materials. The beam is focused towards the joint which causes the materials to change from solid to liquid state. Upon cooling it returns to a solid state.


Gas Laser
Types of Laser
Excimer Laser
Solid State Laser

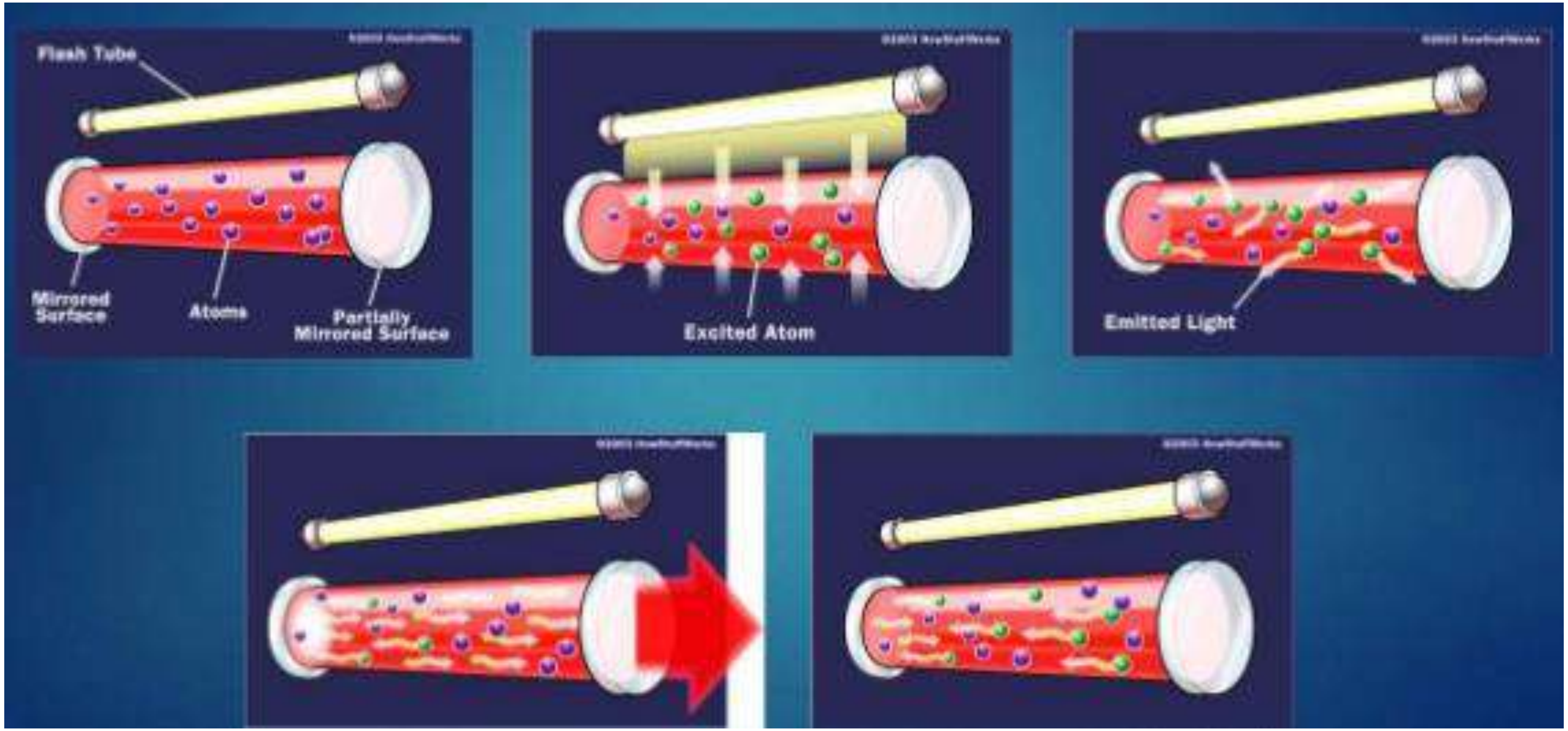
Gas Laser

- Electric current is discharged through a gas to produce a coherent light
- Operate on the principle of converting electric energy into laser light output
- Gas acts as pumping medium to attain the necessary population inversion
- Common gas laser are CO_2 Gas Laser, He-Ne Gas Laser

He-Ne Gas Laser

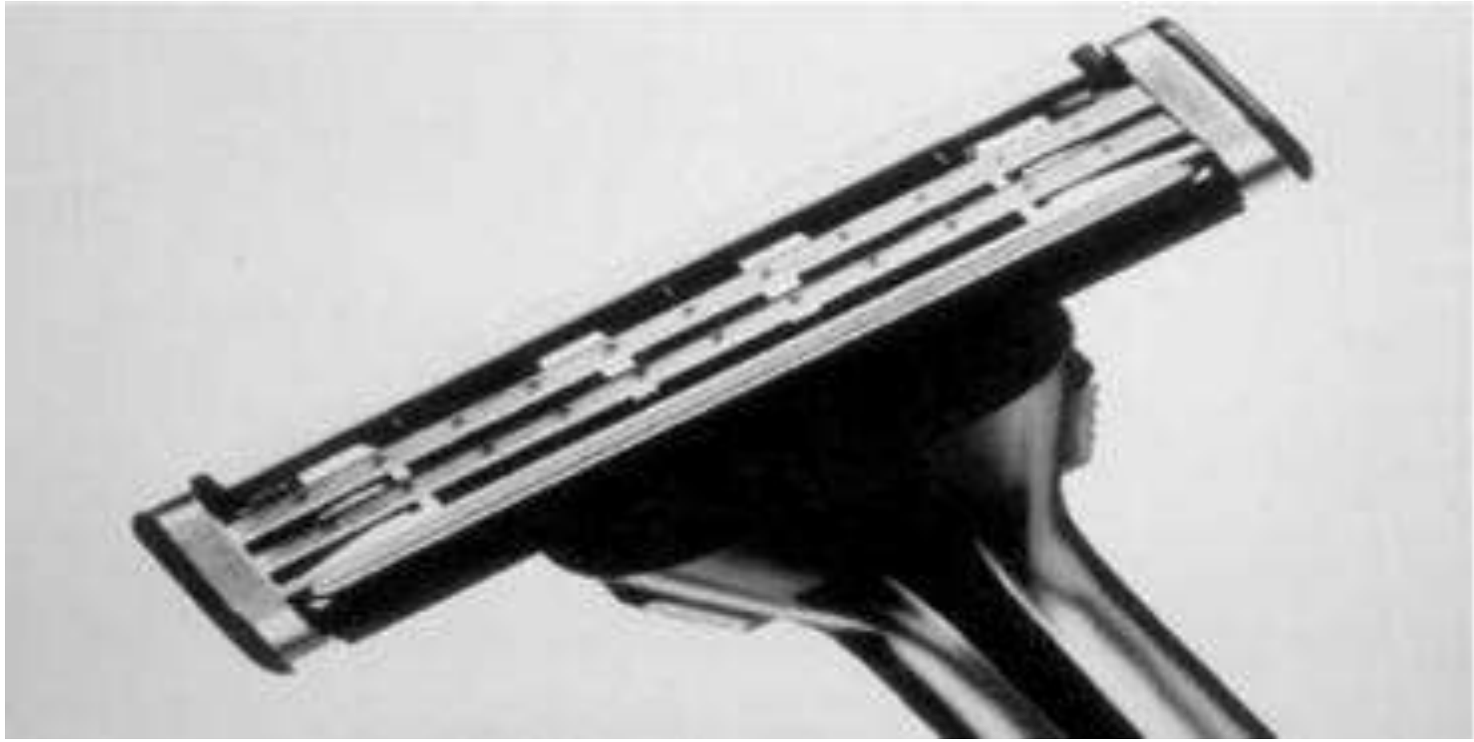


RUBY LASER



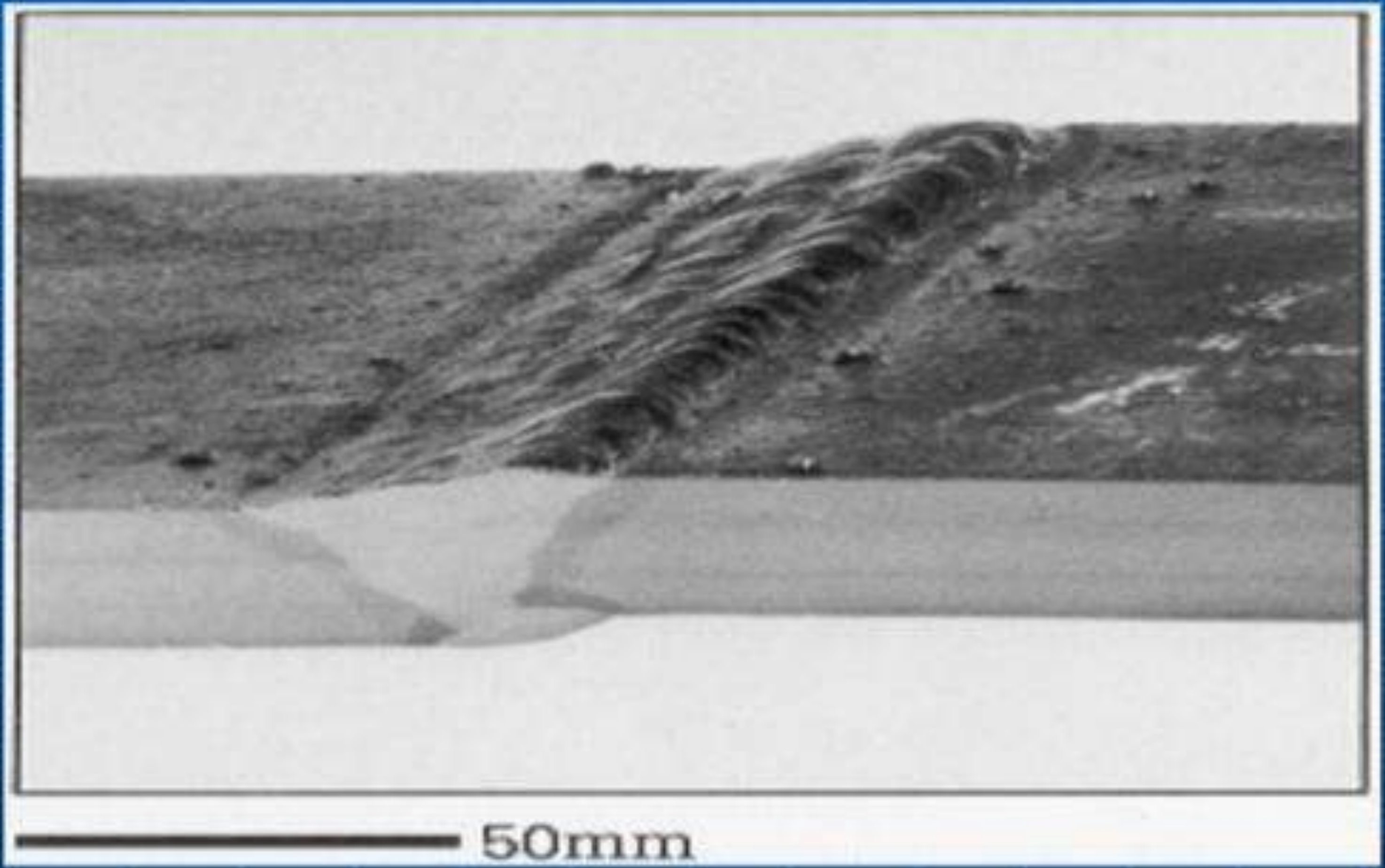
Flash Tube
Mirrored Surface
Atoms
Partially Mirrored Surface
Excited Atom
Emitted Light

LASER WELDED RAZOR BLADE



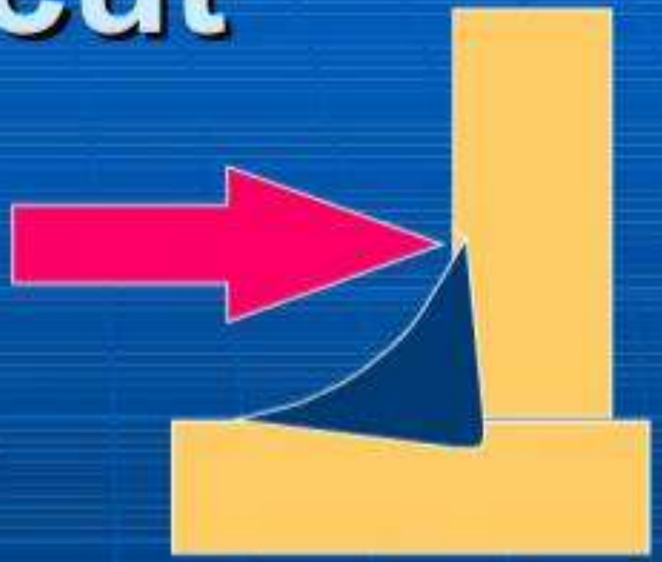
WELDING DEFECTS

Misalignment

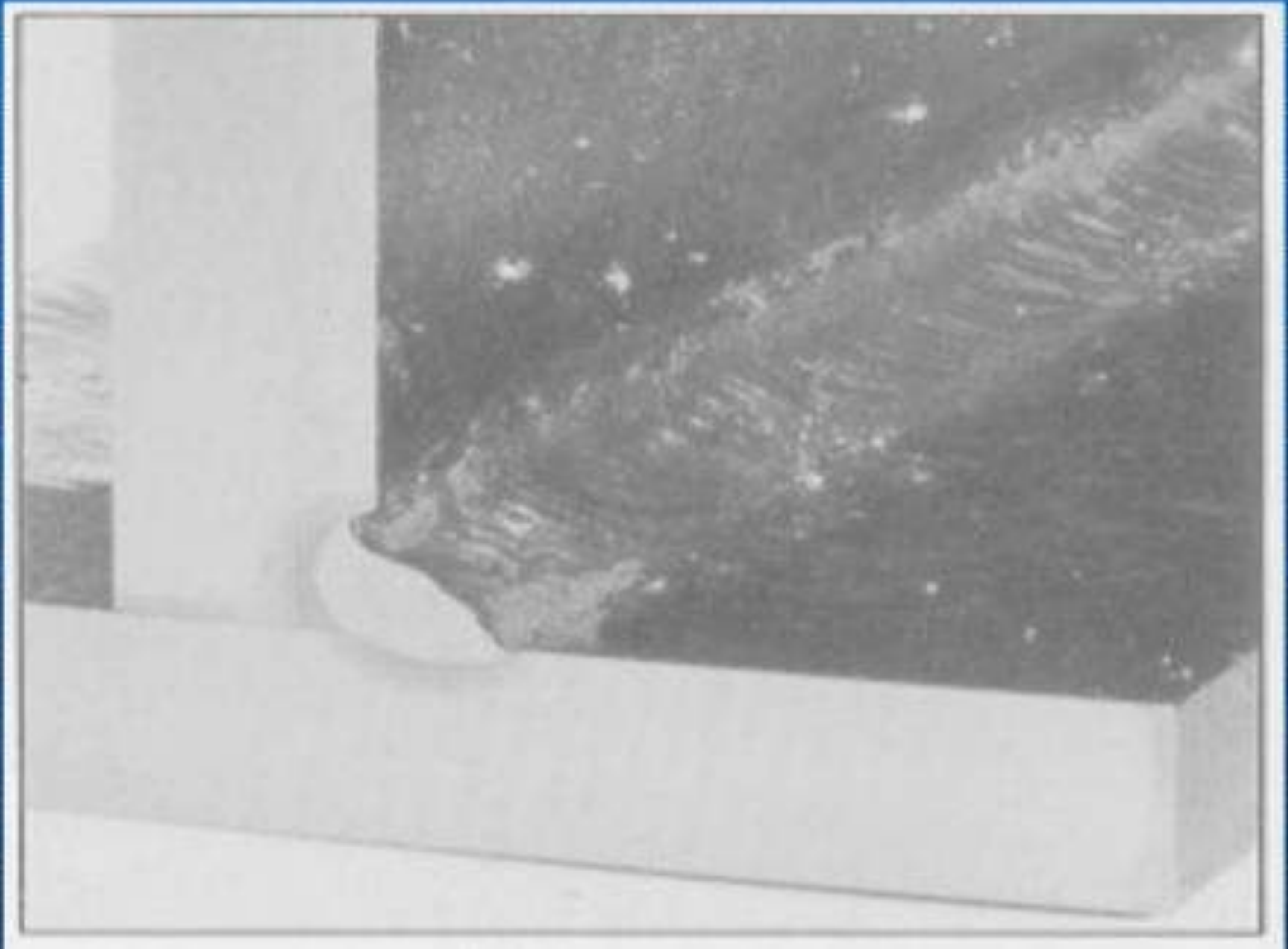


Undercut

- **Definition:** A groove cut at the toe of the weld and left unfilled.
- **Cause:** High amperage, electrode angle, long arc length, rust



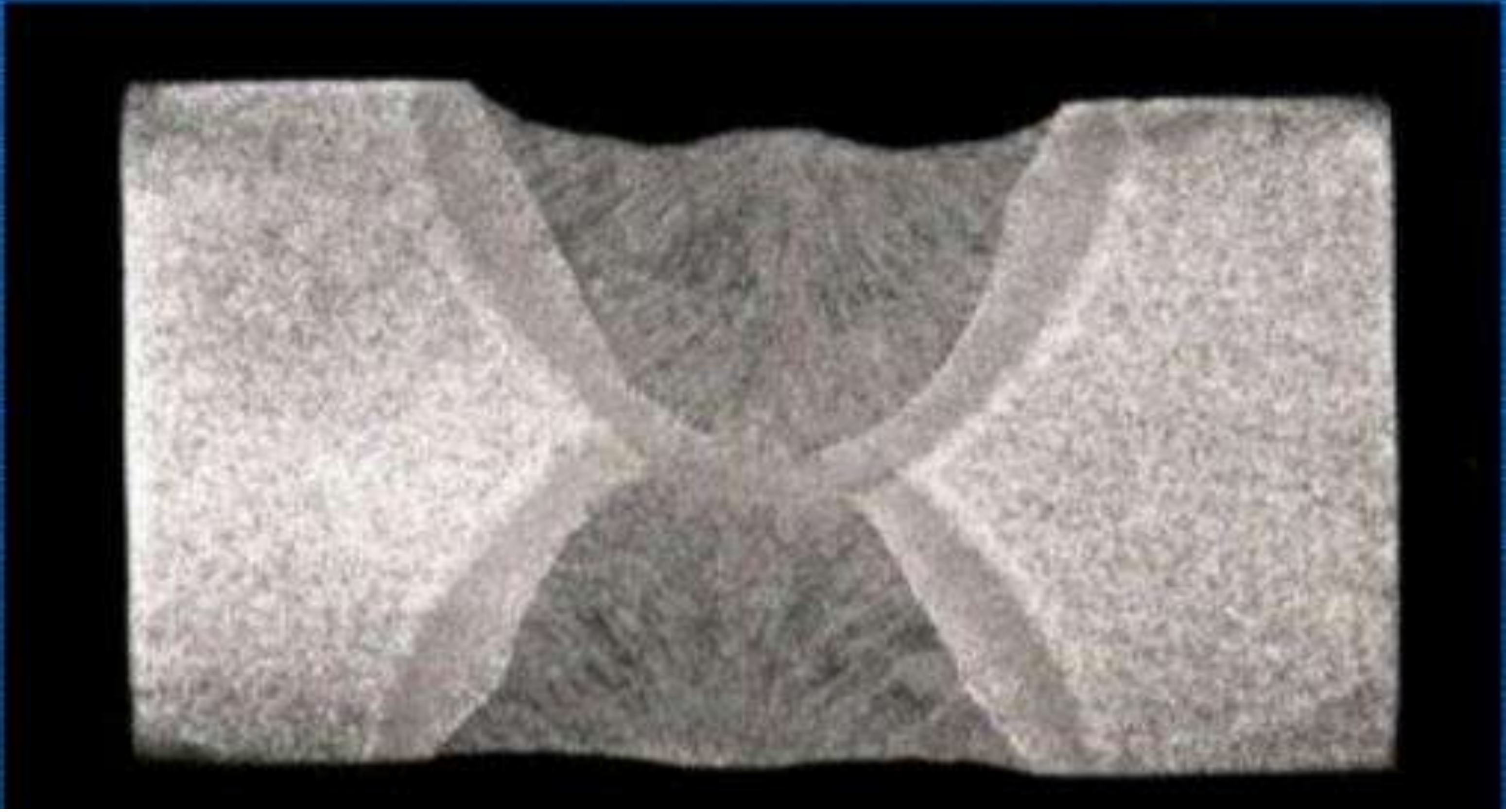
Under Cut



Insufficient Fill or Under fill

- Definition: The weld surface is below the adjacent surfaces of the base metal
- Cause: Improper welding techniques

Under fill



Excessive Concavity or Convexity

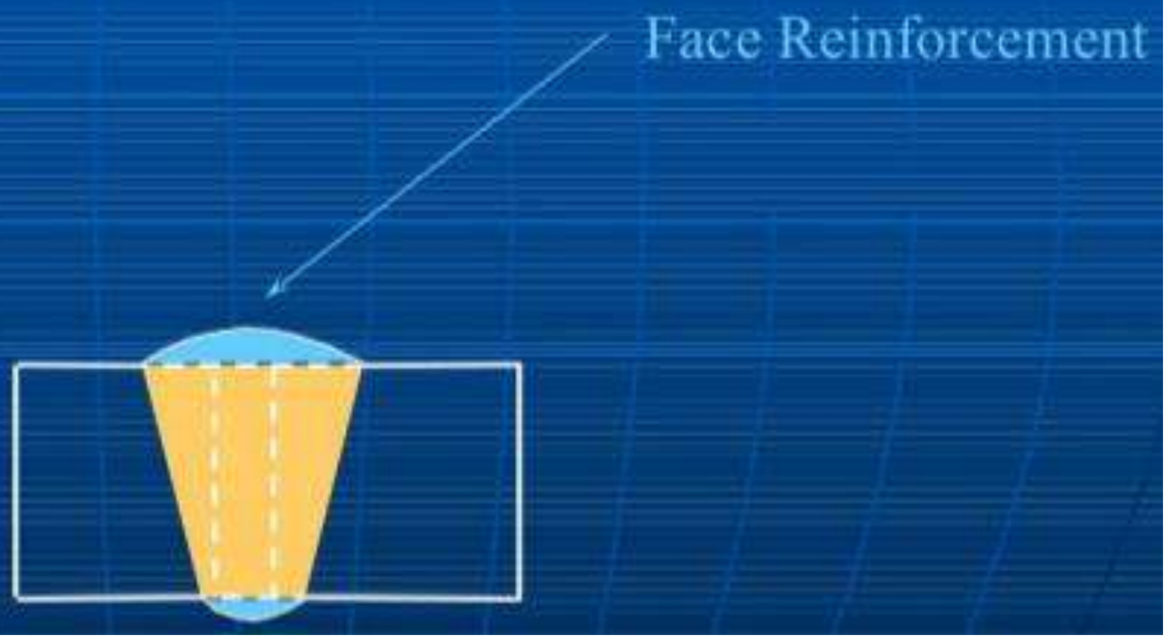
- **Definition:** Concavity or convexity of a fillet weld which exceeds the specified allowable limits
- **Cause:** Amperage and travel speed

Root Concavity

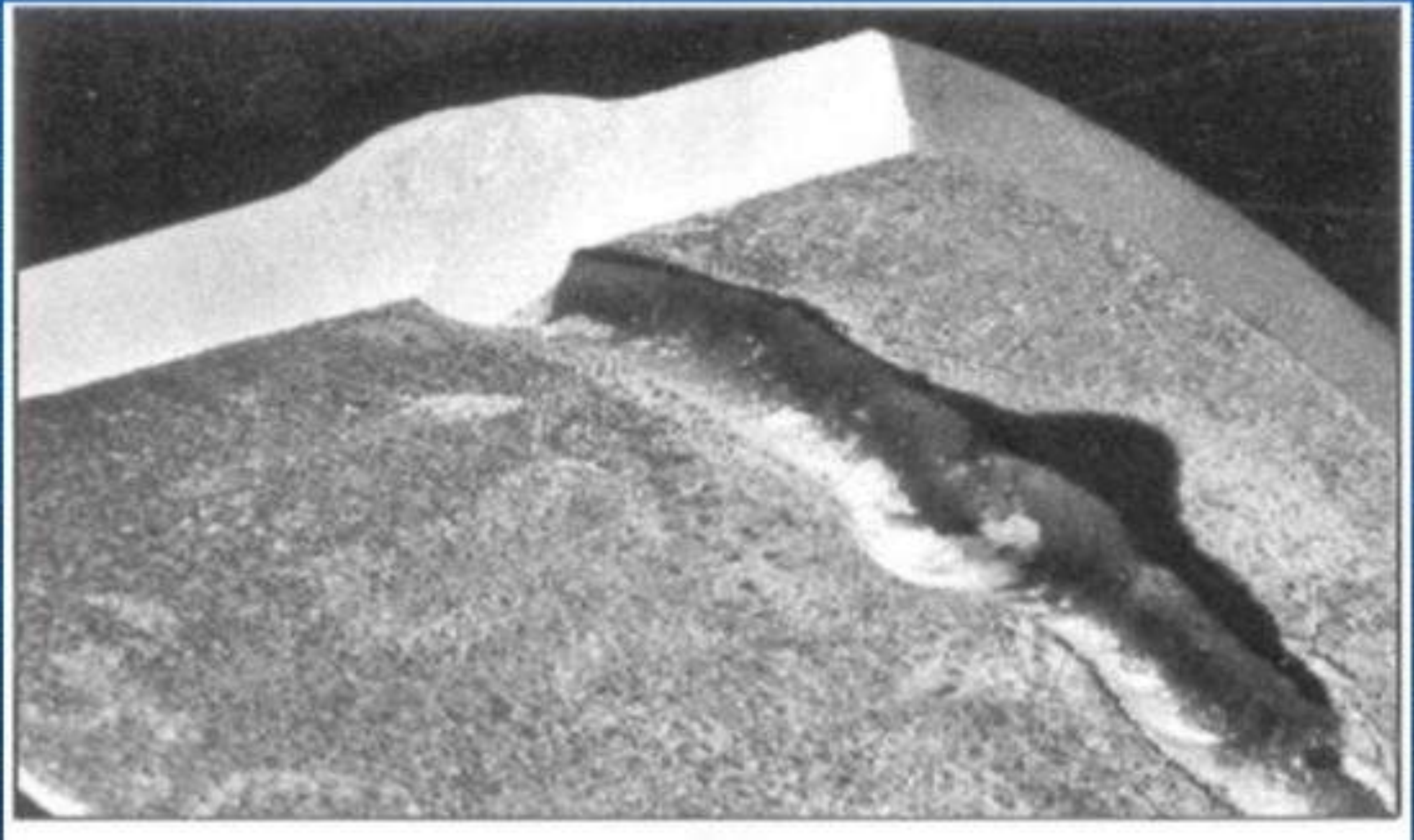
Reinforcement

The amount of a groove weld which extends beyond the surface of the plate

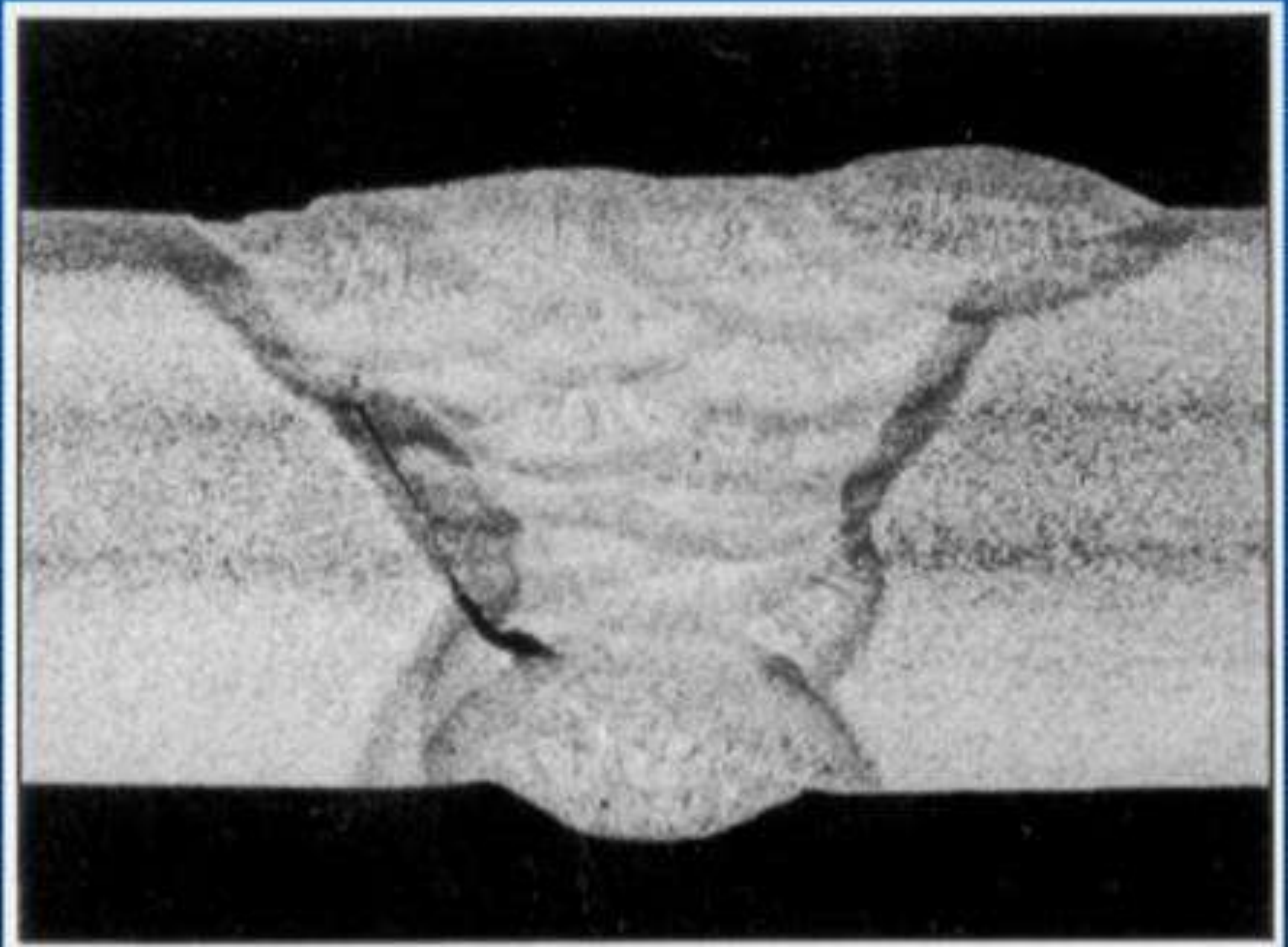
- Excessive
- Insufficient
- Improper contour



Excessive Penetration

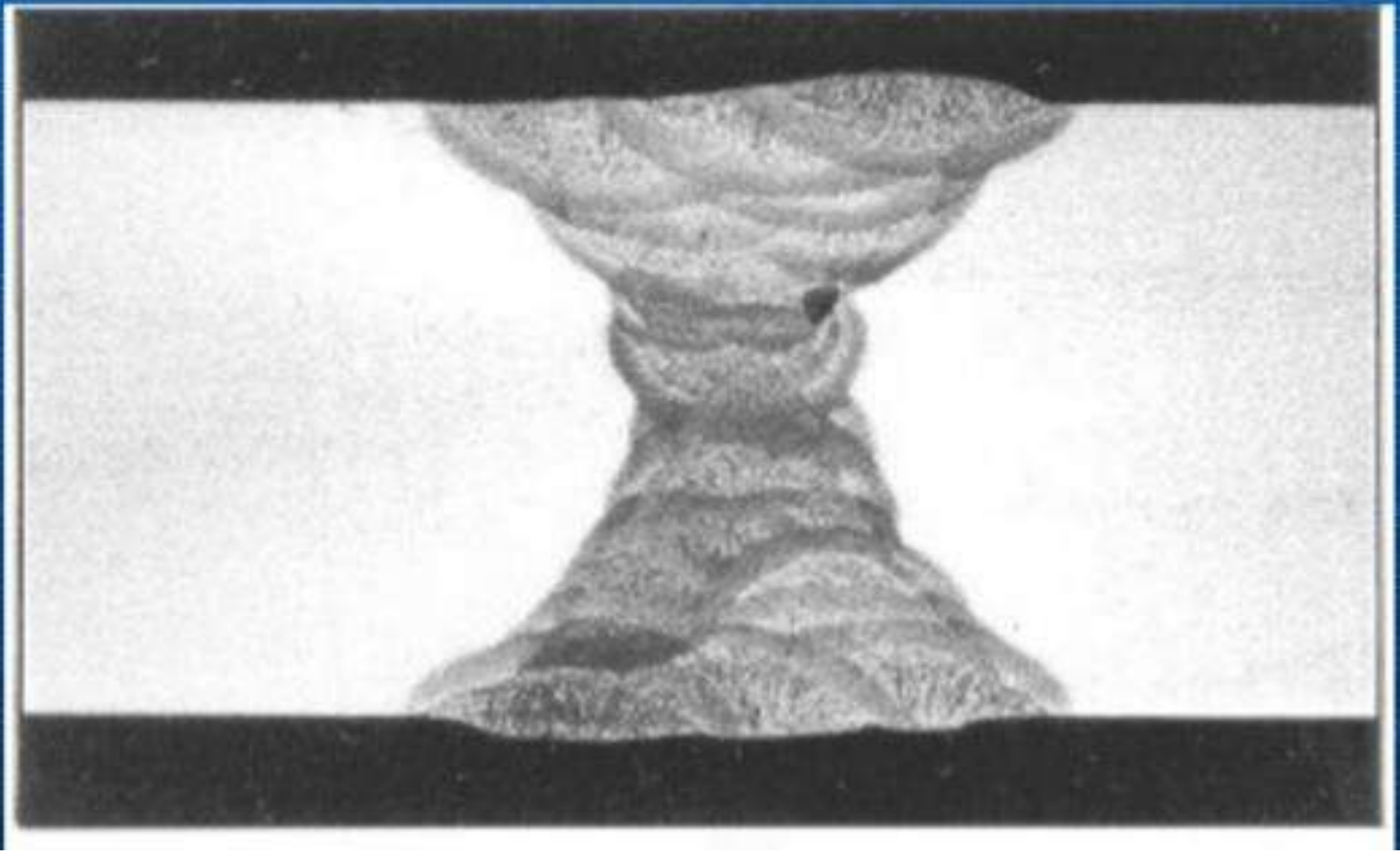


Lack of Side Wall Fusion

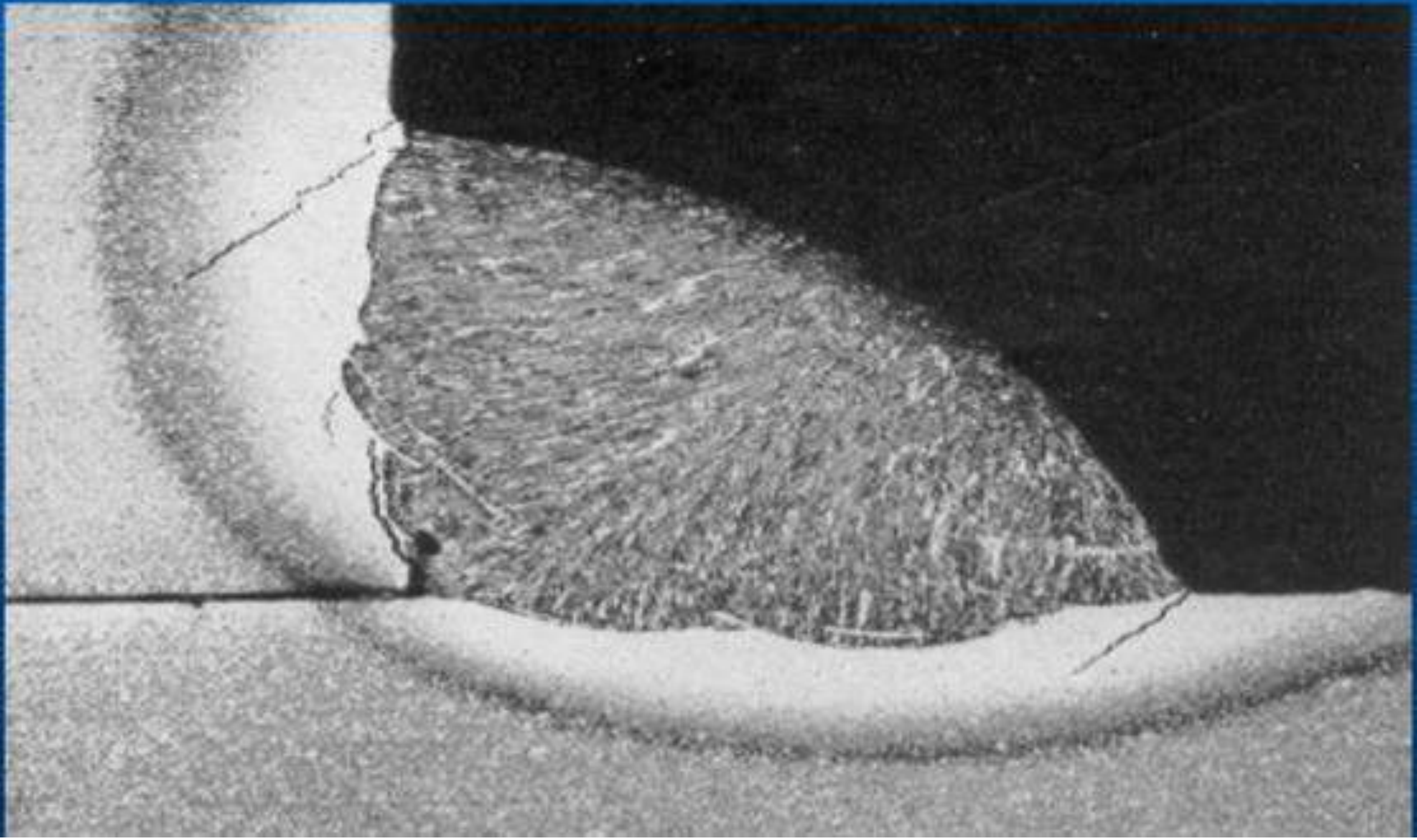


Arc Strike

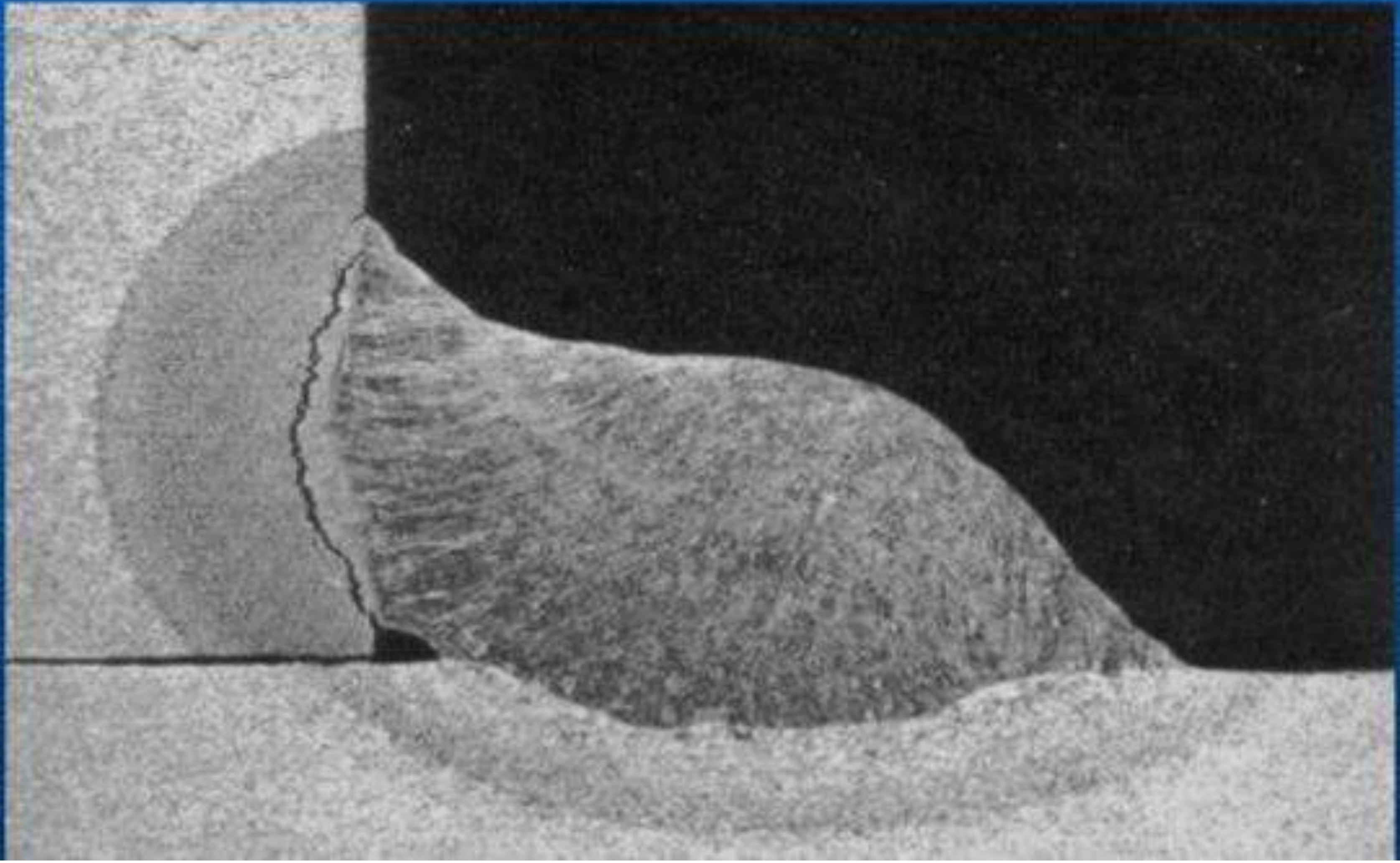
Slag Inclusion



Toe Crack



Root Crack



Lecture 2. Basics of Metal-Casting

2.1. Casting methods

Metal casting process begins by creating a mold, which is the 'reverse' shape of the part we need. The mold is made from a refractory material, for example, sand. The metal is heated in an oven until it melts, and the molten metal is poured into the mould cavity. The liquid takes the shape of cavity, which is the shape of the part. It is cooled until it solidifies. Finally, the solidified metal part is removed from the mould.

A large number of metal components in designs we use every day are made by casting. The reasons for this include:

(a) Casting can produce very complex geometry parts with internal cavities and hollow sections.
(b) It can be used to make small (few hundred grams) to very large size parts (thousands of kilograms)
(c) It is economical, with very little wastage: the extra metal in each casting is re-melted and re-used
(d) Cast metal is isotropic – it has the same physical/mechanical properties along any direction.

Common examples: door handles, locks, the outer casing or housing for motors, pumps, etc., wheels of many cars. Casting is also heavily used in the toy industry to make parts, e.g. toy cars, planes, and so on.

Table 1 summarizes different types of castings, their advantages, disadvantages and examples.

Process	**Advantages**	**Disadvantages**	**Examples**
Sand	Wide range of metals, sizes, shapes, low cost	poor finish, wide tolerance	engine blocks, cylinder heads
Shell mold	better accuracy, finish, higher production rate	limited part size	connecting rods, gear housings
Expendable pattern	Wide range of metals, sizes, shapes	patterns have low strength	cylinder heads, brake components
Plaster mold	complex shapes, good surface finish	non-ferrous metals, low production rate	prototypes of mechanical parts
Ceramic mold	complex shapes, high accuracy, good finish	small sizes	impellers, injection mold tooling
Investment	complex shapes, excellent finish	small parts, expensive	jewellery
Permanent mold	good finish, low porosity, high production rate	Costly mold, simpler shapes only	gears, gear housings
Die	Excellent dimensional accuracy, high production rate	costly dies, small parts, non-ferrous metals	precision gears, camera bodies, car wheels
Centrifugal	Large cylindrical parts, good quality	Expensive, limited shapes	pipes, boilers, flywheels

2.1.1 Sand casting

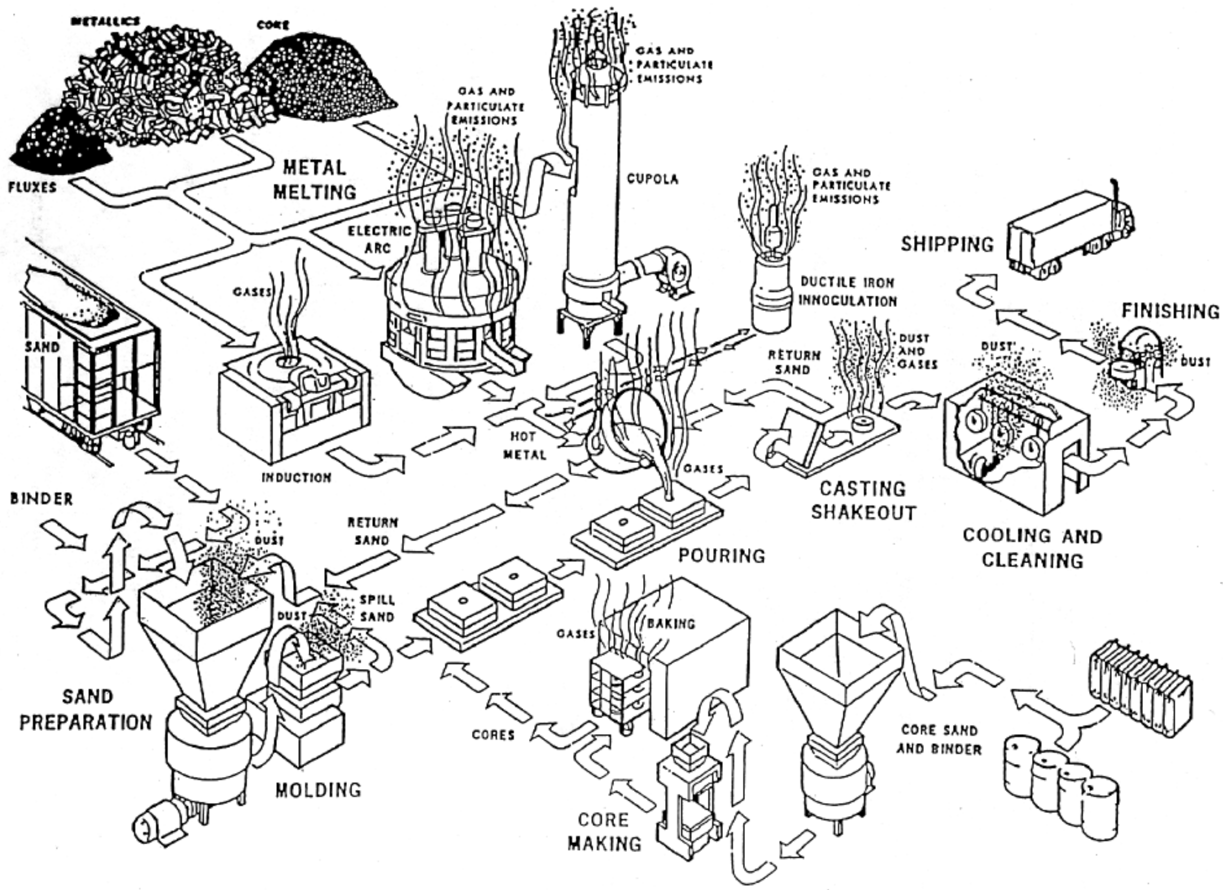


Figure 1. Work flow in typical sand-casting foundries [source: www.p2pays.org]

Sand casting uses natural or synthetic sand (lake sand) which is mostly a refractory material called silica (SiO_2). The sand grains must be small enough so that it can be packed densely; however, the grains must be large enough to allow gasses formed during the metal pouring to escape through the pores. Larger sized molds use green sand (mixture of sand, clay and some water). Sand can be re-used, and excess metal poured is cut-off and re-used also.

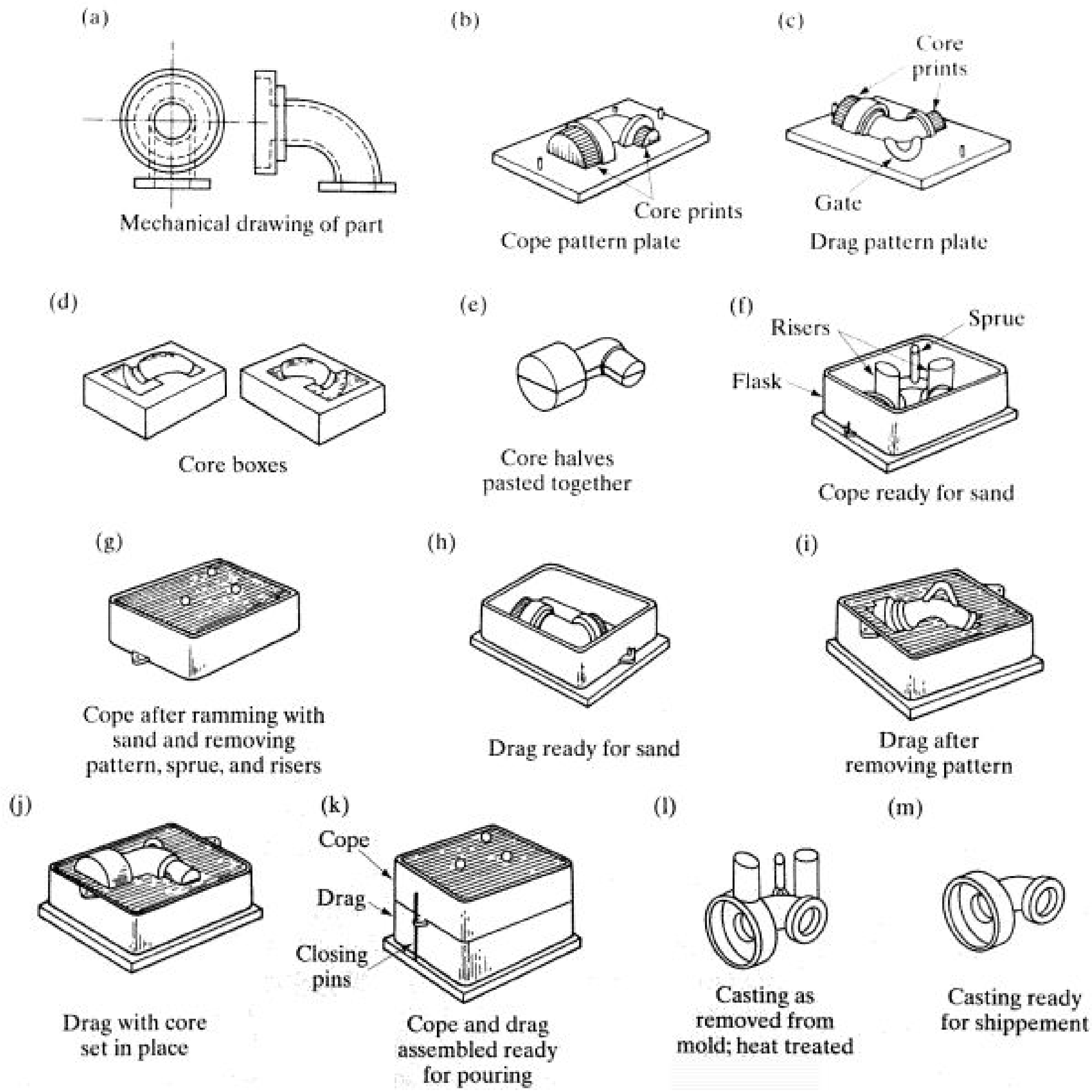


Figure 2. Schematic showing steps of the sand casting process [source: Kalpakjian and Schmid]

Typical sand molds have the following parts (see Figure 2):

- The mold is made of two parts, the top half is called the **cope**, and bottom part is the **drag**.
- The liquid flows into the gap between the two parts, called the mold **cavity**. The geometry of the cavity is created by the use of a wooden shape, called the **pattern**. The shape of the patterns is (almost) identical to the shape of the part we need to make.
- A funnel shaped cavity; the top of the funnel is the **pouring cup**; the pipe-shaped neck of the funnel is the **sprue** – the liquid metal is poured into the pouring cup, and flows down the sprue.
- The **runners** are the horizontal hollow channels that connect the bottom of the sprue to the mould cavity. The region where any runner joins with the cavity is called the **gate**.

- Some extra cavities are made connecting to the top surface of the mold. Excess metal poured into the mould flows into these cavities, called **risers**. They act as reservoirs; as the metal solidifies inside the cavity, it shrinks, and the extra metal from the risers flows back down to avoid holes in the cast part.
- **Vents** are narrow holes connecting the cavity to the atmosphere to allow gasses and the air in the cavity to escape.
- **Cores**: Many cast parts have interior holes (hollow parts), or other cavities in their shape that are not directly accessible from either piece of the mold. Such interior surfaces are generated by inserts called **cores**. Cores are made by baking sand with some binder so that they can retain their shape when handled. The mold is assembled by placing the core into the cavity of the drag, and then placing the cope on top, and locking the mold. After the casting is done, the sand is shaken off, and the core is pulled away and usually broken off.

Important considerations for casting:

(a) How do we make the pattern?

Usually craftsmen will carve the part shape by hand and machines to the exact size.

(b) Why is the pattern not exactly identical to the part shape?

- you only need to make the outer surfaces with the pattern; the inner surfaces are made by the core
- you need to allow for the shrinkage of the casting after the metal solidifies

(c) If you intersect the plane formed by the mating surfaces of the drag and cope with the cast part, you will get a cross-section of the part. The outer part of the outline of this cross section is called the **parting line**. The design of the mold is done by first determining the parting line (why ?)

(d) In order to avoid damaging the surface of the mould when removing the pattern and the wood-pieces for the vents, pouring cup and sprue, risers etc., it is important to incline the vertical surfaces of the part geometry. This (slight) inclination is called a taper. If you know that your part will be made by casting, you should taper the surfaces in the original part design.

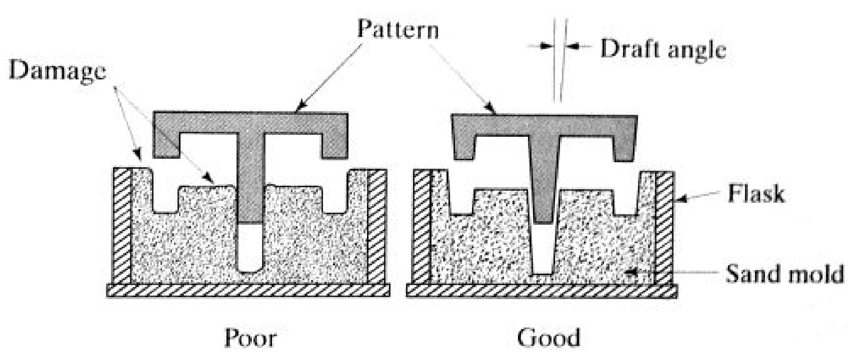


Figure 3. Taper in design

(e) The core is held in position by supporting geometry called core prints (see figure below). If the design is such that there is insufficient support to hold the core in position, then metal supports called chaplets are used. The chaplets will be embedded inside the final part.

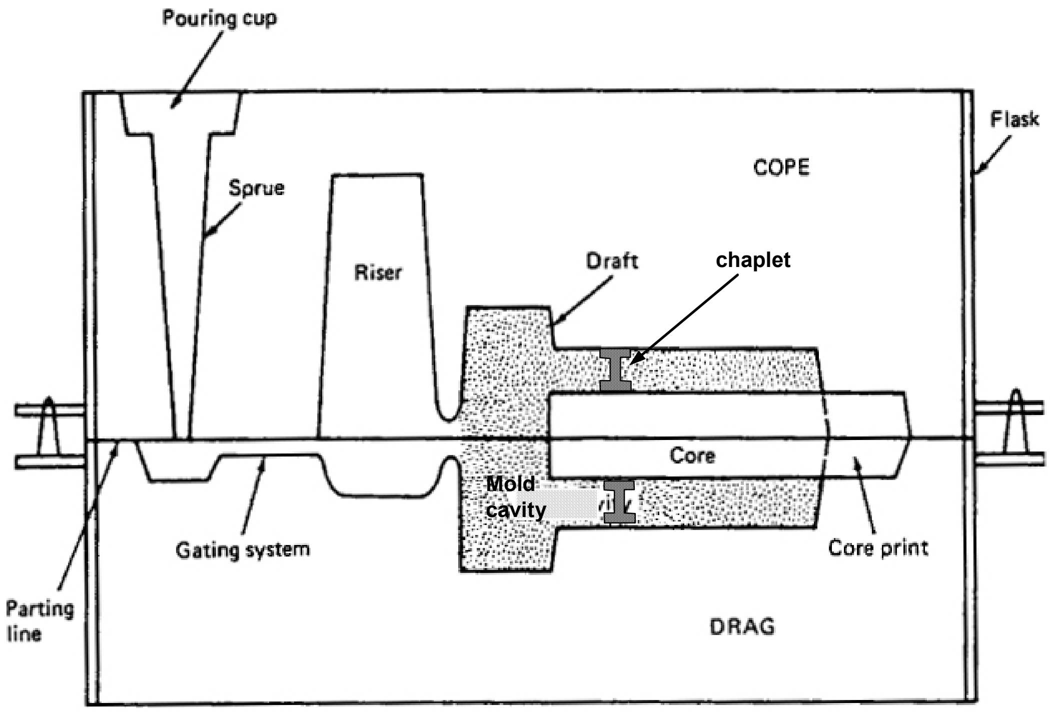


Figure 4. Design components of a mold showing chaplets

(f) After the casting is obtained, it must be cleaned using air-jet or sand blasting

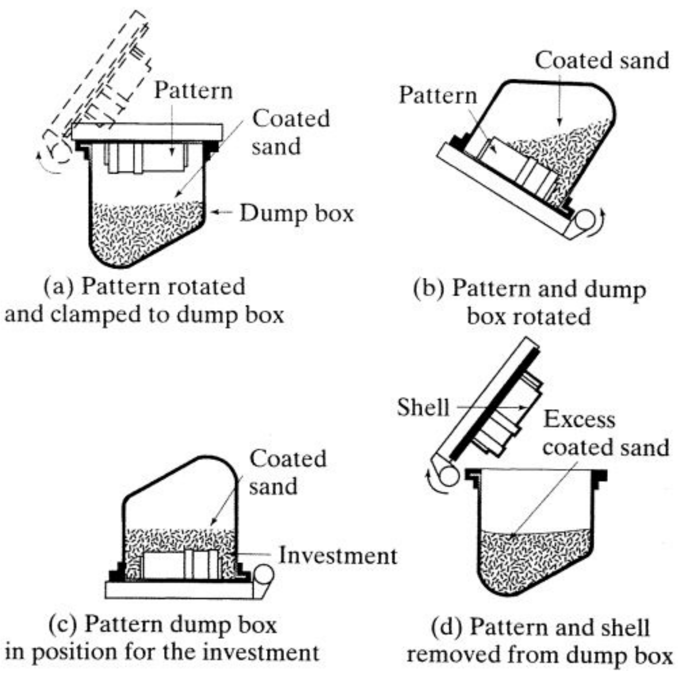
(g) Finally, the extra metal near the gate, risers and vents must be cut off, and critical surfaces are machined to achieve proper surface finish and tolerance.

2.1.2. Shell-mold casting

Shell-mold casting yields better surface quality and tolerances. The process is described as follows:

- The 2-piece *pattern* is made of metal (e.g. aluminum or steel), it is heated to between 175°C-370°C, and coated with a lubricant, e.g. silicone spray.
- Each heated half-pattern is covered with a mixture of sand and a thermoset resin/epoxy binder. The binder glues a layer of sand to the pattern, forming a shell. The process may be repeated to get a thicker shell.
- The assembly is baked to cure it.

- The patterns are removed, and the two half-shells joined together to form the mold; metal is poured into the mold.
- When the metal solidifies, the shell is broken to get the part.



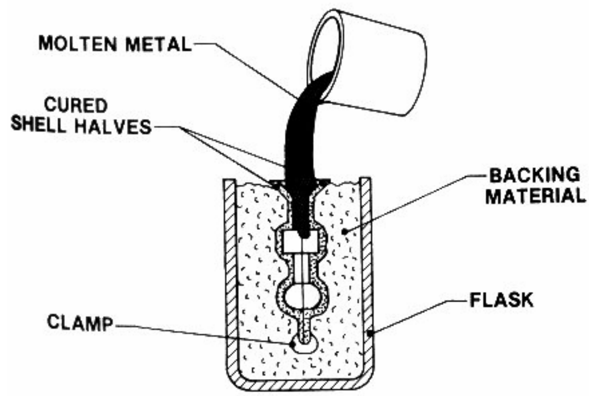


Figure 5. Making the shell-mold [Source: Kalpakjian & Schmid]   Figure 6. Shell mold casting

2.1.3. Expendable-pattern casting (lost foam process)

The pattern used in this process is made from polystyrene (this is the light, white packaging material which is used to pack electronics inside the boxes). Polystyrene foam is 95% air bubbles, and the material itself evaporates when the liquid metal is poured on it.
The pattern itself is made by molding – the polystyrene beads and pentane are put inside an aluminum mold, and heated; it expands to fill the mold, and takes the shape of the cavity. The pattern is removed, and used for the casting process, as follows:
- The pattern is dipped in a slurry of water and clay (or other refractory grains); it is dried to get a hard shell around the pattern.
- The shell-covered pattern is placed in a container with sand for support, and liquid metal is poured from a hole on top.
- The foam evaporates as the metal fills the shell; upon cooling and solidification, the part is removed by breaking the shell.

The process is useful since it is very cheap, and yields good surface finish and complex geometry. There are no runners, risers, gating or parting lines – thus the design process is simplified. The process is used to manufacture crank-shafts for engines, aluminum engine blocks, manifolds etc.

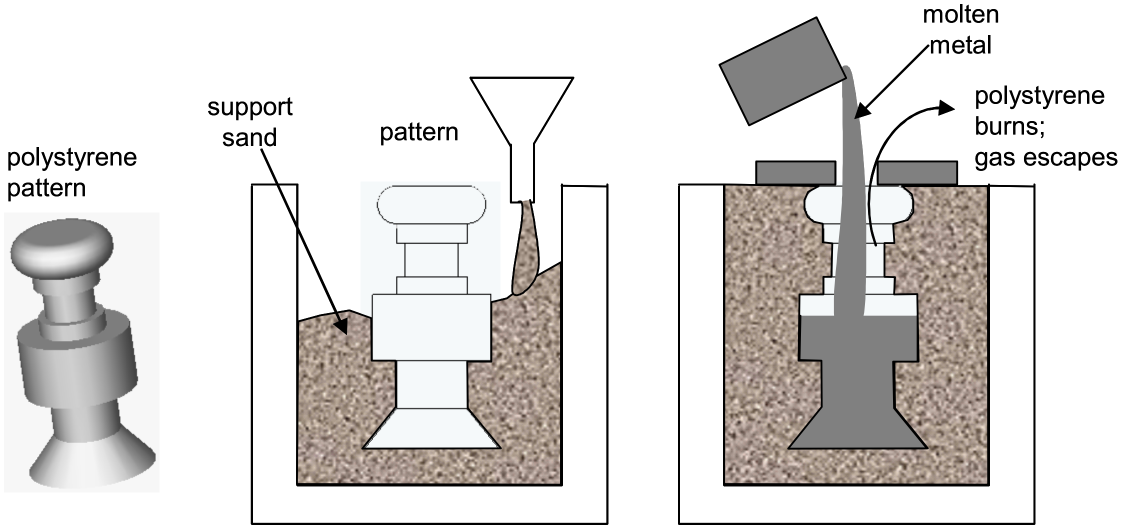


Figure 7. Expendable mold casting

2.1.4. Plaster-mold casting

The mold is made by mixing *plaster of paris* ($CaSO_4$) with talc and silica flour; this is a fine white powder, which, when mixed with water gets a clay-like consistency and can be shaped around the pattern (it is the same material used to make casts for people if they fracture a bone). The plaster cast can be finished to yield very good surface finish and dimensional accuracy. However, it is relatively soft and not strong enough at temperature above 1200°C, so this method is mainly used to make castings from non-ferrous metals, e.g. zinc, copper, aluminum, and magnesium.

Since plaster has lower thermal conductivity, the casting cools slowly, and therefore has more uniform grain structure (i.e. less warpage, less residual stresses).

2.1.5. Ceramic mold casting

Similar to plaster-mold casting, except that ceramic material is used (e.g. silica or powdered Zircon $ZrSiO_4$). Ceramics are refractory (e.g. the clay hotpot used in Chinese restaurants to cook some dishes), and also have higher strength that plaster.

- The ceramic slurry forms a shell over the pattern;
- It is dried in a low temperature oven, and the pattern is removed

- Then it is backed by clay for strength, and baked in a high temperature oven to burn off any volatile substances.
- The metal is cast same as in plaster casting.

This process can be used to make very good quality castings of steel or even stainless steel; it is used for parts such as impellor blades (for turbines, pumps, or rotors for motor-boats).

2.1.6. Investment casting (lost wax process)

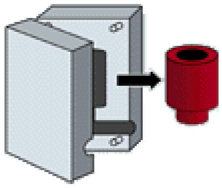
This is an old process, and has been used since ancient times to make jewellery – therefore it is of great importance to HK. It is also used to make other small (few grams, though it can be used for parts up to a few kilograms). The steps of this process are shown in the figure 10 below.

An advantage of this process is that the wax can carry very fine details – so the process not only gives good dimensional tolerances, but also excellent surface finish; in fact, almost any surface texture as well as logos etc. can be reproduced with very high level of detail.

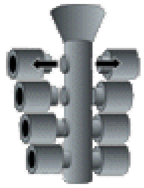
2.1.7. Vacuum casting

This process is also called counter-gravity casting. It is basically the same process as investment casting, except for the step of filling the mold (step (e) above). In this case, the material is sucked upwards into the mould by a vacuum pump. The figure 9 below shows the basic idea – notice how the mold appears in an inverted position from the usual casting process, and is lowered into the flask with the molten metal.

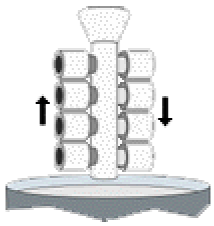
One advantage of vacuum casting is that by releasing the pressure a short time after the mold is filled, we can release the un-solidified metal back into the flask. This allows us to create hollow castings. Since most of the heat is conducted away from the surface between the mold and the metal, therefore the portion of the metal closest to the mold surface always solidifies first; the solid front travels inwards into the cavity. Thus, if the liquid is drained a very short time after the filling, then we get a very thin walled hollow object, etc. (see Figure 10).



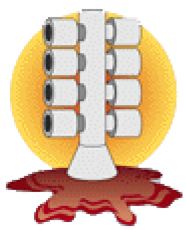
(a) Wax patterns are produced by injection molding



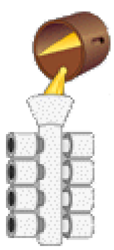
(b) Multiple patterns are assembled to a central wax sprue



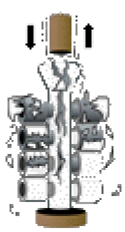
(c) A shell is built by immersing the assembly in a liquid ceramic slurry and then into a bed of extremely fine sand. Several layers may be required.



(d) The ceramic is dried; the wax is melted out; ceramic is fired to burn all wax



(e) The shell is filled with molten metal by gravity pouring. On solidification, the parts, gates, sprue and pouring cup become one solid casting. Hollow casting can be made by pouring out excess metal before it solidifies



(f) After metal solidifies, the ceramic shell is broken off by vibration or water blasting

(g) The parts are cut away from the sprue using a high speed friction saw. Minor finishing gives final part.

Figure 8. Steps in the investment casting process [source: www.hitchiner.com]

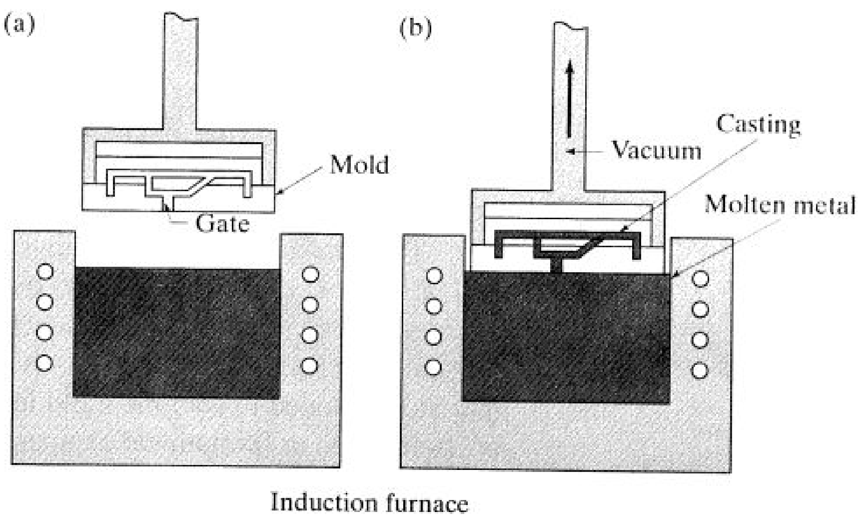


Figure 9. Vacuum casting [source: Kalpakjian & Schmid]

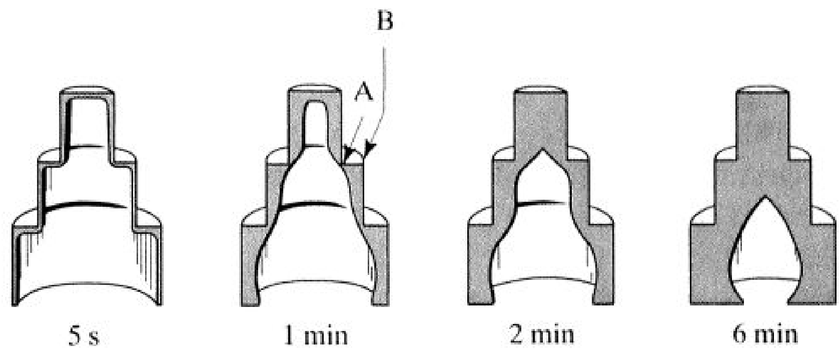


Figure 10. Draining out metal before solidification yields hollow castings [source: Kalpakjian & Schmid]

2.1.8. Permanent mold casting

Here, the two halves of the mold are made of metal, usually cast iron, steel, or refractory alloys. The cavity, including the runners and gating system are machined into the mold halves. For hollow parts, either permanent cores (made of metal) or sand-bonded ones may be used, depending on whether the core can be extracted from the part without damage after casting. The surface of the mold is coated with clay or other hard refractory material – this improves the life of the mold. Before molding, the surface is covered with a spray of graphite or silica, which acts as a lubricant. This has two purposes – it improves the flow of the liquid metal, and it allows the cast part to be withdrawn from the mold more easily. The process can be automated, and therefore yields high throughput rates. Also, it produces very good tolerance and surface finish. It is commonly used for producing pistons used in car engines, gear blanks, cylinder heads, and other parts made of low melting point metals, e.g. copper, bronze, aluminum, magnesium, etc.

2.1.9. Die casting

Die casting is a very commonly used type of permanent mold casting process. It is used for producing many components of home appliances (e.g rice cookers, stoves, fans, washing and drying machines, fridges), motors, toys and hand-tools – since Pearl river delta is a largest manufacturer of such products in the world, this technology is used by many HK-based companies. Surface finish and tolerance of die cast parts is so good that there is almost no post-processing required. Die casting molds are expensive, and require significant lead time to fabricate; they are commonly called dies. There are two common types of die casting: hot- and cold-chamber die casting.

- In a *hot chamber process* (used for Zinc alloys, magnesium) the pressure chamber connected to the die cavity is filled permanently in the molten metal. The basic cycle of operation is as follows: (i) die is closed and gooseneck cylinder is filled with molten metal; (ii) plunger pushes molten metal through gooseneck passage and nozzle and into the die cavity; metal is held under pressure until it solidifies; (iii) die opens and cores, if any, are retracted; casting stays in ejector die; plunger returns, pulling molten metal back through nozzle and gooseneck; (iv) ejector pins push casting out of ejector die. As plunger uncovers inlet hole, molten metal refills gooseneck cylinder. The hot chamber process is used for metals that (a) have low melting points and (b) do not alloy with the die material, steel; common examples are tin, zinc, and lead.
- In a *cold chamber process*, the molten metal is poured into the cold chamber in each cycle. The operating cycle is (i) Die is closed and molten metal is ladled into the cold chamber cylinder; (ii) plunger pushes molten metal into die cavity; the metal is held under high pressure until it solidifies; (iii) die opens and plunger follows to push the solidified slug from the cylinder, if there are cores, they are retracted away; (iv) ejector pins push casting off ejector die and plunger returns to original position. This process is particularly useful for high melting point metals such as Aluminum, and Copper (and its alloys).

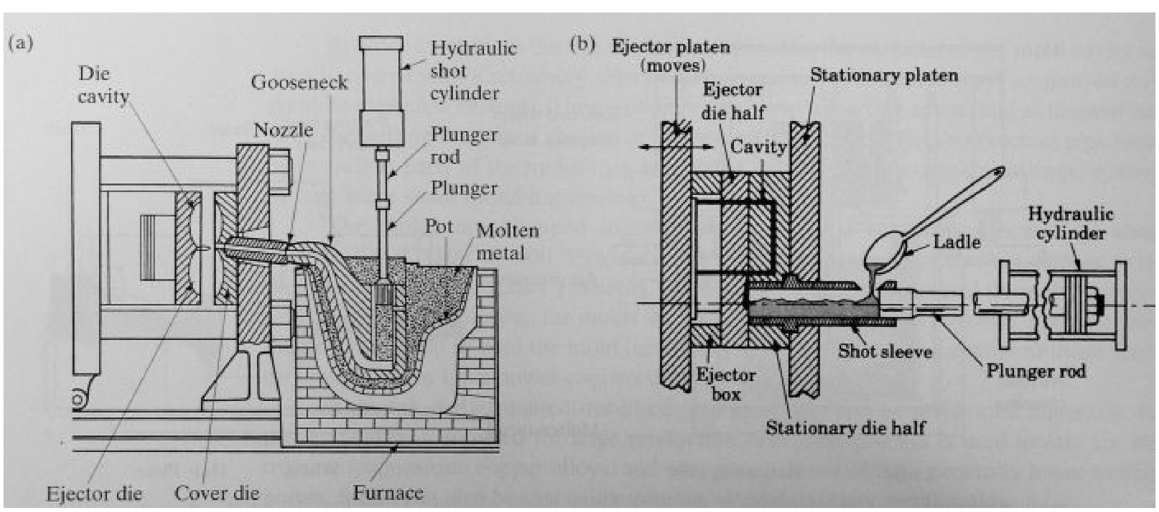


Figure 11 (a) Hot chamber die casting (b) Cold chamber die casting [source: Kalpakjian & Schmid]

2.1.10. Centrifugal casting

Centrifugal casting uses a permanent mold that is rotated about its axis at a speed between 300 to 3000 rpm as the molten metal is poured. Centrifugal forces cause the metal to be pushed out towards the mold walls, where it solidifies after cooling. Parts cast in this method have a fine grain microstructure, which is resistant to atmospheric corrosion; hence this method has been used to manufacture pipes. Since metal is heavier than impurities, most of the impurities and inclusions are closer to the inner diameter and can be machined away. surface finish along the inner diameter is also much worse than along the outer surface.

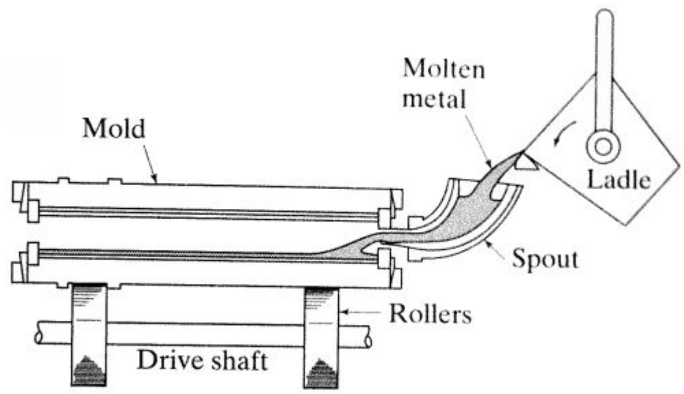


Figure 12. Centrifugal casting schematic [source: Kalpakjian & Schmid]

2.2. Casting design and quality

Several factors affect the quality/performance of cast parts – therefore the design of parts that must be produced by casting, as well as the design of casting molds and dies, must account for these. You may think of these as design guidelines, and their scientific basis lies in the analysis – the strength and behavior of materials.

2.2.1. Corners, angles and section thickness

Many casting processes lead to small surface defects (e.g. blisters, scars, scabs or blows), or tiny holes/impurities in the interior (e.g. inclusions, cold-shuts, shrinkage cavities). These defects are a problem if the part with such a defect is subject of varying loads during use. Under such conditions, it is likely that the defects act like cracks, which propagate under repeated stress causing fatigue failure. Another possibility is that internal holes act as stress concentrators and reduce the actual strength of the part below the expected strength of the design. Figure 14 shows the variation of stress in the presence of holes to illustrate the problem.

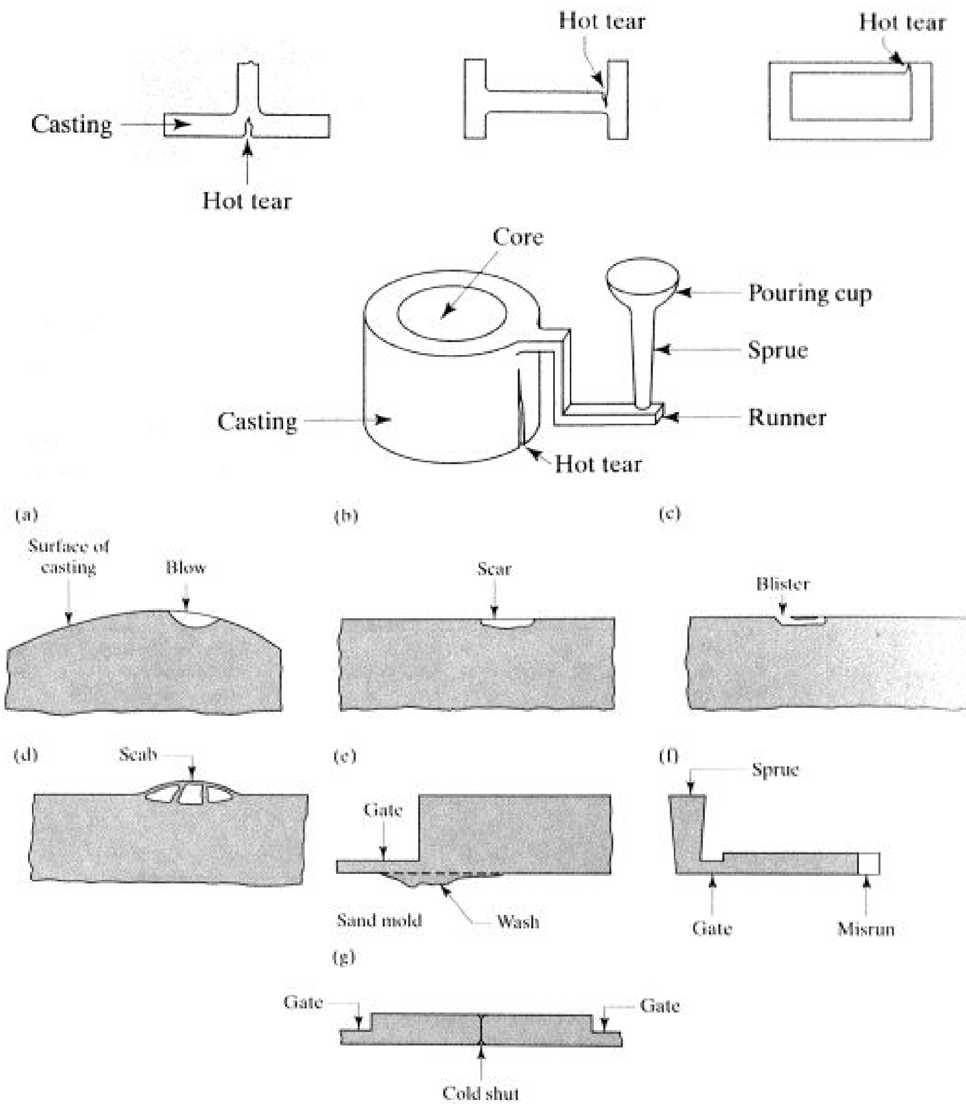


Figure 13. Typical defects in casting [source: Kalpakjian & Schmid]

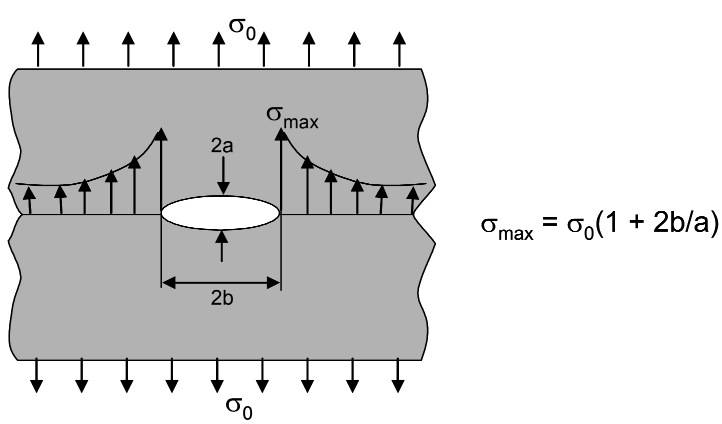


Figure 14. Stress concentration near an elliptical defect

To avoid these problems

(a) sharp corners should be avoided (these behave like cracks and cause stress concentration

(b) Section changes should be blended smoothly using fillets

(c) Rapid changes in cross-section areas should be avoided; if unavoidable, the mold must be designed to ensure that metal can flow to all regions and mechanism is provided for uniform and rapid cooling during solidification. This can be achieved by the use of chills or incorporating fluid-cooled tubes in the mold.

These principles are illustrated in the figures below.

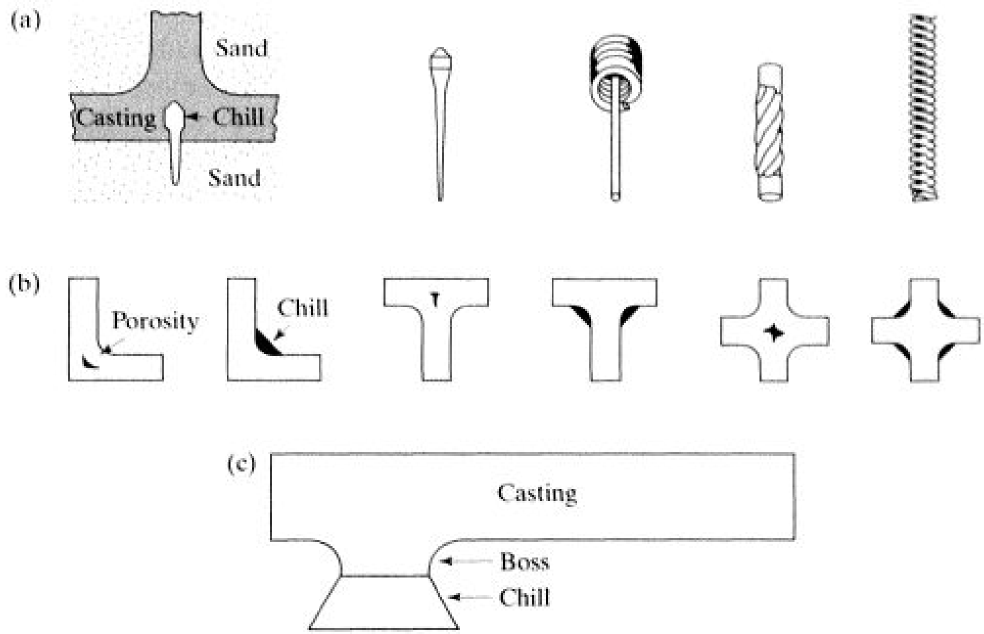


Figure 15. Chills [source: Kalpakjian & Schmid]

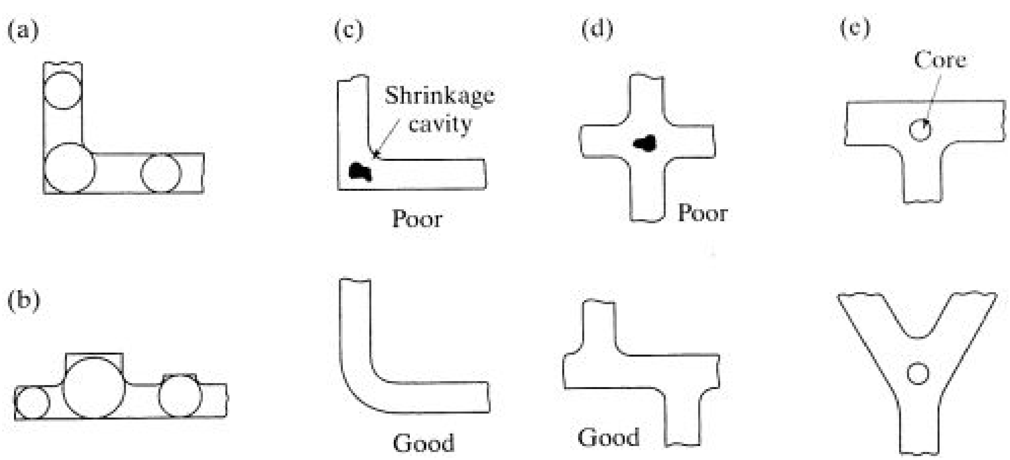


Figure 16. Poor and preferred design examples [source: Kalpakjian & Schmid]

2.2.2. Large, flat regions should be avoided, since they tend to warp due to residual stresses.

- Why do cast parts have residual stresses?

The figure below shows a modification to the flat portion of the stearing-head casting of a Honda CBR 600 motorcycle. The addition of the three ribs increases the stiffness of the casting.

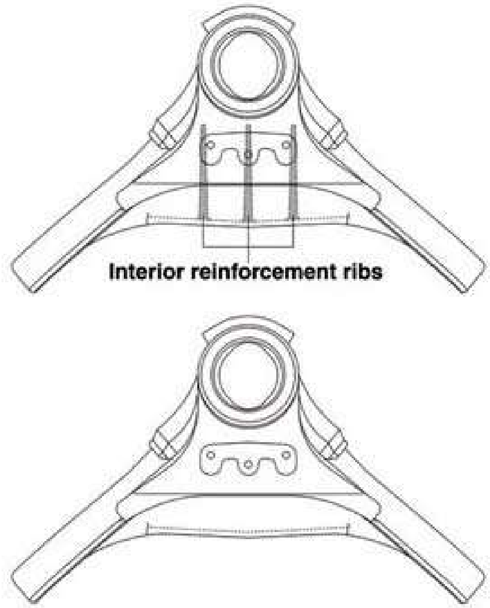


Figure 17. Adding ribs to flat region decreases warping and increases stiffness against bending moments

2.2.3. Drafts and tapers

It is not good for a casting to have surfaces whose normal is perpendicular to the direction along which the part will be ejected from the mold. This can cause the part to stick in the mold and forceful ejection will cause damage to the part (and mold, if the mold is re-usable). Therefore all such surfaces are tilted by a small angle (between 0.5° and 2°) so as to allow easy ejection. Draft angles on the inner surfaces of the part are higher, since the cast part also shrinks a little bit towards the core during solidification and cooling. An illustration of this principle was shown in Figure 3.

2.2.4. Shrinkage

As the casting cools, the metal shrinks. For common cast metals, a 1% shrinkage allowance is designed in all linear dimensions (namely, the design is scaled p by approx 1%). Since the solidification front, i.e. the surface at the boundary of the solidified and the liquid metals, travels from the surface of the mold to the interior regions of the part, the design must ensure that shrinkage does not cause cavities.

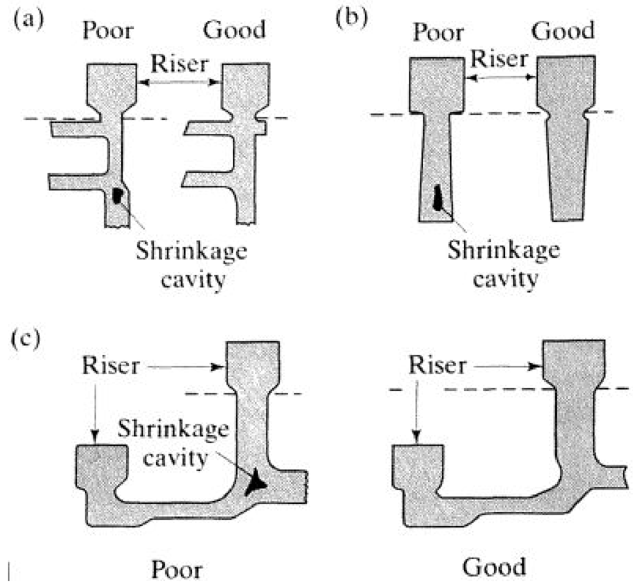


Figure 18. Poor and preferred design examples [source: Kalpakjian & Schmid]

2.2.5. Parting line

The parting line is the boundary where the cope, drag and the part meet. If the surface of the cope and drag are planar, then the parting line is the outline of the cross-section of the part along that plane. You can easily see the parting line for many cast and molded parts that you commonly use. It is conventional that the parting line should be planar, if possible. A very small of metal will always "leak" outside the mold between the cope and the drag in any casting. This is called the "flash". If the flash is along an external surface, it must be machined away by some finishing operation. If the parting line is along an edge of the part, it is less visible – this is preferred.

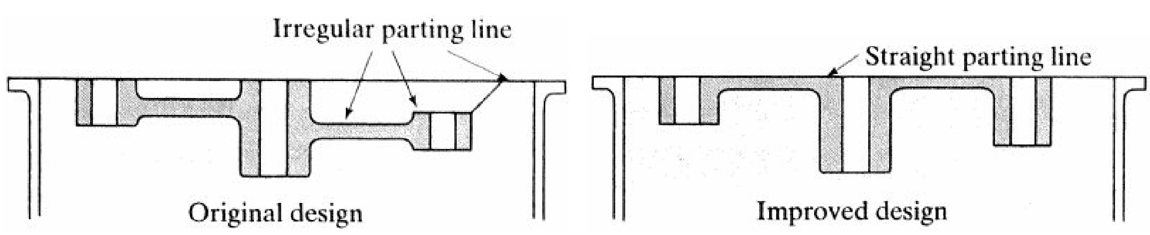


Figure 19. Parting line examples [source: Kalpakjian & Schmid]

Forging

Cold working: Generally done at room temperature or slightly above RT.

Advantages compared to hot forming:

(1) closer tolerances can be achieved; (2) good surface finish; (3) because of strain hardening, higher strength and hardness is seen in part; (4) grain flow during deformation provides the opportunity for desirable directional properties; (5) since no heating of the work is involved, furnace, fuel, electricity costs are minimized, (6) Machining requirements are minimum resulting in possibility of near net shaped forming.

Disadvantages:

(1) higher forces and power are required; (2) strain hardening of the work metal limit the amount of forming that can be done, (3) sometimes cold forming-annealing-cold forming cycle should be followed, (4) the work piece is not ductile enough to be cold worked.

Warm working: In this case, forming is performed at temperatures just above room temperature but below the recrystallization temperature. The working temperature is taken to be 0.3 *Tm where Tm is the melting point of the workpiece.*

Advantages:

(1) enhanced plastic deformation properties,
(2) lower forces required,
(3) Intricate work geometries possible,
(4) Annealing stages can be reduced.

Hot working: Involves deformation above recrystallization temperature, between 0.5*Tm to 0.75Tm.*

Advantages:

(1) significant plastic deformation can be given to the sample,
(2) significant change in work piece shape,
(3) lower forces are required,
(4) materials with premature failure can be hot formed,
(5) absence of strengthening due to work hardening.

Disadvantages:

(1) shorter tool life,
(2) Poor surface finish,
(3) lower dimensional accuracy,
(4) Sample surface oxidation

Important Forging Terms:

1) Forging die: It may be defined as a complete tool consists of a pair of mating members for producing work by hammer or press. Die pair consists of upper and lower die halves having cavities.

2) Billet: A slug cut from rod to be heated and forged.

3) Blocker: Preform die or impression, used when part cannot be made in a single operation.

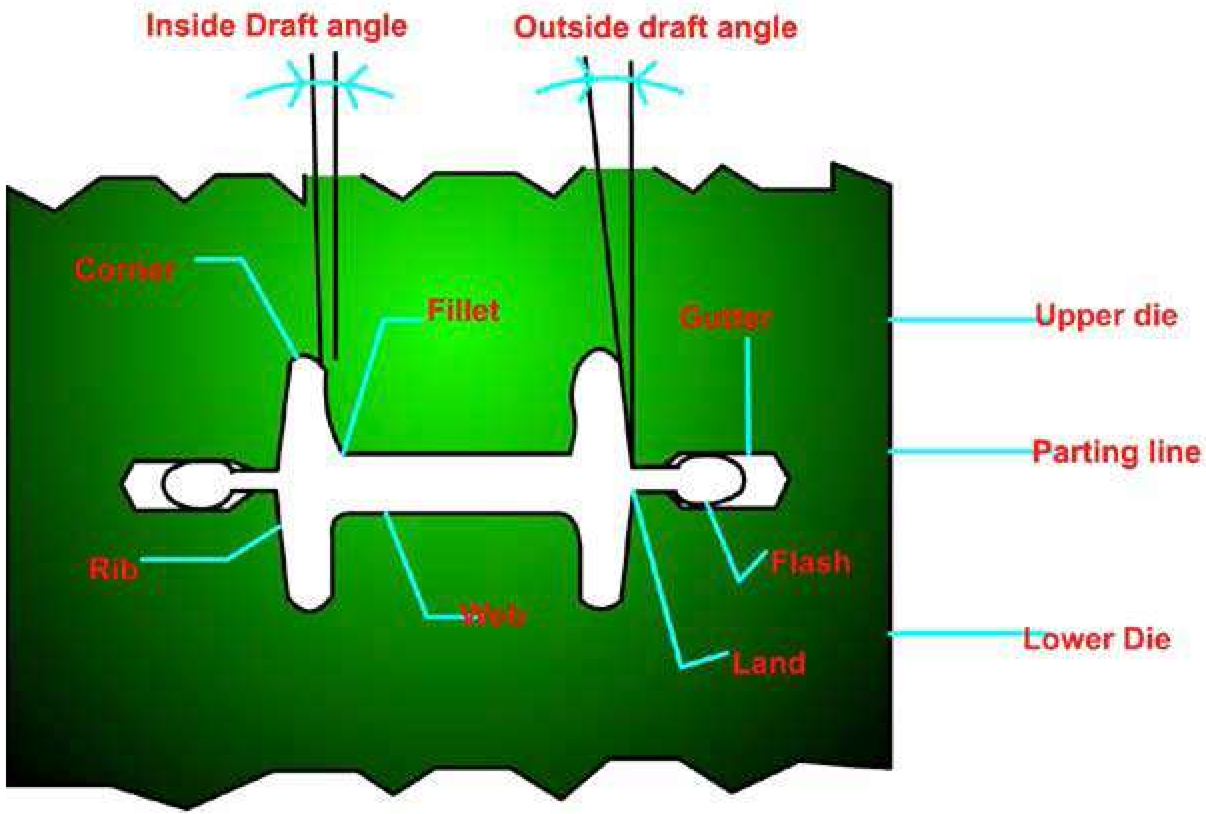
4) Cavity: The impression in upper and lower die.

5) Draft Angle: The taper on a vertical surface to facilitate the easy removal of the forging from the die or punch. Internal draft angles are larger (70 -100), whereas external draft angles are smaller (30 -5 0).

6) Fillet: It is a small radius provided at corners of die cavity to ensure proper and smooth flow of material into die cavity. It helps to improve die life by reducing rapid die wear.

7) Flash: The excess metal that flows out between the upper and lower dies which is required to accomplish a desired forging shape.

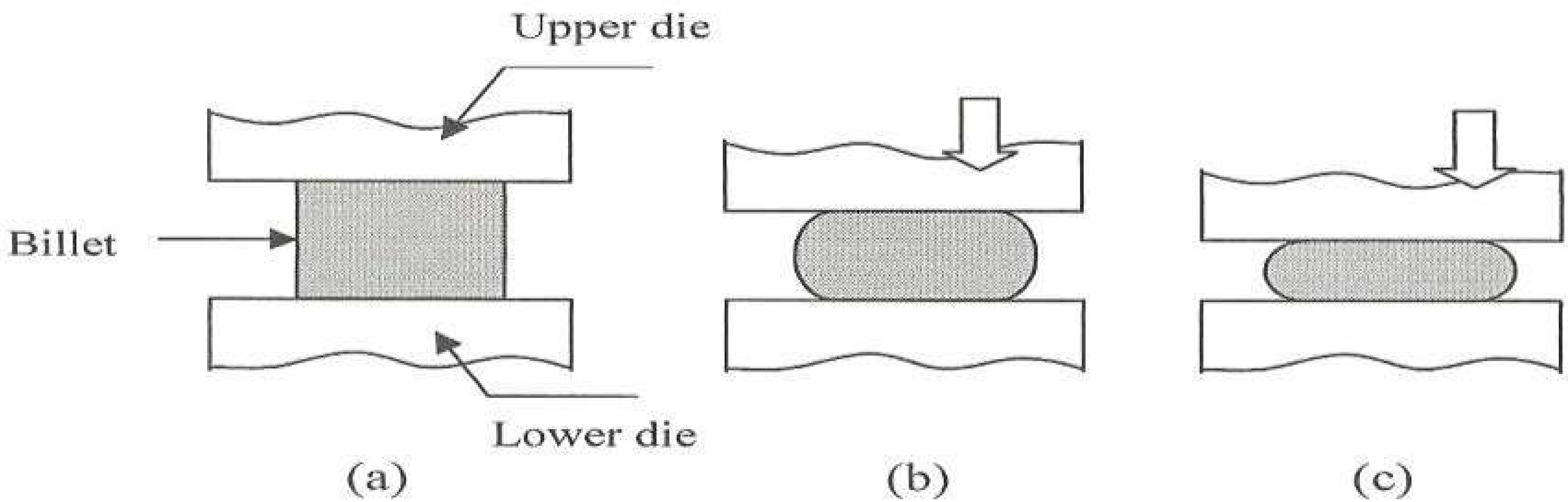
8) Gutter: A slight depression surrounding the cavity in the die to relieve pressure and control flash flow..
9) Parting Line: The location on the forging where excess material in the form of flash is allowed to exit from the forging during the forging operation.
10) Shrinkage: The contraction that occurs when a forging cools.
11) Sink: To cut an impression in a die.
12) Web: The thin section of metal remaining at bottom of a cavity or depression in a forging. The web may be removed by piercing or machining.
13) Die Closure: Refers to the function of closing together the upper and lower members of a forge die during the process of actually producing a forging



Inside Draft angle
Outside draft angle
Corner
Fillet
Gutter
Upper die
Parting line
Rib
Flash
Web
Land
Lower Die

Classification based on Arrangements of Dies

Open-die forging: Forging in which the flat dies of simple shape are used to allow the material to freely deform in lateral directions of applied load.



a) . Figure 1 shows open-die forging operation.

Under frictionless homogeneous deformation, the height of the cylinder is reduced and its diameter is increased. Forging of shafts, disks, rings etc are performed using open die forging technique. Square cast ingots are converted into round shape by this process.

Open die forging is classified into three main types, namely, cogging, fullering and edging.
Fullering and Edging operations are done to reduce the cross section using convex shaped or concave shaped dies. Material gets distributed and hence gets elongated and reduction in thickness happens.
Cogging operation involves sequence of compressions on cast ingots to reduce thickness and lengthen them into blooms or billets.

Flat or contoured dies are used. Swaging is carried out using a pair of concave dies to obtain bars of smaller diameter.

Features: Less dimensional accuracy, Suitable only for simple shapes of work, Requires more skill of the operator, Usually used for a work before subjecting it to closed-die forging (to give approximate shape), Dies are simple and less expensive, It is simplest of all the forging operations.

Closed die forging:

Impression-die forging: Forging in which the material is shaped to fill out a die cavity created by the upper and lower die halves. The dies are not fully closed and allow some material to escape as Flash. Flash formation builds pressure inside the bulk of the work piece, aiding material flow into unfilled impressions. Requires more complex (and more expensive) dies.

Features:

Work is rough forged close to final shape by blocking die

Work is forged to final shape and dimensions by Finishing die,

Both blocking die and finishing die are machined into the same die block.

More number of dies are required depending on the complexity of the job.

Two die halves close-in and work is deformed under high pressure, High dimensional accuracy/close control on tolerances, Suitable for complex shapes, Dies are complex and more expensive, Large production rates are necessary to justify high costs.

C. Die design parameters:

Die design depends on the knowledge of material property like strength and ductility, sensitivity of material to the rate of deformation and temperature, frictional characteristics, shape and complexity of work piece, die distortion under high forging loads. Hardenability and ability to harden uniformly, Resistance to mechanical and thermal shocks, Wear resistance- to resist abrasion wear due to scales present on work piece.

Selection of proper **die material** depends on: Die size, Composition and properties of work piece, Complexity of shape- No. of performing steps, Forging temperature, Type of forging operation, Cost of die material, No. of forgings required, Heat transfer from work piece to dies, etc.

Die materials used: Tool and die steels with Cr, Ni, Mo, Va.

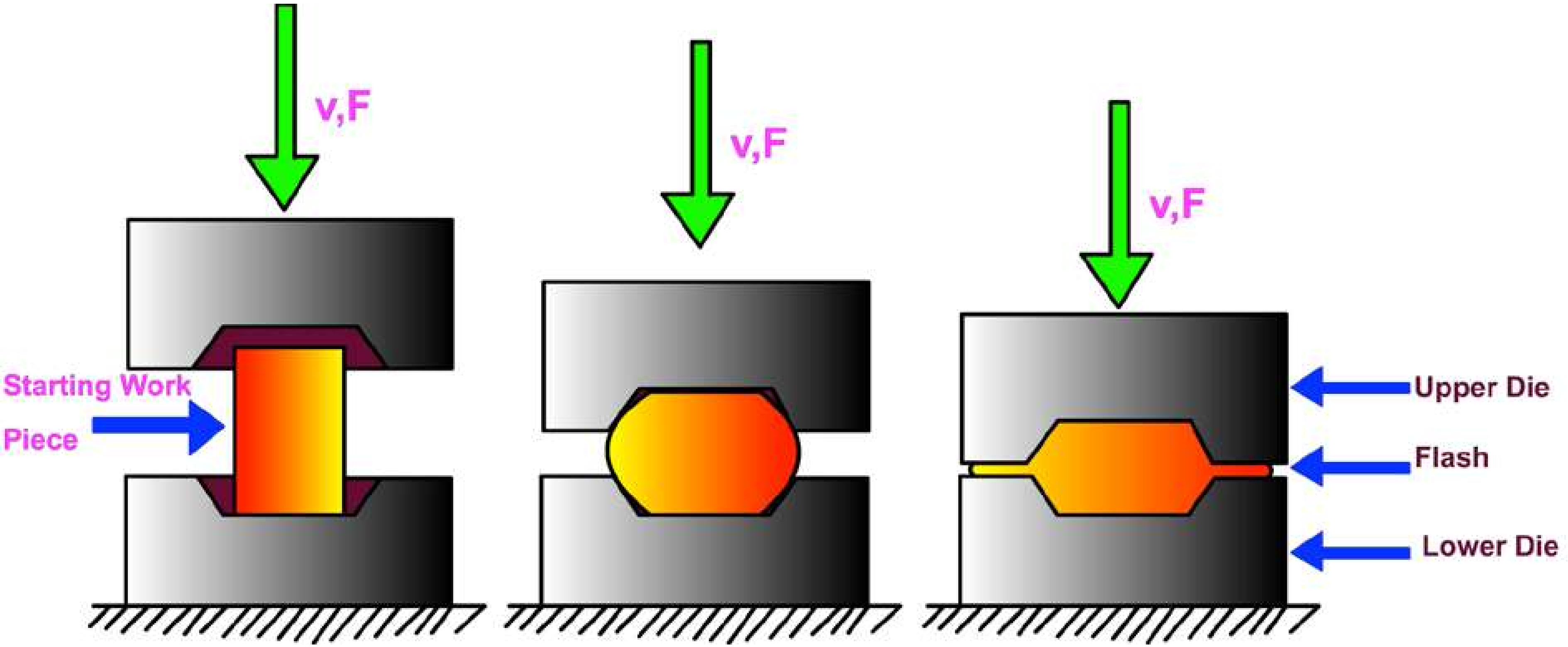


Figure 2 Impression-die forging operation.

Excess metal is squeezed out of the die cavity as a thin strip of metal, called Flash.
A flash gutter is provided to reduce the area of flash. Thin flash increases the flow resistance of the system and builds up the pressure to high values which ensures that all intricate shapes of cavity are filled.
Flash design is very critical and important step. Extremely thin flash results in very high pressure build up which may lead to breaking of the dies.

Forging load for impression die forging:

The forging load for impression die forging is determined empirically due to the complexities of material flow involved. One empirical relation for forging load, given by Schey is as followed:
$F = C1 Y_f A_f$, where C1is a shape factor or constraint factor which depends on the complexity of the forging process.
Y_f is the flow stress of material at the given strain,
A_f is the projected area of the forging. Typical values of C1:

Typical values of C1	
Simple upsetting	1.25 to 2.5
Flashless forging (Coining)	5 to 8
Complex forging with flash	8 to 12

D. Forging equipments

Forged components are shaped either by a hammer or press. Forging on the hammer is carried out in a succession of die impressions using repeated blows.

In press forging, the stock is usually hit only once in each die impression and the design of each impression is important

The equipment i.e. presses and hammers used in forging, influences the forging process, since it affects the deformation rate and temperature conditions, and it determines the rate of production. The requirements of a given forging process must be compatible with the load, energy, time, and accuracy characteristics of a given forging machine

Forging Hammer: The most common type of forging equipment is the hammer and anvil. The hammer is the least expensive and most versatile type of equipment for generating load and energy to carry out a forging process. This technology is characterized by multiple impact blows between contoured dies. Hammers are primarily used for hot forging.

There are basically two types of anvil hammers: **Gravity-drop hammers and Power-drop hammers.**

In a simple gravity-drop hammer, the upper ram is connected to a board (board-drop hammer), a belt (belt-drop hammer), a chain (chain-drop hammer), or a piston (oil-, air-, or steam-lift drop hammer). The ram is lifted to a certain height and then dropped on the stock placed on the anvil. During the down stroke, the ram is accelerated by gravity and builds up the blow energy. The upstroke takes place immediately after the blow.

The operation principle of a power-drop hammer is similar to that of an **air-drop hammer**. In the down stroke, in addition to gravity, the ram is accelerated by steam, cold air, or hot air pressure.

In the **power-drop hammer**, the acceleration of the ram is enhanced with air pressure applied on the top side of the ram cylinder.

Mechanical board hammer- It is a stroke restricted machine. Repeatedly the board (weight) is raised by friction rolls and is dropped on the die. Its rating is in the terms of weight of the ram and energy delivered.

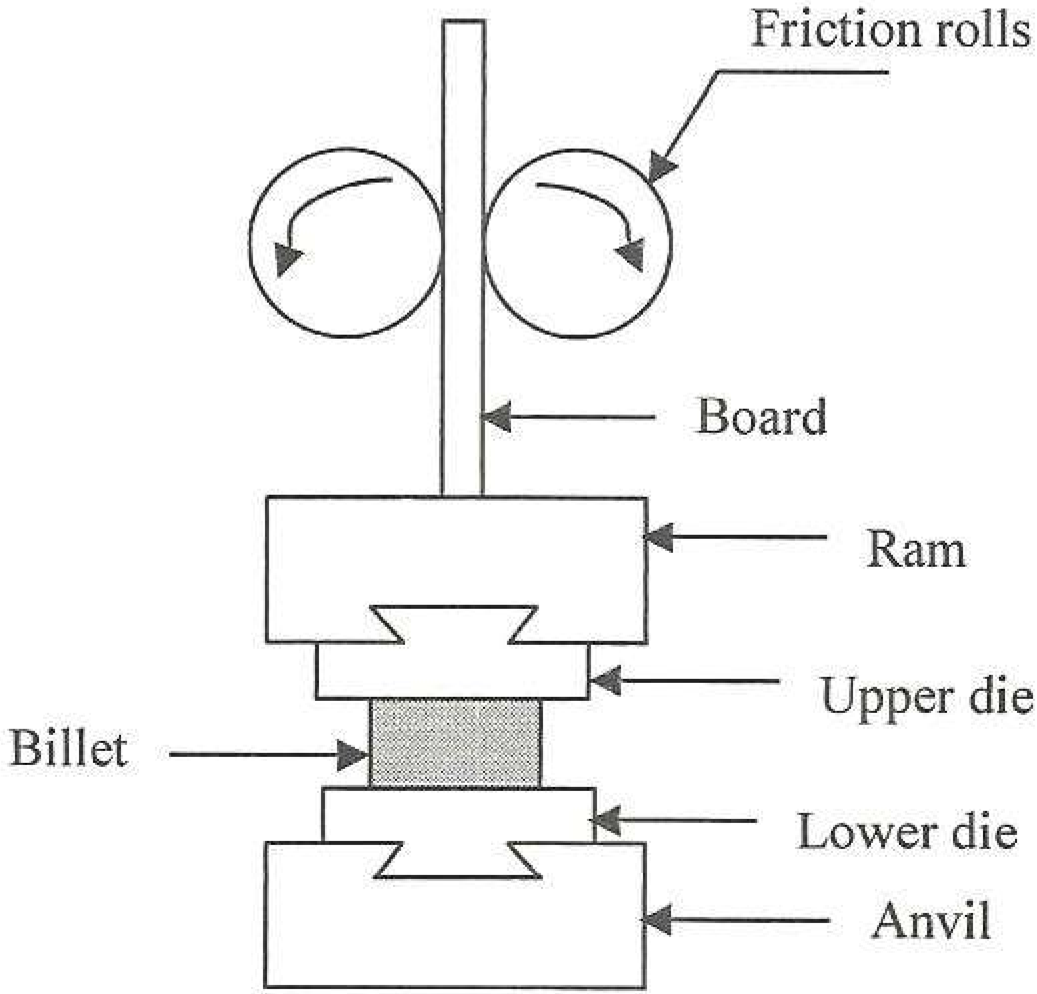


Figure 3: Mechanical board hammer

Steam hammer- It uses steam in a piston and cylinder arrangement. It has greater forging capacity. It can produce forgings ranging from a few kgs to several tones. It is preferred in closed-die forging.

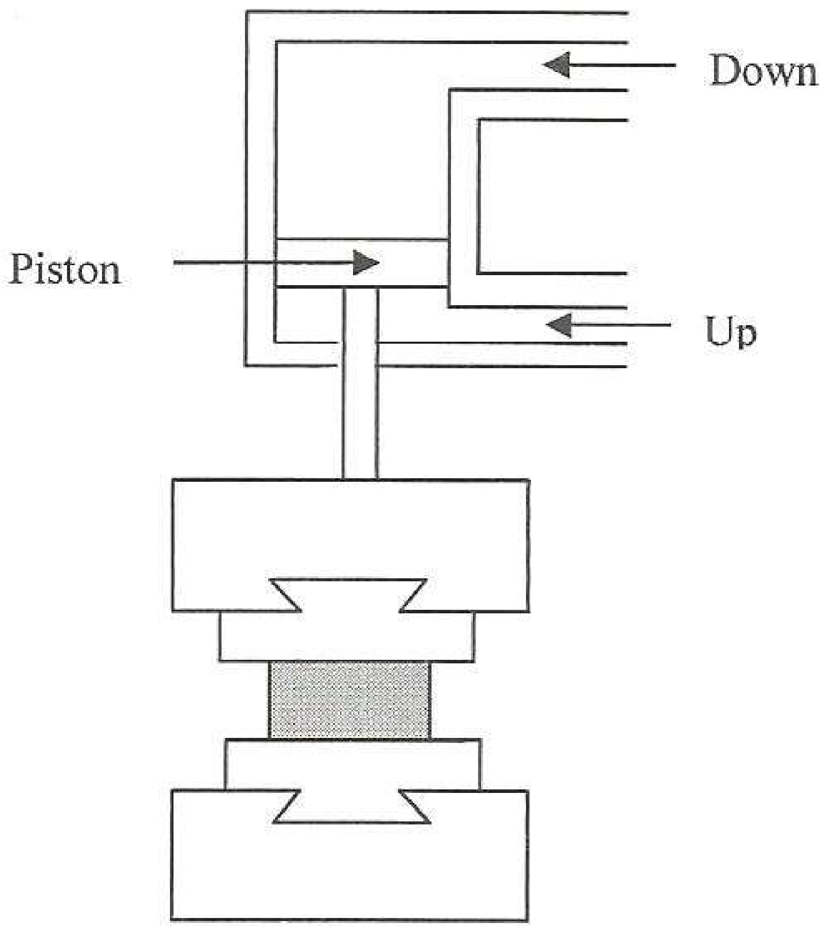


Figure 4: Steam hammer

Forging Press: In press forging, the metal is shaped not by means of a series of blows as in hammer forging, but by means of a single continuous squeezing action.
There are two main types: **mechanical** and **hydraulic** presses.

Mechanical presses function by using cams, cranks and/or toggles to produce a preset (a predetermined force at a certain location in the stroke) and reproducible stroke. Due to the nature of this type of system, different forces are available at different stroke positions. Mechanical presses are faster than their hydraulic counterparts (up to 50 strokes per minute). Their capacities range from 3 to 160 MN (300 to 18,000 short tons-force). Hydraulic presses use fluid pressure and a piston to generate force. It is a load restricted machine. It has more of squeezing action than hammering action. Hence dies can be smaller and have longer life than with a hammer.

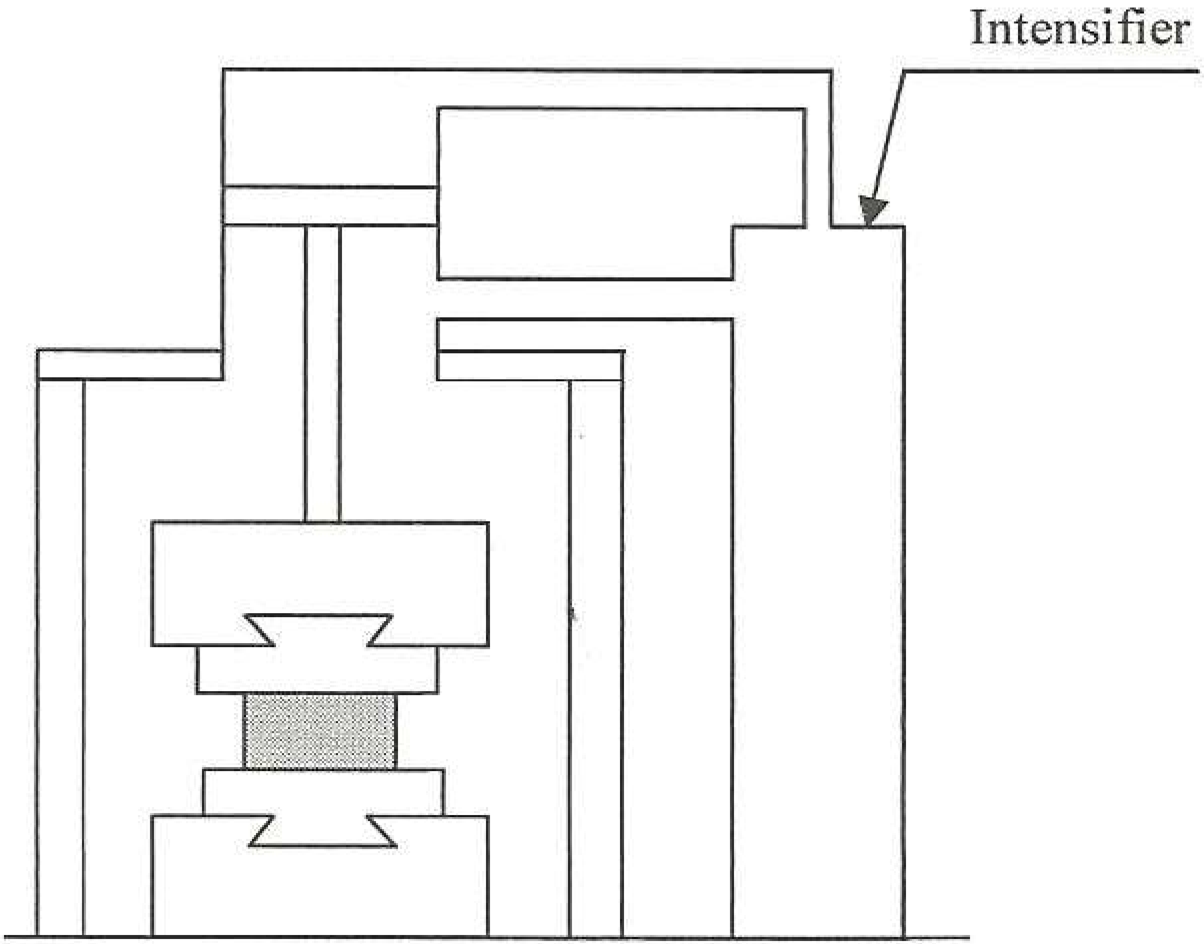


Figure 5: Hydraulic press

Forging Defects

When a forge shop begins to experience defects in their process, they should try to find the root cause of the problem, initiate corrective action and implement procedures to prevent its recurrence.

Description of defects and their remedial methods is given below:

1) Incomplete forging penetration:
Dendritic ingot structure at the interior of forging is not broken.
Actual forging takes place only at the surface.
Cause- Use of light rapid hammer blows
Remedy- To use forging press for full penetration.
2) Surface cracking:
Cause- Excessive working on the surface and too low temperature.
Remedy- To increase the work temperature

3) Cracking at the flash:
This crack penetrates into the interior after flash is trimmed off.
Cause- Very thin flash
Remedy- Increasing flash thickness, relocating the flash to a less critical region of the forging, hot trimming and stress relieving.

4) Cold shut (Fold):
Two surfaces of metal fold against each other without welding completely.
Cause- Sharp corner (less fillet), excessive chilling, high friction
Remedy- Increase fillet radius on the die.

5) Unfilled Section (Unfilling/Underfilling):
Some section of die cavity not completely filled by the flowing metal.
Cause- Improper design of the forging die or using forging techniques, less raw material, poor heating.
Remedy- Proper die design, Proper raw material and Proper heating.

6) Die shift (Mismatch): Misalignment of forging at flash line.
Cause- Misalignment of the die halves.
Remedy- Proper alignment of die halves. Make mistake proofing for proper alignment for eg. provide half notch on upper and lower die so that at the time of alignment notch will match each other.

7) Scale Pits (Pit marks):
Irregular depurations on the surface of forging.
Cause- Improper cleaning of the stock used for forging. The oxide and scale gets embedded into the finish forging surface.
Remedy- Proper cleaning of the stock prior to forging.

8) Flakes:
These are basically internal ruptures.
Cause- Improper cooling of forging. Rapid cooling causes the exterior to cool quickly causing internal fractures.
Remedy- Follow proper cooling practices.

MSE 440/540: Processing of Metallic Materials

Instructors: Yuntian Zhu

Office: 308 RBII

Ph: 513-0559

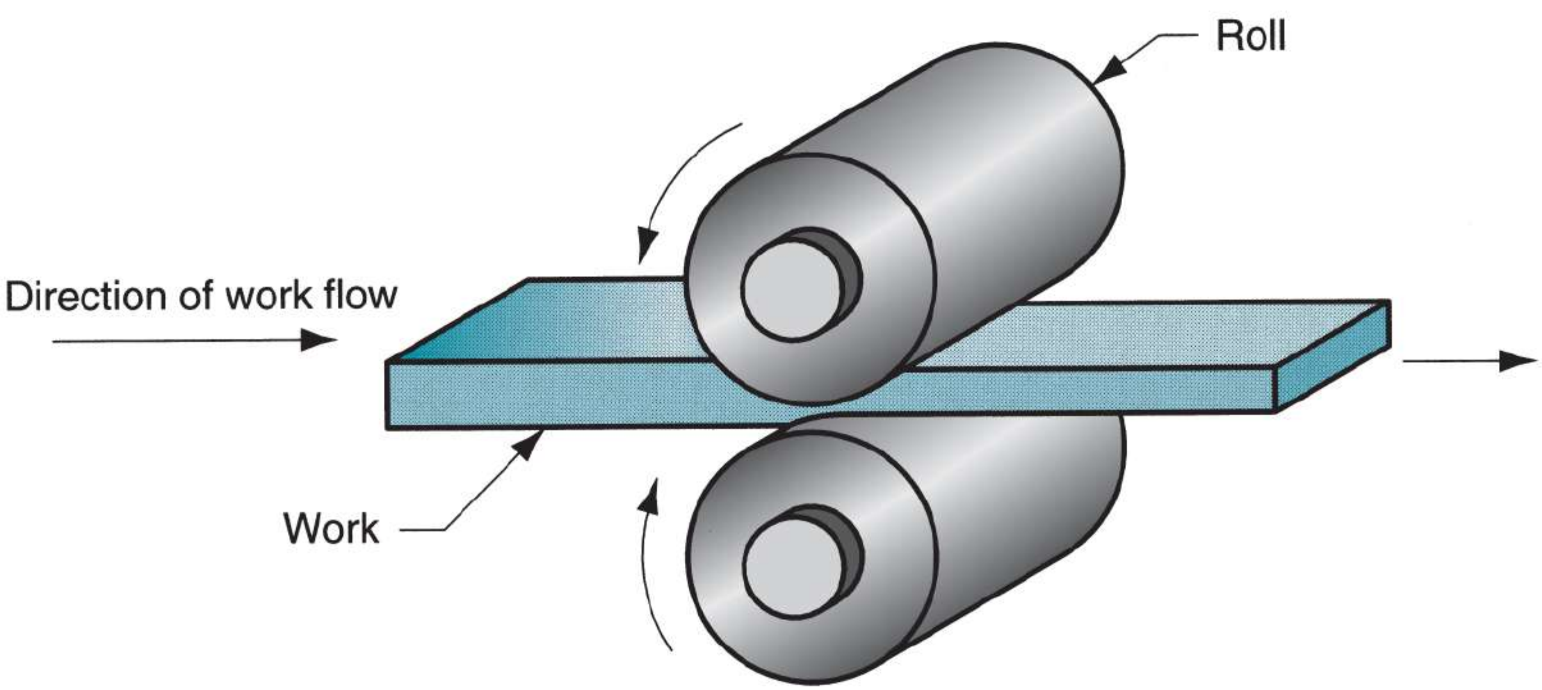
ytzhu@ncsu.edu

Lecture 10: Rolling and Extrusion

Rolling

Rotating rolls perform two main functions:

- Pull the work into the gap between them by friction between workpart and rolls
- Simultaneously squeeze the work to reduce its cross section



Types of Rolling

- Based on workpiece geometry
  - Flat rolling - used to reduce thickness of a rectangular cross section
  - Shape rolling - square cross section is formed into a shape such as an I-beam
- Based on work temperature
  - Hot Rolling – can achieve significant deformation
  - Cold rolling – produces sheet and plate stock

Rolled Products Made of Steel

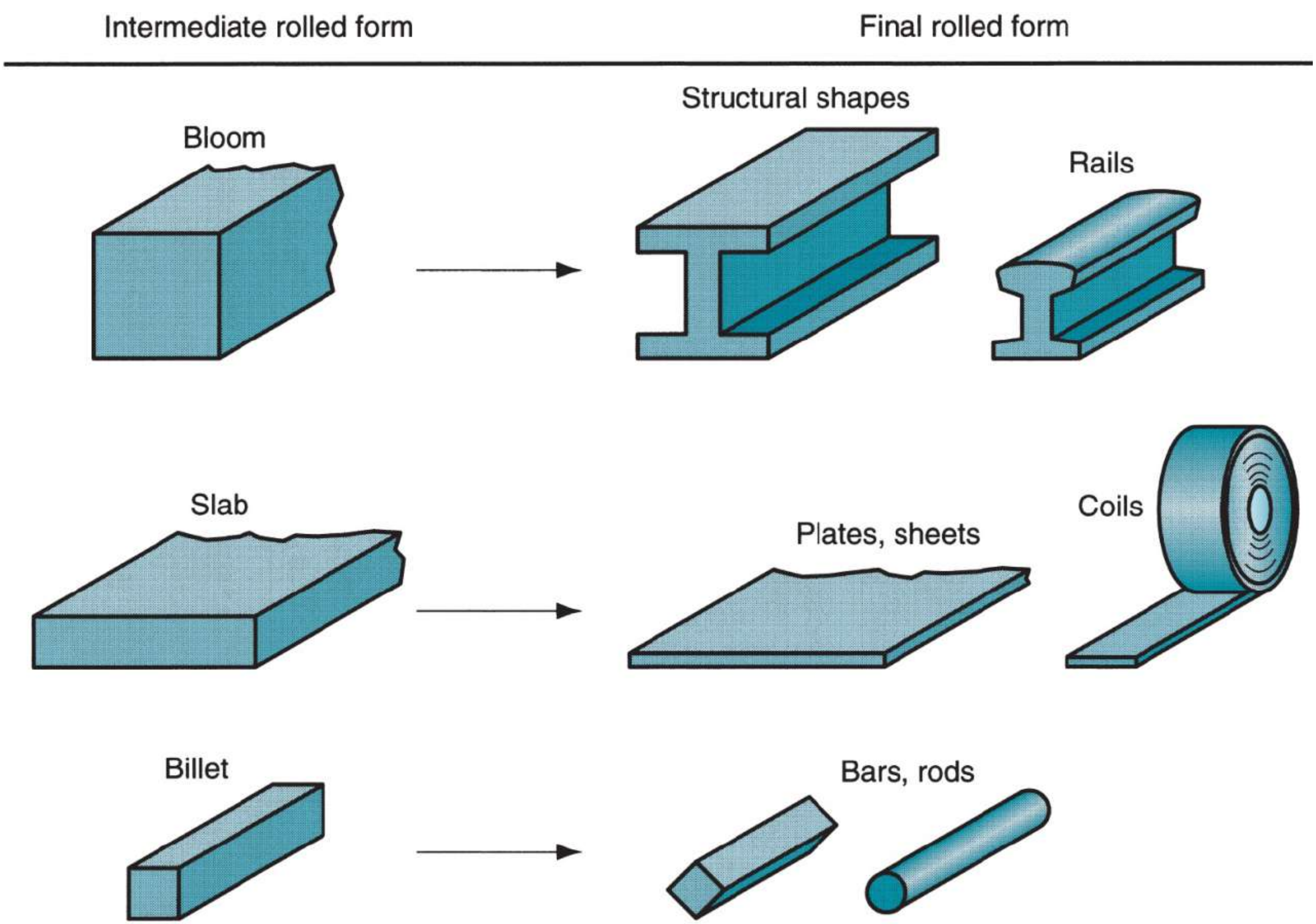


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Diagram of Flat Rolling

- Side view of flat rolling, indicating before and after thicknesses, work velocities, angle of contact with rolls, and other features.

True rolling strain:

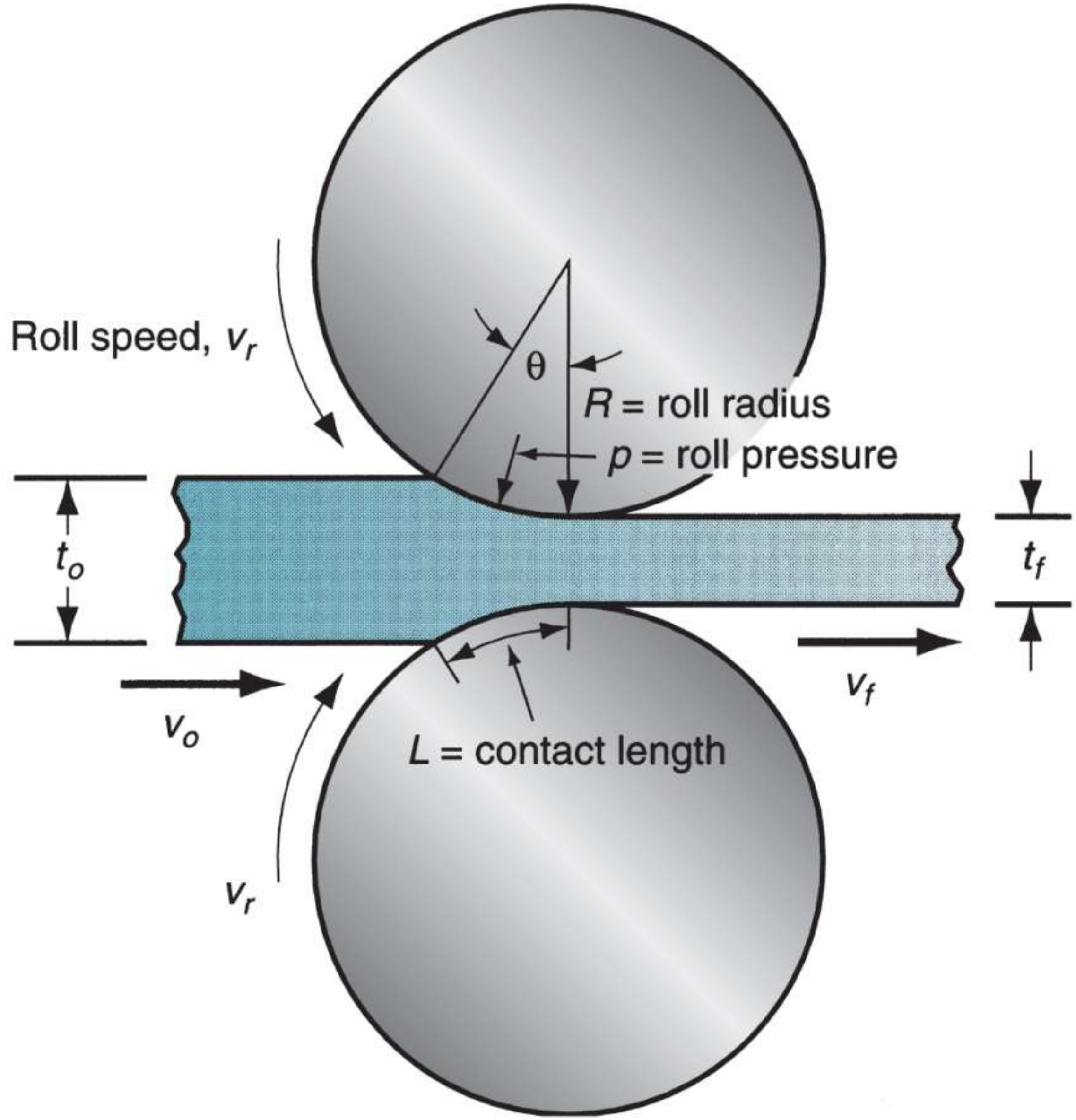
$$\varepsilon = \ln \frac{t_0}{t_f}$$

$$F = \bar{\sigma} w L,$$

$$L = \sqrt{R\left(t_0 - t_f\right)}$$

$$T = 0.5FL$$

$$P = 2\pi NFL$$



Flat Rolling Terminology

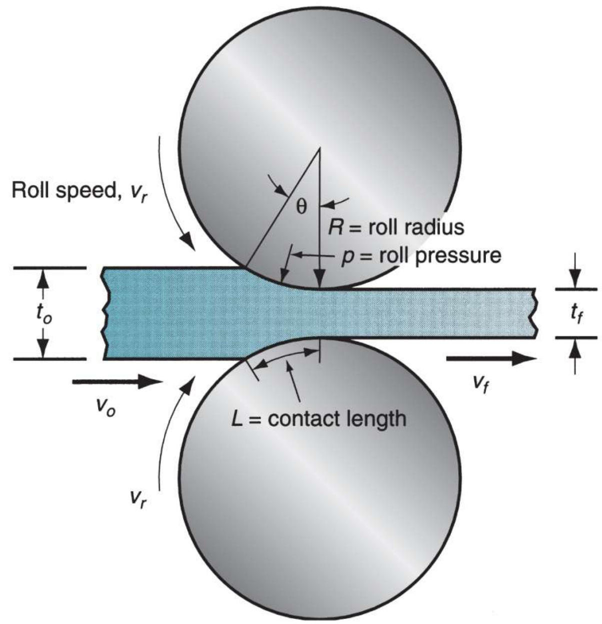
- *Draft* = amount of thickness reduction

$$d = t_o - t_f$$

- *Reduction* = draft expressed as a fraction of starting stock thickness:

$$r = \frac{d}{t_o}$$

Where t_o = starting thickness; t_f = final thickness

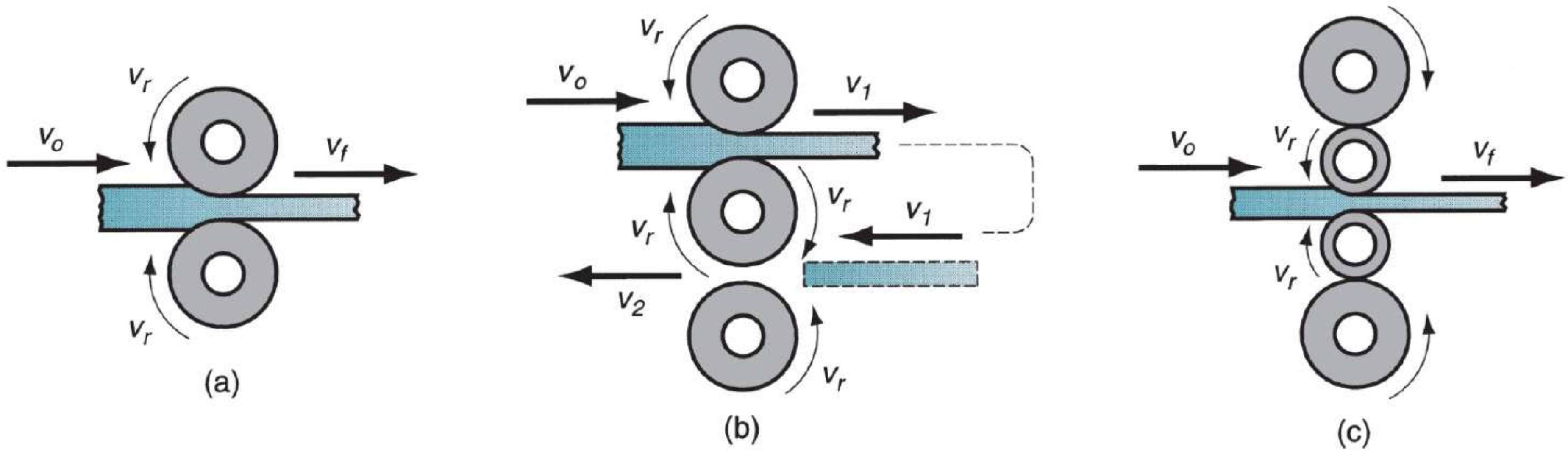


Shape Rolling

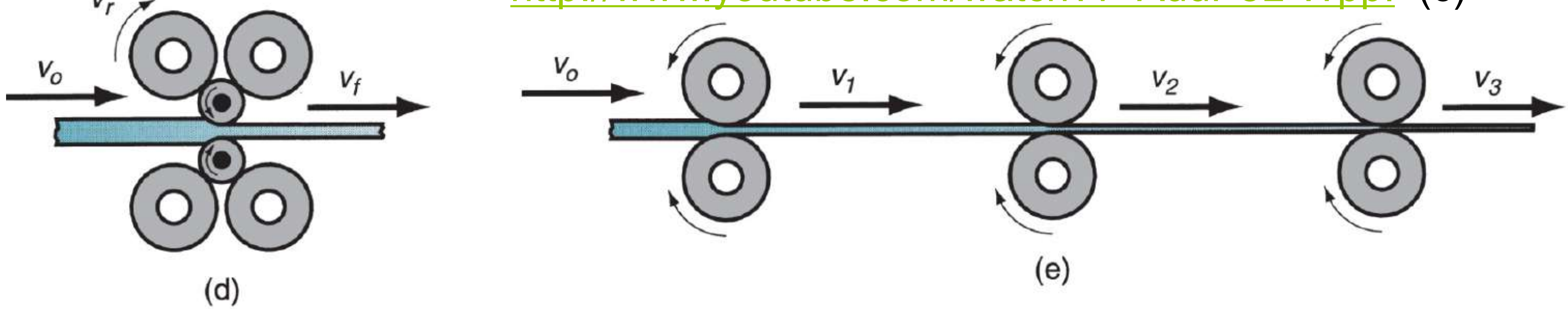
- Work is deformed into a contoured cross section rather than flat (rectangular)
  - Accomplished by passing work through rolls that have the reverse of desired shape
- Products
  - Construction shapes such as I-beams, L-beams, and U-channels
  - Rails for railroad tracks
  - Round and square bars and rods

Rolling Mill Configurations

- (a) Two-high, (b) three-high, (c) four-high



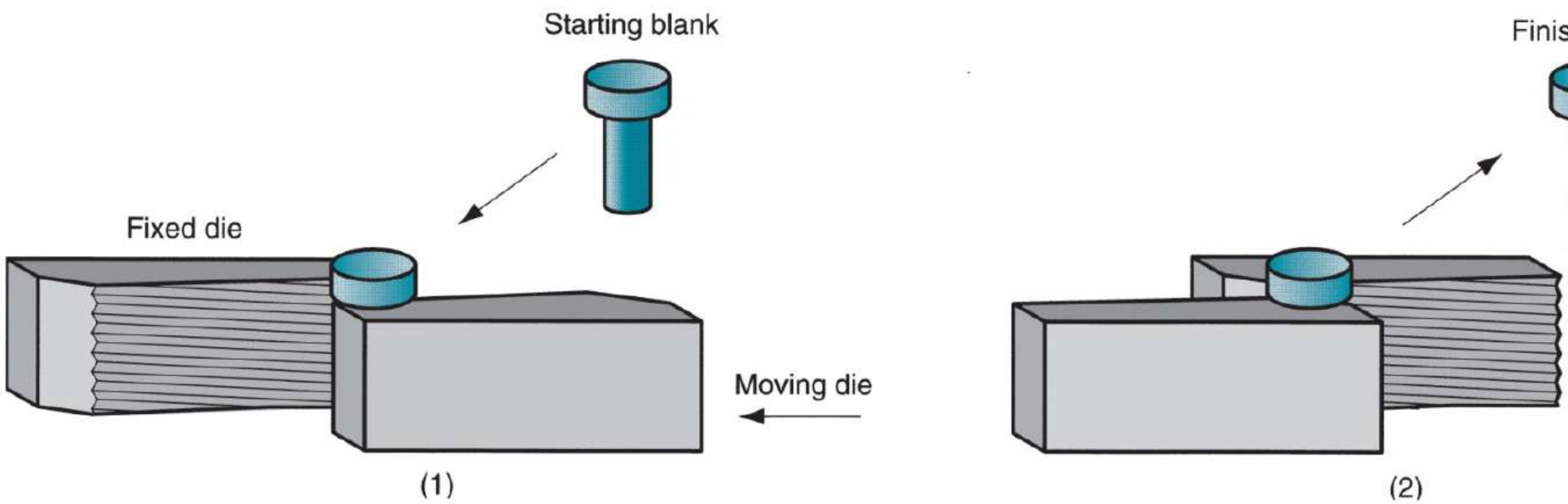
http://www.youtube.com/watch?v=AuuP8L-WppI (c)



- (d) Cluster mill, (e) tandem rolling mill

Thread Rolling

- (1) Start of cycle, and (2) end of cycle



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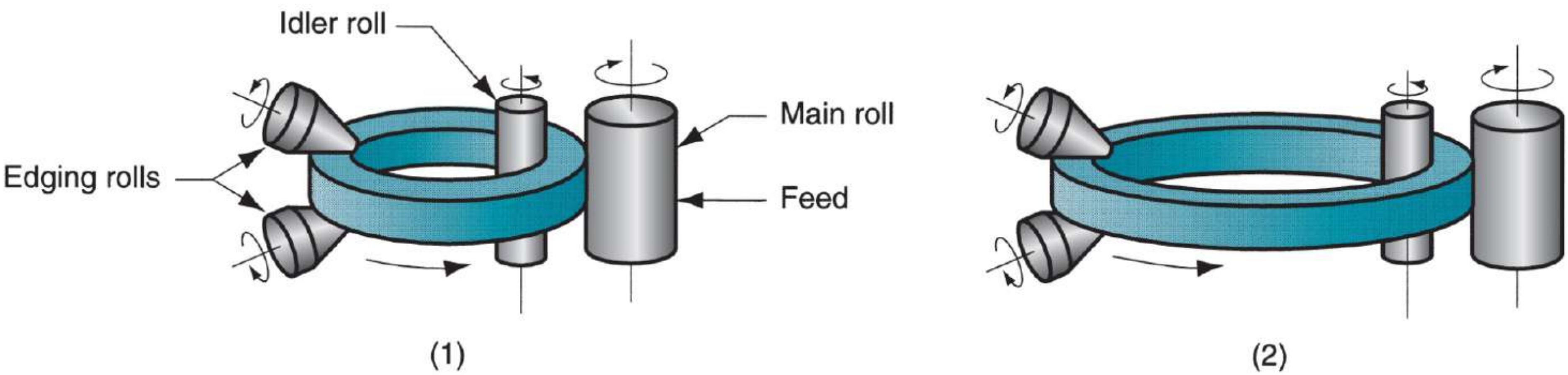
Ring Rolling

- As thick-walled ring is compressed, deformed metal elongates, causing diameter of ring to enlarge
- Hot working process for large rings and cold working process for smaller rings
- Products: ball and roller bearing races, steel tires for railroad wheels, and rings for pipes, pressure vessels, and rotating machinery



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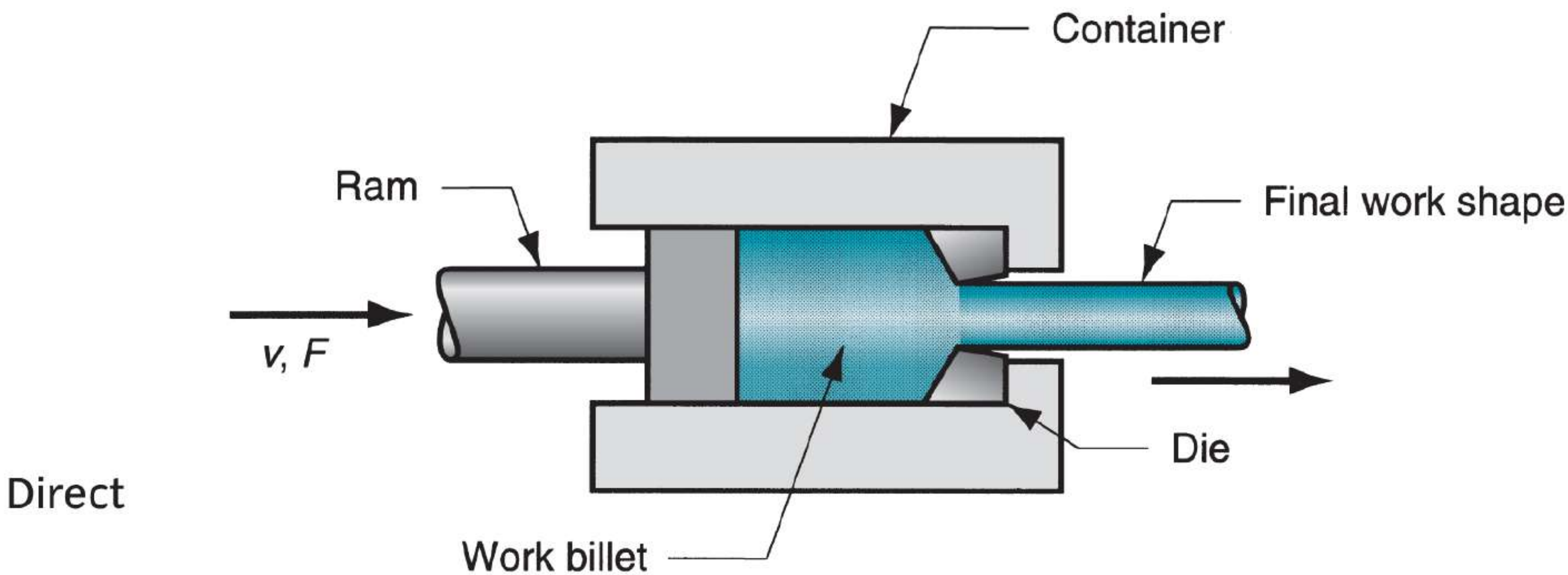
Extrusion

Compression forming process in which work metal is forced to flow through a die opening to produce a desired cross-sectional shape

- Process is similar to squeezing toothpaste out of a toothpaste tube
- In general, extrusion is used to produce long parts of uniform cross sections
- Two basic types:
  - Direct extrusion
  - Indirect extrusion

Direct Extrusion

- Also called *forward extrusion*
- As ram approaches die opening, a small portion of billet remains that cannot be forced through the die
  - This portion, called the *butt*, must be separated from the *extrudate* by cutting it off just beyond the die exit



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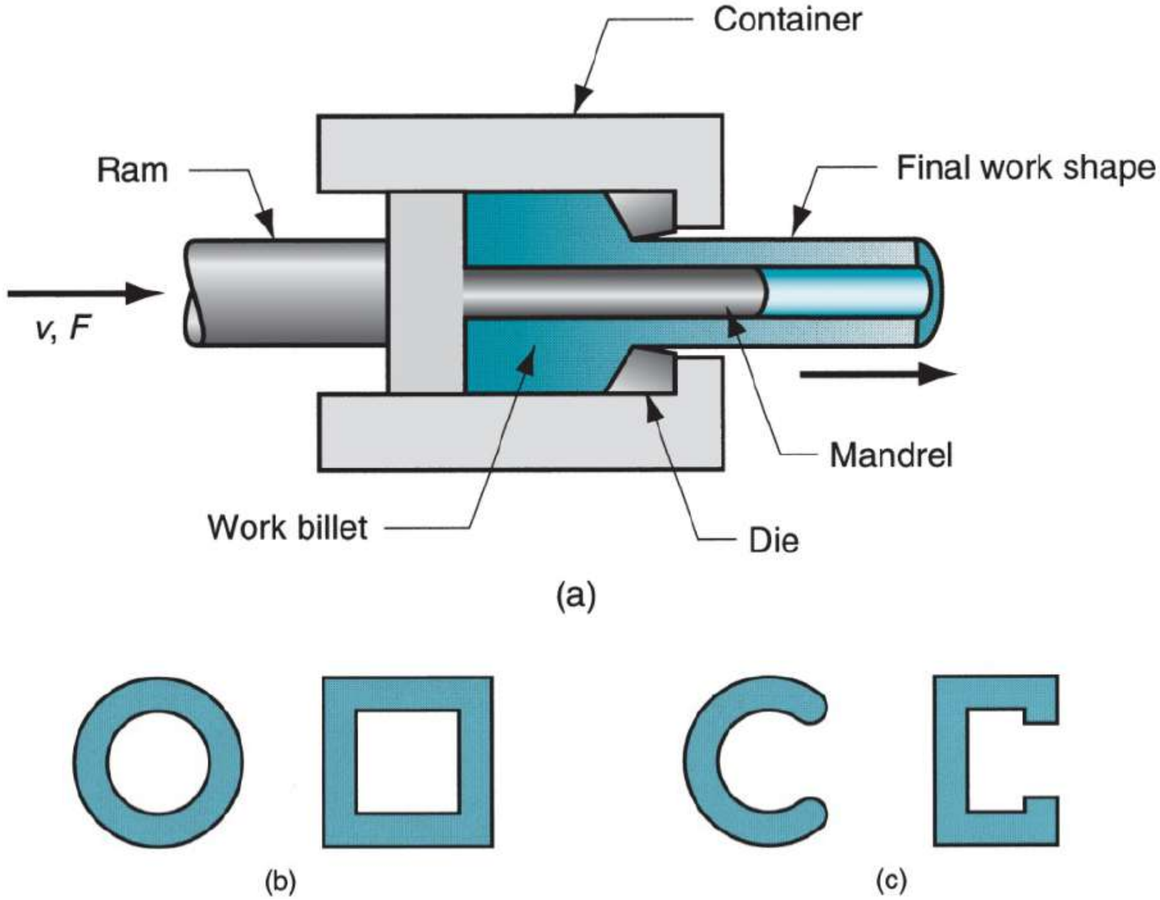
Hollow and Semi-Hollow Shapes

- (a) Direct extrusion to produce hollow or semi-hollow cross sections; (b) hollow and (c) semi-hollow cross sections



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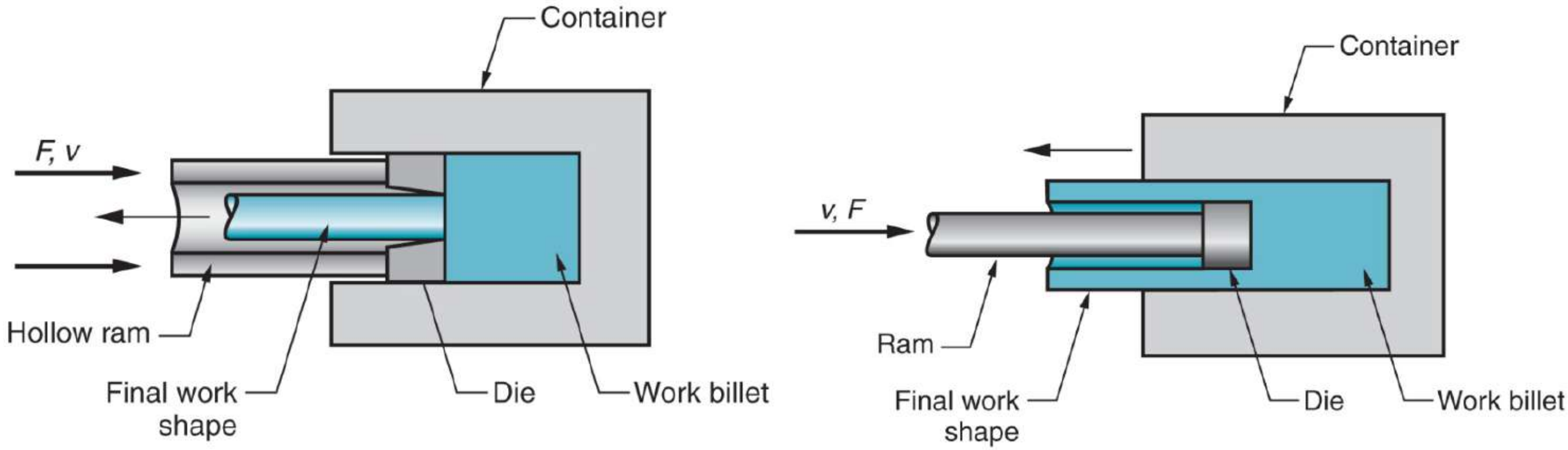
Indirect Extrusion

- Indirect extrusion to produce (a) a solid cross section and (b) a hollow cross section



(a) (b)

Comments on Indirect Extrusion

- Also called *backward extrusion* and *reverse extrusion*
- Limitations of indirect extrusion are imposed by
  - Lower rigidity of hollow ram
  - Difficulty in supporting extruded product as it exits die

Advantages of Extrusion

- Variety of shapes possible, especially in hot extrusion
  - Limitation: part cross section must be uniform throughout length
- Grain structure and strength enhanced in cold and warm extrusion
- Close tolerances possible, especially in cold extrusion
- In some operations, little or no waste of material

Hot vs. Cold Extrusion

- Hot extrusion - prior heating of billet to above its recrystallization temperature
  - Reduces strength and increases plasticity of the metal, permitting more size reductions and more complex shapes
- Cold extrusion - generally used to produce discrete parts
  - The term impact extrusion is used to indicate high speed cold extrusion

Extrusion Ratio

Also called the *reduction ratio*, it is defined as

$$r_x = \frac{A_o}{A_f}$$

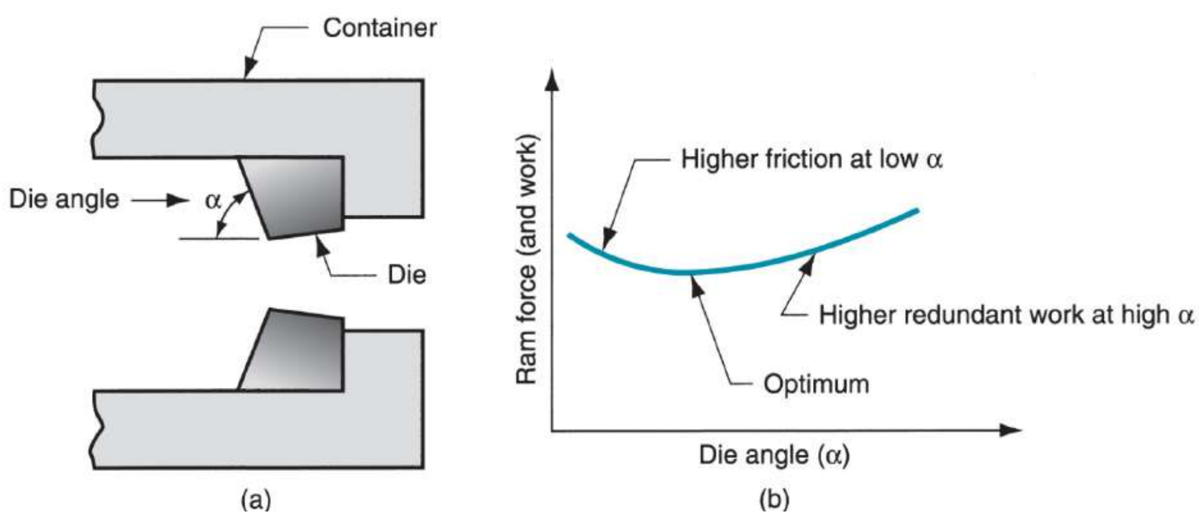
True strain:

$$\varepsilon = \ln r_x = \ln \frac{A_0}{A_f}$$

Quiz: What is the engineering strain?

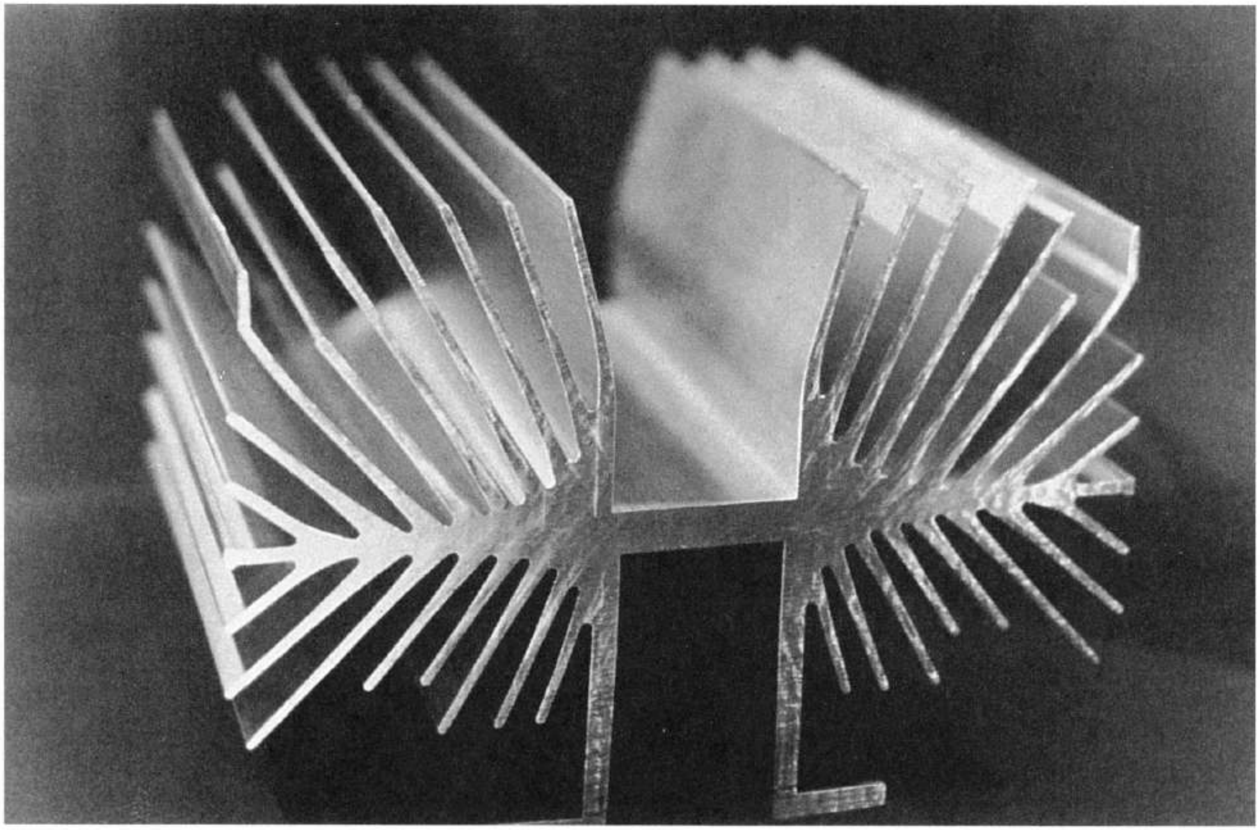
Extrusion Die Features

- Low die angle - surface area is large, which increases friction at die-billet interface
  - Higher friction results in larger ram force
- Large die angle - more turbulence in metal flow during reduction
  - Turbulence increases ram force required
- Optimum angle depends on work material, billet temperature, and lubrication



Complex Cross Section

- Extruded cross section for a heat sink (courtesy of Aluminum Company of America)



HW assignment

- Reading assignment: Chapters 13
- Review Questions: 13.2, 13.5, 13.8, 13.16, 13.17,
- Problems: 13.1, 13.3, 13.5, 13.8, 13.18, 13.20,

UNIT 3 PRESS AND PRESS TOOLS

Structure

3.1 INTRODUCTION

Metal forming is one of the manufacturing processes which are almost chipless. These operations are mainly carried out by the help of presses and press tools. These operations include deformation of metal work pieces to the desired size and size by applying pressure or force. Presses and press tools facilitate mass production work. These are considered fastest and most efficient way to form a sheet metal into finished products.

Objectives

After studying this unit, you should be able to understand

- introduction of press tool,
- major components of press working system,
- different criteria of classification of presses,
- different types of presses,
- description of important parts of a press,
- specifications of a press,
- other press working tools, like punch and die,
- components of press working system,
- different types of die sets, and
- design considerations for die set design.

3.2 PRESS

A press is a sheet metal working tool with a stationary bed and a powered ram can be driven towards the bed or away from the bed to apply force or required pressure for various metal forming operations. A line diagram of a typical pres is explained in the Figure 2.1 hydraulic system. The relative positions of bed and ram in the press are decided by the structure of its frame. The punch is generally gripped into the punch holder and punch holder is attached to ram. A balster steel plate is attached to the bed of the press and die is mounted on the balster steel plate.

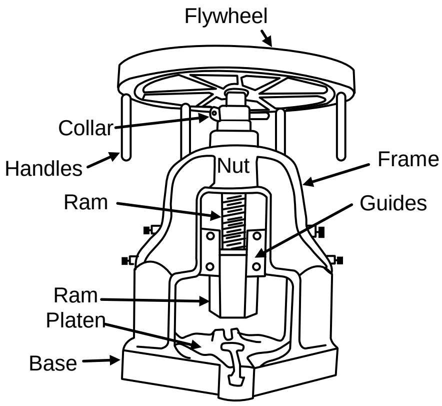


Figure 3.1 : Line Diagram of a Typical Press

Presses are available in a variety of capacities, power systems and frame type. Meaning of capacity of press is its capability to apply the required force to complete the operation.

Power and Drive System

Power systems on presses are either hydraulic presses use a large piston and cylinder to drive the ram. This system is capable to provide longer ram strokes than mechanical dries. It gives a consistent applied load. Its working is comparatively slower. These presses can be single action or double action or so on. Number of actions depends on the number of slides operating independently.

Mechanical presses are used several types of drive mechanisms. These drives includes eccentric, crankshaft, knuckle joint, etc. These drives are used to convert rotational motion given by a motor into linear motion of the ram. A fly wheel is generally used as reservoir of energy for forging operations. These presses are recommended for blanking and punching operations as the involved drives are capable to achieve very high forces at the end of their strokes.

Press working is used in large number of industries like automobile industry, aircraft industry, telecommunication electrical appliance, utensils making industry are major examples.

3.3 TYPES OF PRESSES

There are different criteria of classification of presses into different categories. These criteria, related classifications and their descriptions are discussed below.

According to the Power Source

These power source are categorized as :

Manually Operated or Power Driven

These presses are used to process thin sheet metal working operations where less pressure or force is required. These are operated by manual power. Most of manually operated presses are hand press, ball press or fly press.

Power Presses

Power presses are normally driven by mechanical mechanism or hydraulic system. Power source of these presses may be electric motor or engine.

According to the Type and Design of Frame

The type and design of frame depending on the design of frame these are classified as inclinable, straight side, adjustable bed, gap frame, horning and open end.

Inclinable Frame Press

Its frame is called inclinable due to its capability to tilt back upto some angle. It can be locked into nay of its inclined position as shown in Figure 3.2. Its back is open to exit the scrap so it is also called open back inclinable press.

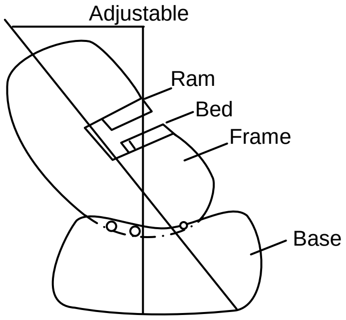


Figure 3.2 : Inclinable Frame Press

Gap Frame Press

These presses have larger frame openings, that means a wide gap between its base and ram to accommodate larger workpieces. It also has longer beds, as shown in Figure 3.3.

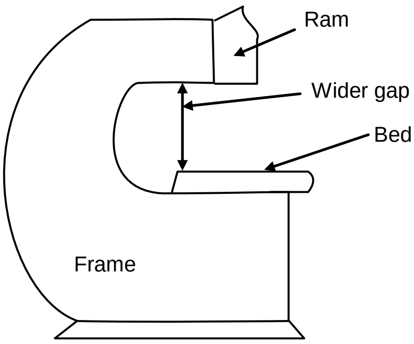


Figure 3.3 : Line Diagram of a Gap Frame Press

Straight Side Press

These presses have straight side type frame which is preferred for presses having larger bed area and high tonnage. This offers greater rigidity and capable of longer strokes. The frame consists of vertical and straight sides so it is called straight side press.

Adjustable Bed Type Press

It is also called column and knee type press because it has a knee type bed supported on its column shaped frame. Its bed (knee) can be adjusted at any desirable height by moving it vertically up or down with the help of power screws. In this structure there is slight lack of rigidity as compared to other structures. It is shown in Figure 3.4.

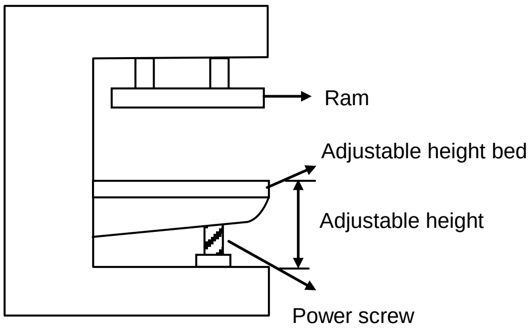


Figure 3.4 : Adjustable Bed Type Press

Open End Press

It has a solid type of vertical frame with all sides open. Driving mechanism is housed at the back and ram controlling mechanism at the front. It is easily to accommodate workpiece and dies in this type of structure. Its is identified as light duty machine.

Horning Press

It consist of a vertical frame, top of which over hangs towards the front. The over hanging portion serves for housing for driving mechanism and ram control. The frame consists of a front face as a work table called horn.

According to the Position of Frame

Presses can also be categorized by the position of frame as described below.

Inclinable Frame

Already described.

Vertical Frame

Vertical frame type of press is already been discussed, it cannot be adjusted like inclinable frame. Gap, adjustable bed, straight side, open end and honing presses are the example of vertical frames.

Horizontal Frame

It has a fixed frame in horizontal position. It provides the facility of auto ejection of produced part and scrap due to gravity.

Inclined Frame

Like inclinable frame, inclined frame press has an inclined frame but fixed, it cannot be adjusted to any other angle.

According to the Actions

According to the number of actions it can be categorized as single action, double action or triple action press. Here number of actions is same as the number of rams on the press.

According to Mechanism Used to Transmit Power to Ram

Crank Press

It consists of crankshaft driven by a flywheel, rotary motion of the crankshaft is converted into reciprocating motion with the help of a connecting rod connected to ram.

Cam Driven Press

In this press, a cam is used to press the ram down words and suitably located springs restore the original position of ram when pressure applied is removed. This mechanism has a limitation of size of the press.

Eccentric Press

In this press, the driving shaft carries an eccentric integral with it. One end of the connecting rod carried an attachment of revolving eccentric and its other end is connected to ram. As the eccentric shaft revolves, the offset between the eccentric centre and the centre of rotation of the shaft provides the required movement.

Knuckle Press

This press is driven with the help of knuckle joint mechanism. The main advantage of this press is partial back thrust is transferred to crankshaft, its major portion is transferred to back crown which is capable to hear. This enables the application of this press for heavier jobs with high intensity of blows. These presses are recommended for coining, squeezing, extruding and embossing. They have a limitation of shorter stroke lengths.

Toggle Press

These presses work on toggle mechanism and used for double and triple action presses for driving the outer rams. However, crankshaft drive is used for the inner ram. These are used for large draw dies, in which this mechanism actuates the blank holder whereas the punch is operated by the crank driven inner ram.

Screw Press

This is known as power screw or percussion press. There is a vertical are like frame, its job forms a nut. There is a flywheel at the top of and engages the ram at its bottom. The flywheel is driven by a friction disc and the rotating screw lowers and raises the ram. The flywheel is accelerated by friction drive. Its total energy is expanded in striking the work, bringing it to a halt. The intensity of blow can be regulated by adjusting the height of the die. Higher the position of the die, lesser the speed of the flywheel and hence lower the intensity of blow. These presses have a limitation that the ram movement is slow so these are recommended for sheet metal work only.

Hydraulic Press

These presses have a piller type construction or carry the hydraulic cylinder at the top of the crown. These presses provide longer stroke than mechanical presses with adjustable intensity of blow. Their stroke length can also be adjusted with full tonnage. These are recommended for deep drawing, extruding and plastic moulding.

Rack and Pinion Press

Rack and pinion driven presses are called rack and pinion presses meant for long strokes. Major advantage is faster operation of this press due to involvement of quick return motion. There are some limitations of this press. Load bearing capability of rack and pinion mechanism is very low so these are light duty machines. Ram movement is slightly slower. These presses have very limited use now-a-days.

According to Number of Drive Gears

Number of drive gears means number of gears attached at the ends of crankshaft, used to drive it. Smaller presses have single drive and larger presses may be double drive crankshafts. Very large presses with longer beds, carry long crankshafts. They have risk of twisting. These crankshafts are provided with one driving gear at each ends, these presses are named as twine drive presses. If a press carries two crankshafts each having a twin drive, such presses are called quadruple drive presses.

According to Number of Crankshaft in a Press

According to the number of crankshafts used in a press, these are directly classified as single crank (having one crankshaft) double crank (having two crankshafts).

Method of transmission of power from Motor to Crankshaft

The method used for transmission of power from motor to crankshaft categorized presses into following categories :

Direct Drive Press

In this case, power is directly transferred through gears pair. Smaller gear is mounted on the motor shaft, called pinion, its mating gear which is larger, mounted on the crankshaft. The larger gear also acts as flywheel. The flywheel is attached to the crankshaft through clutch and equipped with the facility of disengaging it as per the need. Such presses have shorter strokes and these are light duty presses.

Flywheel Driven Presses

These presses consists no gears so also called "No geared presses". For the transmission of power motor pulley is connected to flywheel driven crankshaft by Vee belt and pulley system. A clutch is used to engage or disengage the flywheel with the crankshaft. These presses are light duty presses providing shorter and quicker strokes.

Single Geared Drive Presses

This press consists of a counter shaft between motor shaft and crankshaft. Flywheel is mounted on the countershaft. Power is transferred from motor to flywheel (countershaft) through 'Vee' belt drive and then from counter shaft to crankshaft through pinion and gear. Clutch is mounted between pinion and flywheel to disengaged the power transmission as per the requirements. In these presses there are two steps for rpm reduction and torque enhancement so these are heavy duty mechanics with longer strokes.

Double Geared Drive Presses

In these type of presses an additional shaft named as intermediate shaft is introduced between the countershaft mounted flywheel and the crankshaft of a single geared drive. Twin drive is possible in this case by having similar gear train on other sides of two shafts. This provides slow stroke with larger power.

According to the Purpose of Use

Some of the operations require low stroke strength and some lager stroke strength. In the same way requirements of stroke length is different for different operations. So depending on power and stroke length presses are classified as given below depending on their suitability of performing different operations.

(a) Shearing press

(b) Seaming press

(c) Straightening press

(d) Punching press

(e) Extruding press

(f) Caining press

(g) Forging press

(h) Rolling press

(i) Bending press.

3.4 MAIN PARTS OF A TYPICAL POWER PRESS

Different types of presses have almost common types of main parts. These parts are described below.

Base

The all machine tool, base is the one of the parts of a press. It is main supporting member for workpiece holding dies and different controlling mechanisms of press. Size of the table limits the size of workpiece that can be processed on a press. In case of some special presses the base carries mechanism for tilting the frame in any desirable inclined position too.

Frame

Frame constitute main body of the press located at one edge of its base. It houses support for ram, driving mechanism and control mechanisms. Some of the press have column shaped frame.

Ram

This is main operating part of the press which works directly during processing of a workpiece. Ram reciprocates to and fro within its guideways with prescribed stroke length and power. The stroke length and power transferred can be adjusted as per the requirements. Ram at its bottom end carries punch to process the workpiece.

Pitman

It is the part which connects the ram and crankshaft or ram eccentric.

Driving Mechanism

Different types of driving mechanisms are used in different types of presses like cylinder and piston arrangement in hydraulic press, crankshaft and eccentric mechanisms in mechanical press, etc. these mechanisms are used to drive ram by transferring power from motor to ram.

Controlling Mechanisms

Controlling mechanisms are used to operate a press under predetermined controlled conditions. Normally two parameters are adjusted by controlling mechanisms length of stroke of ram and power of stroke. Transfer of power can be disengaged with the help of clutch provided with driving mechanisms as per need. In most of the presses controlling mechanisms is in built with the driving mechanisms. Now-a-days compute controlled presses are being used in which controlling is guided by microprocessor. These presses provides reliable and accurate control with automation.

Flywheel

In most of the presses driven gear or driven pulley is made of the shape of flywheel, which is used for storing the energy reserve wire of energy) for maintaining constant speed of ram when punch is pressed against the workpiece. Flywheel is placed in the driving mechanism just before the clutch is sequence of power transmission.

Brakes

Brakes are very urgent in any mobile system. Generally two types of brakes are used normal brake, which can bring the driven shaft to rest quickly after disengaging it from flywheel. Other is emergency brakes which are provided as foot brake to any machine. These brakes include power off switch along with normal stronger braking to bring all motions to rest quickly.

Balster Plate

It is a thick plate attached to the bed or base of the press. It is used to clamp the die assembly rigidly to support the workpiece. The die used in press working may have more than one part that is why the phrase die assembly is being used at the place of die.

3.5 SPECIFICATIONS OF A PRESS

Expressing size of a machine (press) includes expressing each of the parameters pertaining to it quantitatively in appropriate units. Expressing size in the above mentioned way is the specifications of press. The following parameters are expressed as specifications of a press.

(a) **Maximum Force :** Maximum force that its ram can exert on the workpiece, this is expressed in tones and called tonnage. It varies from 5 to 4000 tonnes for mechanical press. It may be up to 50,000 tonnes by hydraulic press.

(b) **Maximum Stroke Length :** Maximum distance traveled by the ram from its top most position to extreme down position. It is expressed in mm. the stroke length is adjustable so different values that can be obtained between minimum and maximum of stroke length, these are also the part of specifications.

(c) **Die Space :** Total (maximum) surface area, along with ($b \times d$), of bed, base, ram base. This the area in which die can be maintained.

(d) **Shut Height :** Total opening between the ram and base when ram is at its extreme down position. This is the minimum height of the processed workpiece.

(e) **Press Adjustments :** Different stroke lengths (already covered in point number 2). Different tonnage that can be set as per the requirement.

(f) **Ram Speed :** It is expressed as number of strokes per minute. Generally it can be 5 to 5000 strokes per minute.

3.6 PRESS TOOL

Commonly used tools which are major components of press working are punches and dies. Punch is an important part of the system which is fastened to the ram and forced into the die where workpiece to be processed is supported. Die is a work holding device, designed specifically for a particular design of a product. Die is rigidly held on the base of the press. Die carries an opening which ϕ is perfectly aligned with the punch and its movement. Both die and punch work together as a unit and this is called a die set. Punch and die both are made of high speed steel. Die is the part where strength and wear resistant both properties are required. So normally working surface of the die is made of satellite or cemented carbide. Details of the die set are described below.

Punch

Lower end of the ram holds punch holder which is equipped with the punch plate. Punch plate is generally made of stainless steel or HSS. The punch plate holds the punch rigidly and accurately. Different ways of holding the punch are described below :

(a) Punch can be fastened by forcing it to punch plate, top end of the punch is flattened to fit in the countersunk recess as shown in Figure 3.5.

(b) Punch can be clamped to the punch plate by a set screw. The correct position of the punch is located by cutting a slot into the punch plate as shown in Figure 3.5.

(c) Shank of the punch is forced into the punch plate top end of the punch is made flat to fit into the countersunk recess as shown in Figure 3.5.

(d) Punch can be tightly secured to the punch plate with the help of grubs screws as shown in Figure 3.5.

(e) Set screws are used to fastened the punch to the punch plate as shown in Figure 3.5.

(f) Fastening of punch with the help of a set screw and it is located during fastening with the help of two dowel pins shown in Figure 3.5.

(g) Flange end of the punch is secured to the punch plate by set screws from the punch end as shown in Figure 3.5.

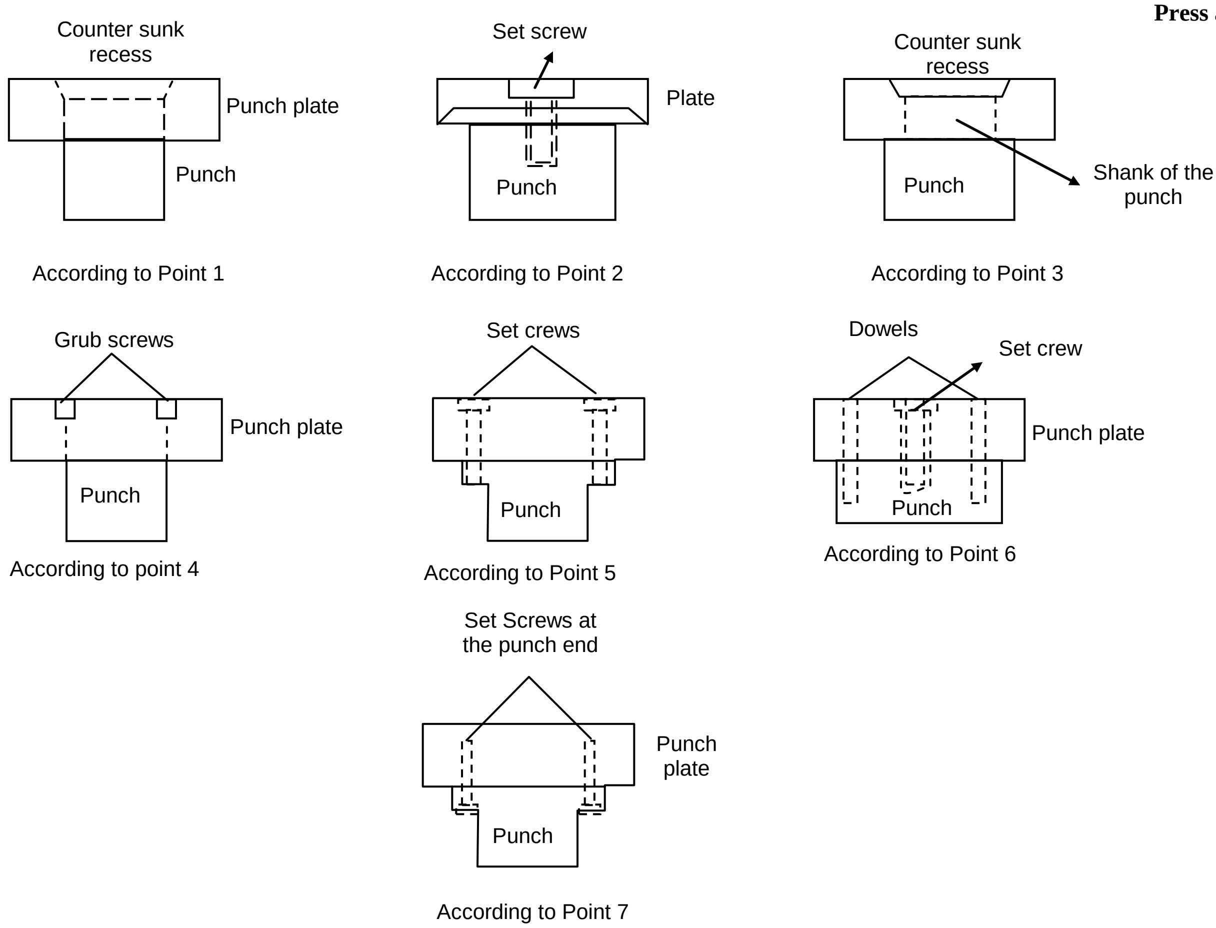


Figure 3.5 : Different Ways of Holding a Punch

3.7 DIE SET AND ITS DETAILS

The complete die set consists of a punch, die and some other accessories which are described in this section later. Perfect alignment of punch and die is most important for satisfactory working of punch. Accessories of die set provides the require alignment and rigidity to the system and improves accuracy of the system performance. These accessories are the finished parts, removal of waste. The die accessories are shown in Figure 3.6. These are described as below.

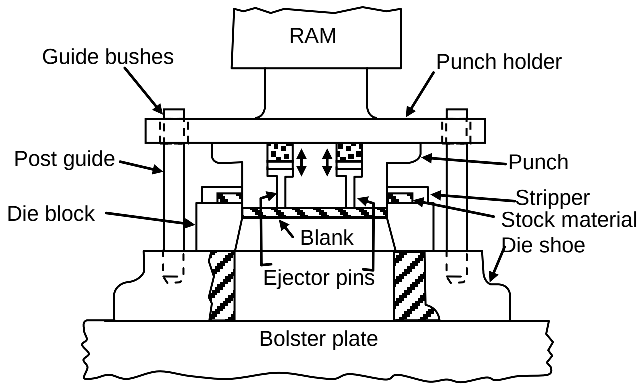


Figure 3.6 : Die Accessories

Punch Holder

It is also known by its other name upper shoe of die set. Punch holder is clamped to the ram of press. It holds the punch below it.

Punch

It is the main tool of die assembly which directly comes in contact of workpiece during its processing, its detail have already been described.

Die Holder

It is also called die shoe. Its work as a support for the die block and it is rigidly fastened to the balster plate of the press.

Stops

Stops are used for maintaining correct spacing of the sheet metal when it is fed below the punch to maintain the quality of output. These restrict the feed of stock (workpiece) to a pre-determined length each time without doing any precise measurements. Normally two types of stops are used bottom stop and lever stop as described below.

Bottom Top

Bottom stop is a tape of mechanical mechanism. This mechanism stops the movement of punch after end of each cut. A button is located in such a manner when fresh stock is fed to die, the button is pressed due to the impact of the fed stock, indicating feeding of true length of the stock. This way the mechanism also acts as a fixture. Pressing of button enables the system ready for next cutting action. The button stop is used in hand presses and in slow acting power presses.

Lever Stop

This mechanism operates with the help of a lever. After the completion of one cut, the stop mechanism stops the downwards movement of punch for next cut when fresh stock is fed it is stopped by a lever after feeding it up to certain length. The lever also enables the punch to move for cut.

Pilots

Pilot is used for correct location of blank when it is fed by mechanical means. The pilot enters into the previously pierced hole and moves the blank to the correct position to be finally spaced by the stops. Normally pilots are fitted to the punch holders.

Strippers

Stripper is used to discard the workpiece out side the press after the completion of cutting or forming operation. After the cutting when punch follows upward stroke the blank is stripped off from the punch cutting edge and prevents it from being lifted along with the punch. This action of prevention is performed by the stripper.

Knockouts

Knockout is also a type of stripper which is used generally in case of invarted dies. After the completion of cutting action, the blank is ejected by the knockout plate out of cutting edge.

Pressure Pads

Pressure pads are plates which grip the workpiece very tightly at the ends when it plastically flows between the punch and the die. This tight griping eliminates the chances of wrinkling in the process of metal forming. A spring loaded plunger acting on the bottom of workpiece plate also serve the same function. The pressure pads do a type of ironing on the sheet metal workpiece.

Guide Posts

Accurate alignment between die opening and punch movement is very important. Guide posts are used for correct alignment of punch and die shoe.

Punch Plate

Punch plate is also known as punch retainer. This is fixed to the punch holder. Punch plate serves as a guide way to hold the punch in right position and properly aligned. This makes the replacement of punch quick and correct.

Backing Plate

Backing plate is used to distribute pressure uniformly over the whole area (maintains uniform stress), it prevents the stress concentration on any portion of punch holder. This is generally made of hardened steel inserted between the punch and punch holder.

Die Retainer

The purpose of die retainer is same that is of punch plate and punch holder. Die retainer is fixed to the bed (base) of the press to hold the die block in correct alignment with the movement of punch. In some specific cases die shoe itself works as a die retainer.

3.8 METHODS OF DIE SUPPORTING

Die is normally held in die holder which is clamped to the balster plate mounted on the table or base of the press. Three different methods of securing die blocks to the die holder are discussed here.

Method 1

The die block is secured to the die holder by four set screws shown in Figure 3.7. Here only one screw is shown. The position of the die is correctly located by dowel pin.

Method 2

The die block is secured by the set screws at the bottom of the die holders shown in Figure 3.7.

Method 3

Die block is secured by an wedge which is clamped to the die holder by set screws, shown in Figure 3.7.

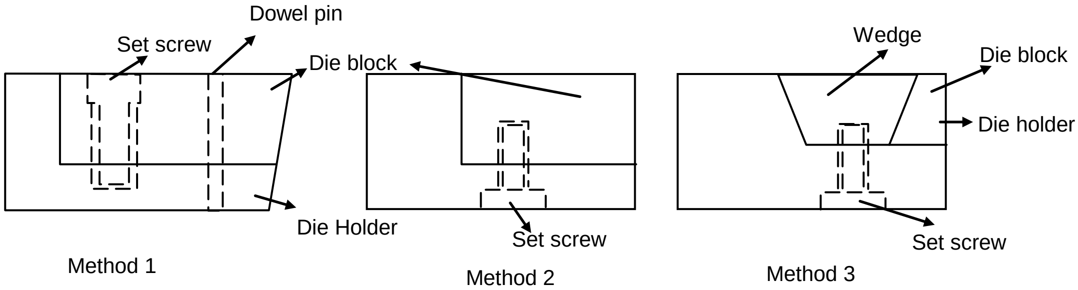


Figure 3.7 : Different Methods of Die Supporting

3.9 CLASSIFICATION OF DIES

There is a broader classification of single operation dies and multi-operation dies.

(a) Single operation dies are designed to perform only a single operation in each stroke of ram.

(b) Multi operation dies are designed to perform more than one operation in each stroke of ram.

Single operation dies are further classified as described below.

Cutting Dies

These dies are meant to cut sheet metal into blanks. The operation performed so is named as blanking operation. These dies and concerned punches are given specific angles to their edges. These are used for operation based on cutting of metal by shearing action.

Forming Dies

These dies are used to change two shape of workpiece material by deforming action. No cutting takes place in these dies. These dies are used to change the shape and size related configuration of metal blanks.

As there is a classification of single operation dies, multi-operation dies are can also be classified (further) as described below.

Compound Dies

In these dies two or more cutting actions (operations) can be executed in a single stroke of the ram.

Combination Dies

As indicated by their names these dies are meant to do combination of two or more operations simultaneously. This may be cutting action followed by forming operation. All the operations are done in a single action of ram.

Progressing Dies

These dies are able to do progressive actions (operations) on the workpiece like one operation followed by another operation and so on. An operation is performed at one point and then workpiece is shifted to another working point in each stroke of ram.

Another classification of dies is also possible on the basis of specific operations that can be performed on them. This classification is described below.

Shearing Operations

These belong to the category of cutting dies. These are used for operations involving shearing action on the workpiece material like blanking, punching, perforating, notch making, slitting, etc.

Drawing Operations

All dies designed for flanging, embossing, bulging and cupping operations fall in the category of drawing operation dies.

Bending Operations

Some of the dies designed for angle bending, curling, forming, folding, plunging, etc. operations fall in the category of dies based on bending operations.

Squeezing Operations

Another category of dies based on squeezing operations are capable to do operations like flattening, planishing, swaging, coining, sizing, extruding and pressing operations.

On the basis of construction, dies can be classified in the following ways :

Cut-off Die

The die designed for cutting off operation is called cut-off die. It provides a vertical surface along which punch slides to cut-off the workpiece by shearing action.

Drop through Die

As indicated by their names, these dies are made hollow where blank fall down after being cut-off.

Return Type Die

In these dies a knockout plate is incorporated, by which the cut blank returns back to the position at which it was cut before it ejected.

Simple and Compound Dies

These are two different dies, simple dies are those dies, used for single exclusive operation in each stroke of ram. These dies have already been discussed in earlier section. In compound dies two or more operations can be done at a single working point. Initial cost of such dies is more due their complicated design and difficult manufacturing. Their low operating cost makes these very economical as a single compound die is equivalent to two or three simple dies.

There is also reduction of cost of using of two or three presses because multiple operations are accomplished in a single press by a single operator.

Continental Dies

These are similar to other dies but the conceptual difference is, these are meant to do research and development work. These cannot do mass production as they may not be very robust.

Sub-press Die

These are designed by incorporating two punch shoe in the die which is actuated by springs to its starting position.

Follow Die

This is designed to do two operations, one followed by other operation. It is like a progressive die which have already been discussed earlier in this unit.

Transfer Die

It is also like a progressive die having more then one working points. It is different form progressive die as it has feeding fingers in the die which transfer the workpiece from one work station to other. In some cases feeding fingers are attached to press, then the press is called transfer press.

Shuttle Die

This is also a type of progressive die having bars in the die just below the workpiece position at each workstation. After the completion of one operation, lift to bear shifts the workpiece from one station to another.

3.10 IMPORTANT CONSIDERATION FOR DESIGN OF A DIE SET

Important points should be considered while designing a die set are listed below :

(a) Cost of manufacturing depends on the life of die set, so selection of material should be done carefully keeping strength and wear resistant properties in mind.

(b) Die is normally hardened by heat treatment so design should accommodate all precautions and allowances to overcome the ill effects of heat treatment.

(c) Accuracy of production done by a die set directly depends on the accuracy of die set components. Design should be focused on maintaining accurate dimensions and tight tolerances.

(d) Long narrow sections should be replaced by block shaped sections to avoid warpage.

(e) Standardized components should be used as much as possible.

(f) Reinforcing grips should be used as per the requirements of the sections.

(g) Easy maintenance should be considered. Replacement of parts should be easy.

(h) The process should be shock proof, if it is unavoidable, shock resistant properties should also be consider while selecting the material of components of die set.

Along with the important design consideration one should also know about the proper material selection for components of a die set various types of tool steels with their suitability for components of die set.

Material or selected tool steel should be very hard to resist wear and strong to hear load to the same time die set components may have very complicated shape, design and need very accurate sizing. Most of them are manufactured by machining and then finishing operations. Their manufacturing involves processing of tool steel to make these components, then these are hardened by different hardening methods like water hardening, oil hardening, air hardening and hard coatings while selecting a die set component material following factors should be taken in care :

(a) Life of the die set component as required.

(b) Their mobility to be manufactured and accuracy level.

(c) Ability to bear wear, shock and load (type of process subjected).

(d) Their costs, both initial cost and operating costs.

3.11 SUMMARY

Metal forming is one of the chip less manufacturing processes. These operations are performed by the press and press tools. Presses can be classified into different categories depending upon their capacity, capabilities and mechanisms used for their operations. Presses can also be categorized depending upon their construction and frame as straight side, adjustable bed type, open end honing press. Method of transmission of power from the place of its generation to the place of its utilization also serve an important criteria for the classification of presses. In general, a press is described by its main parts like base, frame, ram, pitman, driving mechanism, controlling mechanism, flywheel, brakes, balster plate all these parts along with their functions are described here.

Die and punch are the integral part of a pres tool system. Die and punch are normally fitted to a press tool system. Punch and die can be fitted to a press by different methods as described in the unit. Different types of dies are also described in the unit, which are used for different types of workpieces and operations. Accuracy of the operation largely depends on the accuracy of die and punch. So die and punch should be designed and manufactured very carefully. The important considerations for designing die set and punch for pres tool system are described in details.

3.12 ANSWERS TO SAQs

Refer the preceding text for all the Answers to SAQs.

Unit II

Lathe Machine

Manoj Funde

Lathe

Definition

Lathe is a machine, which removes the metal from a piece of work to the required shape and size.

- Lathe is one of the most important machine tools in the metal working industry. A lathe operates on the principle of a rotating workpiece and a fixed cutting tool.

- The cutting tool is feed into the workpiece, which rotates about its own axis causing the workpiece to be formed to the desired shape.

- Lathe machine is also known as “the mother/father of the entire tool family”.

INVENTOR OF CENTRE LATHE

- Henry Maudsley was born on an isolated farm near Gigghleswick in North Yorkshire and educated at University Collage London. He was an outstandingly student, collecting ten Gold Medals and graduating with an

  M.D. degree in 1857.

Henry Maudsley

- **Function of lathe**

  Lathe is to remove excess material in the form of chips by rotating the work piece against a stationary cutting tool

- **Industrial revolution demanded**

  - More production
  - More Precision
  - Changes in Manufacturing process
  - Lead to the Development of High speed
  - Special purpose lathes

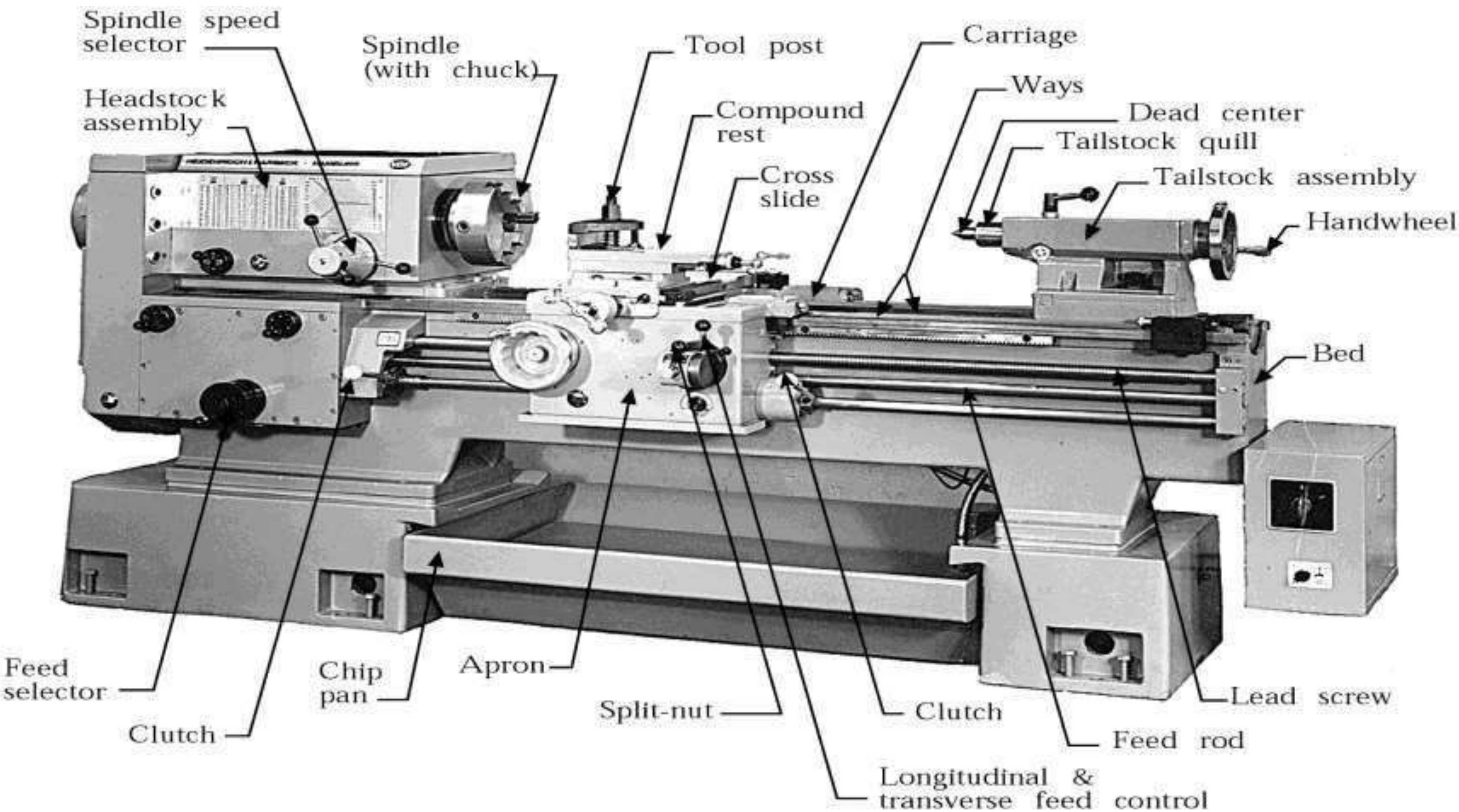
MAIN PARTS

Lathe Machine is also known as “**Centre Lathe**”, because it has two centres between which the job can be held and rotated.

The main parts of centre lathe are:

- Bed,
- Head stock,
- Tail stock,
- Carriage,etc

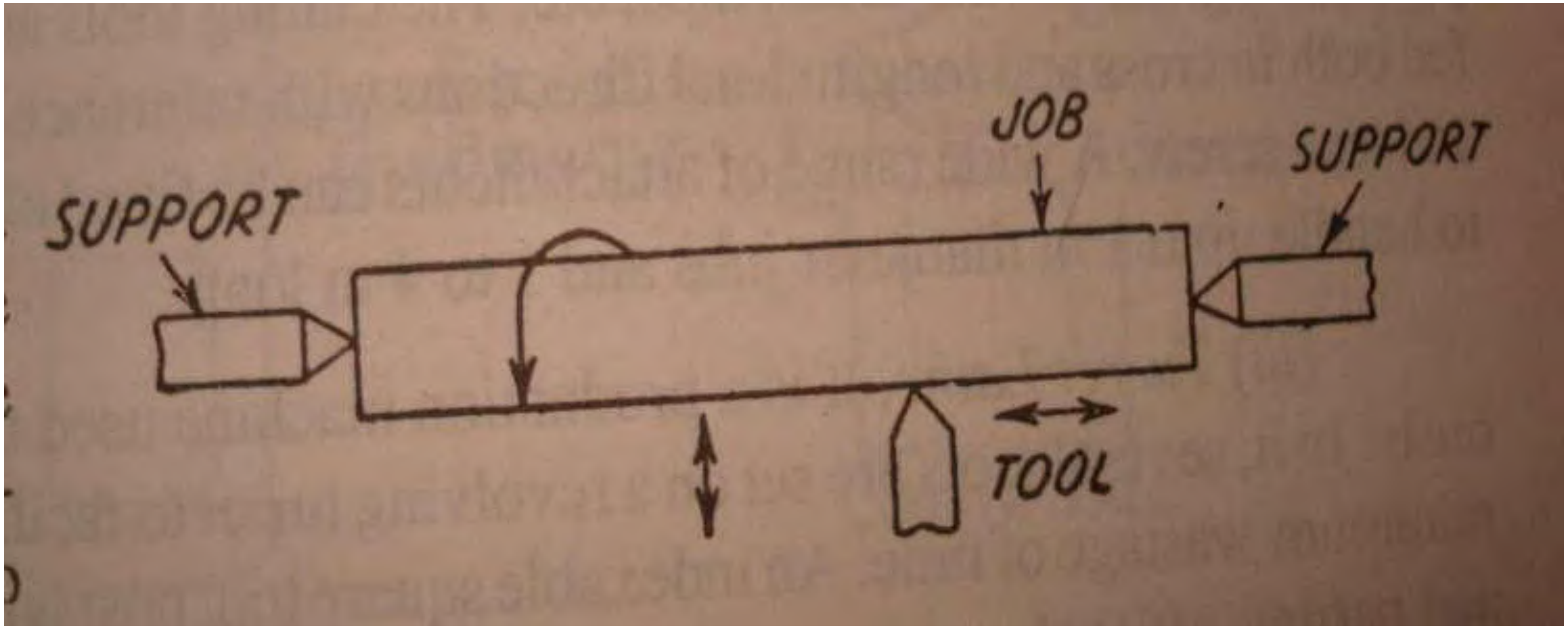
Lathe


Spindle speed selector
Spindle (with chuck)
Tool post
Carriage
Headstock assembly
Ways
Compound rest
Dead center
Tailstock quill
Cross slide
Tailstock assembly
Handwheel
Bed
Feed selector
Chip pan
Apron
Clutch
Split-nut
Clutch
Lead screw
Feed rod
Longitudinal & transverse feed control

Lathes

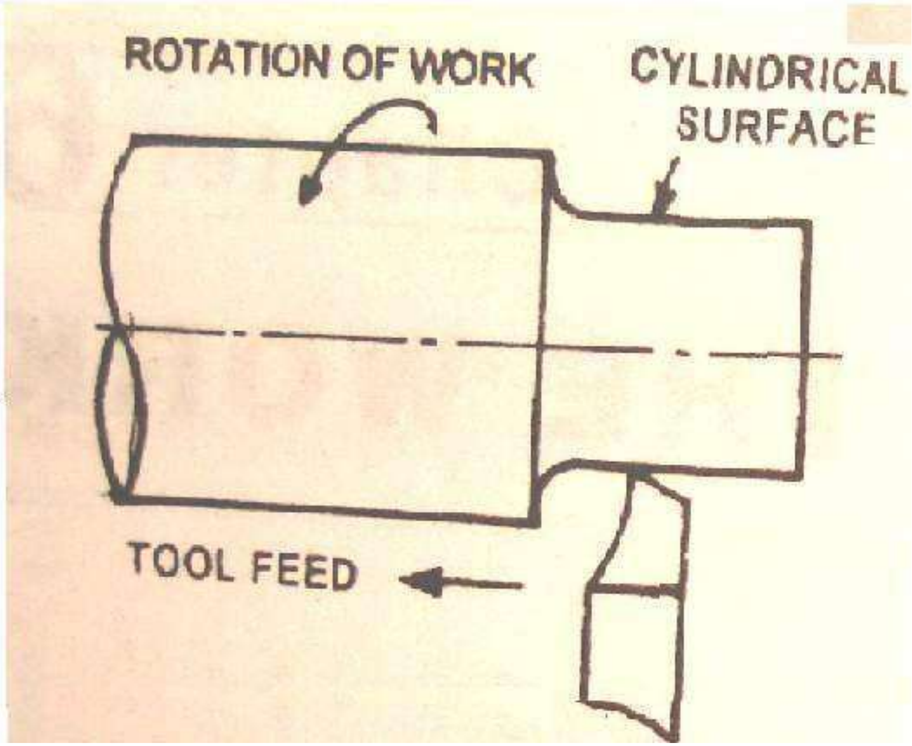
- Lathes are the oldest machine tools
- Lathe Components
  - Bed: supports all major components
  - Carriage: slides along the *ways* and consists of the *cross-slide, tool post, apron*
  - Headstock – Holds the jaws for the work piece, supplies power to the jaws and has various drive speeds
- Tailstock – supports the other end of the workpiece
- Feed Rod and Lead Screw – Feed rod is powered by a set of gears from the headstock

Working principle of lathe



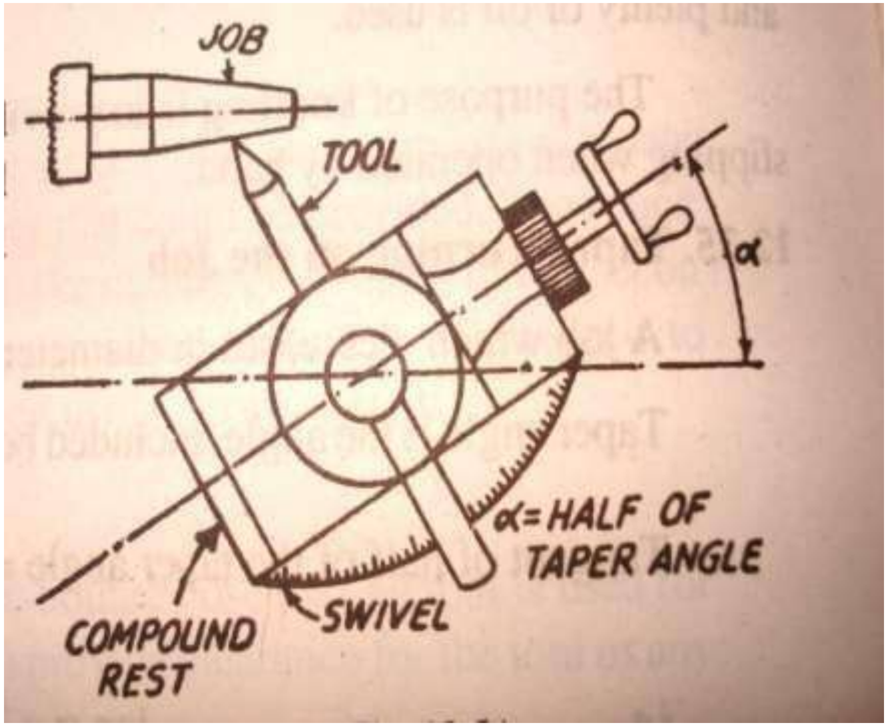
Working principle of lathe

- If the tool moves parallel to work piece cylindrical surface is formed



Working principle of lathe

- If the tool moves inclined to the axis it produces a taper surface and is called taper turning.



Working principle of lathe

- It holds the work between two supports called centers.
- Chuck or Face plate is also used for holding the work.
- Chuck or face plate is mounted on machine spindle
- Cutting tool is held and supported on a tool post.
- Movement of the job is rotation about spindle axis
- Tool is fed against the revolving work
- Movement of the tool is either parallel to or at any inclination to the work axis

Specifications of Lathe

1) a) Height of centers

b)type of bed(straight , semi gap, or gap)

c) center distance

2. a)swing over bed

b)swing over cross slide

c) swing in gap

d) gap in front of face place

3. a) spindle speeds range

b) spindle nose

c) spindle bore

d) taper nose

Specifications of Lathe

4) a)Metric thread piches

   b)lead screw pitch

   c)longitudinal feeds

   d)cross feeds

5) a) cross slide travel

   b)top slide travel

   c) tool section

6) a)tailstock sleeve travel

   b)taper in sleeve bore

7) Motor horsepower and RPM

8) shipping dimensions ---
   length*width*height*weight

TYPES OF LATHES

- **Engine Lathe or center lathe**

- It is most common type of lathe and is widely used in workshop.
- The speed of the spindle can be widely varied as desired which is not possible in a speed lathe.

- **Bench Lathe**

- Small lathe which can mounted on the work bench
- It is used to make small precision and light jobs.

- **Speed lathe**

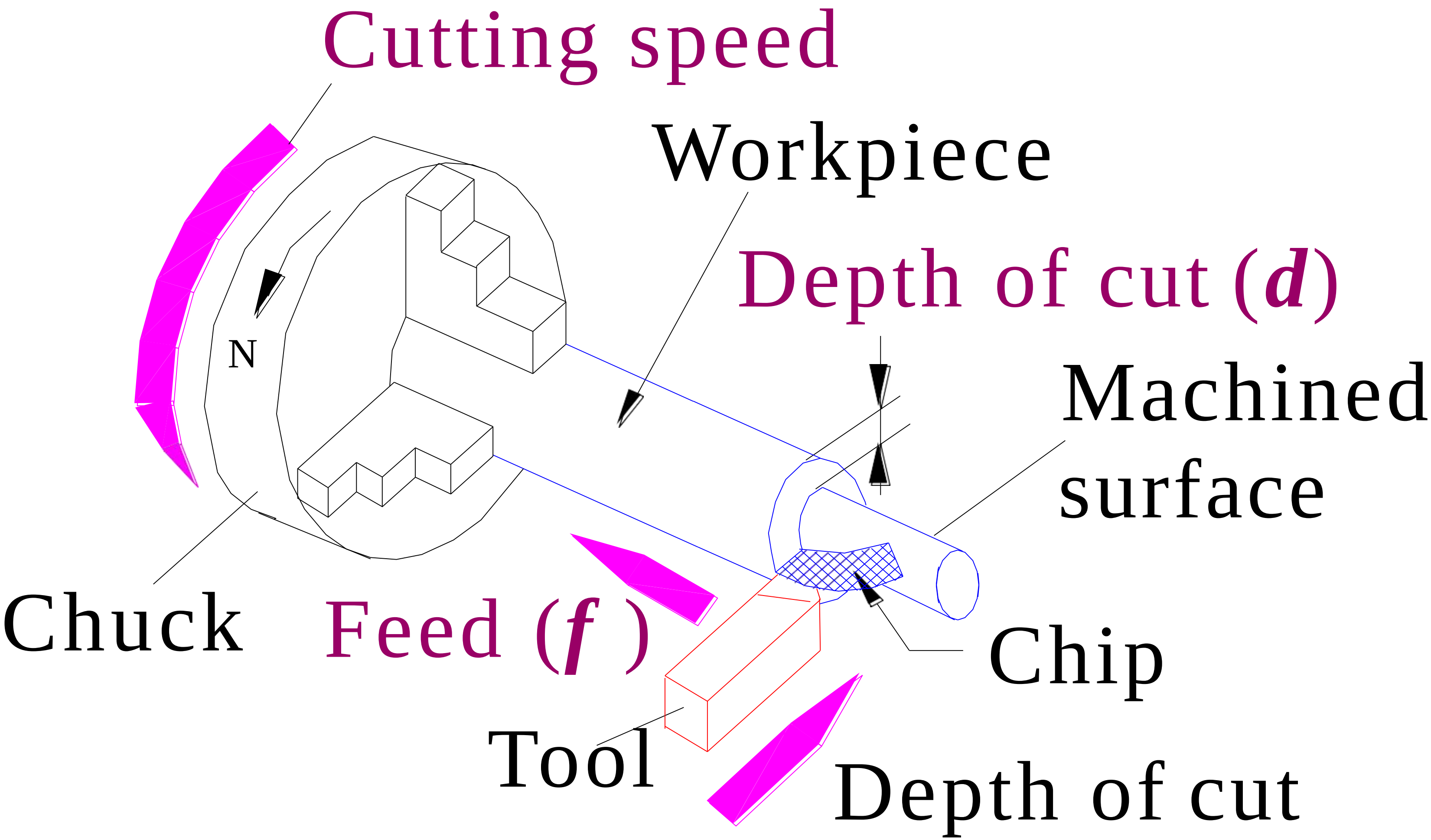
- It is named because of the very high speed of the head stock spindle.
- Consists head stock, a tail stock and tool post. it has no gear box.
- Applicable in wood turning, metal spinning and operations.

TYPES OF LATHES

- **Tool room lathe :**
- It is similar to an engine lathe, designed for obtaining accuracy.
- It is used for manufacturing precision components, dies, tools, jigs etc. and hence it is called as tool room lathe.
- **Special purpose lathes :**
- Gap lathe
- Instrument lathe
- Facing lathe
- Flow turning lathe
- Heavy duty lathe

- **Automatic Lathe**
  - A lathe in which the work piece is automatically fed and removed without use of an operator.
  - It requires very less attention after the setup has been made and the machine loaded.
- **Turret Lathe**
  - Turret lathe is the adaptation of the engine lathe where the tail stock is replaced by a turret slide(cylindrical or hexagonal).
  - Tool post of the engine lathe is replaced by a cross slide which can hold number of tools.
- **Capstan lathe**
  - These are similar to turrent lathe with the difference that turret is not fixed but moves on an auxiliary slide. these are used for fast production of small parts.

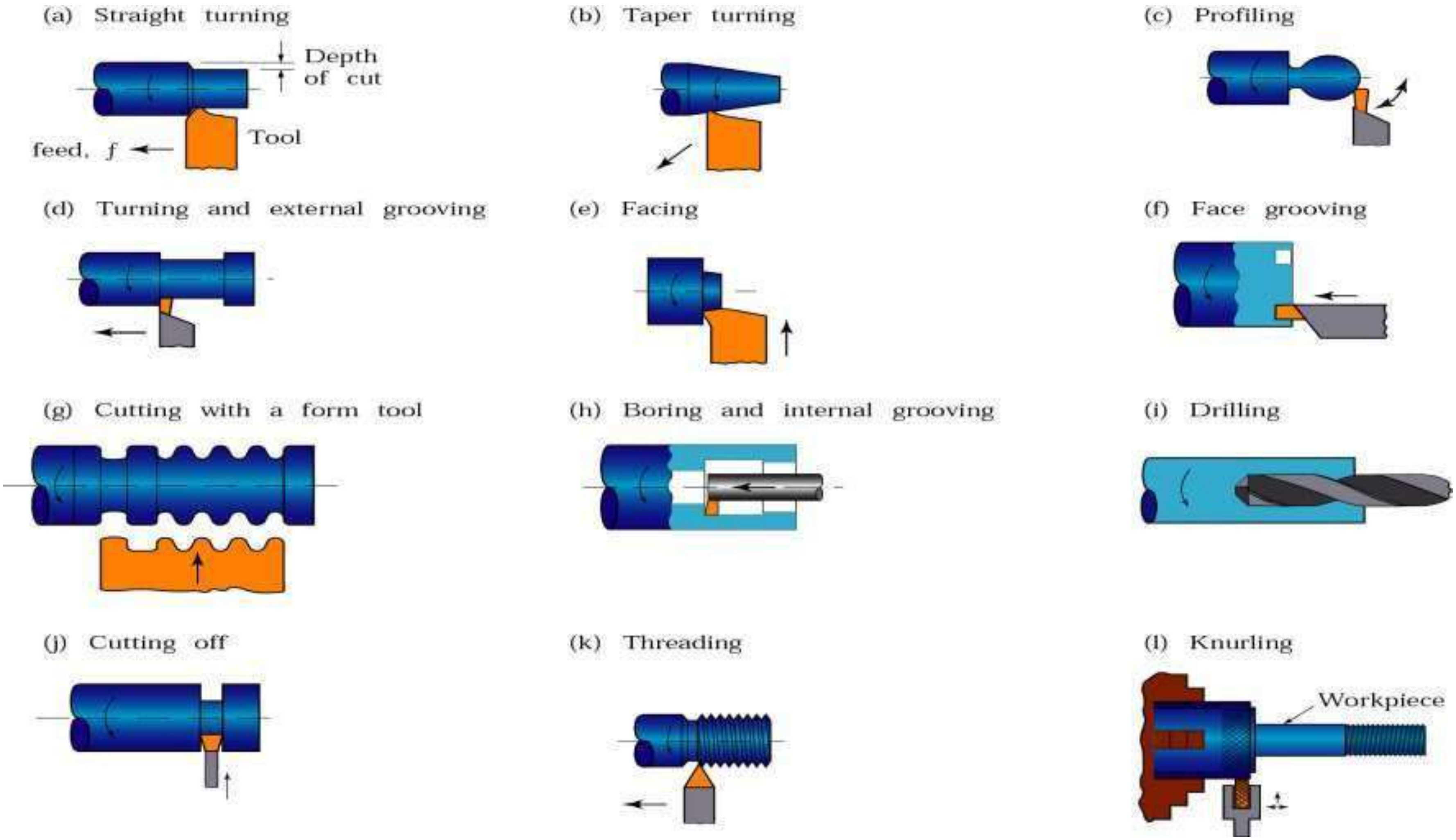
Operating Conditions



LATHE OPERATIONS

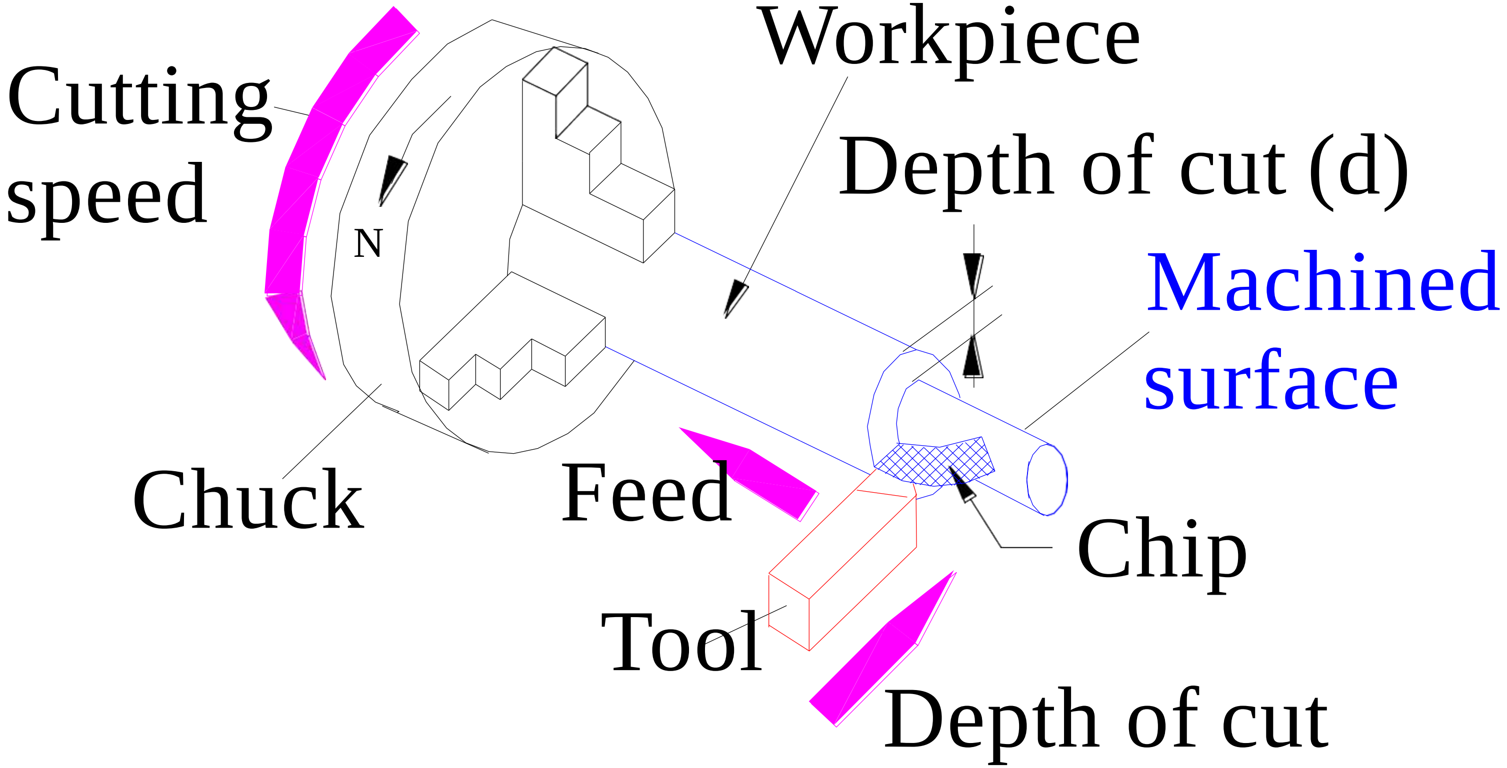
- **Turning:** to remove material from the outside diameter of a workpiece to obtain a finished surface**.**
- **Facing:** to produce a flat surface at the end of the workpiece or for making face grooves**.**
- **Boring:** to enlarge a hole or cylindrical cavity made by a previous process or to produce circular internal grooves.
- **Drilling:** to produce a hole on the work piece.
- **Reaming**: to finishing the drilled hole.
- **Threading:** to produce external or internal threads on the work piece.
- **Knurling:** to produce a regularly shaped roughness on the workpiece.

LATHE OPERATIONS



Turning..

Cylindrical job

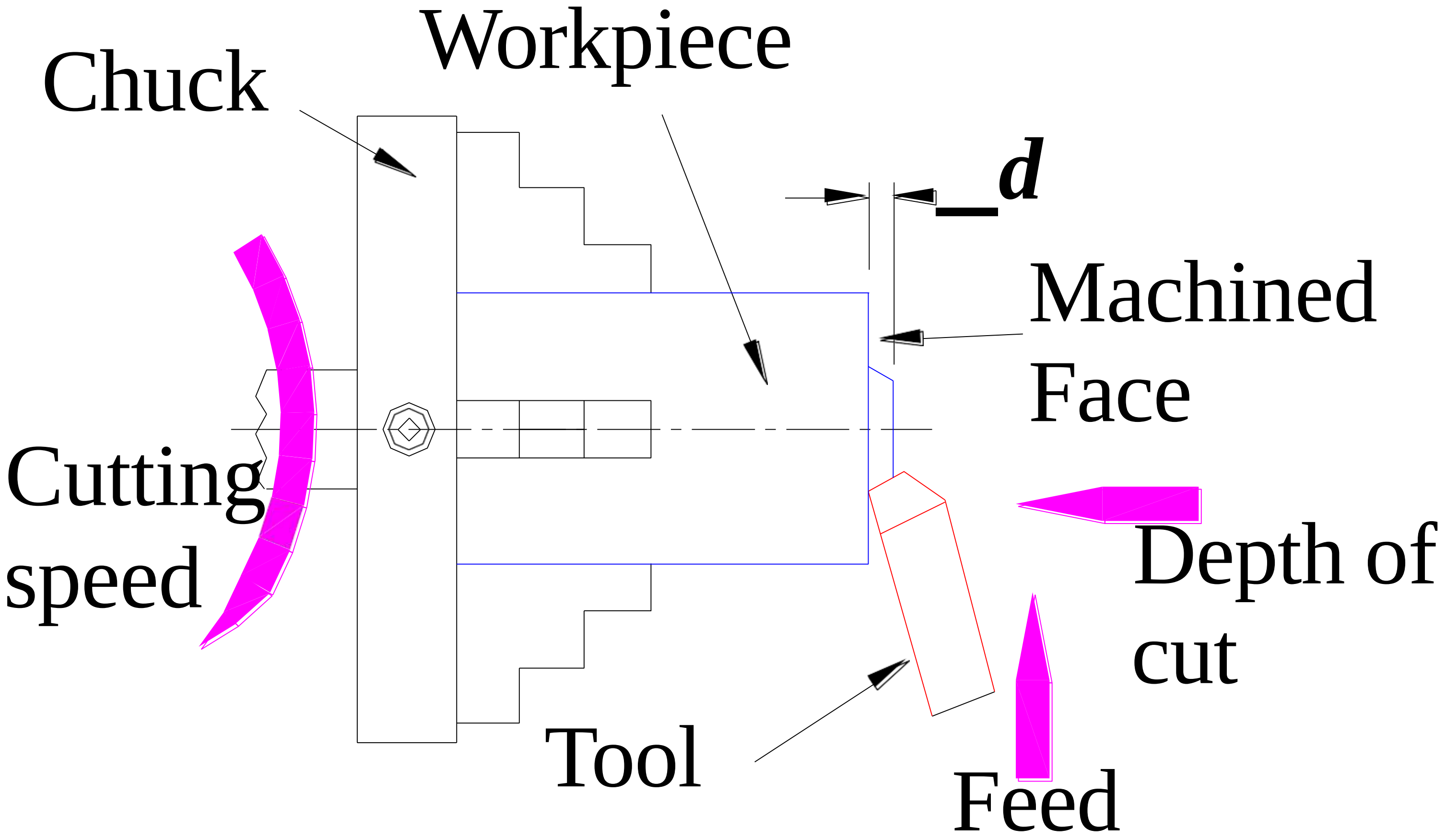


Turning..

- Excess Material is removed to reduce Diameter
- Cutting Tool: *Turning Tool*
- Work is held in either chuck or between centers.
- Longitudinal feed is given to the tool either by hand or power.

Facing

Flat Surface/Reduce length



Facing ..

- machine end of job ⇨ Flat surface or to Reduce Length of Job
- Turning Tool
- Feed: in direction perpendicular to workpiece axis
    - Length of Tool Travel = radius of workpiece
- Depth of Cut: in direction parallel to workpiece axis

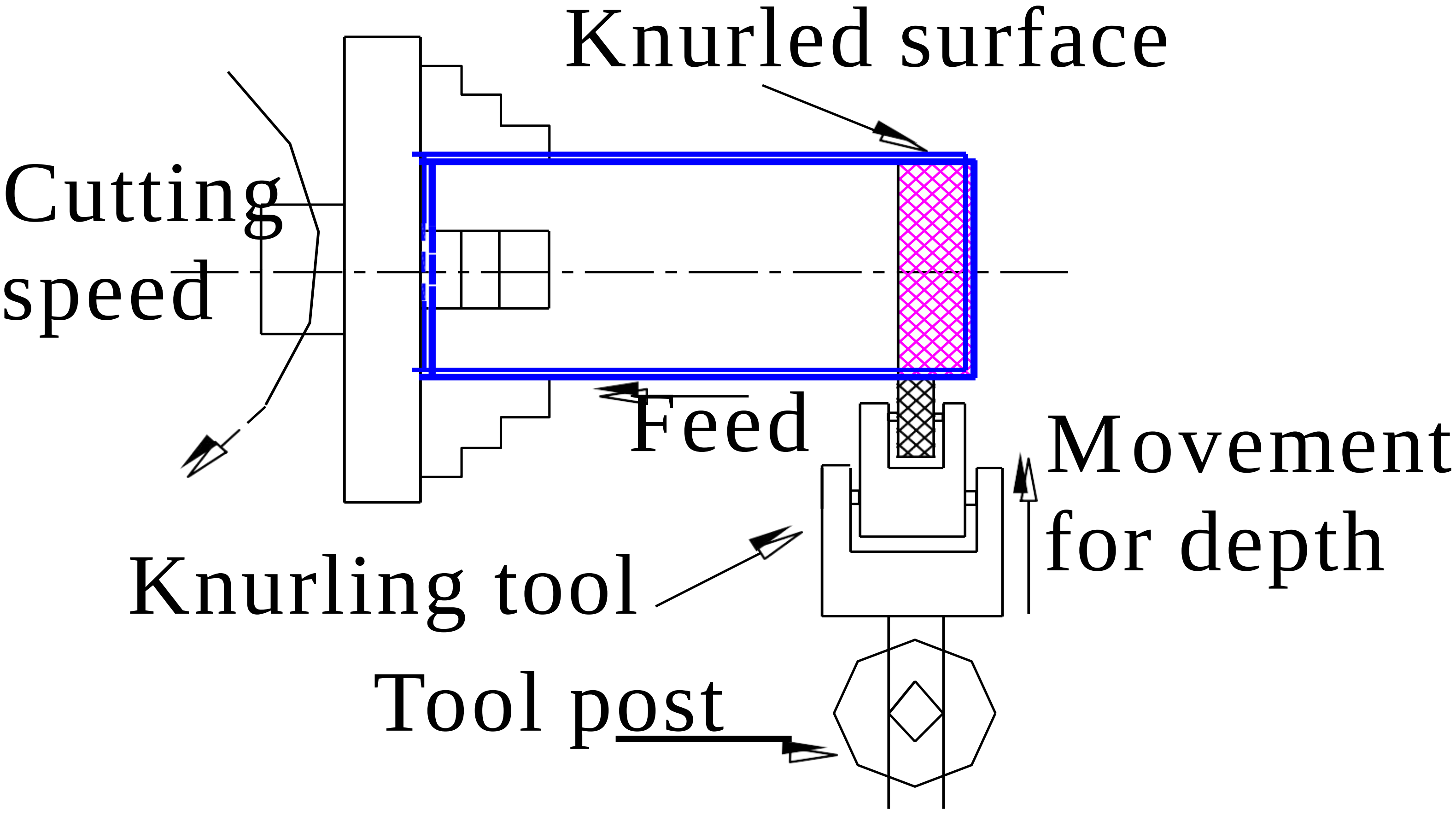
Knurling

- Produce rough textured surface
  - For Decorative and/or Functional Purpose
- *Knurling Tool*

❑ A *Forming* Process

❑ MRR~0

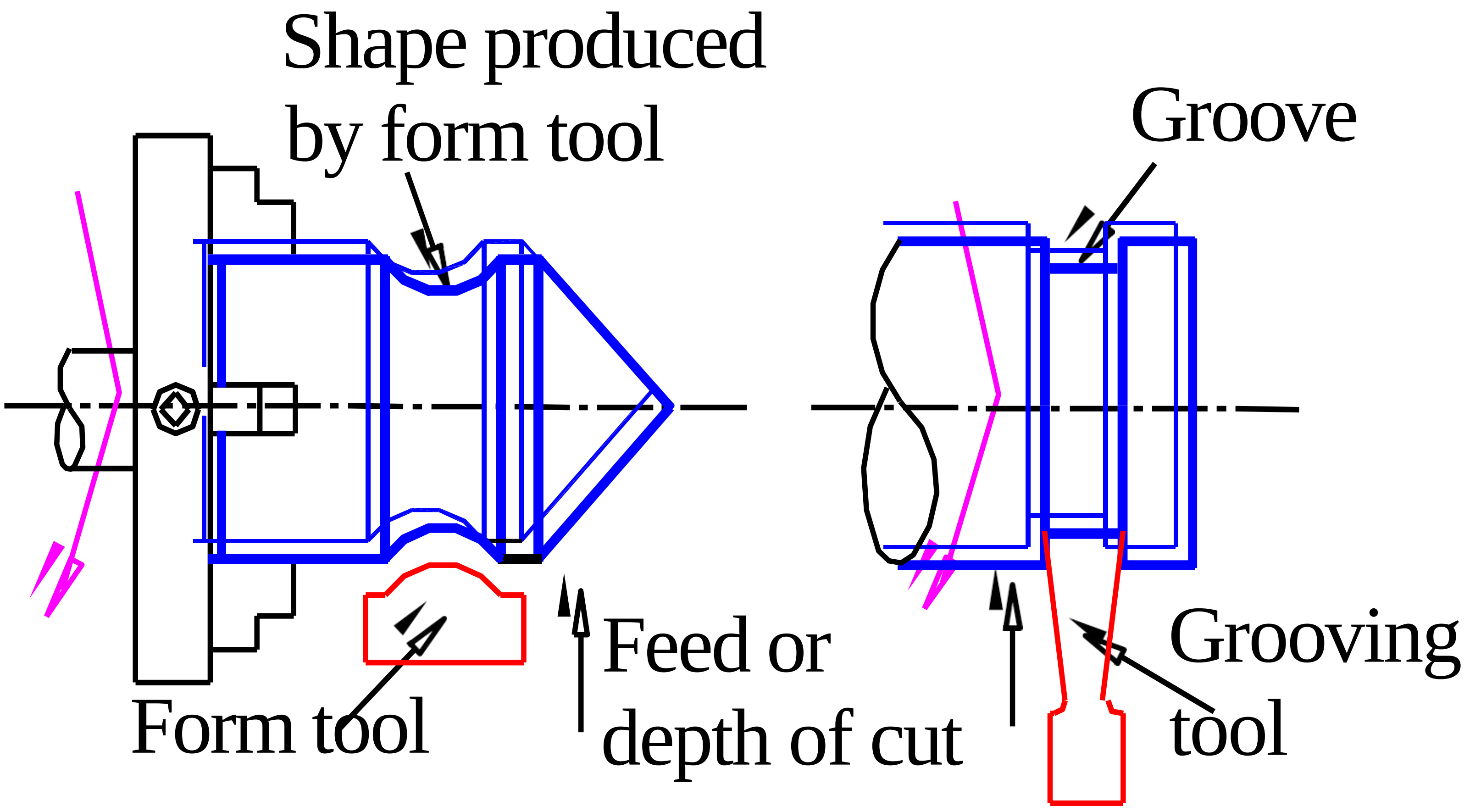
Knurling


Knurled surface
Cutting
speed
Feed
Movement
for depth
Knurling tool
Tool post

Grooving

- Produces a Groove on workpiece
- Shape of tool ⇨ shape of groove
- Carried out using Grooving Tool ⇨ A form tool
- Also called Form Turning

Grooving..

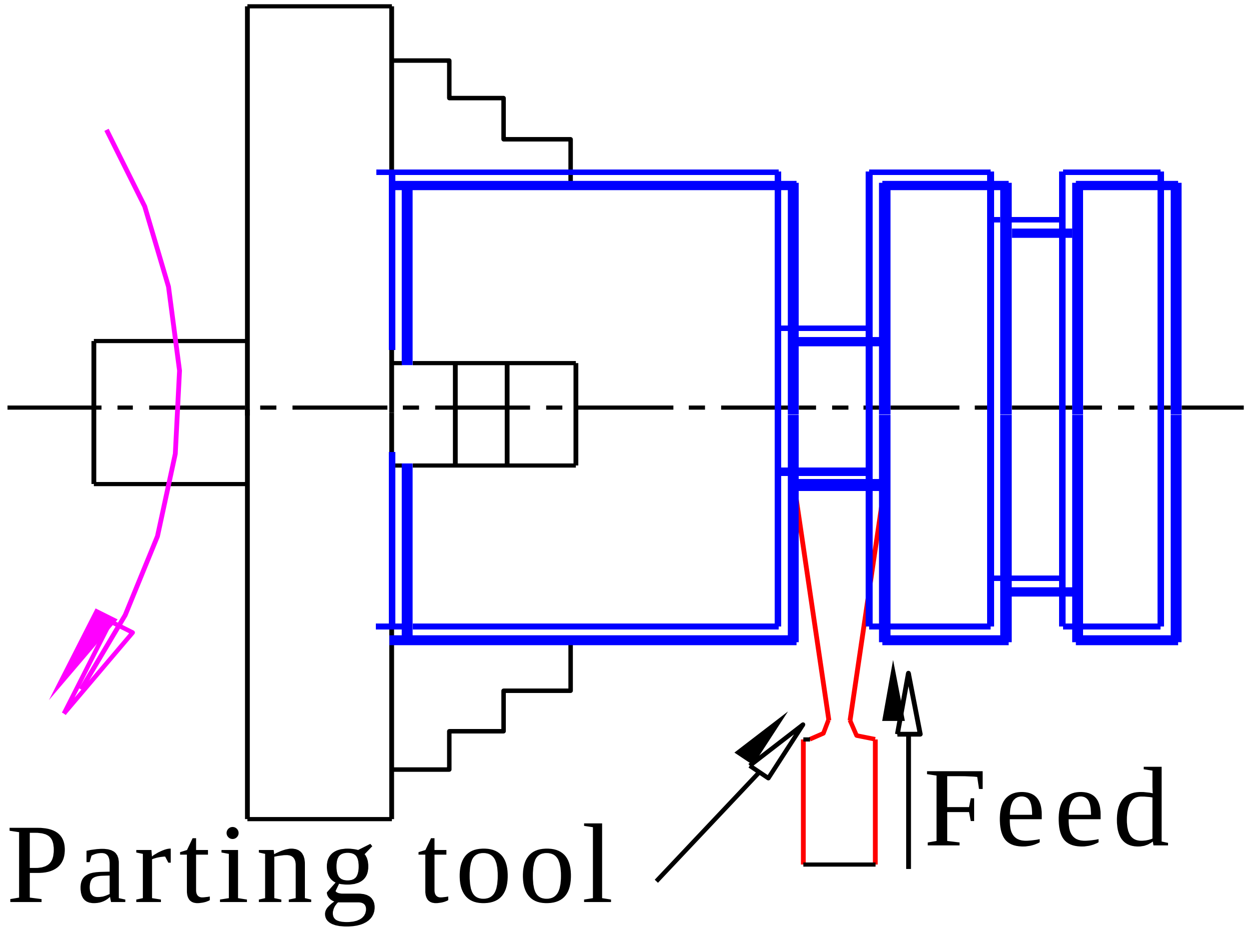


Shape produced
by form tool
Groove
Feed or
depth of cut
Grooving
tool
Form tool

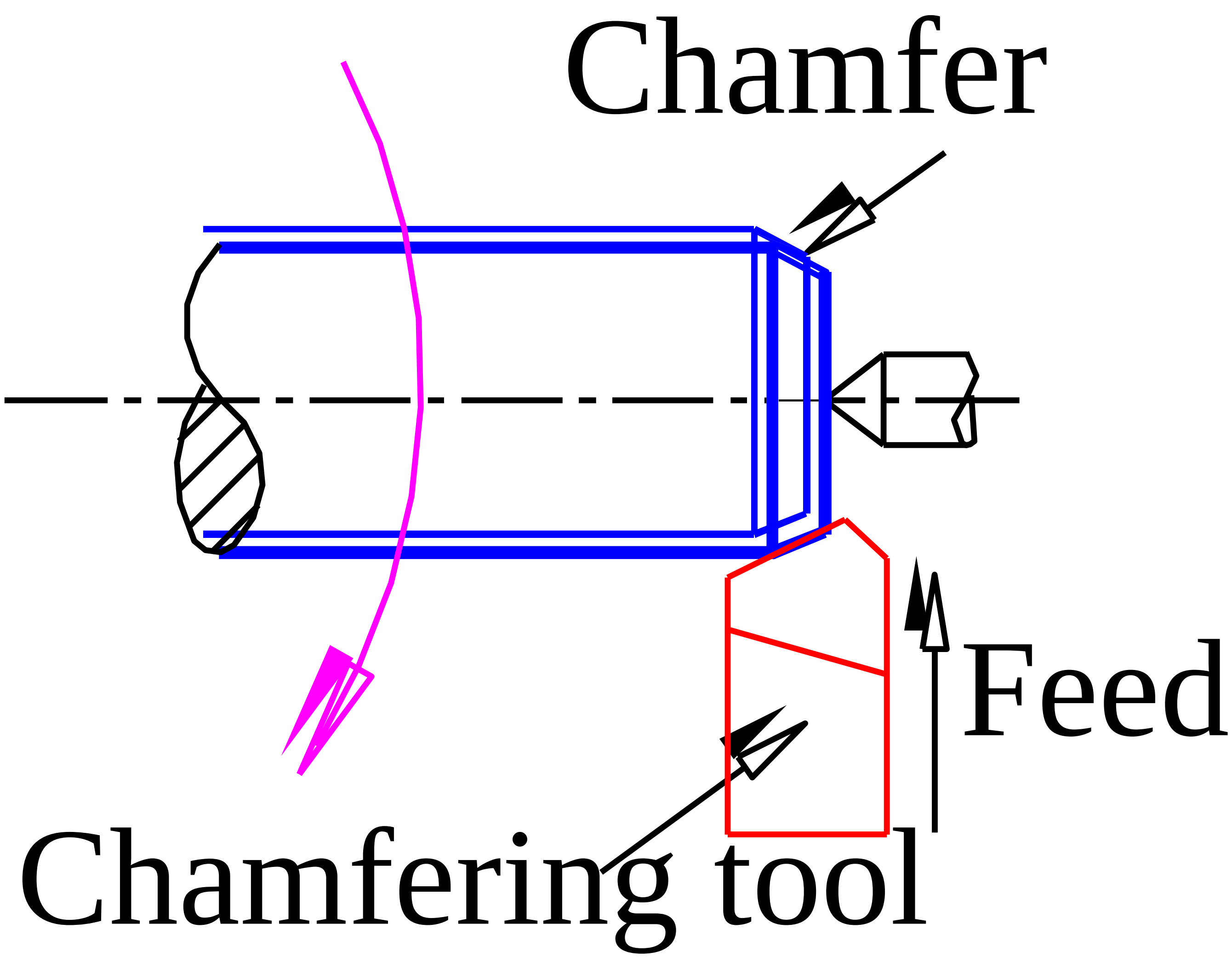
Parting

- Cutting workpiece into **Two**
- Similar to grooving
- ***Parting Tool***
- Tool rides over – at slow feed
- Coolant use

Parting..



Chamfering

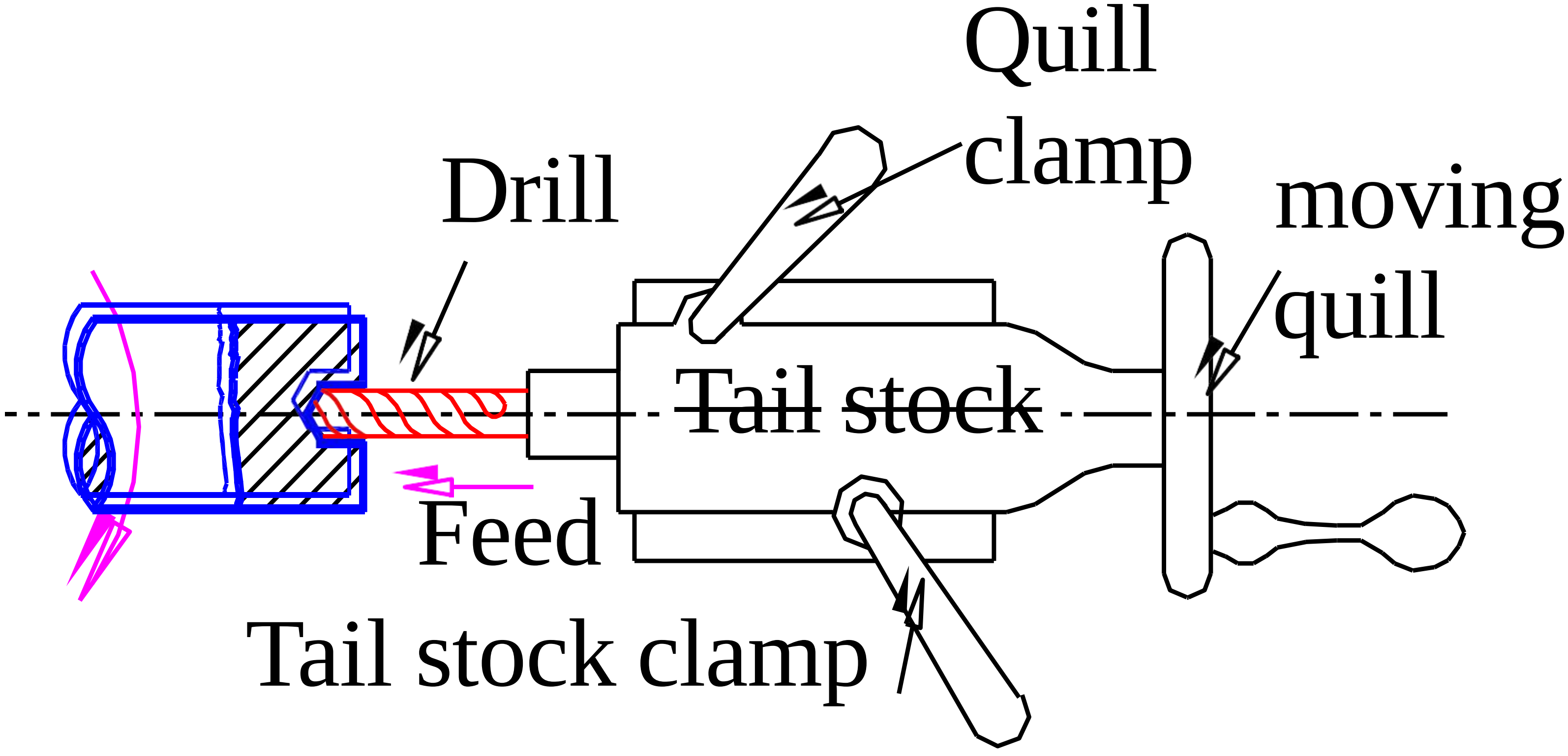


Chamfering

- Beveling sharp machined edges
- Similar to form turning
- Chamfering tool – 45°
- To
  - Avoid Sharp Edges
  - Make Assembly Easier
  - Improve Aesthetics

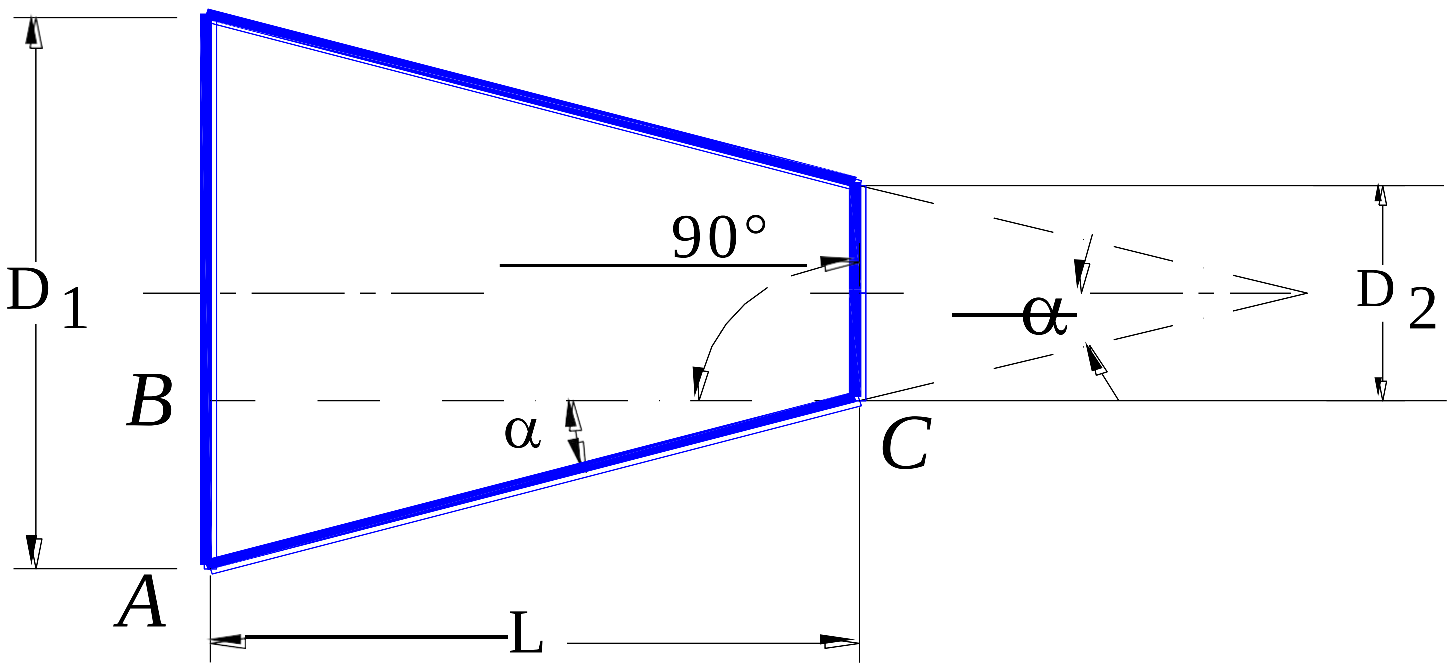
Drilling

Drill – cutting tool – held in TS – feed from TS



Taper Turning

- **Taper:** $$\tan \alpha = \frac{D_1 - D_2}{2L}$$

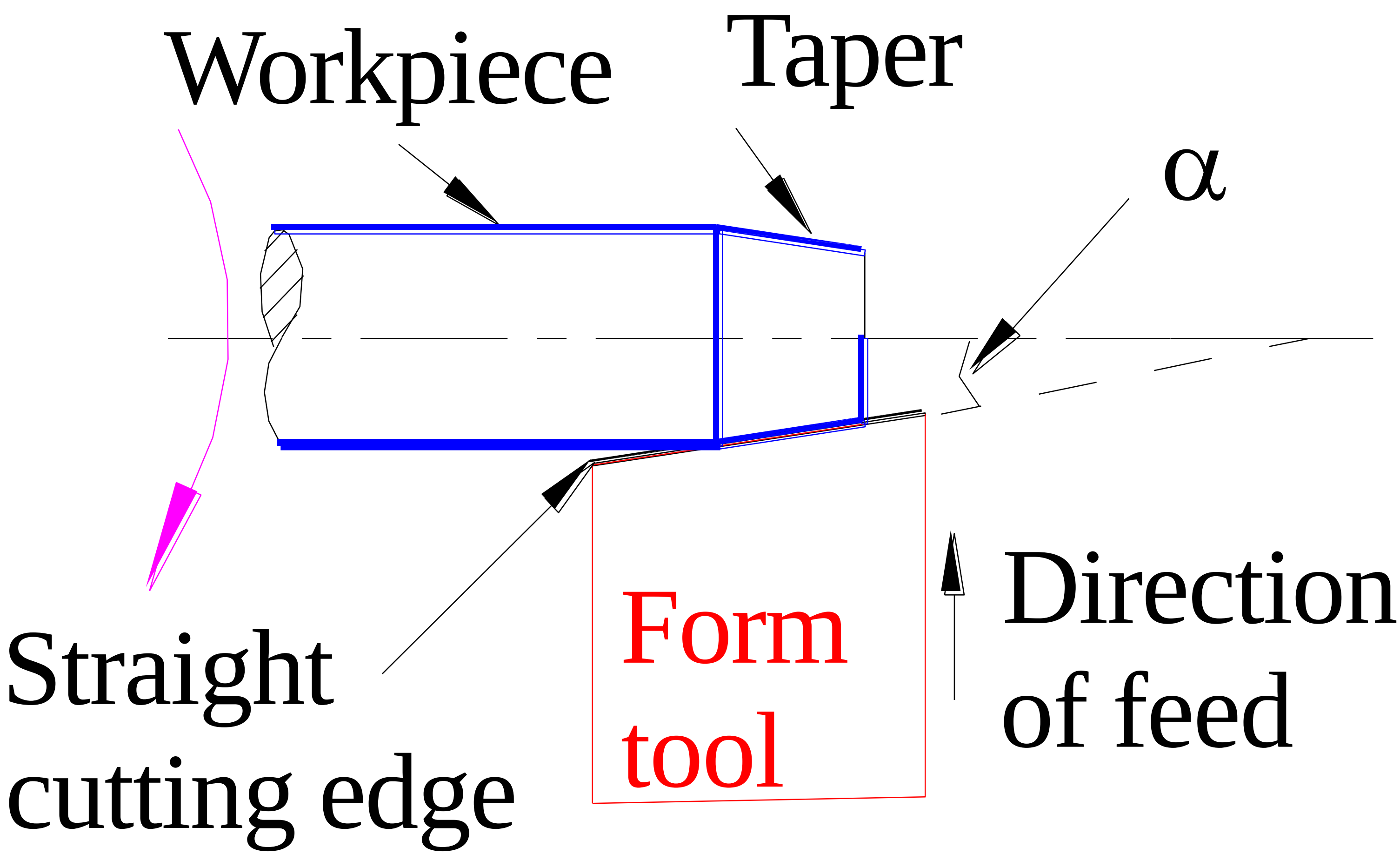


Taper Turning..

Methods

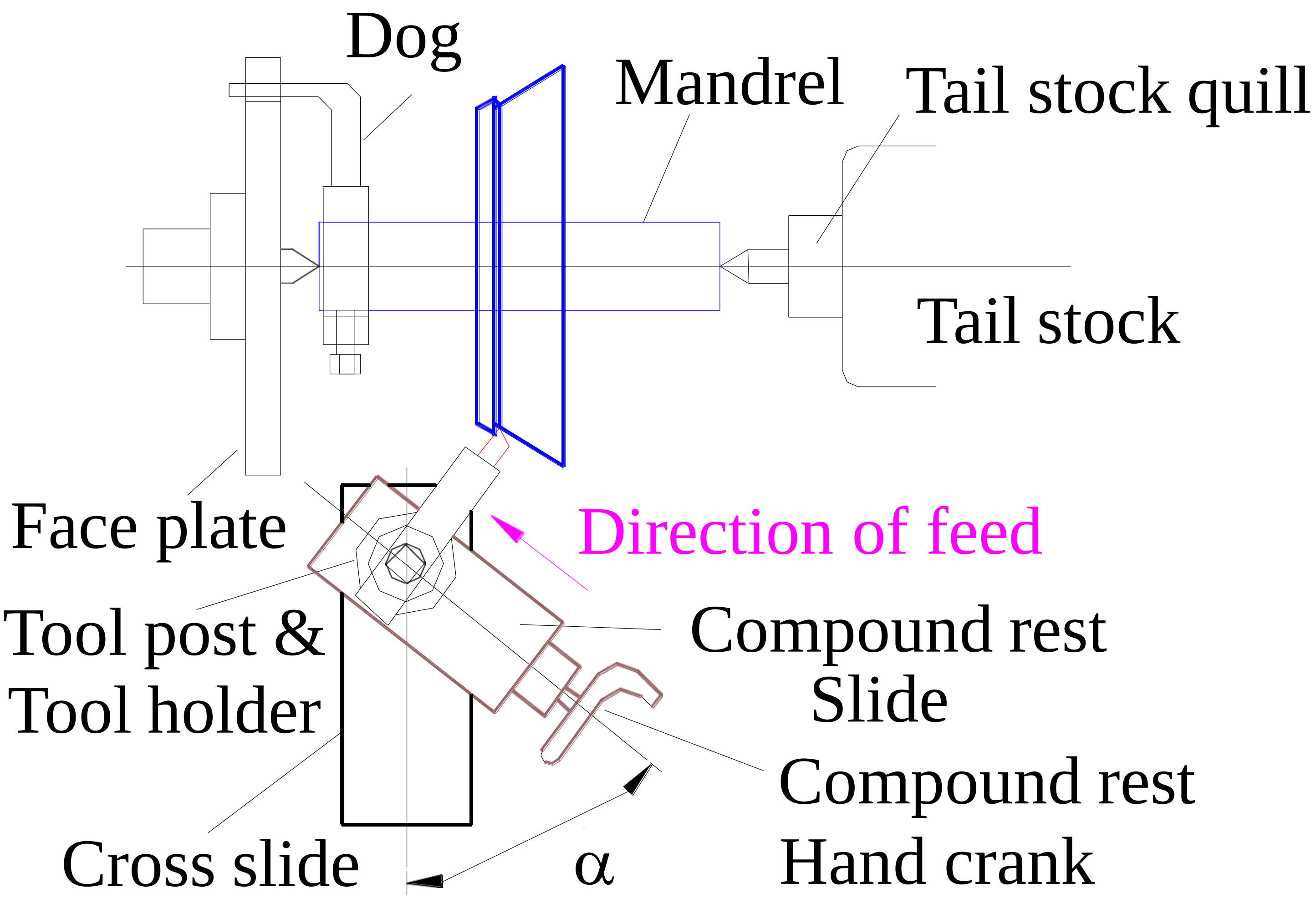
- Form Tool
- Swiveling Compound Rest
- Taper Turning Attachment
- Simultaneous Longitudinal and Cross Feeds

Taper Turning..
by form tool



Taper Turning „

by compound rest



TAPER TURNING ATTACHMENT

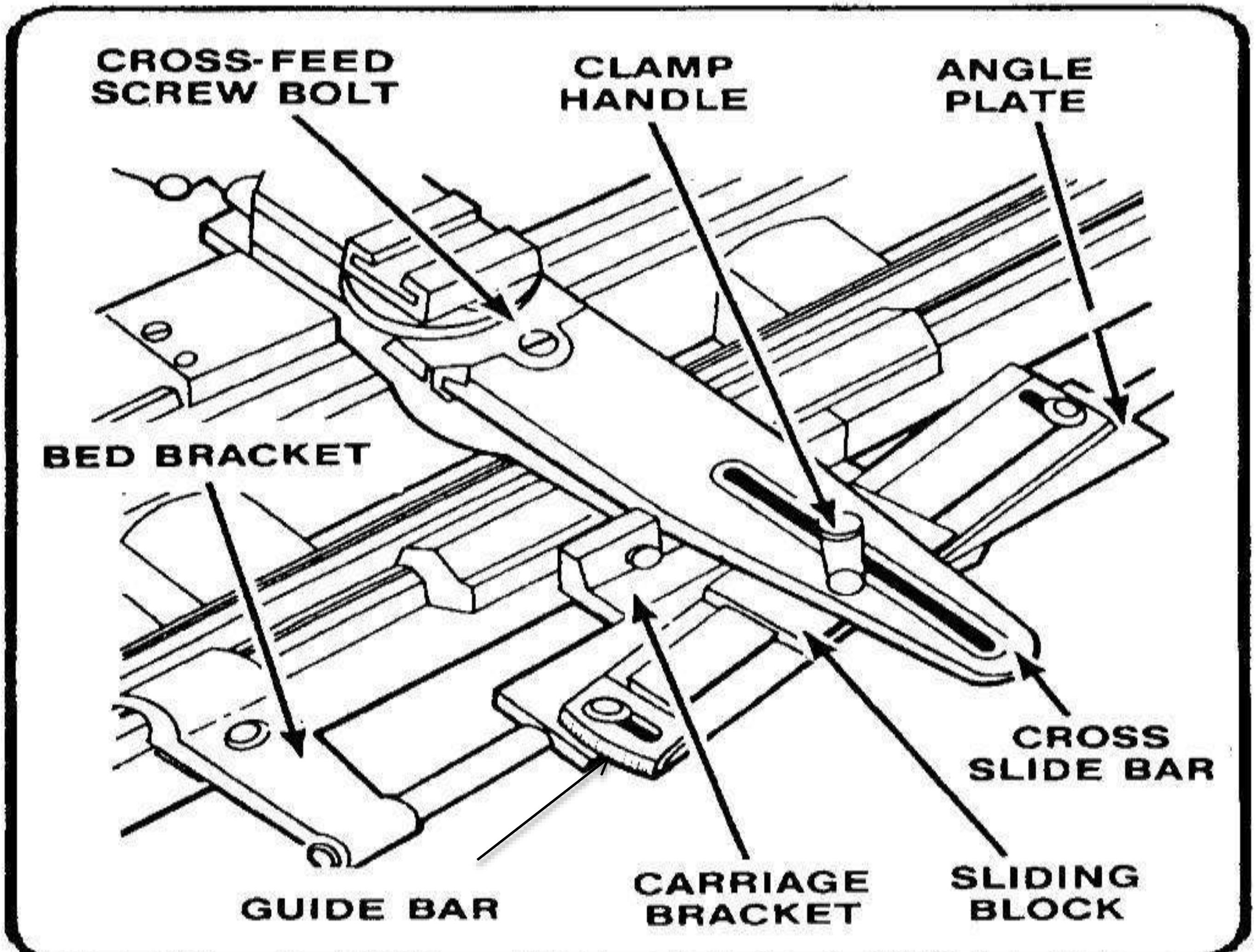


Figure 7-69. Taper attachment.

Taper Attachment

I. A bed bracket and keeps the angle plate from moving to the left or the right.

II. carriage bracket moves angle plate in a dovetail and keeps the angle plate from moving in or out on the bed bracket.

III. Taper to be cut is set by placing the guide bar, which clamps to the angle plate, at an angle to the ways of the lathe bed.

IV. sliding block which rides on a dovetail on the upper surface of the guide bar is secured during the machining operation to the cross slide bar of the carriage, with the cross feed screw of the carriage being disconnected.

V. carriage is traversed during the feeding operation, the cross slide bar follows the guide bar, moving at the predetermined angle from the ways of the bed to cut the taper.

VI. It is not necessary to remove the taper attachment when straight turning is desired.

Thread cutting attachment

- On the lathe internal and external threads are cut either with the help of a thread tool or with the help of tap and die respectively.
- There should be a certain relation between job revolutions and the revolutions of the lead screw to control linear movement of the tool parallel to the job when the half nut is engaged with the lead screw.
- The tool should be ground to the proper shape or profile of the thread to be cut.
- In modern lathes quick change gear box is provided in which different ratios of the spindle and lead screw

Lathe Accessories

- Divided into two categories
  - Work-holding, -supporting, and –driving devices
    - Lathe centers, chucks, faceplates
    - Mandrels, steady and follower rests
    - Lathe dogs, drive plates
  - Cutting-tool-holding devices
    - Straight and offset toolholders
    - Threading toolholders, boring bars
    - Turret-type toolposts

Work holding Devices

- Various work holding attachments such as three jaw chucks, collets, and centers can be held in the spindle.
- Work is held in the lathe with a number of methods,
- Between two centres. The work piece is driven by a device called a dog; this method is suitable for parts with high length-to-diameter ratio.
- A 3 jaw self-centering chuck is used for most operations on cylindrical work-parts. For parts with high length-to-diameter ratio the part is supported by center on the other end.
- Collet consists of tubular bushing with longitudinal slits. Collets are used to grasp and hold bar stock. A collet of exact diameter is required to match any bar stock diameter.
- A face plate is a device used to grasp parts with irregular shapes.

Mandrels

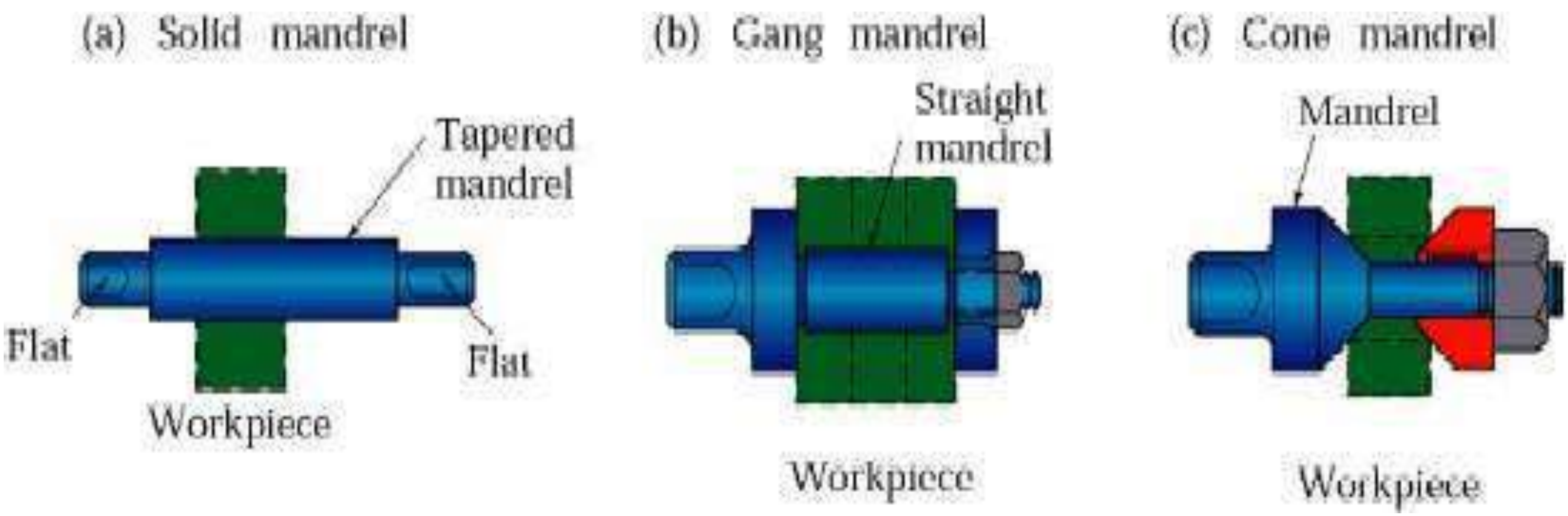


Fig : Various types of mandrels to hold work pieces for turning. These mandrels are usually mounted between centers on a lathe. Note that in (a) both the cylindrical and the end faces of the workpiece can be machined, whereas in (b) and (c) only the cylindrical surfaces can be machined.

Lathe Centers

- Work to be turned between centers must have center hole drilled in each end
  - Provides bearing surface
- Support during cutting
- Most common have solid Morse taper shank

  60º centers, steel with carbide tips

- Care to adjust and lubricate occasionally

Chucks

- Used extensively for holding work for machining operations
  - Work large or unusual shape
- Most commonly used lathe chucks
  - Three-jaw universal
  - Four-jaw independent
  - Collet chuck

Three-jaw Universal Chuck

- Holds round and hexagonal work
- Grasps work quickly and accurate within few thousandths/inch
- Three jaws move simultaneously when adjusted chuck wrench

  - Caused by scroll plate into which all three jaws fit
- Usually has three jaws which move in unison as an adjusting pinion is rotated.
- The advantage of the universal scroll chuck is its ease of operation in centering work for concentric turning.
- This chuck is not as accurate as the independent

Four Jaw Independent Chuck

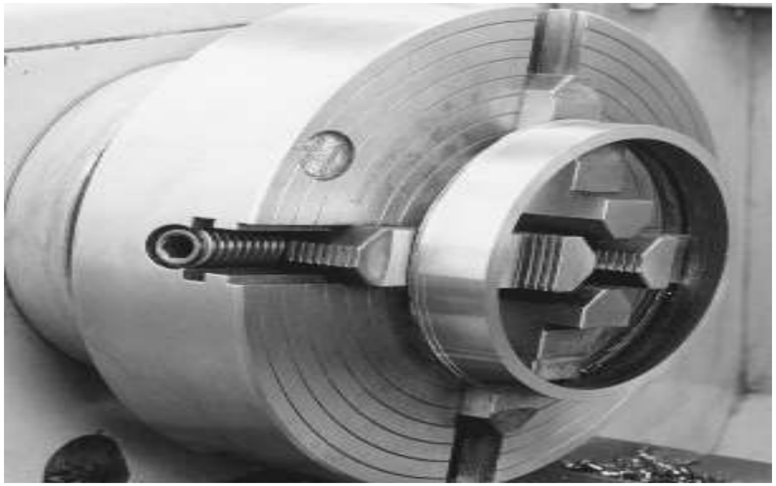
- Used to hold round, square, hexagonal, and irregularly shaped workpieces
- Has four jaws
  - Each can be adjusted independently by chuck wrench
- Jaws can be reversed to hold work by inside diameter

TYPES OF CHUCK

Three jaw chuck

- Forholding cylindrical stock centered.
- For facing/center drilling,etc.

Four-Jaw Chuck



- This is independent chuck generally has four jaws , which are adjusted individually on thechuck face by means of adjusting screws

Collet Chuck

Collet chuck is used to hold small workpieces

Magnetic Chuck

Thin jobs can be held by means of magnetic chucks.

Work holding Devices

Chucks

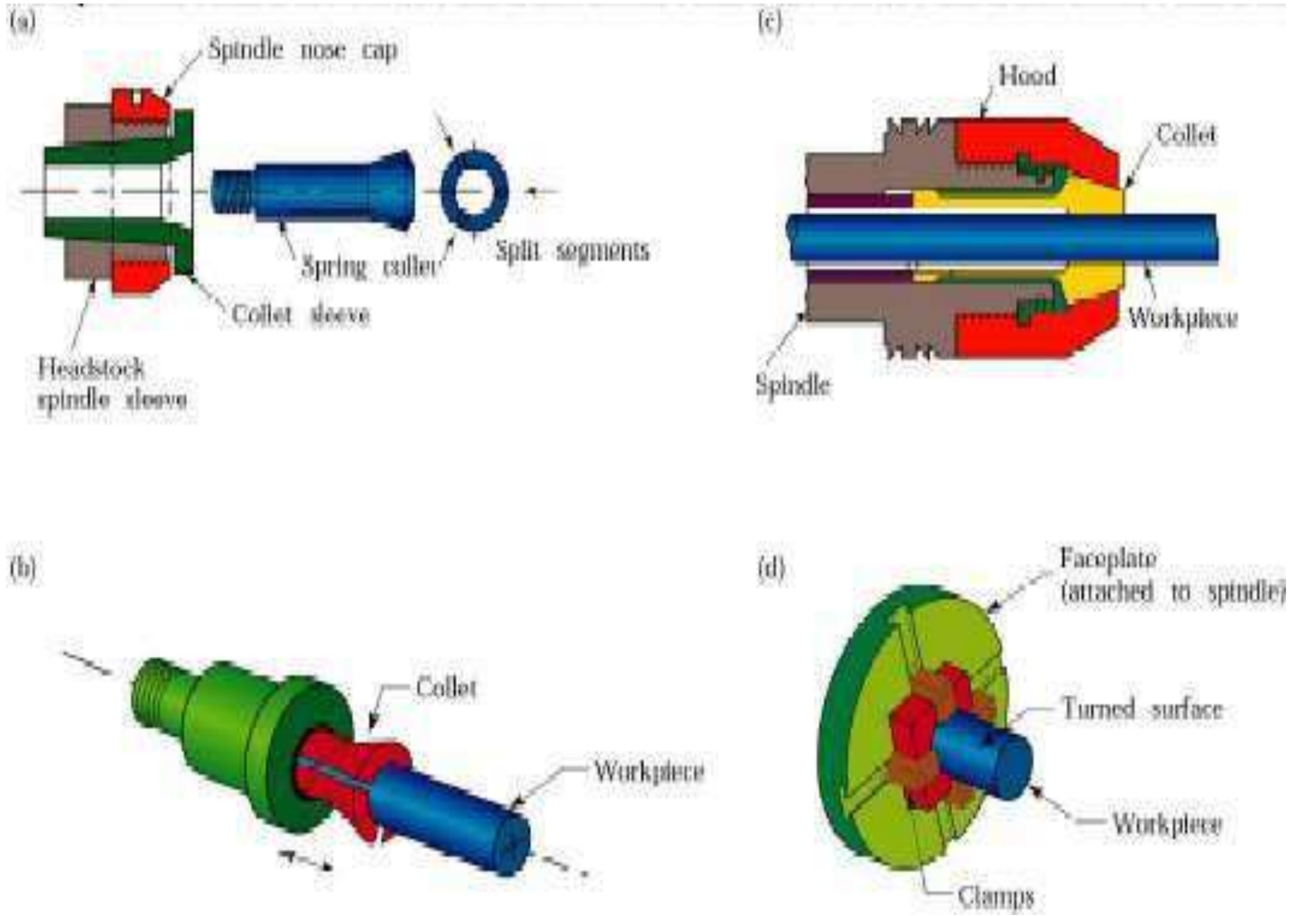
usually equipped with 3 or 4 jaws

3 jaw chucks generally are self centering. Used for round work pieces.

Can be centered within .025mm independently.

4 **jaw chucks** are for square, rectangular, or odd-shaped work pieces

- Can be power actuated

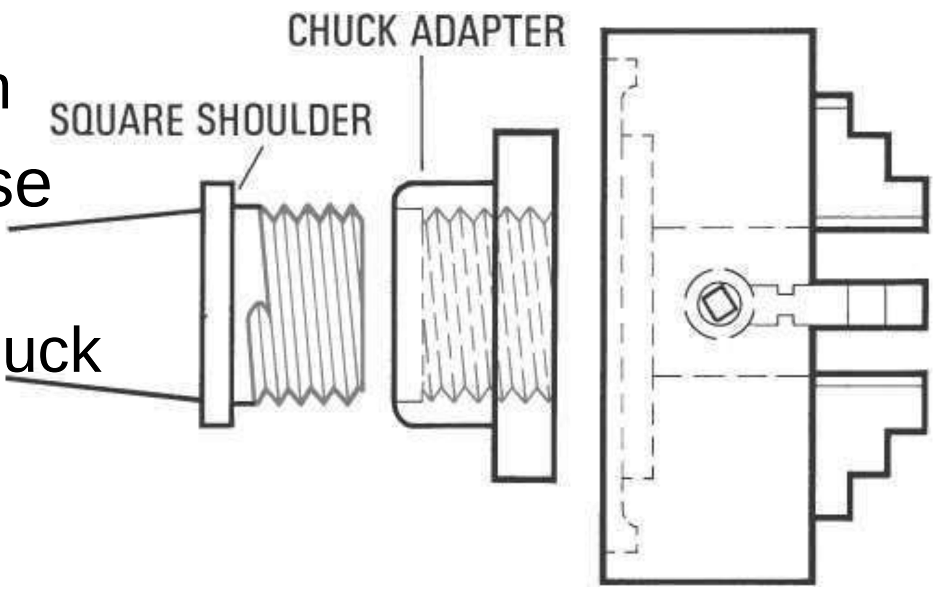


(a) and (b) Schematic illustrations of a draw-in-type collets. *The workpiece is placed in the collet hole, and the conical surfaces of the collet are forced inward by pulling it with a draw bar into the sleeve.* (c) A push-out type collet. (d) Workholding of a part on a face plate.

Headstock Spindles

Universal and independent chuck fitted to three types of headstock spindles

1. Threaded spindle nose
   - Screws on in a clockwise direction
2. Tapered spindle nose
   - Held by lock nut that tightens on chuck



Headstock Spindles

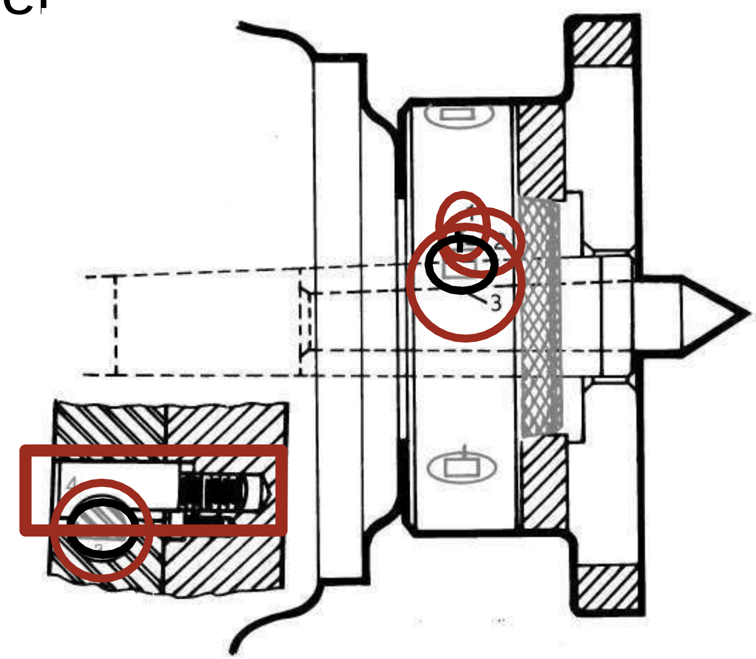
3. Cam-lock spindle nose
   - Held by tightening cam-locks using T-wrench
   - Chuck aligned by taper on spindle nose

Registration lines on spindle nose

Registration lines on cam-lock

Cam-locks

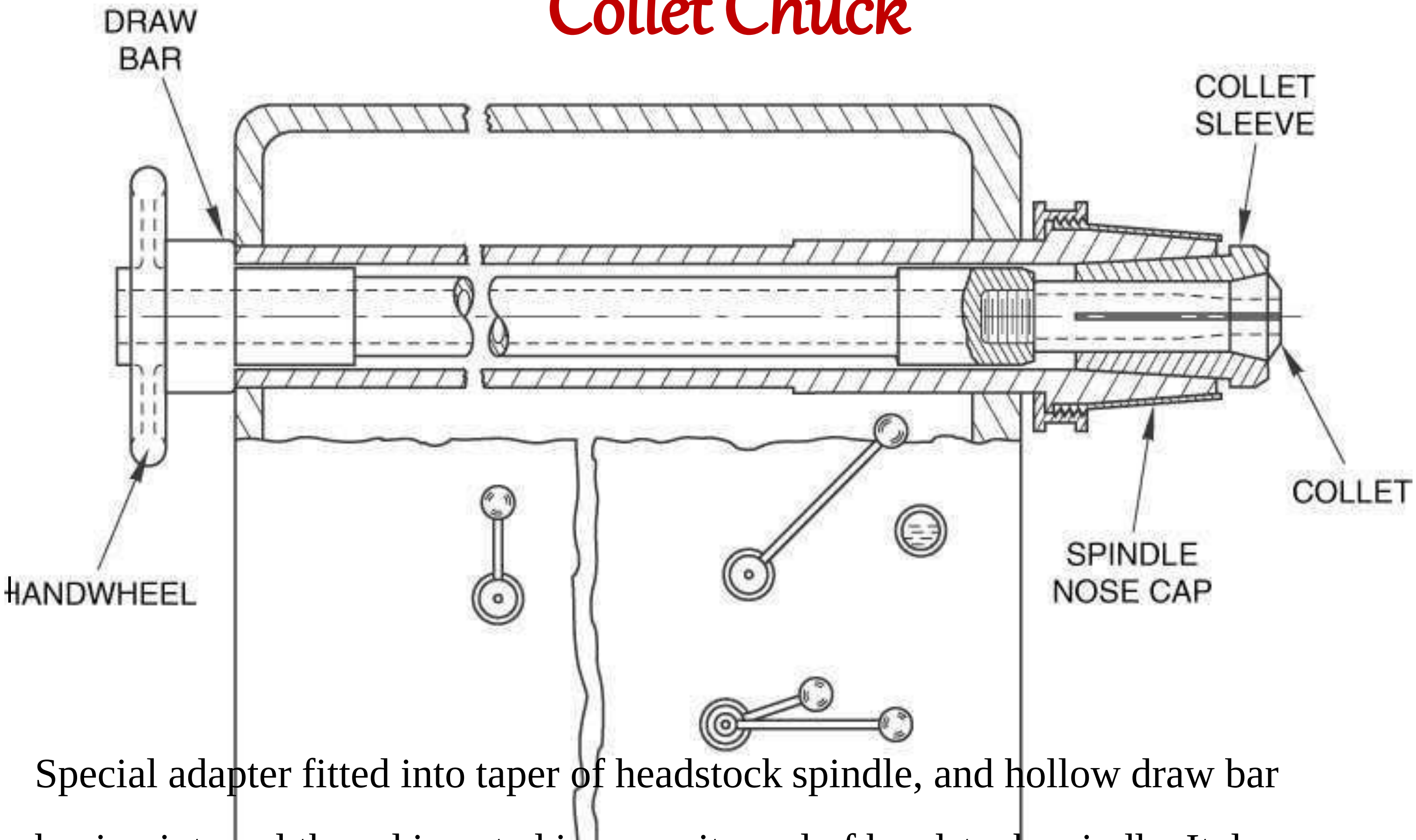
Cam-lock mating stud on chuck or faceplate



Collet Chuck

- Most accurate chuck
- Used for high-precision work
- Spring collets available to hold round, square, or hexagon-shaped work pieces
- Each collet has range of only few thousandths of an inch over or under size stamped on collet

Collet Chuck



Special adapter fitted into taper of headstock spindle, and hollow draw bar having internal thread inserted in opposite end of headstock spindle. It draws collet into tapered adapter causing collet to tighten on workpiece.

Types of Lathe Dogs

- Standard bent-tail lathe dog
  - Most commonly used for round workpieces
  - Available with square-head setscrews of headless setscrews
- Straight-tail lathe dog
  - Driven by stud in drive plate
  - Used in precision turning

Types of Lathe Dogs

- Safety clamp lathe dog
  - Used to hold variety of work
  - Wide range of adjustment

- Clamp lathe dog
  - Wider range than others
  - Used on all shapes

Left-Hand Offset Toolholder

- Offset to the right
- Designed for machining work close to chuck or faceplate and cutting right to left
- Designated by letter L

Right-Hand Offset Toolholder

- Offset to the left
- Designed for machining work close to the tailstock and cutting left to right
  - Also for facing operations
- Designated by letter R

Straight Toolholder

- General-purpose type
- Used for taking cuts in either direction and for general machining operations
- Designated by letter S

Straight Tool holder

- General-purpose type
- Used for taking cuts in either direction and for general machining operations
- Designated by letter S

Semi automatic lathes

- Semi automatic lathes are production lathes with human involvement for certain operations
- Semi automatic lathes are production lathes with human involvement for certain operations
- Capstan and turret lathes with additional attachments become semi automatic lathes
- Also called retrofitting
- Vide range of jobs can be accommodated
- Higher production rates

Semi Automatic Lathes

- Designed for short continuous runs
- Turret or ram in place of tailstock
- Indexable square tool post on cross slide
  - Suitable for Drilling, countersinking, reaming, tapping like operations
  - Turret and Capstan lathes are examples
  - In Turret lathe Turret moves along with saddle
  - In Capstan lathe turret slides over the ram

Turret Lathe

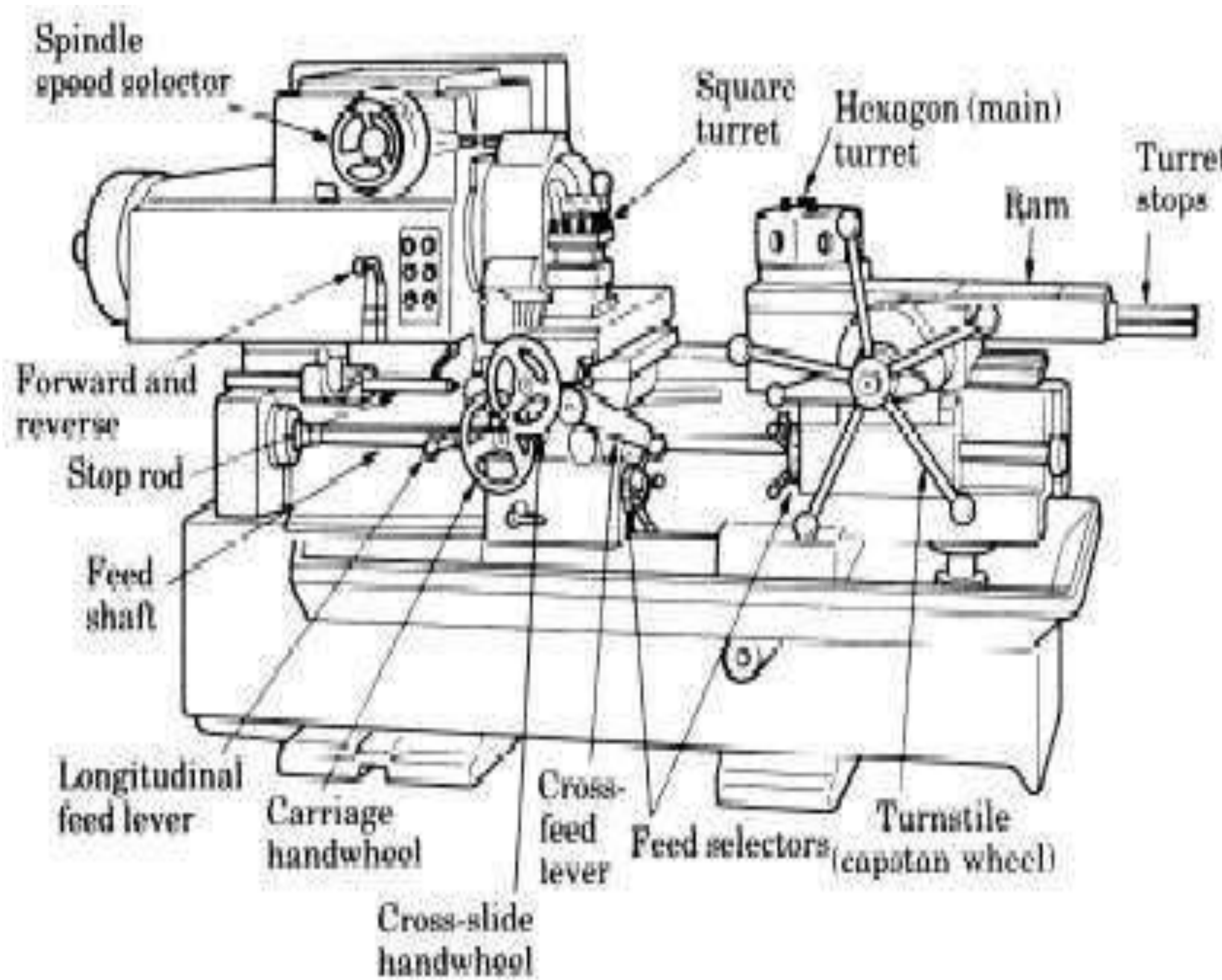
Capable of performing multiple cutting operations on the same workpiece

- Turning
- Boring
- Drilling
- Thread cutting
- Facing

Turret lathes are very versatile

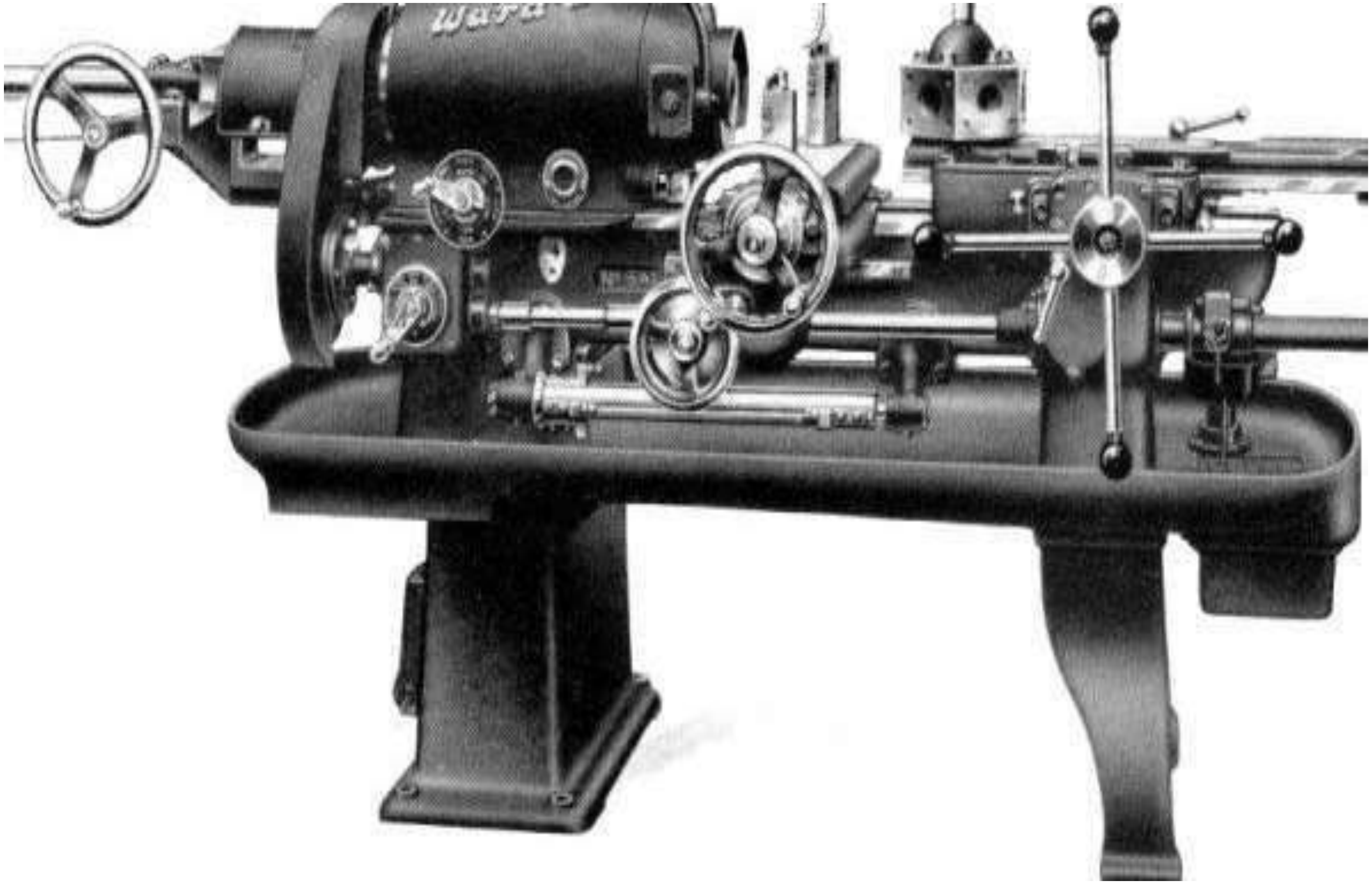
Types of turret lathes

- Ram-type: ram slides in a separate base on the saddle
- Saddle type:
  - more heavily constructed
  - Used to machine large workpeiceces



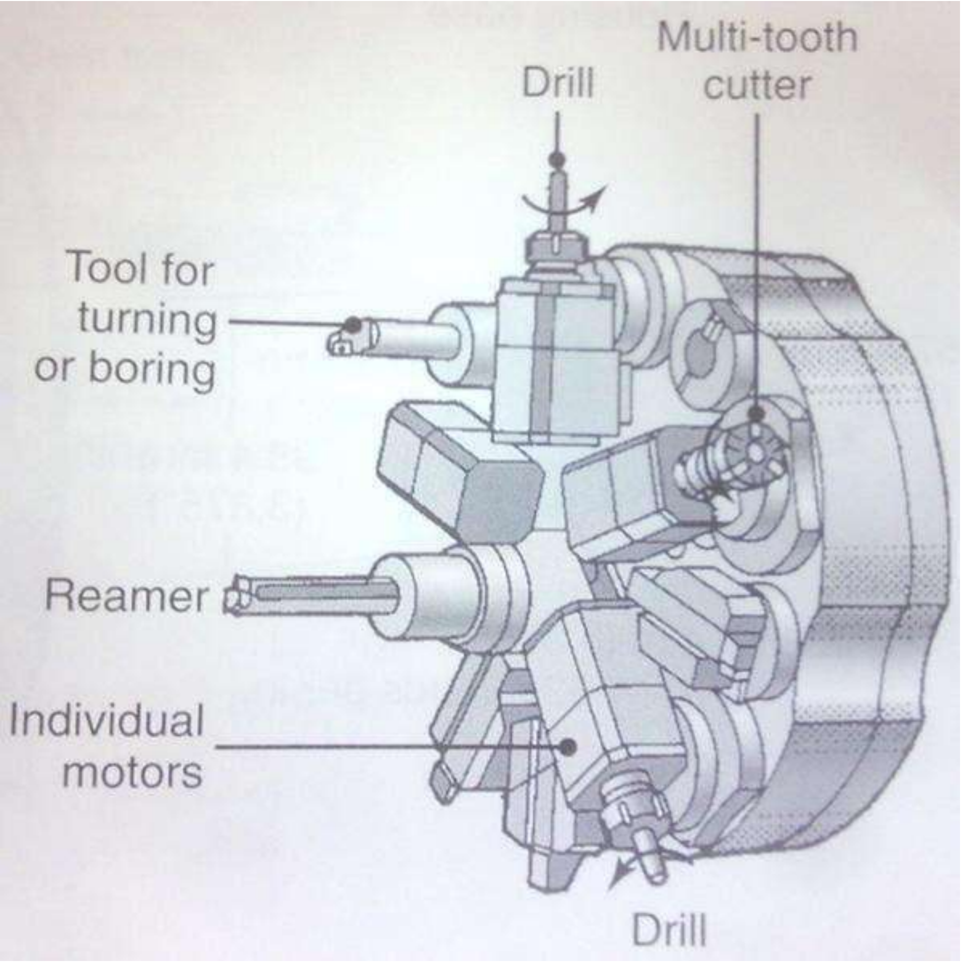
Turret lathe

Capston Lathe



Turret Lathe

- These machines are capable of carrying out multiple cutting operations on the same workpiece.
- Several cutting tools are mounted on a tetra, penta, or hexagonal turret, which replaces the tailstock.
- These tools can be rapidly brought into action against the workpiece one by one by indexing the turret.



Comparision of turret & engine lathe

Turret lathe

- Turret lathes are relatively more robust and heavy duty machines .work on chucking type jobs held in the quick acting chucks
- The heavy turret being mounted on the saddle which directly slides with larger stroke length on the main bed
- One additional guide rod or pilot bar is provided on the headstock of the turret lathes to ensure rigid axial travel of the turret head
- whereas in turret lathes external threads are generally cut, if required, by a single point or multipoint chasing tool being mounted on the front slide and moved by a short leadscrew and a

Capstan lathe

- Capstan lathes generally deal with short or long rod type blanks held in collet,
- In capstan lathe, the turret travels with limited stroke length within a saddle type guide block, called auxiliary bed, which is clamped on the main bed
- External screw threads are cut in capstan lathe, if required, using a self opening die being mounted in one face of the turret,

AUTOMATIC LATHES

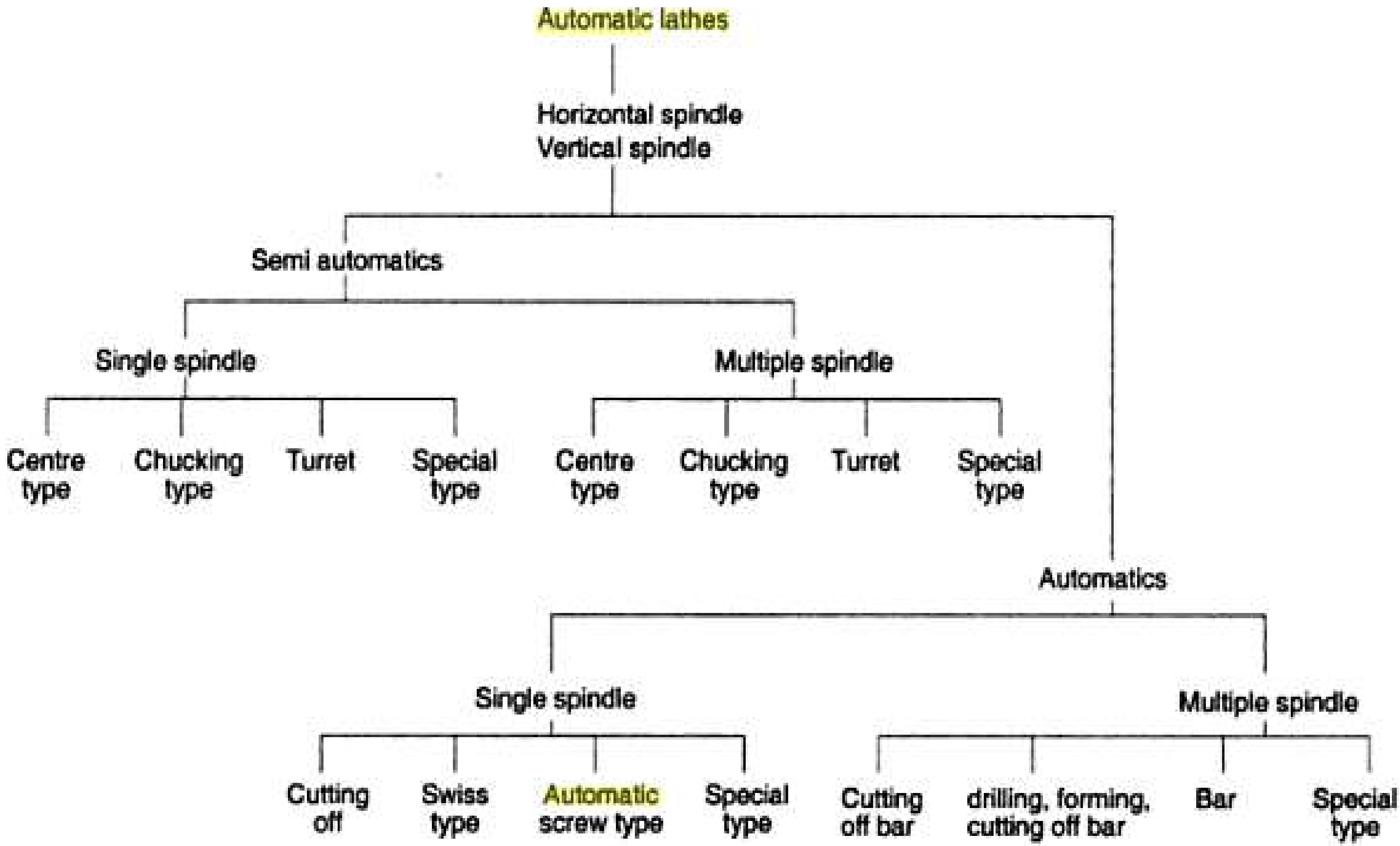


Fig. 5.9 *Classification of automatic lathes*

AUTOMATIC LATHES

- Machine tools in which components are machined automatically.
- The working cycle is fully automatic that is repeated to produce duplicate parts with out participation of operator.
- All movements of cutting tools, their sequence of operations, applications, feeding of raw material, parting off, un loading of finished parts all are done on machine.
- All working & idle operations are performed in definite sequence by control system adopted in automatic which is set up to suit a given work.
- Only operation reqd to be performed manually is loading of bar stock/ individual casting/ forged blanks.
- These machines are used when production requirements are too high for turret lathes to produce economically.

Automatic Lathes

- Manual machine controls replaced by various mechanisms
- Parts are fed and removed automatically
- May have single or multiple spindles
- Automatic lathes uses servo motor
- Automatic lathes Limited ranges of variety and sizes

Automatic Lathe Features

- Minimum man power utilized
- Meant for mass production
- Manual machine controls replaced by various mechanisms
- To eliminate the amount of skilled labour.
- Mechanisms enable to follow certain prescribed frequency
- Parts are fed and removed automatically
- Minimizing the loading and unloading time
- May have single or multiple spindles
- Tool set up may be permanent
- May have horizontal or vertical spindles
- More accuracy can be obtained

Advantages

- Greater production over a given period.
- More economy in floor space.
- Improvement in accuracy.
- Floor space maintenance and inventory requirements are reduced.
- More consistently accurate work than turrets.
- More constant flow of production.
- Scrap loss is reduced by reducing operator error.
- During machine operation operator is free to operate another machine/ can inspect completed parts.

CLASSIFICATION OF AUTOMATIC LATHES

- Depending up on type of work machined these machines are classified as:

1. Magazine loaded Automatics:

- Machines used for producing components from separate blanks.
- Also called as automatic checking machines.

2. Automatic Bar Machines:

- designed for machining components from bar/ pipe stock.
- M/c's are used for manufacture of high quality fasteners (screws, nuts), bushings, shafts, rings, rollers, handles which are usually made of bar / pipe stock.

- Depending upon number of work spindles, automatic lathes are classified as:

1. Single Spindle Automatics.
2. Multi Spindle Automatics.

- Depending upon purpose & arrangement of spindle also automatics are classified as:

1. Purpose→ General & single purpose m/c.
2. Arrangement of spindle→ Horizontal & vertical

1) Type of Single Spindle Automatics:

a) Automatic Cutting Off Machine:

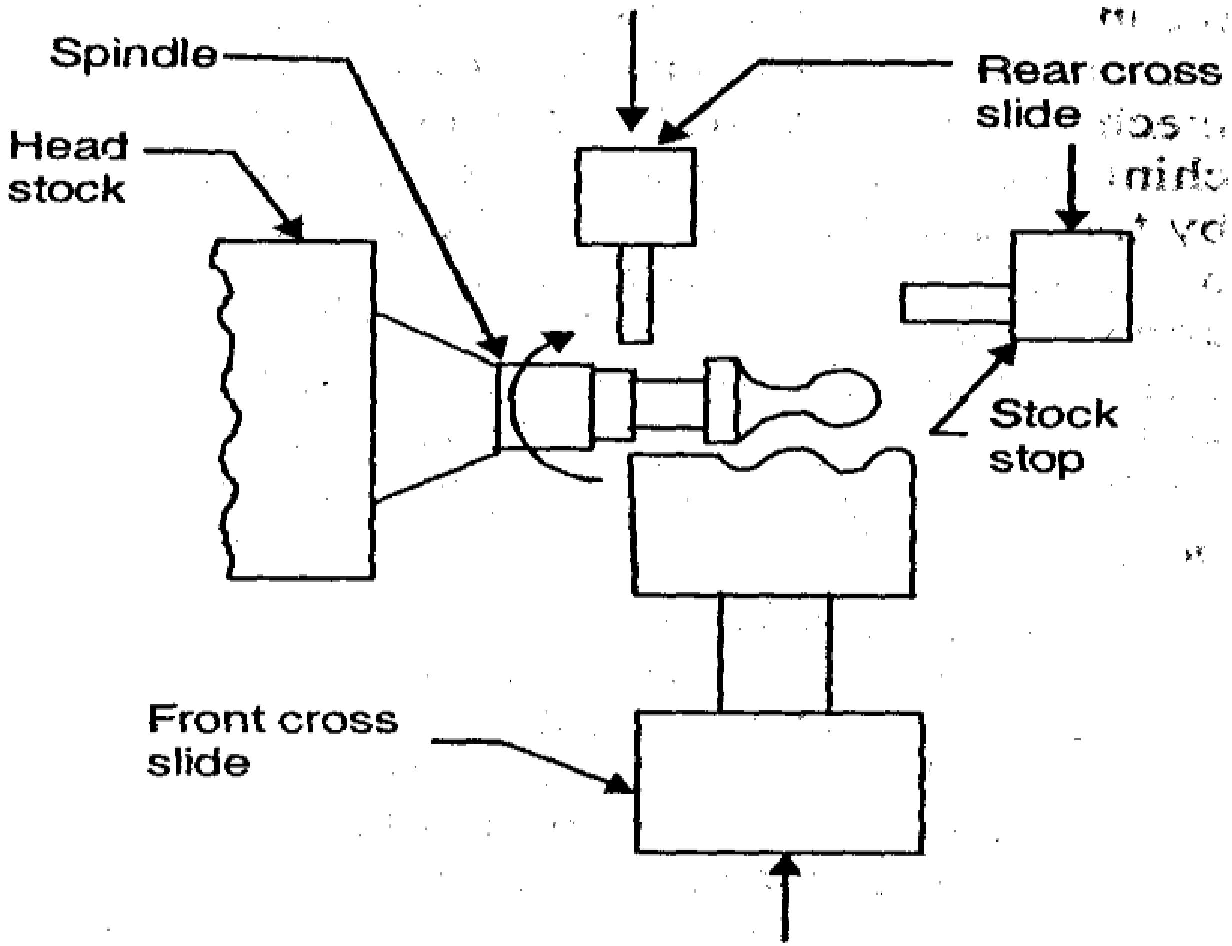


Fig. 8.2. Automatic Cutting-off Machine.

- These machines produce short w/p’s of simple form by means of cross sliding tools. Machines are simple in design.
- Head stock with spindle is mounted on bed.
- 2 cross slides are located on bed at front end of spindle.
- CAMS on cam shaft actuate movements of cross slide through system of levers.

Operation:

- The reqd length of work(stock) is fed out with a cam mechanism, up to stock stop which is automatically advanced in line with spindle axis at each end of cycle.
- Stock is held in collet chuck of rotating spindle.
- Machining is done by tolls that are held in slides operating only in cross wise direction.
- Typical simple parts (3 to 20 mm dia) machined on such a machine is shown in fig.

b) Single spindle Automatic Screwm/c:

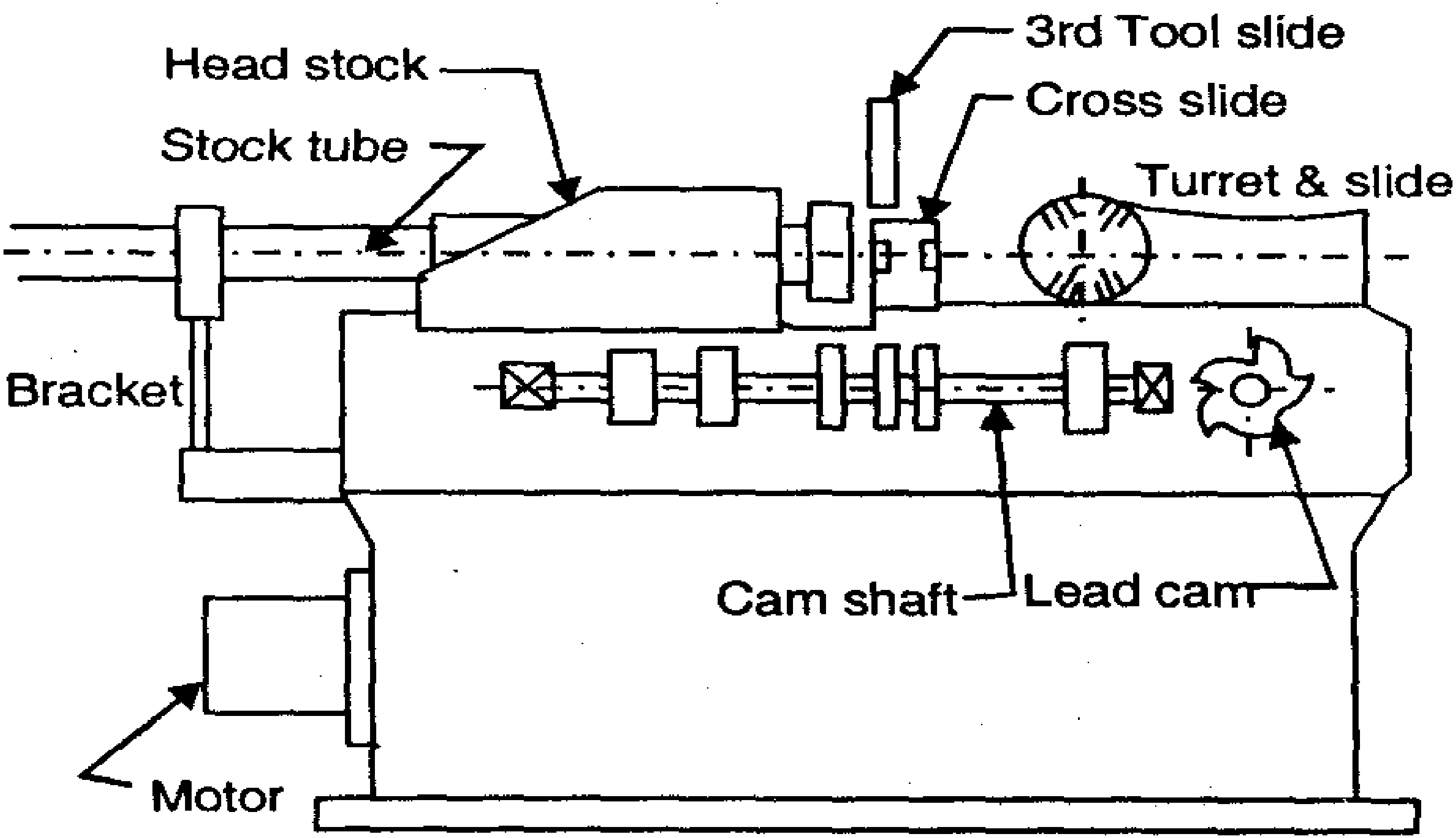


Fig. 8.4. Automatic Screw Machine

- Used for producing small screws(12.7 to 60 mm dia) generally, but also in production of all sorts of small turned parts.
- These are completely automatic bar type turret lathes, designed for machining complex internal & external surfaces on parts made of bar stock/separate blanks.
- Up to 10 different cutting tools can be employed at one time in tooling of this kind of screw machine.
- 2 cross slides(front & rear) are employed for cross feeding tools.
- Vertical tool slides for parting off operation may also be provided .
- Head stock is stationary & houses the spindle.
- Bar stock is held in collet chuck & advanced after each piece is finished & cut off.
- All movements of machine units are actuated by cams mounted on cam shaft.

- Bar stock is pushed through stock tube in a bracket & its leading end is clamped in rotating spindle by means of collet chuck.
- By stock feeding mechanism bar is fed out for next part.
- Machining of central hole is done by tools that are mounted on turret slide.
- Parting off/ Cutting off, form tools are mounted on cross slide.
- At end of each cut turret slide is with drawn automatically & indexed to bring next tool to position.

c) Swiss type automatic screw/Sliding headscrew:

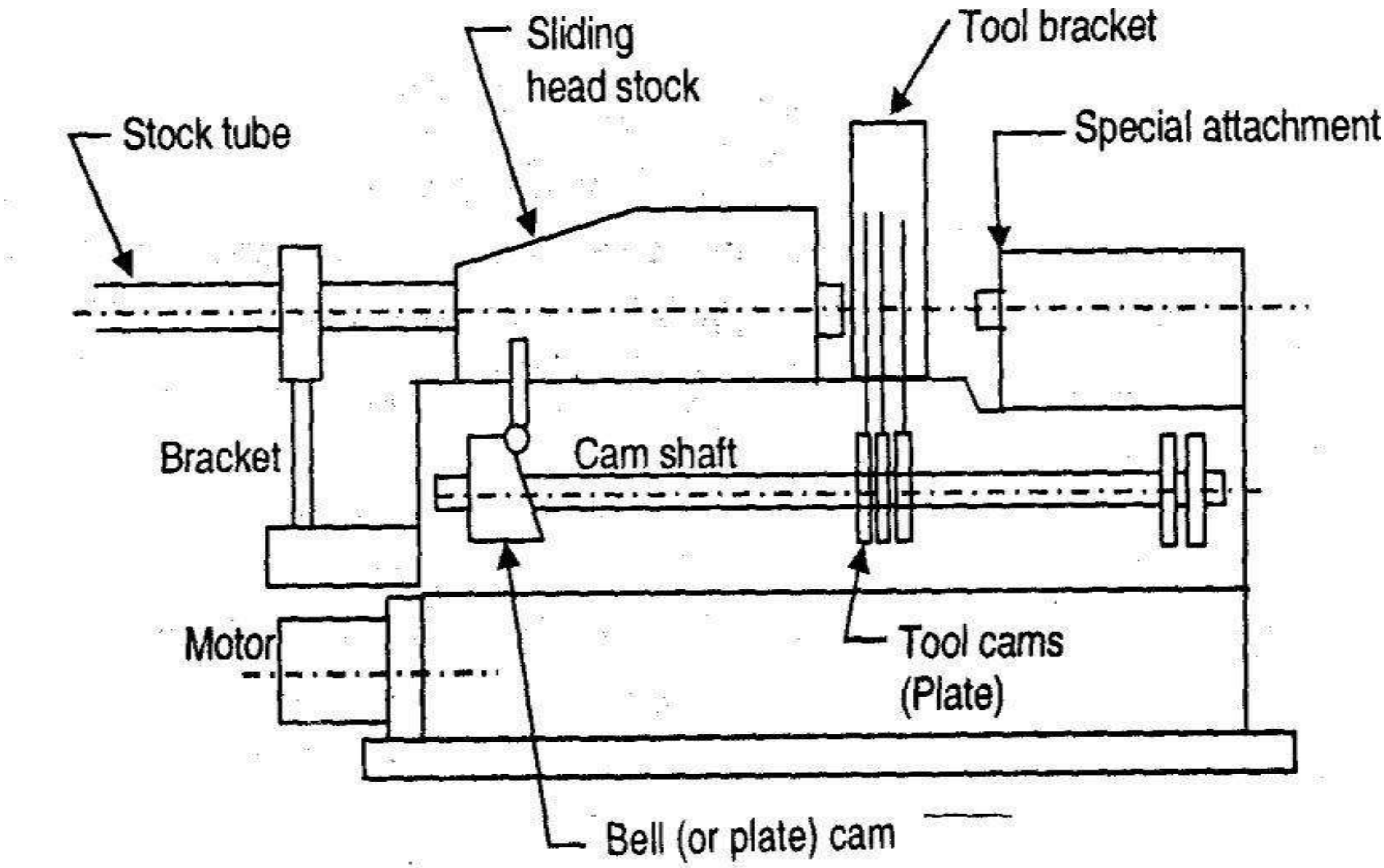
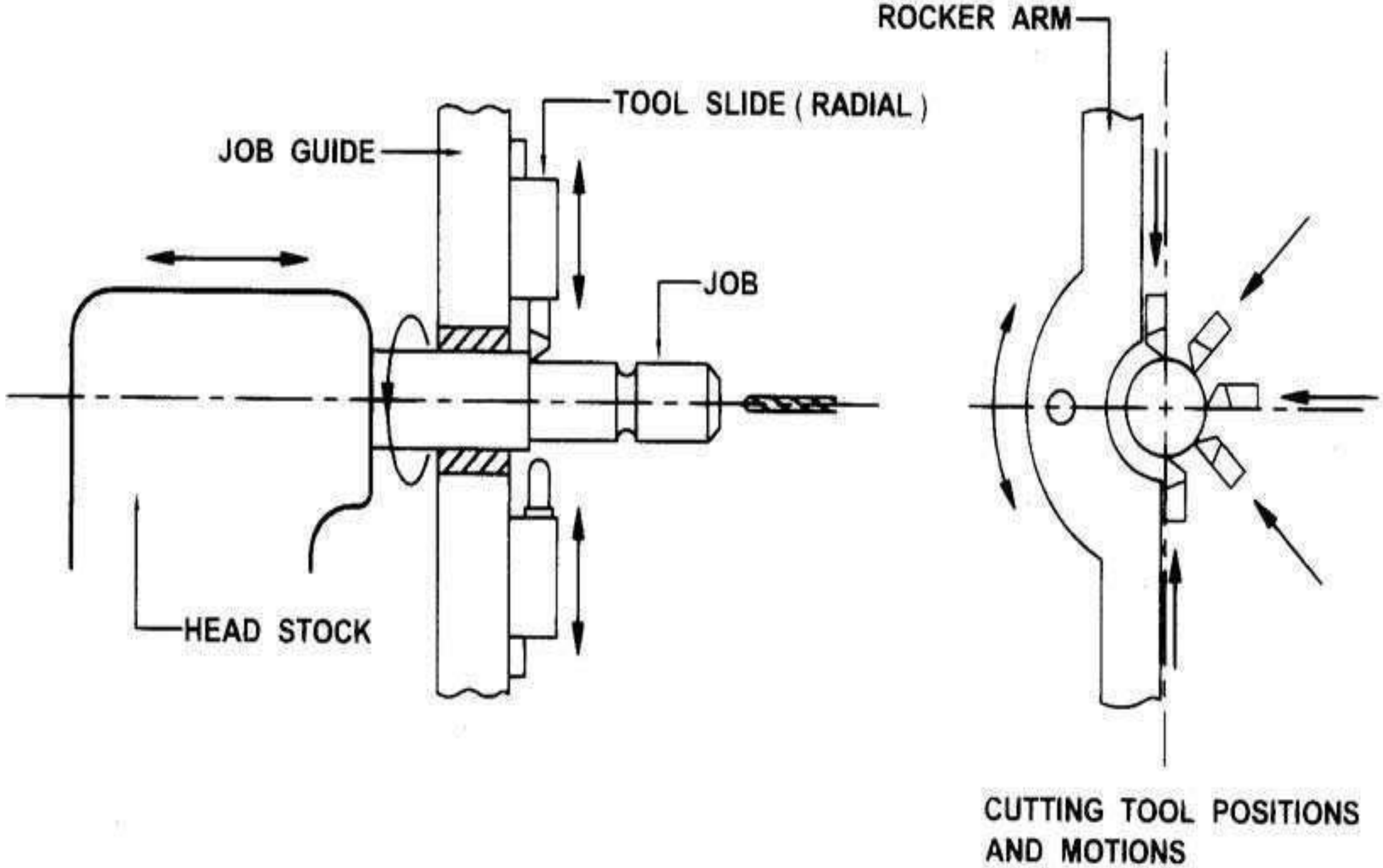


Fig. 8.7. Swiss Type Automatic


ROCKER ARM
TOOL SLIDE (RADIAL)
JOB GUIDE
JOB
HEAD STOCK
CUTTING TOOL POSITIONS
AND MOTIONS

- As name implies in this m/c head stock is movable & tools are fixed.
- These machines are used for machining long accurate parts of small diameter.(2 to 25mm).
- Bar stock is held in rotating collet in head stock & all longitudinal feeds are obtained by cam which moves entire head stock as unit.
- Rotating bar stock is fed through hard bushing in centre of tool head.
- Tool head consists of 5 single point tools is placed radially around bushing.
- Mostly diameter turning is done by 2 horizontal slides, other 3 slides used for operations such as knurling, chamfering, cutoff.
- Tools are controlled & positioned by cams that bring tool in as needed to turn, face, form, cutoff w/p from bar as it emerges from bushing. Close tolerances 0.005 to 0.00125 mm are obtained.

11) Multi Spindle Automatics:

- These are fastest type of production machines and are made in a variety of models with 2,4,5,6,8 spindles.
- In contrast with single spindle m/c where one turret face at a time is working on one spindle, in multi spindle m/c all turret faces works on all spindles at same time.
- Production capacity is higher, machining accuracy is lower compared to single spindle.
- Because of longer set up time, increased tooling cost this machines are less economical than other on short runs, more economical for longer runs.

a) Parallel Action Automatics/ Multiple Flow m/c:

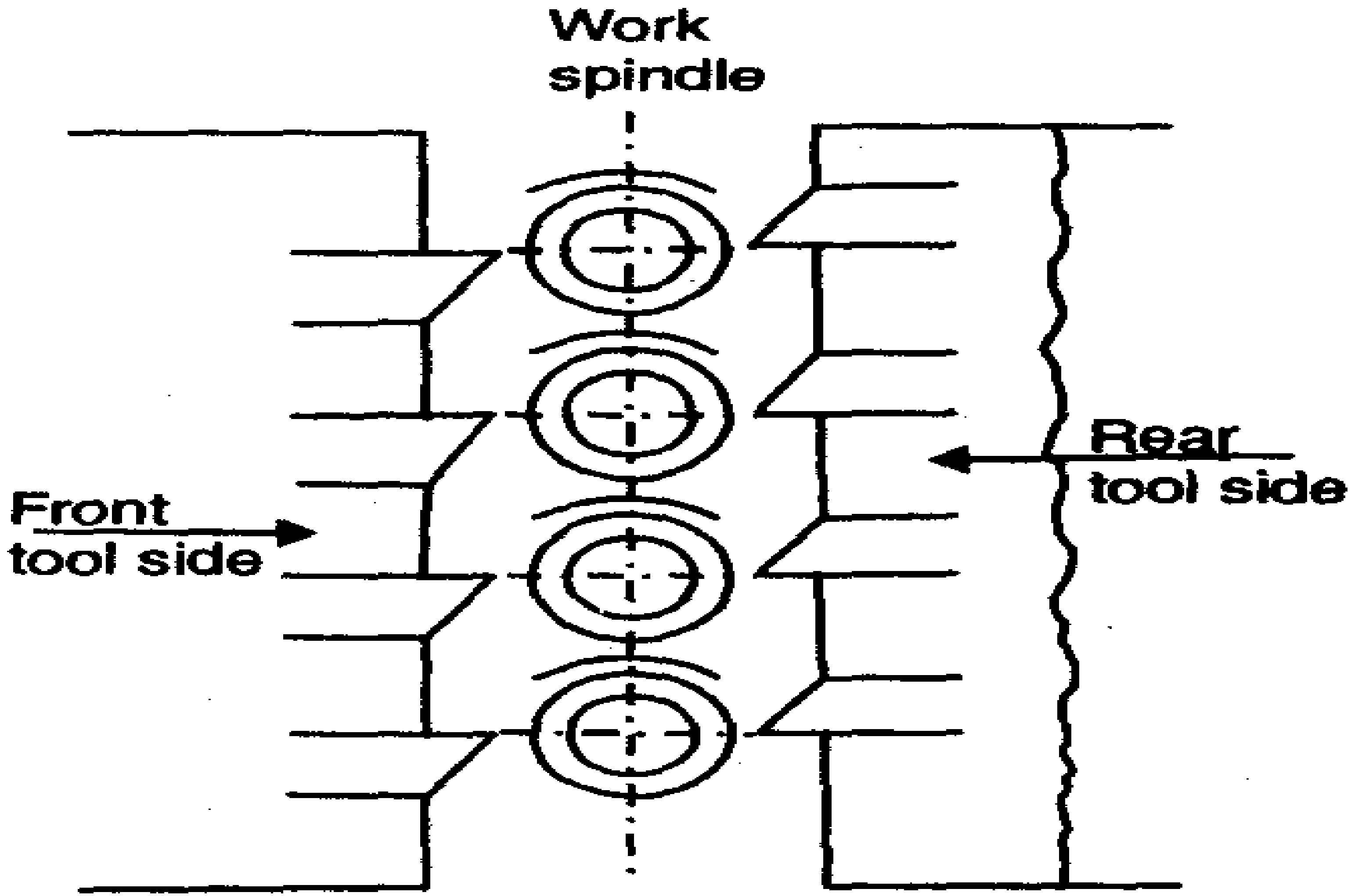


Fig. 8.10. Parallel-action multi-spindle

- In this type of machine same operation is performed on each spindle, w/p is finished in each spindle in one working cycle.
- It means that No. of components being machined== No. of spindles in machine.
- Rate of production is high & machine can be used to machine simple parts only since all the machining processes are done at one position.
- These machines are usually automatic cutting off bar type machines, used to perform same work as single spindle automatic cut off machines.
- Machine consists of frame with head stock at right end.
- Horizontal work spindles that are arranged one above the another are housed in this head stock.
- Cross slides are located at right & left hand sides of spindles & carry cross feeding tools. All working & auxiliary motions of machine unit are obtained from CAM mounted on cam shaft.

b) Six Spindle Progressive Action MultiSpindle:

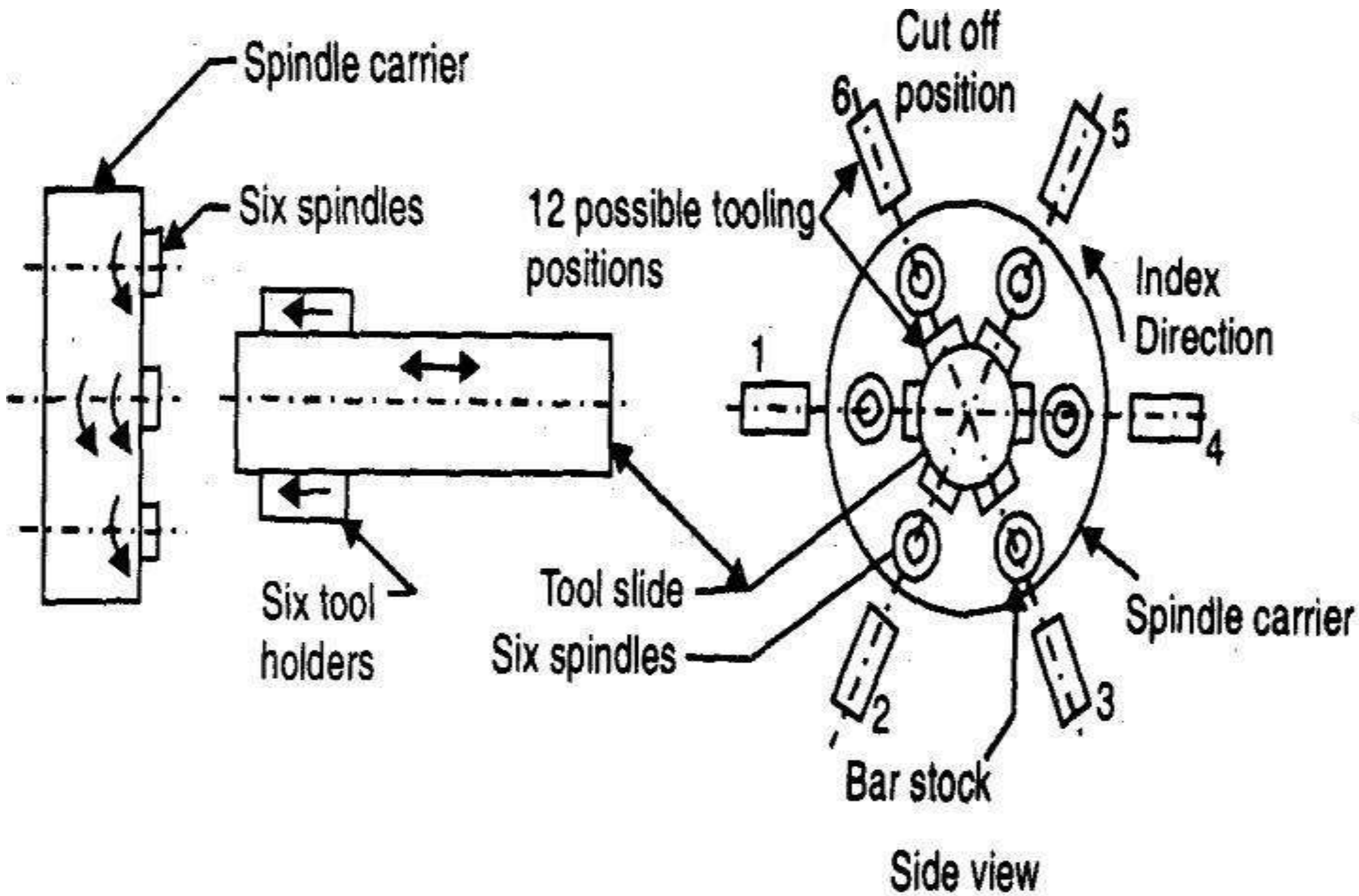
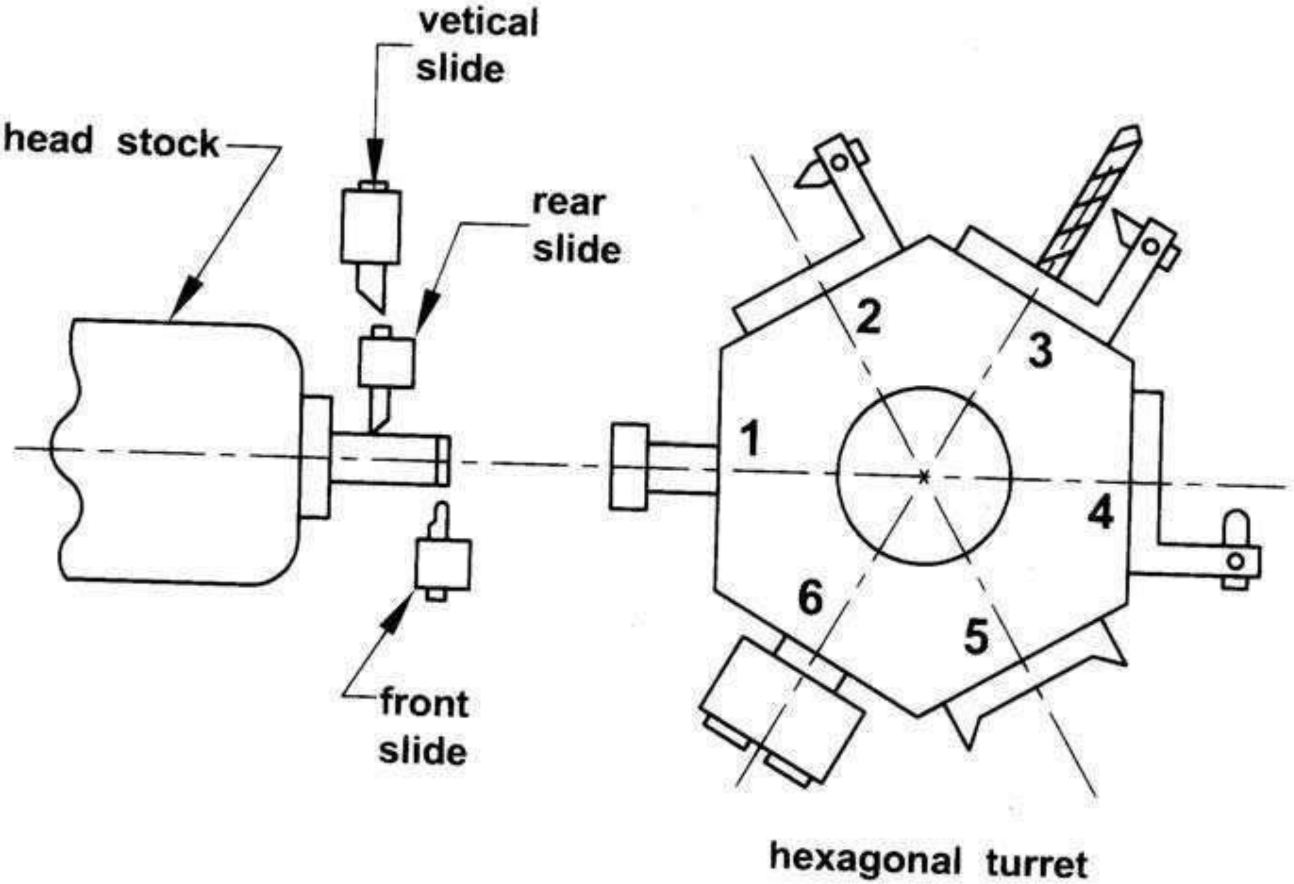


Fig. 8.11. Six Spindle Progressive Action Automatic.

- In this design of machine, the w/p is machined in states & progressively in station after station.
- Head stock is mounted on left end of base of machine.
- It carries spindle carrier which rotates about a horizontal axis through centre of machine.
- Working spindles are mounted on this spindle carriers.
- Spindles carry collets & bars from which w/p’s are machined.
- Bar stock is fed through each spindle from rear side.
- On face of spindle carrier support are mounted cross slides which carry tools for operations such as cutoff, turning, facing, forming, chamfering.

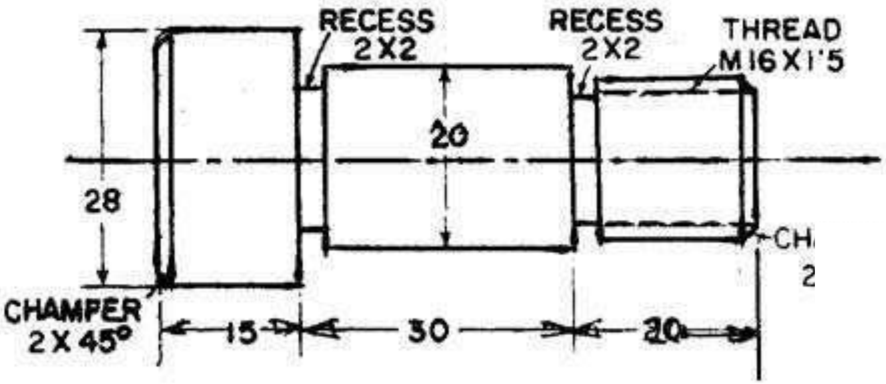
- No. of slides === No. of spindles.
- Main tool slide (end tool slide) extends from middle of this support.
- Fed of each tool, both cross slide & end tool slides is controlled by its own individual cams.
- In this diagram spindle carrier indexes on its own axis by 60° at each cutting tool retraction.
- As spindle carrier indexes, it carries work from one station to another station where different tolls operate on work.
- Stock moves round the circle in counter clock wise direction & returns to station no. 6 for cutting off.

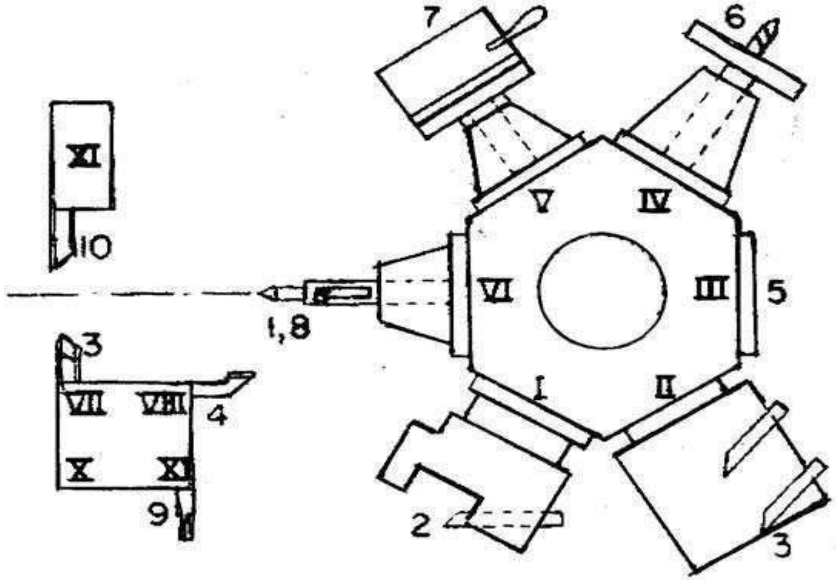
Tool layout



vetical
slide
head stock
rear
slide
front
slide
1
2
3
4
5
6
hexagonal turret

Tool layout





schematically showing the type and configuration of A typical tool layout for a particular job being machined in a single spindle automatic lathe is schematically shown in Fig.

Tool layout and cam design

- Pre determined plan for order and method off machining operations necessary to produce it . Following steps are recommended for lay out for an automatic lathe.

(i) Choose the best available machine taking into consideration the availability as well as economical manufacture of the component.

(ii) Determine the sequence of operations.

(iii) Choose the available standard tooling as far as possible.

(iv) Decide on any possible design for special tooling if needed absolutely.

(v) Based on the machine capability and surface finish desired, decide the cutting process parameters for each of the tool to be used. In case of heavy jobs, the available spindle power of the machine may be verified.

(vi) Check the movement of each of the tool in conjunction with the workpiece for machining.

(vii) Arrange for any overlap of operations to reduce the total cycle time.

(viii) Compute the processing time including the idle time and from that the number of revolutions needed for each operation.

(ix) Calculate the spacing required on the cam periphery.

(x) Draw the tool layout and cam details while verifying all the tool movements and clearances.

Machining Calculations: Turning

- Spindle Speed - N (rpm)
  - v = cutting speed
  - D_o = outer diameter
- Feed Rate - f_r (mm/min -or- in/min)
  - f = feed per rev
- Depth of Cut - d (mm/rev -or- in/rev)
  - D_o = outer diameter
  - D_f = final diameter
- Machining Time - T_m (min)
  - L = length of cut
- Mat'l Removal Rate - MRR (mm³/min -or- in³/min)

$$N = \frac{v}{\pi \quad D_o}$$

$$f_r = N \quad f$$

$$d = \frac{D_o - D_f}{2}$$

$$T_m = \frac{L}{f_r}$$

$$MRR = v \quad f \quad d$$

Thank You !!!

UNIT – III

DRILLING

SYLLABUS

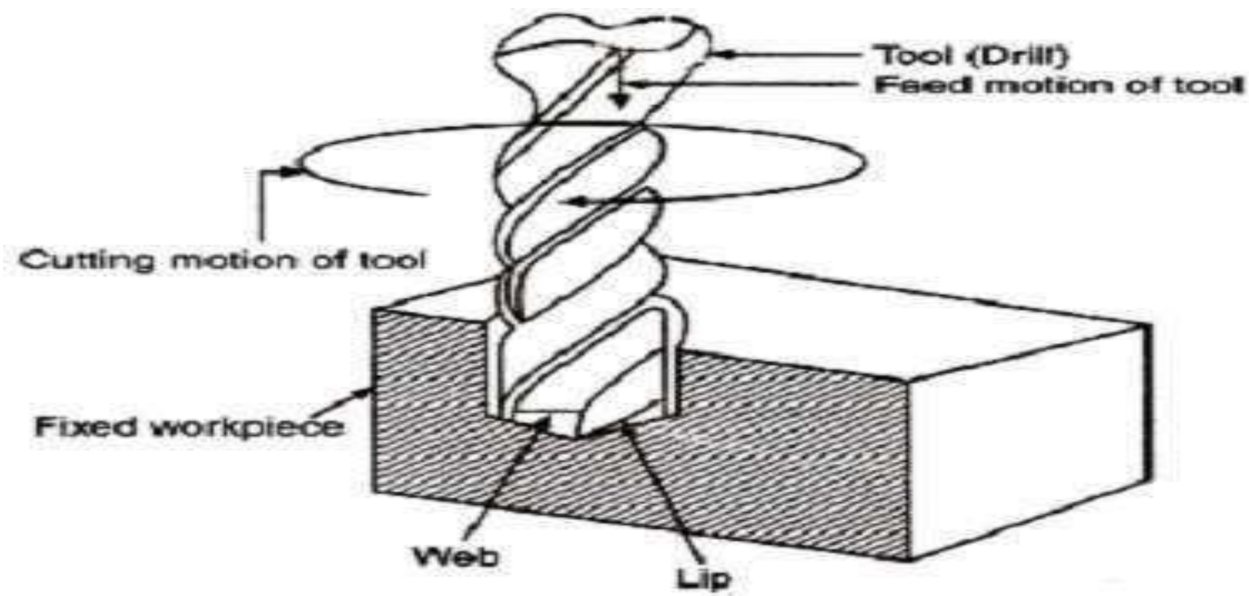
- WORKING PRINCIPLE OFDRILLING
- MAIN PARTS OF DRILLING MACHINE
- TYPES OF DRILLING MACHINE
- OPERATION OF DRILLING MACHINE

- The drilling machine or drill press is one of the most common and useful machine employed in industry for producing forming and finishing holes in a work piece.

1. WORKING PRINCIPLE OFDRILLING

The rotating edge of the drill exerts a large force on the work piece and the hole is generated. The removal of metal in a drilling operation is by

Shearing and extrusion



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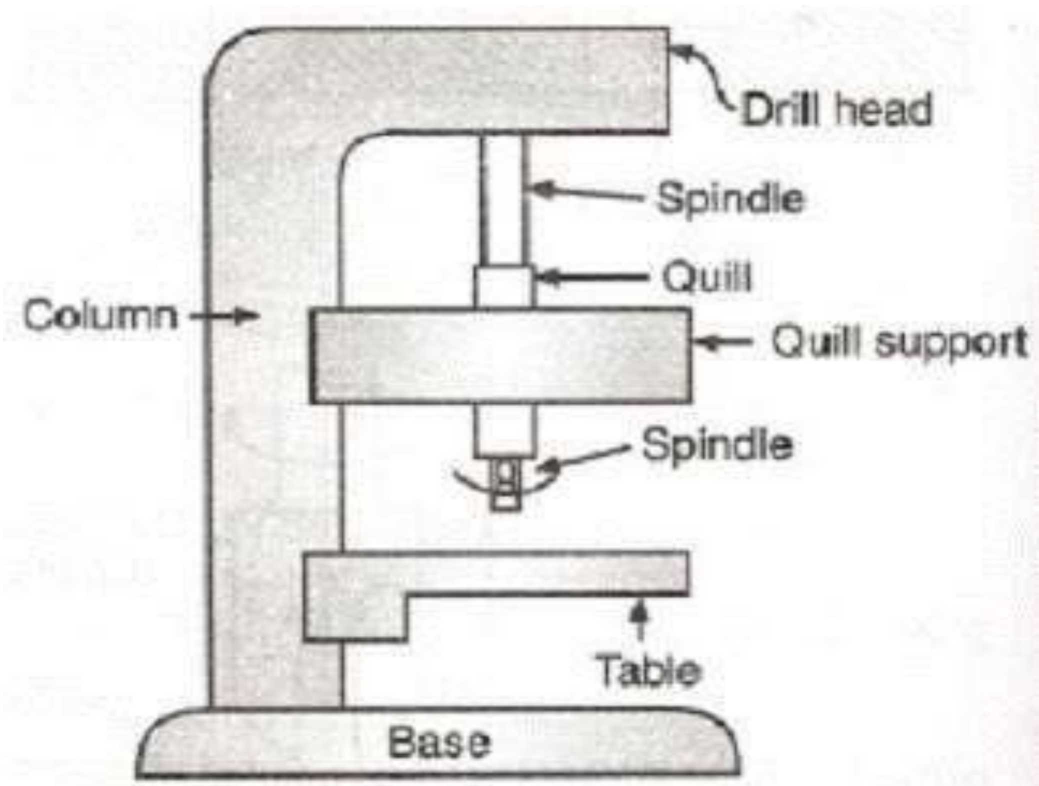
2. MAIN PARTS OF DRILLING MACHINE

The machine has only a hand feed mechanism for feeding the tool into the work piece. This enables the operator to feel how the drill is cutting and accordingly he can control the down feed pressure. Sensitive drill presses are manufactured in bench or floor models.

1.	Base	2.	Column
3.	Adjustable table	4.	Spindle
5.	Head	6.	Drill chuck



3. TYPES OF DRILLING MACHINE

- Portable Drilling Machine
- Sensitive or Bench Drill
- Upright Drilling Machine (Single Spindle)
- Upright Drilling Machine (Turret Type)
- Radial Drilling Machine
- Multiple Spindle Drilling Machine
- Deep Hole Drilling Machine
- Gang Drilling Machine
- Horizontal Drilling Machine
- Automatic Drilling Machine

4. OPERATION OF DRILLING MACHINE

- Drilling
- Reaming
- Boring
- Counter Boring
- Counter Sinking
- Spot Facing
- Tapping
- Core drilling
- Buffing
- Step drilling
- Grinding
- Countersinking

MCQ QUESTUONS:-

1. Which of the following is not the workholding devices.
   a) Direct fitting
   b) Sleeve and socket
   c) Collet chuck
   d) Milling machine

2. How much helix angle is in twist drill
   a) 29°
   b) 30°
   c) 120°
   d) 35°

VERY SHORT ANSWER TYPE QUESTIONS:- (2 MARKS)

1. What is drilling?
2. What is hole milling?
3. What is counterboring?
4. What is the function of flat drill?
5. What is countersinking?

SHORT ANSWER TYPE QUESTIONS:- (4 MARKS)

1. What are the various types of drills?
2. List the various drill holding devices.
3. Explain the principle of drilling.

LONG ANSWER TYPE QUESTIONS:- (10 MARKS)

1. Explain the classification of drilling machine.
2. Explain the various operations performed on drill machine.

UNIT – IV

BORING

SYLLABUS

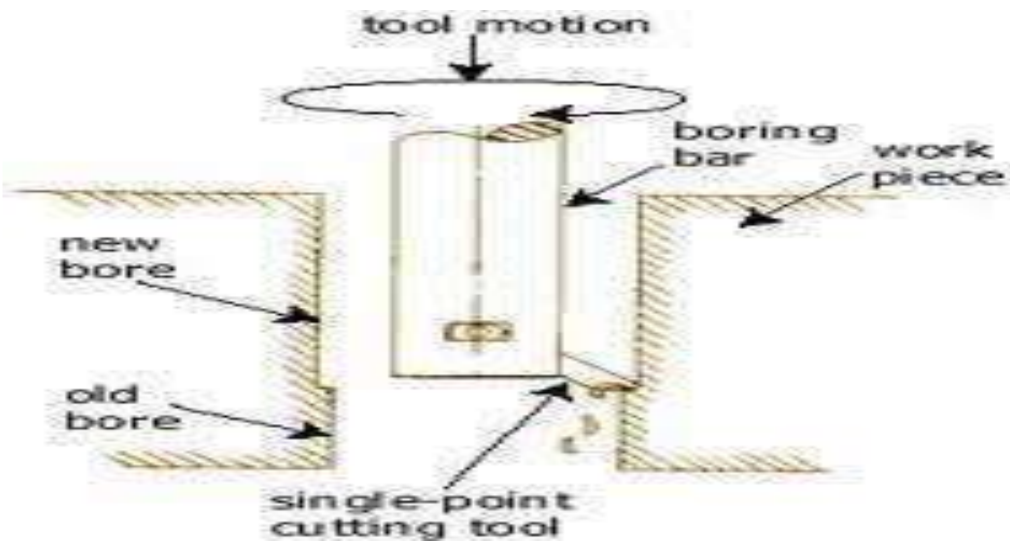
- PRINCIPLE OF BORING
- CLASSIFICATION OF BORING MACHINES
- CUTTING TOOLS FOR BORING
- BORING OPERATIONS

Boring is a process of producing circular internal profiles on a hole made by drilling or another process. It uses single point cutting tool called a boring bar. In boring, the boring bar can be rotated, or the work part can be rotated. Machine tools which rotate the boring bar against a stationary work piece are called boring machines (also boring mills).

Boring can be accomplished on a turning machine with a stationary boring bar positioned in the toolpost and rotating work piece held in the lathe chuck as illustrated in the figure. In this section, we will consider only boring on boring machine.

1. PRINCIPLE OF BORING

In horizontal boring machine, the work piece is held on the machine table and kept stationary, while boring tool revolves. At the same time, the tool may be moved forward or backward in a direction parallel to its axis of rotation and can also be offset in a direction perpendicular to its axis of rotation.



2. CLASSIFICATION OF BORING MACHINES

1. Horizontal boring machine
2. Vertical boring machine
3. Jigs boring machine
4. Special purpose boring machine

3. HORIZONTAL BORING MACHINE

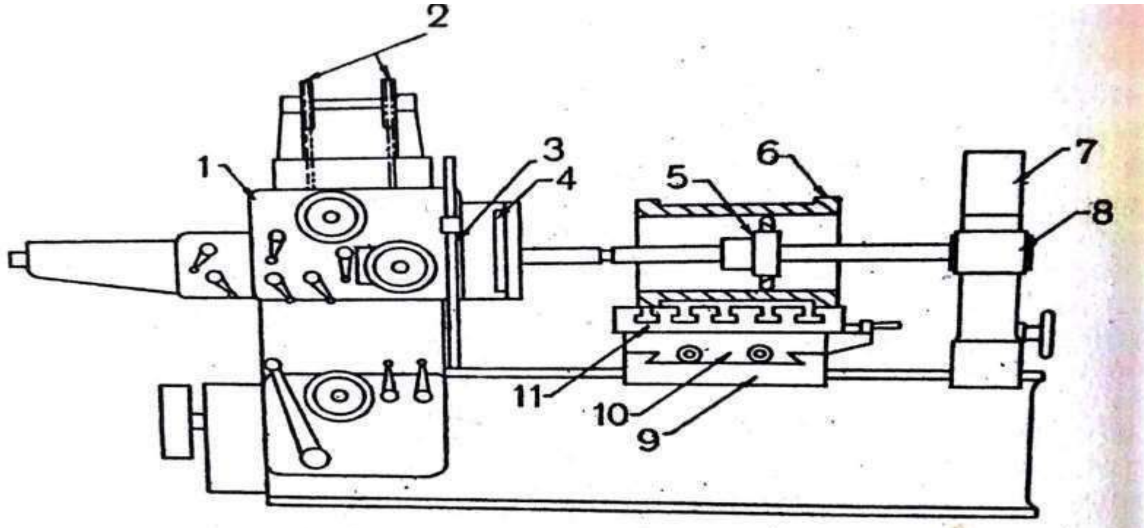


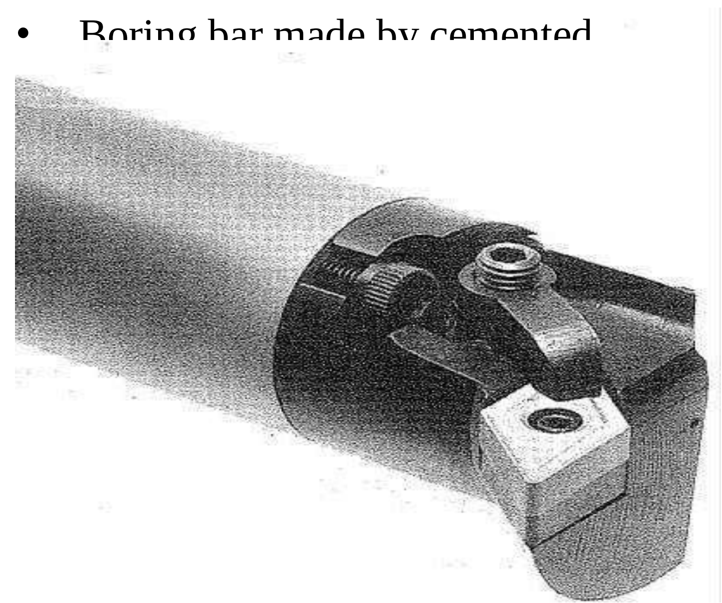
Figure 6.1 Horizontal boring machine
1. Headstock, 2. Pulley for counter balancing weight of headstock, 3. Headstock elevating screw, 4. Boring head, 5. Boring cutter on boring bar, 6. Work, 7. End supporting column, 8. Bearing block, 9. Saddle, 10 Cross-slide, 11. Table.

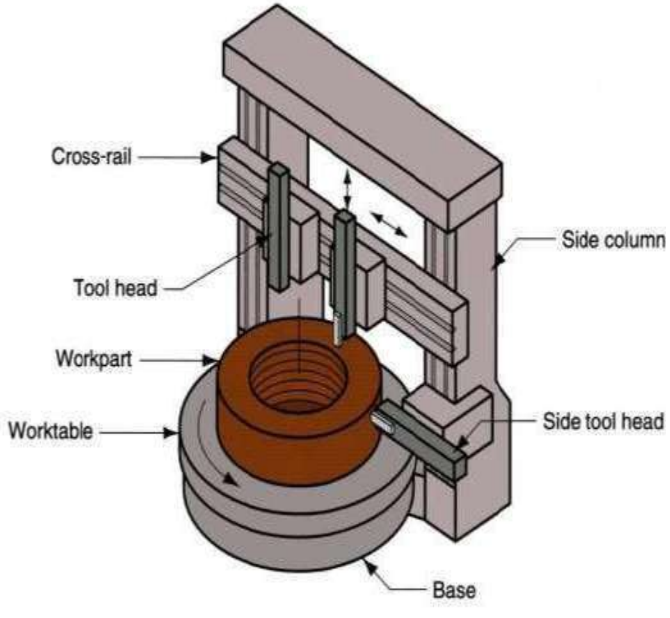
1. Bed
2. Saddle
3. Table
4. Base
5. Column
6. Headstock
7. End support column

4. VERTICAL BORINGMACHINE

A vertical boring mill is used for large, heavy work parts with diameters up to 12 m. The typical boring mill canposition and feed several cutting tools simultaneously.The work part maybe mounted on a rotating worktable.

5. VERTICAL BORINGMACHINE





6. CUTTING TOOLS FOR BORING

The typical boring bar is shown in the figure. When boring with a rotating tool, size is controlled by changing the radial position of the tool slide, which hold the boring bar, with respect to the spindle axis of rotation. For finishing machining, the boring bar is additionally mounted in an adjustable boring head for more precise control of the bar radial position.

1. Forged tool
2. Inserted teeth boring tool
3. Boring tool bit in boring bar

Boring bar with indexable carbide insert (*Left*), and adjustable boring head with accessories (*Right*).

7. BORING OPERATIONS

- Internal taper boring
- External taper boring
- Necking or cutting off
- Boring a large diameter
- Boring a small diameter
- Spot facing
- Reaming
- Counter boring
- Threading
- Facing
- Trepanning
- Milling

MCQ QUESTUONS:-

1. Which of the following is not the type of boring machine
   a) Horizontal boring machine
   b) Vertical boring machine
   c) Jig boring machine
   d) Mig welding

2. The term 'V' in formula of cutting speed of boring machine stands for
   a) Diameter of bored hole
   b) Distance between centres
   c) Maximum diameter
   d) Diameter of the work that can be turned over the cross slide.

VERY SHORT ANSWER TYPE QUESTIONS:- (2 MARKS)

1. What are boring bar?
2. What is the function of boring bar?
3. Define boring.
4. Define the feed of boring tool.
5. What is the function of boring bar?

SHORT ANSWER TYPE QUESTIONS:- (4 MARKS)

1. Write four specifications of boring machine.
2. Explain the classification of boring machine
3. Explain principle of boring.

LONG ANSWER TYPE QUESTIONS:- (10 MARKS)

1. Write the short notes on classification of boring machines & their descriptions.
2. Explain ‘boring heads’.

UNIT – V

SHAPING, PLANNING AND SLOTTING

SYLLABUS

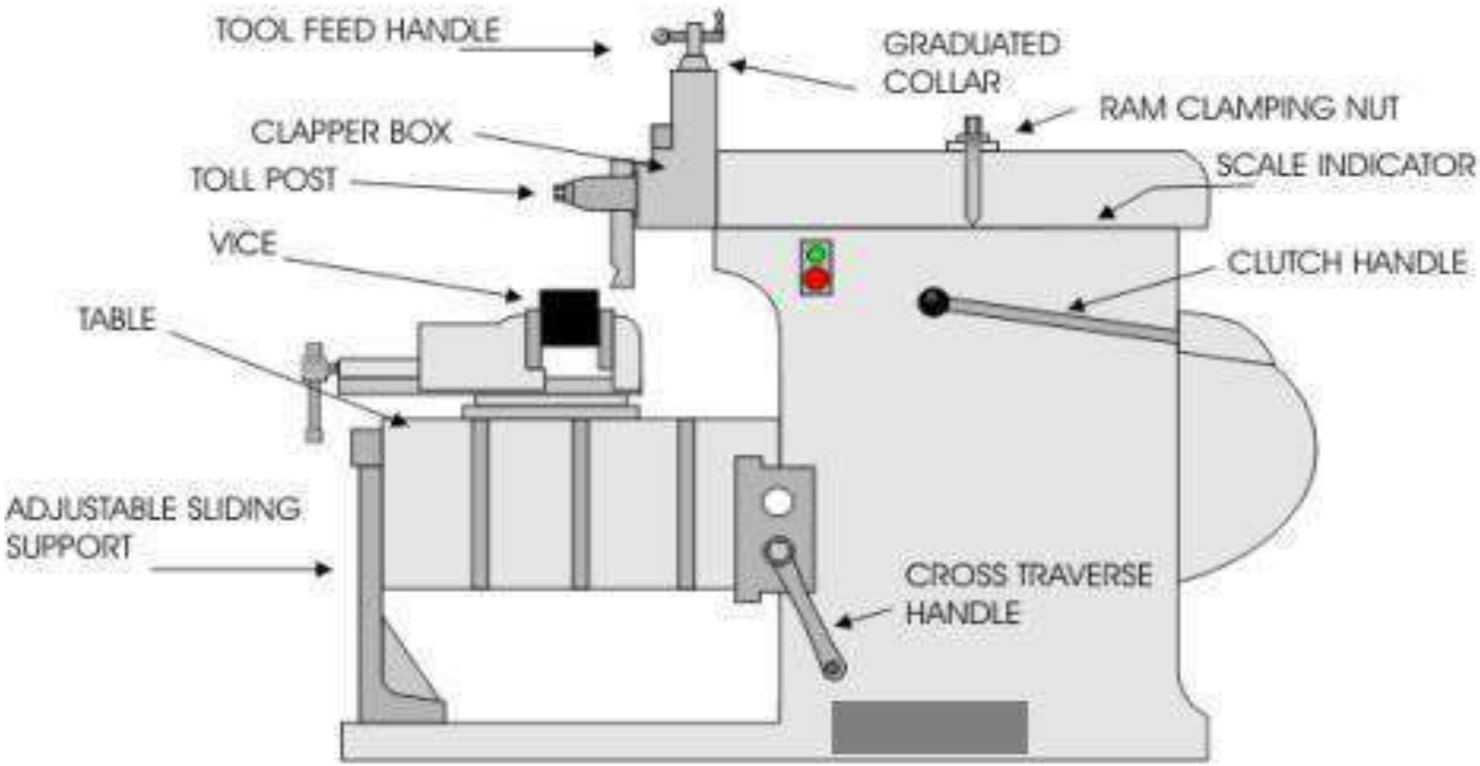
- working principle of shaper, planer and slotter,
- type of shapers ,
- type of planers,
- types of tools used and their geometry,
- speed and feed in above processes.

1. SHAPING

Shaping or shaper machine is a reciprocating type of machine tool used for producing small flat surfaces with the help of a point cutting tool which reciprocates over the stationary work piece.

A shaping machine is used to machine surfaces. It can cut curves, angles and many other shapes. It is a popular machine in a factory workshop because its movement is very simple although it can produce a variety of work. They are less common in school workshops, perhaps because of their moving parts which present a high risk.

2. DESCRIPTION OF SHAPER MACHINE



3. MAIN PARTS OF SHAPER MACHINE

- Base
- Column
- Cross rail
- Saddle
- Table
- Ram
- Tool head
- Shaper head

4. CLASSIFICATION OF SHAPER MACHINE

- Crank shaper
- Geared shaper
- Hydraulic
- Horizontal shaper
- Vertical shaper
- Travelling head shaper
- Plain shaper
- Universal shaper
- Push cut type shaper
- Draw type shaper

5. WORKS ON SHAPER MACHINE

- Shaping a vertical grooves
- Shaping horizontal flat surfaces
- Shaping a dovetail slide
- Shaping flat inclined surfaces
- Shaping v-block
- Shaping a jib and guide jib
- Shaping a curved surface

6. PLANER

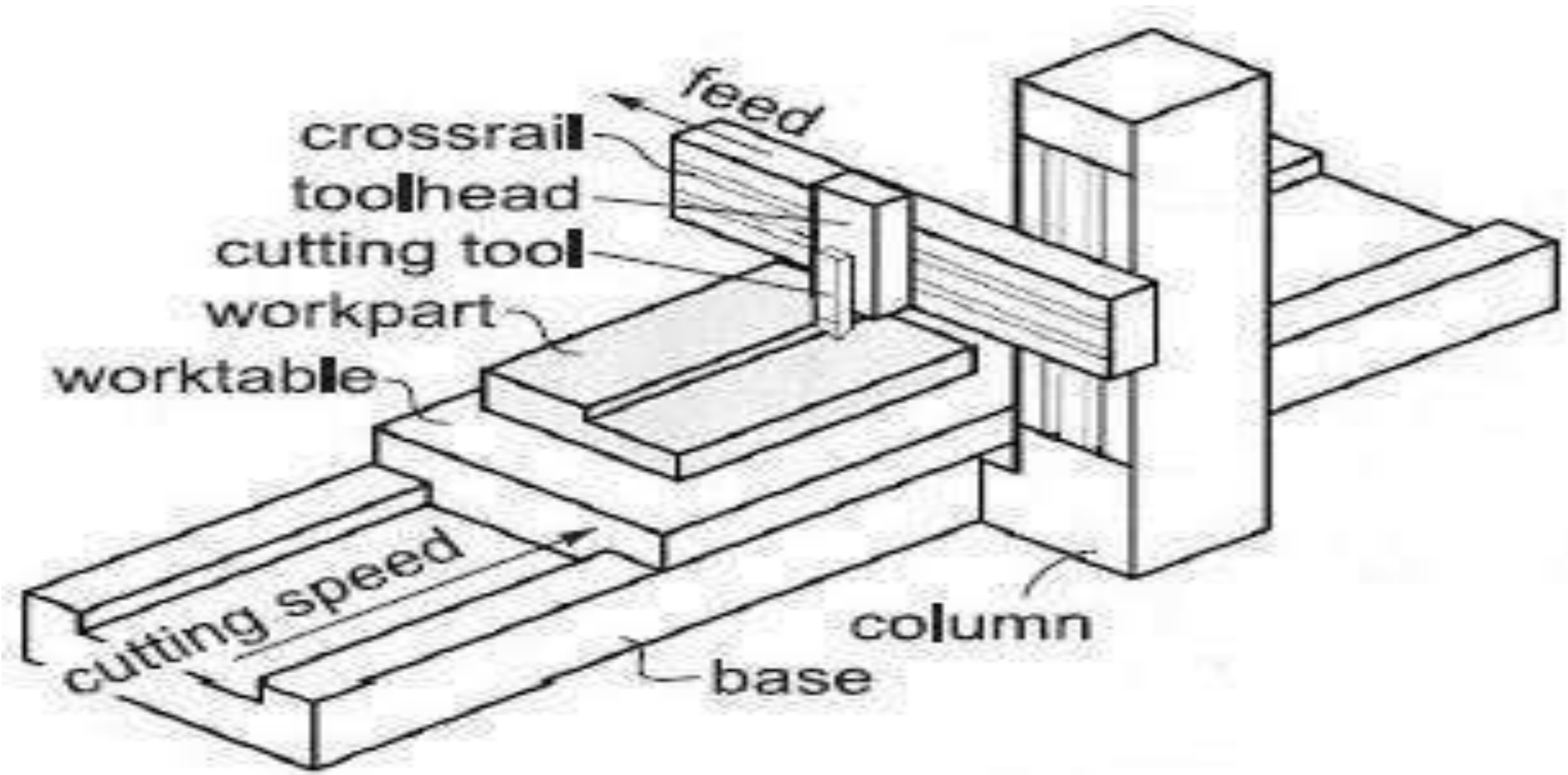
The machine tool for planning is a *planer*. Cutting speed is achieved by a reciprocating worktable that moves the part past the single-point cutting tool. Construction and motion capability of a planer permit much larger parts to be machined than on a shaper.

7. CLASSIFICATION OF PLANING MACHINE

1. Standard or double housing planer
2. Open side planer
3. Pit type planer
4. Edge or plate planer
5. Divided table planer
6. Universal planer

.

8. DESCRIPTION OF PLANER MACHINE



Components of an open-side planer.

9. MAIN PARTS OF PLANER MACHINE

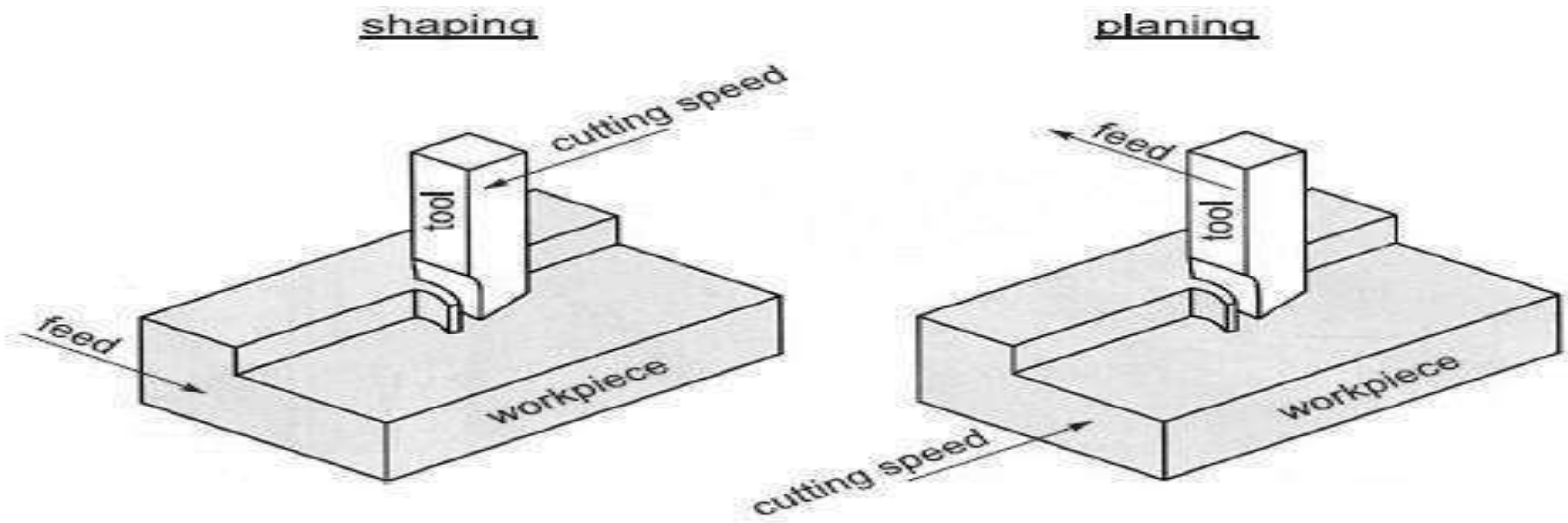
- Bed
- Table
- Housing
- Cross rail
- Saddle
- Tool head

10. WORKS ON PLANER MACHINE

- Bed and slides of all kind of machine
- Large structures and frames of different engine
- Locomotive frames
- Forging hammer die block
- Dies , jigs and fixtures
- Helical grooves on large valves
- Deep slot on large motors
- Roll mill bearing
- Lathe carriage and way
- Pressure plate
- Parts of large hydraulic presses

11. DIFFERENCE SHAPER AND PLANER

Planning and *shaping* are similar operations, which differ in the kinematics of the process. Planning is a machining operation in which the primary cutting motion is performed by the work piece and feed motion is imparted to the cutting tool. In shaping, the primary motion is performed by the tool, and feed by the work piece.



Kinematics of shaping and planing.

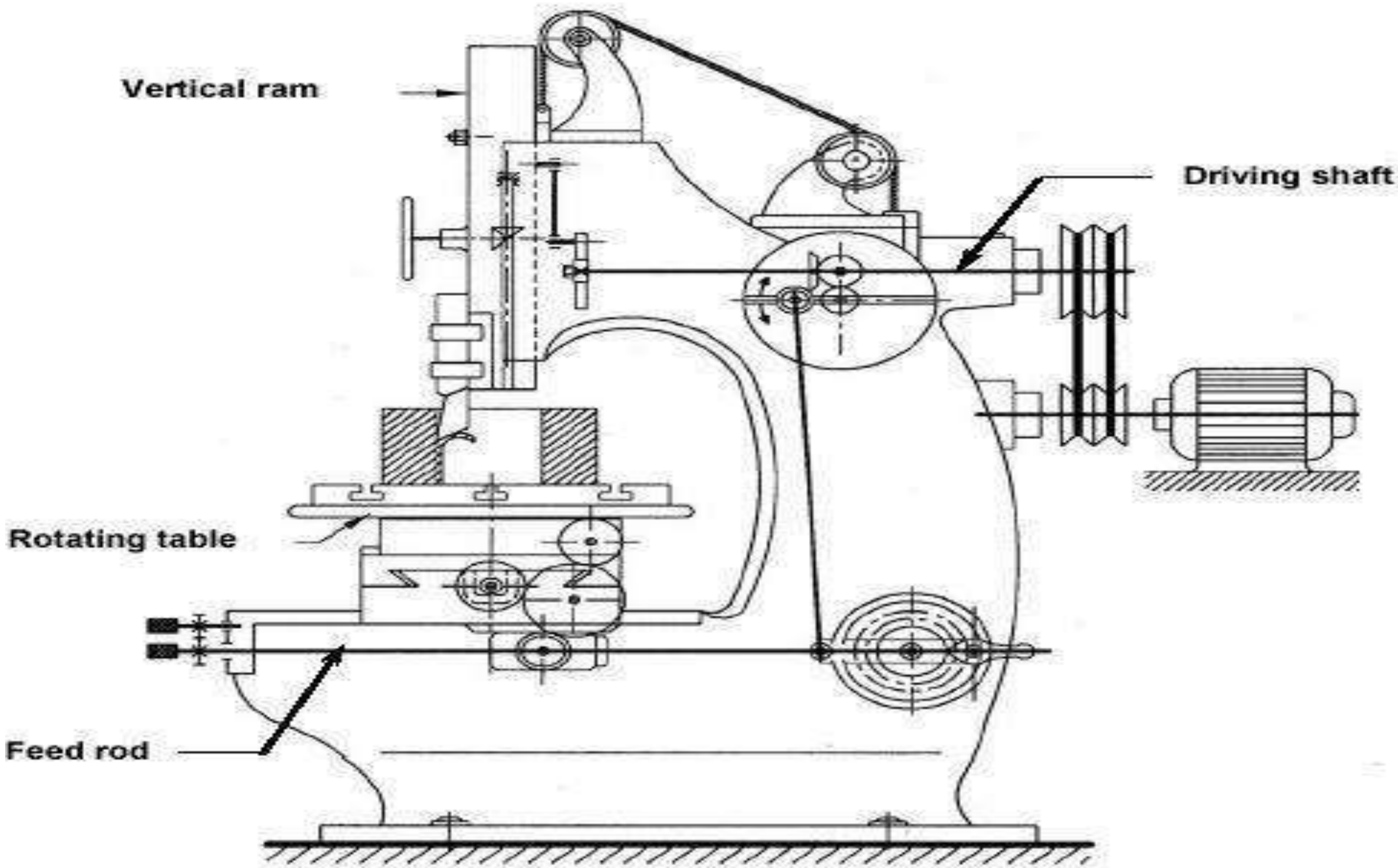
12. SLOTTING MACHINE

Slotting machines can simply be considered as vertical
shaping machine. Unlike shaping and planning machines, slotting machines are generally used to machine internal surfaces (flat, formed grooves and cylindrical.

13. CLASSIFICATION OF SLOTTING MACHINE

1. Punch type slotter machine
2. Precision slotter machine

14. DESCRIPTION OF SLOTTING MACHINE



15. MAIN PARTS OF SLOTTING MACHINE

- Base
- Column
- Saddle
- Cross slide
- Rotary table
- Ram and tool head assembly

16. WORKS ON SLOTTING MACHINE

1. Cutting keyway or spline
2. Cutting serrations
3. Finishing die opening
4. Finishing a punch profile
5. Matching tall or bulky pieces
6. Finishing regular or irregular section
7. Cutting cam profile

17. DIFFERENCE BETWEEN SLOTTER AND PLANER

SALOTTING MACHINE

- Tool reciprocates
- Only one tool operates at a time
- Work is stationary with table feed motion
- Light duty machine
- Material removal rate is less as compared to planer
- Slotter ram of tool can be tilted with respect to table surface

PLANING MACHINE

- Tool is stationary with intermittent feed motion.
- Multiple tools can operate at a time
- Work reciprocates on the table
- Heavy duty machine
- Material removal rate is more
- No tilting of tool heads

MCQ QUESTUONS:-

1. Which of the following is not the type of driving mechanism in shapers.
   a) Crank type
   b) Engine type
   c) Hydraulic type
   d) Geared type

2. Which one is the workholding devices used in slotting
   a) vices
   b) D- blocks
   c) V- slot clamps
   d) Angle clamps

VERY SHORT ANSWER TYPE QUESTIONS:- (2 MARKS)

1. List the types of planner machine?
2. Write some examples of slotting machine work?
3. Define shaping process.
4. Write the advantages of planner.
5. Enlist the principal parts of planner.

SHORT ANSWER TYPE QUESTIONS:- (4 MARKS)

1. Explain the working principle of a shaper.
2. What is gear type quick return mechanism.
3. How gear are cut on shaper.

LONG ANSWER TYPE QUESTIONS:- (10 MARKS)

1. Explain the construction & working of slotter machine.
2. Explain principle parts of planner with help of neat sketch.

UNIT – VI

BROACHING

SYLLABUS

- PRINCIPLE OF BROACHING MACHINE
- NOMENCLATURE OF BROCHING TOOL
- NOMENCLATURE OF BROCHING TOOL
- TYPES OF BROACHES MACHINE
- CLASSIFICATION OF BROACHING MACHINE
- BROACHING TECHNIQUES

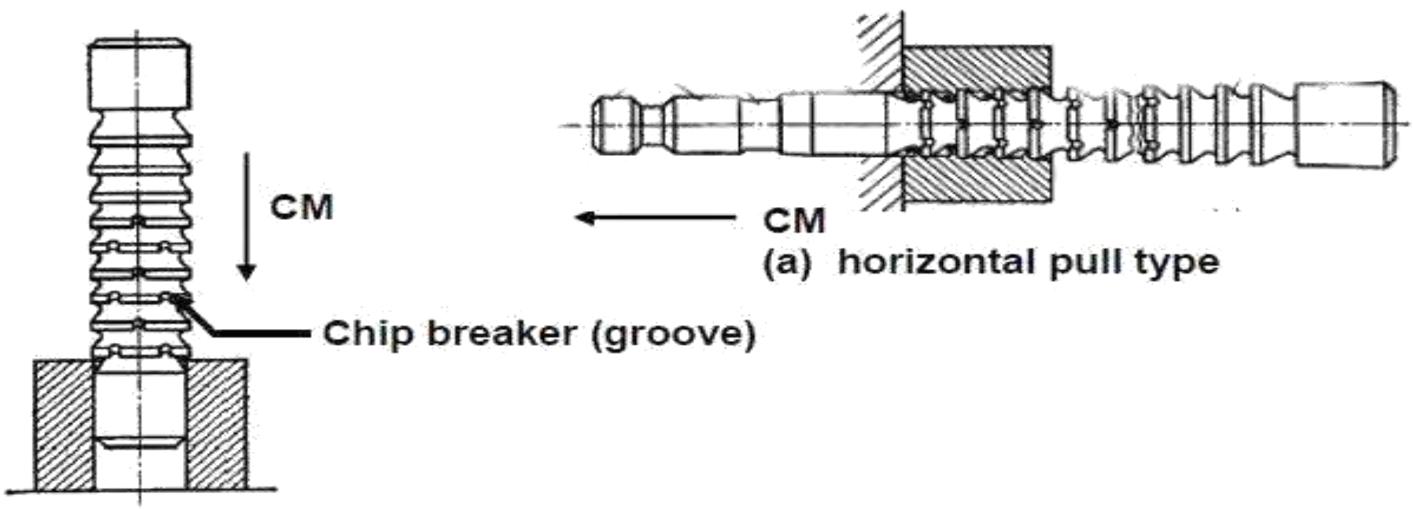
Broaching is a machining operation in which a tool used is called as broach having series of cutting teeth.

In this operation broach is either Pulled or Pushed with the help of broaching machine on the work piece surface.

Parts that is produced by the broaching have good surface
finish and dimensional accuracy.

1. PRINCIPLE OF BROACHING MACHINE

Broaching is a machining process for removal of a layer of material of desired width and depth usually in one stroke by a slender rod or bar type cutter having a series of cutting edges with gradually increased protrusion as indicated in Fig.a. In shaping, attaining full depth requires a number of strokes to remove the material in thin layers step – by – step by gradually in-feeding the single point tool (Fig.b).. Whereas, broaching enables remove the whole material in one stroke only by the gradually rising teeth of the cutter called broach. The amount of tooth rise between the successive teeth of the broach is equivalent to the in feed given in shaping.

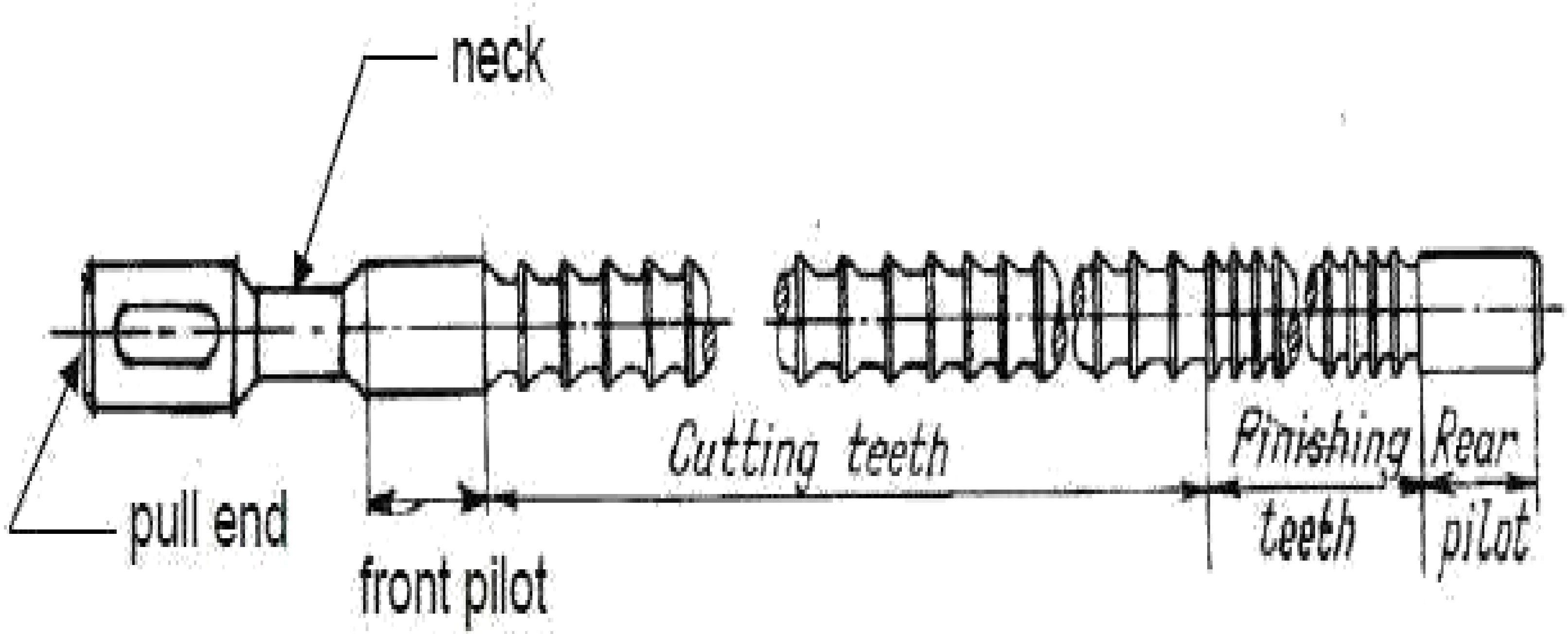


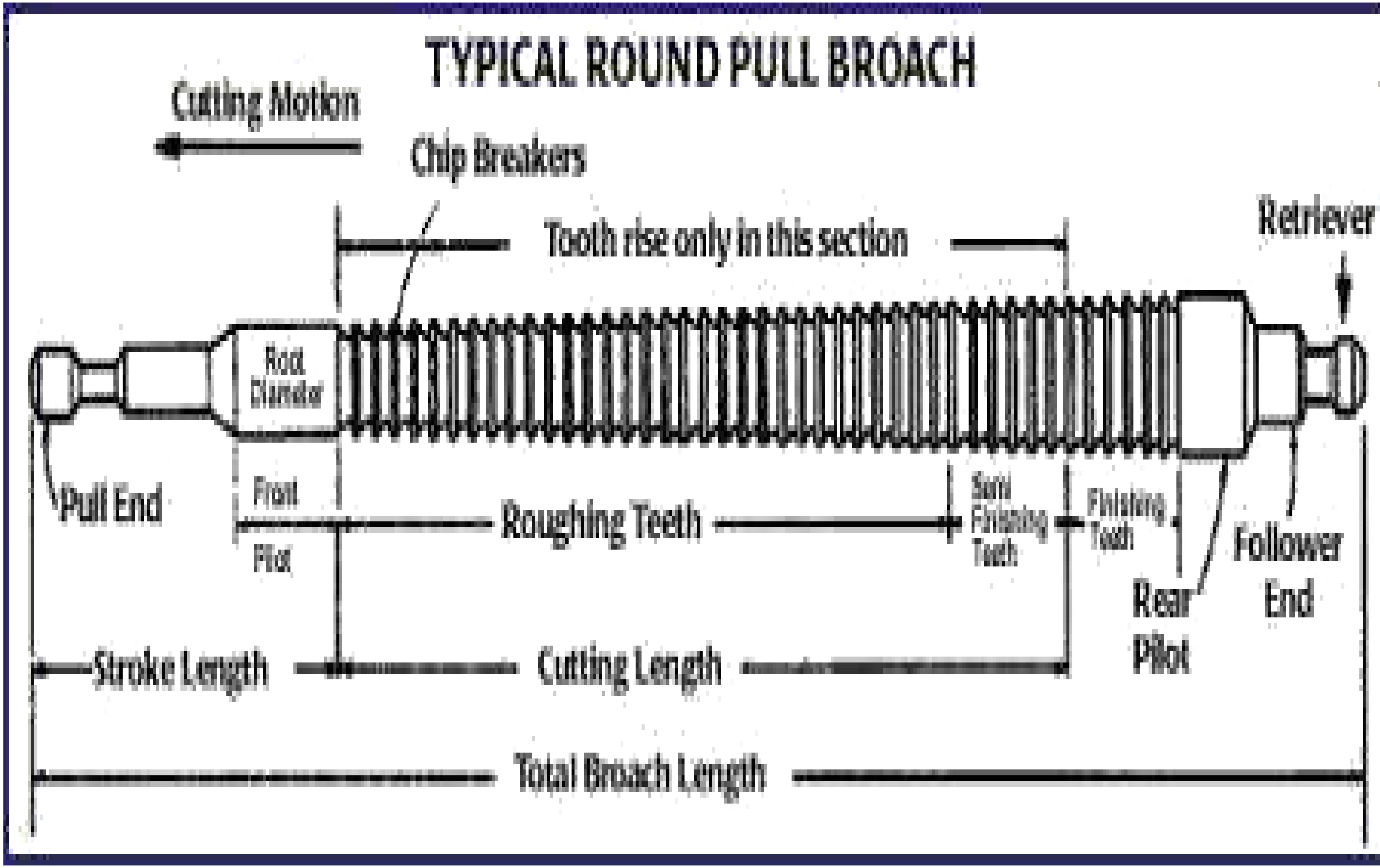
(a) horizontal pull type

(b) vertical push type

2. NOMENCLATURE OF BROCHING TOOL

- Both pull and push type broaches are made in the form of slender rods or bars of varying section having along its length one or more rows of cutting teeth with increasing height (and width occasionally). Push type broaches are subjected to compressive load and hence are made shorter in length to avoid buckling.
- The general configuration of pull type broaches, which are widely used for enlarging and finishing preformed holes, is schematically shown in Fig.





TYPICAL ROUND PULL BROACH
Cutting Motion
Chip Breakers
Tooth rise only in this section
Retriever
Root Diameter
Pull End
Front Pilot
Roughing Teeth
Semi Finishing Teeth
Finishing Teeth
Follower End
Rear Pilot
Stroke Length
Cutting Length
Total Broach Length

3. NOMENCLATURE OF BROCHING TOOL

- Pull end for engaging the broach in the machine.
- Neck of shorter diameter and length, where the broach is allowed to fail, if at all, under overloading.
- Front pilot for initial locating the broach in the hole.
- Roughing and finishing teeth for metal removal
- Finishing and burnishing teeth for fine finishing
- Rear pilot and follower rest or retriever

4. TYPES OF BROACHES MACHINE

- According to method of operation Push , pull or stationary broaches.
- According to type of operation Internal or external broaches.
- According to shape

  Solid , inserted tooth, built up or replaceable.
- According to function

  Roughing , finishing , keyways , burnishing, sizing and serrating.

  Internal and external broaches

5. CLASSIFICATION OF BROACHING MACHINE

- Horizontal broaching machine.
- Vertical broaching machine.
- Duplex head broaching machine.
- Surface broaching machine.
- Continuous broaching machine.

6. BROACHING TECHNIQUES

1. Internal broaching

2. External broching

MCQ QUESTUONS:-

1. Which of the following is not the type of construction in broaches
   a) Solid
   b) Built up
   c) Inserted tooth
   d) Aggressive cut

2. Choose the commonly used broach material.
   a) HCS
   b) ceramic
   c) diamond
   d) HSS.

VERY SHORT ANSWER TYPE QUESTIONS:- (2 MARKS)

1. Name the various types of broaching machines.
2. Name the principle elements of broach.
3. Define broaching
4. Define internal broach.
5. Write the function of horizontal broaching machines?

SHORT ANSWER TYPE QUESTIONS:- (4 MARKS)

1. Explain the principle of broaching.
2. Draw the sketch of a broach tool with complete nomenclature.
3. Name the various types of broaches.

LONG ANSWER TYPE QUESTIONS:-   (10 MARKS)

1. Explain briefly the types of broaching machine
2. Explain the construction & working of duplex ram type broaching machine in detail.

UNIT – VII

JIGS AND FIXTURES

SYLLABUS

- ELEMENT OF JIG AND FIXTURE
- USES OF JIGS AND FIXTURES
- MATERIALS FOR JIGS AND FIXTURES
- PRINCIPLES OF JIG AND FITURE DESIGN
- CLAMPING DEVICES
- JIG BUSHES
- PRINCIPLE OF LOCATION
- LOCATING DEVICES
- PRINCIPLES OF CLAMPING
- TYPES OF CLAMPING
- TYPES OF DRILLING JIGS
- JIG BUSHES
- DIFFERENCE BETWEEN JIGS AND FIXTURE

Jigs and fixtures are special devices used for large scale production. The production of components with the help of jigs and fixtures is based on the concept of interchangeability where components are produced with in established tolerances. Jigs and fixture provide the means of clamping the components rapidly without any additional set up.

JIG : A device that holds the work and locates the path of the tool.

FIXTURE: A device fixed to the worktable of a machine
and locates the work in an exact position relative to the cutting tool.

1. ELEMENT OF JIG AND FIXTURE

- Locating elements
- Clamping elements
- A rigid body in to which work piece are loaded
- Tool guiding element or tool setting element.
- Element for positioning or fastening the jig or fixture on the machine on which it is used.

2. USES OF JIGS AND FIXTURES

1) To reduce production cost
2) To increase production rate
3) To ensure high accuracy in part manufacture
4) To enable heavy and complicated complex shaped parts to be machined by being held rigidly to a machine
5) To provide interchange ability
6) Reduce quality control expenses
7) Less skilled labour & save labour costs
8) Improve work safety

3. MATERIALS FOR JIGS AND FIXTURES

- Timber
- Cast iron
- Light metals
- Brasses and bronzes
- Steels

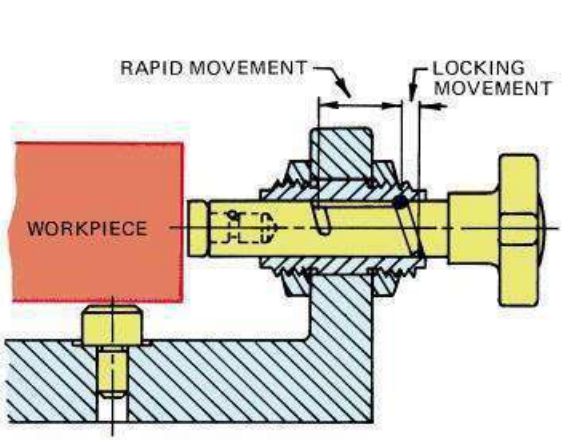
4. PRINCIPLES OF JIG AND FITURE DESIGN

- Reduction of ideal time
- Study of component
- Study of machine
- Production requirement
- Rigidity
- Location
- Loading
- Ejection of component
- Design for safety
- Coolant passage
- Swarf clearance
- Clamping
- Bushes
- Burr grooves
- Trunnions
- Jig base
- Spring location
- Wear

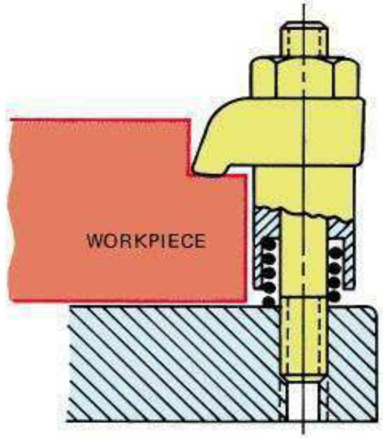
5. PRINCIPLES OF JIG AND FITURE DESIGN

- Reduction of ideal time
- Study of component
- Study of machine
- Production requirement
- Rigidity
- Location
- Loading
- Ejection of component
- Design for safety
- Coolant passage
- Swarf clearance
- Clamping
- Bushes
- Burr grooves
- Trunnions
- Jig base
- Spring location
- Wear

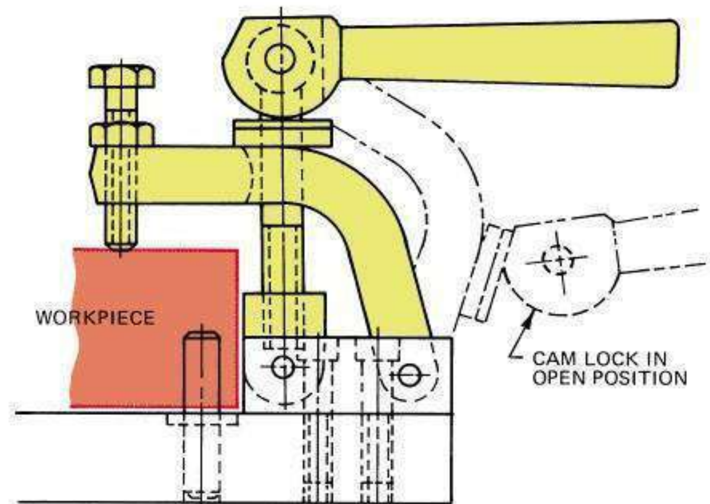
6. CLAMPING DEVICES



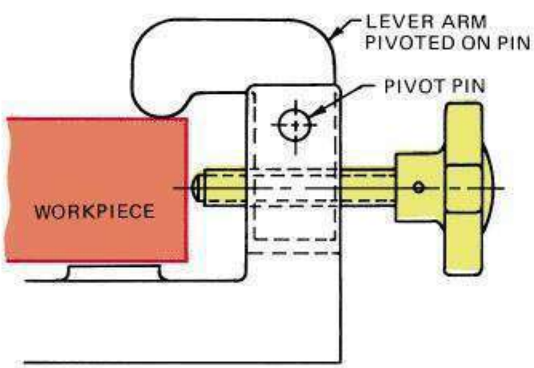
(A) LONG-TRAVEL CAM-LOCK CLAMP



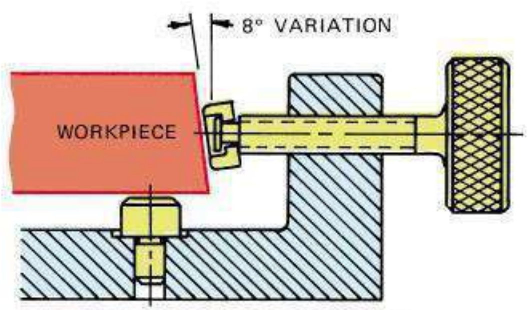
(B) SPRING-LOADED HOOK CLAMP



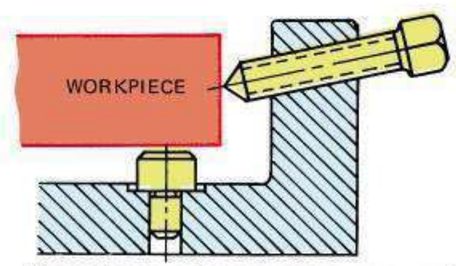
(C) HINGED CAM-ASSEMBLY CLAMP



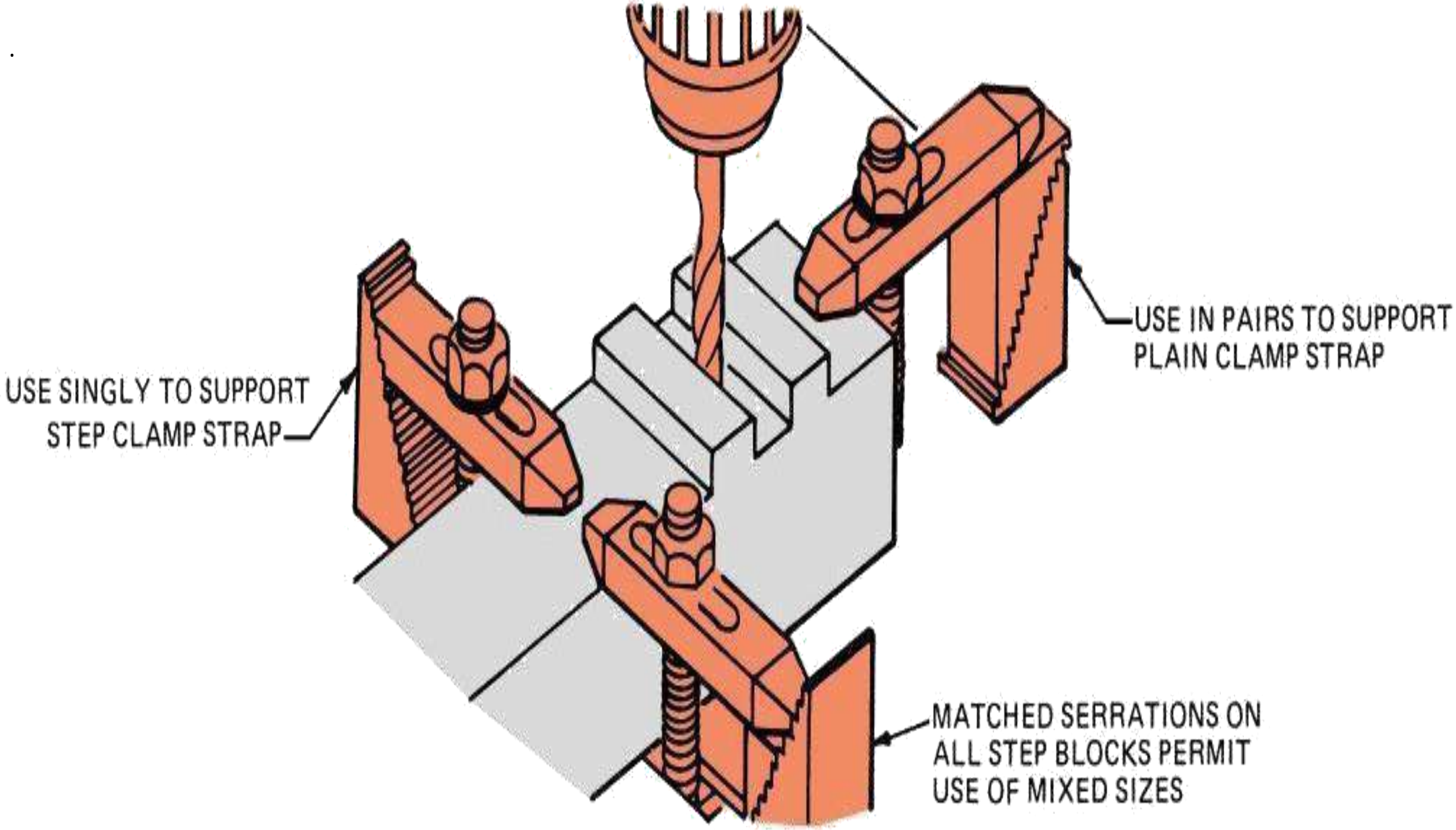
(D) TWO-DIRECTION CLAMP



(E) TOGGLE-SCREW CLAMP

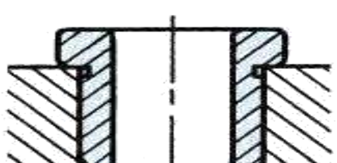


(F) CONICAL-POINT SETSCREW CLAMP


USE IN PAIRS TO SUPPORT
PLAIN CLAMP STRAP
USE SINGLY TO SUPPORT
STEP CLAMP STRAP
MATCHED SERRATIONS ON
ALL STEP BLOCKS PERMIT
USE OF MIXED SIZES

7. JIG BUSHES

(A) HEADLESS

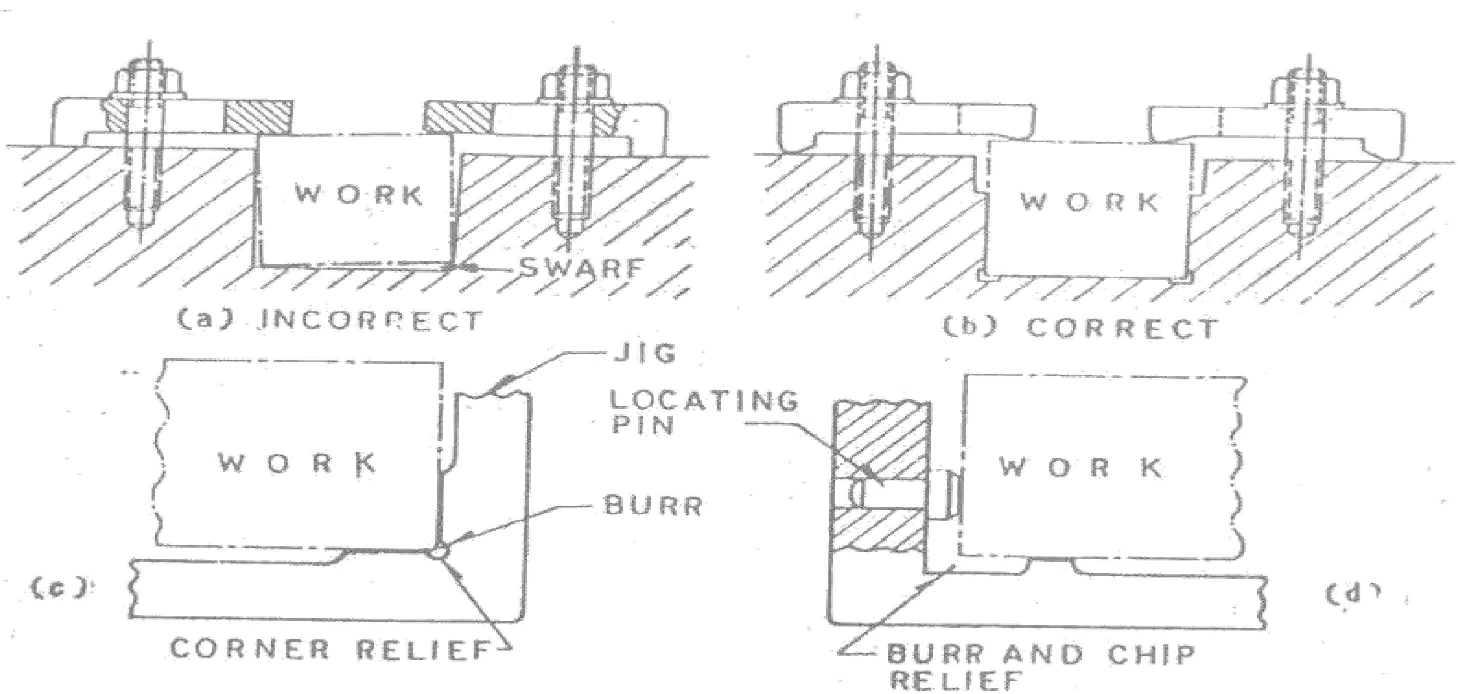


(B) HEAD TYPE

8. PRINCIPLE OF LOCATION

1) The principle of minimum locating points
2) The principle of mutually perpendicular planes
3) The principle of extreme position of pins
4) Relief should be provided where burr or swarf will get collected
5) Locating surface should be raised above the surrounding surfaces of J/F so that chips can be swept off readily.
6) Sharp corners in the locating surfaces must be avoided
7) Adjustable type locators to be used for rough surfaces

.

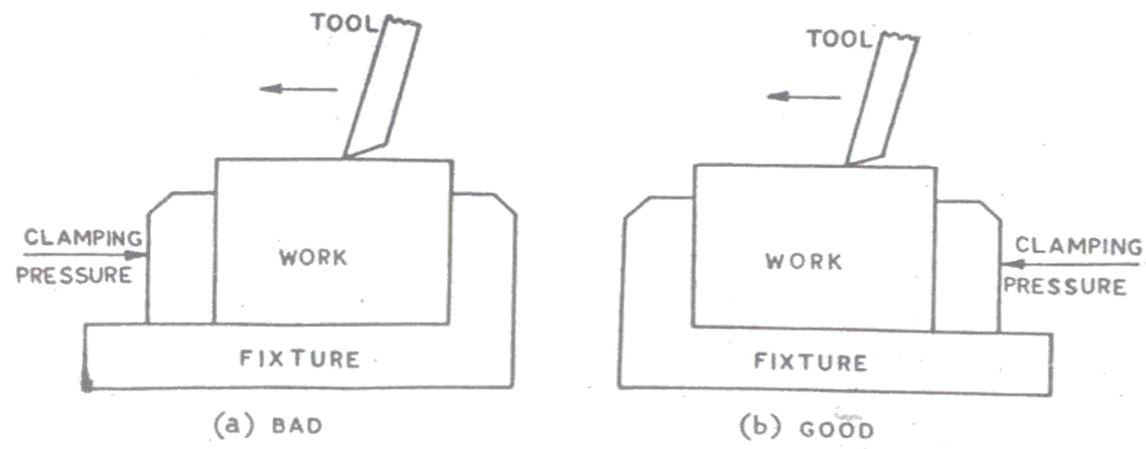


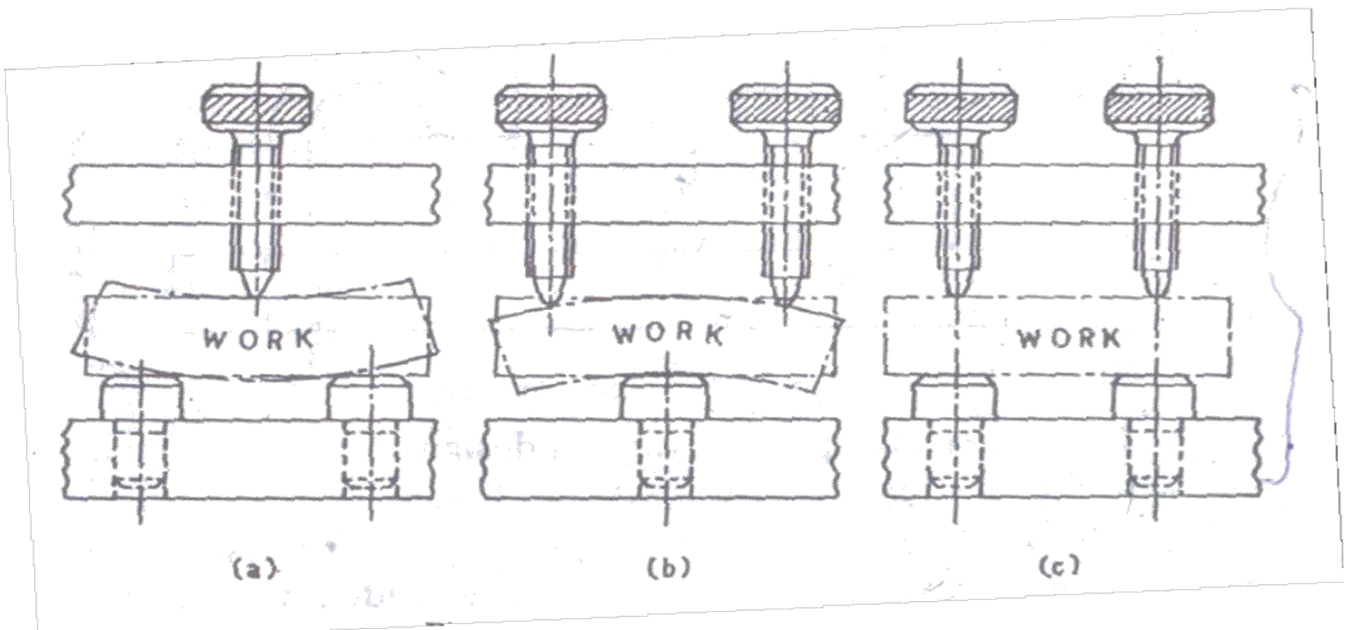
9. LOCATING DEVICES

- Flat locators
- Cylindrical locators
- Conical locators
- Jack pin locators
- Vee locators
- Adjustable locators
- Flattened locators

10. PRINCIPLES OF CLAMPING

1) The clamping pressure applied against the work piece must counteract the tool forces
2) The clamping pressure should not be directed towards the cutting operation. Wherever possible it should be directed parallel to it.
3) The clamping pressure must not damage/deform the work surface.
4) Clamps should be arranged directly above the points supporting the work, otherwise distortion of work may occur.
5) Clamping pressure should be directed towards the points of support, else the work will tend to rise from support
6) Clamping should be simple, effective and fool proof.
7) Fibre pads should be riveted to clamp faces to avoid damage to fragile work pieces


TOOL
CLAMPING
PRESSURE
WORK
FIXTURE
(a) BAD
TOOL
WORK
CLAMPING
PRESSURE
FIXTURE
(b) GOOD


WORK
WORK
WORK
(a)
(b)
(c)

11. TYPES OF CLAMPING

- Screw clamp
- Pivoted clamp
- Equalizing clamp
- Retractable clamp
- Two way clamp
- Edge clamp
- Special strap clamp
- Button clamp
- Plate strap clamp
- Hook bolt clamp
- Eccentric or cam clamp
- Swing leaf or latch type clamp
- Toggle clamp
- C- clamp

12. TYPES OF DRILLING JIGS

1. Template jig
2. plate type jig
3. Open type jig
4. Channel jig
5. Leaf Jig
6. Box type jig
7. Post jig
8. Pot jig
9. Indexing jig
10. Vice type jig

Template Jig

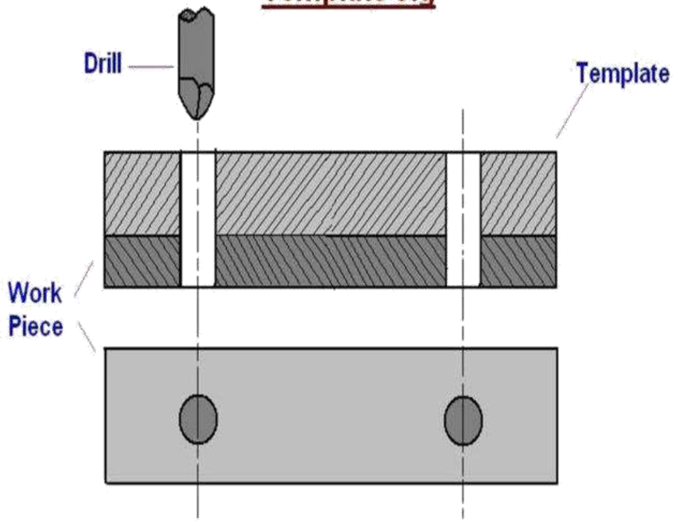
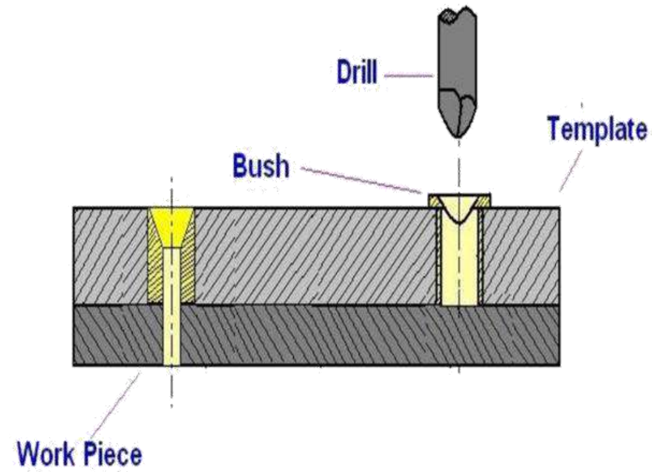
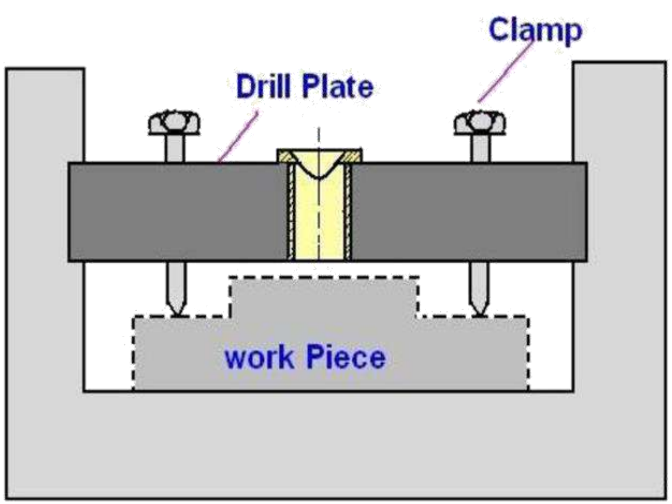


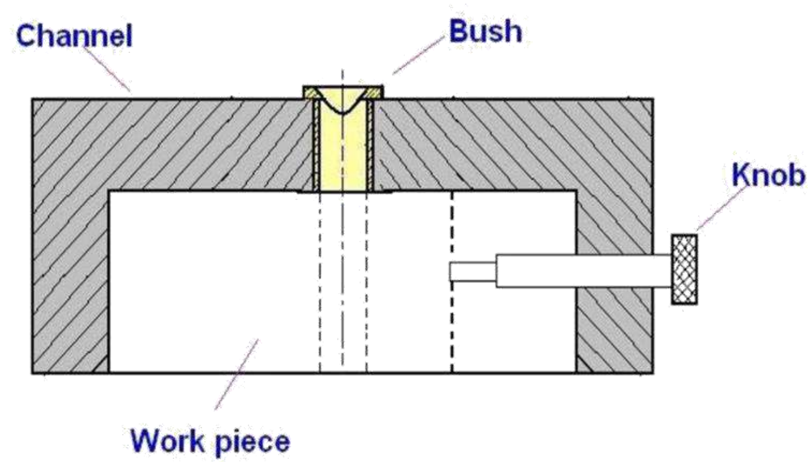
Plate Type Jig



Open Type Jig



Channel Jig



13. JIG BUSHES

- Fixed bushes
- Linear bushes
- Slip bushes
- Renewable bushes
- Special bushes
- Extended drill bush
- Screwed drill bush

14. DIFFERENCE BETWEEN JIGS AND FIXTURE

JIG

- Locates and Holds the work and guides the cutting tool in true position of the work
- Work Locating elements, Tool Guiding elements & Work Clamping elements
- Light
- Drilling, reaming , Tapping, Counterboring, Countersinking
- Drill bushes used for tool guiding

FIXTURE

- Only Holds & Positions the work, but doesn’t guide the work
- Work Locating elements, Tool setting elements & Work Clamping elements
- Heavy
- Milling, Turning, Grinding, Broaching etc
- Feeler gauges, setting blocks to adjust position of tool in relation to work

MCQ QUESTUONS:-

1. Which of the following is not the type of locating devices of jigs.
   a) Flat locators
   b) Cylindrical locators
   c) Spherical locators
   d) Vee locators

2. Choose the one drilling jig from the following options
   a) Template jig
   b) Closed jig
   c) Stem jig
   d) Box type jig

VERY SHORT ANSWER TYPE QUESTIONS:- (2 MARKS)

1. What is jig?
2. Define clamping devices for jigs.
3. Name the locating devices of jigs.
4. Which material is used for guiding bushes.
5. What is fixture?

SHORT ANSWER TYPE QUESTIONS:- (4 MARKS)

1. What is 3-2-1 principle of locating.
2. List the advantages of jigs and fixtures.
3. Differentiate between jigs and fixtures.

LONG ANSWER TYPE QUESTIONS:-   (10 MARKS)

1. Sketch and explain the various types of fixtures.
2. Explain the clamping devices.

UNIT – VIII

CUTTING FLUIDS AND LUBRICANTS

SYLLABUS

- CUTTING FLUID
- FUNCTIONS OF CUTTING FLUID
- PROPERTIES OF CUTTING FLUID
- TYPES OF CUTTING FLUIDS
- APPLICATION OF CUTTING FLUIDS
- TYPES OF LUBRICATION
- COMMON METHODS OF LUBRICATION OF MACHINE TOOLS
- LUBRICANT

1. CUTTING FLUID

- Essential in metal-cutting operations to reduce heat and friction Centuries ago, water used on grindstones
- 100 years ago, tallow used (did not cool) Lard oils came later but turned rancid Early 20th century saw soap added to water Soluble oils came in 1936
- Chemical cutting fluids introduced in 1944

2. FUNCTIONS OF CUTTING FLUID

- To reduce cutting forces.
- To decrease wear and tear of the tool and increase tool life.
- To provide lubrication effect to the tool , work piece and chip.
- To improve surface finish and machinability.
- To protect the finished surface from oxidation and corrosion.
- To wash away the chip, scale and dust from and in between the working surfaces.
- To minimize friction at the matting surfaces thus prevent rapid rate increase of temperature

3. PROPERTIES OF CUTTING FLUID

- It should be chemically stable.
- It should be non corrosive.
- It should be high flash point.
- It should cause no skin irritation.
- It should prevent the electrochemical effect of corrosion.
- It should not deteriorate on storage.
- It should be low cost.
- It should be readily available in qualities required for use.

4. TYPES OF CUTTING FLUIDS

- Neat cutting oils.
- Soluble oils.
- Synthetic fluids.
- Semi synthetic fluids.
- Mineral cutting oils.
- Chemical additive oils.
- Sulphurised mineral oils.

Chemical compounds

5. APPLICATION OF CUTTING FLUIDS

- By hand or brush
- Flood method
- Jet method
- Mist method

6. LUBRICANT

The function of a lubricant is simple. It The function of a lubricant is simple. It reduces friction between moving metal surfaces. A lubricant coats surfaces and resists being displaced by the pressure, keeping the metal parts separated. Lubricants also prevent corrosion, block contaminants and can serve as a coolant. A good lubricant flows easily under pressure and remains in contact with moving surfaces. It does not leak out from gravitational or centrifugal forces nor does it stiffen in cold temperatures.

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parts separated. Lubricants also prevent corrosion, block contaminants and can serve asa coolant. A good lubricant flows easily under

pressure and remains in contact with moving surfaces. It does not leak out from gravitational or centrifugal forces nor does i t stiffen in coldtemperatures.

7. TYPES OF LUBRICATION

- Solid lubrication

  Graphite , Zinc oxide , Molybdenum

- Semi – solid lubrication Greases
- Liquid lubrication

  Oils

8. COMMON METHODS OF LUBRICATION OF MACHINE TOOLS

- Grease cup
- Gravity feed
- Oil can
- Force feed
- Splash lubrication
- Hand oiling

MCQ QUESTUONS:-

1. Which of the following is not the type of cutting fluids
   a) Neat cutting oils
   b) Engine oils
   c) Synthetic oils
   d) Chemical compounds

2. The function of cutting fluids is ______________.
   a) Add chips to the workpiece.
   b) Wash away the chips
   c) Fade the colour of job
   d) To paint the workpiece.

VERY SHORT ANSWER TYPE QUESTIONS:- **(2 MARKS)**

1. Why cutting fluid is used?
2. Give the examples of cutting fluids used.
3. Define cutting fluids.
4. Define lubricant.
5. Define viscosity.

SHORT ANSWER TYPE QUESTIONS:- **(4 MARKS)**

1. Write short notes on mineral oils.
2. List the types of cutting fluids
3. Define flash point and fire point of the lubricant.

LONG ANSWER TYPE QUESTIONS:-   (10 MARKS)

1. Differentiate between cutting fluid and lubricant.
2. Explain the methods of lubrication.

8

MAINTENANCE MANAGEMENT

CHAPTER OUTLINE

8.1 INTRODUCTION AND MEANING

Past and current maintenance practices in both the private and Government sectors would imply that maintenance is the actions associated with equipment repair after it is broken. The dictionary defines maintenance as "the work of keeping something in proper condition, upkeep." This would imply that maintenance should be actions taken to prevent a device or component from failing or to repair normal equipment degradation experienced with the operation of the device to keep it in proper working order. Data obtained in many studies over the past decade indicates that most private and Government facilities do not expend the necessary resources to maintain equipment in proper working order. They wait for equipment failure to occur and then take whatever actions are necessary to repair or replace the equipment. Nothing lasts forever and all equipment has associated with it some predefined life expectancy or operational life.

8.2 OBJECTIVES OF MAINTENANCE

Equipments are an important resource which is constantly used for adding value to products. So, it must be kept at the best operating condition. Otherwise, there will be excessive downtime and also interruption of production if it is used in a mass production line. Poor working of equipments will lead to quality related problems. Hence, it is an absolute necessity to maintain the equipments in good operating conditions with economical cost. Hence, we need an integrated approach to minimize the cost of maintenance. In certain cases, the equipment will be obsolete over a period of time. If a firm wants to be in the same business competitively, it has to take decision on whether to replace the equipment or to retain the old equipment by taking the cost of maintenance and operation into account.

8.3 TYPES OF MAINTENANCE

The design life of most equipment requires periodic maintenance. Belts need adjustment, alignment needs to be maintained, proper lubrication on rotating equipment is required, and so on. In some cases, certain components need replacement, *e.g.*, a wheel bearing on a motor vehicle, to ensure the main piece of equipment (in this case a car) last for its design life. Different approaches have been developed to know how maintenance can be performed to ensure equipment reaches or exceeds its design life. In addition to waiting for a piece of equipment to fail (reactive maintenance) the other approaches are preventive maintenance, predictive maintenance, or reliability centered maintenance.

8.3.1 Breakdown (Reactive) Maintenance

Breakdown maintenance is basically the 'run it till it breaks' maintenance mode. No actions or efforts are taken to maintain the equipment as the designer originally intended to ensure design life is reached. Studies as recent indicate that, this is still the predominant mode of maintenance.

Advantages to breakdown maintenance can be viewed as a double-edged sword. If we are dealing with new equipment, we can expect minimal incidents of failure. If our maintenance program is purely reactive, we will not expend manpower or incur capital cost until something breaks. Since we do not see any associated maintenance cost, we could view this period as saving money. In reality, during the time we believe we are saving maintenance and capital cost, we are really spending more money than we would have under a different maintenance approach. We are spending more money associated with capital cost because, while waiting for the equipment to break, we are shortening the life of the equipment resulting in more frequent replacement. We may incur cost upon failure of the primary device associated with its failure causing the failure of a secondary device. This is an increased cost we would not have experienced if our maintenance program was more proactive.

Our labour cost associated with repair will probably be higher than normal because the failure will most likely require more extensive repairs than would have been required if the piece of equipment had not been run to failure. Chances are the piece of equipment will fail during off hours or close to the end of the normal workday. If it is a critical piece of equipment that needs to be back on-line quickly, we will have to pay maintenance overtime cost. Since we expect to run equipment to failure, we will require a large material inventory of repair parts. This is a cost we could minimize under a different maintenance strategy.

Advantages

1. Involves low cost investment for maintenance.
2. Less staff is required.

Disadvantages

1. Increased cost due to unplanned downtime of equipment.
2. Increased labour cost, especially if overtime is needed.
3. Cost involved with repair or replacement of equipment.
4. Possible secondary equipment or process damage from equipment failure.
5. Inefficient use of staff resources.

8.3.2 Preventive Maintenance

Preventive maintenance can be defined as, "Actions performed on a time or machine-run-based schedule that detect, preclude, or mitigate degradation of a component or system with the aim of sustaining or extending its useful life through controlling degradation to an acceptable level."

Preventive maintenance is a means to increase the reliability of their equipment. By simply expending the necessary resources to conduct maintenance activities intended by the equipment designer, equipment life is extended and its reliability is increased. In addition to an increase in reliability, lot of amount will be saved over that of a program just using reactive maintenance. Studies indicate that this savings can amount to as much as 12% to 18% on the average.

Advantages

1. Cost effective in many capital intensive processes.
2. Flexibility allows for the adjustment of maintenance periodicity.
3. Increased component life cycle.
4. Energy savings.
5. Reduced equipment or process failure.
6. Estimated 12% to 18% cost savings over reactive maintenance program.

Disadvantages

1. Catastrophic failures still likely to occur.
2. Labour intensive.
3. Includes performance of unneeded maintenance.
4. Potential for incidental damage to components in conducting unneeded maintenance.

Depending on the facilities current maintenance practices, present equipment reliability, and facility downtime, there is little doubt that many facilities purely reliant on reactive maintenance could save much more than 18% by instituting a proper preventive maintenance program.

While preventive maintenance is not the optimum maintenance program, it does have several advantages over that of a purely reactive program. By performing the preventive maintenance as the equipment designer envisioned, we will extend the life of the equipment closer to design. This translates into dollar savings. Preventive maintenance (lubrication, filter change, etc.) will generally run the equipment more efficiently resulting in dollar savings. While we will not prevent equipment catastrophic failures, we will decrease the number of failures. Minimizing failures translate into maintenance and capital cost savings.

8.3.3 Predictive Maintenance

Predictive maintenance can be defined as "Measurements that detect the onset of a degradation mechanism, thereby allowing causal stressors to be eliminated or controlled prior to any significant deterioration in the component physical state. Results indicate current and future functional capability".

Basically, predictive maintenance differs from preventive maintenance by basing maintenance need on the actual condition of the machine rather than on some preset schedule. Preventive maintenance is time-based. Activities such as changing lubricant are based on time, like calendar time or equipment run time. For example, most people change the oil in their vehicles every 3,000 to 5,000 miles travelled. This is effectively basing the oil change needs on equipment run time. No concern is given to the actual condition and performance capability of the oil. It is changed because it is time. This methodology would be analogous to a preventive maintenance task. If, on the other hand, the operator of the car discounted the vehicle run time and had the oil analyzed at some periodicity to determine its actual condition and lubrication properties, he may be able to extend the oil change until the vehicle had travelled 10,000 miles. This is the fundamental difference between predictive maintenance and preventive maintenance, whereby predictive maintenance is used to define needed maintenance task based on quantified material/equipment condition.

There are many advantages of predictive maintenance. A well-orchestrated predictive maintenance program will eliminate catastrophic equipment failures. Schedule of maintenance activities can be made to minimize or delete overtime cost. It is possible to minimize inventory and order parts, as required, well ahead of time to support the downstream maintenance needs and optimize the operation of the equipment, saving energy cost and increasing plant reliability. Past studies have estimated that a properly functioning predictive maintenance program can provide a savings of 8% to 12% over a program utilizing preventive maintenance alone. Depending on a facility's reliance on reactive maintenance and material condition, it could easily recognize savings opportunities exceeding 30% to 40%. Independent surveys indicate the following industrial average savings resultant from initiation of a functional predictive maintenance program:

1. Return on investment—10 times
2. Reduction in maintenance costs—25% to 30%
3. Elimination of breakdowns—70% to 75%
4. Reduction in downtime—35% to 45%
5. Increase in production—20% to 25%.

Advantages

1. Increased component operational life/availability.
2. Allows for pre-emptive corrective actions.
3. Decrease in equipment or process downtime.
4. Decrease in costs for parts and labour.
5. Better product quality.
6. Improved worker and environmental safety.
7. Improved worker moral.
8. Energy savings.
9. Estimated 8% to 12% cost savings over preventive maintenance program.

Disadvantages

1. Increased investment in diagnostic equipment.
2. Increased investment in staff training.
3. Savings potential not readily seen by management.

Concept of Reliability in Maintenance

Reliability is the probability of survival under a given operating environment. For example, the time between consecutive failures of a refrigerator where continuous working is required is a measure of its reliability. If this time is more, the product is said to have high reliability.

In a textile mill, generally the light is maintained at a minimum specified level. To achieve this, let us assume that there are 100 bulbs in use and the guaranteed life time of these bulbs is 5000 hours. If we collect statistics about the number of bulbs survived till 5000 hours, we can compute the reliability of the bulbs. In this case,

$$\text{Reliability} = \text{Failurerate} = \frac{\text{Number of bulbs survived till the specified time limit}}{\text{Number of bulbs used}}$$

If the number of bulbs survived till 5000 hours is 80, then we can say that the reliability is 0.8 (*i.e.*, 80/100)

The reliability of railway signalling system, aircraft, and power plant are some of the interesting examples for demonstrating the reliability concept. In these cases, a failure will lead to heavy penalty.

The concept of reliability can be matched with systems concept. Generally, products/equipments will have many components which may function with serial relationship or parallel relationship. So, the individual component's reliability affects the reliability of the product. Hence, enough attention must be given at the design, stage such that the product's reliability is maximized. The cost of maintenance is also to be considered along with the reliability while improving it.

The general failure pattern of any product is given in Fig. 8.1. This is called bath-tub curve. In Fig. 8.1, there will be large number of failures in the early period. This is mainly due to non-alignment while shipping the product, or misfit while manufacturing (assembling), or very high initial friction between moving parts, etc.

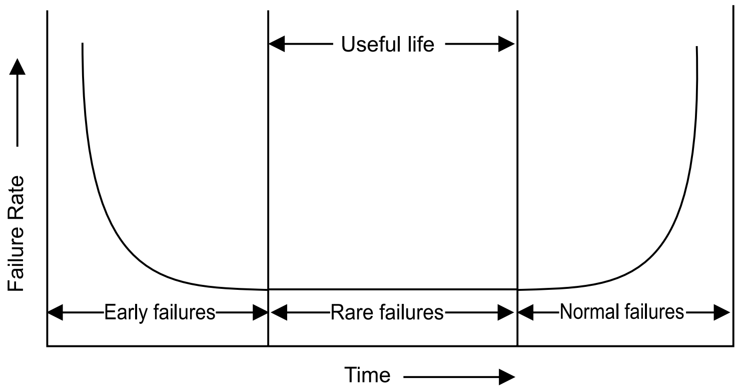


Fig. 8.1 *Product failure rate*

Reliability Improvement

The reliability of a system/product depends on many factors. So, we should concentrate at the grassroot level to improve product's reliability.

Some of the ways of improving systems reliability are listed below:

- Improved design of components
- Simplification of product structure
- Usage of better production equipments
- Better quality standards
- Better testing standards
- Sufficient number of standby units
- Usage of preventive maintenance if necessary at appropriate time.

8.4 MAINTENANCE PLANNING

Planning of maintenance jobs basically deals with answering two questions, 'what' and 'How' of the job; 'what activities are to be done?' and 'how those jobs and activities are to be done?' While answering these two questions, other supplementary questions are to be answered, *e.g.*, 'where the jobs is to be done?' and 'why the job is to be done?' etc., but all these will be helping in developing 'what' and 'how' of the job. It is very essential that engineering knowledge must be applied extensively to maintenance jobs for development of appropriate job plans using most suited techniques, tools materials and special facilities etc.

As the job planning forms the basic foundations, over which the efficiency and cost of actions depends, persons responsible for job planning should have adequate capabilities, such as, knowledge about jobs and available techniques, facilities and resources, analytical ability, conceptual logical ability and judgmental courage etc.

Steps of Job Planning

The main steps to be followed for proper job planning are:

1. **Knowledge base:** It includes knowledge about equipment, job, available techniques, materials and facilities.
2. **Job investigation at site:** It gives a clear perception of the total jobs.
3. **Identify and document the work:** Knowing the earlier two steps and knowing the needs of preventive, predictive and other maintenance jobs.
4. **Development of repair plan:** Preparation of step by step procedures which would accomplish the work with the most economical use of time, manpower and material.
5. **Preparation tools and facilities list** indicating the needs of special tools, tackles and facilities needed.
6. **Estimation of time required to do the job** with work measurement technique and critical path analysis.

8.5 MAINTENANCE SCHEDULING

Scheduling is the function of coordinating all of the logistical issue around the issues regarding the execution phase of the work. Scheduled of maintenance jobs basically deals with answering two questions—'Who' and 'When' of job, *i.e.*, "who would do the job" and "when the job would be started and done".

Effective scheduling essentially needs realistic thinking, based on substantial data and records. Majority of scheduling work needs to occur in areas such as overhead labour hours safety and toolbox meetings, break times and training times etc. Addition of corrective and approved improvement actions as dictated by the prioritization system and operations plan etc.

Requirements for Schedulers

A scheduler should also have knowledge about job, techniques, facilities, analytical ability and judgmental courage. The scheduler must obtain knowledge/information about following ability and judgmental courage. The scheduler must obtain information about following facts, before starting his job:

1. Manpower availability by trade, location, shift, crew arrangement and permissible overtime limit etc.
2. Man hour back log on current or unfinished jobs.
3. Availability of the equipment or area where the work has to be performed.
4. Availability of proper tools, tackles, spares, consumables, structural and other required materials.
5. Availability of external manpower and their capabilities; these may be from other shops/ departments of the plant or from contractors (local, nearby, ancillary etc).
6. Availability of special equipments, jigs/fixtures, special lifting and handling facilities and cranes etc. This should also include labour and time saving devices like pneumatic hammers and excavators etc.

7. Starting date of the job; also often completion time of total job is predetermined and, in that case, resources are to be arranged accordingly.
8. Past schedules and charts (updated) if the same job has been done earlier, etc.

8.6 MAINTENANCE SCHEDULE TECHNIQUES

Different types of schedules are made suiting the respective job plans and different techniques are used for making and following those schedules. The first step of all scheduling is to break the job into small measurable elements, called activities and to arrange them in logical sequences considering the preceding, concurrent and succeeding activities so that a succeeding activity should follow preceding activities and concurrent activities can start together.

Arranging these activities in different fashion makes different types of schedules. They are as follows:

1. **Weekly general schedule** is made to provide weeks worth of work for each employee in an area.
2. **Daily schedule** is developed to provide a day's work for each maintenance employee of the area.
3. **Gantt charts** are used to represent the timings of tasks required to complete a project.
4. **Bar charts** used for technical analysis which represents the relative magnitude of the values.
5. **PERT/CPM** are used to find the time required for completion of the job and helps in the allocation of resources.

[Note: Discussed in detail in Chapter 5.]

8.6.1 Modern Scientific Maintenance Methods

Reliability centered maintenance: Reliability centered maintenance (RCM) is defined as "a process used to determine the maintenance requirements of any physical asset in its operating context".

Basically, RCM methodology deals with some key issues not dealt with by other maintenance programs. It recognizes that all equipment in a facility is not of equal importance to either the process or facility safety. It recognizes that equipment design and operation differs and that different equipment will have a higher probability to undergo failures from different degradation mechanisms than others. It also approaches the structuring of a maintenance program recognizing that a facility does not have unlimited financial and personnel resources and that the use of both need to be prioritized and optimized. In a nutshell, RCM is a systematic approach to evaluate a facility's equipment and resources to best mate the two and result in a high degree of facility reliability and cost-effectiveness.

RCM is highly reliant on predictive maintenance but also recognizes that maintenance activities on equipment that is inexpensive and unimportant to facility reliability may best be left to a reactive maintenance approach. The following maintenance program breakdowns of continually top-performing facilities would echo the RCM approach to utilize all available maintenance approaches with the predominant methodology being predictive.

- <10% Reactive
- 25% to 35% Preventive
- 45% to 55% Predictive.

Because RCM is so heavily weighted in utilization of predictive maintenance technologies, its program advantages and disadvantages mirror those of predictive maintenance. In addition to these advantages, RCM will allow a facility to more closely match resources to needs while improving reliability and decreasing cost.

Advantages

(*a*) Can be the most efficient maintenance program.
(*b*) Lower costs by eliminating unnecessary maintenance or overhauls.
(*c*) Minimize frequency of overhauls.
(*d*) Reduced probability of sudden equipment failures.
(*e*) Able to focus maintenance activities on critical components.
(*f*) Increased component reliability.
(*g*) Incorporates root cause analysis.

Disadvantages

(*a*) Can have significant startup cost, training, equipment, etc.
(*b*) Savings potential not readily seen by management.

How to Initiate Reliability Centered Maintenance?

The road from a purely reactive program to a RCM program is not an easy one. The following is a list of some basic steps that will help to get moving down this path.

1. Develop a master equipment list identifying the equipment in your facility.
2. Prioritize the listed components based on importance to process.
3. Assign components into logical groupings.
4. Determine the type and number of maintenance activities required and periodicity using:
   - Manufacturer technical manuals
   - Machinery history
   - Root cause analysis findings—Why did it fail?
   - Good engineering judgment
5. Assess the size of maintenance staff.
6. Identify tasks that may be performed by operations maintenance personnel.
7. Analyze equipment failure modes and effects.
8. Identify effective maintenance tasks or mitigation strategies.

8.6.2 Six Sigma Maintenance

It is the application of six sigma principles in maintenance. Six sigma is a maintenance process that focuses on reducing the variation in business production processes. By reducing variation, a business can achieve tighter control over its operational systems, increasing their cost effectiveness and encouraging productivity breakthrough.

Six sigma is a term created at Motorola to describe the goal and process used to achieve breakthrough levels of quality improvement. Sigma is the Greek symbol used by statisticians to refer to the six standard deviations. The term six sigma refers to a measure of process variation (six standard deviations) that translates into an error or defect rate of 3.4 parts per million. To achieve quality performance of six sigma level, special sets of quality improvement methodologies and statistical tools developed. These improvement methods and statistical tools are taught to a small group of workmen known as six sigma champions who are assigned full-time responsibility to define, measure, analyze, improve and control process quality. They also facilitate the improvement process by removing the organizational roadblocks encountered. Six sigma methodologies improve any existing business process by constantly reviewing and re-tuning the process. To achieve this, six sigma uses a methodology known as DMAIC (Define opportunities, Measure performance, Analyse opportunity, Improve performance, Control performance). This six sigma process is also called DMAIC process.

Six sigma relies heavily on statistical techniques to reduce failures and it incorporates the basic principles and techniques used in Business, Statistics, and Engineering. Six sigma methodologies can also be used to create a brand new business process from ground up using design for six sigma principles.

SIX SIGMA MAINTENANCE PROCESS

The steps of six sigma maintenance are same as DMAIC process. To apply six sigma in maintenance, the work groups that have a good understanding of preventive maintenance techniques in addition to a strong leadership commitment. Six sigma helps in two principal inputs to the maintenance cost equation: Reduce or eliminate the need to do maintenance (reliability of equipment), and improve the effectiveness of the resources needed to accomplish maintenance. Following are the steps involved in six sigma maintenance process.

Define

This step involves determining benchmarks, determining availability and reliability requirements, getting customer commitments and mapping the flow process.

Measure

This step involves development of failure measurement techniques and tools, data collection process, compilation and display of data.

Analysis

This step involves checking and verifying the data and drawing conclusions from data. It also involves determining improvement opportunities, finding root causes and map causes.

Improve

This step involves creating model equipment and maintenance process, total maintenance plan and schedule and implementing those plans and schedule.

Control

This step involves monitoring the improved programme. Monitor improves performance and assesses effectiveness and will make necessary adjustments for the deviation if exists.

8.6.3 Enterprise Asset Management (EAM)

Enterprise asset management is an information management system that connects all departments and disciplines within a company making them an integrated unit. EAM is also referred as computerised maintenance management system. It is the organized and systematic tracking of an organization's physical assets *i.e.*, its plant, equipment and facilities. EAM aims at best utilisation of its physical assets. It ensures generation of quality data and timely flow of required data throughout the organization. EAM reduces paper work, improves the quality, quantity and timeliness of the information and provides information to technicians at the point of performance and gives workers access to job specific information at the work site.

8.6.4 Lean Maintenance

Lean maintenance is the application of lean principle in maintenance environments. Lean system recognises seven forms of waste in maintenance. They are over production, waiting, transportation, process waste, inventory, waste motion and defects. In lean maintenance, these wastes are identified and efforts are made for the continuous improvement in process by eliminating the wastes**.** Thus, lean maintenance leads to maximise yield, productivity and profitability.

Lean maintenance is basically equipment reliability focussed and reduces need for maintenance troubleshooting and repairs. Lean maintenance protects equipments and system from the route causes of malfunctions, failures and downtime stress. From the sources of waste uptime can be improved and cost can be lowered for maintenance.

8.6.5 Computer Aided Maintenance

For effective discharge of the maintenance function, a well designed information system is an essential tool. Such systems serve as effective decision support tools in the maintenance planning and execution. For optimal maintenance scheduling, large volume of data pertaining to men, money and equipment is required to be handled. This is a difficult task to be performed manually. For a planned and advanced maintenance system use of computers is essential. Here programmes are prepared to have an available inputs processed by the computer. Such a computer based system can be used as and when required for effective performance of the maintenance tasks. There are wide varieties of software package available in the market for different types of maintenance systems.

A computerised maintenance system includes the following aspects:

- Development of a database
- Analysis of past records if available
- Development of maintenance schedules
- Availability of maintenance materials

- Feedback control system
- Project management.

Following are some computer based maintenance systems which can be implemented:

Job card system: It is essential to prepare a job card for each component to record the maintenance work carried out or the work to be done. Job card shows the plant code, equipment code, the job code, the nature of the jobs, the start time and finishing time of the card, man-hour spent and etc. The use of computers facilitates the issue of job cards, recording of job history and control of manpower.

Spare part life monitoring system: Under this system, information about a spare part such as its description, anticipated life and date of its installation in equipment is recorded. As and when a particular sparepart is replaced during breakdown failures or scheduled maintenance, the updating of this information is done in their respective files stored in the computer. This helps to prepare the following reports:

- Spares repeatability in various machines indicating the performance of such spare parts.
- Comparisons of the actual life with the estimated life of the spare parts.

Spare parts tracking system: In most of the cases maximum time is consumed in procurement of spare parts. The total time required to rectify the breakdown is summation of the time to identify the cause of the failure, time to determine the requirements of spare parts, time to procure spare parts and the time to rectify the failure. In a computerised system, the spare part tracking system is beneficial in getting required material at the earliest. A spare part file is created that contains the information about the material code, spare part identification number, the assembly or sub-assembly number and the place where the spare part is used. This helps in knowing the current position about a particular spare part and facilitates timely requirement for future demands.

8.7 TOTAL PRODUCTIVE MAINTENANCE (TPM)

Total productive maintenance (TPM) is a maintenance program, which involves a newly defined concept for maintaining plants and equipment. The goal of the TPM program is to markedly increase production while, at the same time, increasing employee morale and job satisfaction. It can be considered as the medical science of machines.

TPM brings maintenance into focus as a necessary and vitally important part of the business. It is no longer regarded as a non-profit activity. Downtime for maintenance is scheduled as a part of the manufacturing day and, in some cases, as an integral part of the manufacturing process. The goal is to hold emergency and unscheduled maintenance to a minimum.

TPM was introduced to achieve the following objectives. The important ones are listed below.

- Avoid wastage in a quickly changing economic environment.
- Producing goods without reducing product quality.
- Reduce cost.

- Produce a low batch quantity at the earliest possible time.
- Goods send to the customers must be non-defective.

8.7.1 Similarities and Differences between TQM and TPM

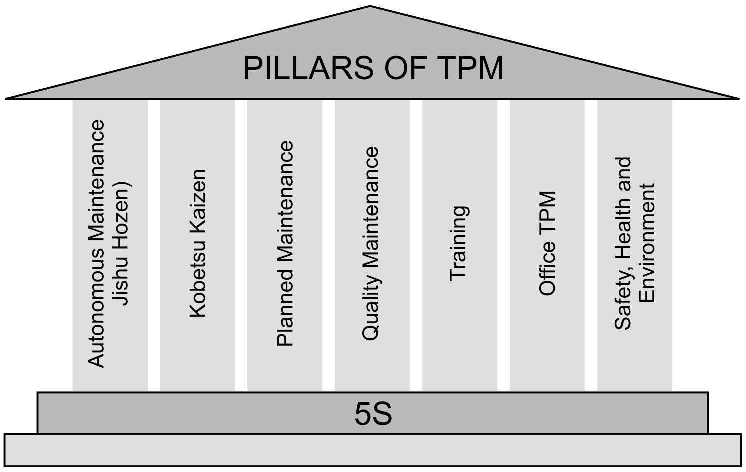
The TPM program closely resembles the popular Total Quality Management (TQM) program. Many of the tools such as, employee empowerment, benchmarking, documentation, etc. used in TQM are used to implement and optimize TPM. Following are the similarities between the two:

1. Total commitment to the program by upper level management is required in both programmes,
2. Employees must be empowered to initiate corrective action, and
3. A long-range outlook must be accepted as TPM may take a year or more to implement and is an on-going process. Changes in employee mind-set toward their job responsibilities must take place as well.

The differences between TQM and TPM are summarized below.

Category	*TQM*	*TPM*
Object	Quality (Output and effects)	Equipment (Input and cause)
Mains of attaining goal	Systematize the management. It is software oriented	Employees participation and it is hardware oriented
Target	Quality for PPM	Elimination of losses and wastes.

8.7.2 Pillars of TPM



PILLAR 1-5S

TPM starts with 5S. Problems cannot be clearly seen when the work place is unorganized. Cleaning and organizing the workplace helps the team to uncover problems. Making problems visible is the first step of improvement.

Japanese term	*English translation*	*Equivalent 'S' term*
Seiri	Organization	Sort
Seiton	Tidiness	Systematise
Seiso	Cleaning	Sweep
Seiketsu	Standardisation	Standardise
Shitsuke	Discipline	Self-discipline

SEIRI—Sort out

This means sorting and organizing the items as critical, important, frequently used items, useless, or items that are not need as of now. Unwanted items can be salvaged. Critical items should be kept for use nearby and items that are not be used in near future, should be stored in some place. For this step, the worth of the item should be decided based on utility and not cost. As a result of this step, the search time is reduced.

Priority	Frequency of use	How to use
Low	Less than once per year, Once per year<	Throw away, Store away from the workplace
Average	At least 2/6 months, Once per month, Once per week	Store together but offline
High	Once per day	Locate at the workplace

SEITON—Organise

The concept here is that "Each items has a place, and only one place". The items should be placed back after usage at the same place. To identify items easily, name plates and coloured tags has to be used. Vertical racks can be used for this purpose, and heavy items occupy the bottom position in the racks.

SEISO—Shine the Workplace

This involves cleaning the work place free of burrs, grease, oil, waste, scrap etc. No loosely hanging wires or oil leakage from machines.

SEIKETSU—Standardization

Employees has to discuss together and decide on standards for keeping the work place/ machines/pathways neat and clean. This standards are implemented for whole organization and are tested/inspected randomly.

SHITSUKE—Self-discipline

Considering 5S as a way of life and bring about self-discipline among the employees of the organization. This includes wearing badges, following work procedures, punctuality, dedication to the organization etc.

PILLAR 2—JISHU HOZEN (AUTONOMOUS MAINTENANCE)

This pillar is geared towards developing operators to be able to take care of small maintenance tasks, thus freeing up the skilled maintenance people to spend time on more value added activity and technical repairs. The operators are responsible for upkeep of their equipment to prevent it from deteriorating.

Steps in JISHU HOZEN

1. **Train the employees:** Educate the employees about TPM, its advantages, JH advantages and steps in JH. Educate the employees about abnormalities in equipments.

2. **Initial cleanup of machines**
   - Supervisor and technician should discuss and set a date for implementing step 1.
   - Arrange all items needed for cleaning.
   - On the arranged date, employees should clean the equipment completely with the help of maintenance department.
   - Dust, stains, oils and grease has to be removed.
   - Following are the things that have to be taken care while cleaning. They are oil leakage, loose wires, unfastened nits and bolts and worn out parts.
   - After clean up problems are categorized and suitably tagged. White tags are place where operators can solve problems. Pink tag is placed where the aid of maintenance department is needed.
   - Contents of tag are transferred to a register.
   - Make note of area, which were inaccessible.
   - Finally close the open parts of the machine and run the machine.

3. **Counter measures**
   - Inaccessible regions had to be reached easily, *e.g.*, if there are many screw to open a flywheel door, hinge door can be used. Instead of opening a door for inspecting the machine, acrylic sheets can be used.
   - To prevent work out of machine parts necessary action must be taken.
   - Machine parts should be modified to prevent accumulation of dirt and dust.

4. **Tentative standard**
   - JH schedule has to be made and followed strictly.
   - Schedule should be made regarding cleaning, inspection and lubrication and it also should include details like when, what and how.

5. **General inspection**
   - The employees are trained in disciplines like pneumatics, electrical, hydraulics, lubricant and coolant, drives, bolts, nuts and safety.
   - This is necessary to improve the technical skills of employees and to use inspection manuals correctly.
   - After acquiring this new knowledge the employees should share this with others.
   - By acquiring this new technical knowledge, the operators are now well aware of machine parts.

6. **Autonomous inspection**
   - New methods of cleaning and lubricating are used.
   - Each employee prepares his own autonomous chart/schedule in consultation with supervisor.
   - Parts which have never given any problem or part which don't need any inspection are removed from list permanently based on experience.
   - Including good quality machine parts. This avoid defects due to poor JH.
   - Inspection that is made in preventive maintenance is included in JH.
   - The frequency of cleanup and inspection is reduced based on experience.
7. **Standardization**
   - Up to the previous stem only the machinery/equipment was the concentration. However, in this step the surroundings of machinery are organized. Necessary items should be organized, such that there is no searching and searching time is reduced.
   - Work environment is modified such that there is no difficulty in getting any item.
   - Everybody should follow the work instructions strictly.
   - Necessary spares for equipments is planned and procured.
8. **Autonomous management**
   - OEE and OPE and other TPM targets must be achieved by continuous improve through Kaizen.
   - PDCA (Plan, Do, Check and Act) cycle must be implemented for Kaizen.

PILLAR 3—KAIZEN

'Kai' means change, and 'Zen' means good (for the better). Basically Kaizen is for small improvements, but carried out on a continual basis and involve all people in the organization. Kaizen is opposite to big spectacular innovations. Kaizen requires no or little investment. The principle behind is that "a very large number of small improvements are more effective in an organizational environment than a few improvements of large value." This pillar is aimed at reducing losses in the workplace that affect our efficiencies. By using a detailed and thorough procedure we eliminate losses in a systematic method using various Kaizen tools. These activities are not limited to production areas and can be implemented in administrative areas as well.

Kaizen Policy

1. Practice concepts of zero losses in every sphere of activity.
2. Relentless pursuit to achieve cost reduction targets in all resources.
3. Relentless pursuit to improve overall plant equipment effectiveness.
4. Extensive use of PM analysis as a tool for eliminating losses.
5. Focus of easy handling of operators.

Kaizen Target

Achieve and sustain zero loses with respect to minor stops, measurement and adjustments, defects and unavoidable downtimes. It also aims to achieve 30% manufacturing cost reduction.

Tools used in Kaizen

1. PM analysis
2. Why-Why analysis
3. Summary of losses
4. Kaizen register
5. Kaizen summary sheet.

The objective of TPM is maximization of equipment effectiveness. TPM aims at maximization of machine utilization and not merely machine availability maximization. As one of the pillars of TPM activities, Kaizen pursues efficient equipment, operator and material and energy utilization, which is extremes of productivity and aims at achieving substantial effects. Kaizen activities try to thoroughly eliminate 16 major losses.

16 Major Losses in a Organization

Loss	*Category*
1. Failure losses—Breakdown loss	
2. Setup/adjustment losses	
3. Cutting blade loss	
4. Start up loss	
5. Minor stoppage/Idling loss	
6. Speed loss—operating at low speeds	
7. Defect/rework loss	
8. Scheduled downtime loss	
9. Management loss	Losses that impede equipment efficiency
10. Operating motion loss	Losses that impede human work efficiency
11. Line organization loss	
12. Logistic loss	
13. Measurement and adjustment loss	
14. Energy loss	
15. Die, jig and tool breakage loss	Losses that impede effective use of
16. Yield loss	production resources

PILLAR 4—PLANNED MAINTENANCE

It is aimed to have trouble free machines and equipments producing defect free products for total customer satisfaction. This breaks maintenance down into 4 'families' or groups, which was defined earlier.

1. Preventive maintenance
2. Breakdown maintenance

3. Corrective maintenance
4. Maintenance prevention

With planned maintenance, we evolve our efforts from a reactive to a proactive method and use trained maintenance staff to help train the operators to better maintain their equipment.

Policy

1. Achieve and sustain availability of machines;
2. Optimum maintenance cost;
3. Reduces spares inventory; and
4. Improve reliability and maintainability of machines.

Target

1. Zero equipment failure and breakdown;
2. Improve reliability and maintainability by 50%;
3. Reduce maintenance cost by 20%; and
4. Ensure availability of spares all the time.

Six Steps in Planned Maintenance

1. Equipment evaluation and recoding present status;
2. Restore deterioration and improve weakness;
3. Building up information management system;
4. Prepare time based information system, select equipment, parts and members and map out plan;
5. Prepare predictive maintenance system by introducing equipment diagnostic techniques; and
6. Evaluation of planned maintenance.

PILLAR 5—QUALITY MAINTENANCE

It is aimed towards customer delight through highest quality through defect free manufacturing. Focus is on eliminating non-conformances in a systematic manner, much like Focused Improvement. We gain understanding of what parts of the equipment affect product quality and begin to eliminate current quality concerns, then move to potential quality concerns. Transition is from reactive to proactive (Quality Control to Quality Assurance).

QM activities is to set equipment conditions that preclude quality defects, based on the basic concept of maintaining perfect equipment to maintain perfect quality of products. The conditions are checked and measure in time series to very that measure values are within standard values to prevent defects. The transition of measured values is watched to predict possibilities of defects occurring and to take counter measures before hand.

Policy

1. Defect free conditions and control of equipments;
2. QM activities to support quality assurance;

3. Focus of prevention of defects at source;
4. Focus on poka-yoke (fool proof system);
5. In-line detection and segregation of defects; and
6. Effective implementation of operator quality assurance.

Target

1. Achieve and sustain customer complaints at zero;
2. Reduce in-process defects by 50%; and
3. Reduce cost of quality by 50%.

Data Requirements

Quality defects are classified as *customer end* defects and *in house* defects. For customer-end data, we have to get data on:

1. Customer end line rejection; and
2. Field complaints.

In-house, data include data related to products and data related to process.

Data Related to Product

1. Product-wise defects;
2. Severity of the defect and its contribution—major/minor;
3. Location of the defect with reference to the layout;
4. Magnitude and frequency of its occurrence at each stage of measurement;
5. Occurrence trend in beginning and the end of each production/process/changes (like pattern change, ladle/furnace lining etc.); and
6. Occurrence trend with respect to restoration of breakdown/modifications/periodical replacement of quality components.

Data Related to Processes

1. The operating condition for individual sub-process related to men, method, material and machine;
2. The standard settings/conditions of the sub-process; and
3. The actual record of the settings/conditions during the defect occurrence.

PILLAR 6—TRAINING

It is aimed to have multi-skilled revitalized employees whose morale is high and who has eager to come to work and perform all required functions effectively and independently. Education is given to operators to upgrade their skill. It is not sufficient know only 'Know-How' by they should also learn 'Know-Why'. By experience they gain, 'Know-How' to overcome a problem what to be done. This they do without knowing the root cause of the problem and why they are doing so. Hence, it becomes necessary to train them on knowing 'Know-Why'. The employees should be trained to achieve the four phases of skill. The goal is to create a factory full of experts. The different phase of skills is:

Phase 1: Do not know.

Phase 2: Know the theory but cannot do.

Phase 3: Can do but cannot teach.

Phase 4: Can do and also teach.

Policy

1. Focus on improvement of knowledge, skills and techniques;
2. Creating a training environment for self-learning based on felt needs;
3. Training curriculum/tools/assessment etc. conducive to employee revitalization; and
4. Training to remove employee fatigue and make work enjoyable.

Target

1. Achieve and sustain downtime due to want men at zero on critical machines;
2. Achieve and sustain zero losses due to lack of knowledge/skills/techniques; and
3. Aim for 100% participation in suggestion scheme.

Steps in Educating and Training Activities

1. Setting policies and priorities and checking present status of education and training;
2. Establish of training system for operation and maintenance skill upgradation;
3. Training the employees for upgrading the operation and maintenance skills;
4. Preparation of training calendar;
5. Kick-off of the system for training; and
6. Evaluation of activities and study of future approach.

PILLAR 7—OFFICE TPM

Office TPM should be started after activating four other pillars of TPM (JH, KK, QM, PM). Office TPM must be followed to improve productivity, efficiency in the administrative functions and identify and eliminate losses. This includes analyzing processes and procedures towards increased office automation. Office TPM addresses twelve major losses. They are:

1. Processing loss;
2. Cost loss including in areas such as, procurement, accounts, marketing, sales leading to high inventories;
3. Communication loss;
4. Idle loss;
5. Set-up loss;
6. Accuracy loss;
7. Office equipment breakdown;
8. Communication channel breakdown, telephone and fax lines;
9. Time spent on retrieval of information;
10. Non availability of correct on-line stock status;

11. Customer complaints due to logistics; and
12. Expenses on emergency dispatches/purchases.

Office TPM and its Benefits

1. Involvement of all people in support functions for focusing on better plant performance;
2. Better utilized work area;
3. Reduce repetitive work;
4. Reduced inventory levels in all parts of the supply chain;
5. Reduced administrative costs;
6. Reduced inventory carrying cost;
7. Reduction in number of files;
8. Reduction of overhead costs (to include cost of non-production/non-capital equipment);
9. Productivity of people in support functions;
10. Reduction in breakdown of office equipment;
11. Reduction of customer complaints due to logistics;
12. Reduction in expenses due to emergency dispatches/purchases;
13. Reduced manpower; and
14. Clean and pleasant work environment.

PILLAR 8—SAFETY, HEALTH AND ENVIRONMENT

Target

1. Zero accident,
2. Zero health damage, and
3. Zero fires.

In this area focus is on to create a safe workplace and a surrounding area that is not damaged by our process or procedures. This pillar will play an active role in each of the other pillars on a regular basis.

A committee is constituted for this pillar, which comprises representative of officers as well as workers. The committee is headed by senior vice President (Technical). Utmost importance to safety is given in the plant. Manager (safety) is looking after functions related to safety. To create awareness among employees various competitions like safety slogans, quiz, drama, posters, etc. related to safety can be organized at regular intervals.

Today, with competition in industry at an all time high, TPM may be the only thing that stands between success and total failure for some companies. It has been proven to be a program that works. It can be adapted to work not only in industrial plants, but also in construction, building maintenance, transportation, and in a variety of other situations. Employees must be educated and convinced that TPM is not just another ‘program of the month’ and that management is totally committed to the program and the extended time frame necessary for full implementation. If everyone involved in a TPM program does his or her part, an unusually high rate of return compared to resources invested may be expected.

EXERCISES

Section A

1. Define maintenance.
2. What is reactive maintenance?
3. What is preventive maintenance?
4. What is predictive maintenance?
5. What is maintenance planning?
6. What is scheduling?
7. What is reliability centred maintenance?
8. What is six sigma maintenance?

Section B

1. Explain the steps of job planning.
2. What are the requirements of schedules?
3. What are the maintenance techniques used?
4. Explain the six sigma maintenance process.

Section C

1. Discuss the different types of maintenance.
2. Discuss the enterprise asset management.

Skill development

FAST FOOD RESTAURANT VISIT: Get the information for the following questions:

1. Method of maintenance of equipment. (i.e. preventive maintenance or Breakdown maintenance)
2. Maintenance schedule followed.