PRODUCTION TECHNOLOGY

Semester: 3RD

STUDY MATERIAL

PT

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PRODUCTION TECHNOLOGY
(THEORY-1)

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METAL FORMING PROCESS

Lecture-1

Metal forming:

Set of manufacturing processes in which the material is deformed **plastically** to take the shape of the die geometry.

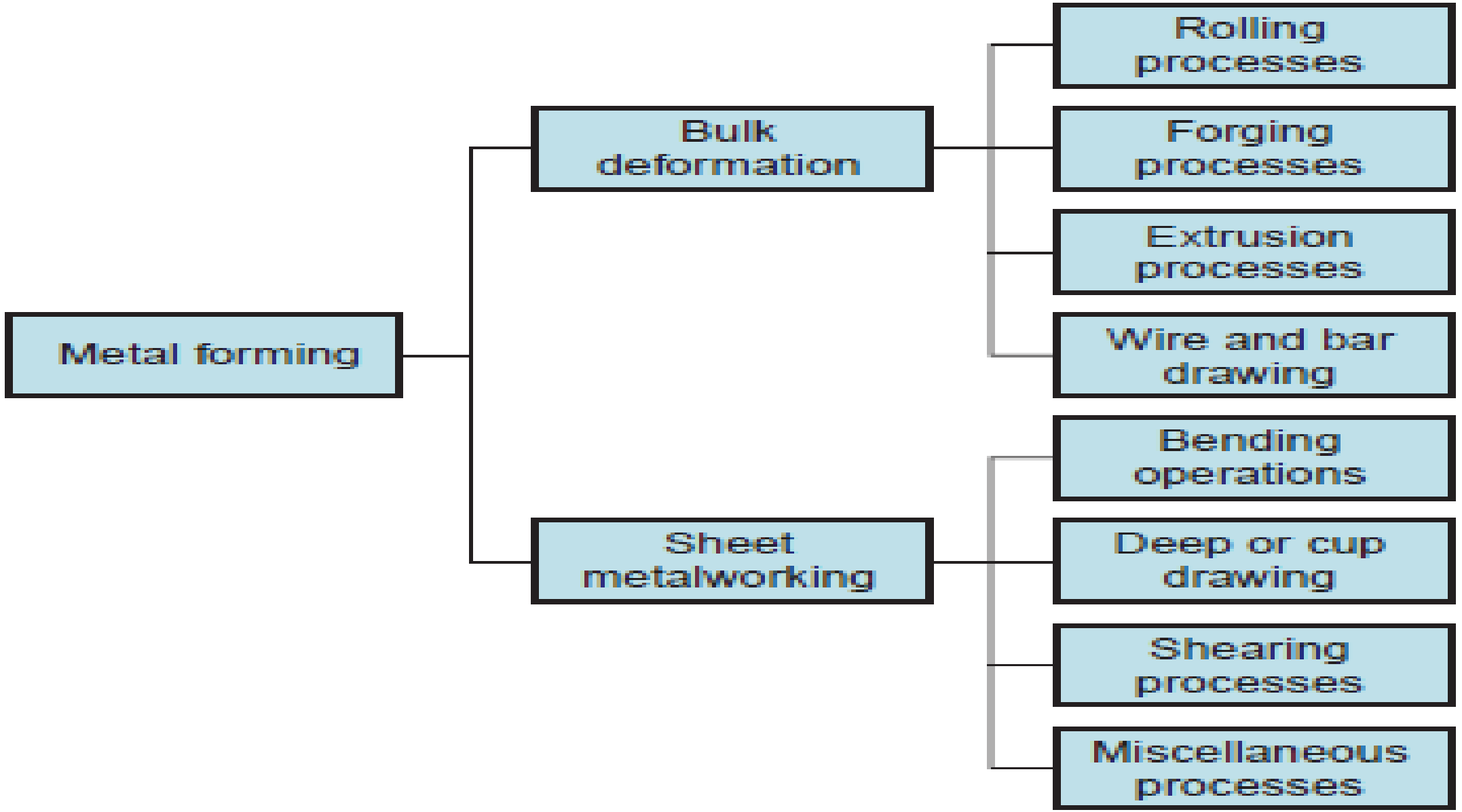
The tools used for such deformation are called die, punch etc. depending on the type of process.

Plastic deformation

is the permanent deformation that occurs when a material is subjected to tensile, compressive, bending, or torsion stresses that exceed its **yield strength** and cause it to elongate, compress, buckle, bend, or twist.

Yield strength

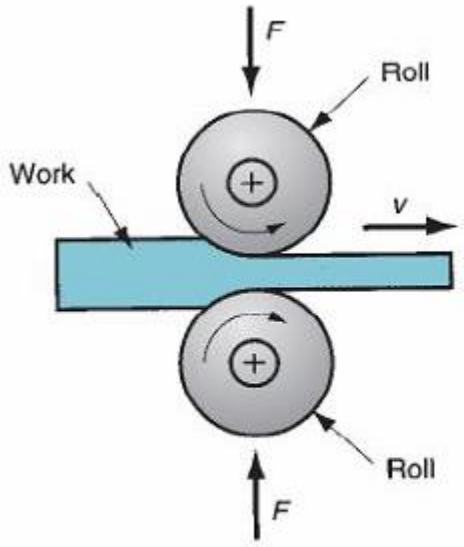
indicates the limit of elastic behavior and the beginning of plastic behavior. Prior to the yield point, a material will deform elastically and will return to its original shape when the applied stress is removed.


Metal forming
Bulk deformation
Sheet metalworking
Rolling processes
Forging processes
Extrusion processes
Wire and bar drawing
Bending operations
Deep or cup drawing
Shearing processes
Miscellaneous processes

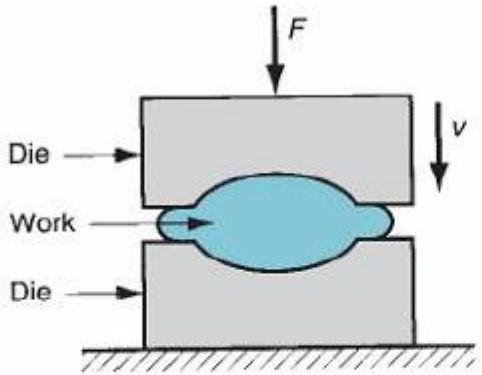
Classification of basic bulk forming processes

Bulk forming:

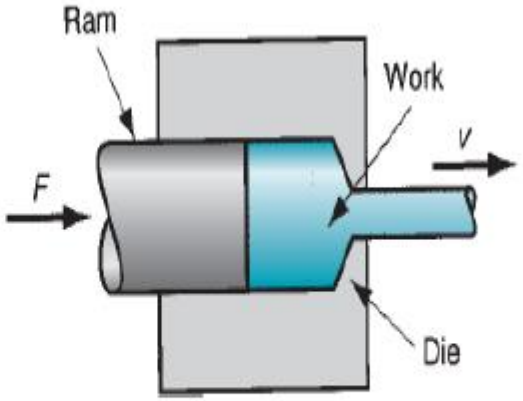
- It is a severe deformation process resulting in massive shape change. The surface area-to-volume of the work is relatively small. Mostly done in hot working conditions.



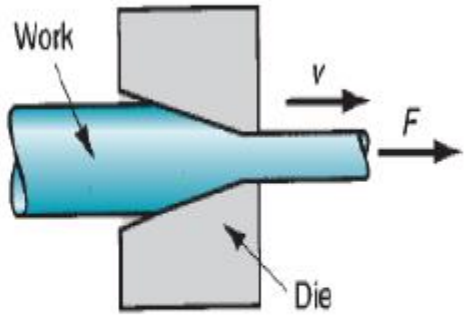
Rolling



Forging

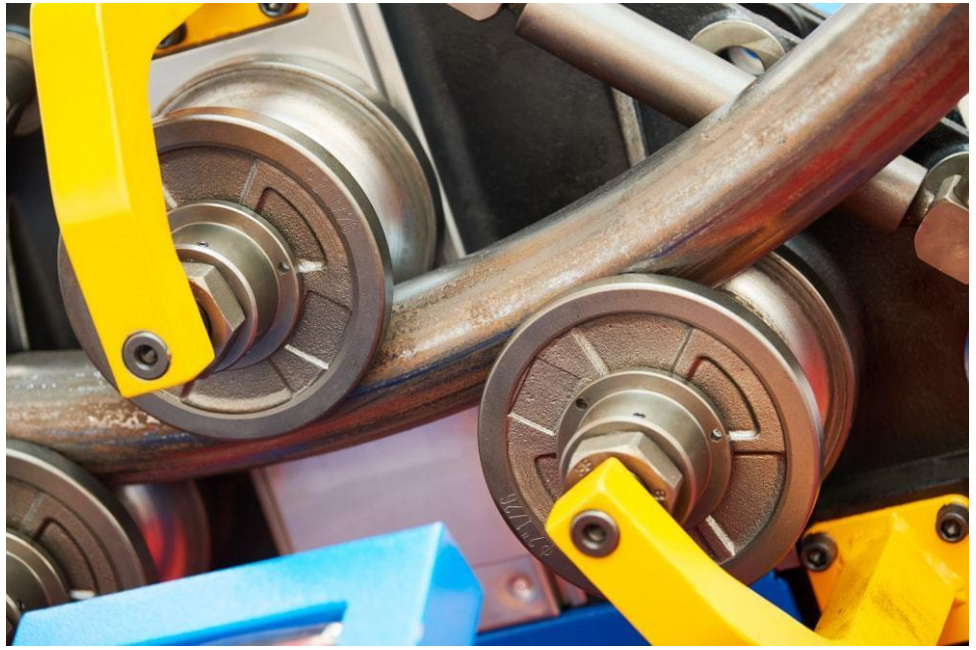


Extrusion



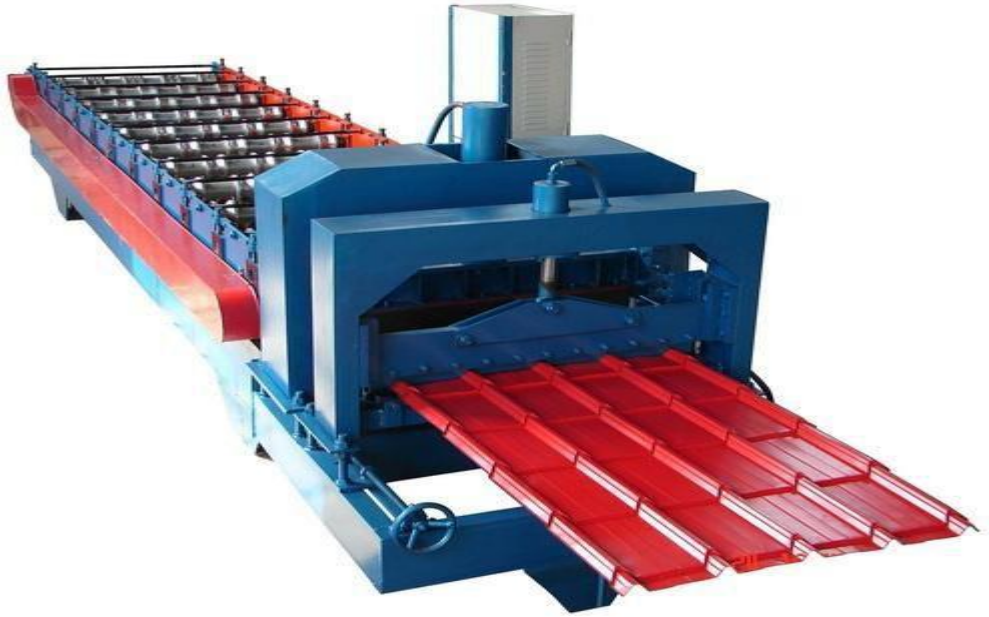
Wire drawing

1.R**olling** is a **metal forming** process in which **metal** stock is passed through one or more pairs of rolls to reduce the thickness and to make the thickness uniform.

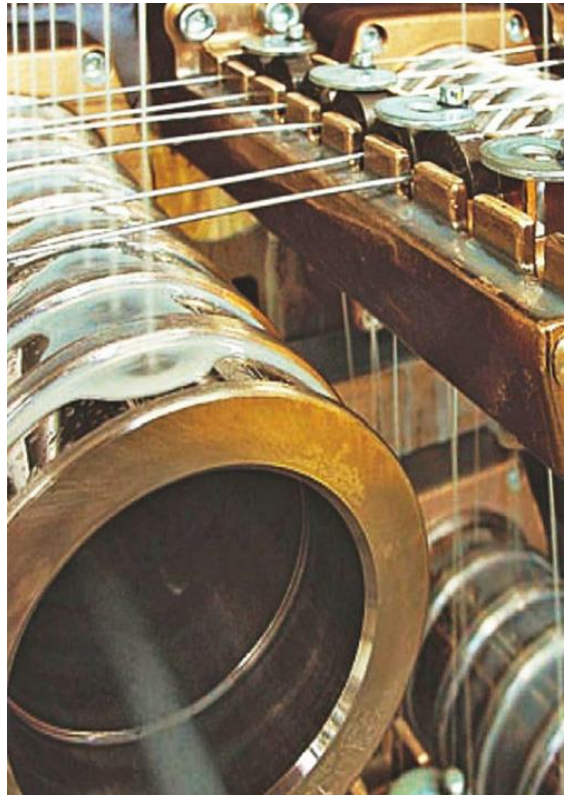


2. **Metal forging** is a **metal forming** process that involves applying compressive forces to a work piece to deform it, and create a desired geometric change to the material.

- **Metal Extrusion** is a **metal forming** manufacturing process in which a cylindrical billet inside a closed cavity is forced to flow through a die of a desired cross section.



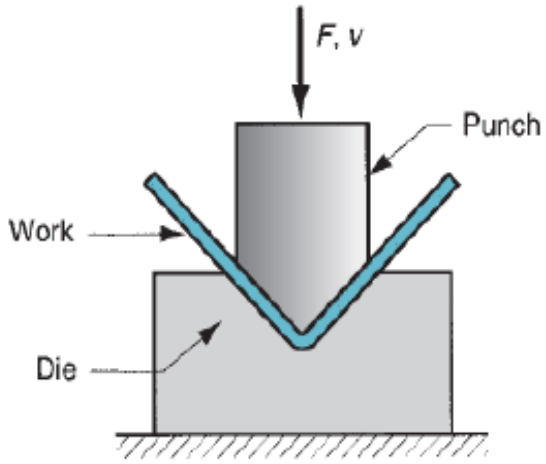
- **Wire drawing** is a **metal working** process used to reduce the cross section of **wire** by pulling it through a series of dies.



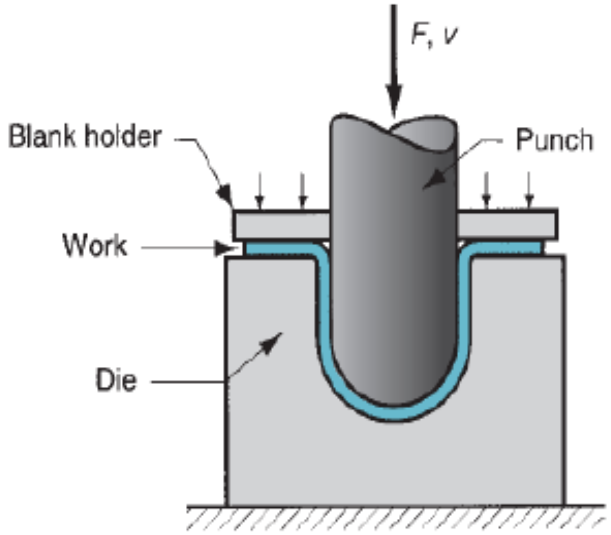
Classification of basic sheet forming processes

Sheet forming:

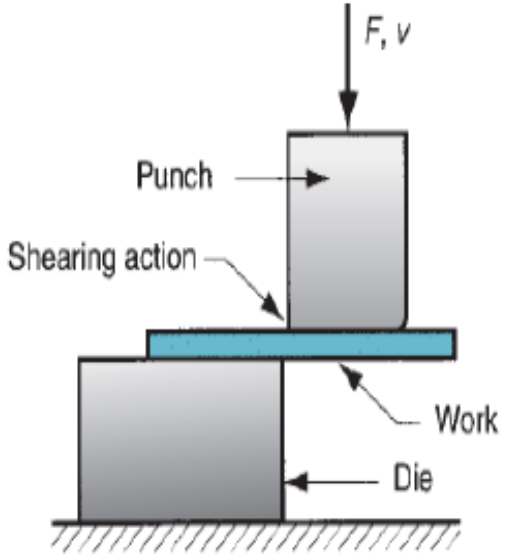
- Sheet metal forming involves forming and cutting operations performed on metal sheets, strips, and coils. The surface area-to-volume ratio of the starting metal is relatively high. Tools include punch, die that are used to deform the sheets.

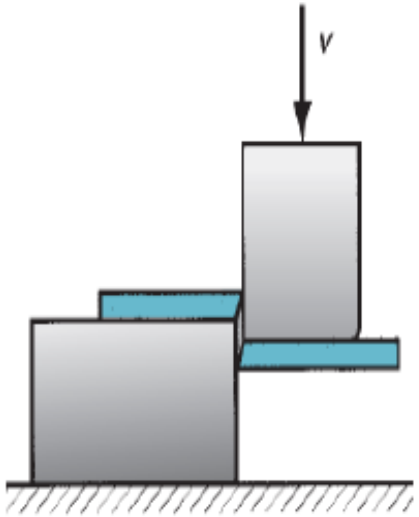


Bending



Deep drawing





shearing

Bending. **Bending** is a **metal forming** process in which a force is applied to a piece of **sheet metal**, causing it to **bend** at an angle and form the desired shape.

Deep drawing is a **sheet metal forming** process in which a **sheet metal** blank is radially **drawn** into a **forming** die by the mechanical action of a punch.

Shearing is a **metal** fabricating process used to cut straight lines on flat **metal** stock. During the **shearing** process, an upper blade and a lower blade are forced past each other

Lecture-2

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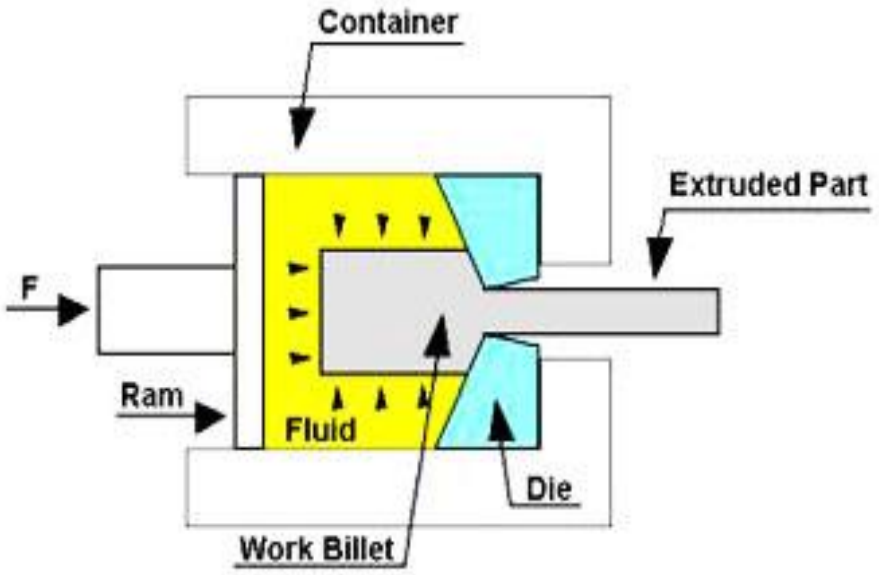
EXTRUSION:

Extrusion as an industrial process was invented around
1800 in England.

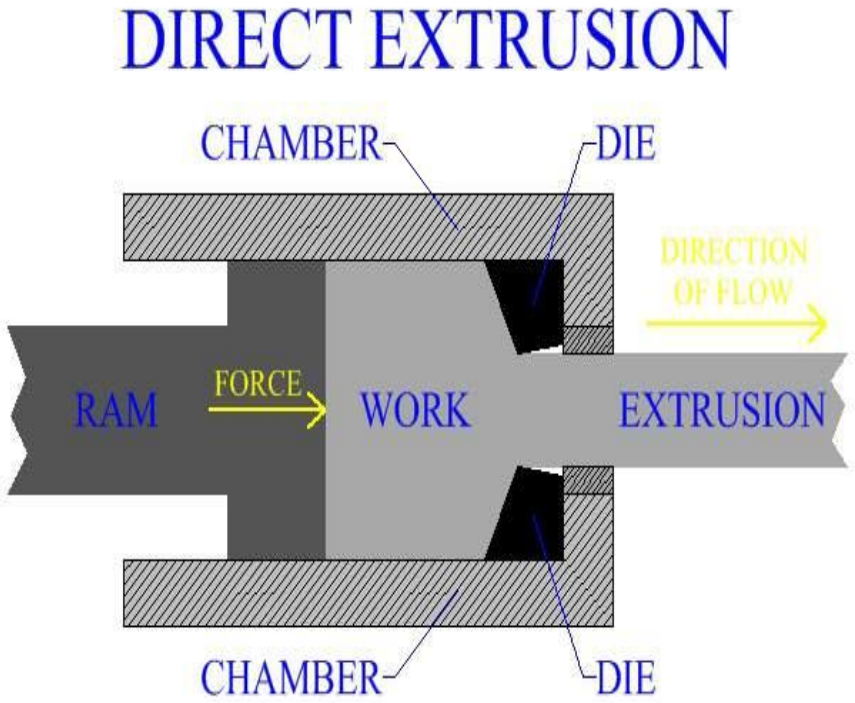
Extrusion is a compression process in which the work metal is forced to flow through a die opening to produce a desired cross-sectional shape. The process can be likened to squeezing toothpaste out of a toothpaste tube.



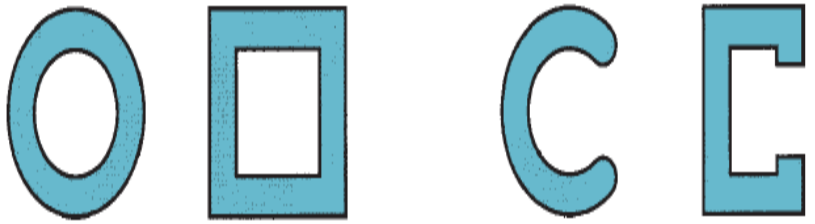
DIRECT VS. INDIRECT EXTRUSION

- **Direct extrusion**

also called forward extrusion is illustrated in Figure . A metal billet is loaded into a container, and a ram compresses the material, forcing it to flow through one or more openings in a die at the opposite end of the container.



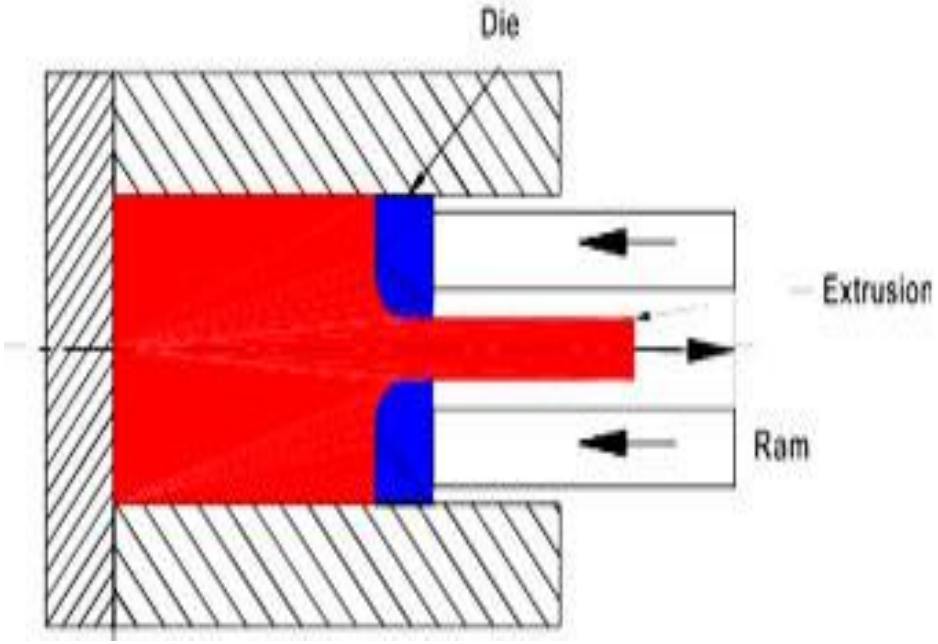
- One of the problems in direct extrusion is the significant friction that exists between the work surface and the walls of the container as the billet is forced to slide toward the die opening.



- This friction causes a substantial increase in the ram force required in direct extrusion.
- Hollow sections (e.g., tubes) are possible in direct extrusion

INDIRECT EXTRUSION

- In indirect extrusion, also called backward extrusion and reverse extrusion, Figure the die is mounted to the ram rather than at the opposite end of the container.



- the metal is forced to flow through the clearance in a direction opposite to the motion of the ram.

- Since the billet is not forced to move relative to the container, there is no friction at the container walls, and the ram force is therefore lower than in direct extrusion.

HOT VERSUS COLD EXTRUSION

- Hot extrusion involves prior heating of the billet to a temperature above its **recrystallization temperature**.

- This reduces strength and increases ductility of the metal, permitting more extreme size reductions and more complex shapes to be achieved in the process.

- Additional advantages include reduction of ram force, increased ram speed

- Cooling of the billet as it contacts the container walls is a problem

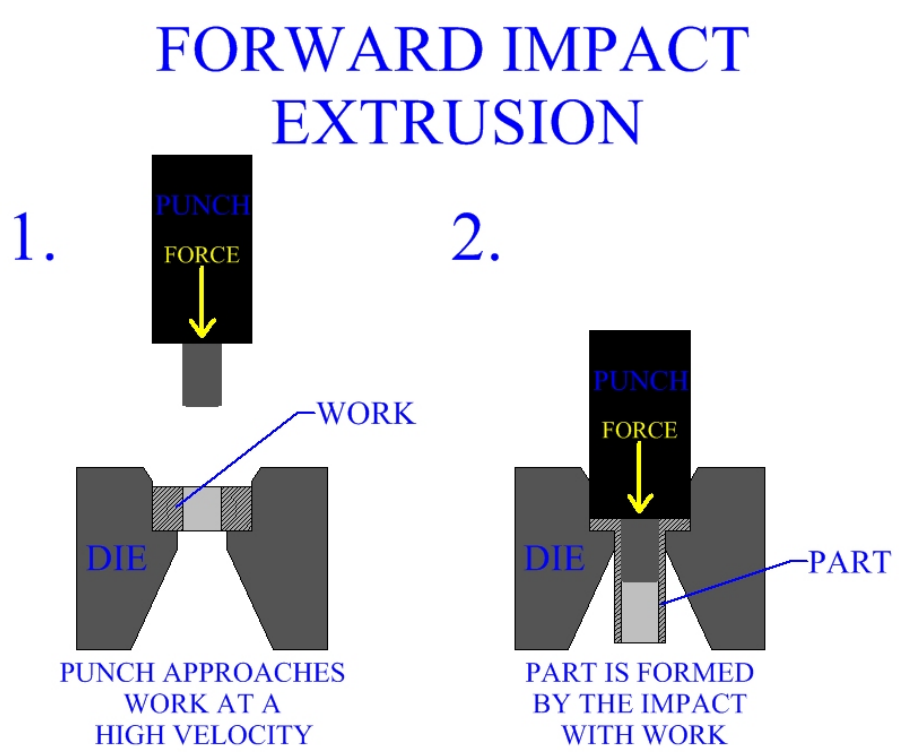
- Glass is sometimes used as a lubricant in hot extrusion; in addition to reducing friction, it also provides effective thermal insulation between the billet and the extrusion container

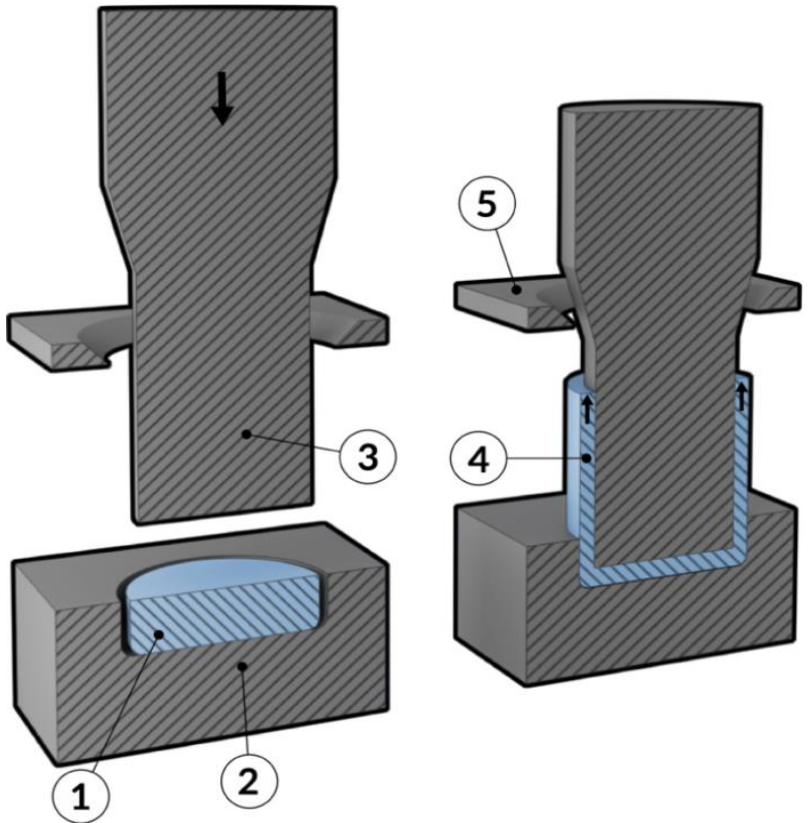
COLD EXTRUSION

- **Cold extrusion** is done at room temperature or near room temperature. The advantages of this over hot extrusion are the, higher strength due to cold working, closer tolerances, better surface finish, and fast extrusion speeds if the material is subject to hot shortness.
- Materials that are commonly cold extruded include: lead, tin, aluminum, copper, zirconium, titanium, molybdenum, beryllium, vanadium, niobium, and steel.
- Below its **recrystallization temperature**.

OTHER EXTRUSION PROCESSES

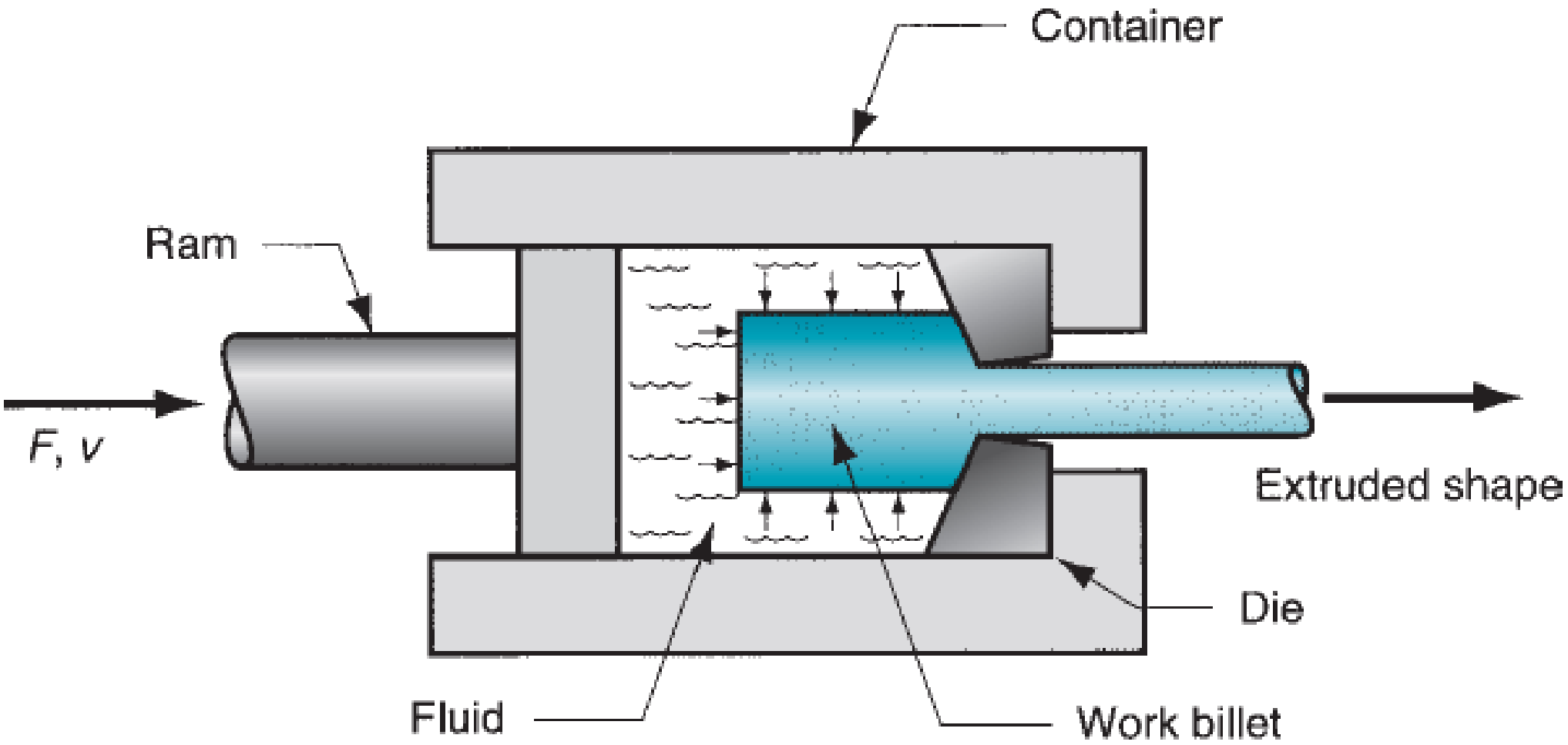
- **Impact extrusion** is a manufacturing process, in which a metal part is **extruded** through the **impact** of a die with the work stock.
- The part is formed at a high speed and over a relatively short stroke. In standard metal **extrusions**, the force to extrude the work is commonly delivered by way of a hydraulic press





HYDROSTATIC EXTRUSION

- Hydrostatic Extrusion in direct extrusion is friction along the billet– container interface by surrounding the billet with fluid inside the container and pressurizing the fluid by the forward motion of the ram.
- This way, there is no friction inside the container, and friction at the die opening is reduced.
- Consequently, ram force is significantly lower than in direct extrusion. The fluid pressure acting on all surfaces of the billet gives the process its name.
- It can be carried out at room temperature or at elevated temperatures. Special fluids and procedures must be used at elevated temperatures. Hydrostatic extrusion is an adaptation of direct extrusion.
- Several different kinds of **liquids** are used when manufacturing by **hydrostatic extrusion**, including oils, waxes, melted polymers and molten glass.


Container
Ram
F, v
Extruded shape
Die
Fluid
Work billet

LECTURE-3

PRODUCTION TECHNOLOGY

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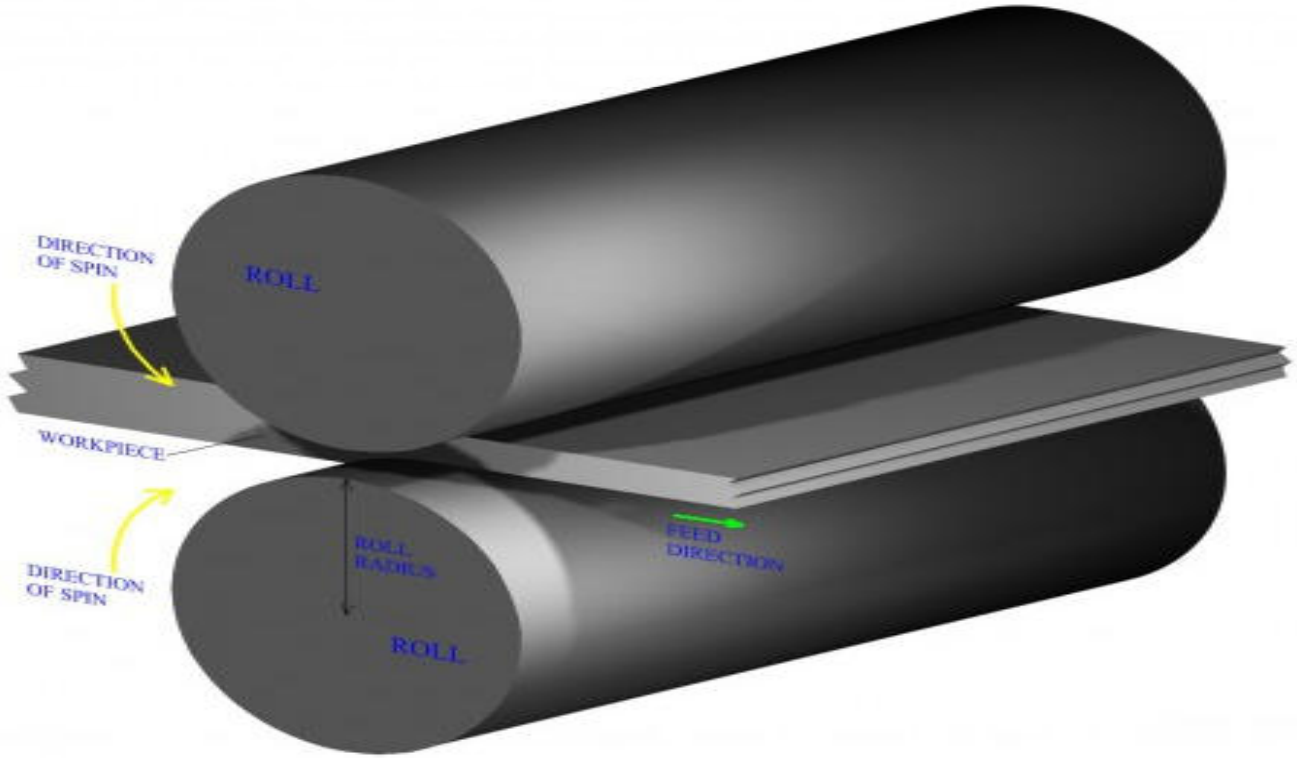
ROLLING

is a **metal forming** process in which **metal** stock is passed through one or more
reduce the thickness and to make the thickness uniform.

OR

s a deformation process in which the thickness of the work is reduced by compres

xerted by two opposing rolls



rolling is carried out by hot working, called **hot ro**lling, owing to the la
unt of deformation required.

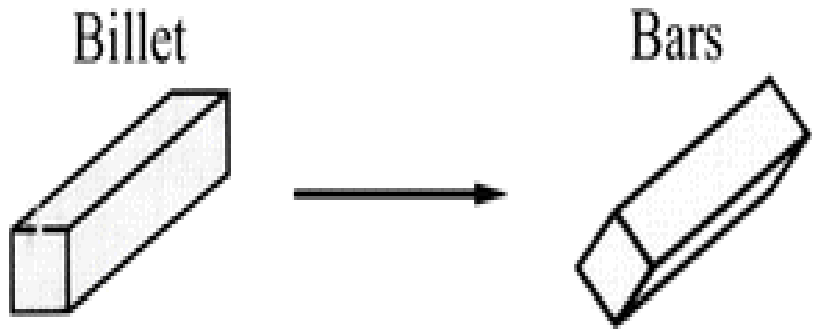
olled plates are used in shipbuilding, bridges, boilers, welded structure
us heavy machines, tubes and pipes, and many other products.

dvantages of hot rolling are that the product cannot be held to close
ances, and the surface has a characteristic oxide scale.

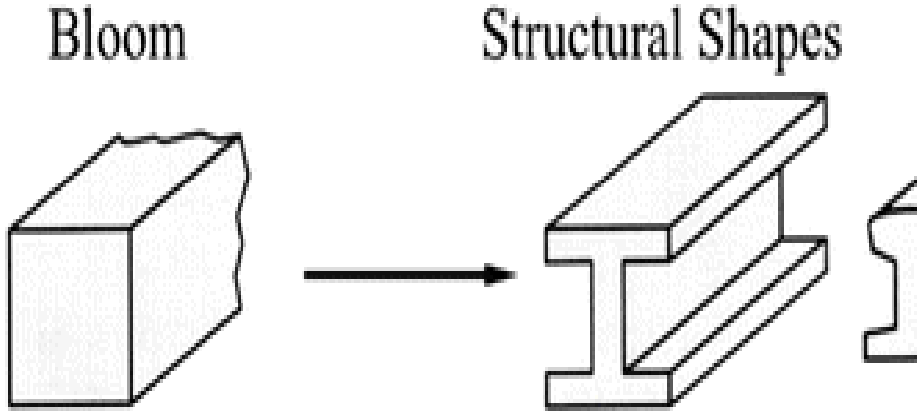
er flattening of hot-rolled plates and sheets is often accomplished by c
g, in order to prepare them for subsequent sheet metal operations.

olling strengthens the metal and permits a tighter tolerance on thickn

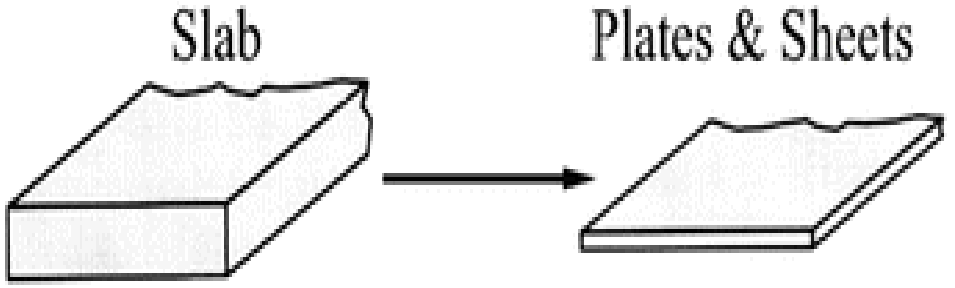
It is rolled from a bloom and is
in cross-section with dimensions
on a side or more



n: It has a square cross section
m x 150 mm or more



t is rolled from an ingot or a bloom
s a rectangular cross section of 250
dth or more and thickness 40 mm
e.



ms are rolled into structural shapes like rails for railroad tracks.

s are rolled into bars, rods. They become raw materials for machining,
ing, forging, extrusion etc.

s are rolled into plates, sheets, and strips. Hot rolled plates are general
in shipbuilding, bridges, boilers, welded structures for various heavy
hines, and many other products

IAT ARE MAIN TYPES OF ROLLING MACH

TYPES OF ROLLING MILLS:

High Rolling Mill

e High Rolling Mill

High Rolling Mill

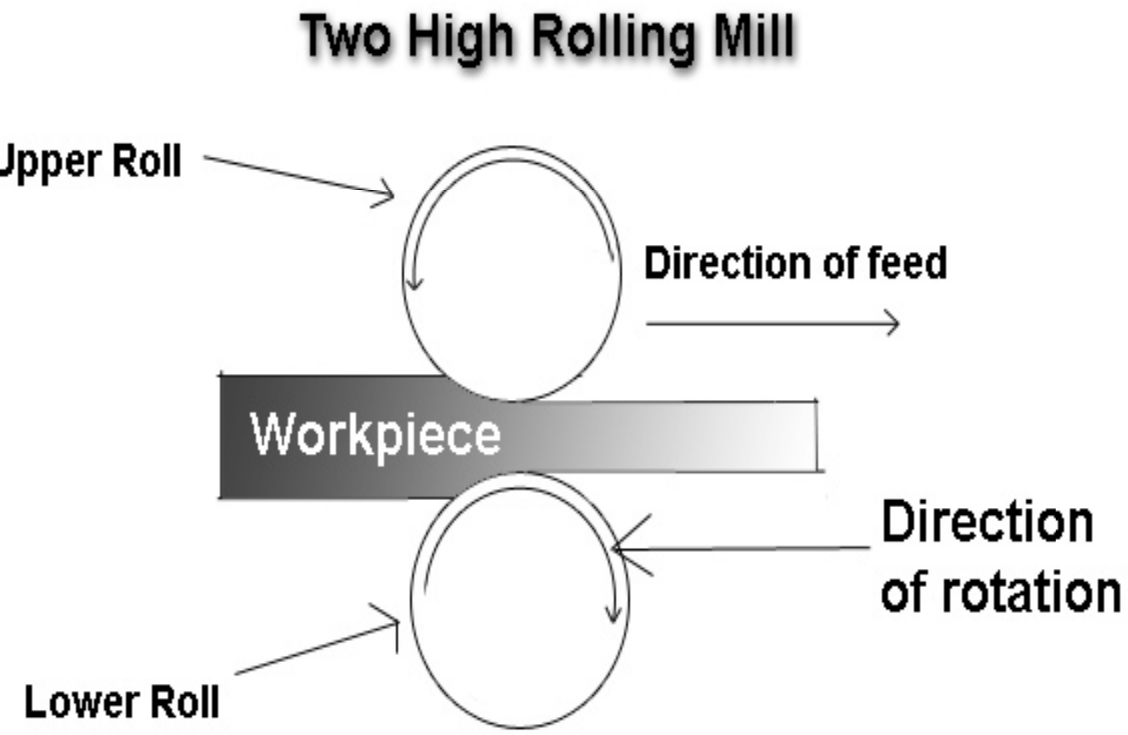
em Rolling Mill

er Rolling Mill

etary Rolling Mill

Two High Rolling Mill

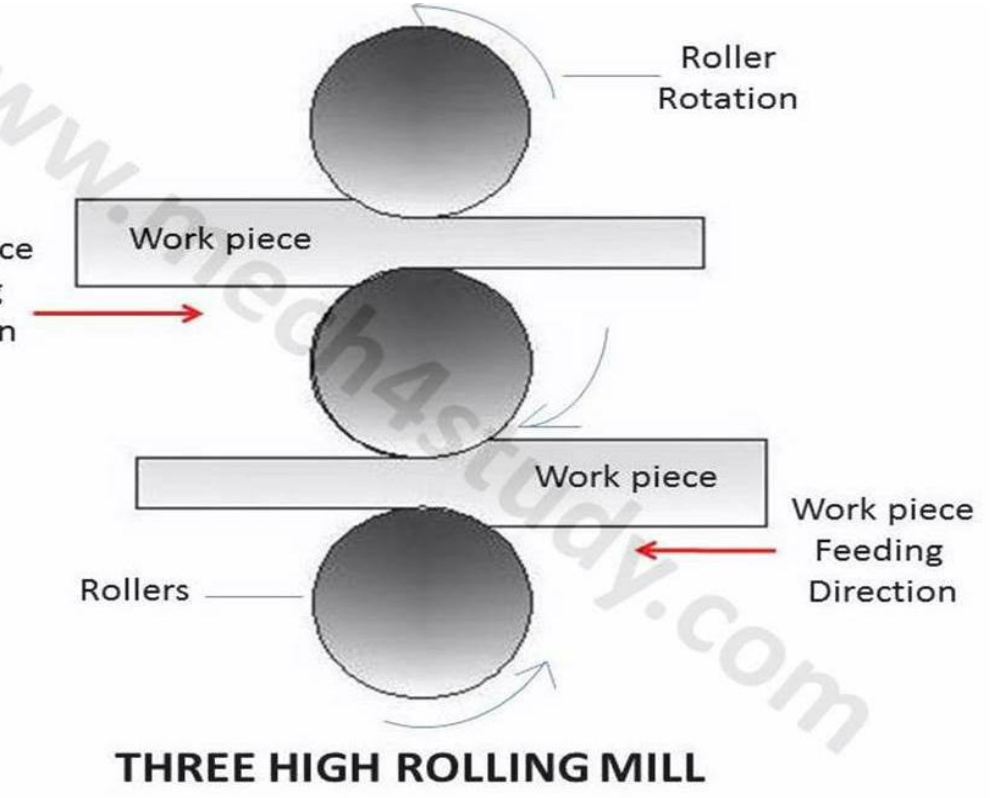
High **Rolling Mills**. It consists of two rollers, which rotate in the oppos
ction for the desired movement of the workpiece.



Three High Rolling Mill

type of rolling mills consists of three rolls arranged one above other . T
tion of rotation of upper and lower rolls are same but the middle roll r
e opposite direction.

type of rolling mills are used for rolling of continuous passes in a rollin
ence without reversing the drives. This results in a higher rate of produ
the two-high rolling mill.



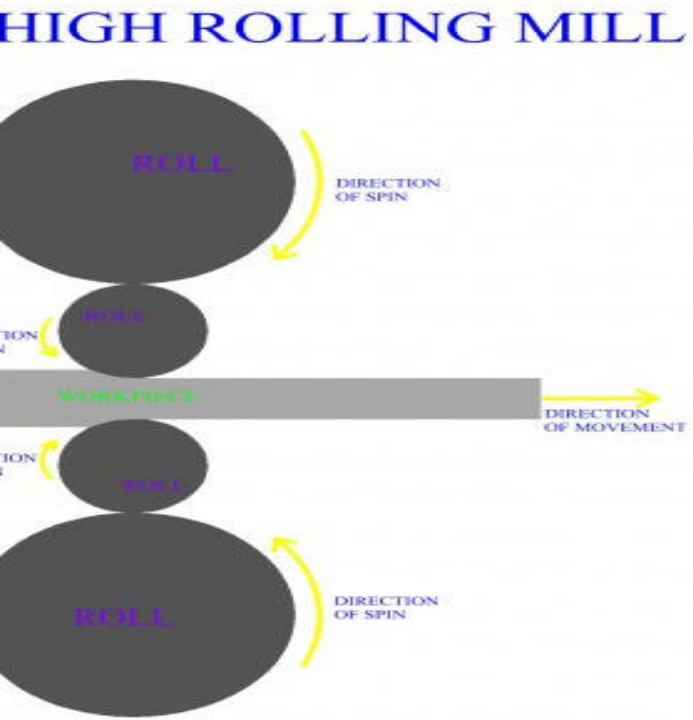
THREE HIGH ROLLING MILL

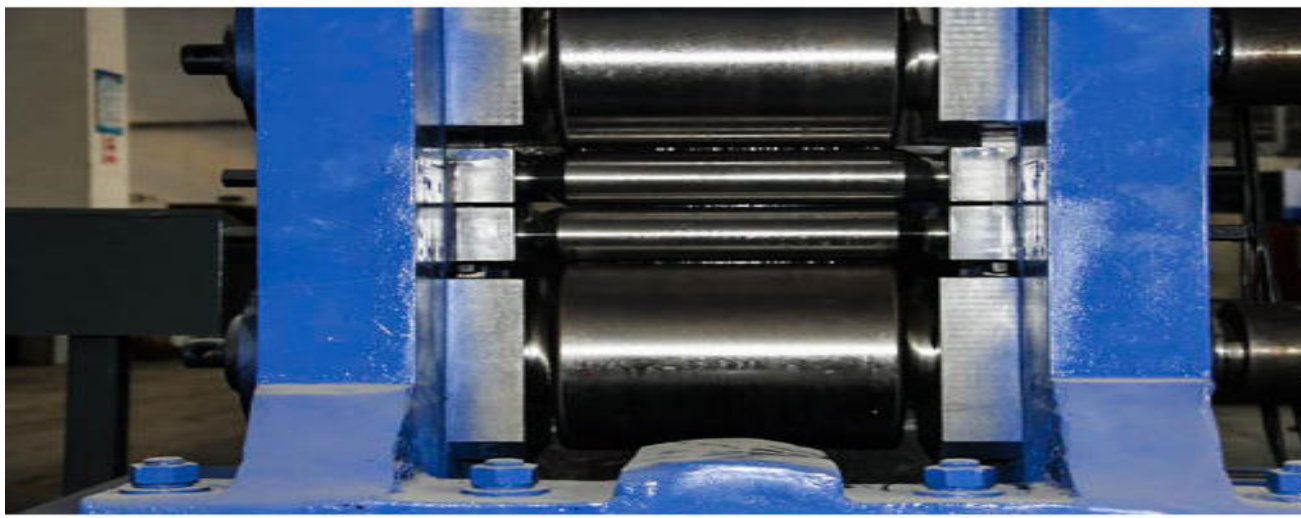
Four High Rolling Mill

s type of rolling machine, two rolls are in direct contact with the workp
he other two rolls are used as backup rolls.

wo rolls which are in direct contact with the workpiece are smaller tha
up rolls and are called working rolls.

up rolls are used to prevent the deflection of the smaller rolls, which
rwise would result in thickening of rolled plates at the center.

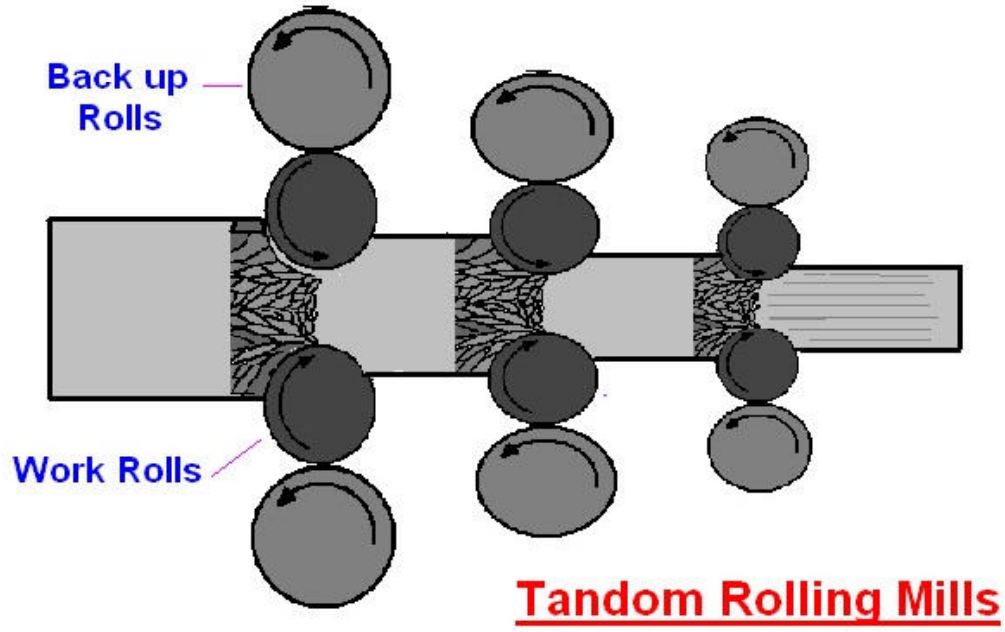




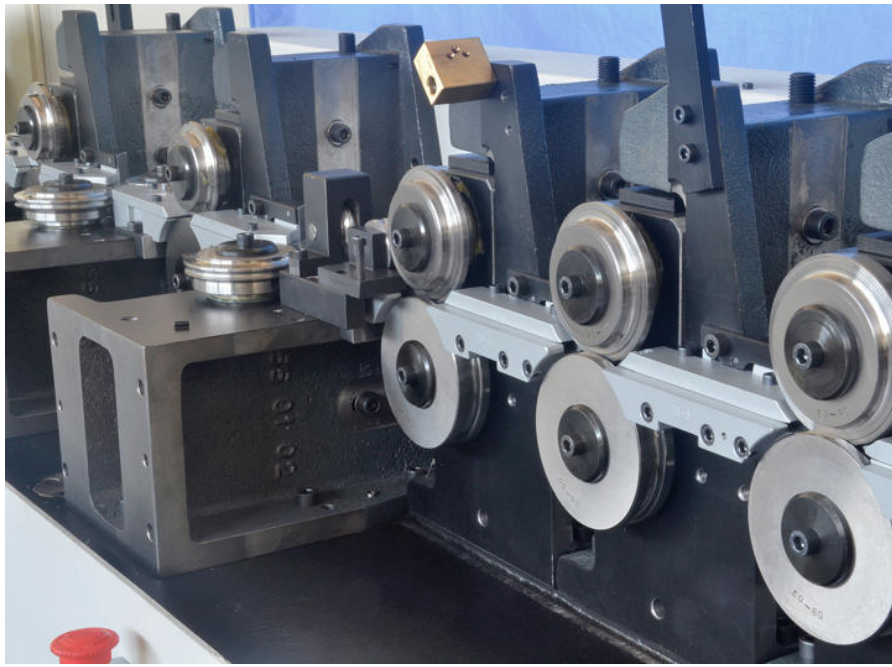
Tandem Rolling Mill

nsists of a number of non reversing two-high rolling mills arrange one a
r. So that the material can be passed through all of them in sequence.

uitable for mass production work only, because for smaller quantities
ges of set up will be required and they will consume lot of labor and w



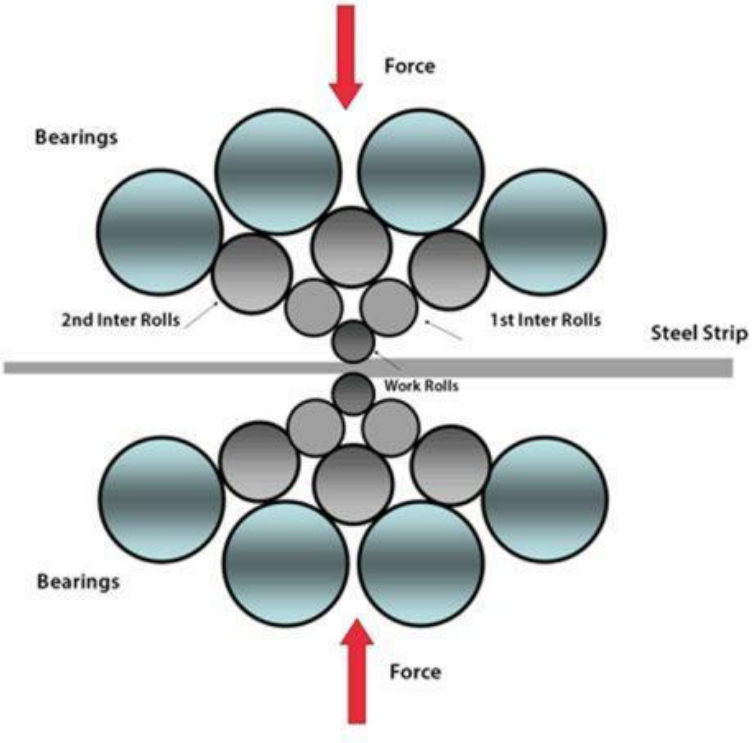
Tandom Rolling Mills

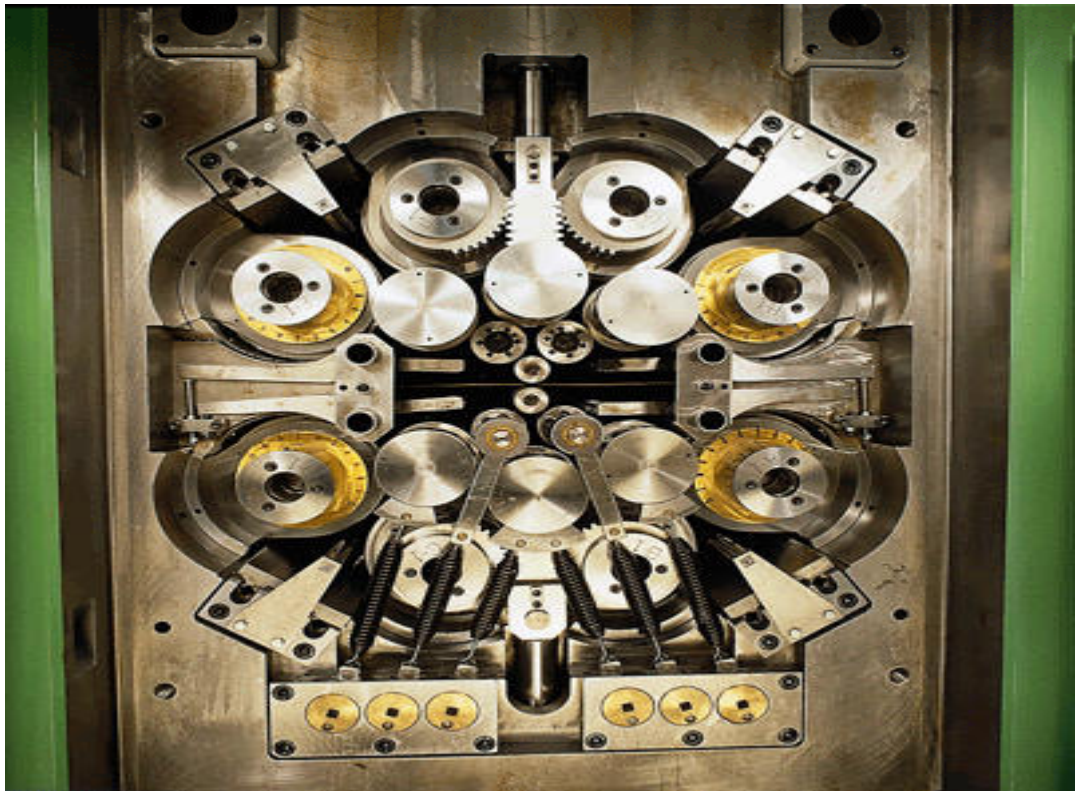


Cluster Rolling Mill

s type of rolling mill, each of working roll is backed up by two or more up rolls. These rolls are arranged as shown in figure. This rolling mill ar lling hard thin materials.

olling hard thin materials, it may be necessary to employ work rolls of diameter but of considerable length . In such cases adequate support ing rolls can be obtained by using a cluster-mill.

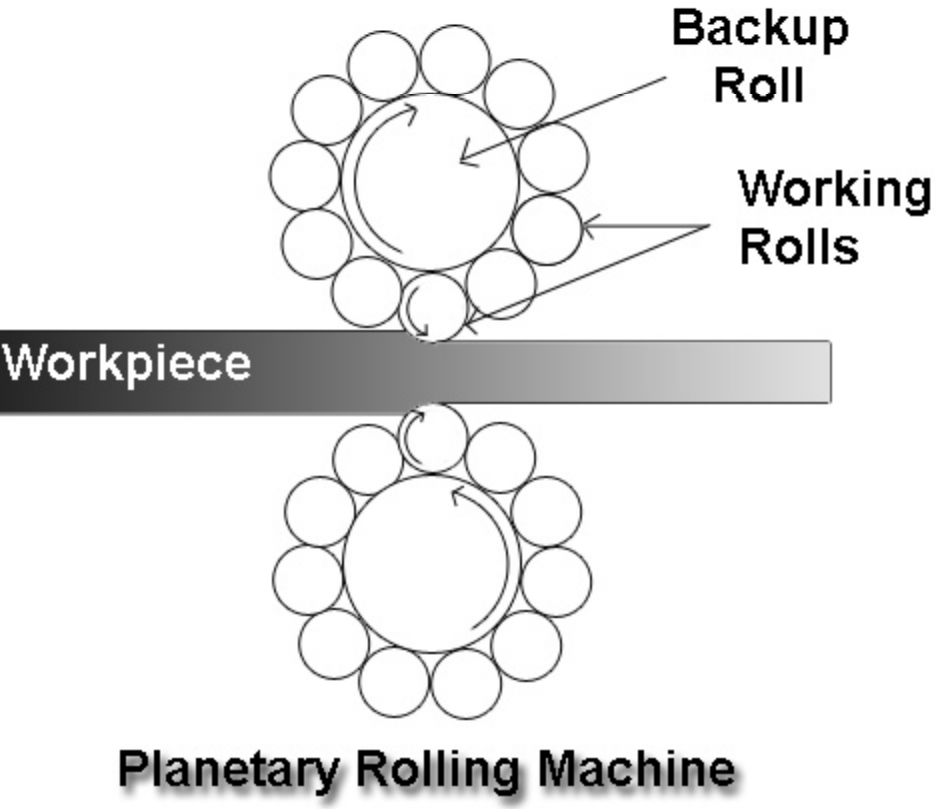




Planetary Rolling Mill

s type of rolling mill, a large backup roller is surrounded by many plane
ing rolls. Each planetary rolls gives constant reduction.

used to reduce large thickness of single pass of steel strip. Its rolling ca
re than cluster rolling mill but less than rolling mill.



Planetary Rolling Machine

LECTURE-4

RODUCTION TECHNOLOG

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HOT ROLLING VS. COLD ROLLING

nportant to note that the main **difference between hot rolled and col**
d steel is one of process.

rolling" refers to processing done with heat. "**Cold rolling**" refers to
esses done at or near room temperature

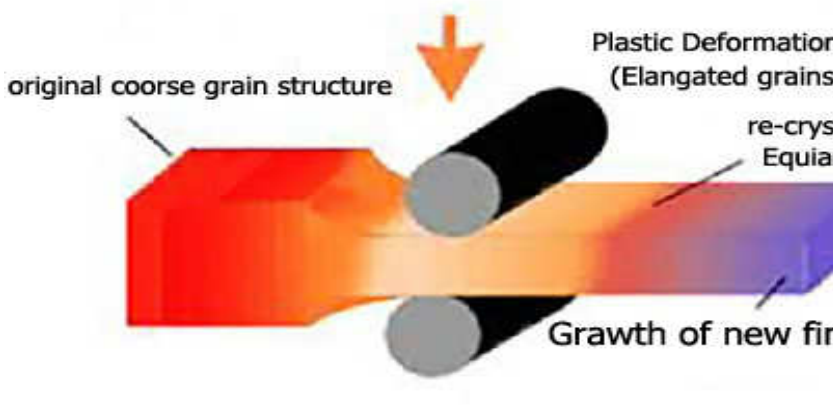
olled steel is steel that has been roll-pressed at very high temperature
1,700˚F, which is above the re-crystallization temperature for most ste

ocess hot rolled steel, manufacturers start with a large, rectangular length of l, called a billet.

billet is heated and then sent for pre-essing, where it is flattened into a large From there, it is kept at a high erature and run through a series of rs to achieve its finished dimensions.

shrinks slightly as it cools. Since hot d steel is cooled after processing, there is control over its final shape, making it less ble for precision applications.

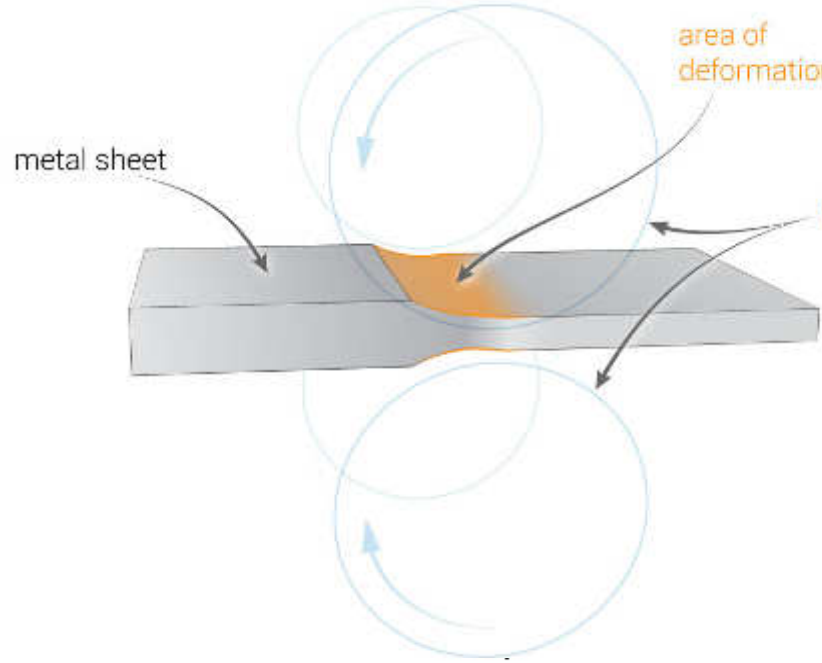
rolled steel is often used in applications e minutely specific dimensions aren't al. Railroad tracks and construction cts often use hot rolled steel.



Hot Rolling Process

COLD ROLLING

hot rolled steel has cooled, it is then re-
d at room temperature(below
stallization) to achieve more exact
nsions and better surface qualities.



“rolled” steel is often used to describe a
e of finishing processes, though technically
rolled” applies only to sheets that
rgo compression between rollers. Steel
s that are pulled, such as bars or tubes,
drawn,” not rolled.

er cold finishing processes include turning,
ing, and polishing—each of which is used
odify existing hot rolled stock into more
ed products.

Different types of rolling mills

ng mills may be classified according to the number and arrangement o

high **rolling mills**

ee high **rolling mills**.

high **rolling mills**.

dem **rolling mills**.

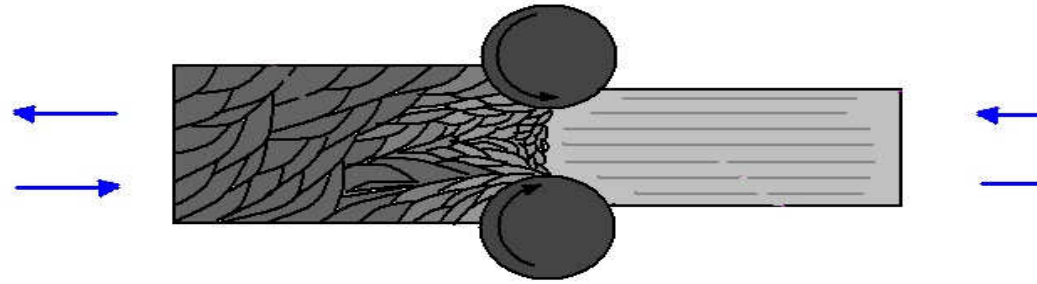
ster **rolling mills**.

Two high rolling mills

high rolling mills may
r classified as
ersing mill
reversing mill

o high reversing rolling mills
olls rotate in one direction
hen in the other, so that
d metal may pass back and
through the rolls several
s.

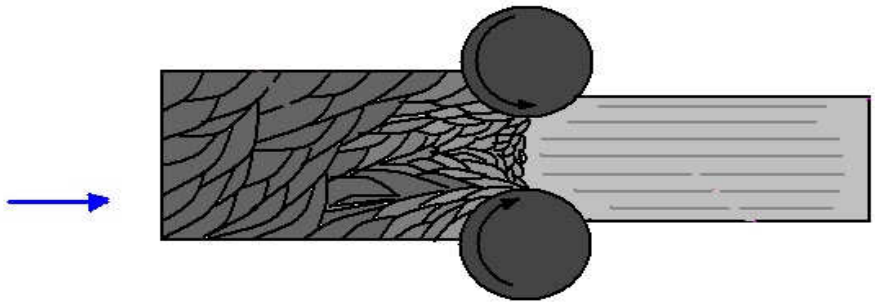
type is used in plumbing and
ng mills and for roughing
in plate , rail , structural and
r mills



Reversing Mills

Non reversing mill

o high non reversing mills as two
which revolve continuously in
direction therefore smaller and
costly motive power can be used.



Non Reversing Mills

ever every time material is to be
ed back over the top of the mill for
passing in through the rolls. Such
rangement is used in mills through
n the bar passes once and in open
plate mill.

LECTURE

RODUCTION TECHNOLOG

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SHIELDED METAL ARC WELDING & ELECTRODE CLASSIFICATION

WELDING

ing is a process for joining two similar or dissimilar metals by fusion.
rent metals/alloys, with or without the application of pressure and w
out the use of filler metal.

fusion of metal takes place by means of heat. The heat may be gen
r from combustion of gases, electric arc, electric resistance or by ch
ion.

e of the typical applications of welding include the fabrication of
ure vessels, automobile bodies, off-shore platform bridges, welded

electric arc **welding**, a major **use** for the **filler rod** is as a consu
rode that also generates heat in the workpiece.

tungsten arc welding (GTAW), or tungsten/inert-gas (TIG) welding
ual welding process that uses a non-consumable electrode
ngsten, an inert or semi-inert gas mixture, and a separate filler materia

ARC WELDING PROCESSES

oon Arc Welding

lded Metal Arc Welding

merged Arc Welding

Tungsten Arc Welding

Metal Arc Welding

ma Arc Welding

mic Hydrogen Welding

tro-slag Welding

l Arc Welding

ctro-gas Welding


Electrode
Diameter

ECTRIC ARC ?

electric arc is a discharge of electric current across a gap i
cuit

s sustained by an ionized column of gas (*plasma*) through wh
current flows

initiate the arc in AW, electrode is brought into contact with w
l then quickly separated from it by a short distance

o Basic Types of AW Electrodes

onsumable

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

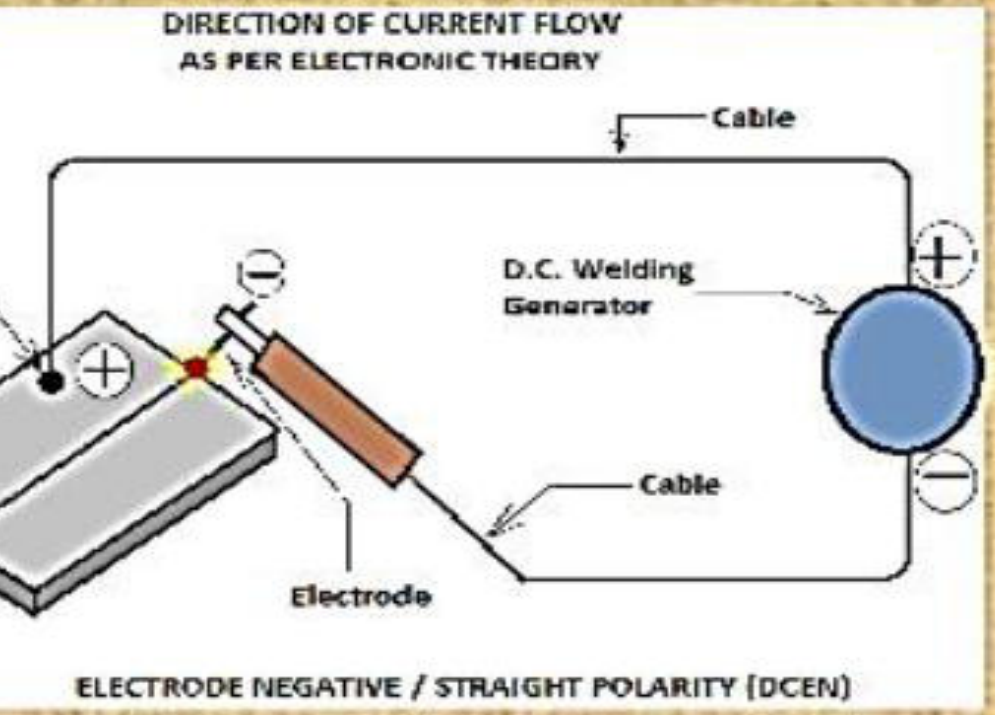
onconsumable

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

Kinds of polarity

raight polarity / electrode gative (DCEN):

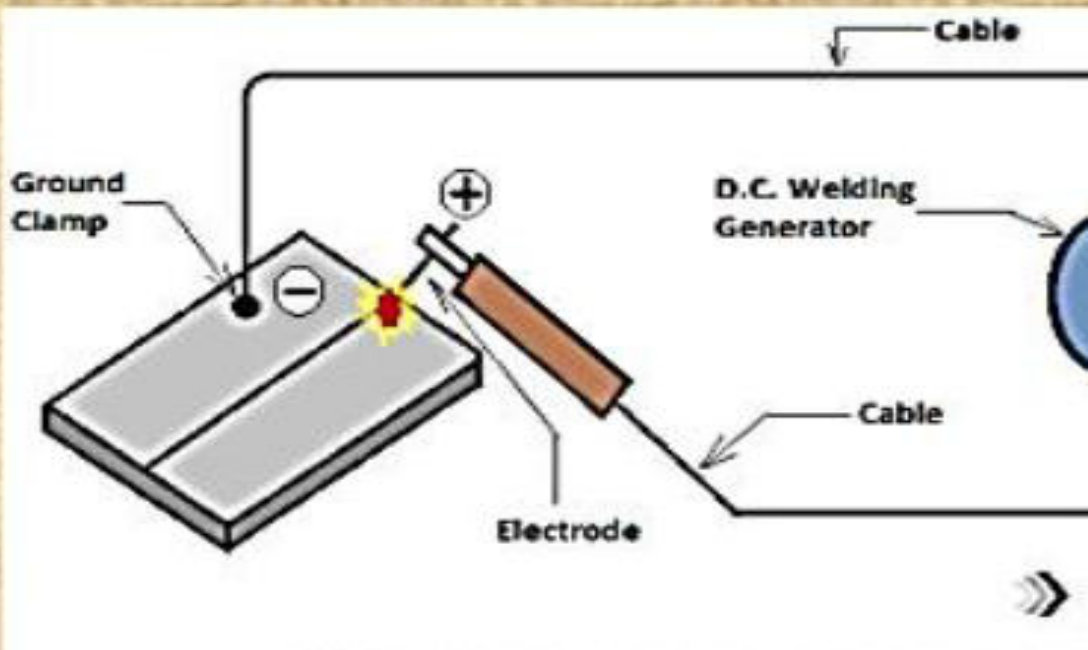
straight polarity the electrode is nnected to the negative and the rk to the positive terminal of the wer source.



ELECTRODE NEGATIVE / STRAIGHT POLARITY (DCEN)

Reverse polarity / electrode positive (DCEP):

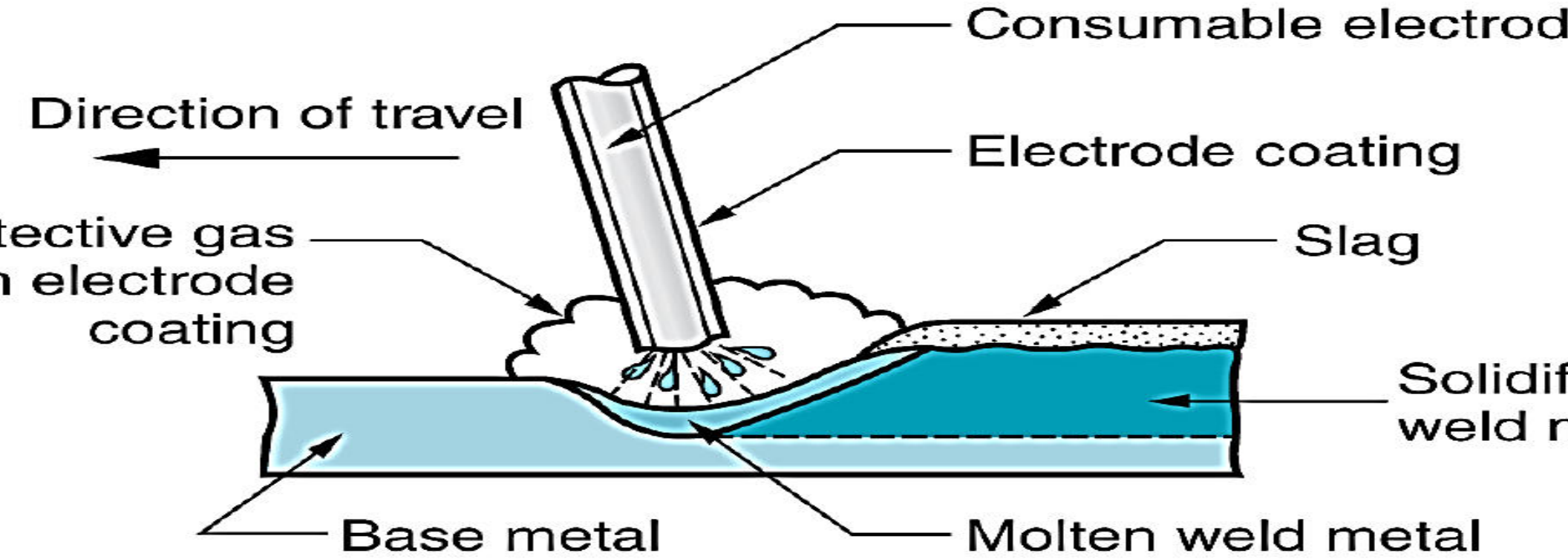
In reverse polarity the electrode is connected to the positive and the work to the negative terminal of the power source.



ELECTRODE POSITIVE / REVERSE POLARITY (DCEP)

Shielded metal arc welding (SMAW) is a commonly used arc welding process manually carried by welder(MMAW). It is an arc welding process in which heat for welding is produced through an electric arc set up between a flux coated electrode and the workpiece.

The flux coating of electrode decomposes due to arc heat and serves many functions, like weld metal protection, arc stability etc. Inner core of the electrode supply the filler material for making a weld.



SMAW

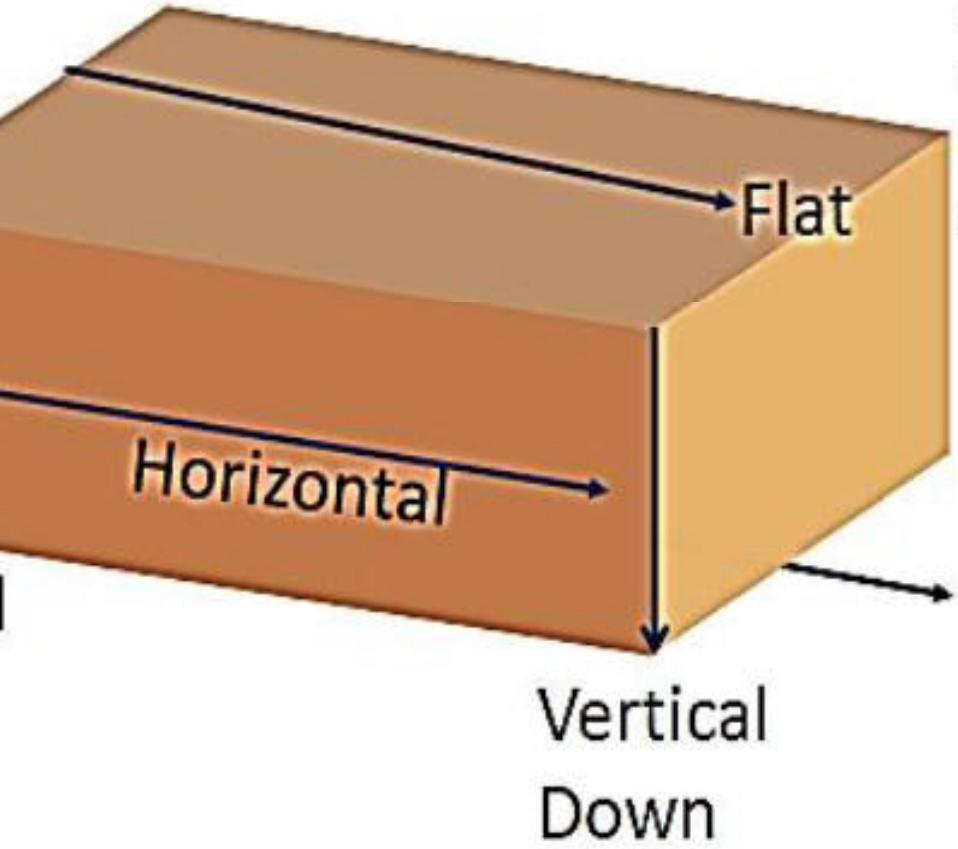
elding Stick in SMAW

mposition of filler metal usually close to base metal

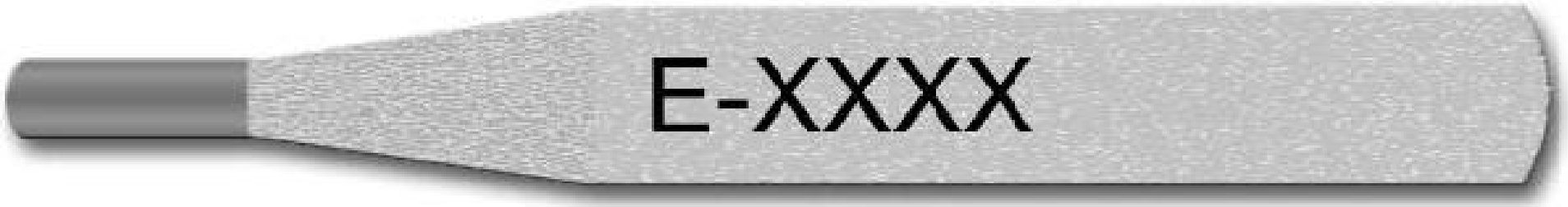
ting: powdered cellulose mixed with oxides and carbonates, and
ner by a silicate binder

lding stick is clamped in electrode holder connected to power so

e Welding Positions



Arrow shows the direction motion of the electrode / torch. The torch is held approximat normal to this direction.



E

(X)XX

X

ode

um Tensile Strength

wo Digits Of A Four Digit Or
hree Digits of a Five Digit Number

on

Positions

at & Horizontal Fillet

rtical Down

ity, Type of Coating,
Current Type, & Polarity


6011
6013
6013
7014

	Type of Coating	Capable of Producing Satisfactory Welds In Positions[a]	Type of Current[b]
eries — Miniumum Tensile Strength of Deposited Metal in As-Welded Condition 60,000 PSI			
	High cellulose sodium	F,V,OH,H	DC, Reverse polarity
	High cellulose potassium	F,V,OH,H	AC or DC, Electrode Po
	High titania sodium	F,V,OH,H	AC or DC, Electrode Ne
	High titania potassium	F,V,OH,H	AC or DC, Either Polarit
	Iron oxide titania potassium	F,V,OH,H	AC or DC, Either Polarit
	High iron oxide	H-Fillets, F	AC or DC, Electrode Ne
[c]	High iron oxide	H-Fillets, F	AC or DC, Either Polarit
	Iron powder, iron oxide	H-Fillets, F	AC or DC, Electrode Ne
eries — Minimum Tensile Strength of Deposited Metal in As-Welded Condition 70,000 PSI			
	Iron powder, titania	F,V,OH,H	AC or DC, Either Polarit
	Low hydrogen sodium	F,V,OH,H	DC, Electrode Positive
	Low hydrogen potassium	F,V,OH,H	AC or DC, Electrode Po
	Iron powder, low hydrogen	F,V,OH,H	AC or DC, Electrode Po
	Iron powder, titania	H-Fillets, F	AC or DC, Either Polarit
	High iron oxide, iron powder	H-Fillets, F	AC or DC, Electrode Ne
	Iron powder, low hydrogen	H-Fillets, F	AC or DC, Electrode Po
	Low hydrogen potassium, iron powder	F,OH,H,V-down	AC or DC, Electrode Po

The abbreviations are as follows: F–Flat; H–Horizontal; H-Fillets–Horizontal Fillets; V-down–V cal down; OH–Overhead; V–Vertical (For electrodes 3/16" and under, except 5/32" and under classifications E-7014, E-7015, E-7016 and E-7018).

Electrodes of the E-6022 classification are for single-pass welds only.

PRODUCTION TECHNOLOGY

(THEORY-1)

BY-PRASANNA MOHANTY
iiPM-SET KANSBAHAL

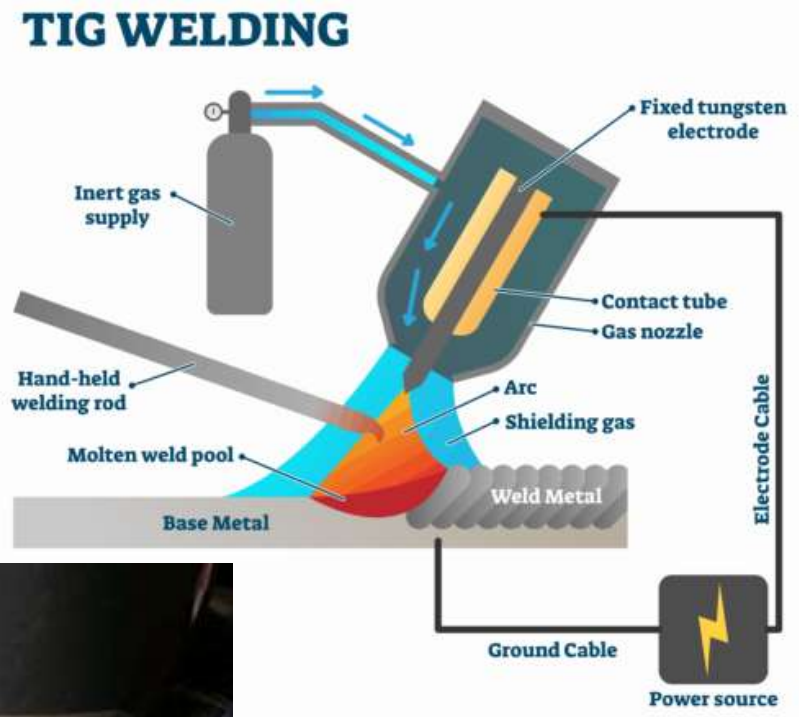
CLASSIFICATION OF WELDING

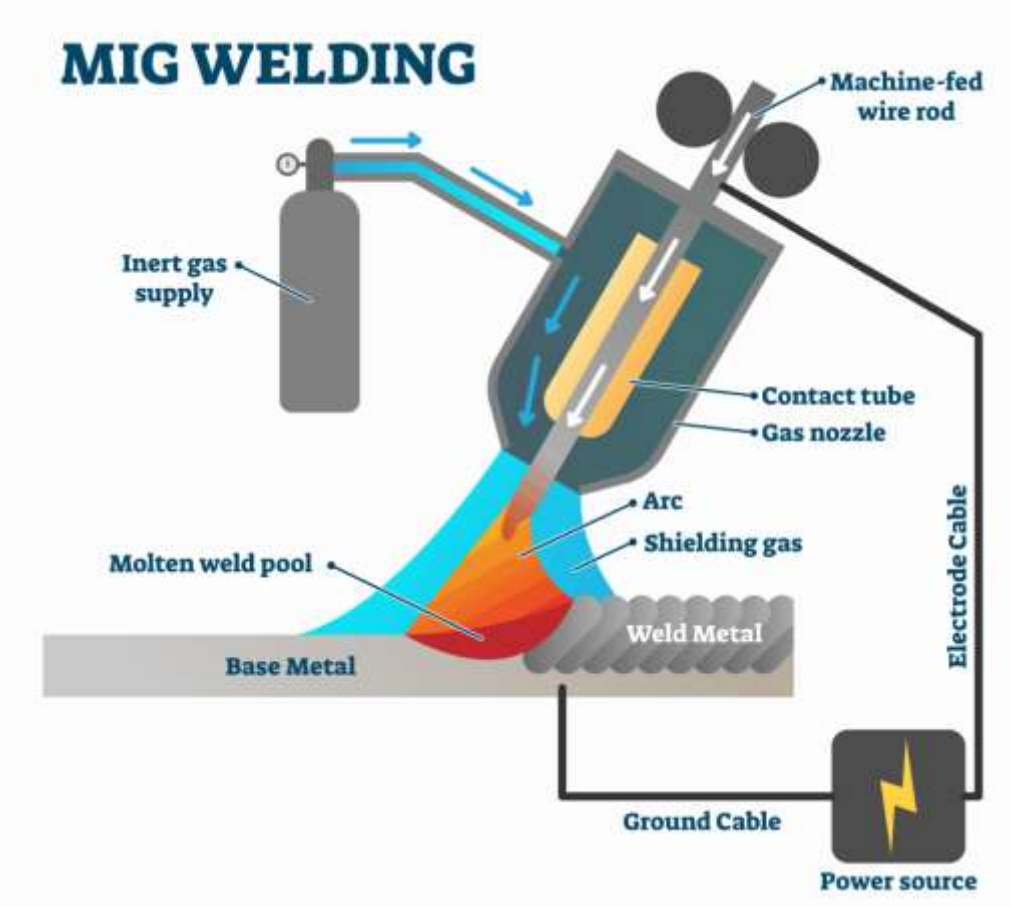
Welding processes

Arc welding

- Carbon Arc Welding
- Shielded Metal Arc Welding (SMAW)
- Submerged Arc Welding (SAW)
- Metal Inert Gas Welding (MIG, GMAW)
- Tungsten Inert Gas Arc Welding (TIG, GTAW)
- Electroslag Welding (ESW)
- Plasma Arc Welding (PAW)

- Resistance Welding (RW)
  - Spot Welding (RSW)
  - Flash Welding (FW)
  - Resistance Butt Welding (UW)
  - Seam Welding (RSEW)




MIG WELDING
Machine-fed wire rod
Inert gas supply
Contact tube
Gas nozzle
Arc
Shielding gas
Molten weld pool
Weld Metal
Base Metal
Electrode Cable
Ground Cable
Power source

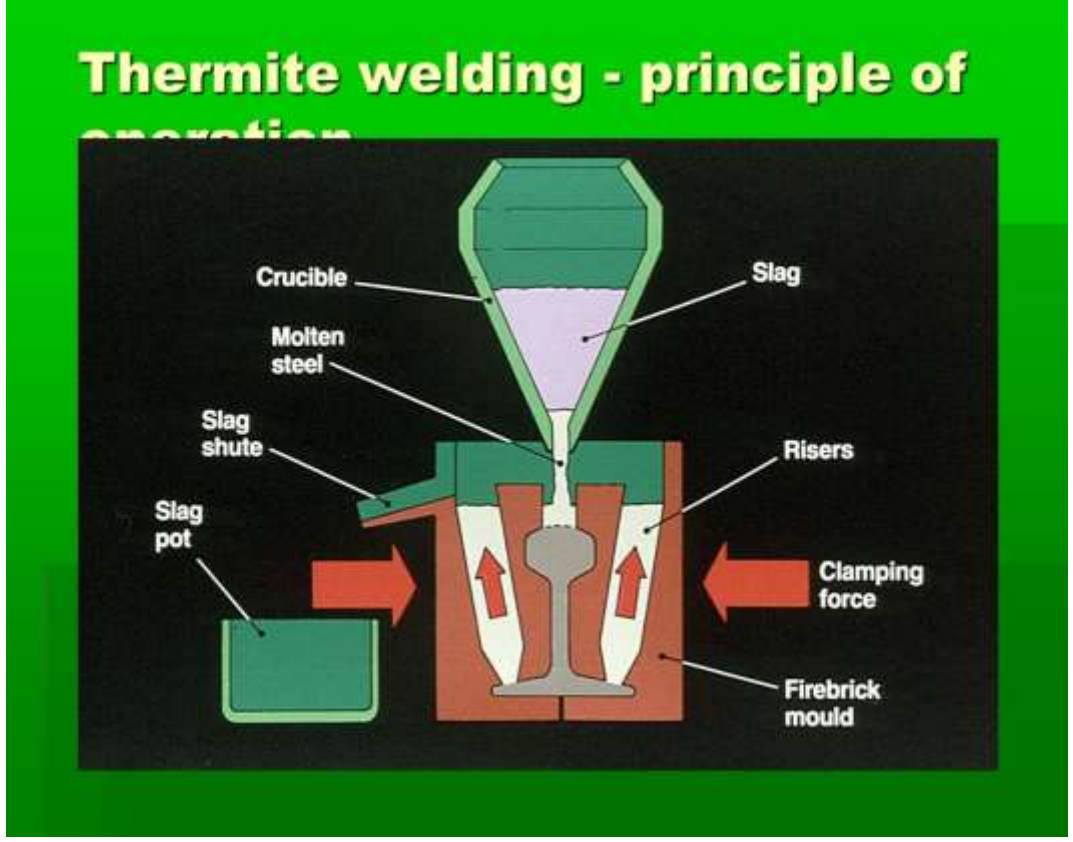
- **<u>Gas Welding (GW);</u>**

Oxyacetylene Welding (OAW)

Oxyhydrogen Welding (OHW)

Pressure Gas Welding (PGW)

- **<u>Solid State Welding (SSW)</u>**
  - Forge Welding (FOW)
  - Cold Welding (CW)
  - Friction Welding (FRW)
  - Explosive Welding (EXW)
  - Diffusion Welding (DFW)
  - Ultrasonic Welding (USW)
- **Thermite Welding (TW)**
- **Electron Beam Welding (EBW)**
- **Laser Welding (LW)**



Oxyacetylene Welding (OAW)

- **Oxyacetylene Welding** is a Gas Welding process using a combustion mixture of acetylene (C_2H_2) and oxygen (O_2) for producing gas welding flame.

  Oxyacetylene flame has a temperature of about 6000°F (3300°C). Combustion of acetylene proceeds in two stages:

  1. Inner core of the flame. $C_2H_2 + O_2 = 2CO + H_2$

  2. Outer envelope of the flame: $CO + H_2 + O_2 = CO_2 + H_2O$

  Acetylene is safely stored at a pressure not exceeding 300 psi (2000 kPa) in special steel cylinders containing acetone. Outside of cylinder acetylene is used at a absolute pressure not exceeding 30 psi (206 kPa). Higher pressure may cause explosion.

- Welding is generally carried out using the neutral flame setting which has equal quantities of oxygen and acetylene.

- The oxidizing flame is obtained by increasing just the oxygen flow rate while the carburising flame is achieved by increasing acetylene flow in relation to oxygen flow.

- Because steel melts at a temperature above 1,500° C, the mixture of oxygen and acetylene is used as it is the only gas combination with enough heat to weld steel.

- However, other gases such as propane, hydrogen and coal gas can be used for joining lower melting point non-ferrous metals, and for brazing and silver soldering.

Neutral flame

Oxidising flame

Carburising flame

- Oxyacetylene equipment is portable and easy to use. It comprises oxygen and acetylene gases stored under pressure in steel cylinders.

- The cylinders are fitted with regulators and flexible hoses which lead to the blowpipe. Specially designed safety devices such as flame traps are fitted between the hoses and the cylinder regulators.

- The flame trap prevents flames generated by a 'flashback' from reaching the cylinders; principal causes of flashbacks are the failure to clean the hoses and overheating of the blowpipe nozzle.

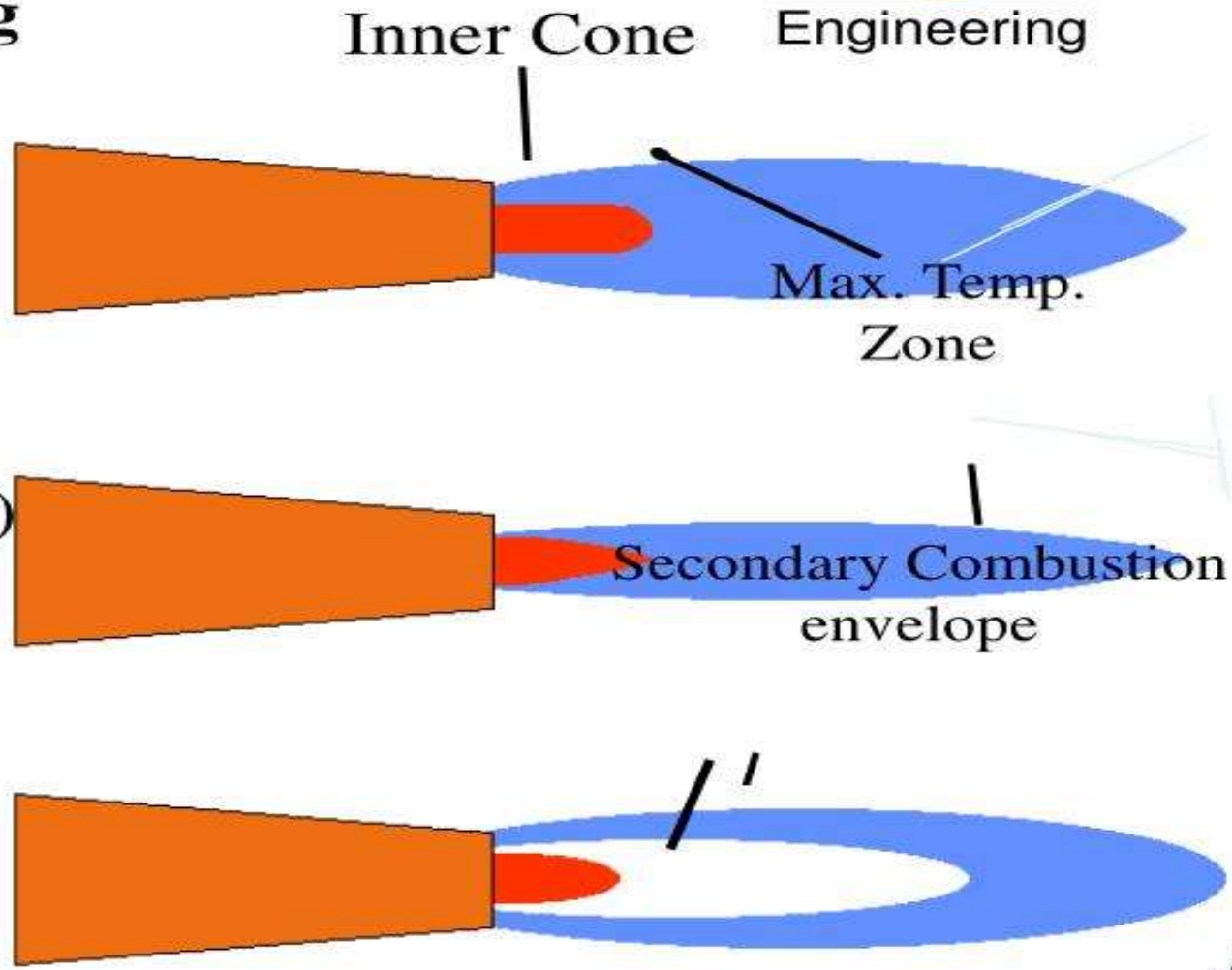
The Oxy-acetylene welding Flame

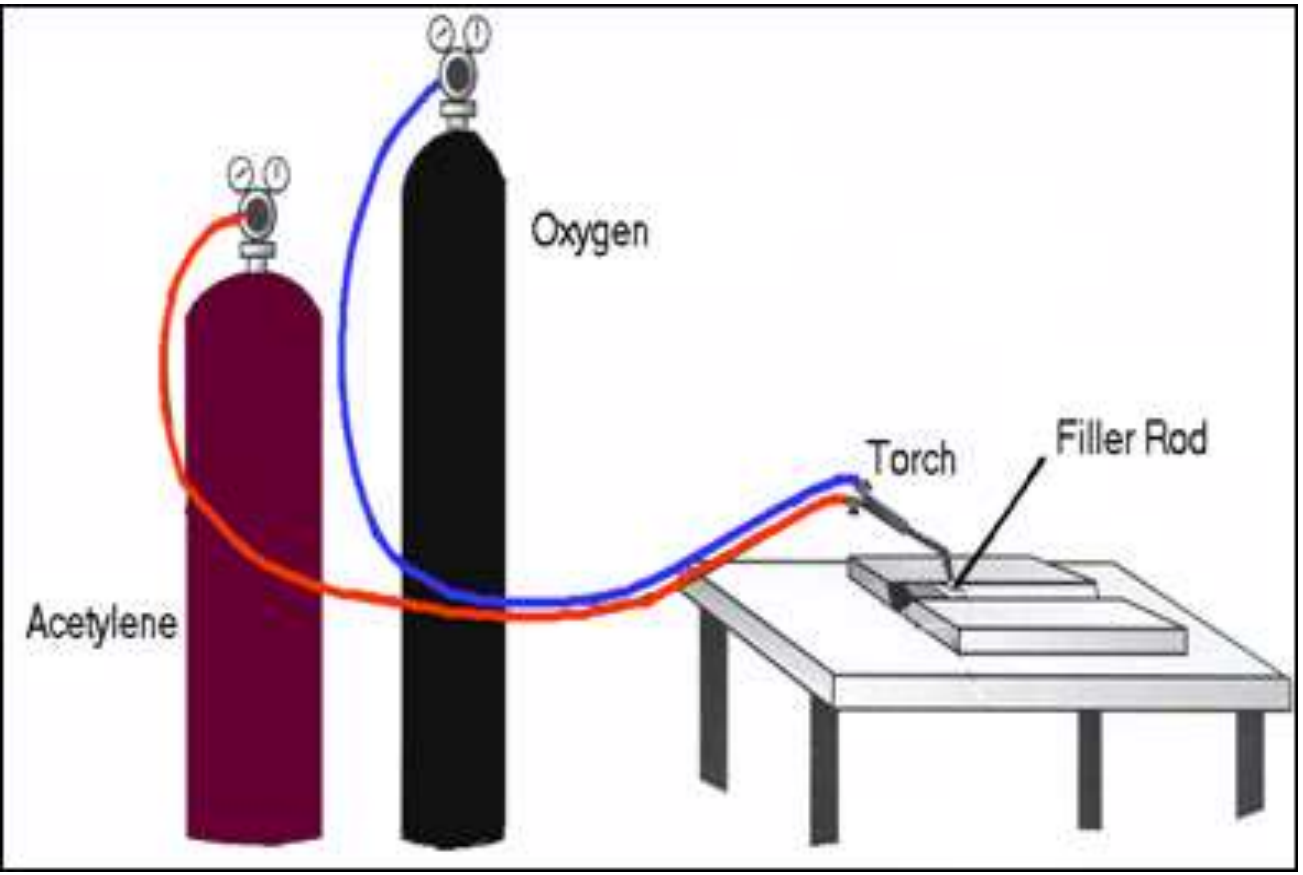
Engineering

Reducing or Carburizing
Excess acetylene (0.9:1)
(Alloy steels and
aluminium alloys)

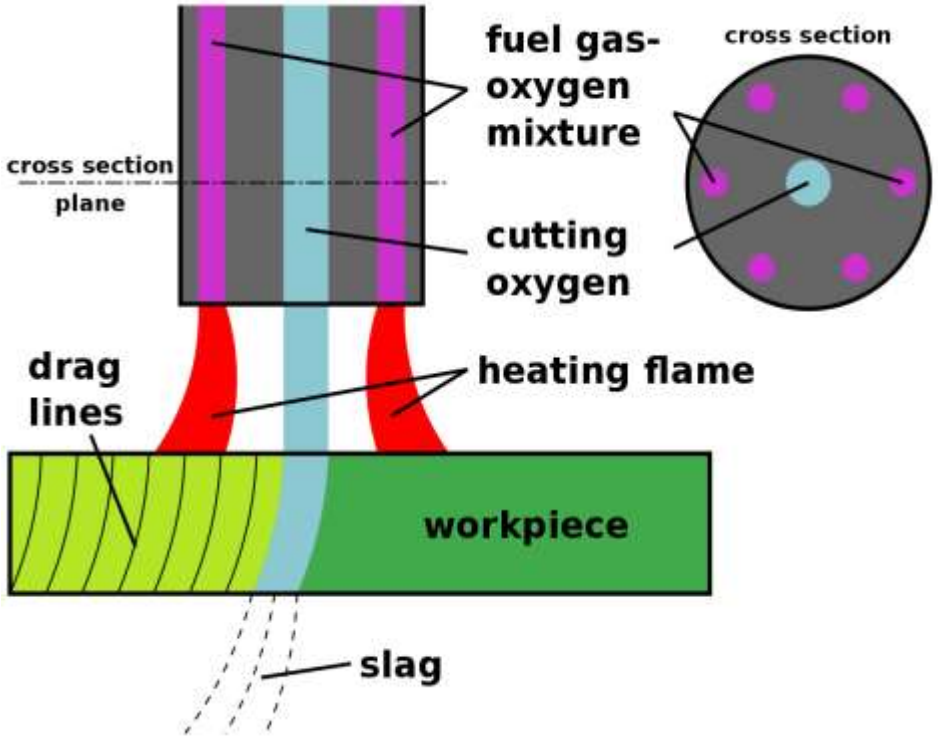
Oxidizing
Excess oxygen (1.5:1)
(Brasses, Bronzes, copper)

Neutral
Equal acetylene & oxygen
(low carbon steel, mild
steels).




Oxygen
Acetylene
Torch
Filler Rod

- **The cutting process**
- Basically, a mixture of oxygen and the fuel gas is used to preheat the metal to its 'ignition' temperature which, for steel, is 700°C - 900°C (bright red heat) but well below its melting point.
- A jet of pure oxygen is then directed into the preheated area instigating a exothermic chemical reaction between the oxygen and the metal to form iron oxide or slag. The oxygen jet blows away the slag enabling the jet to pierce through the material and continue to cut through the material.

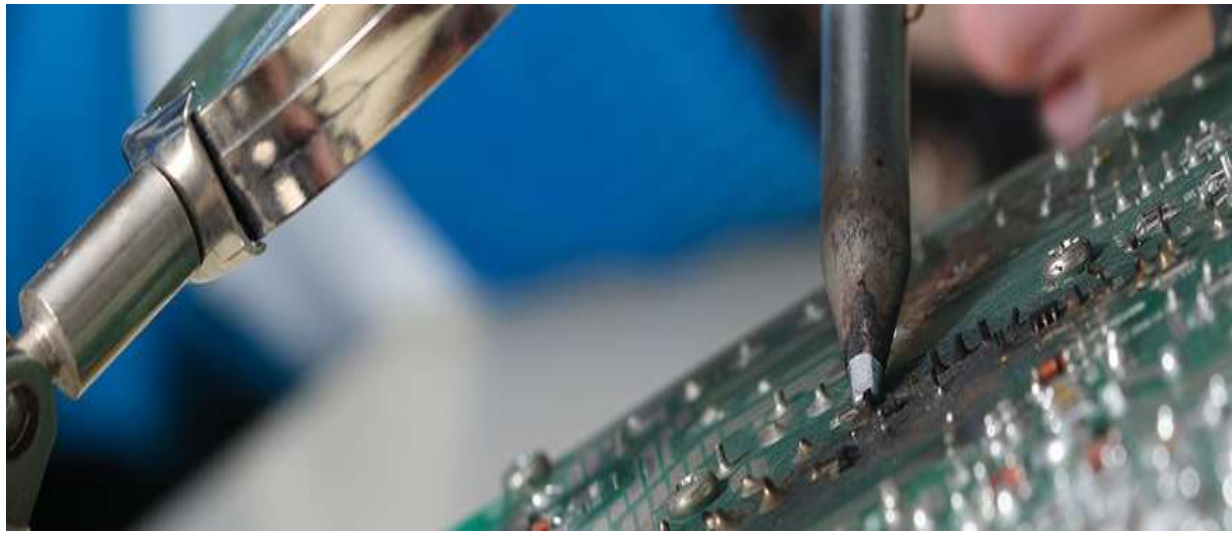


Soldering vs Brazing

Comparison Chart

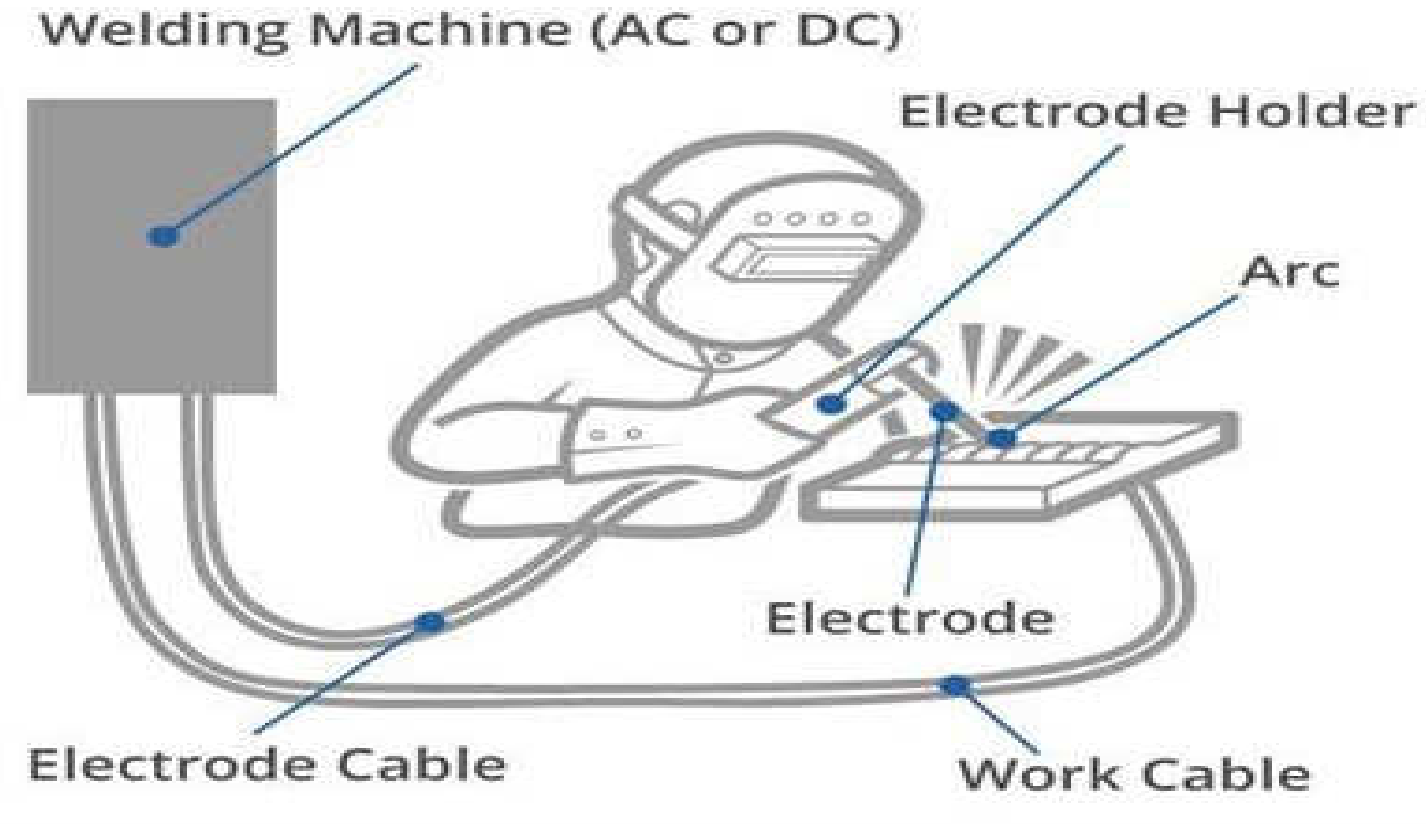
Soldering	Brazing
It is a low-temperature analog to brazing.	It is used to join a wide variety of similar or dissimilar metals.
It uses filler alloys with melting temperatures below 450 °C (840 °F).	It is done at temperatures above 450 °C but below the critical temperature of metal.
It is mainly used in electronic industries to form a permanent connection between the electronic components.	It is mainly used to join all kinds of metals used in electronic circuitry, pipe fittings, automotive
Base metal does not require preheating.	Base metal requires preheating.
Soldering creates stronger joints.	The joints are relatively weaker than with soldering.
The soldering process is comparatively cheaper than other metal-joining methods.	The brazing process is a bit pricey than soldering.

DB Difference Between.net



Arc welding process

elding is a fusion welding process used to join metals. An electric arc f
C or DC power supply creates an intense heat of around 6500°F which
netal at the join between two work pieces.



rc can be either manually or mechanically guided along the line of the
e the electrode either simply carries the current or conducts the curren
s into the weld pool at the same time to supply filler metal to the join.

use the metals react chemically to oxygen and nitrogen in the air when
ed to high temperatures by the arc, a protective shielding gas or slag is
nimize the contact of the molten metal with the air. Once cooled, the
en metals solidify to form a metallurgical bond.

What are the Different Types of Arc ding?

process can be categorised into two different types; consumable and n
umable electrode methods.

umable Electrode Methods

l Inert Gas Welding (MIG) and

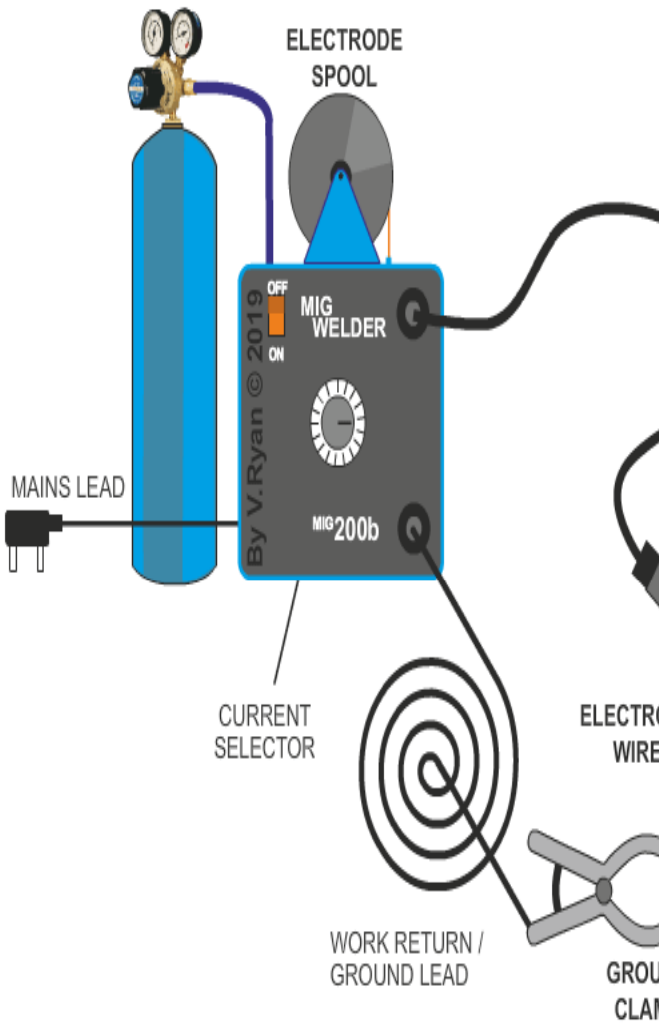
l Inert Gas (MIG) and Metal Active Gas (MAG) welding are gas metal a
ing (GMAW) processes that use heat created from a DC electric arc bet
sumable metal electrode and a workpiece which melt together to crea
pool that fuses to form a join.

(Metal Inert Gas) welding is a welding process in which an electric arc
een a consumable wire electrode and the work piece. This process use
gases or gas mixtures as the shielding gas. Argon and helium are typica
for the MIG welding of non-ferrous metals such as aluminium.

/MAG is similar to MMA in that heat for
ing is produced by forming an arc between a
umable metal electrode and the workpiece;
lectrode melts to form the weld bead.

main difference is that the metal electrode is
all diameter wire fed through the contact tip
a wire feeding spool gun, while a shielding
fed through the welding torch. As the wire is
nuously fed, the manual process is
etimes referred to as semi-automatic welding.

and MAG welding both use gas bottles to
de the shielding gas and compatible filler
rials. For example, to weld aluminium, an
inium wire should be used, whereas steel
welding would require an appropriate steel
wire.



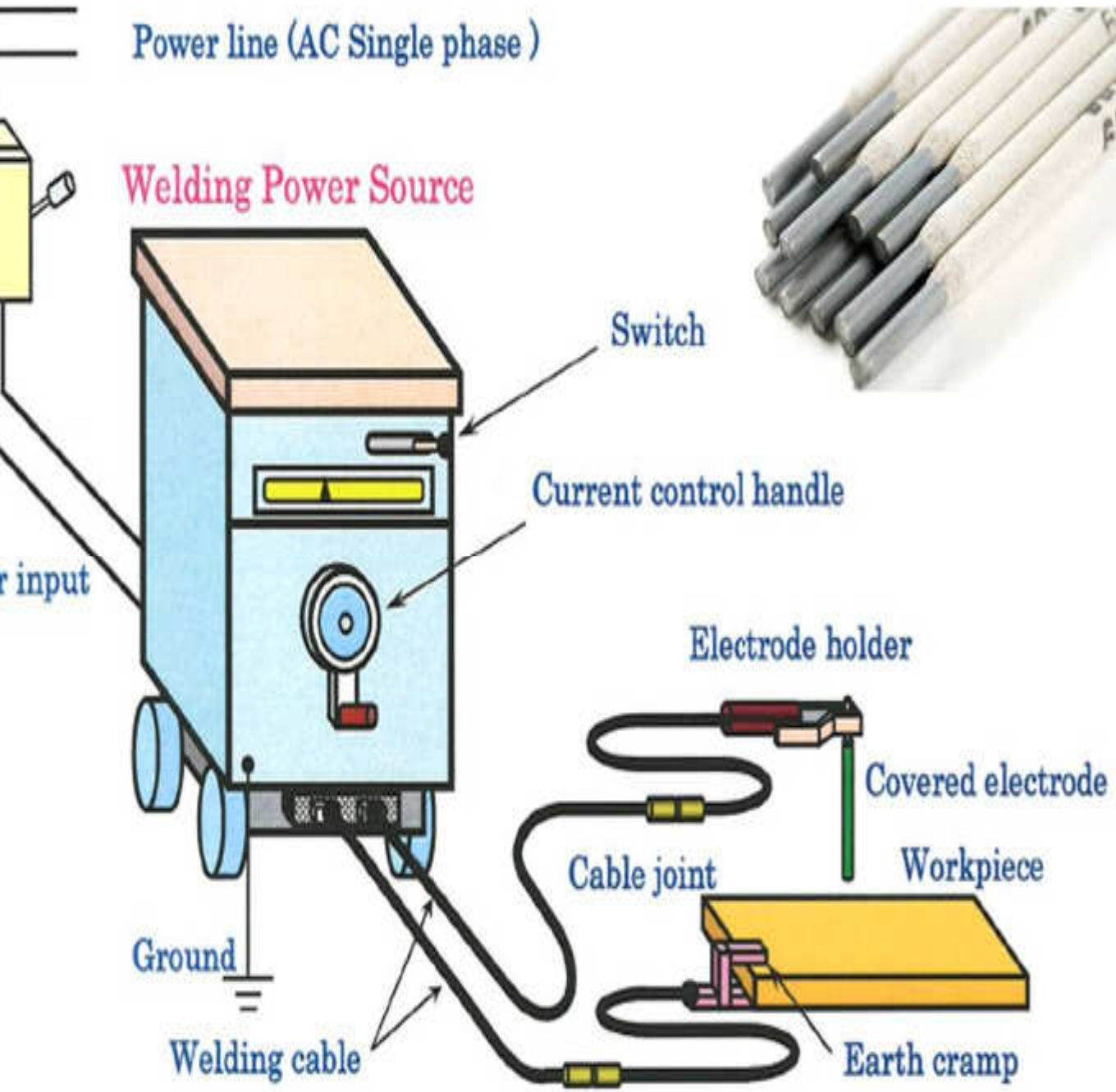
NUAL METAL ARC WELDING (MMA, AW OR STICK WELDING)

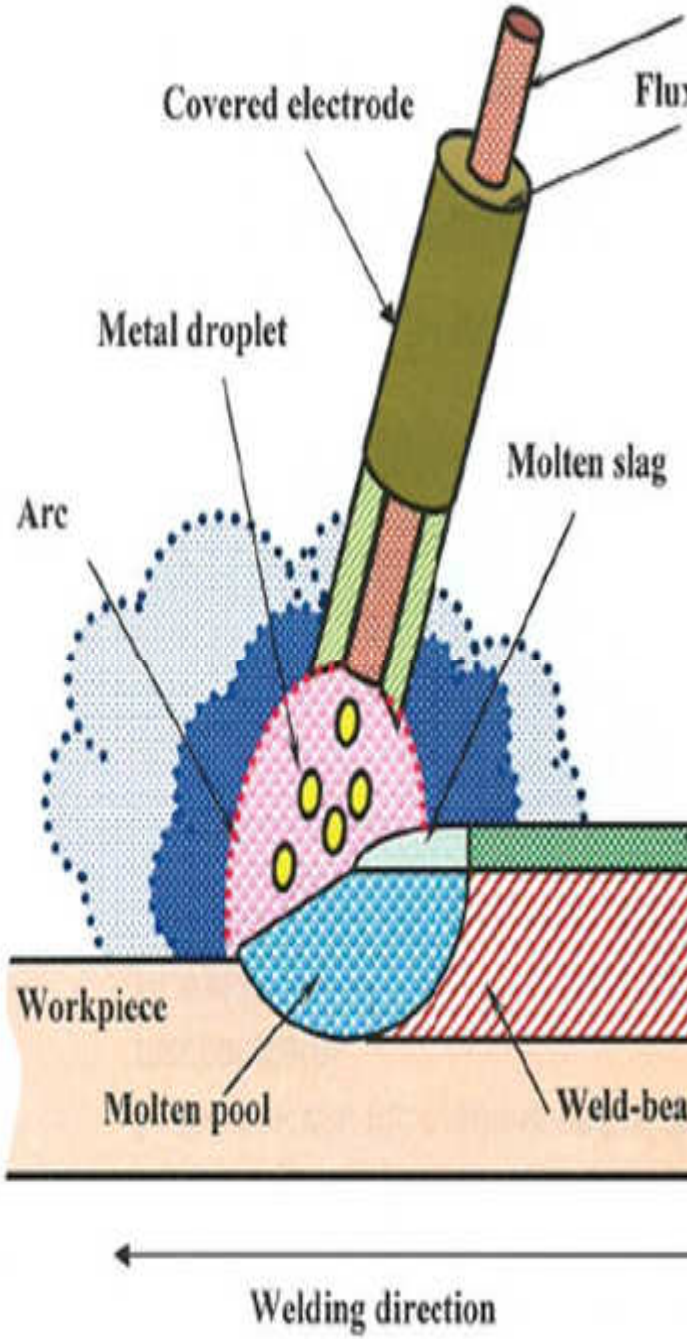
ual metal arc welding (MMA or MMAW), also known as shielded metal ing (SMAW), flux shielded arc welding or stick welding, is a process wh rc is struck between an electrode flux coated metal rod and the work p the rod and the surface of the work piece melt to create a weld.

AW is a welding process that creates an electric arc between a hand he coated, consumable filler wire and the work piece.

rc heat melts the parent metal and filler wire. The flux coating breaks e arc to produce a gaseous shield that excludes atmospheric gases from zone. The flux coating also provides a de-oxidizing action and forms a e cooling weld.

MMAW welding process needs a suitable and constant current power s r DC), a hand piece, a work clamp, leads and flux-covered consumable rodes.


Power line (AC Single phase)
Welding Power Source
Switch
Current control handle
r input
Electrode holder
Covered electrode
Cable joint
Workpiece
Ground
Welding cable
Earth cramp


Covered electrode
Metal droplet
Molten slag
Arc
Workpiece
Molten pool
Weld-bea
Welding direction