Production Engineering

University of Basrah

Mechanical Engineering Department

Production Engineering Course

(BEM125)

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Delivery Plan (Weekly Syllabus) المنهاج الاسبوعي النظري	
	Material Covered
Week 1	Engineering Materials: Classification of engineering materials, Mechanical properties of materials
Week 2	Engineering Materials: Destructive and non-destructive tests
Week 3	Ferrous Metal Production: Production of cast iron
Week 4	Ferrous Metal Production: Steel production
Week 5	Non-Ferrous Metal Production: Copper metal production
Week 6	Non-Ferrous Metal Production: Aluminum metal production
Week 7	Non-Ferrous Metal Production: Zinc, lead, and tin production
Week 8	Plastic Industry: Properties and classification of plastics
Week 9	Plastic Industry: Plastics production
Week 10	Ceramic Industry: Classification of ceramics, Ceramics production
Week 11	Cold and Hot Working: Principles of cold and hot working processes
Week 12	Hot Rolling: Principles of rolling processes, Rolling types, Force analysis in rolling
Week 13	Drawing Process: Types of hot drawing, Drawing analysis, Hot Extrusion
Week 14	Welding technology
Week 15	Powder Metallurgy: Principles of powder metallurgy, Powder metallurgy production Casting: Casting types, Casting sandy process
Week 16	**Preparatory week before the final Exam**

Lecture 01 Material Properties and Tensile Test

1.1 PROPERTIES OF METALS

The important properties of an engineering material determine the utility of the material which influences quantitatively or qualitatively the response of a given material to imposed stimuli and constraints. The various engineering material properties are given as under.

1. Physical properties
2. Chemical properties
3. Thermal properties
4. Electrical properties
5. Magnetic properties
6. Optical properties
7. Mechanical properties

1.1.1 Physical Properties

The important physical properties of the metals are density, color, size, and shape (dimensions), specific gravity, porosity, luster etc.

1.1.2 Chemical Properties

The study of chemical properties of materials is necessary because most of the engineering materials, when they meet other substances with which they can react, suffer from chemical deterioration of the surface of the metal. Some of the chemical properties of the metals are corrosion resistance, chemical composition and acidity or alkalinity.

1.1.3 Thermal Properties

The study of thermal properties is essential to know the response of metal to thermal changes i.e., lowering or raising of temperature. Different thermal properties are thermal conductivity, thermal expansion, specific heat, melting point, thermal diffusivity.

1.1.4 Electrical Properties

The various electrical properties of materials are conductivity, temperature coefficient of resistance, dielectric strength, resistivity, and thermoelectricity.

1.1.5 Magnetic Properties

Magnetic properties of materials arise from the spin of the electrons and the orbital motion of electrons around the atomic nuclei. Many materials except ferromagnetic material which can form permanent magnet, exhibit magnetic affects only when subjected to an external electro-magnetic field.

1.1.6 Optical Properties

The main optical properties of engineering materials are refractive index, absorptivity, absorption co-efficient, reflectivity and transmissivity.

1.1.7 Mechanical Properties

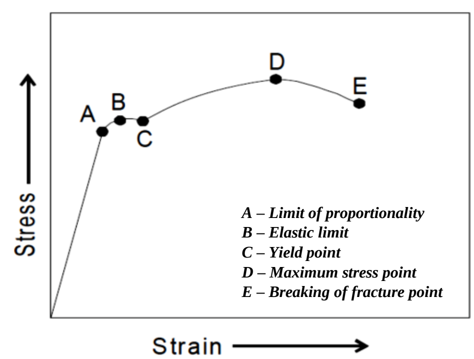
The mechanical properties of materials are of great industrial importance in the design of tools, machines, and structures

1. **Elasticity**

   It is defined as the property of a material to regain its original shape after deformation when the external forces are removed. It can also be referred as the power of material to come back to its original position after deformation when the stress or load is removed.

2. **Proportional limit**

   It is defined as the maximum stress under which a material will maintain a perfectly uniform rate of strain to stress.



3. **Elastic limit**

   Many metals can be put under stress slightly above the proportional limit without taking a permanent set. The greatest stress that a material can endure without taking up some permanent set is called elastic limit.

4. **Yield point**

   At a specific stress, ductile metals particularly cease, resisting tensile forces. This means, the metals flow and a relatively large permanent set takes place without a noticeable increase in load. This point is called yield point.

5. **Strength**

   Strength is defined as the ability of a material to resist the externally applied forces with breakdown or yielding. This property of material therefore determines the ability to withstand stress without failure. Strength varies according to the type of loading. It is always possible to assess tensile, compressive, shearing, and torsional strengths. The maximum stress that any material can withstand before destruction is called its ultimate strength.

6. **Stiffness**

   It is defined as the ability of a material to resist deformation under stress. The resistance of a material to elastic deformation or deflection is called stiffness or rigidity.

7. **Plasticity**

   Plasticity is defined the mechanical property of a material which retains the deformation produced under load permanently. This property of the material is required in forging, in stamping images on coins and in ornamental work. Plastic deformation takes place only after the elastic range of material has been exceeded.

8. **Ductility**

   Ductility is termed as the property of a material enabling it to be drawn into wire with the application of tensile load. A ductile material must be strong and plastic. The ductility is usually measured by the terms, percentage elongation and percent reduction in area which is often used as empirical measures of ductility.

9. **Brittleness**

   Brittleness is the property of a material opposite to ductility. It is the property of breaking of a material with little permanent distortion. The materials having less than 5% elongation under loading behavior are said to be brittle materials. Brittle materials when subjected to tensile loads, snap off without giving any sensible elongation. Glass, cast iron, brass and ceramics are considered as brittle material.

10. **Hardness**

   Hardness is defined as the ability of a metal to cut another metal. A harder metal can always cut or put impression to the softer metals by virtue of its *hardness. It is a very important property of the metals and has a wide variety of meanings.*

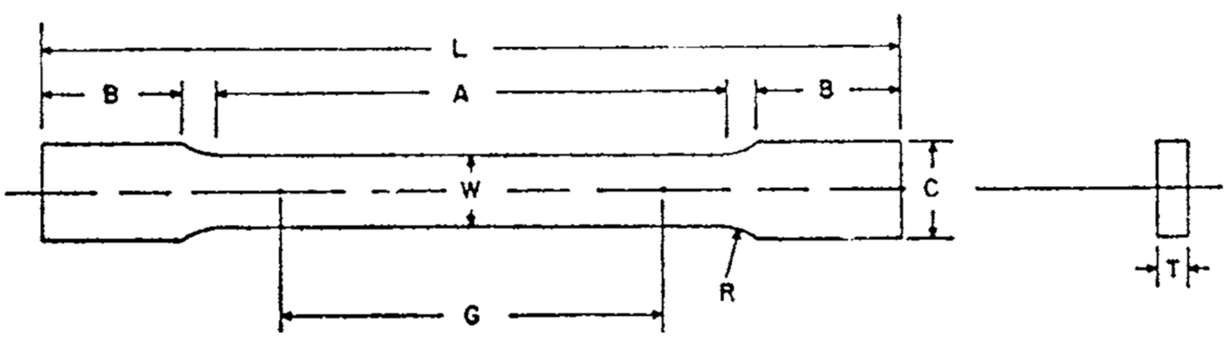
1.2 Destructive and Non-Destructive Tests

The purpose of metal testing is estimating the behavior of metal under loading (tensile, compressive, shear, torsion and impact, cyclic loading etc.). Also, it is very important that the material shall be tested so that their mechanical properties especially their strength can be assessed and compared.

- Destructive tests of metal include various mechanical tests such as tensile, compressive, hardness, impact, fatigue, and creep testing.
- Non-destructive testing includes visual examination, radiographic tests, ultrasound test, liquid penetrating test and magnetic particle testing.

1.2.1 Tensile test

A tensile test is carried out on standard tensile test specimen in universal testing machine. A standard test specimen for tensile test is shown in Fig. 1.1 according to ASTM E8/E8M standard while Fig. 1.2 shows a schematic set up of universal testing machine reflecting the test specimen griped between two cross heads. Fig. 1.3 shows the stress strain curve for ductile material. Fig. 1.4 shows the properties of a ductile material.



Tensile Test Plate Specimen [ASTM E8/E8M]	
Item	mm
G—Gauge length	200
W—Width	40
T—Thickness	-
R—Radius of fillet, min	25

L—Overall length, min	450
A—Length of reduced section, min	225
B—Length of grip section, min	75
C—Width of grip section, approximate	50

Fig. 1.1 Tensile test specimen

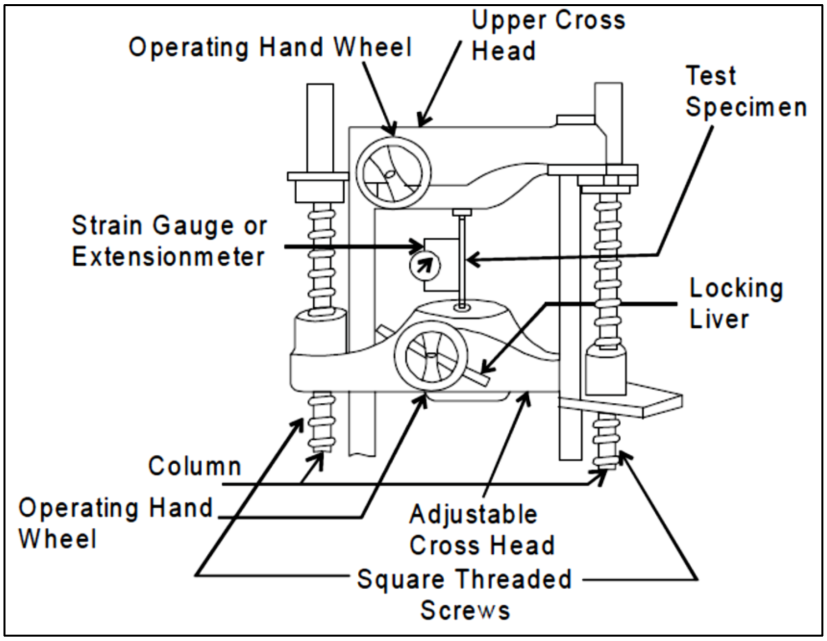


Fig. 1.2 Stress strain curve for ductile material

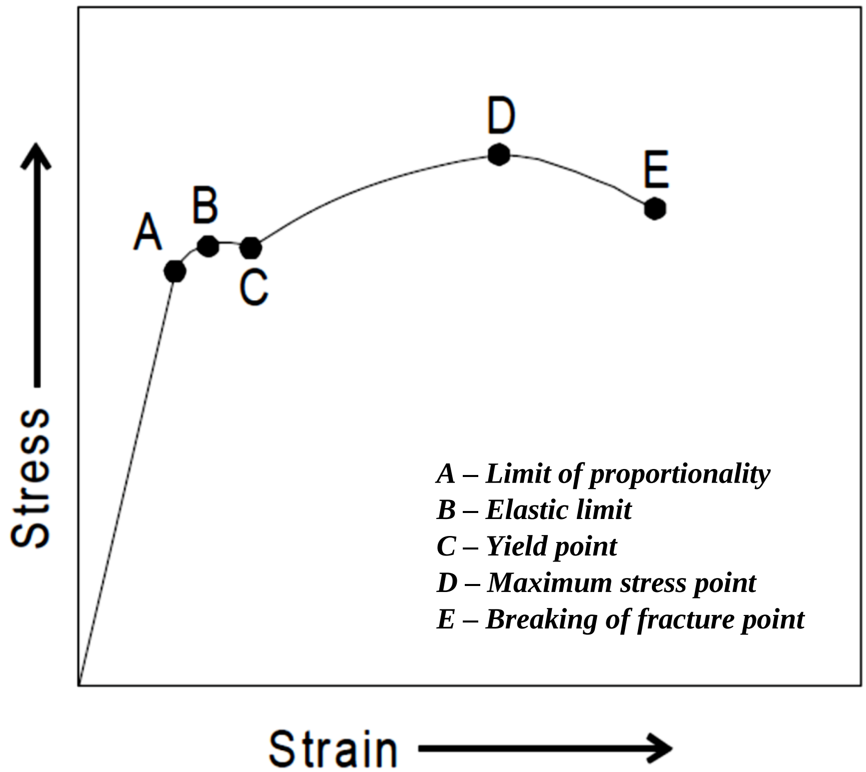


Fig. 1.3 Stress strain curve for ductile material

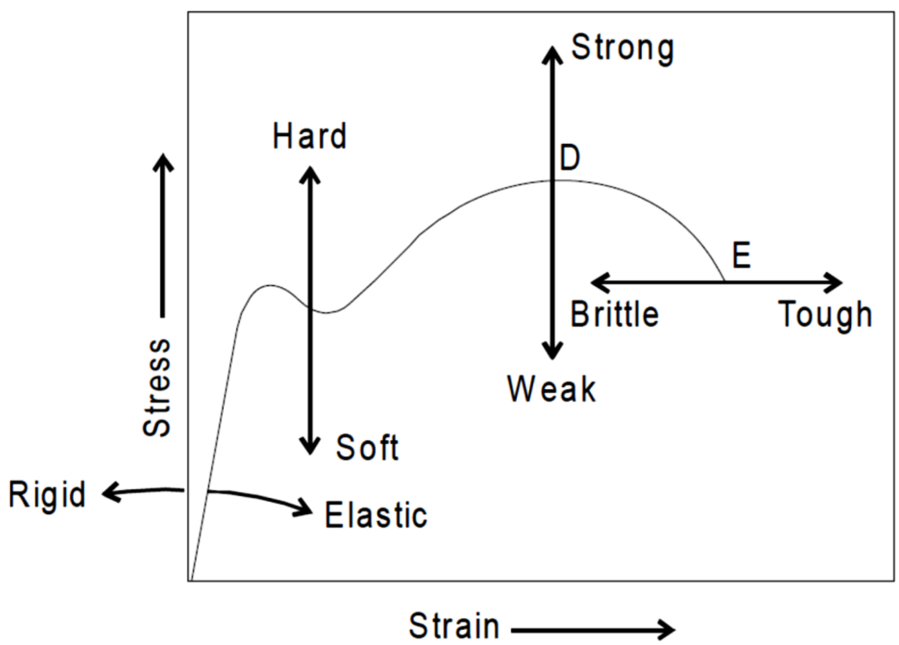


Fig. 1.4 Properties of a ductile material

Tensile Strain: The ratio of increase in length to the original length.
The stress can be calculated by two formulae which are distinguished as engineering stress and true stress, respectively.

Engineering Stress $\sigma = P/A_o$

P = load (N)
A_o = original cross-sectional area (m^2)

True Stress $\sigma_T = P/A_i$

P = load (N)
A_i = instantaneous cross-sectional area (m2)

Strain: is the ratio of change in dimension to the original dimension.

Engineering Strain $\varepsilon = (l_f - l_o)/ l_o = \Delta l / l_o$

l_f = final gage length (m)
l_o= original gage length (m)

True Strain $\varepsilon T = \ln (l_i / l_o) = \ln (1 + \varepsilon)$

l_i = instantaneous gage length (m)
l_o= original gage length (m)
ln = natural logarithm

Hook's Law: states that when a material is loaded within elastic limit (up to proportional limit), stress is proportional to strain.
Compressive Strain: The ratio of decrease in length to the original length.
Modulus of Elasticity: The ratio of tensile stress to tensile strain or compressive stress to compressive strain. It is denoted by E. It is also called as Young's modulus of elasticity.

E = Tensile Stress/Tensile Strain

Modulus of Rigidity: The ratio of sheer stress to shear strain. It is denoted by G.

G = Shear Stress/Shear Strain

YouTube: https://youtu.be/Lg0JnsNyON8

Lecture 02 Hardness Test and Impact Test

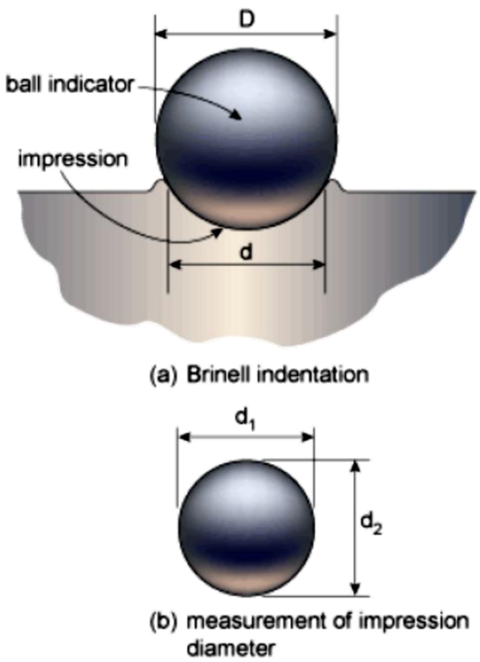
1.2.2 Testing of Hardness

It is a very important property of the metals and has a wide variety of meanings. It embraces many different properties such as resistance to wear, scratching, deformation, and machinability etc. It also means the ability of a metal to cut another metal. The hardness of a metal may be determined by the following tests.

a) Brinell hardness test
b) Rockwell hardness test
c) Vickers hardness (also called Diamond Pyramid) test

Brinell hardness test

Dr. J. A. Brinell invented the Brinell test in Sweden in 1900. The oldest of the hardness test methods in common use today, the Brinell test is frequently used to determine the hardness of forgings and castings. Therefore, Brinell tests are frequently done on large parts. The Brinell hardness number is a function of the test force divided by the curved surface area of the indent. The Brinell hardness test method consists of indenting the test material with a 10 mm diameter hardened steel or carbide ball. The average of the two diagonals is used in the following formula to calculate the Brinell hardness.



(a) Brinell indentation

(b) measurement of impression diameter

Metal Hardness Formula

$$BHN = \frac{2P}{\pi D\left(D - \sqrt{D^2 - d^2}\right)}$$

$BHN - Brinell\ Hardness\ Number$ in kg/mm^2
$P - load\ in\ kgf$
$D - steel\ ball\ diameter\ in\ mm$
$d - depression\ diameter\ in\ mm$

Fig. 1.5 Brinell hardness test

Brinell hardness for several materials	
Lead	5 -22 HB
Pure Aluminium	15 HB
Copper	35 HB
Hardened AW-6060 Aluminium	75 HB
Mild steel	120 HB
stainless steel annealed	200 HB
Hardened tool steel	600–900 HB

Vickers Hardness Test

The Vickers hardness test method consists of indenting the test material with a diamond indenter, in the form of a right pyramid with a square base and an angle of 136 degrees between opposite faces subjected to a load of 1 to 100 kgf. The full load is normally applied for 10 to 15 seconds. The two diagonals of the indentation left in the surface of the material after removal of the load are measured using a microscope and their average calculated. The area of the sloping surface of the indentation is calculated. The Vickers hardness is the quotient obtained by dividing the kgf load by the square mm area of indentation.

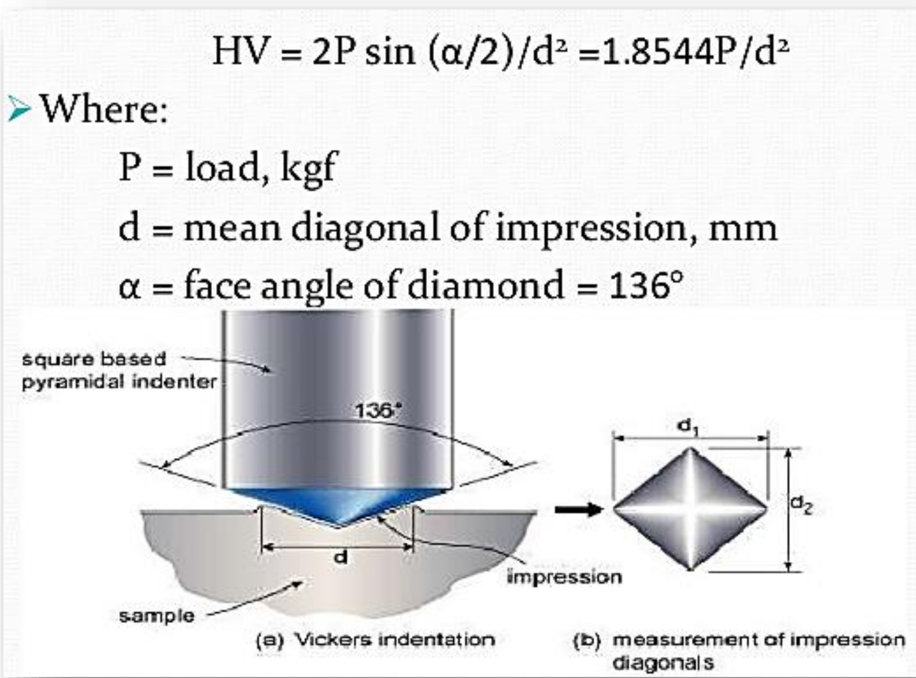


Fig. 1.6 Vickers hardness test

Vickers hardness for several materials	
Material	Value
316L stainless steel	140HV30
347L stainless steel	180HV30
Carbon steel	120HV5
Iron	80HV5
Martensite	1000HV
Diamond	10000HV

Rockwell hardness test

Stanley P. Rockwell invented the Rockwell hardness test. Rockwell hardness test enabled the user to perform an accurate hardness test on a variety of sized parts in just a few seconds. There are two types of Rockwell tests:

1. Rockwell: the minor load is 10 kgf, the major load is 60, 100, or 150 kgf.
2. Superficial Rockwell: the minor load is 3 kgf and major loads are 15, 30, or 45 kgf.

In both tests, the indenter may be either a diamond cone or steel ball, depending upon the characteristics of the material being tested.

The principles of the Rockwell Test are:

1. The indenter moves down into position on the part surface
2. A minor load is applied, and a zero-reference position is established
3. The major load is applied for a specified time (dwell time) beyond zero
4. The major load is released leaving the minor load applied

The resulting Rockwell number represents the difference in depth from the zero-reference position as a result of the application of the major load.

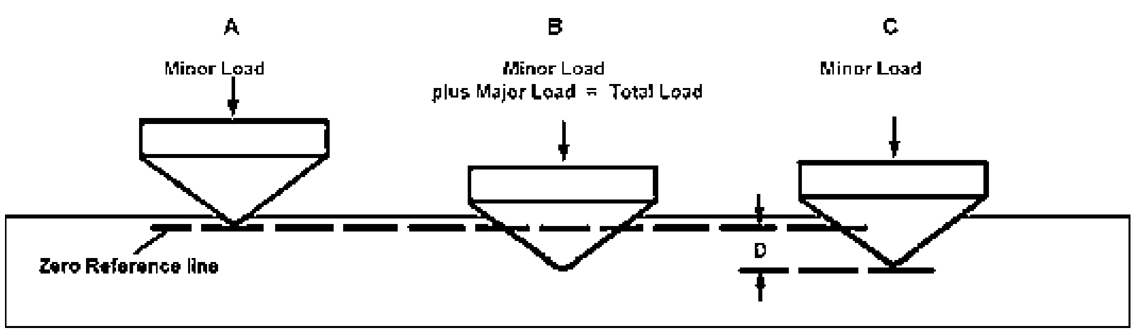


Fig. 1.6 Rockwell hardness test

Hardness vs. Minimum Thickness						
	Rockwell Superficial Hardness Scales			Rockwell Regular Hardness Scales		
	15-N	30-N	45-N	A	D	C
	15 KFG	30 KFG	45 KFG	60 KFG	100 KFG	150 KFG
Thickness in In. (mm)	N Brale indenter			Brale indenter		
0.006 (0.15)	92	-	-	-	-	-
0.008 (0.20)	90	-	-	-	-	-
0.010 (0.25)	88	-	-	-	-	-
0.012 (0.30)	83	82	77	-	-	-
0.014 (0.36)	76	78.5	74	-	-	-
0.016 (0.41)	68	74	72	86	-	-
0.018 (0.46)	X	66	68	84	-	-
0.020 (0.51)	X	57	63	82	77	-
0.022 (0.56)	X	47	58	79	75	69
0.024 (0.61)	X	X	51	76	72	67
0.026 (0.66)	X	X	37	71	68	65
0.028 (0.71)	X	X	20	67	63	62
0.030 (0.76)	X	X	X	60	58	57
0.032 (0.81)	X	X	X	X	51	52
0.034 (0.86)	X	X	X	X	43	45
0.036 (0.91)	X	X	X	X	X	37
0.038 (0.96)	X	X	X	X	X	28
0.040 (1.02)	X	x	X	X	X	20

Table 1 Rockwell hardness test values

1.2.3 Impact Test

When metal is subjected to suddenly applied load or stress, it may fail. In order to assess the capacity of metal to stand sudden impacts, the impact test is employed. The impact test measures the energy necessary to fracture a standard notched bar by an impulse load and as such is an indication of the notch toughness of the material under shock loading. Izod test and the Charpy test are commonly performed for determining impact strength of materials. These methods employ same machine and yield a quantitative value of the energy required to fracture a special V notch shape metal.

The beams may be simply loaded (Charpy test) or loaded as cantilevers (Izod test). Fig. 1.7 shows the impact testing set up arrangement for Charpy test.

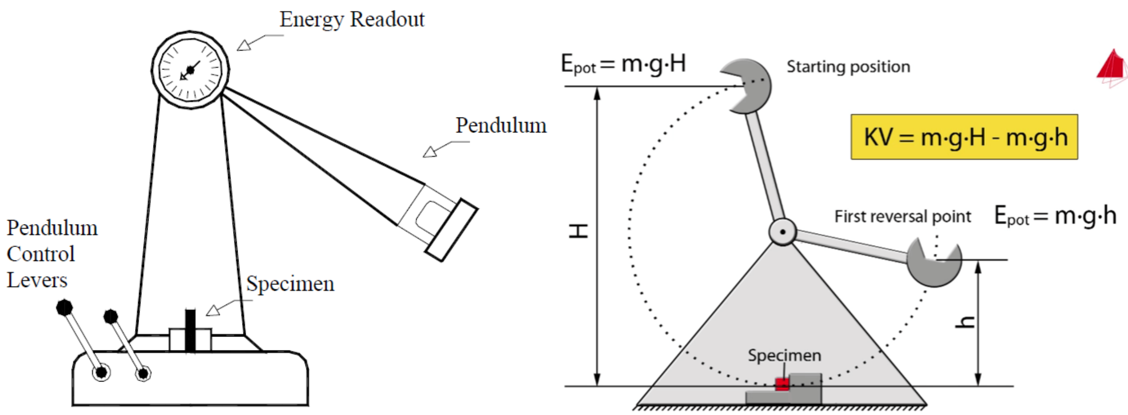


Fig. 1.7 Impact test

Charpy tests show whether a metal can be classified as being either brittle or ductile. This is particularly useful for ferritic steels that show a ductile to brittle transition with decreasing temperature. A brittle metal will absorb a small amount of energy when impact tested, a tough ductile metal absorbs a large amount of energy. The appearance of a fracture surface also gives information about the type of fracture that has occurred; a brittle fracture is bright and crystalline; a ductile fracture is dull and fibrous.

1.3 CHOICE OF MATERIALS

The choice of materials for the engineering purposes depends upon the following factors:

1. Availability of the materials,
2. Properties needed for meeting the functional requirements,
3. Suitability of the materials for the working conditions in service, and
4. The cost of the materials.

YouTube: https://youtu.be/NK1iRSMbSz0

Lecture 03: Ferrous Metal Production

1. Classification of Engineering Materials

Some commonly used engineering materials are broadly classified as shown in Fig. 2.1. Engineering materials may also be categorized into metals and alloys, ceramic materials, organic polymers, composites and semiconductors. The metal and alloys have tremendous applications for manufacturing the products required by the customers.

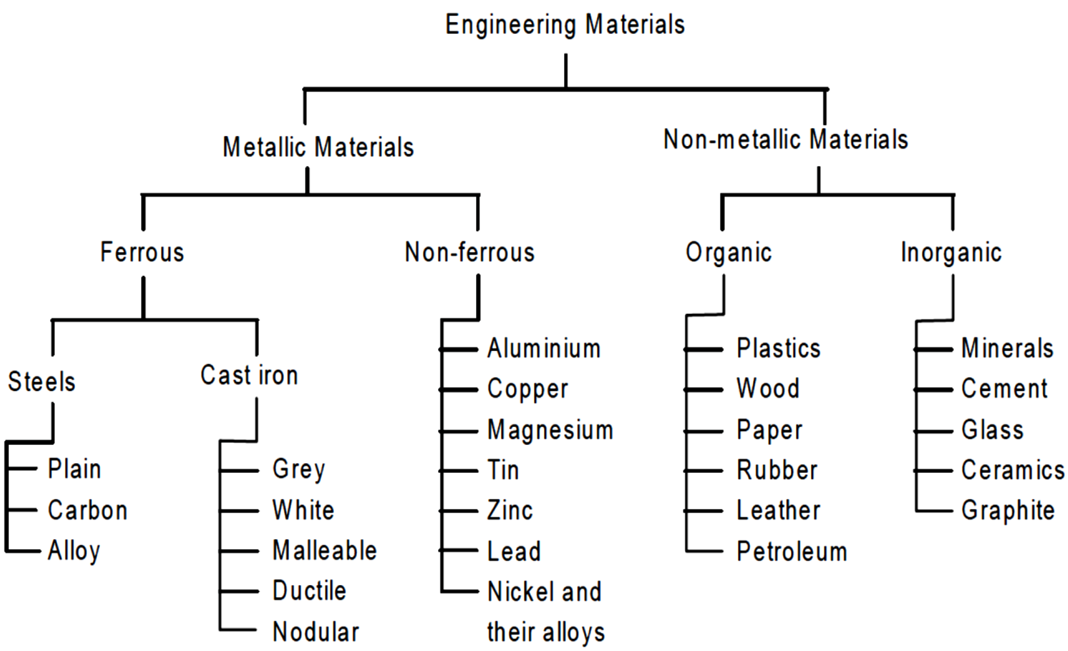


Fig. 2.1 Classification of engineering materials

Metals and Alloys

<u>Pure metals</u> possess low strength and do not have the required properties.

<u>Alloys</u> are produced by melting or sintering two or more metals or metals and a non-metal, together. Alloys may consist of two more components.

a. **<u>Ferrous metals</u>** are those which have the iron as their main constituent, such as crude (pig) iron, cast iron, wrought iron and steels.
b. **<u>Non-ferrous metals</u>** are those which have a metal other than iron as their main constituent, such as copper, aluminium, brass, bronze, tin, silver zinc, invar etc.

2. Ferrous Metals

The ferrous metals are those which have iron as their main constituents. The ferrous metals commonly used in engineering practice are *cast iron, wrought iron, steel and alloy steels*. The basic principal raw material for all ferrous metals is crude (pig iron) which is obtained by smelting ***iron ore***, coke and limestone, in the ***blast furnace***. The principal iron ores with their metallic contents are shown in Table 2.1.

S.No.	Iron ore	Color	Iron %
1.	Haematite (Fe_3O_4)	Red	70%
2.	Magnetite (Fe_2O_3)	Black	72%
3.	Limonite	Brown	62.5%
4.	Siderite	Brown	48%

2.1.Main Types of Iron

1. **Cast iron:** Cast iron is basically an alloy of iron and carbon and is obtained by re-melting pig iron with coke, limestone and steel scrap in a furnace known as cupola. The carbon content in cast iron varies from 1.7% to 6.67%. It also contains small amounts of silicon, manganese, phosphorus and sulphur in form of impurities elements.
   a. White cast iron
   b. Gray cast iron
   c. Malleable cast iron
   d. Ductile cast iron
   e. Meehanite cast iron
   f. Alloy cast iron

2. **Wrought iron**: Wrought iron is the assumed approximately as purest iron which possesses at least 99.5% iron. It contains a large number of minute threads of slag lying parallel to each other, thereby giving the metal a fibrous appearance when broken. It is said as a mechanical mixture of very pure iron and a silicate slag.

3. **Steel:** Steel is an alloy of iron and carbon with carbon content maximum up to 1.7%. The carbon occurs in the form of iron carbide, because of its ability to increase the hardness and strength of the steel
    a. Plain carbon steels
        i. *Dead Carbon steels*
        ii. *Low Carbon steels*
        iii. *Medium Carbon steels*
        iv. *High Carbon steels*
    b. Alloy steels
        i. *High speed steel*
        ii. *Stainless steel*

2.2. Cast Iron Production (Blast furnace)

Blast furnace was invented in 14th century. A typical blast furnace along with its various parts is shown in Fig. 2.2. Modern blast furnaces range in size from 20 to 35 m diameter. It is set on the top of brick foundation. There are four major parts of blast furnace from bottom to top:

1. hearth,
2. bosh,
3. stack and
4. top.

The hearth acts as a storage region for molten metal and molten slag. The charge of blast furnace possesses successive layers of iron ore, scrap, coke, and limestone and some steel scrap which is fed from the top of the furnace.

Iron ore exists as an aggregate of iron-bearing minerals. These mineral aggregates are oxides of iron called hematite, limonite, and magnetite. They all contribute to the smelting process. *It takes about 1.6 tons of iron ore, 0.65 ton of coke, 0.2 ton of lime-stone and about 0.05 ton of scrap iron and steel to produce 1 ton of crude (pig) iron. For burning this charge, about 4 tons of air is required*.

The impurities or other minerals are present in the ore. These impurities may be silicon, sulfur, phosphorus, manganese, calcium, titanium, aluminum, and magnesium. *The amounts of silicon, phosphorus, and sulfur present will determine the purification process used in the manufacture of the steel.*

The output from the furnace in form of crude (pig) iron is collected in large ladles from the tap hole existing at lower portion of furnace. As the coke burns, aided by the air forced into the furnace, the ore melts and collects in the hearth. As the melting process proceeds, the entire mass settles and thus makes room for the addition of charges at the top. While the melting is going on, the limestone forms a slag with the impurities.

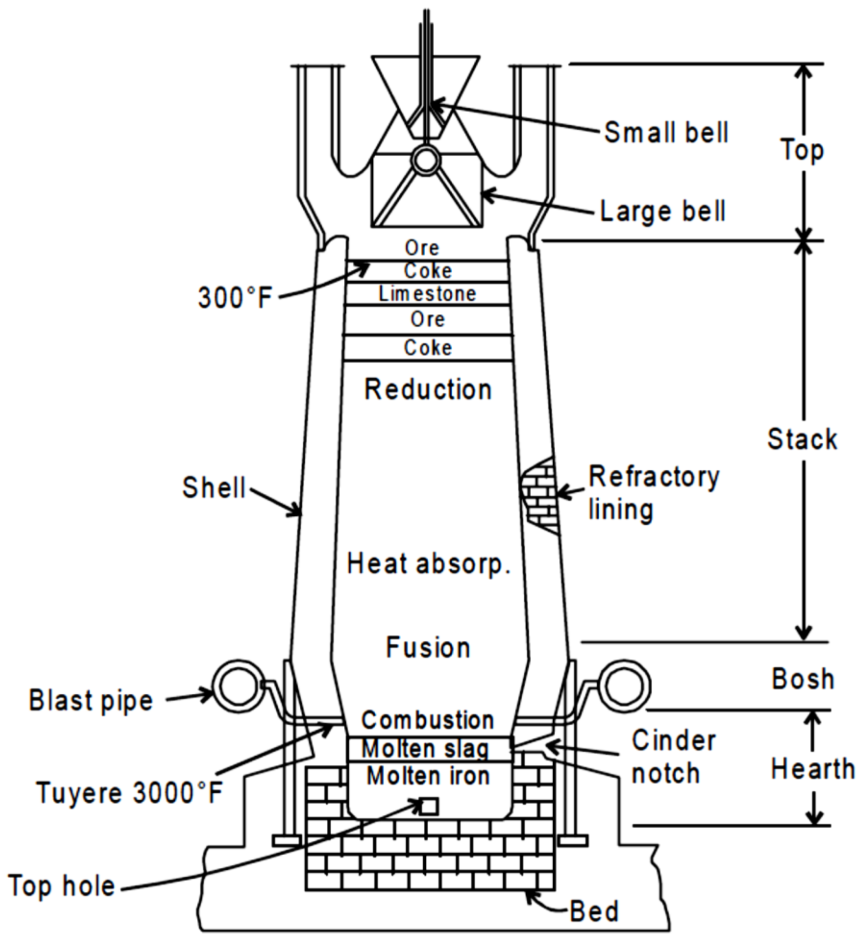


Fig. 2.2 Typical blast furnace

2.3. Steel Production Furnaces

The iron picks up carbon from the coke and impurities from the ore. The amount of carbon picked up by the iron is more than is needed in the production of steel. The carbon becomes part of the pig iron used in the making of steel. *The control of this carbon during the subsequent processes determines the properties of the steel*.

The crude (pig) iron is then processed for purification work for production of various kinds of iron and steel in form of ingots (large sections) using different furnaces. The steel ingots can be further processed in rolling mill or blooming mill to produce different structural shapes and sections of steel.

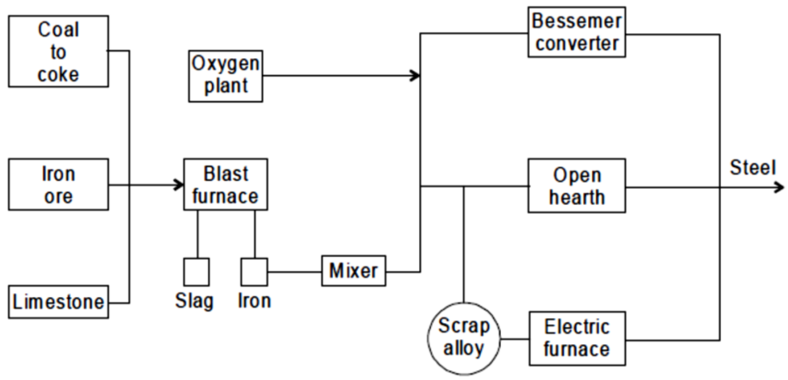


Fig. 2.3 Flow chart for converting pig iron into useful iron and steel

2.3.1. Bessemer Convertor

The Bessemer process was the first inexpensive industrial process for the mass-production of steel from molten pig iron. The process is named after its inventor, Henry Bessemer, who took out a patent on the process in 1855. The key principle is removal of impurities from the iron by oxidation with air being blown through the molten iron. The oxidation also raises the temperature of the iron mass and keeps it molten. The process is carried on in a large ovoid steel container lined with clay or dolomite called the Bessemer converter. The capacity of a converter was from 8 to 30 tons of molten iron.

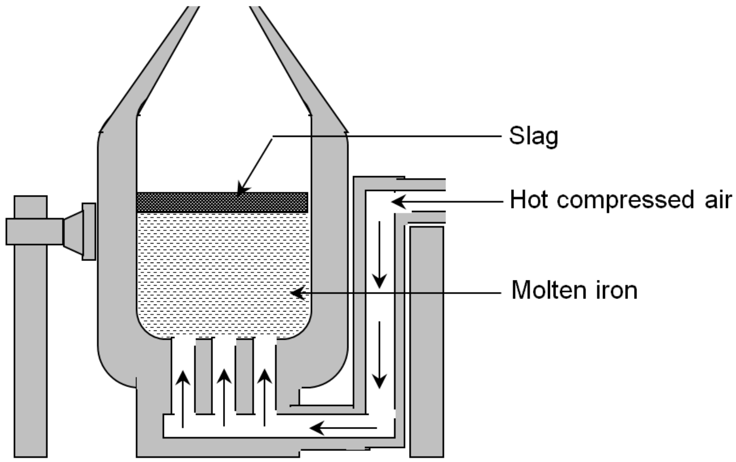


Fig. 2.4 Bessemer Convertor

2.3.2. Open Hearth Furnace

In open hearth furnace, pig iron, steel scrap etc. are melted to obtain steel. The hearth is surrounded by roof and walls of refractory bricks as shown in Fig. 2.5. The charge is fed through a charging door and is heated to 1650°C mainly by radiation of heat from the burning of gaseous fuels above it. The products of combustion at the same time pass through the checkers at the other end of the furnace, then process then reverses itself.

Oxygen is one of the most important elements used in the reduction of the molten metal. Twice the oxygen input quantity will double the carbon reduction and increases the steel production of the furnace.

For magnesite lined furnace, the charge consists of pig iron, limestone, and scrap iron. The slag reacts with the sulfur and the phosphorus in the metal, while the bubbling air causes oxidation of the carbon and silicon. For acid lining furnace, the charge should be scrap iron and low-phosphorus pig iron.

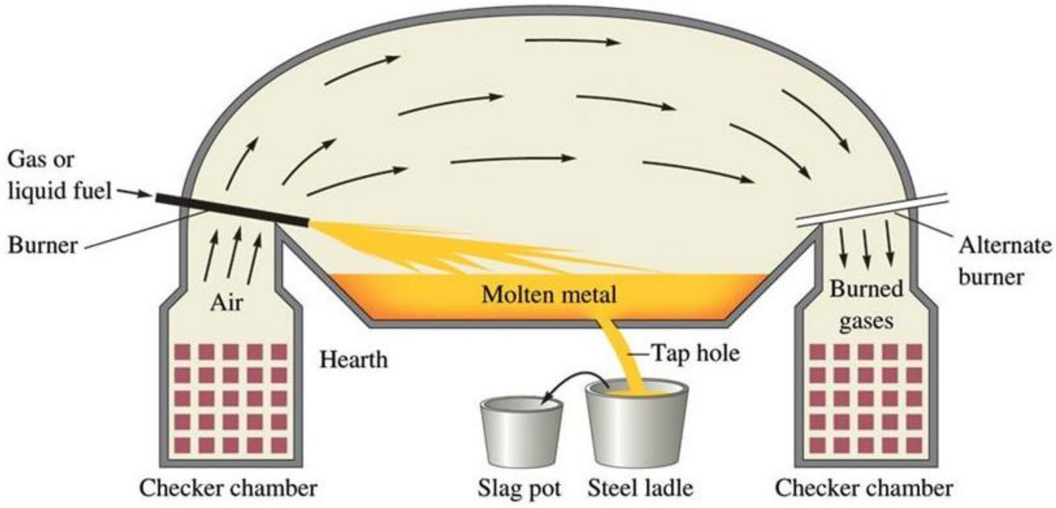


Fig 2.6 open hearth furnace

2.3.3. Electric-arc steelmaking Furnace

About one-quarter of the world's steel is produced by the electric-arc method, which uses high-current electric arcs to melt steel scrap and convert it into liquid steel of a specified chemical composition and temperature. External arc heating permits better thermal control than does the basic oxygen process, in which heating is accomplished by the exothermic oxidation of elements contained in the charge.

The electric-arc furnace (EAF) is a squat, cylindrical vessel made of heavy steel plates. It has a dish-shaped refractory hearth and three vertical electrodes that reach down through a dome-shaped, removable roof (see figure). The shell diameter can be reached to 9m and can produce about 300-ton.

The roof is also made of water-cooled panels and has three circular openings, equally spaced, for insertion of the cylindrical electrodes. Another large roof opening, the so-called fourth hole, is used for off-gas removal. Additional openings in the furnace wall, with water-cooled doors, are used for lance injection, sampling, testing, inspection, and repair.

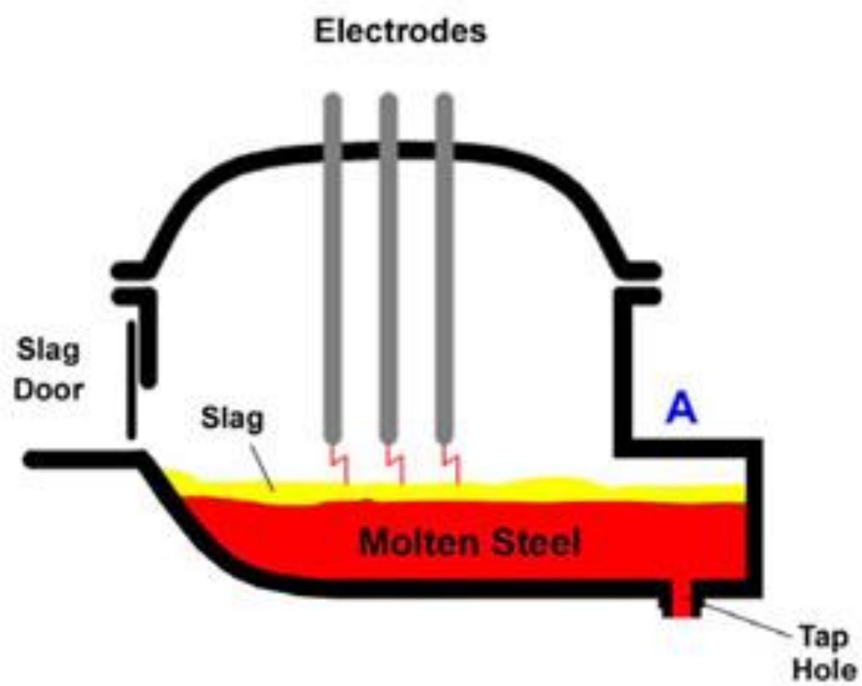


Fig 2.6 Electric-arc steelmaking furnace

YouTube: https://youtu.be/JrH9m5wfIBs

Lecture 04 Non-ferrous Materials Production

1. Non-Ferrous Materials

Non-ferrous metals contain metals other than iron as their main constituents such as aluminum, copper, zinc, magnesium, lead, tin, nickel and their alloys and non-metallic materials.

1.1. Aluminum

Pure aluminium has silvery color. It is ductile, malleable and very good conductor of heat and electricity. It has a very high resistance to corrosion than the ordinary steel. Its good electrical conductivity is an important property and is broadly used for overhead cables. There are several of alumimum alloys depending upon the main additive items as shown in table

Series Number	Alloying Element	Alloy Category
1XXX	Aluminum	Commercially Pure
2XXX	Copper	Heat-Treatable
3XXX	Manganese	Non Heat-Treatable
4XXX	Silicon	Non Heat-Treatable
5XXX	Magnesium	Non Heat-Treatable
6XXX	Magnesium and Silicon	Heat-Treatable
7XXX	Zinc	Heat-Treatable

Extraction of Aluminium

The aluminium production process can be broken down into three stages:

- first Bauxite, ore which contain aluminium, are extracted from the ground.
- Second, bauxites are processed into aluminium oxide or alumina (white powder from which aluminium can be extracted)
- Third, pure aluminium is produced using electrolytic reduction,

Fig 2.6 Bauxite Ore of Aluminium

The extraction is done by electrolysis which it does dissolve in molten cryolite (double fluoride of aluminium and sodium). The negative electrodes (cathodes) and the positive electrodes (anodes) are made of graphite, a form of carbon.

During electrolysis:

- positively charged aluminium ions gain electrons from the cathode, and form molten aluminium
- oxide ions lose electrons at the anode, and form oxygen molecules. The oxygen reacts with the carbon in the electrodes, forming carbon dioxide which bubbles off. Carbon is therefore lost from the positive electrodes, so they must be replaced frequently. This adds to the cost of the process.

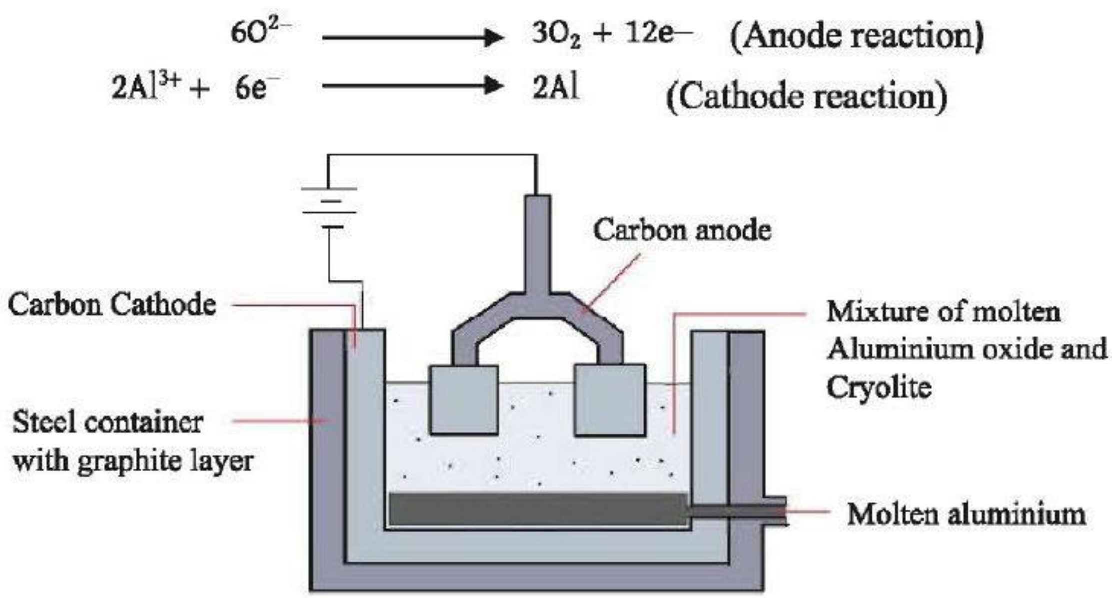


Fig 2.7 Extraction of Aluminium

A process in which aluminium oxide is broken down into its components using electric current. About 4-5 tons of bauxites get processed into 2 tons of alumina from which about 1 ton of aluminium can be made.

1.2. Copper

Copper is one of the most widely used non-ferrous metals in industry. Pure copper is soft, malleable and ductile metal with a reddish-brown appearance. It is a good conductor of electricity. It is non-corrosive under ordinary conditions and resists weather very effectively.

1.2.1. Copper Ores

Name	Formula	% Copper
Chalcopyrite	$CuFeS_2$	34.5
Chalcocite	Cu_2S	79.8
Malachite	$CuCO_3.Cu(OH)_2$	57.7
Azurite	$2CuCO_3.Cu(OH)_2$	55.1

1.2.2. Copper Extraction

It is extracted from ores of copper such as copper glance, copper pyrites, melachite and azurite. Copper ore is first ground and then smelted in a reverberatory or small blast furnace for producing an impure alloy. Then the air is blown through the molten metal to remove Sulphur and iron contamination to obtain blister copper in the converter. Copper is then refined further using electrolysis processes.

The following copper alloys are important

a. Copper-zinc alloys (Brasses)
b. Copper-tin alloys (Bronzes)

Copper is mainly used in:

1. making electric cables and wires for electric machinery, motor winding, electric conducting appliances, and electroplating etc.
2. It can be easily forged, casted, rolled and drawn into wires.
3. Copper in the form of tubes is used widely in heat transfer work of boilers, condensers, roofing etc.

1.3. LEAD

Lead is a bluish grey metal with a high metallic lustre when freshly cut. It is a very durable and versatile material. The heavy metal obtained from the bottom of the furnace is further oxidized in Bessemer's converter to remove most of the impurities.

Lead has properties of high density and easy workability. It has very good resistance to corrosion and many acids have no chemical action on it. It is the softest and heaviest of all the common metals. It can readily be scratched with fingernail when pure.

Applications

a. Lead is used in safety plug in boilers, fire door releases and fuses.
b. It is also used in various alloys such as brass and bronze.
c. In the soldering process, an alloy of lead and tin is most widely utilized as a solder material for joining metals in joining processes.

1.4. ZINC

Zinc is bluish grey in color and is obtained from common ores of zinc are zinc blende (ZnS), zincite (ZnO), calamine (ZnCO3). These ores are commonly available in Burma. The oxide is heated in an electric furnace where the zinc is liberated as vapor. The vapors are then cooled in condensers to get metallic zinc. Zinc possesses high resistance to corrosion.

Zinc is the fourth most utilized metal after iron, aluminium, and copper. It is commonly used as:

a. a protective coating on iron and steel in the form of a galvanized or sprayed surface.
b. It is used for generating electric cells and making brass and other alloys.
c. The oxide of zinc is used as pigment in paints.
d. Parts manufactured by zinc alloys include carburetors, fuel pumps, automobile parts, and so on.

1.5. TIN

Tin is considered as a soft and ductile material. It possesses very good malleability. Tin is recognized as brightly shining white metal. It does not corrode in wet and dry conditions. Therefore, it is commonly used as a protective coating material for iron and steel. The main source of tin is tinstone.

Applications

a. Tin-base white metals are commonly used to make bearings that are subjected to high pressure and load.
b. Tin is used as coating on other metals and alloys owing to its resistance to corrosion.
c. Because of its high malleability, it finds application in tin cans for storing food and food items.

YouTube: https://youtu.be/DhJVR0ZAAm8

Lecture 05: Plastics Properties

1. Plastics

Plastics are commonly known as synthetic resins or polymers. In Greek terminology, *the term polymer comprises 'poly' means 'many' and 'mers' means 'parts'*. Thus, the term, polymer represents a substance built up of several repeating units, each unit being known as a monomer. Thousands of such units or monomers join in a polymerization reaction to form a 'polymer'.

Some natural polymers like starch, resins, shellac, cellulose, proteins, etc are very common in today's use. Synthetic polymers possess several large applications in engineering work. Therefore, *plastic materials are hard and rigid and can be readily molded into different shapes by heating or pressure or both*.

Various useful articles can be produced from them rapidly, *accurately and with very good surface quality*. *They can be easily produced in different colors or as transparent*. They are recognized by their extreme lightness, good corrosion resistance and high dielectric strength. These materials have extensive applications in industrial and commercial work such as electrical appliances, automotive parts, communication products bodies (Telephone, Radio, TV), and those making household goods. They possess a combination of properties which make them preferable to other materials existing in universe.

1.1. Properties of plastics

The properties of plastics are given as under.

1. Plastics are light in weight and at the same time they possess good toughness strength and rigidity.
2. They are less brittle than glass, yet they can be made equally transparent and smooth.
3. They resist corrosion and the action of chemicals.
4. The ease with which they can be mass-produced contributes greatly to their popularity as wrappers and bags.
5. They can be easily molded to desired shapes.
6. They can easily be made colored.
7. They are hard, rigid and heat resistance.

1.2.The structure of polymers

To understand how plastics are made, and why certain plastics are suitable for some uses, and others not, you have to understand a little about the structure of polymers. ***Polymers*** *are large molecules made up of many smaller molecules. 'Poly' means many and 'mer' means units. These smaller units are called* **monomers** *(mono = one, mer = unit) and are joined together through* ***polymerisation*** *to form polymers. A polymer contains hundreds of thousands of monomers*.

Polymerisation, which means the linking of monomers to form polymers results from two kinds of chemical reaction called condensation and addition.

The basic structure of plastics (or polymers) is given by macromolecule chains, formulated from monomer units by chemical reactions. Typical reactions for chain assembling are ***polyaddition*** (continuous or step wise) and condensation polymerization (***polycondensation***).

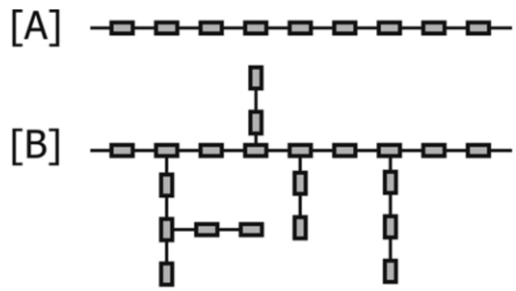
- **Polyaddition as chain reaction**: Process by chemical combination of a large number of monomer molecules, in which the monomers will be combined to a chain. No hydrogen atoms will be moved within the chain during the reaction.
- **Polyaddition as step reaction**: Process by combination of monomer units without a reaction. Hydrogen atoms can change position during the process.
- **Polycondensation**: Generation of plastics by buildup of polyfunctional compounds. Typical small molecules like water or ammonia can be set free during the reaction. The reaction can occur as a step reaction.

1.3.Classification of Plastics

Plastics are broadly classified into thermos-plastics and thermo-setting plastics.

1.3.1. Thermo-Plastics

Those plastics which can be easily softened again and again by heating are called thermoplastic. They can be reprocessed safely. They retain their plasticity at high temperature, i.e. they preserve an ability to be repeatedly formed by heat and pressure.



Structure of thermoplastic types (A) linear and (B) with side chains

Types of Thermo-Plastics

(A) Amorphous

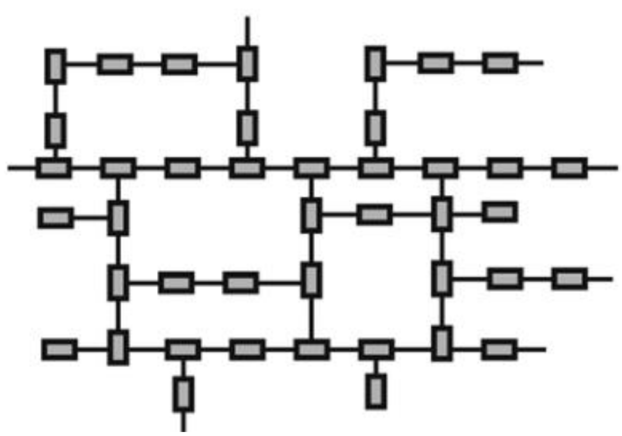
1. Polystyrene
2. P.V.C (Polyvinyl chloride)

(B) Crystalline

1. Polyethylene
2. Polypropylene

1.3.2. Thermo-Setting Plastics

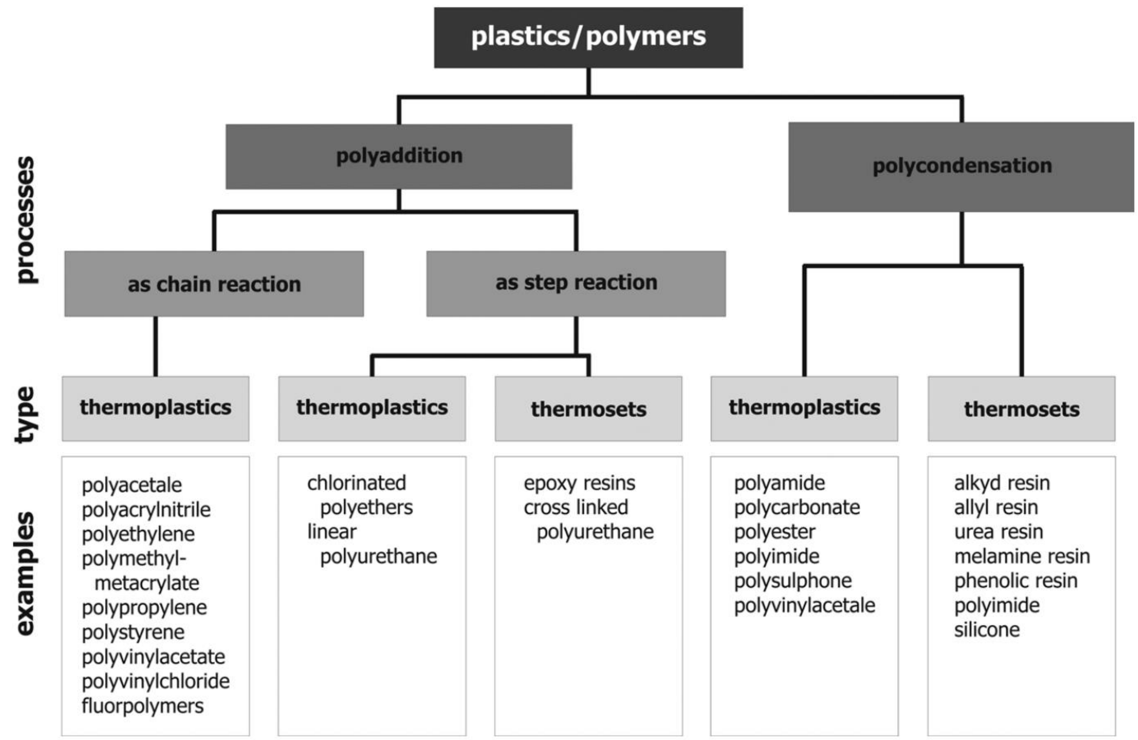
Those plastics which are hardened by heat, effecting a non-reversible chemical change, are called thermo-setting. Alternatively, these plastics materials acquire a permanent shape when heated and pressed and thus cannot be easily softened by reheating. They are commonly known as heat-setting or thermosets.



Structure of strong crosslinking thermosets

Thermosetting resins samples

1. Phenol-formaldehyde resins
2. Polyester resins
3. Epoxy resins
4. Silicone resins



Processes for generating plastics and examples

Comparison between Thermo Plastic and Thermosetting Plastic		
	Thermo-Plastic	**Thermosetting Plastic**
1	They can be repeatedly softened by heat and hardened by cooling.	Once hardened and set, they do not soften with the application of heat.
2	They are comparatively softer and less strong.	They are stronger and harder than thermoplastic resins
3	Objects made by thermoplastic resins cannot be used at comparatively higher temperature as they will tend to soften under heat	Objects made by thermosetting resins can be used at comparatively higher temperature without damage
4	They are usually supplied as granular material	They are usually supplied in monomeric or partially polymerized material form in which they are either liquids or partially thermoplastic solids
5	Themo-plastics can be formed by Injection molding, Extrusion, Blow molding, Thermo-forming, and Casting.	Thermosetting plastics can be formed by Compression or transfer molding and Casting
6	Applications. Toys, combs, toilet goods, photographic films, insulating tapes, hoses, electric insulation, etc.	Applications. Telephone receivers, electric plugs, radio and T.V. cabinets, camera bodies, automobile parts, tapes, hoses, circuit breaker switch panels, etc.

YouTube: https://youtu.be/pOjq4oi0Y40

Lecture 06: Plastics Processes

1.1.Plastics Processes

1. Extrusion

- Raw materials are thermoplastic pellets, granules, or powder
- Placed in hopper and fed into extruder barrel
- Screw blends pellets and pushes them down the barrel –through the feed, transition/melt, and pumping sections
- Barrel is heated from outside, and by friction
- Plastic is liquefied and forced through a die under pressure
- Pellets for other plastics processes are made by extruding small-diameter rod and chopping into short segments
- Equipment costs on the order of $300,000
- Rated by barrel diameter (D, 1-8 inch) and L/D ratio (5 to 30)

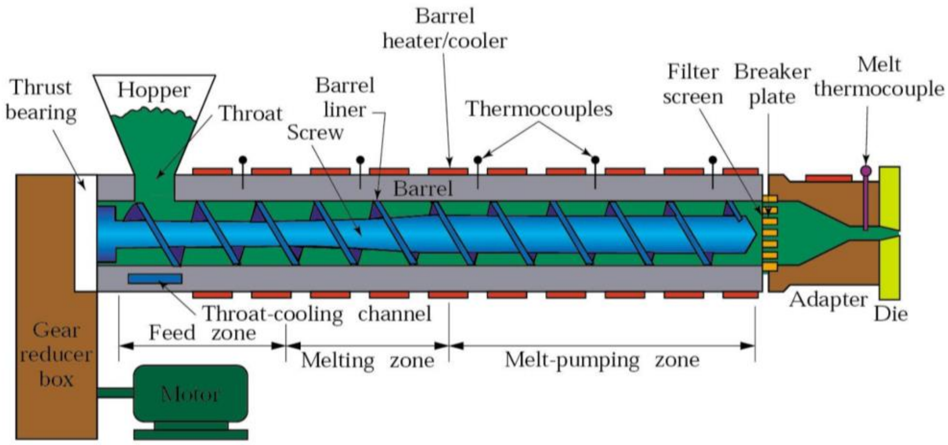


Fig. 1 extrusion process for plastic

Fig. 2 Several samples plastic extrusion products

2. Injection Molding

- Similar to hot chamber die casting of metals
- Pellets, granules, or powder are fed into heated cylinder, then forced into die chamber by hydraulic plunger or rotating screw system
- Pressures from 70-200 MPa (10-30 Kpsi)
- Cool molds for thermoplastics. Heated molds for thermosets
- Complex shapes and good dimensional accuracy
- Using metallic inserts, multiple materials/colors, and printed films can eliminate post processing or assembly operations
- Injection Molding Capabilities
  - High production rates
  - Good dimensional control
  - Machines are usually horizontal with clamping forces (100-250 tons)

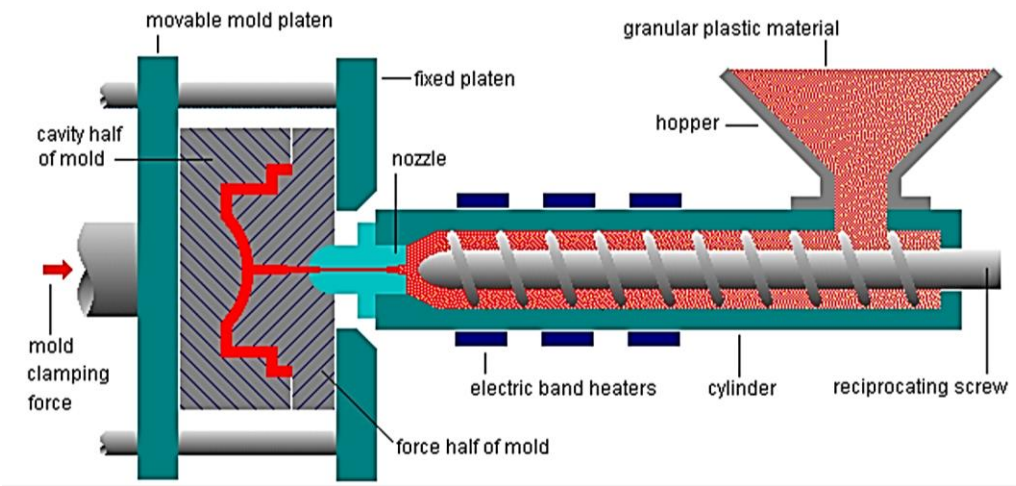


Fig. 3 Plastic Injection molding process

Fig. 4 Samples of Plastic Injection molding products

3. Structural Foam Molding

- A variation of the injection molding process developed for applications where stiffness is a primary concern, and particularly for large structural parts.
- Parts consist of a rigid, closed-cellular core surrounded by a continuous, solid skin.
- The polymer melt contains a dissolved inert gas; most commonly nitrogen, introduced in the extrusion screw.
- A predetermined shot size is injected into the mold cavity, the extruder valve is closed, and the foam material generates internal pressure and expands to fill mold cavity.
- A much lower pressure operation than the conventional injection molding system, which allows much larger parts to be molded

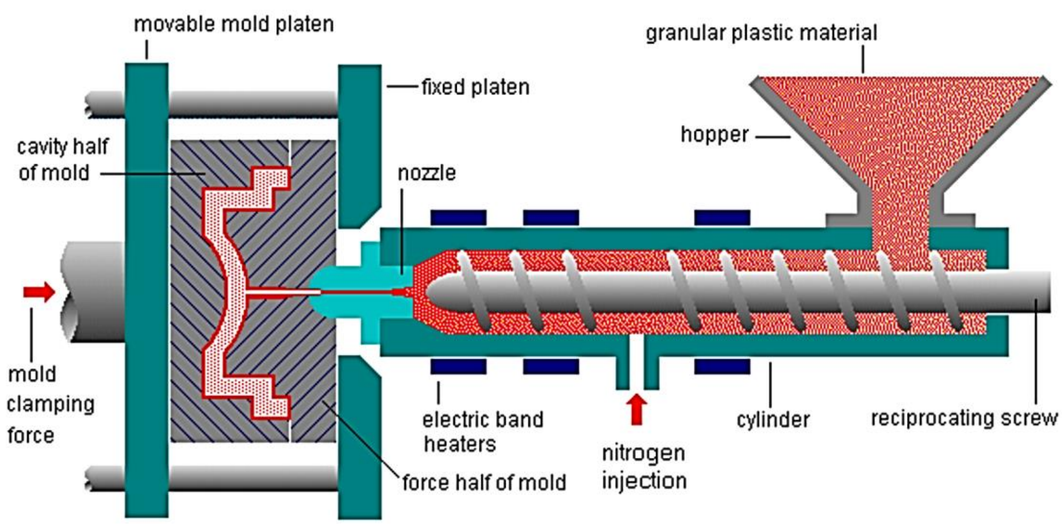


Fig. 5 Plastic Structural Foam Molding process

Fig. 6 Samples of Plastic Structural Foam Molding products

4. Blow Molding

- Modified extrusion and injection molding processes
- Extrusion Blow Molding
  - ➢ Small tube is first extruded, usually vertically, then clamped and air blown inside to expand it to fit a much larger diameter mold
  - ➢ Air pressures 350-700 kPa (50-100 psi)
- Injection blow molding
  - ➢ Short tubular piece (parison) injection molded, transferred to a blow-molding die
  - ➢ Plastic beverage bottles and hollow containers
- Multilayer blow molding
  - ➢ Plastic packaging for food and beverages, cosmetics and pharmaceutical industries

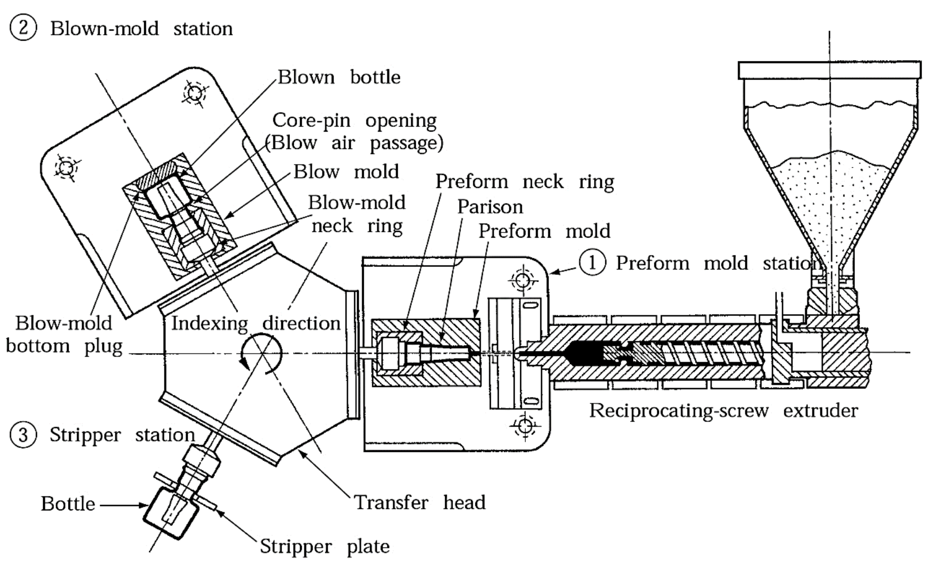


Fig. 7 A three station injection blow-molding machine

Fig. 8 Samples of Plastic blow-molding products

5. Reaction Injection Molding

- Chemical reaction between two polymer materials – thermoset
- Large parts
- Low tooling costs
- Car bumpers are good examples for this process

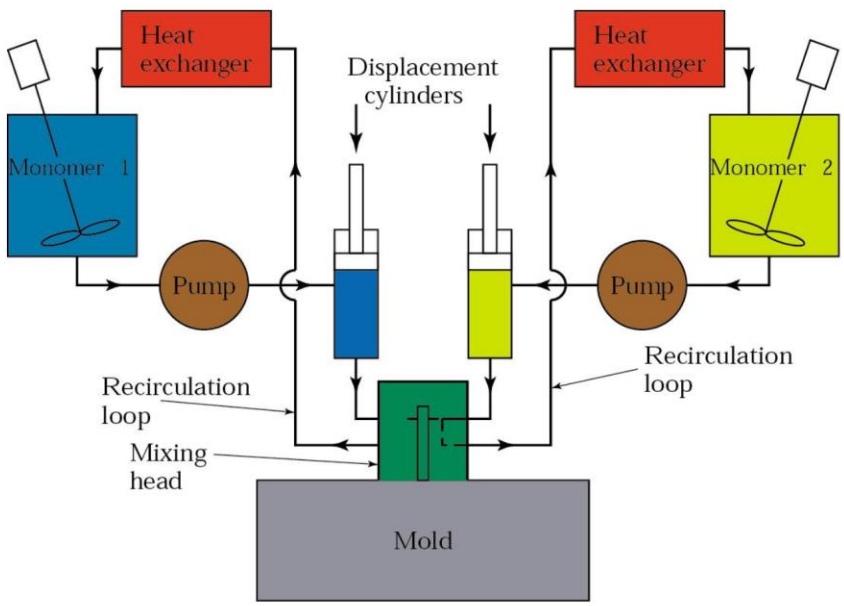


Fig. 9 Plastic Reaction Injection Molding process

Fig. 10 Samples of Plastic Reaction Injection Molding products

6. Rotational Molding

- Premeasured quantity of powder placed inside warm mold
- Rotated on two axes inside a heated furnace
- Low equipment costs
- Longer process times
- Trash cans, boat hulls, buckets, toys, footballs
- 0.4 mm wall thickness possible

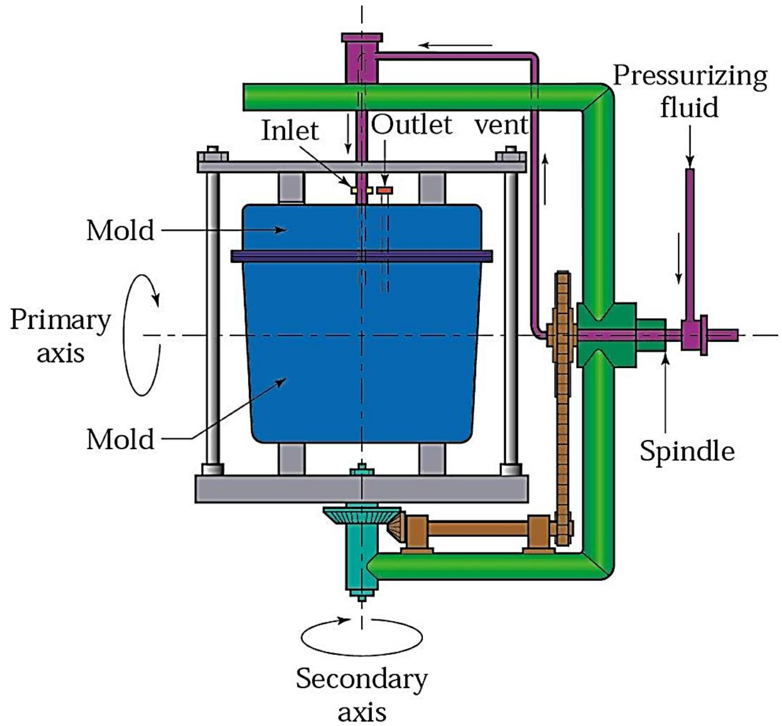
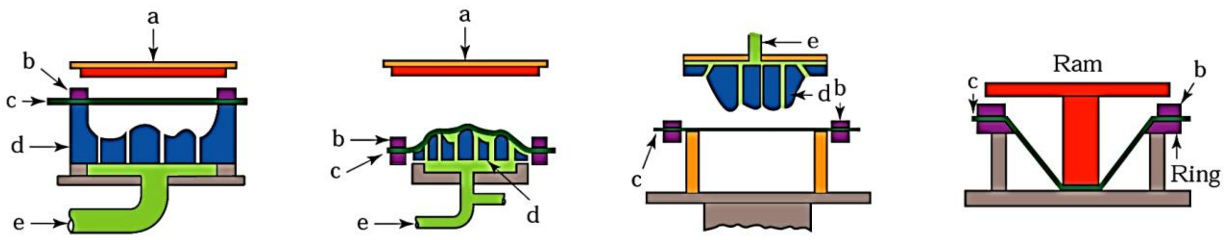


Fig. 11 Plastic Rotational Molding process

Fig. 12 Samples of Plastic Rotational Molding products

7. Thermoforming

- Plastic sheet is heated to a sag point (softened, but not melted)
- Heated sheet placed over a room-temperature mold and forced against it by vacuum pressure
- Stretch forming process – material thickness variations
- Advertising signs, refrigerator liners, appliance housings, shower stalls, packaging



1.Straight vacuum forming | 2.Drape vacuum forming | 3Force above sheet | 4Plug and ring forming

a. Heater
b. Clamp
c. Plastic sheet
d. Mold
e. Vacuum line

Fig. 13 Plastic Thermoforming process

Fig. 14 Samples of Plastic Thermoforming products

Plastics Processes (summary)

Extrusion	Long, uniform, solid or hollow complex cross-sections; high production rates; low tooling costs; wide tolerances.
Injection molding	Complex shapes of various sizes, eliminating assembly; high production rates; costly tooling; good dimensional accuracy.

Structural foam molding	Large parts with high stiffness-to-weight ratio; less expensive tooling than in injection molding; low production rates
Blow molding	Hollow thin-walled parts of various sizes; high production rates and low cost for making containers.
Rotational molding	Large hollow shapes of relatively simple shape; low tooling cost; low production rates
Thermoforming	Shallow or relatively deep cavities; low tooling costs; medium production rates.
Compression molding	Parts similar to impression-die forging; relatively inexpensive tooling; medium production rates
Transfer molding	More complex parts than compression molding and higher production rates; some scrap loss; medium tooling cost.
Casting	Simple or intricate shapes made with flexible molds; low production rates.
Processing of composite materials	Long cycle times; tolerances and tooling cost depend on process.

YouTube: https://youtu.be/-saKpxY4-no

Lecture 07: Ceramic Manufacturing Industry

1. Introduction

The term ‘ceramics’ is derived from the Greek ‘keramos’ meaning ‘burned earth’ and is used to describe materials of the pottery industry.

Ceramics are defined as a class of inorganic, nonmetallic solids that are subjected to high temperature in manufacture and/or use. The most common ceramics are composed of oxides, carbides, and nitrides.

Traditional ceramics refers to ceramic products that are produced from unrefined clay and combinations of refined clay and powdered or granulated non-plastic minerals. Often, traditional ceramics is used to refer to ceramics in which the clay content exceeds 20 percent.

2. Traditional Ceramics classifications

1. **Pottery** is sometimes used as a generic term for ceramics that contain clay and are not used for structural, technical, or refractory purposes.
2. **Whiteware** refers to ceramic ware that is white, ivory, or light gray in color after firing. Whiteware is further classified as earthenware, stoneware, chinaware, porcelain, and technical ceramics.
3. **Stoneware** is vitreous or semivitreous ceramic ware of fine texture, made primarily from nonrefractory fire clay or some combination of clays, fluxes, and silica that, when fired, has properties like stoneware made from fire clay. Applications for stoneware include artware, chemicalware, cookware, drainpipe, kitchenware, tableware, and tile.
4. **Chinaware** is vitreous ceramic ware of zero or low absorption after firing that are used for nontechnical applications. Applications for chinaware include artware, ovenware, sanitaryware, and tableware.
5. **Porcelain** is defined as glazed or unglazed vitreous ceramic ware used primarily for technical purposes. Applications for porcelain include artware, ball mill balls, ball mill liners, chemical ware insulators, and tableware.
6. **Technical ceramics** include vitreous ceramic whiteware used for such products as electrical insulation, or for chemical, mechanical, structural, or thermal applications.

3. Properties of Ceramic Materials

- Density – in general, ceramics are lighter than metals and heavier than polymers.
- Melting temperatures - higher than for most metals
- Electrical and thermal conductivities - lower than for metals; (some ceramics are insulators while others are conductors).
- Brittle and High hardness, electrical and thermal insulating.
- Ceramics are substantially stronger in compression than in tension.

4. Ceramic Manufacturing Process Description

The ceramics sectors can be summarized in two groups:

1. ‘coarse’ or ‘construction’ ceramics including the bricks and roof tiles, vitrified clay pipes, refractory products and expanded clay aggregates sectors.
2. ‘fine’ or ‘traditional and industrial ceramics’, including the wall and floor tiles, table- and ornamental ware, sanitaryware, technical ceramics and inorganic bonded abrasives sectors.

The border between ‘fine’ or ‘traditional and industrial’ and ‘coarse’ or ‘construction’ ceramics varies between equivalent particle diameters of 0.1 and 0.2 mm. ‘Coarse' or ‘construction’ ceramic products show an inhomogeneity of more than 0.2 mm.

4.1. Ceramic Manufacturing Equipment

1. Pressure vessel
2. Conveyers
3. Jaw Crushers
4. Ball Mill
5. Screens
6. Trommel Screens
7. Tray dryer

4.2. Main steps for ceramic manufacturing

Step #1: Milling & Raw Material Procurement

The raw materials used in the process are milled materials typically found in mining sites that have been reduced from a large size to smaller sizes.

Step #2: Sizing

The milling materials must be sized to separate desirable material by controlling the particle size using Fine mesh vibratory sifting equipment, the result will give you proper bonding and a smooth surface on the finished product.

Figure 2: Sizing Machine of Ceramic products

Step #3: Batching

Calculates amounts, weighing and initial blended of the raw materials. For consistent material flow into a pub mill hopper, Vibratory Feeders can be applied in the process.

Step #4: Mixing

To obtain a more homogeneous material prior to forming, the constituents of the ceramic powder are combined using the method of mixing. Pug mills are the preferred piece of machinery used in this step of the process.

Step #5: Forming

The materials such as dry powders, pastes are consolidated and molded. In the case of dry forming, vibratory compaction can be used to achieve the desired shape.

Step #6: Drying

The formed materials hold water and binder in its mix that can in turn cause shrinkage, warping or distortion of the product. Convection drying is the most used method by heated air.

Step #7: Glazing

This step is added to the process prior to firing. Typically, the glaze consists of oxides that give the product the desired finish look. The glaze can be applied using spraying or dipping methods.

Step #8: Firing or sintering or densification.

The ceramics pass through a controlled heat process where the oxides are consolidated into a dense, cohesive body made up of uniform grain. Some general points to remember about different types of firing end products:

- Short Firing Time: gives porous and low-density products.
- Intermediate Firing: gives fine-grained, high-strength products.
- Long Firing Time: gives coarse-grained products and will not distort when under a load for an extended period.

Final Processing

- Following firing, some ceramic products are processed further to enhance their characteristics or to meet dimensional tolerances.
- Ceramics can be machined by abrasive grinding, chemical polishing, electrical discharge machining, or laser machining.
- Annealing at high temperature, followed by gradual cooling can relieve internal stresses within the ceramic and surface stresses due to machining.
- Coatings also may be applied to improve strength, and resistance to corrosion or for decoration.

YouTube: https://youtu.be/SikbHFTiy10

Lecture 08: Powder Metallurgy

1. Introduction

Powder metallurgy is used for manufacturing products or articles from powdered metals by placing these powders in molds and are compacting the same using heavy compressive force. Typical examples of such article or products are grinding wheels, filament wire, magnets, welding rods, tungsten carbide cutting tools, self-lubricating bearings electrical contacts and turbines blades having high temperature strength.

The manufacture of parts by powder metallurgy process involves the manufacture of powders, blending, compacting, sintering and several secondary operations such as sizing, machining, infiltration, plating, and heat treatment.

The compressed articles are then heated to temperatures much below their melting points to bind the particles together and improve their strength and other properties. Few non-metallic materials can also be added to the metallic powders to provide adequate bond or impart some the needed properties.

The products made through this process are very costly on account of the high cost of metal powders as well as of the dies used. The powders of almost all metals and a large quantity of alloys, and nonmetals may be used.

2. POWDER METALLURGY PROCESS

The powder metallurgy process consists of the following basic steps:

1. Formation of metallic powders.
2. Mixing or blending of the metallic powders in required proportions.
3. Compressing and compacting the powders into desired shapes and sizes in form of articles.
4. Sintering the compacted articles in a controlled furnace atmosphere.
5. Subjecting the sintered articles to secondary processing if needed so.

3. ADVANTAGES OF POWDER METALLURGY

1. The processes of powder metallurgy are quite and clean.
2. Articles of any complicated shape can be manufactured.
3. The dimensional accuracy and surface finish obtainable are much better for many applications and hence machining can be eliminated.
4. No material is being wasted as scrap and the process makes utilizes full raw material.
5. High production rates can be easily achieved.
6. This process facilitates production of many such parts, which cannot be produced through other methods, such as sintered carbides and self-lubricating bearings.
7. The components produced by this process are highly pure and bears longer life.
8. It enables production of parts from such alloys, which possess poor cast ability.

4. LIMITATIONS OF POWDER METALLURGY

1. Powder metallurgy process is not economical for small-scale production.
2. The cost of tool and die of powder metallurgical set-up is relatively high.
3. Articles made by powder metallurgy in most cases do not have as good physical properties as wrought or cast parts.
4. The process is not found economical for small-scale production.
5. It is not easy to convert brass, bronze and a number of steels into powdered form.

5. Production of Metal Powders

The commonly used powder making processes are given as under

1. **Atomization:** In this process, the molten metal is forced through an orifice and as it emerges, a high-pressure stream of gas or liquid impinges on it causing it to atomize into fine particles. The inert gas is then employed to improve the purity of the powder. It is used mostly for low melting point metals such as tin, zinc, lead, aluminum, cadmium etc.

2. **Chemical Reduction Process**: In this process, the compounds of metals such as iron oxides are reduced with CO or H2 at temperatures below the melting point of the metal in an atmosphere-controlled furnace.

$$Fe_3O_4 + 4C = 3Fe + 4CO$$

$$Fe_3O_4 + 4CO = 3Fe + 4CO2$$

   Copper powder is also produced by the same procedure by heating copper oxide in a stream of hydrogen.

$$Cu_2 + H_2 = 2Cu + H_2O$$

   Powders of W (Tungsten), Mo (Molybdenum), Ni (Nickle) and CO can easily be produced or manufactured by reduction process because it is convenient, economical, and flexible technique and perhaps the largest volume of metallurgy powders is made by the process of oxide reduction.
3. **Electrolytic Process:** It is quite like electroplating and is principally employed to produce extremely pure, powders of copper and iron. For making copper powder, copper plates are placed as anodes in a tank of electrolyte, whereas aluminum plates are placed into the electrolyte to act as cathodes.
4. **Crushing Process**: The crushing process requires equipment such as crushers, or gyratory crushes. Various ferrous and non-ferrous alloys can be heat-treated to obtain a sufficiently brittle material which can be easily crushed into powder form.
5. **Milling Process**: It is commonly used for production of metallic powder. It is carried out by using equipment such as ball mill, impact mill, eddy mill, disk mill, vortex mill, etc. Milling and grinding process can easily be employed for brittle, tougher, malleable, ductile, and harder metals to pulverize them.
6. **Condensation of Metal Powders**: This process can be applied in case of metals, such as Zn, Cd and Mg, which can be boiled, and the vapors are condensed in a powder form. Generally, a rod of metal say Zn is fed into a high temperature flame and vaporized droplets of metal are then allowed to condense on to a cool surface of a material to which they will not adhere.

6. Characteristic of Metal Powders

6.1. Powder particle size

Particle size of metal powder is expressed by the diameter for spherical shaped particles and by the average diameter for non-spherical particle as determined by sieving method or microscopic examination. Metal powders used in powder metallurgy usually vary in size from 20 to 200 microns. Particle size influences density/porosity of the compact, mold strength, permeability, flow and mixing characteristics.

6.2. Particle shape

There are various shapes of metal powders namely spherical, sub-rounded, rounded, angular, sub-angular, flakes etc. Particle's shape influences the packing and flow characteristics of the powders.

6.3. Chemical composition

Chemical composition of metallic powder implies the type and percentage of alloying elements and impurities. It usually determines the particle hardness and compressibility. The chemical composition of a powder can be determined by chemical analysis methods.

6.4. Particle microstructure

Particle microstructure reveals various phases, inclusions, and internal porosity.

6.5. Apparent density

Apparent density is defined as the weight, of a loosely heated quantity of powder necessary to fill a given die cavity completely.

6.6. Flow characteristics

Flow-ability of metal powders is most important in cases where moulds have to be filled quickly. Metal powders with good flow characteristics fill a mould cavity uniformly.

QUESTIONS

1. What do you understand by powder metallurgy? What are the main stages of powder metallurgy process?
2. Explain the objectives of powder compaction and list important products of powder metallurgy.
3. Describe the atomization process of making powder in detail.

4. What are the effects of sintering on the powder compact produced by pressing?
5. Describe the process of blending, compacting, and sintering in detail.
6. What are the effects of sintering on the powder compact produced by pressing?
7. Name the products of powder metallurgy.
8. List the advantages, dis-advantages of powder metallurgy process.

YouTube: https://youtu.be/-5p9smqlGX8

Lecture 09 Sand Casting

Sand casting, also known as sand molded casting, is a metal casting process characterized by using sand as mold material. It is relatively cheap and sufficiently refractory even for steel foundry use. A suitable bonding agent (usually clay) is mixed or occurs with the sand. The mixture is moistened with water to develop strength and plasticity of the clay and to make the aggregate suitable for molding. The term "sand casting" can also refer to a casting produced via the sand-casting process. Sand castings are produced in specialized factories called foundries.

Over 70% of all metal castings are produced via a sand-casting process.

BASIC STEPS IN MAKING SAND CASTINGS

1. Patterns are required to make molds. The mold is made by packing molding sand around the pattern. The mold is usually made in two parts so that the pattern can be withdrawn.
2. If the casting is to be hollow, additional patterns, referred to as core boxes, are needed to shape the sand forms, or cores, that are placed in the mold cavity to form the interior surfaces and sometimes the external surfaces as well of the casting.
3. **Molding** is the operation necessary to prepare a mold for receiving the metal. It consists of ramming sand around the pattern placed in support, or **flask**, removing the pattern, setting cores in place, and creating the gating/feeding system to direct the metal into the mold cavity created by the pattern, either by cutting it into the mold by hand or by including it on the pattern, which is most used.
4. **Melting** and **pouring** are the processes of preparing molten metal of the proper composition and temperature and pouring this into the mold from transfer **ladles**.
5. **Cleaning** includes all the operations required to remove the **gates** and **risers** that constitute the gating/feeding system and to remove the adhering sand, scale, parting fins, and other foreign material that must be removed before the casting is ready for shipment or other processing.

KINDS OF MOULDING SAND

1) Green sand

Green sand is also known as tempered or natural sand which is a just prepared mixture of silica sand with 18 to 30 percent clay, having moisture content from 6 to 8%. The clay and water furnish the bond for green sand. This sand is easily available, and it possesses low cost.

2) Dry sand

Green sand that has been dried or baked in suitable oven after the making mold and cores, is called dry sand. It is mainly suitable for larger castings.

3) Loam sand

Loam is mixture of sand and clay with water to a thin plastic paste. Loam sand possesses high clay as much as 30-50% and 18% water. This is particularly employed for loam molding used for large grey iron castings.

4) Facing sand

Facing sand is just prepared and forms the face of the mold, gives surface finish to casting. It is directly next to the surface of the pattern, and it comes into contact molten metal when the mold is poured. It is made of silica sand and clay, without the use of used sand.

5) Backing sand

Backing sand or floor sand is used to back up the facing sand and is used to fill the whole volume of the molding flask. Used molding sand is mainly employed for this purpose. The backing sand is sometimes called black sand.

6) Core sand

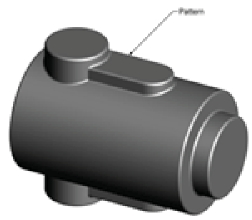
Core sand is used for making cores and it is sometimes also known as oil sand. This is highly rich silica sand mixed with oil binders.

PATTERN

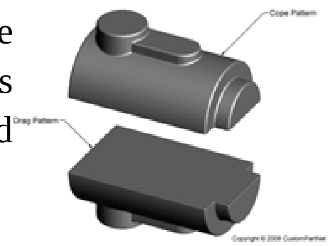
The pattern is the principal tool during the casting process. It is the replica of the object to be made by the casting process, with some modifications. The main modifications are the addition of pattern allowances, and the provision of core prints. If the casting is to be hollow, additional patterns called cores are used to create these cavities in the finished product.

Types of Patterns

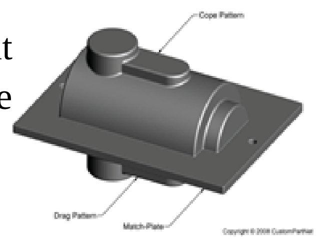
Solid pattern - A solid pattern is a model of the part as a single piece. It is the easiest to fabricate but can cause some difficulties in making the mold. Solid patterns are typically used for geometrically simple parts that are produced in low quantities.



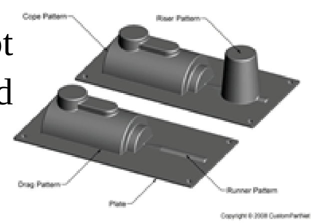
Split pattern - split pattern models the part as two separate pieces that meet along the parting line of the mold. Split patterns are typically used for parts that are geometrically complex and are produced in moderate quantities.



Match-plate pattern - A match-plate pattern is similar to a split pattern, except that each half of the pattern is attached to opposite sides of a single plate.



Cope and drag pattern - It is similar to a match plate pattern, except that each half of the pattern is attached to a separate plate. Cope and drag patterns are often desirable for larger castings.



CLASSIFICATION OF MOLDING PROCESSES

Molding processes can be classified in several ways. Broadly they are classified either based on the method used or based on the mold material used.

a) Sand molding: Molding processes where a sand aggregate is used to make the mold produce by far the largest quantity of castings. Whatever the metal poured into sand molds, the product may be called a sand casting.

b) Plaster molding: The mold material in plaster molding is gypsum or plaster of paris, additives like talc, fibers, asbestos, silica flour etc. are added to control the contraction characteristics of the mold as well as the settling time. The pattern is usually made of brass, and it is generally in the form of half portion of job to be cast and is attached firmly on a match plate which forms the bottom of the molding flask. Wood patterns are not used because the water in the plaster raises the grains on them and makes them difficult to withdraw.

c) Metallic molding: Metallic mold is also known as permanent mold because of their long life. The metallic mold can be reused many times before it is discarded or rebuilt. Permanent molds are made of dense, fine grained, heat resistant cast iron, steel, bronze, anodized aluminum, graphite, or another suitable refractoriness. The mold is made in two halves to facilitate the removal of casting from the mold. Usually, the metallic mold is called dies and the metal is introduced in it under gravity.

Lecture 10: Cold and Hot Working

1. METAL FORMING

Metal forming is also known as the mechanical working of metals. Metal forming operations are frequently desirable either to produce a new shape or to improve the properties of the metal. The main objectives of metalworking processes are to provide the desired shape and size under the action of externally applied forces in metals.

Shaping in the solid-state may be divided into

1. non-cutting shapings, such as forging, rolling, pressing, etc.,
2. cutting shaping, such as the machining operations performed on various machine tools.

Metals are commonly worked by plastic deformation because of the beneficial effect that is imparted to the mechanical properties by it. The necessary deformation in a metal can be achieved by application of mechanical force only or by heating the metal and then applying a small force. This plastic deformation of a metal takes place when the stress caused in the metal, due to the applied forces reaches the yield point.

2. RECRYSTALLISATION

During the process of plastic deformation in metal forming, the plastic flow of the metal takes place, and the shapes of the grains are changed. If the plastic deformation is carried out at higher temperatures, new grains start growing at the location of internal stresses caused by the metal. If the temperature is sufficiently high, the growth of new grains is accelerated and continuous till the metal comprises entirely only the new grains. This process of formation of new grains is known as recrystallization. *The temperature at which recrystalisation is completed is known* *as the recrystallisation temperature of the metal*. It is this point which draws the line of difference between cold working and hot working processes. *Mechanical working of a metal below its recrystallization temperature is called as cold working and that accomplished above this temperature but below the melting or burning point is known as hot working*.

3. Cold Working

The cold working of metal is carried out below its recrystallization temperature. Although average room temperatures are ordinarily used for cold working of various types of steel, temperatures up to the recrystallization range are sometimes used. In cold working, recovery processes are not effective.

The cold working process increases:

- Ultimate tensile strength
- Yield strength
- Hardness
- Fatigue strength
- Residual stresses

Cold working processes decreases:

- Percentage elongation
- Reduction of area
- Impact strength
- Resistance to corrosion
- Ductility

3.1.Purpose of Cold Working

The common purpose of cold working is given as under

1. Cold working is employed to obtain a better surface finish on parts.
2. It is commonly applied to obtain increased mechanical properties.
3. It is widely applied as a forming process of making steel products using pressing and spinning.
4. It is used to obtain thinner material.

3.2. Advantages of Cold Working

1. In cold working processes, smooth surface finish can be easily produced.
2. Accurate dimensions of parts can be maintained.
3. The strength and hardness of the metal are increased, but ductility decreases.
4. Since the working is done in a cold state, no oxide would form on the surface.
5. It is far easier to handle cold parts and it is also economical for smaller sizes.

3.3.Disadvantages of Cold Working

1. Some materials, which are brittle, cannot be cold worked easily.
2. Since the material has higher yield strength at lower temperatures, the amount of deformation that can be given is limited.
3. Since the material gets strain hardened, the maximum amount of deformation that can be given is limited.
4. Internal stresses are set up, which remain in the metal unless they are removed by proper heat-treatment.

4. Hot Working

Mechanical working processes done above the recrystallization temperature of the metal are known as hot working processes. Some metals, such as lead and tin, have a low recrystallization temperature and can be hot worked even at room temperature, but most commercial metals require some heating.

In hot working, the temperature of completion of metalworking is essential since any extra heat left after working aid in grain growth. This increase in the size of the grains occurs by process of coalescence of adjoining grains and is a function of time and temperature. *Grain growth results in poor mechanical properties*. *If the hot working is completed just above the recrystallization temperature, then the resultant grain size would be fine*.

4.1. Advantages of Hot Working

1. At a high temperature, the material would have higher amount of ductility and therefore there is no limit on the amount of hot working that can be done on a material. Even brittle materials can be hot worked.
2. In hot working process, the grain structure of the metal is refined, and thus mechanical properties improved.
3. The porosity of the metal is considerably minimized.
4. If the process is appropriately carried out, hot work does not affect tensile strength, hardness, corrosion resistance, etc.
5. Larger deformation can be accomplished more rapidly as the metal is in the plastic state.
6. No residual stresses are introduced in the metal due to hot working.
7. Mechanical properties, especially elongation and reduction of area, are improved.

4.2.3.2. Disadvantages of Hot Working

1. Due to high temperature in hot working, rapid oxidation or scale formation take place on the metal surface leading to poor surface finish and loss of metal.
2. The weakening of the surface layer may give rise to a fatigue crack which may ultimately result in fatigue failure of the component.
3. Some metals cannot be hot worked because of their brittleness at high temperatures.
4. Because of the thermal expansion of metals, the dimensional accuracy in hot working is difficult to achieve.
5. Handling and maintaining hot working setups are complicated and troublesome.

5. CLASSIFICATION OF HOT WORKING PROCESSES

The classification of hot working processes is given as under.

1. Hot rolling
2. Hot extrusion
3. Hot drawing

Comparison of Hot Working with Cold Working		
	Hot Working	**Cold Working**
1	Hot-working is carried out above the recrystallization temperature and below the melting point. Hence the deformation of metal and recovery take place simultaneously.	Cold working is carried out below the recrystallisation temperature. As such, there is no appreciable recovery.
2	No internal or residual stresses are set up in the metal in hot working.	In this process, internal or residual stresses are set up in the metal.
3	It helps in irradiating irregularities in metal composition, breaking up the nonmetallic impurities into tiny fragments and dispersing them through composition in the metal	It results in a loss of uniformity of metal composition and thus affects the metal properties.
4	Close tolerance cannot be maintained	Close tolerance is accepted
5	The surface finish of this process is comparatively not good.	The surface finish of this process is better.
6	Due to higher deformation temperatures, the stress required for deformation is much less.	The stress required to cause deformation is much higher

YouTube: https://youtu.be/3J1lzJq1rPc

Lecture 11: Principles Rolling Processes

1.1.Hot Rolling

Rolling is the most rapid method of forming metal into desired shapes by plastic deformation through compressive stresses using two or more two rolls. It is one of the most widely used of all the metalworking processes. *The main objective of rolling is to convert larger sections such as ingots into smaller sections*. The coarse structure of cast ingot is convened into a fine-grained structure using the rolling process as shown in Fig. 3.1. The hot rolling process is being widely used in producing a large number of valuable products such as rails, sheets, structural sections, plates, etc.

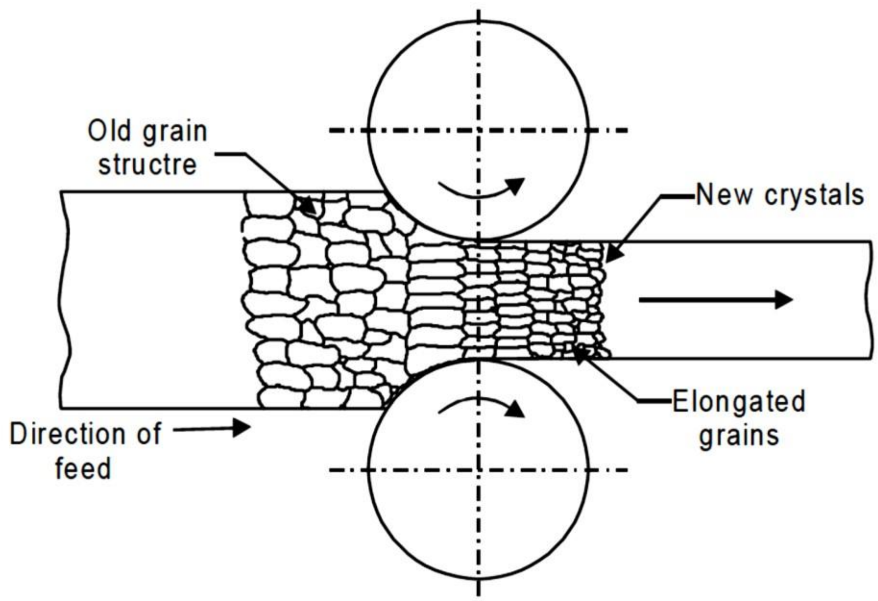


Fig. 3.1 Grain refinement in the hot rolling process

1.2.Hot Rolling Mill Types

1. **Two-High Rolling Mill:** A two-high rolling mill has two horizontal rolls revolving at the same speed but in the opposite direction. The rolls are supported on bearings housed in sturdy upright side frames called stands. The space between the rolls can be adjusted by raising or 1owering the upper roll.
2. **Three-High Rolling Mills:** It consists of three parallel rolls arranged above the other. The rotation directions of the upper and lower rolls are the same, but the intermediate roll rotates in a direction opposite to both.

3. **Four-High Rolling Mill:** It is essentially a two-high rolling mill with small-sized rolls. Practically, it consists of four horizontal rolls; the two middle rolls are smaller in size than the top and bottom rolls.
4. **Cluster Mill:** It is a particular type of four-high rolling mill in which each of the two smaller working rolls is backed up by two or more of the larger backup rolls for rolling hard thin materials

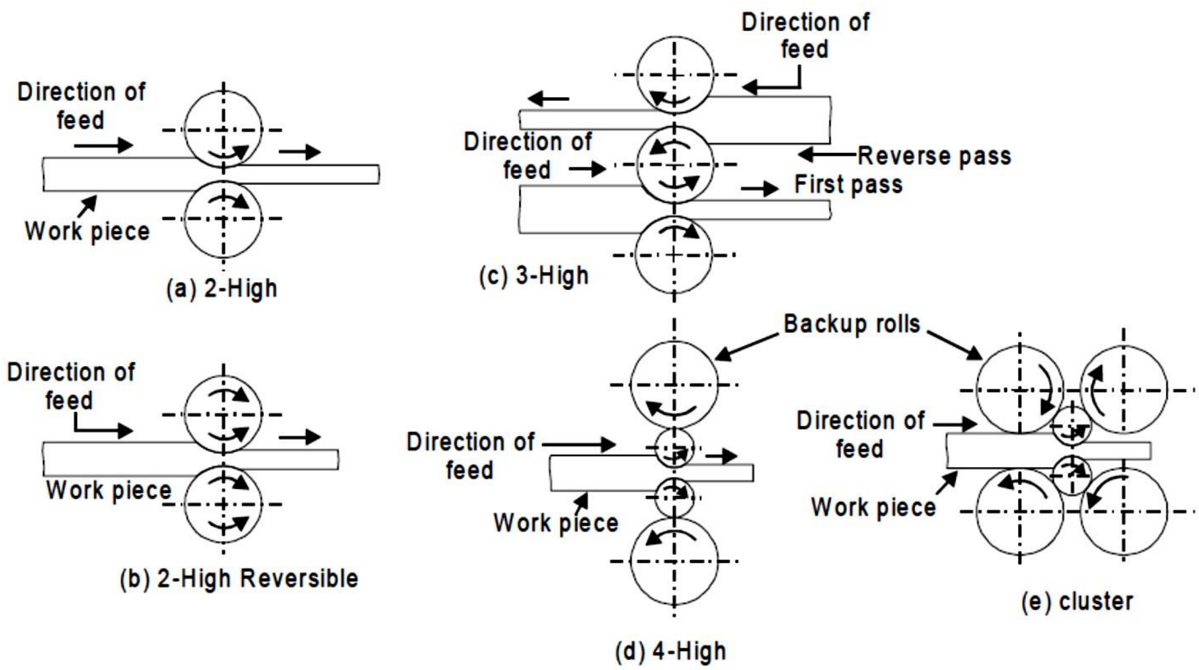
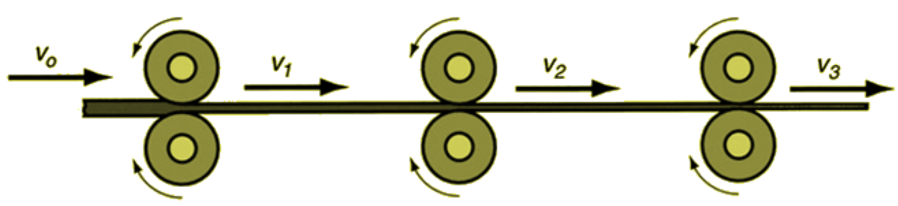


Fig. 3.2 Hot rolling stand arrangements

5. **Continuous (Tandem) Rolling Mill** consists of several non-reversing two-high rolling mills arranged one after the other so that the material can be passed through all of them in sequence. It is suitable for mass production work only because quick set-up changes will be required for smaller quantities and will consume a lot of time and labor.



1.3. Shape Rolling

Shape rolling of steels is a process that requires a lot of heat and a lot of force. Reheating is carried out to around 1200°C, and then the metal is continuously fed through rollers to draw the desired dimensions. Popular shapes have promising applications in the construction business as I, H, and U-shaped beams or girders can be produced for structural integrity.

Steel is a strong material resistant to shaping at ordinary temperatures, but this resistance lessens considerably at higher temperatures. For that reason, the billets, blooms, and slabs from the steelmaking process are shaped into essential products at carefully controlled elevated temperatures.

The most used method for shaping is to heat the steel to around 1,200°C in a reheat furnace and roll the steel, squeezing it between cylinders or rolls. Rolls are arranged in pairs and housed in a 'stand.'

For long products, a series of specially shaped and angled rolls (referred to as stands) are used to transform the section to the required shape. The figure shows the frame used to create open sections.

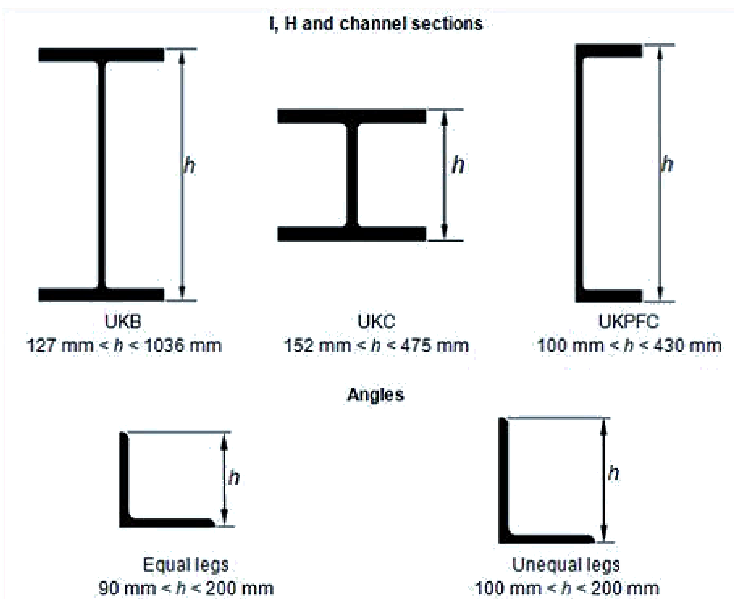


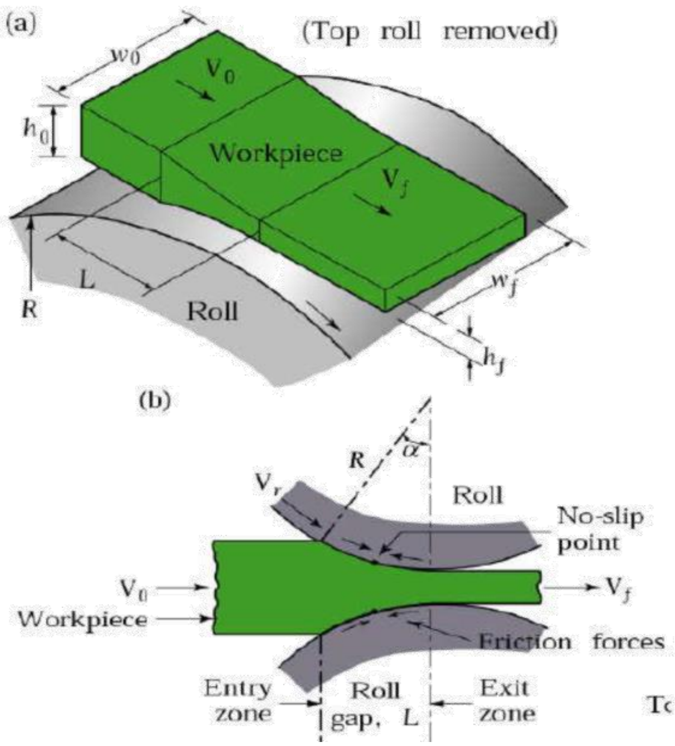
Figure 1: Standard open sections

1.4.Flat Rolling Analysis:

the volume of metal exiting the rolls equals the volume entering.

$$h_{\circ} w_{\circ} L_{\circ} = h_f w_f L_f$$

w_o and w_f are the *widths* before and after work, mm



To keep constant the volume rate of the material, the velocity of the strip must increase as it moves through the roll gap

$$V_f = V_0\left(\frac{h_0}{h_f}\right)$$

NEUTRAL POINT: point in the arc of contact where the roll velocity and the strip velocity are the same

$$\text{Forward slip} = \frac{V_f - V_r}{V_r}$$

Draft thickness (d)

$$d = h_{\circ} - h_f = 2R\,(1-\cos\alpha)$$

h_o= starting thickness, mm (in); and
h_f= final thickness, mm (in).
R = roll radius in mm
(α) = bite angle in degree.

The maximum draft (dmax)

$$d_{max} = \mu^2 R$$

coefficient of friction, μ

Reduction (r)

$$r = \frac{d}{h_\circ}$$

Contact length (L)

$$L = \sqrt[2]{R(h_\circ - h_f)}$$

True strain (ε)

$$\varepsilon = \ln \frac{h_\circ}{h_f}$$

Average flow stress (Yf)

$$\overline{Y_f} = \frac{K\varepsilon^n}{1+n}$$

K and n: (strength and strain hardening)

Roll force in flat rolling:

$$F = \overline{Y_f}\ w\ L$$

The torque in rolling

$$T = 0.5FL$$

The power

$$\text{Power (in Kw)} = \frac{2\pi FLN}{60000}$$

F is in newtons,

L is in meters, and

N is the revolutions per minute (rpm)

Ex: A 300-mm-wide strip 25-mm thick is fed through a rolling mill with two powered rolls of radius = 250 mm. The working thickness must be reduced to 22 mm in one pass at a roll speed of 50 rev/min. The work material has a flow curve defined by K = 275 MPa and n = 0.15, and the coefficient of friction between the rolls and the work is assumed to be 0.12. Determine if the friction is sufficient to permit the rolling operation to be accomplished. If so, calculate the roll force, torque, and power.

Solution:

The draft attempted in this rolling operation is

$$d = h_\circ - h_f$$

d = 25 - 22 = 3mm

Maximum draft

$$d_{max} = \mu^2 R$$

d_{max} = (0.12)^2(250) = 3.6mm

The contact length

$$L = \sqrt[2]{R(h_\circ - h_f)} \qquad L = \sqrt[2]{250(25-22)} = 27.4 \text{ mm}$$

$$\varepsilon = \ln\frac{h_\circ}{h_f}$$

$$\varepsilon = \ln\frac{25}{22} = 0.128$$

$$\bar{Y_f} = \frac{275X0.128^{0.15}}{1+0.15} = 175.7 \text{ MPa}$$

Rolling force is determined

$$F = \bar{Y_f}\ w\ L \qquad F = 175.7(300)(27.4) = 1{,}444{,}254 \text{ N}$$

Torque required to drive each roll

$$T = 0.5FL \qquad T = 0.5(1{,}444{,}254)(27.4)(10^{-3}) = 19.786 \text{ N-m}$$

Power:

$$\text{Power (in Kw)} = \frac{\mathbf{2\pi FLN}}{\mathbf{60000}}$$

$$\text{Power (in Kw)} = \frac{2\pi X1.444.786X0.274X50}{60000} = 207.284 \text{ Kw}$$

Questions:

1. Two thick slabs of 300mm each, the first one is used in cold rolling where μ=0.08 while the second is used in cold rolling where μ=0.5. The mill roll diameter in each case is the same as 600mm. Determine the max draft (reduction) in both cases. Discuss the wide difference in results.
2. A tensile specimen of the metal of 100 mm is length stretched to a length = of 157 mm during the rolling process. If the metal has a flow curve with parameters: K = 850 MPa and strain hardening exponent n = 0.30. Determine the average flow stress that the metal has been subjected to during the deformation.
3. During the rolling process, the average flow stress is 20,000 lb/in^2, determining the amount of reduction in the cross-sectional area (use n = 0.40 and K = 35,000 lb/in^2).
4. A plate of 270 mm wide and 25 mm thick from carbon steel. A two-high rolling mill is used to reduce the thickness to 20 mm. Roll radius = 600 mm, and roll speed = 8 rpm. Strength coefficient = 500 MPa, and strain hardening exponent = 0.25. Determine (a) roll force, (b) roll torque, and (c) power required to perform the operation.

YouTube: https://youtu.be/Kq86U1-PvCQ

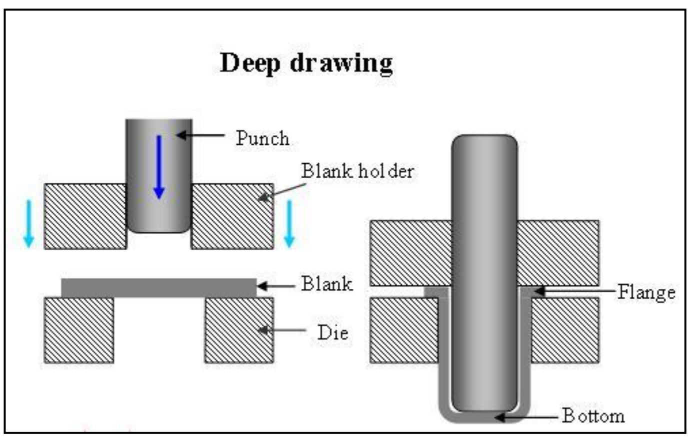
Lecture 12: Drawing Processes

Drawing is a metal forming process (cold working process). In this process rod or tube is pulled through a tapered hole in a die which results in reduction in cross section area. The shape of die determines the final product shape. Quality of product obtained is excellent. This process increases strength and hardness of the metal.
Cold drawing is performing important functions in hydraulic system of vehicles, aero planes, ships, industries, etc.….
When the metal is forced through the die by a ***tensile force*** *applied to the metal at* ***exist*** *of die it is called* ***drawing****, while when a* ***compressive force*** *is applied at the* ***entry*** *of the die it is called* ***extruding****.*

Drawing Types:

1- Deep Drawing:

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**. It is thus a shape transformation process with material retention. *The process is considered "deep" drawing when the depth of the drawn part exceeds its diameter*. This is achieved by redrawing the part through a series of dies. The flange region (sheet metal in the die shoulder area) experiences a radial drawing stress and a tangential compressive stress due to the material retention property. These compressive stresses (hoop stresses) result in **flange wrinkles** (wrinkles of the first order). *Wrinkles can be prevented by using a blank holder*, the function of which is to facilitate controlled material flow into the die radius.



In pure deep drawing there is no reduction of sheet metal thickness, forming is achieved in stretch forming purely because of a decrease in sheet metal thickness.

The recommended metals for Deep Drawing are: Aluminum, Brass, Bronze, cold rolled steel, Copper, Iron, Molybdenum, Nickel, Silver, Stainless steel, and others.

Deep Drawing Advantages:

1. Tool construction costs are lower in comparison to similar manufacturing processes.
2. The technique is ideal for products that require significant strength and minimal weight.
3. The process is also recommended for product geometries that are unachievable through other manufacturing techniques.
4. Deep drawing is especially beneficial when producing high volumes since unit cost decreases considerably as unit count increases.

Deep Drawing Disadvantages:

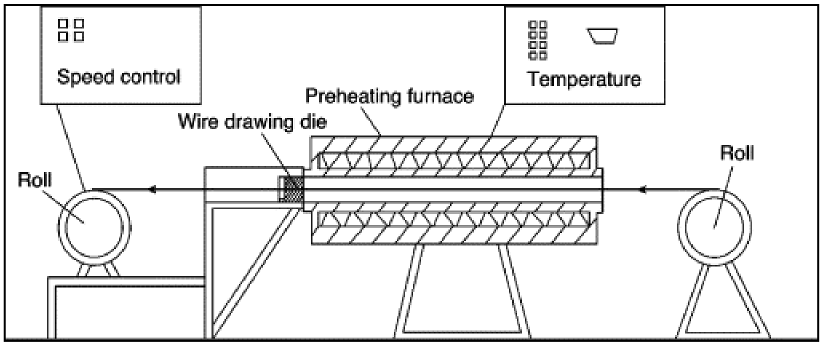
1. Material thickness has a large effect on processing price.
2. Special sleeves required to assist in driving the parts into the dies.
3. This process is costly for low production rate.
4. Limited shapes

2- Wire drawing:

To begin the wire drawing process, a ***spool*** *of wire is placed at beginning of the machine on a spool*. To feed it through the machine, the end of wire must be cut or flattened. It is fed through the machine and through a series of dies to achieve its final cross-sectional area. The end of the machine usually has a spool or coiler, so the finished product is a coil of wire at the desired cross-sectional area. The end process may also be a barrel packer where a barrel is placed, and the coiled wire is spooled directly into the barrel using a turntable.

It is vitally important the temperature of the machinery does not get too hot (primarily caused by the energy released while deforming of the metal) and the wire has a constant tension and speed as it moves through the series of dies.

There are many applications for wire drawing, including electrical wiring, cables, tension-loaded structural components, springs, paper clips, spokes for wheels, and stringed musical.



Wire drawing Advantages

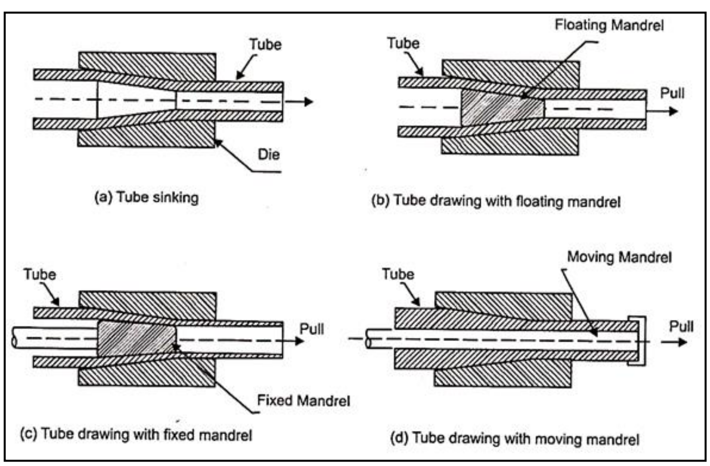
1. Close dimensional control
2. Improved mechanical properties such as strength and hardness.
3. Adaptability to economical batch or mass production

Wire and Tube Drawing Disadvantages:

1. That lengths are limited by the length of the mandrel, usually no more than 100 feet (30 m), and that a second operation is required to remove the mandrel, called reeling. This type of process is usually used on heavy walled or small (inner diameter) tubes.

3- Tube Drawing:

Tube producers often use tube drawing to change tube IDs, ODs, and wall thicknesses. Drawing also can improve the surface finish and refine the grain structure. Tubing is used in applications as varied as aircraft hydraulic lines, diesel fuel lines, thermocouple sheathing, chromatography, and semiconductor manufacture.



a- Tube Sinking:

In this process, tube is simply pulled through the die. The outer diameter is regulated by the die diameter but there is no regulation of inner diameter or thickness of tube. The surface finish on inner diameter is also not good. During the drawing operation the thickness of tube generally changes.

b- Tube Drawing with Floating Mandrel:

The process of tube drawing with a floating mandrel. The position of mandrel with respect to the die gets adjusted by the normal and tangential forces exerted by tube material on the mandrel. The frictional force tends to pull the mandrel into the die while the normal force tries to it push out. Since there is no external control on the position of the mandrel, it may change its position if the frictional condition changes, thus resulting in change in tube thickness.

c- Tube Drawing with Fixed Mandrel:

The tube is drawn through a die and a mandrel. The position of mandrel may be adjusted by the bar attached to its rear end to change the thickness of tube and the internal diameter. The external diameter is determined by the die diameter. The surface quality of both the surfaces, internal as well as external gets improved. The pull required is certainly more than that in tube sinking because of the additional deformation in the thickness of tube and due to frictional force between the tube and the mandrel.

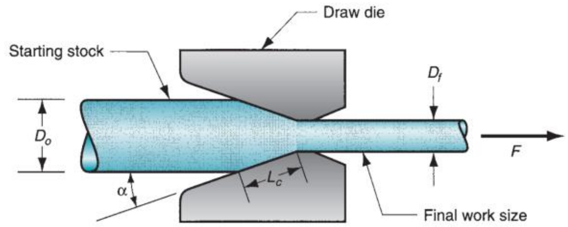
d- Tube Drawing with Moving Mandrel:

The process is illustrated the cylindrical mandrel and the tube are pulled together through the die. The process is generally used to reduce the thickness of tube. Since the area of cross section of tube increases towards the entry side its speed decreases while the mandrel being rigid moves with the same speed as the speed of tube at the exit. Therefore, in the deformation zone the mandrel moves faster than the tube. The frictional force between the tube and the mandrel pulls the tube inside the die while the frictional stress between the tube and die acts in the opposite direction.

Tube drawing Advantages:

1. Low equipment and tooling cost
2. Good surface finish and dimensional accuracy
3. High production rate
4. Long lengths of rounds, tubing, square, angles, etc. can be produced.

Drawing Analysis



Area Reduction

$$r = \frac{A_o - A_f}{A_o}$$

where r area reduction in drawing; A_o original area of work, and A_f final area

Draft

$$d = D_o - D_f$$

where d draft; D_o original diameter; and D_f final work diameter.

True strain:
$$\epsilon = \ln\frac{A_o}{A_f} = \ln\frac{1}{1-r}$$

Average flow stress(Y_f**)**:
$$\overline{Y}_f = \frac{K\epsilon^n}{1+n}$$

Stress (ideal deformation)
$$\sigma = \overline{Y}_f\epsilon = \overline{Y}_f \ln\frac{A_o}{A_f}$$

Draw Stress
$$\sigma_d = \overline{Y}_f\left(1 + \frac{\mu}{\tan\alpha}\right)\phi \ln\frac{A_o}{A_f}$$

where σ_d draw stress; μ die-work coefficient of friction; α die angle (half-angle) φ factor that accounts for inhomogeneous deformation:

$$\phi = 0.88 \pm 0.12\frac{D}{L_c}$$

Average diameter (D)
$$D = \frac{D_o + D_f}{2}$$

Contact length (Lc)
$$L_c = \frac{D_o - D_f}{2\sin\alpha}$$

Draw Force
$$F = A_f\sigma_d = A_f\overline{Y}_f\left(1 + \frac{\mu}{\tan\alpha}\right)\phi \ln\frac{A_o}{A_f}$$

Ex: *Wire is drawn through a draw die with entrance angle 15°. Starting diameter is 2.5 mm and final diameter 2.0 mm. The coefficient of friction at the work–die interface 0.07. The metal has a strength coefficient K=205 MPa and a strain-hardening exponent n = 0.20. Determine the draw stress and draw force in this operation.*

$$D = \frac{D_o + D_f}{2} \qquad = (2.5+2)/2=2.25$$

$$L_c = \frac{D_o - D_f}{2 \sin \alpha} \qquad =(2.5-2)/(2*\sin 15) = 0.966$$

$$\phi = 0.88 \pm 0.12 \frac{D}{L_c} \qquad \phi = 0.88 + 0.12 \frac{2.25}{0.966} = 1.16$$

The areas before and after drawing:

A_o=4.91mm^2 and A_f =3.14 mm^2.

True strain $\varepsilon = \ln (4.91/3.14) = 0.446$

Average Flow Stress $\overline{Y}_f = \frac{K\epsilon^n}{1+n}$ $\qquad \overline{Y}_f = \frac{205(0.446)^{0.20}}{1.20} = 145.4 \text{ MPa}$

Draw stress

$$\sigma_d = \overline{Y}_f \left(1 + \frac{\mu}{\tan \alpha}\right) \phi \ln \frac{A_o}{A_f}$$

$$\sigma_d = (145.4)\left(1 + \frac{0.07}{\tan 15}\right)(1.16)(0.446) = 94.1 \text{ MPa}$$

Draw force

$$F = A_f \sigma_d \qquad F = 94.1(3.14) = 295.5 \text{ N}$$

Questions

Q1: A spool of copper wire has a starting diameter of 2.5 mm. It is drawn through a die with an opening that is 2.1 mm. The entrance angle of the die = 18°. Coefficient of friction at the work die interface is 0.08. The pure copper has a strength coefficient = 300 MPa and a strain hardening coefficient = 0.50. The operation is performed at room temperature. Determine (a) area reduction, (b) draw stress, and (c) draw force required for the operation.

Q2: Aluminum rod stock with a starting diameter = 0.50 in is drawn through a draw die with an entrance angle = 13°. The final diameter of the rod is = 0.375 in. The metal has a strength coefficient = 25,000 lb/in^2 and a strain hardening exponent = 0.20. Coefficient of friction at the work-die interface = 0.1. Determine (a) area reduction, (b) draw force for the operation.

Q3: Bar stock of initial diameter = 90 mm is drawn with a draft = 15 mm. The draw die has an entrance angle = 18°, and the coefficient of friction at the work-die interface = 0.08. The metal behaves as a perfectly plastic material with yield stress = 105 MPa. Determine (a) area reduction, (b) draw stress, (c) draw force required for the operation.

YouTube: https://youtu.be/uCThQTUNdWU

Lecture 13: Welding Technology

1. Introduction

Welding is a process for joining two similar or dissimilar metals by fusion. It joins different metals/alloys, with or without the application of pressure and with or without the use of filler metal.

Weldability may be defined as property of a metal which indicates the ease with which it can be welded with other similar or dissimilar metals.

2. Welding joints

Some common welding joints are shown in Fig. 17.3. Welding joints are of generally of two major kinds namely lap joint and butt joint.

2.1. Lap weld joint

1. **Single-Lap Joint:** This joint, made by overlapping the edges of the plate, is not recommended for most work. The single lap has very little resistance to bending.
2. **Double-Lap Joint:** This is stronger than the single-lap joint but has the disadvantage that it requires twice as much welding.

2.2. Butt weld joint

1. **Single-Vee Butt Weld:** It is used for plates up to 15.8 mm thick. The angle of the vee depends upon the technique being used, the plates being spaced approximately 3.2 mm.
2. **Double-Vee Butt Weld** It is used for plates over 13 mm thick when the welding can be performed on both sides of the plate. The top vee angle is either 60° or 80°, while the bottom angle is 80°, depending on the technique being used.

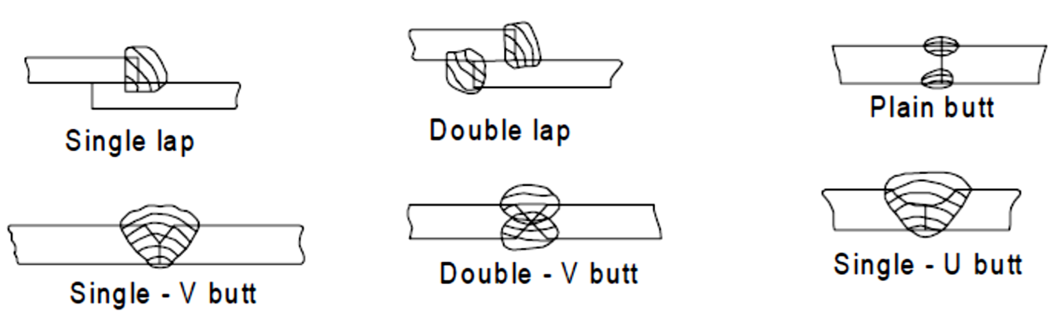


Fig. 4.1 lap and butt-welding joints

3. Welding Positions

There are four types of welding positions, which are given as:

1. Flat or down hand position
2. Horizontal position
3. Vertical position
4. Overhead position

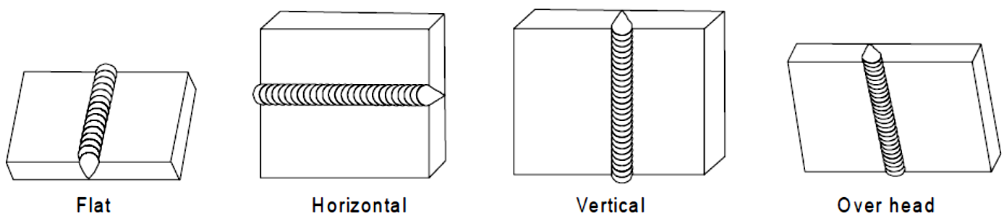


Fig. 4.2 Kinds of welding positions

4. CLASSIFICATION OF WELDING PROCESSES

1. Oxy-Fuel Gas Welding Processes
   a. Air-acetylene welding
   b. Oxy-acetylene welding
2. Arc Welding Processes
   a. Shielded Metal Arc Welding
   b. Gas Metal Arc Welding
   c. Gas Tungsten Arc Welding
   d. Submerged Arc Welding
   e. Plasma Arc Welding
3. Resistance Welding
   a. Spot Welding
   b. Seam Welding
4. Solid-State Welding Processes
   a. Forge Welding
   b. Friction Welding
   c. Explosive Welding
5. Thermit Welding Processes
6. Radiant Energy Welding Processes
   a. Laser Welding
   b. Electron Beam Welding

4.1. Oxy-Acetylene Welding

In this process, acetylene is mixed with oxygen in correct proportions in the welding torch and ignited. The flame resulting at the tip of the torch is sufficiently hot to melt and join the parent metal. The oxy-acetylene flame reaches a temperature of about 3300°C and thus can melt most of the ferrous and non-ferrous metals in common use. A filler metal rod or welding rod is generally added to the molten metal pool to build up the seam slightly for greater strength.

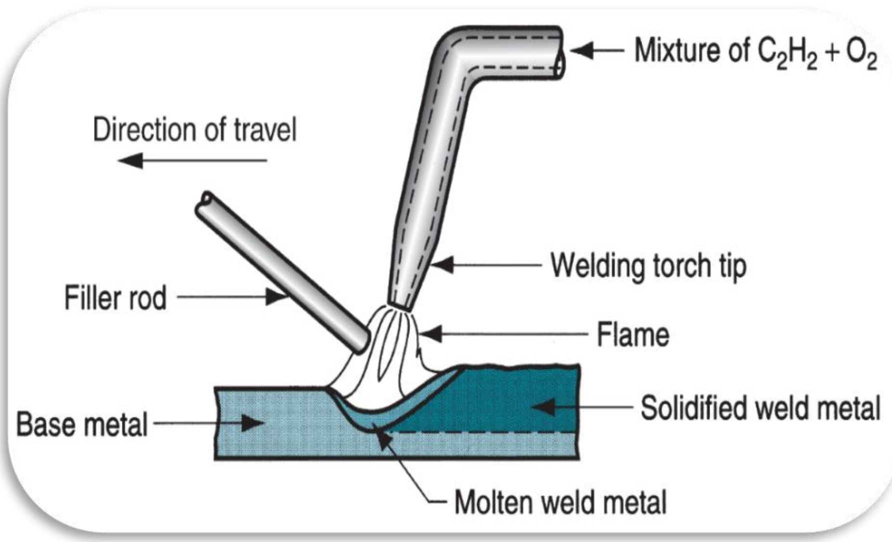


Fig. 4.3 Gas welding operation

4.2. Arc Welding Processes

4.2.1. Shielded Metal Arc Welding (SMAW)

Shielded metal arc welding (SMAW) is a commonly used arc welding process manually carried by welder. 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 supplies the filler material for making a weld. SMAW can be carried out in any position with highest weld quality and is the simplest of all the arc welding processes.

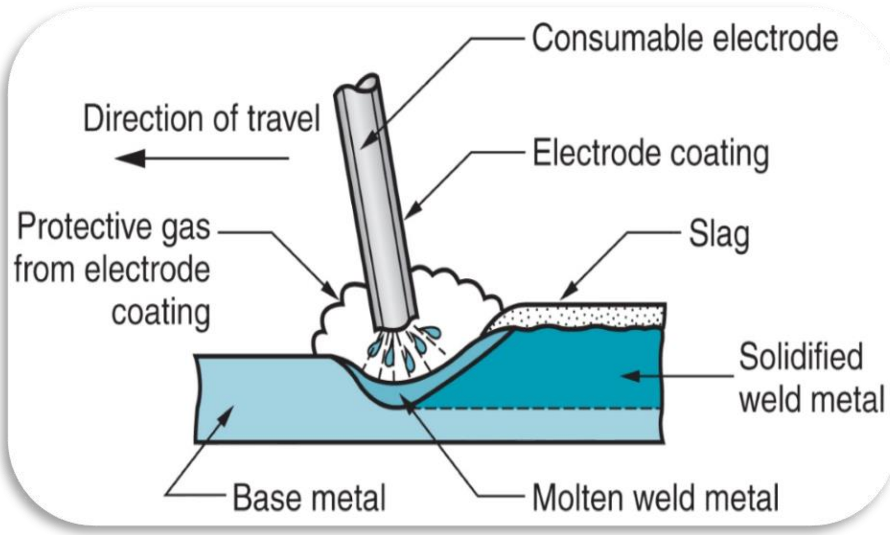


Fig. 4.4 Schematic SMAW Process

4.2.2. Gas Metal ARC Welding (GMAW) or Metal Inert Gas Welding (MIG)

Metal inert gas arc welding (MIG) or more appropriately called as gas metal arc welding (GMAW) utilizes a consumable electrode. The typical setup for GMAW or MIG welding process is shown in Fig. 4.5. The consumable electrode is in the form of a wire reel which is fed at a constant rate, through the feed rollers. The welding torch is connected to the gas supply cylinder which provides the necessary inert gas. The electrode and the workpiece are connected to the welding power supply. The power supplies are always of the constant voltage type only.

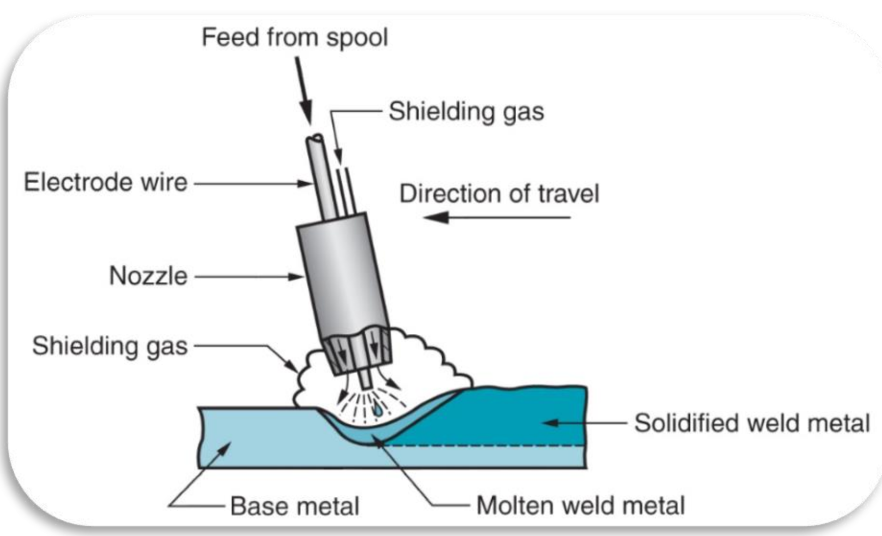


Fig. 4.5 Gas metal arc welding (GMAW) set up

4.2.3. Tungsten Inert Gas Welding (TIG)

In this process a non-consumable tungsten electrode is used with an envelope of inert shielding gas around it. The shielding gas protects the tungsten electrode and the molten metal weld pool from the atmospheric contamination. The shielding gases generally used are argon, helium, or their mixtures. Typical tungsten inert gas welding setup is shown in Fig. 5.5.

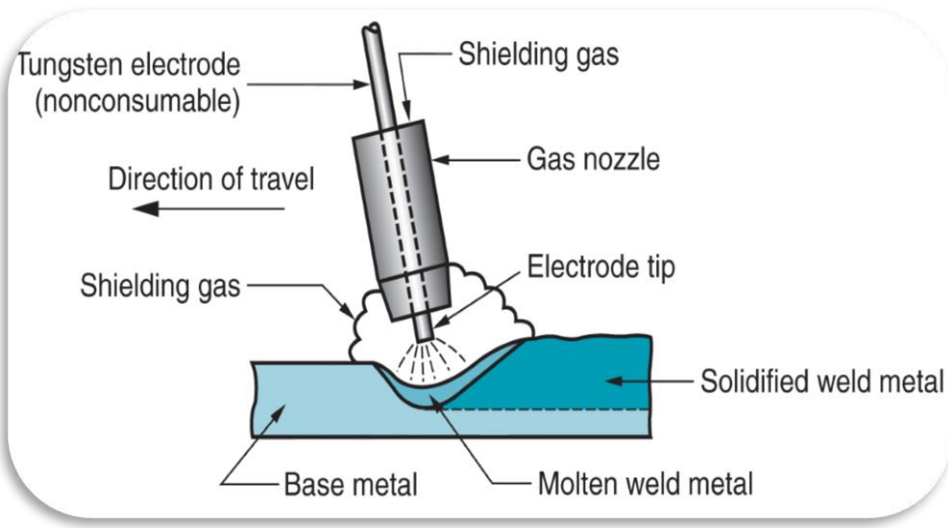


Fig. 5.5 Tungsten inert gas welding setup

4.2.4. Submerged Arc Welding

Schematic submerged arc welding process is shown in Fig. 5.6. In this welding process, a consumable bare electrode is used in combination with a flux feeder tube. The arc, end of the bare electrode and molten pool remain completely submerged under blanket of granular flux. The feed of electrode and tube is automatic, and the welding is homogenous in structure. No pressure is applied for welding purposes. This process is used for welding low carbon steel, bronze, nickel, and other non-ferrous materials.

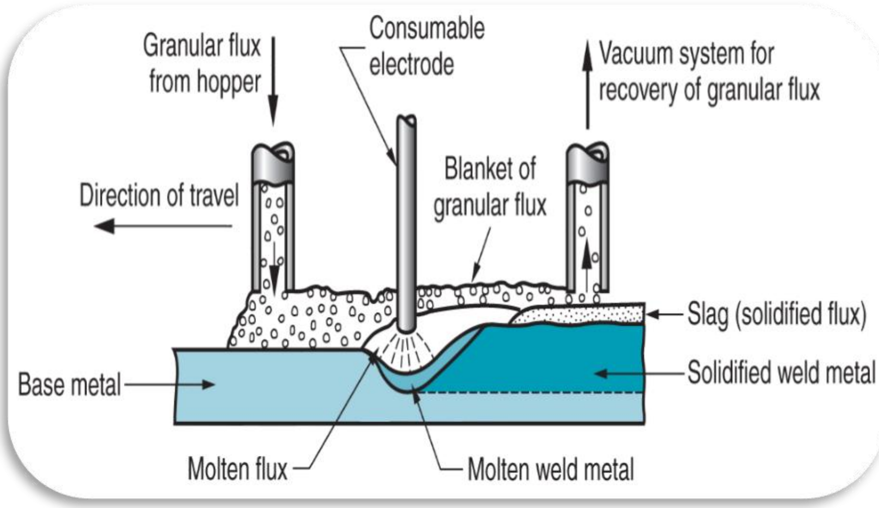


Fig. 5.6 Schematic submerged arc welding process

4.3.RESISTANCE WELDING

In resistance welding the metal parts to be joined are heated by their resistance to the flow of an electrical current. The process applies to practically all metals and most combinations of pure metals and those alloys, which have only a limited plastic range, are welded by heating the parts to fusion (melting).

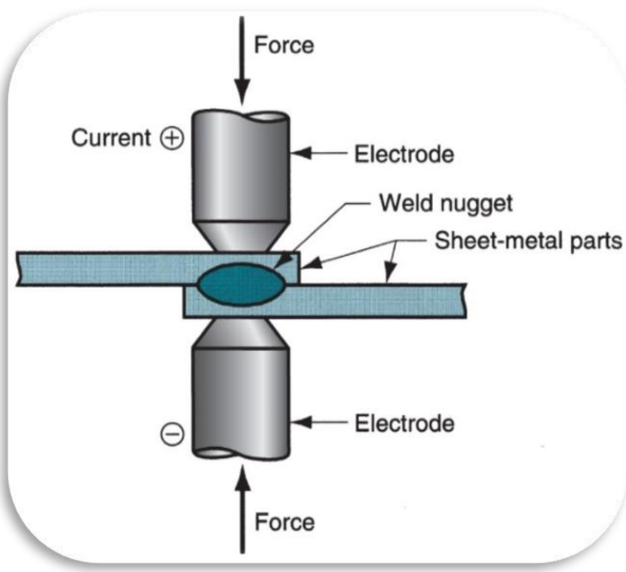


Fig. 5.7 Resistance spot welding machine

4.4. SOLID STATE WELDING PROCESSES

4.4.1. Friction Welding

In this process, the heat for welding is obtained from mechanically induced sliding motion between rubbing surfaces of workpieces as shown in Fig. 5.8. In friction welding, one part is firmly held while the other (usually cylindrical) is rotated under simultaneous application of axial pressure. As these parts are brought to rub against each other under pressure, they get heated due to friction. When the desired forging temperature is attained, the rotation is stopped, and the axial pressure is increased to obtain forging action and hence welded joint. Most of the metals and their dissimilar combinations such as aluminum and titanium, copper and steel, aluminum and steel etc. can be welded using friction welding.

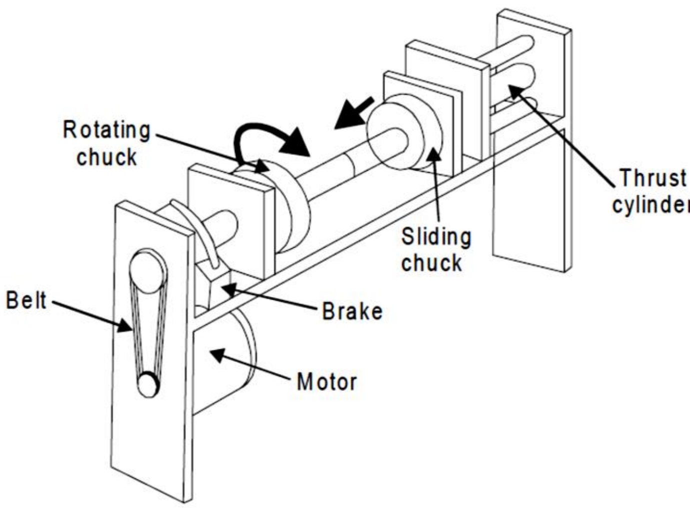


Fig. 5.8 Friction welding process

YouTube: https://youtu.be/IGgIgb6qDR0