

1. Tool Materials

- ✓ Cutting tool materials are materials that are used to make cutting tools that are used in machining (drill bits, tool bits, milling cutters, etc.) but no other cutting tools like knives or punches.
- ✓ Cutting tool materials must be harder than the material of the workpiece, even at high temperatures during the process.
- ✓ The following properties are required for the cutting tool
 - hardness, hot hardness (hardness at high temperature)
 - bending strength and toughness
 - wear & abrasion resistance
 - oxidation & chemical resistance





1.1 Different Cutting Tool Materials

Most common engineering materials used in tool making are:

a) Carbon Steel Tool:

Carbon Steel is widely used for machining soft materials like, Magnesium, Aluminum, Wood etc. It contains carbon, silicon and magnesium as its constitute. This material used for making hand drills narrow blade, taps, dies, chisels etc. Its cutting speed is about 10 mm and highest temperature up to which it can work is 200 – 250 degree centigrade.

b) High Speed Steel (HSS):

High speed steel is very common tool material which is an alloy of steel tungsten, Chromium and Vanadium. It contains 18% Tungsten, 4% Chromium and 1% Vanadium. This material is deep hardening and can be quenched in oil, air or salt. It has highest toughness. Its cutting speed is about 30 – 50 mmm. It can work up to 650 degree centigrade.

c) Cemented Carbide Tool:

It is made by powder metallurgy technique. In this material, cobalt acts as binding material.

Its highest speed up to which it can work is about 60-200 mm and its working temperature limit is up to 1000-1200 degree centigrade. All carbides when finished are extremely brittle and weak in their resistance to impact and shock loading. That's why vibrations are very harmful for carbide tools.

d) Ceramics:

This tool is combination of silicon carbide and aluminum oxide. It is also made by powder metallurgy. It cannot work at low speed. This tool material has very high abrasion resistance and hard compare to cemented carbide

tool. It is particularly used for machining cast iron and high tensile steel with higher cutting speed compare to cemented carbide tool. Its highest working temperature is about 1400 degree centigrade. Its cutting speed is about 300 – 600 mm.

e) Cubic Boron Nitride

It is the second hardest material after diamond. It is not a natural material. It consists of atoms of nitrogen and boron. This has high hardness and high thermal conductivity. CBN is chemically inert and is used as a substitute of diamond for machining steel. It is mostly used as abrasive in grinding wheel. Its highest cutting speed is about 600 – 800 mmm.

f) Diamond

Diamond is a highest known hard tool material on the earth. It has good thermal conductivity, low thermal expansion and low friction coefficient. It's cutting speed is about 1500 – 2000 mmm. It is used for machining hard material like hard carbide, nitrides etc. It is mostly used to machining nonferrous material.

g) SiAlON

SiAlON ceramics are a specialist class of high-temperature refractory materials, with high strength at ambient and high temperatures, good thermal shock resistance and exceptional resistance to wetting or corrosion by molten non-ferrous metals, compared to other refractory materials such as, for example, alumina. A typical use is with handling of molten aluminium. They also are exceptionally corrosion resistant and hence are also used in the chemical industry. SiAlONs also have high wear resistance, low thermal expansion and good oxidation resistance up to above ~1000 °C.

SiAlONs are ceramics based on the elements silicon (Si), aluminium (Al), oxygen (O) and nitrogen (N). They are solid solutions of silicon nitride (Si_3N_4), where Si–N bonds are partly replaced with Al–N and Al–O bonds. The substitution degrees can be estimated from the lattice parameters.



2. Steel

- ✓ Steel is an alloy made up of iron with typically a few tenths of a percent of carbon to improve its strength and fracture resistance compared to other forms of iron. Many other elements may be present or added.
- ✓ The carbon in typical steel alloys may contribute up to 2.14% of its weight.

2.1 Advanced Steel

a) Case Hardening Steel

- ✓ A tough core and a hard case are the desired attributes of case-hardened steel components.
- ✓ Case-hardening steels have a relatively low carbon content mostly ranging between 0.10 and 0.30%. They are intended for case hardening, a special variant of hardening. It consists of the process steps carburizing, hardening and tempering.
- ✓ A diffusion process is used to introduce carbon into the surface layer up to a C content of approx. 0.8%. The surface hardness and the properties of the core are obtained by hardening and tempering. This process leads to a hard, wear-resistant surface layer, while the core is comparatively tough, which enables the steel to withstand impact stresses without fracture and lends it a high resistance to wear.
- ✓ Case-hardening steel is used in automotive engineering as well as in mechanical and plant engineering for parts such as cardan shafts, coupling parts, gears and bolts.

b) Cold Work Tool Steel

- ✓ Cold work tool steels are high carbon steels containing smaller amounts of manganese, tungsten, molybdenum, and chromium. They have good dimensional stability and hardenability. They are further classified into three subgroups: Air-hardening steels, High-carbon, high-chromium steels, Oil-hardening steels.
- ✓ The applications of the oil-hardening cold-work steels are as follows:
 - Shear blades, draw dies, stamping dies, coining tools, and burnishing tools.
 - Trimming, blanking, flanging, drawing, and forming dies and punches.
 - Machinery components and gages in order to achieve good dimensional stability and wear resistance properties.
 - Blanking and piercing dies, gages, forming and banding rolls, shears, mandrels, lathe centers, reamers, broaches, threading dies, taps, and knurling tools.
 - Molds for wire cutting, rolling cutters, wheels, screw molds, and drawing dies in screw industry, and shaping wheels in steel tube industry.

c) Hot Work Tool Steels

- ✓ Hot work tool steels are steels capable of withstanding high abrasion, heat and pressure conditions that prevail in manufacturing units that perform processes such as forming, shearing and punching of metals at high temperatures of 480 to 760°C (900 to 1400°F).
- ✓ In general, hot-work steels are of the medium and high-alloy type and most of them has relatively low carbon content (0.25 to 0.6%). Hot work steels should have the following physical characteristics:
 - Resistance to deformation at the working temperature.
 - Resistance to shock.
 - Resistance to wear at the working temperature.
 - Resistance to heat treating deformation.
 - Resistance to heat checking.
 - Good machinability in the annealed condition.

d) High-Speed Steel

- ✓ High-speed steel is special alloy steel which is obtained by alloying tungsten, Chromium, Vanadium, Cobalt and molybdenum with steel.
- ✓ HSS is an alloy of 18% tungsten, 4% chromium and 1% Vanadium
- ✓ This term is descriptive of their ability to cut metals at 'high speeds'.
- ✓ It is superior to the older high-carbon steel tools used extensively through the 1940s in that it can withstand higher temperatures without losing its temper (hardness). This property allows HSS to cut faster than high carbon steel, hence the name high-speed steel.
- ✓ The main use of high-speed steels continues to be in the manufacture of various cutting tools: drills, taps, milling cutters, tool bits, hobbing (gear) cutters, saw blades, planer and jointer blades, router bits, etc., although usage for punches and dies is increasing.

3. Cast Iron

- ✓ Cast iron is a class of iron–carbon alloys with a carbon content more than 2%.
- ✓ Carbon percentage varies from 2 to 4 percent along with varying amounts of silicon and manganese and traces of impurities such as sulfur and phosphorus. It is made by reducing iron ore in a blast furnace.

Aspect	Steel	Cast Iron (CI)
Definition	Alloy of Fe & C; %C is less than 2%	Alloy of Fe & C; %C is more than 2%
Furnace	Electric	Cupola
Hardness	Less	More
Ductility	More	Less/Brittle
Wear Resistance	Less	More
Vibration Damping	Less	More
Compressive Strength	Less	High
Tensile Strength	High	Low
Castability	Low	High
Machinability	Low	High
Melting Point	High	Low
Cost	High	Low

Product Applications. Due to its low cost, gray C.I. is preferred in all fields where ductility and high strength are not required, for example, weights; frames; motor, gear and pump housings; sanitary wares; pipe fittings and gas and water pipes for underground purposes etc. Due to its high compressive strength and good damping characteristics, gray C.I. is used for machine tool bases and supports for structures. Again, due to its fluidity and excellent wear properties, gray C.I. is used extensively in the manufacture of engine blocks, brake drums, sliding surfaces of machines, gearing, gear housings, piston rings, and so on. Gray C.I. has also been used for the manufacture of engine crankshafts, because of its good damping properties, high torsional shear strength and low notch sensitivity. Other product applications of gray C.I. are : Household appliances, manhole covers, cylinder heads for engines and in rolling mill and general machinery parts.

3.1 Malleable Cast Iron

Malleable Cast Iron. Malleable castings are first made from white cast iron and then malleabilized by two methods : “Black heart method” and “white heart method”

(i) **Black heart Method.** In this method, the white iron castings are annealed by heating them for a prolonged period of several days (to a temperature of 850 – 1000°C) in air tight pots filled with inert material such as ferrous silicate scale (or iron oxide) or slag. The action of heat and iron oxide partially removes the carbon and reduces the remainder from combined state to a globular form of free carbon, so that after a slow cooling, a strong soft and somewhat ductile casting is obtained. This method, which is also called “decomposition” is used in U.S.A. and the material is Ferritic malleable iron.

(ii) **White heart Method.** In this method (decarburisation), the castings are placed in pots packed with an oxidising material. The oxygen combines with carbon in the castings, reducing its amount to less than 1%. This method is used in Europe, and the material is pearlitic malleable iron.

The difference between gray C.I. and malleable C.I. is the form in which the free carbon occurs. In gray C.I., the free carbon occurs in the form of flat or plate like particles, whereas in malleable C.I., the graphite is in the form of irregularly shaped spherical particles which are much

more desirable from a strength point of view than flakes.

Malleable C.I. is stronger and tougher, ductile, resistant to impact and easily machinable (due to the presence of graphite). Since the carbon change reaches only to a depth of about 10 mm, this process is not suitable for heavy castings. The application of malleable C.I. is considerably more limited than that of gray C.I., because it is more expensive to produce and better mechanical properties are not required in most cases.

The use of malleable cast iron usually involves parts of complex shape that often need considerable machining to meet the specifications, such as, : in automotive and agricultural equipment industries (housings, yokes, wheel hubs), hinges, door-keys, spanners, mountings of all sorts, cranks, levers, thin walled components of sewing machines, textile machines and others, brake pedals in cars, spring hangers and so on.

3.2 Gray Cast Iron

Gray Cast Iron. When the molten C.I. is cooled, its final structure will depend upon the form in which the carbon solidifies, which in turn will depend upon the cooling rates as well as composition. The control will be affected by the total C and Si (also P) and their total effect is expressed by the 'carbon equivalent', (C.E.) :

$$\text{C.E.}(\%) = \text{C}\% + \frac{\text{Si}\% + \text{P}\%}{3}$$

At relatively high C.E. and slower cooling rates, the solidified cementite, being unstable, breaks up into austenite and graphite flakes. The process is called as "graphitization". The presence of certain elements, of which Si is most important, promotes graphitization. The graphite flakes give the cast iron the gray appearance when fractured, hence the name "gray" C.I.

Gray C.I. is the most widely used of all cast irons. In fact, it is common to speak of gray cast iron just as cast iron. It contains 2.50 to 3.75% C and upto 2.5% Si.

Gray cast iron is soft, easily machined and only moderately brittle. Its main advantages are : low cost, low melting point, fluidity and good damping capacity. Another good property it possesses is that the free graphite in its structure acts as a lubricant and when very large machine slides are made of it, a very free-working action is obtained.

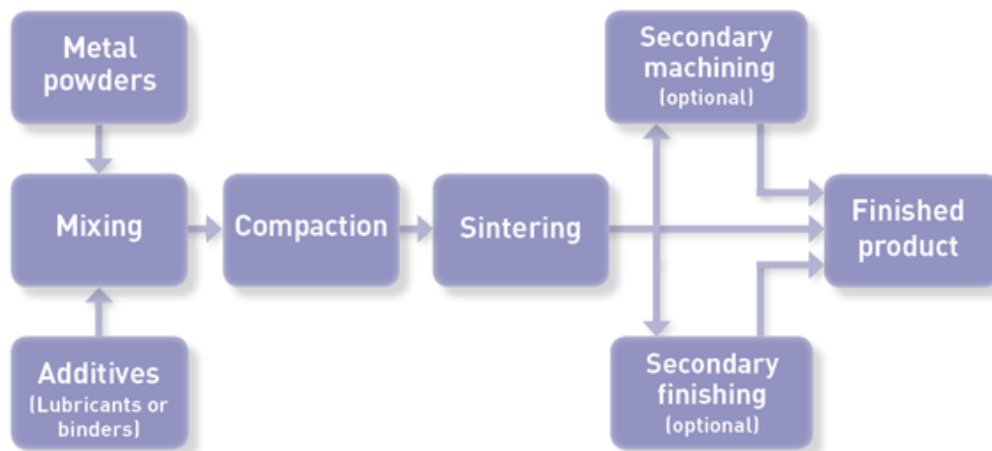
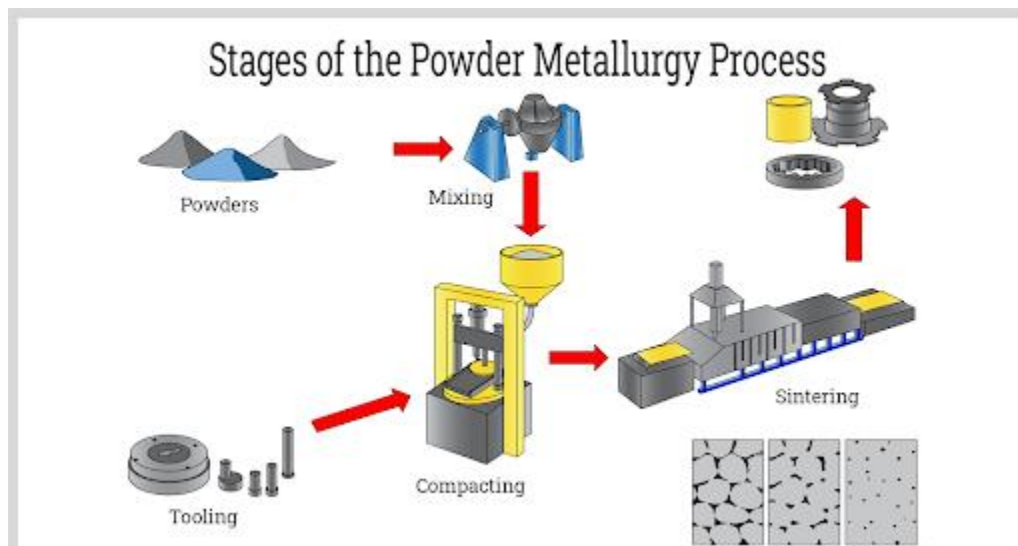
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Table

<i>Metal</i>	<i>C</i>	<i>Si</i>	<i>Mn</i>	<i>S</i>	<i>P</i>
Pig iron	3.00 – 4.00	0.50 – 3.00	0.10 – 1.00	0.02 – 0.10	0.03 – 2.00
Gray cast iron	2.50 – 3.75	1.00 – 2.50	0.40 – 1.00	0.06 – 0.12	0.10 – 1.00
Malleable cast iron	2.20 – 3.60	0.40 – 1.10	0.10 – 0.40	0.03 – 0.30	0.10 – 0.20
White cast iron	1.75 – 2.30	0.85 – 1.20	0.10 – 0.40	0.12 – 0.35	0.05 – 0.20

4. Powder Metallurgy

- ✓ Powder metallurgy (PM) is a metal processing technology in which parts are produced from metallic powders.
- ✓ In the usual PM production sequence, the powders are compressed into the desired shape and then heated to cause bonding of the particles into a hard, rigid mass. Compression, called pressing.
- ✓ The heating treatment, called sintering, is performed at a temperature below the melting point of the metal.



4.1 Making Metal Powder

The first step in the overall powder metallurgy (PM) process is making metal powders. There are four main processes used in powder production: solid-state reduction, atomization, electrolysis, and chemical.

Solid-State Reduction

In solid-state reduction, selected ore is crushed, typically mixed with carbon, and passed through a continuous furnace. In the furnace, a reaction takes place, reducing the carbon and oxygen from the powder, that leaves a cake of sponge metal which is then crushed, separated from all non-metallic material, and sieved to produce powder. Since no refining operation is involved, the purity of the powder is dependent on the purity of the raw materials. The irregular sponge-like particles are soft, readily compressible, and give compacts of good pre-sinter ("green") strength.

Atomization

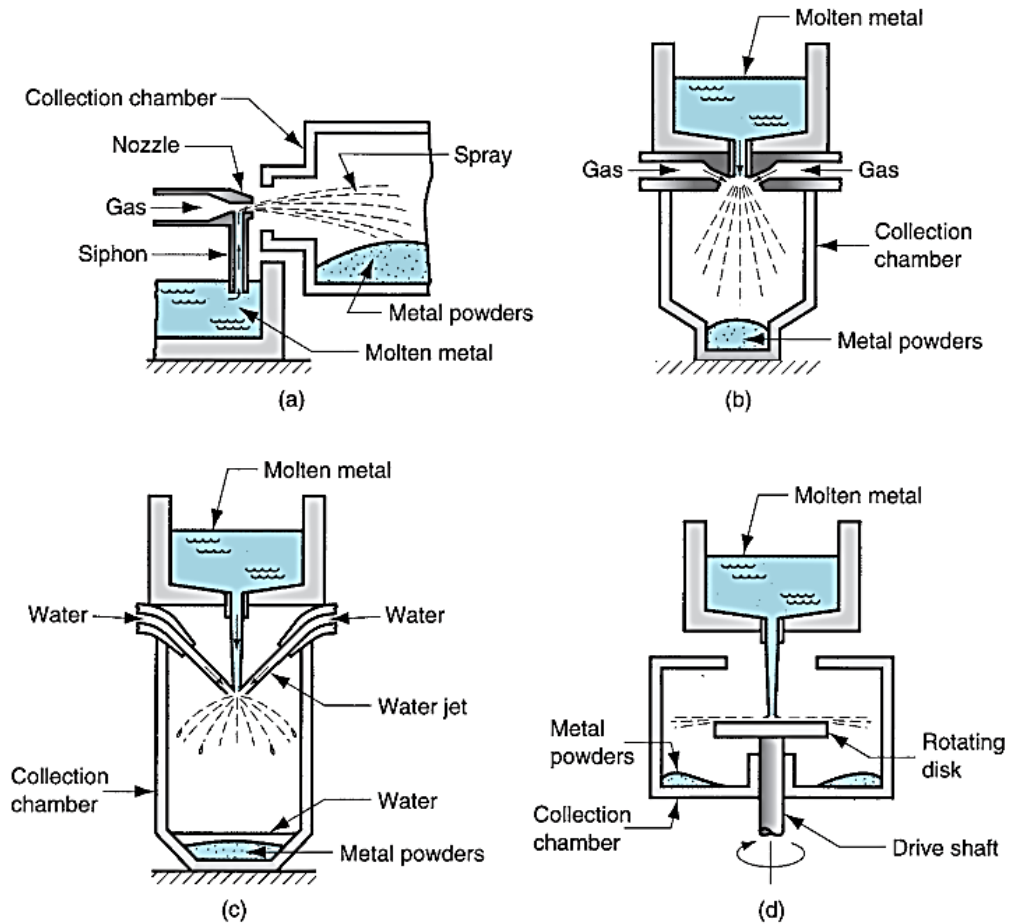
In this process, molten metal is separated into small droplets and frozen rapidly before the drops come into contact with each other or with a solid surface. Typically, a thin stream of molten metal is disintegrated by subjecting it to the impact of high-energy jets of gas or liquid. In principle, the technique is applicable to all metals that can be melted and is used commercially for the production of iron; copper; alloy steels; brass; bronze; low-melting-point metals such as aluminum, tin, lead, zinc, and cadmium; and, in selected instances, tungsten, titanium, rhenium, and other high-melting-point materials.

Electrolysis

By choosing suitable conditions, such as electrolyte composition and concentration, temperature, and current density, many metals can be deposited in a spongy or powdery state. Further processing—washing, drying, reducing, annealing, and crushing—is often required, ultimately yielding high-purity and high-density powders. Copper is the primary metal produced by electrolysis but iron, chromium, and magnesium powders are also produced this way. Due to its associated high energy costs, electrolysis is generally limited to high-value powders such as high-conductivity copper powders.

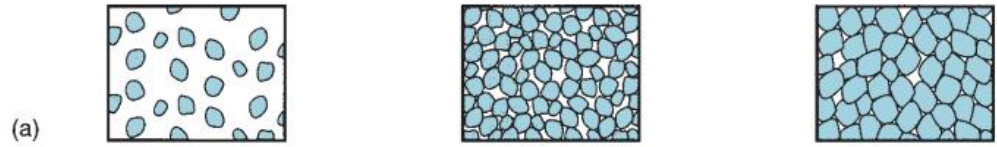
Chemical

The most common chemical powder treatments involve oxide reduction, precipitation from solutions, and thermal decomposition. The powders produced can have a great variation in properties and yet have closely controlled particle size and shape. Oxide-reduced powders are often characterized as "spongy," due to pores present within individual particles. Solution-precipitated powders can provide narrow particle size distributions and high purity. Thermal decomposition is most often used to process carbonyls. These powders, once milled and annealed, exceed 99.5% purity.

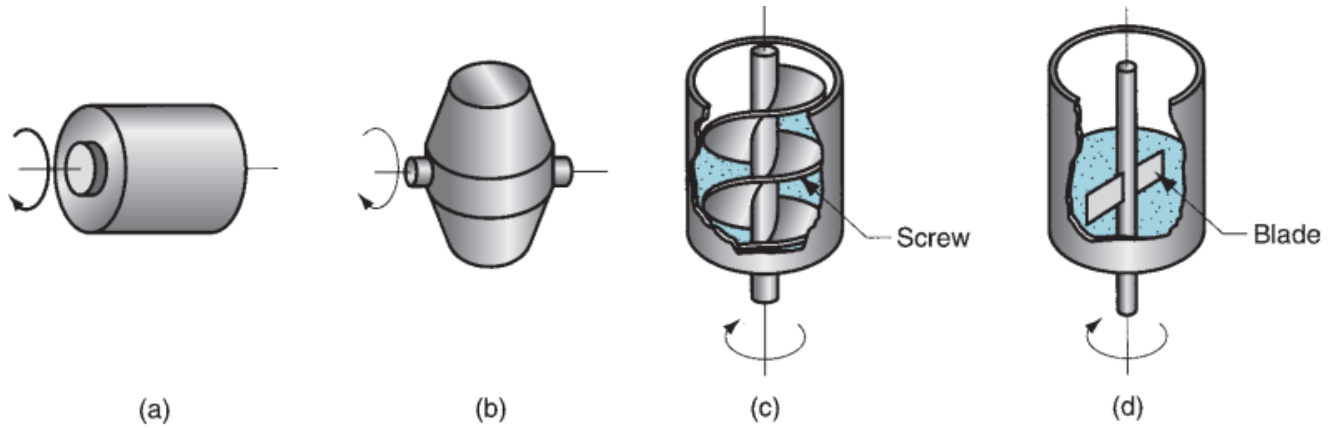
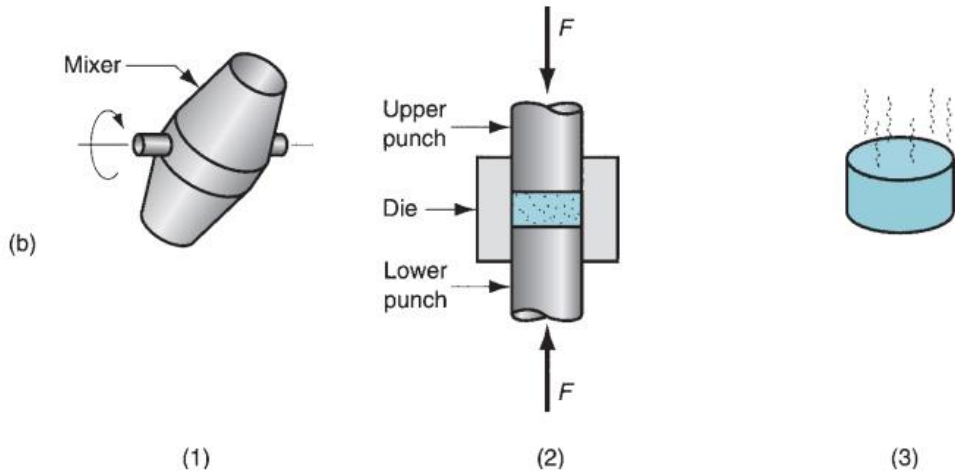


4.2 Blending and Mixing of The Powders

- ✓ Blending refers to when powders of the same chemical composition but possibly different particle sizes are intermingled. Different particle sizes are often blended to reduce porosity.
- ✓ Mixing refers to powders of different chemistries being combined. An advantage of PM technology is the opportunity to mix various metals into alloys that would be difficult or impossible to produce by other means.
- ✓ Other ingredients are usually added to the metallic powders during the blending and/or mixing step. These additives include (1) **lubricants**, such as stearates of zinc and aluminum, in small amounts to reduce friction between particles and at the die wall during compaction; (2) **binders**, which are required in some cases to achieve adequate strength in the pressed but unsintered parts; and (3) **deflocculants**, which inhibit agglomeration of powders for better flow characteristics during subsequent processing.



The conventional powder metallurgy production sequence: (1) blending, (2) compacting, and (3) sintering; (a) shows the condition of the particles, whereas (b) shows the operation and/or workpart during the sequence.



Several blending and mixing devices: (a) rotating drum, (b) rotating double-cone, (c) screw mixer, and (d) blade mixer.

5. Non-Ferrous Alloys

ALUMINIUM

It is a white metal produced by electrical process from the oxide (alumina), which is prepared from a clayey mineral called bauxite. It is a light weight metal having specific gravity 2.7 and melting point 660°C.

In its pure state, the metal would be weak and soft for most purposes. But when mixed with small amounts of other alloys, it becomes hard and rigid. So, it may be blanked, formed, drawn turned, cast, forged and die cast. Its good electrical conductivity is an important property and is widely used for overhead cables. The high resistance to corrosion and its non toxicity makes it a useful metal for cooking utensils under ordinary conditions. It is extensively used in aircraft and automobile components where saving of weight is an advantage.

ALUMINIUM ALLOYS

The aluminium may be alloyed with one or more other elements like copper, magnesium, manganese, silicon and nickel. The addition of small quantities of alloying elements converts the soft and weak metal into hard and strong metal, while still retaining its light weight. The main aluminium alloys are:

1. Duralumin
2. Y-alloy
3. Mangalium
4. Hindalium

These alloys are discussed as below:

1. *Duralumin*. It is an important and interesting wrought alloy. Its composition is as follows:

Copper = 3% to 4.5%; Manganese = 0.4% to 0.7%
Magnesium = 0.4% to 0.7% and rest is aluminium.

The alloy possesses maximum strength after heat treatment and age hardening. After working, if the metal is allowed to age for 3 or 4 days, it will be hardened. This phenomenon is known as age hardening.

It is widely used in wrought conditions for forging, stamping, bars, sheets, tubes and rivets. It can be worked in hot conditions at a temperature of 500°C. However, after forging and annealing, it can also be cold worked. Due to its high strength and light weight, this alloy may be used in automobile and aircraft components.

2. *Y-alloy*. It is also called copper-aluminium alloy. The addition of copper to pure aluminium creases its strength and machinability. The composition of this alloy is as follows:

Copper = 3.5% to 4.5%; Manganese = 1.2% to 1.7%
Nickel = 1.8% to 2.3%, Silicon, Magnesium, Iron = 0.6% each and
the rest is aluminium.

This alloy is heat treated and age hardened like duralumin. The ageing process is carried out at room temperature for about five days.

It is mainly used for casting purposes. But it can also be used for forged components like duralumin. Since Y-alloy, has better strength (than duralumin) at high temperatures, therefore it is mainly used in aircraft engines, for cylinder heads and pistons.

3. *Magnalium*. It is made by melting the aluminium with 2% to 10% magnesium in a vacuum and then cooling it in a vacuum or under a pressure of 100 to 200 atmospheres. It also contains about 1.75% copper. Due to its light weight and good mechanical properties, it is mainly used for aircraft and automobile components.
4. *Hindalium*. It is an alloy of aluminium and magnesium with a small quantity of chromium. It is the trade name of aluminium alloy produced by Hindustan Aluminium Corporation Ltd., Renukoot (U.P). It is produced as a rolled product in 16 gauge, mainly for anodized utensil manufacture.

ZINC

The zinc is a bluish white metal which in pure state has bright smooth crystals at its fracture. Its specific gravity is 7.1. And its melting point is 420°C. It boils at 940°C and can easily be distilled. It is not very malleable and ductile at ordinary temperatures. But it can be readily worked and rolled into thin sheets or drawn into wires by heating it to 100°C–150°C. At about 200°C, it becomes so brittle that it may be powdered. Its tensile strength is 19 to 25 MPa. It offers high resistance to atmospheric corrosion.

It is used for covering steel sheets to form galvanised iron due to its high resistance to atmospheric corrosion. The covering is done by dipping the sheets into the molten metal after initial fluxing. The galvanised wire, nails etc. are also made by this process. When rolled into sheets, zinc is used for roof covering and for providing a damp proof non-corrosive lining to containers etc. The other important uses of zinc are in the manufacture of brasses and in the production of zinc base die casting alloys. The oxide of zinc is used as pigment in paints.

ZINC BASE ALLOYS

The most of the die castings are produced from zinc base alloys. These alloys can be casted easily with a good finish at fairly low temperatures. They have also considerable strength and low cost. The usual alloying elements for zinc are aluminium, copper and magnesium and they are all held in close limits. The composition of two standard die casting zinc alloys are as follows :

1. Aluminium 4.1%, copper 0.1%, magnesium 0.04% and the rest is zinc.
2. Aluminium 4.1%, copper 1%, magnesium 0.04% and the rest is zinc.

The aluminium improves mechanical properties and also reduces the tendency of zinc to dissolve iron. Copper increases the tensile strength, hardness and ductility. Magnesium has the beneficial effect of making the castings permanently stable. These alloys are widely used in the automotive industry and for other high production markets such as washing machines, oil burners, refrigerators, radios, phonographs, television sets, business machines etc.

COPPER ALLOYS

The copper alloys are broadly classified into the following two groups:

1. Copper-zinc alloys (Brasses), in which zinc is the principal alloying metal, and
2. Copper-tin alloys (Bronzes), in which tin is the principal alloying metal.

BRASS

The most widely used copper zinc alloy is brass. There are various types of brasses, depending upon the proportion of copper and zinc. This is fundamentally a binary alloy of copper with zinc each 50%. By adding small quantities of other elements, the properties of brass may be greatly changed. For example, the addition of lead (1% to 2%) improves the machining quality of brass. It has a greater strength than that of copper, but has a lower thermal and electrical conductivity. Brasses are very resistant to atmospheric corrosion and can be easily fabricated by processes like spinning and Y-chromium. The Table 13.2 shows the composition of various types of brasses according to Indian Standards.

<i>I.S.I. designation</i>	<i>Composition in percentages</i>	<i>Uses</i>
Cartridge brass	Copper = 70 Zinc = 30	It is a cold working brass used for cold rolled sheets, wire drawing, deep drawing pressing and tube manufacture.
Yellow brass (Muntz metal)	Copper = 60 Zinc = 40	It is suitable for hot working by rolling, extrusion and stamping.
Leaded brass	Copper = 62.5 Zinc = 36 Lead = 1.5	These are used for plates, tubes etc.
Admiralty brass	Copper = 70 Zinc = 29 Tin = 1	
Naval brass	Copper = 59 Zinc = 40 Tin = 1	It is used for marine castings.
Nickel brass (German silver)	Copper = 60.45 Zinc = 35.20 Nickel = 5.35	It is used for valves, plumbing fittings, automobile fittings, type writer parts and musical instruments.

BRONZE

The alloys of copper and tin are, usually, termed as bronzes. The useful range of composition is 75 to 95% copper and 5 to 25% tin. The metal is comparatively hard, resists surface wear and can be shaped or rolled into wires, rods and sheets very easily. In corrosion resistant properties, bronzes are superior to brasses. Some of the common types of bronzes are as follows:

1. *Phosphor bronze*. When bronze contains Phosphorus, it is called phosphor bronze. Phosphorus increases the strength, ductility and soundness of castings. The alloy possesses good wearing qualities and high elasticity. The metal is resistant to salt water corrosion. The composition of the metal varies according to whether it is to be forged wrought or made into castings. A common type of phosphor bronze has the following composition according to Indian Standards:

Copper = 87% to 90%

Tin = 9% to 10%

Phosphorus = 0.1% to 0.3%

It is used for bearings, worm wheels, gears, nuts for machine lead screws, pump parts, linings and for many other purposes. It is also suitable for making springs.

2. *Silicon bronze*. It contains 96% copper, 3% silicon and 1% manganese or zinc. It has good general corrosion resistance of copper combined with higher strength. It can be casted, rolled, stamped, forged and pressed either hot or cold and it can be welded by all the usual methods.

It is widely used for boilers, tanks, stoves or where high strength and good corrosion resistance is required.

3. *Beryllium bronze*. It is a copper base alloy containing about 97.75% copper and 2.25% beryllium. It has high yield point, high fatigue limit and excellent cold and hot corrosion resistance. It is particularly by suitable material for springs, heavy duty electrical switches, cams and bushes. Since the wear resistance of beryllium copper is five times that of phosphor bronze, therefore it may be used as a bearing metal in place of phosphor bronze. It has a film forming and soft lubricating property, which makes it more suitable as bearing metal.
4. *Manganese bronze*. It is an alloy of copper, zinc and little percentage of manganese. The usual composition of this bronze is as follows :

Copper = 60%

Zinc = 35%

Manganese = 5%

This metal is highly resistant to corrosion. It is harder and stronger than phosphor bronze. It is generally used for bushes, plungers, feed pumps, rods etc. Worm gears are frequently made from this bronze.

5. *Aluminium bronze*. It is an alloy of copper and aluminium. The aluminium bronze with 6 to 8% aluminium has valuable cold working properties. They are most suitable for making components exposed to severe corrosion conditions. When iron is added to these bronzes, the mechanical properties are improved by refining the grain size and improving the ductility.

The aluminium bronzes are widely used for making gears, propellers condenser bolts, pump components, tubes, air pumps, slide valves and bushes, etc. Cams and rollers are also made from this alloy. A 6% aluminium alloy has a fine gold colour, which is used for imitation jewellery and decorative purposes.

GUN METAL

It is an alloy of copper, tin and zinc. It usually contain 88% copper, 10% tin and 2% zinc. This metal is also known as admiralty gun metal. The zinc is added to clean the metal and to increase its fluidity.

It is not suitable for working in the cold state. But it may be forged when at about 600°C. The metal is very strong and resistant to corrosion by water and atmosphere. Originally, it was made for casting guns. It is extensively used for casting boiler fittings, bushes, bearings, glands etc.