3.2.8. Comparison of Cast Iron, Wrought Iron, Mild Steel and Hard Steel

Table 3.4. Comparison of cast iron, wrought iron, mild steel and hard steel

S.No.	Cast iron	Wrought iron	Mild steel (Low carbon steel)	Hard steel (High carbon steel)
1.	It contains 2 to 5% carbon.	Purest form of iron containing 0 to 0.25% carbon.	Contains 0.08 to 0.35% carbon.	Contains 0.55 to 1.3% carbon.
2.	It has a crystalline, coarse granular structure.	Fibrous structure of bluish colour.	Bright fibrous structure.	Fine granular structure.
3.	Hard and brittle.	Tough and more elastic than cast iron.	Tough and more elastic than wrought iron.	Tough and more elastic than mild steel.
4.	Can be hardened by heating and sudden cooling but cannot be tempered.	Can niether be hardened not tempered.	Can be hardened and tempered but not easily.	Can be hardened and tempered but readily.
5.	Can niether be forged nor welded.	Can be easily forged and welded.	Can be readily forged and welded.	Can be easily forged and welded.
6.	Cannot be magnetised.	Can be temporarily magnetised.	Can be permanently magnetised.	Can be permanently magnetised.
7.	Melting point = 1200°C.	Melting point = 1530°C.	Melting point = 1400°C.	Melting point = 1300°C.
8.	Neither malleable not ductile.	Very malleable and ductile.	Malleable and ductile.	Brittle and less ductile
9.	Does not rust easily.	Rusts more rapidly than cast iron.	Rusts readily.	Rusts rapidly.
10.	Cannot absorb shocks.	Can stand sudden and excessive shocks.	Absorbs shocks.	Absorbs shocks.
11.	Tensile strength fair and compressive strength good.	Tensile strength better and compressive strength less than cast iron.	Tensile strength is better than cast iron and wrought iron while compressive strength better than wrought iron but less than cast iron.	Both tensile and compressive strength better than cast iron, wrought iron and mild steel.
12.	Becomes soft in salty water.	Stands salty water better than cast iron.	Not much affected by salty water.	Not much affected by salty water.
	Uses : *(i)* It is used for making bed plates, columns, rail chairs, brackets and machine parts	*(i)* It is used for making rolled iron joints, angle irons etc.	*(i)* Used for all kinds of structural work in bridges and buildings, for making channels, griders, rails, angle	*(i)* Used for dies, cultery and edge tools.

(Contd...)

S.No.	Cast iron	Wrought iron	Mild steel (Low carbon steel)	Hard steel (High carbon steel)
	not subjected to heavy shocks or tension.		iron etc.	
	(ii) As it does not rust easily it is used for making sewers, drain pipes, water pipes etc.	*(ii)* Since it can withstand shocks it may be used for crane hooks, chains, railway coupling etc.	*(ii)* Also used for rivets, bolts, wire tapes and for making sheets.	*(ii)* Also used in prestress concrete.
	(iii) As it is poor in tension therefore, least suitable for structural purposes.	*(iii)* Also used for small size water pipes fitting, corrugated sheets, core of electro-magnets etc.		

3.2.9. Alloy Steels

When certain special properties are desired some elements such as nickel, chromium, manganese, vanadium, tungsten etc. are added to the carbon steels. The steels thus obtained are called *alloy steels.*

The first investigation on the effect of alloying elements in steel were made from 1875 to 1890. But the use of alloyed steel found little application until 1901, when reduced cost of alloys made their use practicable.

Purposes of alloying :

The alloying elements are added to *accomplish one or more of the following* :

1. *To impart a fine grain size to steel.*
2. *To improve casehardening properties.*
3. *To improve elasticity.*
4. *To improve corrosion and fatigue resistance.*
5. *To improve hardness, toughness and tensile strength.*
6. *To improve machinability.*
7. *To strengthen the ferrite.*
8. *To improve high or low temperature stability.*
9. *To improve cutting ability.*
10. *To improve wear resistance.*
11. *To improve ductility.*

The Effects of alloying elements :

Metal	*Remarks*
Nickel	*(i)* Increases toughness.
	(ii) Improves response to heat treatment especially in large sections.
	(iii) In large amounts provides special electrical and magnetic properties.

	(iv)	Improves forming properties of stainless steel.
Chromium	(i)	Provides stainless property in steel.
	(ii)	Used widely in tool steels and in electric plates.
Vanadium	(i)	Improves response to heat treatment.
	(ii)	Provides control of structure.
	(iii)	Used in high speed tool steels.
Tungsten	(i)	Retention of hardness and toughness at high temperatures.
	(ii)	Used in tools, dies, valves, magnets etc.
Silicon	(i)	High electrical resistance and magnetic permeability.
	(ii)	Used in electrical machinery.
Copper	(i)	In small amounts improves atmospheric corrosion resistance.
	(ii)	Acts as a strengthening agent.
Carbon	(i)	Affects melting point.
	(ii)	Affects tensile strength, hardness and machinability.
Silicon	(i)	Improves oxidation resistance.
	(ii)	Strengthens low alloy steels.
	(iii)	Acts as a deoxidiser.
Titanium	(i)	Prevents formation of austenite in high chromium steels.
	(ii)	Reduces martensitic hardness and hardenability in medium chromium steels.
	(iii)	Prevents localized depletion of chromium in stainless steel during long heating.
Molybdenum	(i)	Enhances corrosion resistance in stainless steels.
	(ii)	Makes steel usually tough at various hardness levels.
	(iii)	Promotes hardenability of steel.
	(iv)	Forms abrasion resisting particles.
	(v)	Raises tensile and creep strength at high temperatures.
	(vi)	Makes steel fine grained.
	(vii)	Counteracts tendency towards temper brittleness.
Manganese	(i)	Counteracts brittleness from sulphur.
	(ii)	Increases strength and hardness markedly.
	(iii)	Lowers both ductility and malleability if it is present in high percentage with high carbon content in steel.
Boron	(i)	Increases hardenability or depth to which steel will harden when quenched.
Aluminium	(i)	Acts as a deoxidiser.
	(ii)	If present in an amount of about 1%, it helps promoting nitriding.
Cobalt	(i)	Refines the graphite and pearlite.
	(ii)	Improves heat resistance.

tungsten. The best and most expensive cobalt steels contain 35% cobalt together with several-percent of both chromium and tungsten. An important permanent magnet alloy (Alnico) contains approximately 60% iron, 20% nickel, 8% cobalt and 12% aluminium. This alloy cannot be forged and is used as a casting hardened by precipitation heat treatments.

3.3. NON-FERROUS METALS AND ALLOYS

3.3.1. Aluminium

Although aluminium is very abundant in the earth it is never found free, nor can it, by present methods be obtained commercially from clay in which it exists in such great quantities. There is but one commercial ore called *'bauxite'*. *Bauxite is hydrated aluminium oxide* generally believed to consist of mixture of monohydrate $Al_2O_3 . H_2O$ and trihydrate $Al_2O_3 . 3H_2O$. The chief impurities are oxide, silica, clay and titanium oxide. It is found in districts of Bihar, Madras and Madhya Pradesh.

Manufacture : Bauxite is first purified and then dissolved in fused cryolite (double fluoride of aluminium and sodium). The aluminium is then separated from this solution by electrolysis at about 910°C.

Physcial and mechanical properties :

(i) Pure aluminium has silvery colour and lustre, while the commercial grades show a characteristic bluish tinge.

(ii) The high purity aluminium has a much greater resistance to corrosion than the ordinary steel.

(iii) It is ductile and malleable.

(iv) Its specific gravity is 2.7.

(v) In proportion to its weight it is quite strong.

(vi) Melting point = 658°C, boiling point = 2057°C.

(vii) Its electrical resistivity is 2.669 micro ohms/cm^3 at 20°C.

(viii) Its tensile strength varies from 95 to 157 MN/m^2.

(ix) It is a good conductor of heat and electricity.

(x) It forms useful alloys with iron, copper, zinc and other metals.

(xi) It is unaffected by ordinary atmospheric influences but is corroded in sea water. It is soluble in solutions of caustic alkalies and in hydrochloric acid. *When there is an excess of silicon present in the metal it does not withstand atmospheric actions.*

(xii) Aluminium is electron positive to most other metals *e.g.*, iron, chromium, zinc, copper, nickel, tin, lead etc. Care is necessary therefore, to prevent it from coming into metallic contact with other metals under conditions where moisture is present in order to avoid electrolytic action *i.e.*, corrosion.

Uses :

1. Because of its softness and difficulty of making sound castings, *little pure aluminium is used in the cast form. The largest quantity is employed after it has been mechanically worked in some manner*, as by rolling, wire drawing, drop forging or extruding. After being rolled into sheets, it may be stamped into a variety of shapes.

2. It is employed, often alloyed with small amounts of other metals, in the manufacture of *furniture, rail-road and trolley cars, automobile bodies and pistons, electric cables and bus bars, rivets, kitchen utensils and collapsible tubes for pastes.*

3. In a finely divided flake form, aluminium is employed as a *pigment in paint*. Aluminium paint is used as a priming coat for wood, as a protective coat for metals.

4. Aluminium is used in *deoxidizing molten iron and steel*, especially in the top of the ingot when

steel is poured in the ingot mould. In a similar manner it is used to prepare the metals from their oxides by heating a mixture of powdered aluminium and the oxide of the metal to be reduced. The mixture is known as *Thermit.*

5. *Aluminium foil is used as silver paper for packing chocolates etc.*

Annealing

Aluminium sheet which has been hardened by cold working, such as hammering or rolling can be annealed by heating it to about 350°C and afterwards cooling in air or water. The period of heating need only be for a few minutes. As a rough guide to correct temperature of heating for annealing, the surface may be rubbed, during the heating process, with a dry match stick from time to time, the heating being stopped when wood begins to char.

The annealing of aluminium wire for electrical purposes require more care, since the aim is to obtain a high electrical conductivity by obtaining the correct structure. For high conductivity a long exposure at a lower temperature, namely 250° to 300°C appears to give the best results. In passing, it may be remarked that the *aluminium alloys require higher annealing temperature, from about 350°C to 400°C.*

3.3.2. Copper

Copper is one of the comparatively few metals that are found in the metallic state. It occurs in some minerals such as copper glance (Cu_2S), copper pyrites ($CuFeS_2$), malachite ($CuCO_3.CuO_2H_2$) and azurite ($2CuCO_3.CuO_2H_2$). Copper ores are found in Burma, Sikkim and, Singhbhoom (Bihar).

Manufacture

- Copper is extracted from its ores by several different methods that chosen depending upon the character of the ore and local conditions.
- Refining of the metal is usually considered to begin when the copper is in the *blister* stage, the surfaces of the cast material being irregular and blistered due to the generation of gases during cooling. This copper is 99% pure and is *further refined in the furnace by oxidation process which removes sulphur and other impurities.* The excess of oxygen is removed from the metal by operation known as **poling.** Green wooden poles or tree trunks are thrust under the surface of the molten metal, which is covered with charcoal, coke or similar material rich in carbon. Although this process may seen crude it is still almost invariably used, owing to its cheapness and efficiency. Poling is discontinued when sample casting indicates that the oxygen content has been reduced to 0.08-0.025 percent. The copper is then known as *tough pitch copper.*
- *Deoxidized copper is needed for intricate castings, welding and certain other processes. Special reducing agents such as phosphorus, silicon, lithium, magnesium, beryllium or calcium are added to the molten metal to eliminate the oxygen just sufficient of the deoxidizer being used to prevent any residue in the metal.*
- *Arsenic*, in amounts upto approximately *5 percent* is added to improve the strength and toughness of the metal, and most copper products, other than electrical gear, are manufactured from arsenical copper.

Physical and mechanical properties :

(i) Copper is a *reddish-brown* metal.

(ii) Although pure copper is *one of the best conductors of heat and electricity*, its electrical conductivity is highly sensitive to the presence of impurities.

(iii) If copper is heated to red heat and cooled slowly it becomes brittle; but if cooled readily it is soft, malleable and ductile. The brittleness is due to the coarsely crystalline structure that develops during slow cooling.

(iv) Copper *can be welded at red heat.*

(v) Like aluminium, *pure copper does not cast well.* When molten it absorbs gases, such as carbon monoxide, hydrogen and sulphur dioxide which separate out on cooling and cause *blow holes.*

(vi) Melting point = 1084°C, boiling point = 2595°C.

(vii) Specific gravity = 8.9, Electrical resistivity = 1.682 microhms per cm.

(viii) It is *highly resistant to corrosion by liquids.*

(ix) Its tensile strength varies from 300 to 470 MN/m^2.

(x) It forms important alloys like *bronze and gun metal.*

(xi) It is strongly attacked by nitric acid but only very slowly by dilute hydrochloric and sulphuric acids in the absence of air; ammonical solutions also attack copper.

For copper that is to be worked, lead is sometimes added in order that metal may be worked more easily, but if more than about 0.5 per cent is employed, it causes the copper to be brittle. In copper alloys, for casting, as much as 10 to 20 per cent may be added to cheapen the product but this lead largely separates out in globular masses on cooling. At the melting point of lead, copper is practically insoluble in liquid lead and less than 0.05 per cent of the lead enters into the solid solution in the copper.

Uses :

1. It is largely used in *making electric cables and wires and electric machinery and appliances.*
2. Used in *electroplating, electrotyping and/or soldering iron bits.*
3. Used as a *damp proof material and for making alloys.*
4. It is used for *sheeting, roofing, spouts, boilers, condensers and other purposes where corrosion resistance with fair strength and flexibility is essential.*

3.3.8.1. Copper Alloys

The copper alloys can be divided into two principal classes : *(i) Brasses* and *(ii) Bronzes*. The *'brasses' are primarily alloys of copper and zinc and 'bronzes' of copper and tin*, but there are numerous modifications of them produced by the addition of smaller amounts of other elements.

In addition there are cupro-nickels, containing principally copper and nickel, and nickel silvers (German silvers) in which zinc of brass is partially replaced by nickel.

I. Brasses :

With range of composition from 5 to 45 per cent of zinc, the brasses are among the most useful alloys. *They possess excellent mechanical properties, and are corrosion resistant and are readily machinable.*

The composition of these alloys is given in the Table 3.5.

Table 3.5. Classification of Brasses

Name	Composition		Colour	Typical uses
	Cu	Zn		
Muntze metal	9	41	Reddish	Architectural work, welding rod, condenser tubes, valve stems.
Cartridge or spinning brass	70	30	Typical brass colour	Cartridges, tubes, spinning, drawing.
Brazing brass	75	25	Typical brass colour	Drawing, spinning, springs, particularly suitable for brazing.
Red brass	85	15	Red	Hardware, radiator cores, plumbing pipe, condenser tubes, flexible hose.
High brass	66	34	Typical brass colour	Stamping, blanking, drawing, spinning, springs, rivets, chains.
Low brass	80	20	Red gold	Drawing, forming, flexible hose.

II. Bronzes :

These are essentially alloys of *copper and tin*. The effect of composition on physical properties is given below :

- The tensile strength of bronze increases gradually with the amount of tin, reaching a maximum with about 20% of tin, but as the tin increases beyond this amount the tensile strength very rapidly decreases.
- Bronze is *most ductile when it contains about 5% of tin*, with this amount it may be rolled satisfactorily at red heat. Bronze is used chiefly for casting.
- As the amount of tin increases above 5%, the ductility gradually lessens and *practically disappears with about 20% of tin*; since ductility is co-ordinate with toughness, these alloys are very brittle. They are also *very hard.*
- The most useful of bronzes are those that contain from 8 to 11% of tin, since the maximum combined strength and toughness are secured with about these amounts. Bronze containing tin within these limits was *formerly*, known as **gun metal,** since because of this strength it was used for making guns, but now *steel has entirely replaced it for this purpose.* At the present time, the term *gun metal is very loosely used and cannot be said to have definite significance.*
- As cast the alloy containing 9% of the tin has a tensile strength of about 215 MN/m^2.
- The bronze containing 4 to 8% tin is called ***'coinage bronze'*** and used for making coins and metals.
- The copper-tin series of alloys containing 15 to 25% of tin is known as **'bell metal'.** Such *alloys are very hard and brittle, but are sonorous and are employed, therefore, in making bells.*

structure during heat treatment. Some of the important aluminium...

1. Duralumin :

Composition : Al = 94%, Cu = 4%, Mg, Mn, Si, Fe 0.5% each.

Properties :

(i) It can be *cast, forged and stamped.*

(ii) It has *high tensile strength.*

(iii) It possesses *high electrical conductance.*

(iv) It hardens spontaneously when exposed to room temperature.

(v) The alloy is soft enough for a workable period after it has been quenched.

(vi) The temperature employed for the solution heat treatment of the alloy is the lowest that is applicable to any commercial light alloy.

(vii) Specific gravity = 2.8, specific heat = 0.214.

(viii) Melting point = 650°C.

(ix) Brinell hardness : Annealed = 60, age hardened = 100.

Uses :

1. It is widely used for *sheets, tubes, forgings, rivets, nuts, bolts and similar parts.*
2. Used in making *cables.*
3. It is also extensively used for *air planes and other machines where weight is a deciding factor.*
4. It is also employed in *surgical and orthopaedic* work and for non-magnetic and other instrument parts.

Heat treatment :

- Annealing is carried out at 360-400°C and the metal is cooled in air. It is then ductile and can be cold worked. Normalising is carried out at a temperature of 490°C plus or minus 10 degrees. After normalising the metal is quenched in clean cold water.
- A salt bath is used for heat treatment generally consisting of 50% silver nitrate, with 50% potassium nitrate. For built up fittings a muffle furnace is sometimes used.

2. Y- alloy :

Composition : Al = 92.5%; Cu = 4%; Ni = 2%; Mg = 1.5%.

Properties :

(i) Its strength at 200°C is better than aluminium.

(ii) It retains its high strength and hardness at high temperature.

(iii) It can be easily cast and hot worked.

Uses :

1. It is extensively used for such components as *piston cylinder heads and crankcases of internal combustion engines.*

2. It is also used for *die casting, pump rods and in sparking chisel in place of steel.*

Heat treatment and age hardening :

- The heat treatment range of Y-alloy is 5000°C - 5200°C ; this is higher than for aluminium.
- It has been found that *muffle furnace* is best medium for heat treating Y-alloy. The period of treatment at 500-520°C required to bring about solution of age-hardening constituents depends on the fineness of grain and distribution of constituents. For chilled cast bars, 2.5 cm diameter, about 6 hours are required. For coarser grain material a longer period becomes necessary, whilst for large castings 24 hours or more may be required. In all cases the period of treatment at 500° - 520°C (solution treatment) must be regulated in relation to the micro- structure. Treatment at the temperature 500°C to 520°C is followed by *quenching in boiling water.* After quenching, *age hardening* at room temperature, substantially completes in 5 days.
- Age hardening can be accelerated by retaining the alloy immersed in the water at boiling temperature after quenching. Under these conditions age hardening is substantially complete in from 1/2 hour for the wrought to 2 hours for the cast alloy.
- By subjecting normally heat-treated material, cast or wrought, to temperatures between 150°C to 250°C the tensile strength and hardness are substantially increased, but the ductility is diminished.

Above 250°C permanent softening results.

Note : Y-alloy is annealed in the wrought state by heating it to 350°C to 400°C and allowing it to cool in the air.

3. Hindalium :

- Hindalium is an alloy of *aluminium, magnesium, manganese, chromium and silicon etc.*, and is the trade name of the aluminium alloy produced by Hindustan Aluminium Corporation Ltd., Renukoot Distt. Mirzapur (U.P).
- It is manufactured as a rolled product (16 gauge) mainly for *anodized utensile manufacture.* During processing special care is taken to maintain the necessary mechanical and surface characteristics.

Hindalium utensils possess the following **advatnages :**

1. *Strong and hard.*
2. *Cannot be easily scratched.*
3. *Can take fine finish.*
4. *Do not absorb much heat and thus save fuel while cooking.*
5. *Can be easily cleaned.*
6. *Do not react with the food acids.*
7. *Low cost* (about one-third of stainless steel).

4. M...

.3.8.2. Aluminium Alloys

- The principal elements which are alloyed with pure aluminium to improve its tensile strength and hardness are copper, silicon, manganese, zinc, magnesium and nickel. One element may be used alone but often two, three or four additions are made to the base metal to produce a metal having specific physical properties.
- *Copper* (for instance) is the *main hardening element* added while the addition of a small percentage of magnesium to an aluminium copper alloy still further improves the hardness and