3.0 CAST IRON

Cast iron is the refined form of pig iron.The pig iron is melted and refined in cupola furnace.Then it is poured into the moulds.

The term cast iron refers to those iron carbon silicon alloys which contain 1.8 % – 4 carbon (C) and usually 0.5 % – 3 % silicon (Si). Cast iron is an important engineering material with a number of advantages, mainly good castability and machinability and moderate mechanical properties.

Types of Cast Iron

1) **White Cast Iron**.

2) **Grey Cast Iron**.

3) **Ductile Cast Iron.** ...

4) **Malleable Cast Iron**.

White Cast Iron

White cast iron contains 1.8 % -3.6 % C, 0.5 % -1.9 % Si and 1 % – 2 % manganese (Mn). White cast irons are so called because when broken, the fracture surface is white. This is unlike the grey fracture surface normally associated with other cast irons which contain graphite.

While not as common as grey cast iron, white cast iron is another type worth mentioning. It receives its namesake from its off-white colour, which is the result of iron compounds known as cementite. Like grey cast iron, white cast iron features many small fractures. The difference is that white cast iron features cementite below its surface, whereas grey cast iron features graphite below its surface. The graphite creates the appearance of a grey colour, while the cementite creates the appearance of a whitecolour. White cast iron is hard and offers excellent resistance against abrasions.

Fig 3.1 White cast iron

Grey Cast Iron

Gray cast iron is a broad term used for a number of cast irons whose microstructure is characterized by the presence of flake graphite in the ferrous matrix. Such castings often contain 2.5%–4% carbon, 1%–3% silicon, and some additions of manganese ranging from 0.1% to 1.2%.

The most common type, grey cast iron features a graphite microstructure consisting of many small fractures. It's called "grey cast iron" because the presence of these small fractures creates the appearance of a grey colour. When grey cast iron is produced, the fractures open up to reveal the grey-coloured graphite underneath the surface. Grey cast iron isn't as strong as steel, nor is it able to absorb the same shock as steel. With that said, grey cast iron offers similar compressive strength as steel. As a result, it's become a popular choice of metal for applications involving compressive strength.

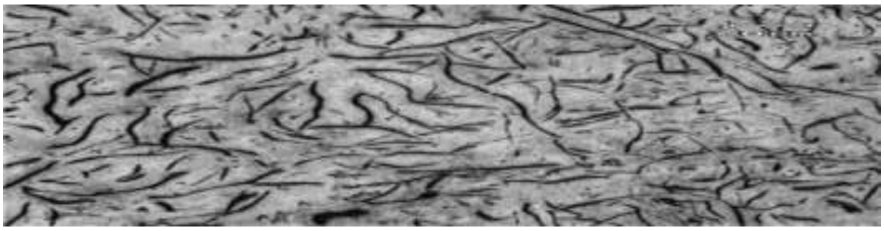


Fig 3.2 Grey cast iron

Ductile Cast Iron

Ductile iron—also referred to as spheroidal or nodular iron—is actually a group of irons that exhibit high strength, flexibility, durability, and elasticity due to their unique microstructure. Cast ductile iron normally contains over 3 percent carbon; it can be bent, twisted, or deformed without fracturing. Its mechanical properties are similar to steel, and far exceed those of standard cast irons.

Also known as nodular cast iron, ductile cast iron is a type of soft, ductile iron alloy with a high carbon content. It's typically made with trace amounts of other compounds, including magnesium and cerium. When added, these trace compounds inhibit the speed at which graphite grows, thereby keeping the metal soft and ductile. Ductile cast iron was invented in the early to mid-1940s.

Malleable Cast Iron

Malleable cast iron also contains sometimes small amounts of chromium (0.01 % to 0.03 %), boron (0.0020 %), copper (up to 1.0 %), nickel (0.5 % to 0.8 %), and molybdenum (0.35 % to 0.5 %).

Malleable cast iron that easily “workable.” It’s typically created using heat treatment processes on white cast iron. The white cast iron is heated treated for up to two days, after which it’s cooled. When finished, malleable cast iron can be bent and manipulatedto achieve unique shapes and sizes.

Applications of cast iron

- It is used in making **pipes**, to carry suitable fluids.
- It is used in making different machines.
- It is used in making automotive parts.
- It is used in making pots pans and utensils.
- It is used in making anchor for ships

2.5 EFFECTS OF ALLOYING ELEMENTS ON THE IRON- CARBON (Fe-C) SYSTEM

Alloy steels are those steels which contain other elements like Ni,Mn,Cr,Mo,V etc. These elements are added to plain carbon to improve one or more of the following properties.

1.Greater strength,hardness,toughness at low and high temperature.

2.High hardenability

3.Greater wear resistance

4. Improve machinability

Effects of alloying elements on steel

The following factors are the effects of alloying elements on steel.

1.Formation of carbide

2.Solid solution strengthening

3.Neutral elements

4.Graphitising elements

5.Hardenability

1.Formation of carbides:

Certain alloying elements combine with carbon present in steel to form their respective carbides.The carbides increase wear resistance of steel.

2.Solid solution strengthening

Solid solutions provide hardness and strength to plain carbon steel.

3. Neutral elements:

Cobalt is the only element that

does not form carbide .

4. Graphitising elements:

These elements try to decompose carbides into graphite .Ex.Si,Al and Cu.

5. Hardenability:

Even a small percentage of (0.002%) of boron increases the hardenability.

2.2 IRON-CARBON EQUILIBRIUM DIAGRAM

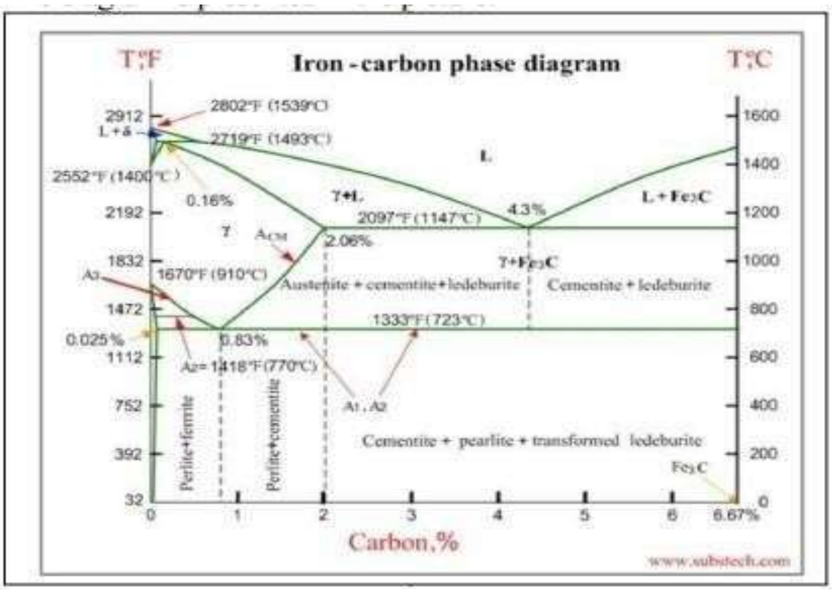


Fig 2.2.1 Iron-Carbon phase Diagram

The following phases are involved in the transformation, occurring with iron-carbon alloys: L-Liquid solution of carbon - iron;

δ- ferrite-Solid solution of carbon iron.

Maximum concentration of carbon in δ-ferrite is 0.09% at 2719 ºF (1493ºC) – temperature of the peritectic transformation.

The crystal structure of δ-ferrite is BCC (cubic body centered). Austenite - interstitial solid solution of carbon in γ-iron.

Austenite has FCC (cubic face centered) crystal structure, permitting high solubility of carbon-upto2.06%at2097ºF(1147ºC).

Austenitedoesnotexistbelow1333ºF(723ºC)andmaximumcarbonconcentrati on atthistemperatureis0.83%.

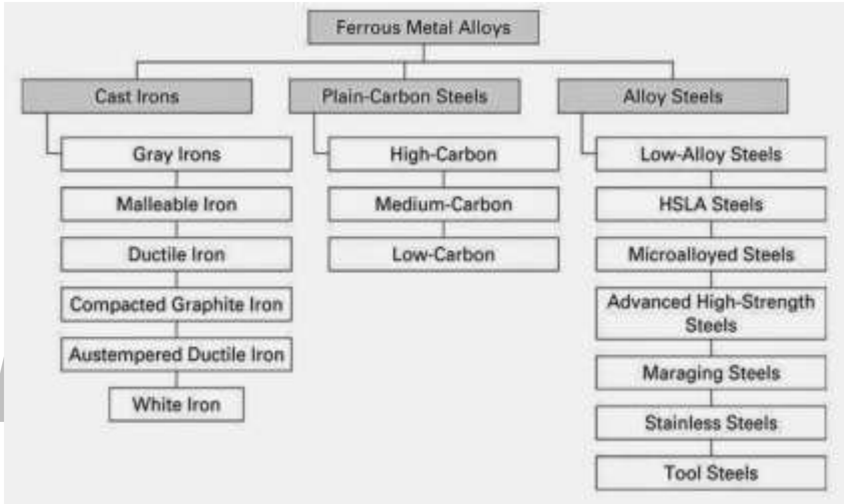
α-ferrite - solid solution of carbon in α- iron. α- ferrite has BCC crystal structureand low solubility of carbon - up to 0.25% at 1333 ºF (723ºC). α- ferrite exists atroom temperature.

UNIT II- FERROUS ALLOYS

2.1 Introduction

Metals used for specific industrial applications are metal alloys and not pure metals. The different composition of the metal alloys are used to obtain the required properties.

Ferrous alloys are important engineering materials used for different applications. The major content present in the ferrous alloy is iron. The general classification of metal alloys is shown in fig.



Iron-Iron Carbon diagram is essential to understand the basic differences among iron alloys and control of properties.

- Iron above1390 degrees is known as delta iron

Iron between1390 and 910degrees is known as gamma iron , Iron below 910 degrees is known as alpha iron.

2.6 DIFFUSION IN SOLIDS

Diffusion is defined as the mechanism by which matter is transported through matter.

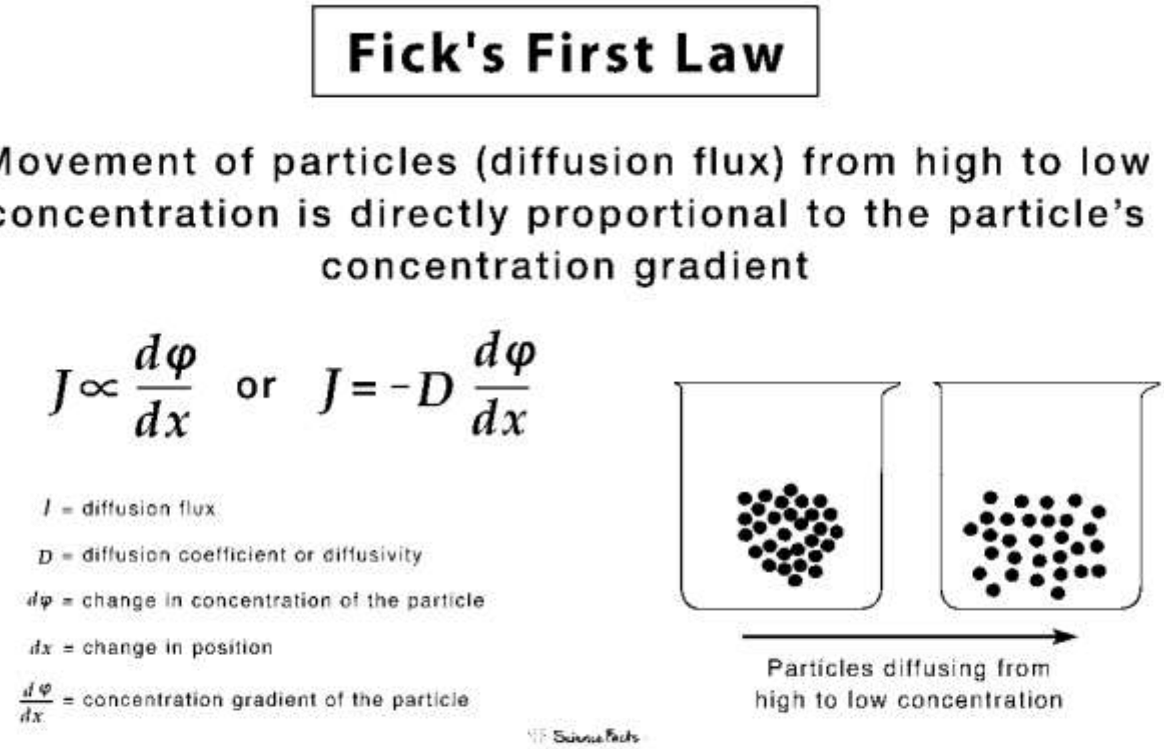


Fig 2.6.1 fick''s first law

Fick's I law

- Fick's first law states that the flux is directly proportional to the concentration gradient

$$J \equiv atoms / area / time \propto concentration\ gradient$$

$J \propto \frac{dc}{dx}$ OR $J = -D\frac{dc}{dx}$ ...(2)

flux in steady state flow

Negative sign indicates a decrease in concentration But flux is positive quantity

dc=change in conc. of material g/cm^3.
D=diffusion coefficient of a penetrant, cm/sec^2.
Dx=change in the distance, cm.

Combining equation $J = \frac{1}{S}\frac{dM}{dt}$ and $J = -D\frac{dc}{dx}$ i.e. $J = \frac{1}{S}\frac{dM}{dt} = -D\frac{dc}{dx}$

We get $\frac{dM}{dt} = -DS\frac{dc}{dx}$ ...(3)

Eqn 3 explains Rate of mass transfer as per fick's first law

D is effected by temperature, pressure etc hence it is not constant it is coefficient

FICK"S SECOND LAW:

It states that the time rate of change of concentration is directly proportional to the second derivative of concentration gradient.

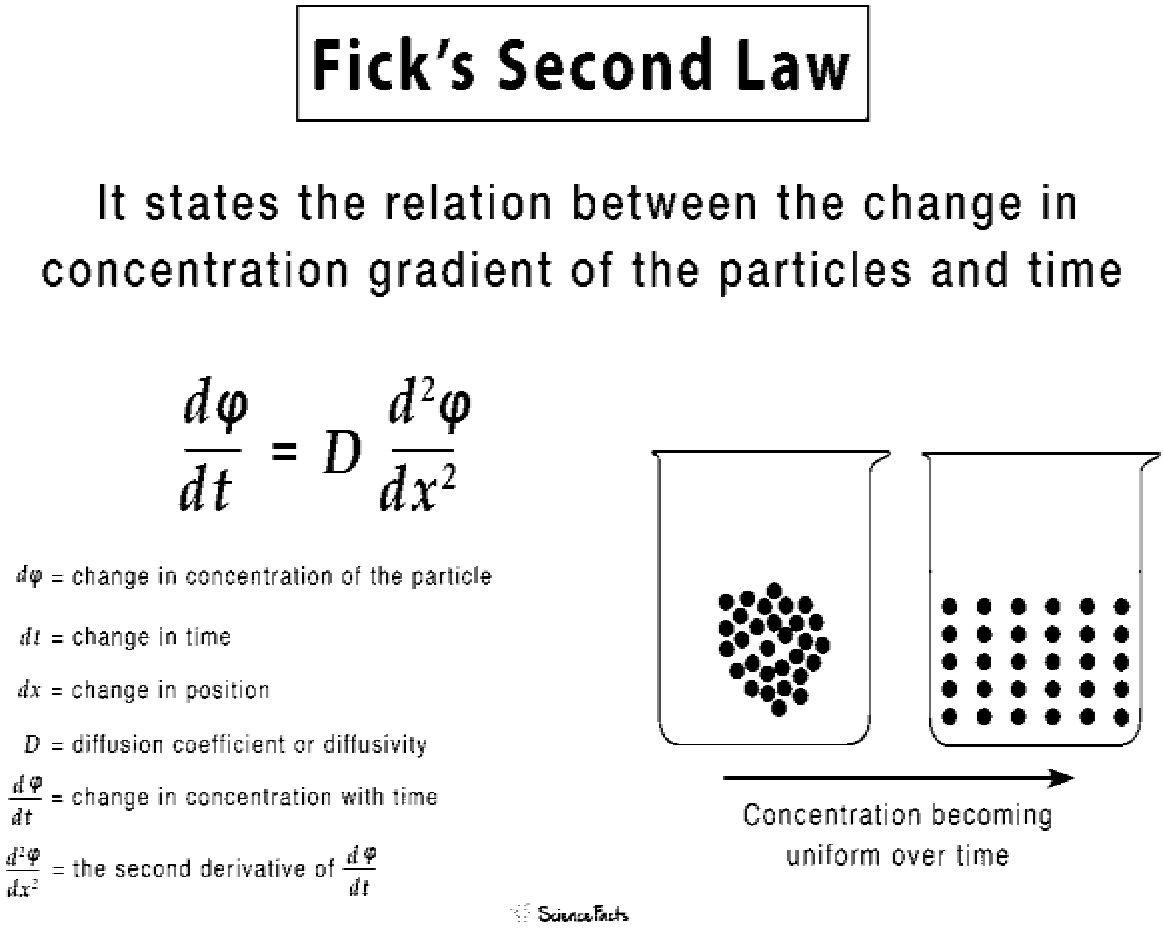


Fig 2.6.2 fick"s second law

Deriving Fick's Second Law

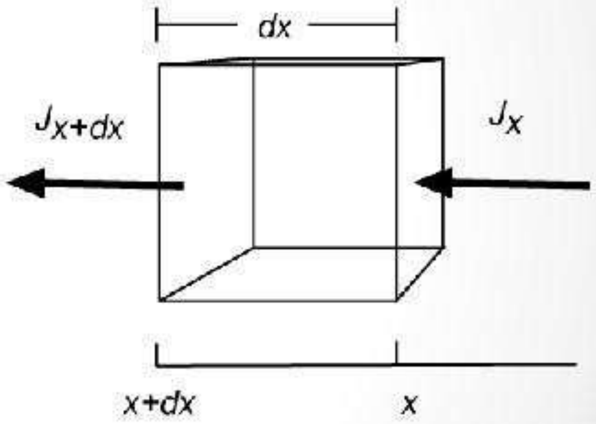
$$\left(\frac{\partial c}{\partial t}\right)_x = -\left(\frac{\partial J}{\partial x}\right)_t$$

- Continuity equation relates any change in flux along the gradient to change in concentration with time.
- Since:

$$\left(\frac{\partial c}{\partial t}\right)_x = \left(\frac{\partial(-D\partial c/\partial x)}{\partial x}\right)_t$$

- we have:

$$\boxed{\left(\frac{\partial c}{\partial t}\right)_x = D\left(\frac{\partial^2 c}{\partial x^2}\right)_t}$$



2.4 MICROSTRUCTURE OF SLOWLY COOLED STEELS

2.4.1. Eutectoid steel

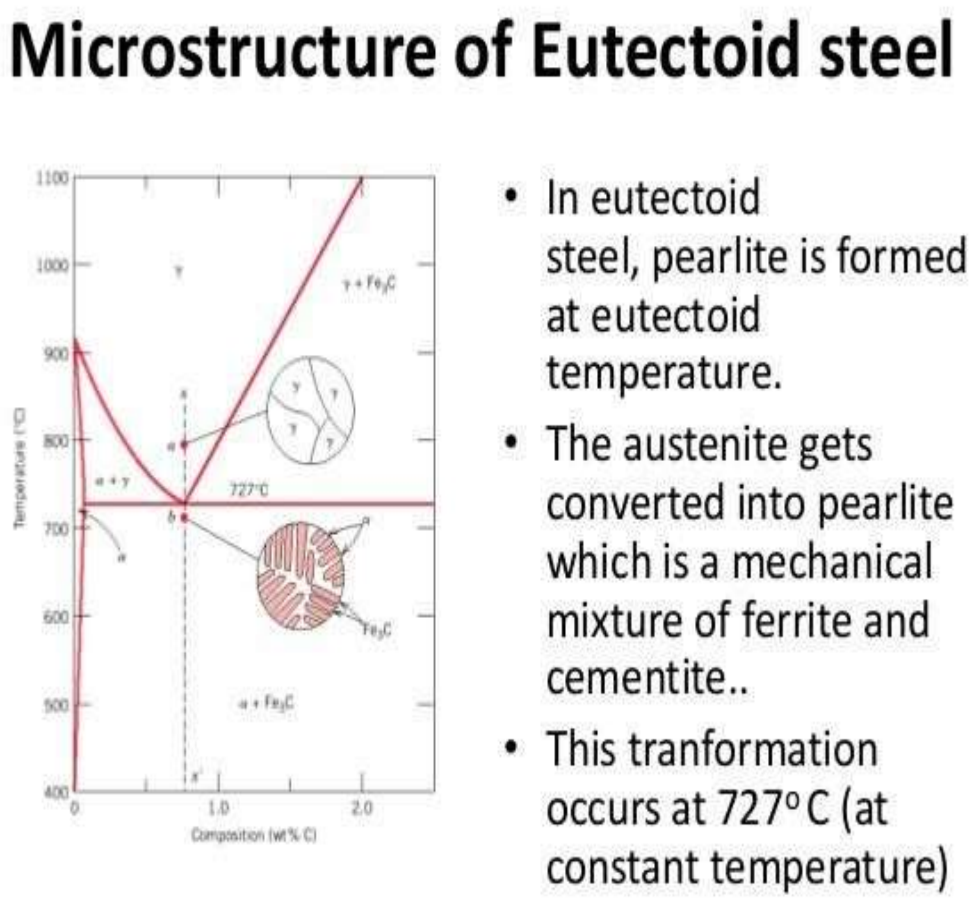
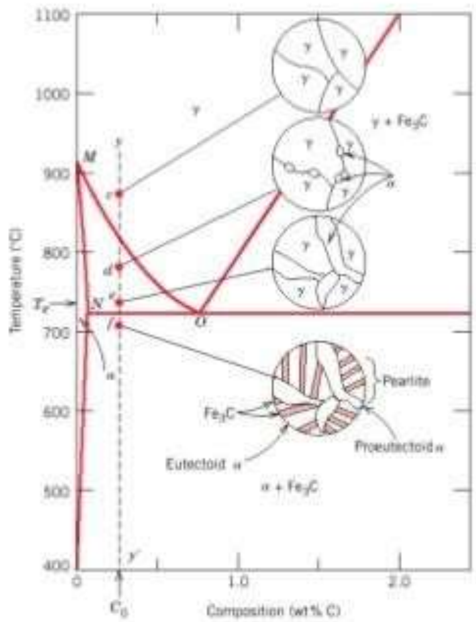


Fig 2.4.1.(a) Microstructure of eutectoid steel

2.4.2 HYPOEUTECTOID STEEL

Microstructure of Hypoeutectoid Steel



Compositions to the left of eutectoid (0.022 - 0.76 wt % C) is **hypoeutectoid (*less than eutectoid) alloys. Microstructure change is***

$$\gamma \rightarrow \alpha + \gamma \rightarrow \alpha + P$$

1. First ferrite is formed when temperature comes down below Ae_3 temperature.

$$\gamma \rightarrow \alpha + \gamma$$

2. The amount of ferrite increases with decrease in temperature till eutectoid temperature.

3. Remaining austenite changes to pearlite at eutectoid temperature.

$$\alpha + \gamma \rightarrow \alpha + P$$

Fig 2.4.2(b) Microstructure of hypoeutectoid steel

2.4.3 . HYPEREUTECTOID STEEL

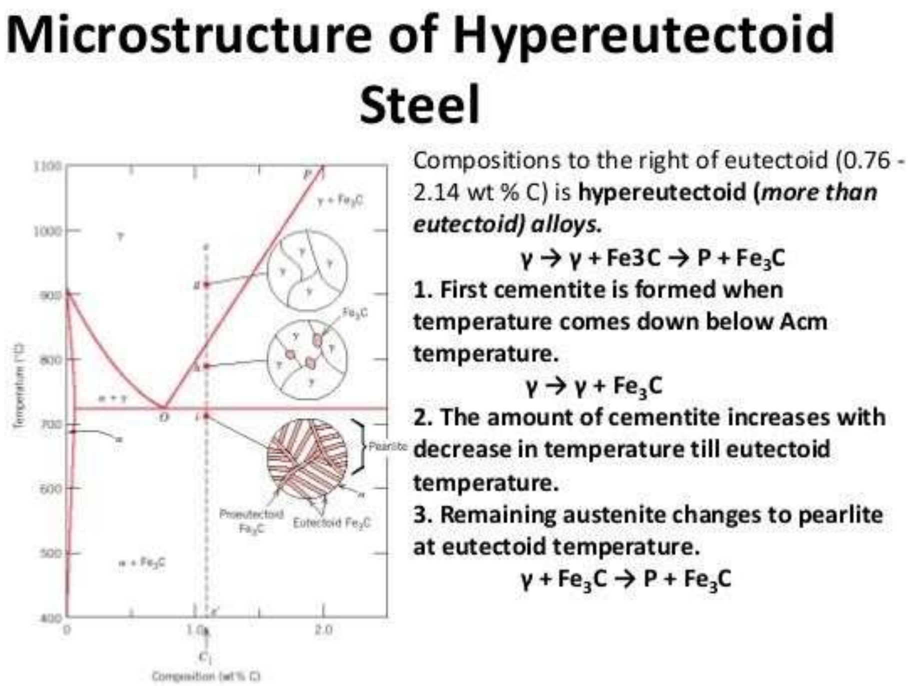


Fig 2.4.3(c) Microstructure of hypereutectoid steel

2.3 Phases in Iron –Carbon Phase Diagram

The following phase transformations occur with iron-carbon alloys:

Iron-carbon alloys,containing upto2.06%of carbon,are called steels.

Alloys,containing from2.06 to6.67% of carbon,experience eutectic transformation at 2097 ºF (1147 ºC). The eutectic concentration of carbon is4.3%.

In practice only hypo eutectic alloys are used. These alloys (carbon content from 2.06% to 4.3%) are called cast irons. When temperature of an alloyfrom this range reaches 2097 ºF(1147ºC), it contains primary austenite crystals and some amount of the liquid phase. The latter decomposes by eutectic mechanism to a fine mixture of austenite and cementite, called ledeburite.

Alloys(steels and castirons)experience eutectoidtransformationat1333ºF(723ºC).

The eutectoid concentration of carbon is 0.83%

.

When the temperature of analloy reaches 1333ºF(733ºC),austenite transforms to pearlite (fine ferrite-cementite structure,forming as a result of decomposition of austenite at slow cooling conditions).

Phase compositions of the iron-carbon alloys at room temperature

o Hypoeutectoidsteels(carboncontentfrom0to0.83%)consistofprimary(proeutectoid)ferrite(accordingtothe curveA3) and pearlite.

o Eutectoid steel(carboncontent0.83%) entirely consists of pearlite.

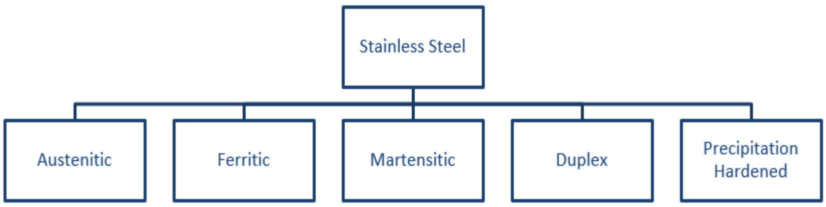
o Hypereutectoidsteels(carboncontentfrom0.83to2.06%)consistofprimary(proeu tectoid)cementite(according to the curve ACM) and pearlite.

o Cast irons (carbon content from 2.06% to 4.3%) consists ofpro eutectoid cementite C2ejected from austenite.

2.9 STAINLESS STEEL

Stainless steel, any one of a family of alloy steels usually containing 10 to 30 percent chromium. In conjunction with low carbon content, chromium imparts remarkable resistance to corrosion and heat.

Classification of stainless steel



1.AUSTENITIC.

This type of steel is very tough and ductile in the as-welded condition; therefore,it is ideal for welding and requires no annealing under normal atmospheric conditions.The most well-known types of steel in this series are the 302 and 304. They are commonly called 18-8 because they are composed of 18% chromium and 8% nickel.

Low-Carbon Steel 0.05% to 0.30% carbon are the most widely used

and are normally non magnetic.

Medium-Carbon Steel 0.30% to 0.45% carbon

High-Carbon Steel ....0.45% to 0.75% carbon their crystalline structure.

2. Martensitic Steel

Chromium usually accounts for 11.5-18% of the composition of martensitic steel, along with 1.2% carbon and nickel. robust. While the lower nickel content makes it less corrosion resistant in comparison with other types of stainless steel, the high percentage of carbon results in the steel having a molecular structure that is particularly manganese, nickel, and molybdenum are among the other alloying elements in martensitic steel.

3. Ferritic Stainless Steel

Ferritic steel is a grade of stainless steel alloy that contains over 12% chromium. It differs from other forms of stainless steel in two critical regards: its molecular grain structure and its chemical composition.

Ferritic stainless steel is actually defined as a straight chromium non-hardenable class of stainless alloys that have chromium contents ranging from 10.5% to 30% and a carbon content of less than 0.20%

Applications

Most often, stainless steel is used for applications requiring the unique properties of steel along with resistance to corrosion. You'll find this alloy milled into coils, sheets, plates,bars, wire, and tubing. It is most often made into:

Culinary uses

- Kitchen sinks
- Cutlery
- Cookware

Surgical tools and medical equipment

- Hemostats
- Surgical implants
- Temporary crowns (dentistry)

Architecture

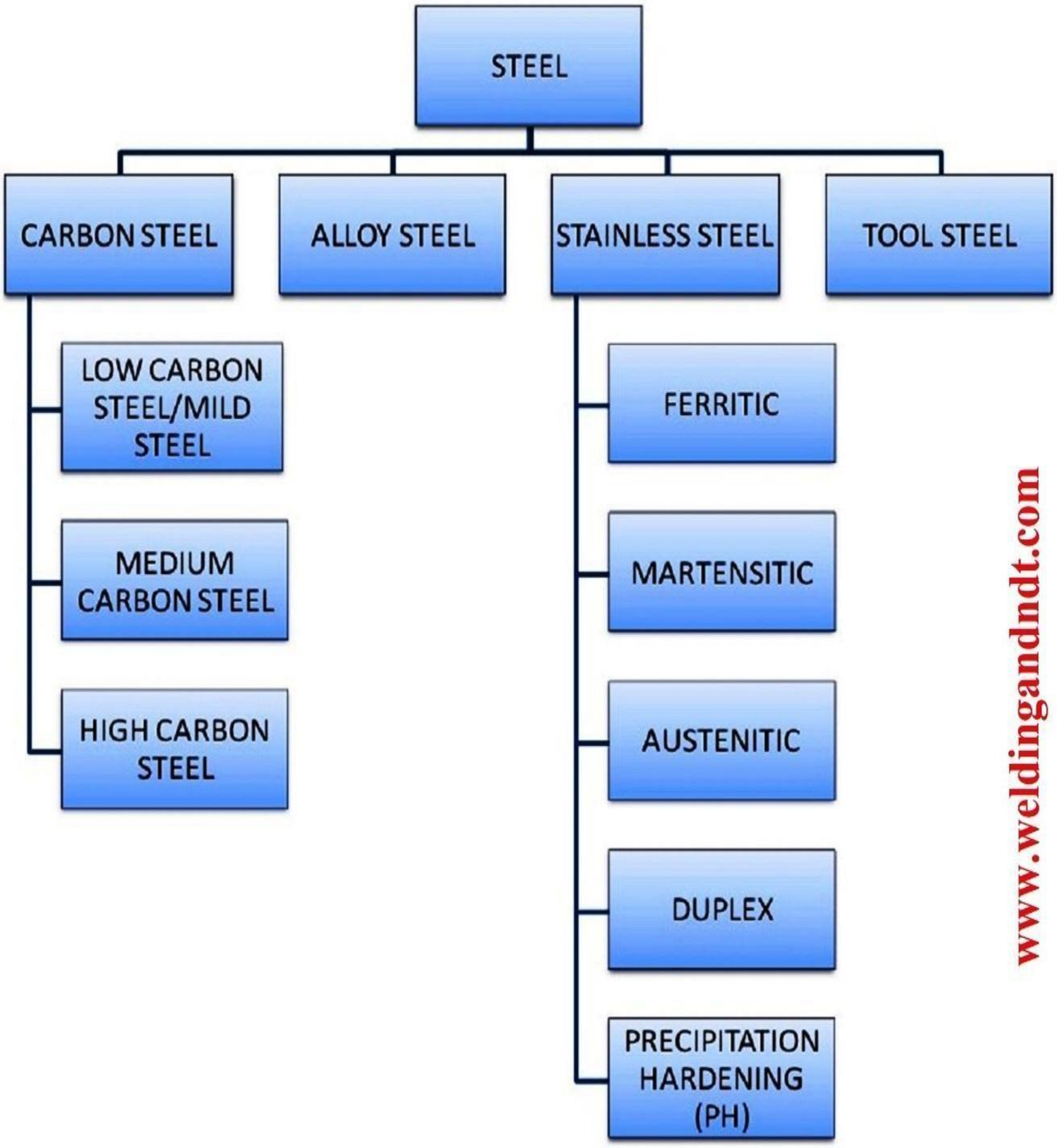
- Bridges
- Monuments and sculptures
- Airport roofs

Automotive and aerospace applications

- Auto bodies
- Rail cars
- Aircraft

2.8 STEEL

Steel is an alloy of iron and iron carbide in which the maximum percentage of carbon is 1.5%



Low-Carbon Steel

Low-carbon steel is characterized by a low ratio of carbon to iron. By definition, low-carbon consists of less than 0.30% of carbon. Also known as mild steel, it costs less to produce than both medium-carbon and high-carbon steel. In addition to its low cost, low-carbon steel is more pliable, which may improve its effectiveness for certain applications while lowering its effectiveness for other applications.

Properties

1. Low hardness and cost.

2. High ductility, toughness, machinability and weldability.

Applications

1. Steel Frame Buildings.

Chosen for its unique structural **properties**, low carbon steel has good enough strength for building frames in **construction** projects. ...

2. Machinery Parts.

Steel in its most basic form, is a combination of two elements; carbon and iron used in steel Industries.

3. Production of Cookware materials.

4. Pipeline manufacturing Industries.

Medium-Carbon Steel

Medium-carbon steel has a higher ratio of carbon to iron than low-carbon steel but still less than that of high-carbon steel. While low-carbon steel consists of less than 0.30% carbon, medium-carbon steel contains anywhere from 0.30% to 0.60% carbon. Many automotive parts are made of medium-carbon steel. It's stronger and more durable than low-carbon steel but still offers at least some ductility.

Properties

1. Carbon content in the range of 0.3 – 0.6%.
2. Can be heat treated - austenitizing, quenching and then tempering.
3. Most often used in tempered condition – tempered martensite.
4. Medium carbon steels have low hardenability.
5. Addition of Cr, Ni, Mo improves the heat treating capacity.
6. Heat treated alloys are stronger but have lower ductility.

Applications

1.Used in railway tracks and wheels, gears, crankshafts.

High-Carbon Steel

High-carbon steel, of course, has the highest ratio of carbon to iron. It consists of more than 0.60% carbon, thereby changing its physical properties. Also known as carbon tool steel, it has around 0.61% to 1.5% carbon. With such a high carbon content, high-carbon steel is stronger and harder but less ductile than low-carbon and medium-carbon steel.

Properties

High carbon steel properties include a very **high strength**, extreme **hardness** and **resistance** to wear, and moderate **ductility**, a measure of a material's **ability** to tolerate being deformed without actually breaking.

Applications

Common **applications of higher carbon steels** include forging grades, rail **steels**, spring **steels** (both flat rolled and round), pre-stressed concrete, wire rope, tire reinforcement, wear resistant **steels** (plates and forgings), and **high** strength bars.

2.7 T-T-T DIAGRAM FOR EUTECTOID STEEL

T-T-T diagram is also called isothermal transformation diagram [Temperature-Time – Transformation]. It is a plot of temperature versus the logarithm of time for a steel alloy of definite composition. It is used to determine when transformations begin and end for an isothermal [constant thermal] heat treatment of a previously austenitized alloy.

TTT Diagram For Eutectoid Steel (Isothermal Transformation Diagram)

Time-Temperature-Transformation (TTT) diagram or S-curve refers to only one steel of a particular composition at a time, which applies to all carbon steels. This diagram is also called as C-curve isothermal (decomposition of austenite) diagram and Bain's curve. The effect of time-temperature on the microstructure changes of steel can be shown by the TTT diagram.

These diagrams are extensively used in the assessment of the decomposition of austenite in heat-treatable steels. We have seen that the iron-carbon phase diagram does not show time as a variable and hence the effects of different cooling rates on the structures of steels are not revealed. Moreover, equilibrium conditions are not maintained in heat treatment

. Although, the iron-carbon equilibrium diagram reveals on the phases and corresponding microstructures under equilibrium conditions but several useful properties of the steels can be obtained under non-equilibrium conditions, e.g. variable rates of cooling as produced during quenching and better transformation of austenite into pearlite and martensite

For each steel composition, different IT diagram is obtained. Fig shows the TTT diagram of eutectoid steel (i.e. steel containing 0.8% C).

Austenite is stable above eutectoid temperature 727 °C. When steel is cooled to a temperature below this eutectoid temperature, austenite is transformed into its transformation product. TTT diagram relates the transformation of austenite to time and temperature conditions.

Thus, the TTT diagram indicates transformation products according to temperature and also the time required for complete transformation.Curve 1 is transformation begin curve while curve 2 is the transformation end curve. The region to the left of curve 1 corresponds to austenite (A'). The region to the right of curve 2 represents the complete transformation of austenite (F+C). The interval between these two curves indicates partial decomposition of austenite into ferrite and Cementite (A'+F+C).

TTT Diagram for Eutectoid Steel :

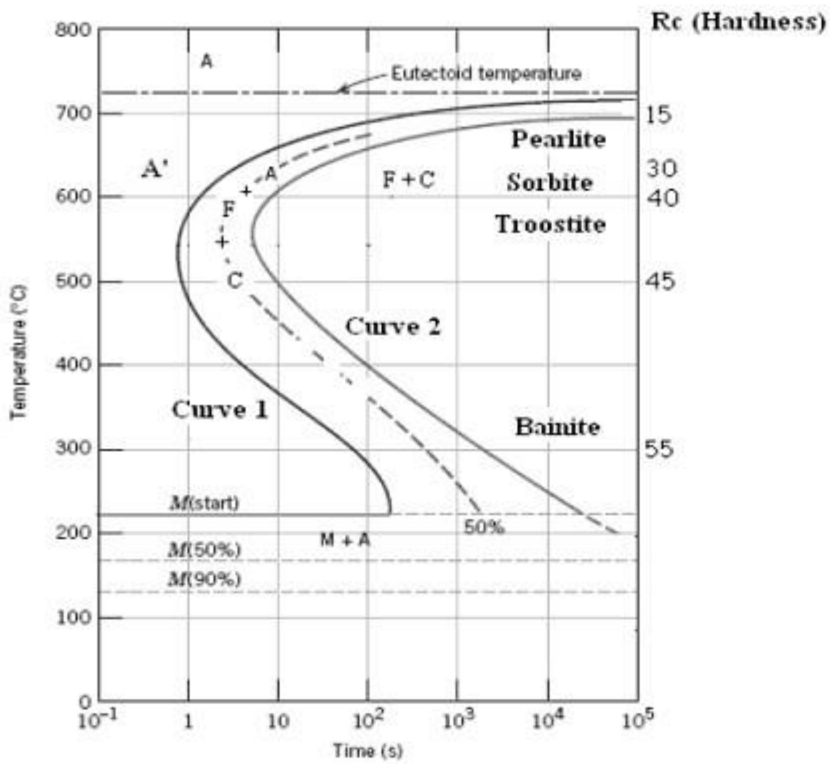


Fig 2.3: TTT diagram of eutectoid steel

At temperatures just below eutectoid temperature, austenite decomposes into pearlite; at lower temperatures (600 deg C) **sorbite** is formed and at 500 – 550 degree C **troostites** is formed.

If the temperature is lowered from 500 deg C to 220 deg C acicular troostite or **bainite** is formed.

In eutectoid steels, the ***martensite*** transformation begins at MS (240 deg C) and ends at MF (50 deg C).

The change in the hardness of the structures is shown in Rockwell units (RC) at the right-hand side of the diagram.