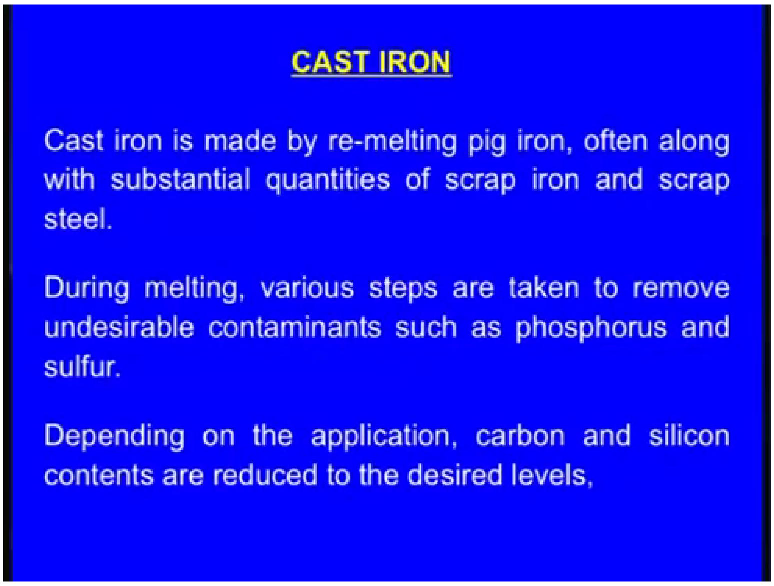
Metal Casting
Dr. D. B. Karunakar
Department of Mechanical and Industrial Engineering
Indian Institute of Technology, Roorkee

Module - 04
Common Cast Alloys
Lecture - 01
Cast Irons and Steels

Good morning friends. In the previous lectures we have been learning about the principles involved in the green sand moulding. What say, properties of the green sand, design of the gating system, casting defects and so on. Next, we were learning about the melting practices next treatment of the molten metal. Now in the next few lectures we will be learning about the important cast metals and alloys. Now today we will see the cast irons and steels.

(Refer Slide Time: 01:00)



First, we will see the cast irons, next will be learning about the steels. Now cast iron. Cast iron is made by re melting pig iron, often along with substantial quantities of scrap iron and scrap steel. During melting of this cast iron various steps are taken to remove undesirable contaminants such as phosphorus and sulfur. Because this phosphorus and sulfur are detrimental they can cause cracking to the castings. That is why they should be minimized; their proportion should be minimized. And depending upon the application carbon and silicon contents are reduced to the desired levels. Cast iron in the cast iron carbon and silicon are also present, but they should be within the prescribed limits.

So, we will take every measure so that if there is any excessive carbon or silicon we will reduce it.

(Refer Slide Time: 01:59)

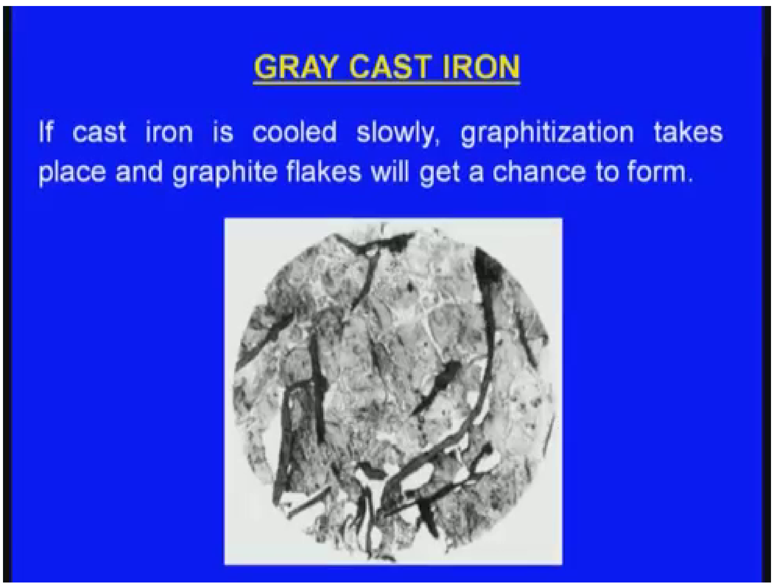
Now, cast irons can easily be cast into intricate shapes. We can make complex shaped castings. Next one they have good wear resistance. And they have high hardness and they possess good machinability. So, these are the important features and characteristics of cast iron.

(Refer Slide Time: 02:23)

Now, there are mainly 4 types of cast irons. One is the gray cast iron. Second one is the white cast iron. Third one is the ductile cast iron. And the 4th one is the malleable cast iron.

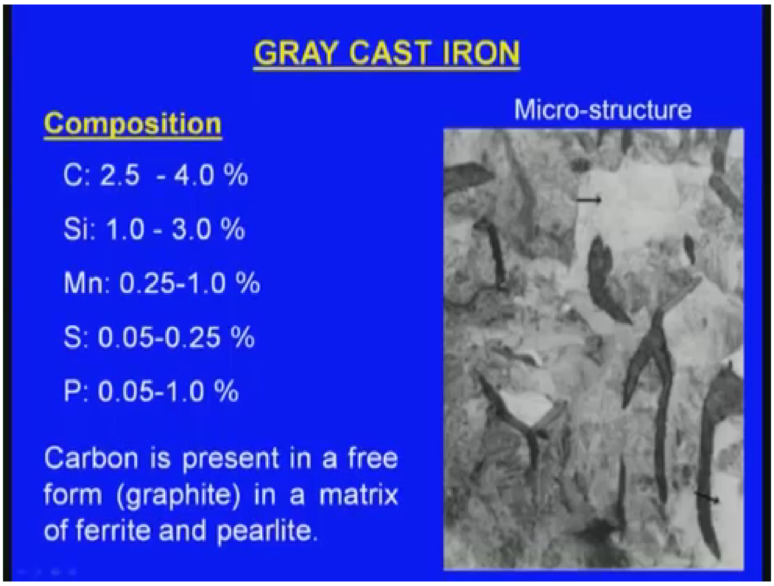
Now, we will be learning all these one by one. Initially we will see the gray cast iron. Now what is what are the characteristics and features of gray cast iron? If cast iron is cooled slowly, what will happen? Graphitization takes place. And during this graphitization graphite flakes will get a chance to form.

(Refer Slide Time: 03:01)



Now, this is the microstructure of gray cast iron. And we can see here these are all the graphite flakes. And several such flakes will be there all along the casting. So, this is the what say simple characteristic of the gray cast iron.

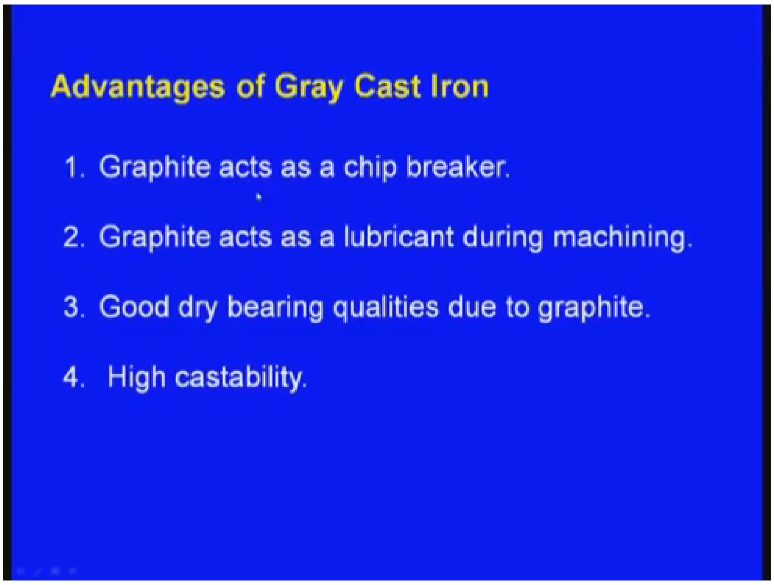
(Refer Slide Time: 03:19)



Now, this is the composition carbon will be present from 2.5 percent to 4 percent, silicon 1 percent to 3 percent. Manganese 0.25 to 1 percent. Sulfur 0.05 to 0.25 percent. And phosphorous 0.05 to 1 percent. Remember the what say proportion of sulfur and phosphorus are extremely small.

Now, again we have to note that the carbon is present in a free form graphite, in a matrix of ferrite and pearlite. And here we can see these are the graphite flakes. This is one flake, and this is a another graphite flake, this is a graphite flake, this is a graphite flake. Likewise, we can see several such graphite flakes.

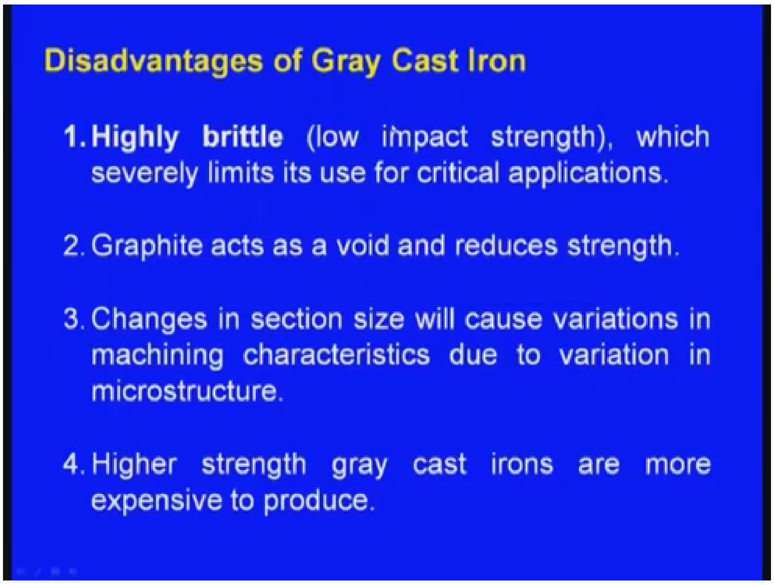
(Refer Slide Time: 04:10)



Now, these are the advantages of gray cast iron. Graphite acts as a chip breaker during machining. During the machining we require discontinuous chips. Because continuous chips would harm the tool as well as the surface finish of the job.

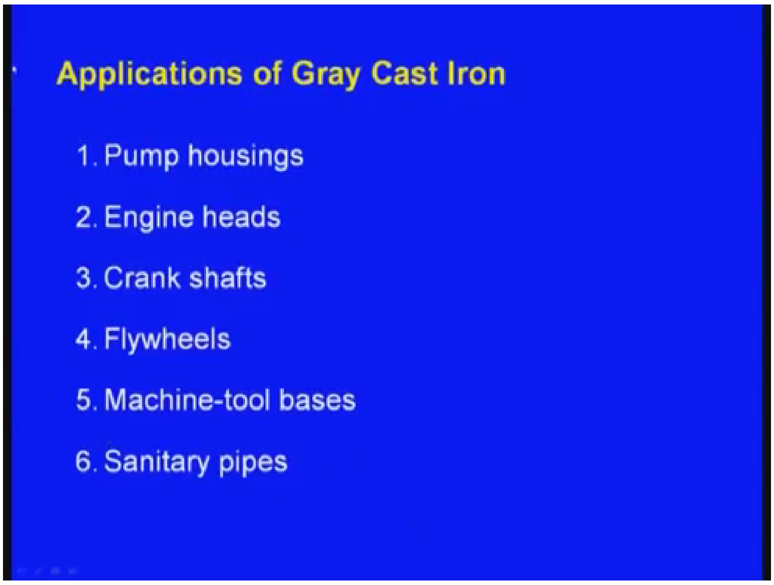
Now, we always discontinuous chips are preferred. Now what happens during machining? When that graphite flakes comes flakes come in contact with the tool immediately, because this graphite flake is soft the chip will be breaking. That is how we get the discontinuous chips, because of the presence of the graphite flakes. That way this graphite acts as the chip breaker during machining. Now not only that graphite acts as a lubricant during machining. This graphite is a what say good lubricant during machining of cast iron gray cast iron. Next one it has good dry bearing qualities due to graphite. Next one it has got the high castability. Means what is the meaning? It is able to penetrate into all the what say what say intricate shapes minuet shapes of the cavity.

(Refer Slide Time: 05:27)



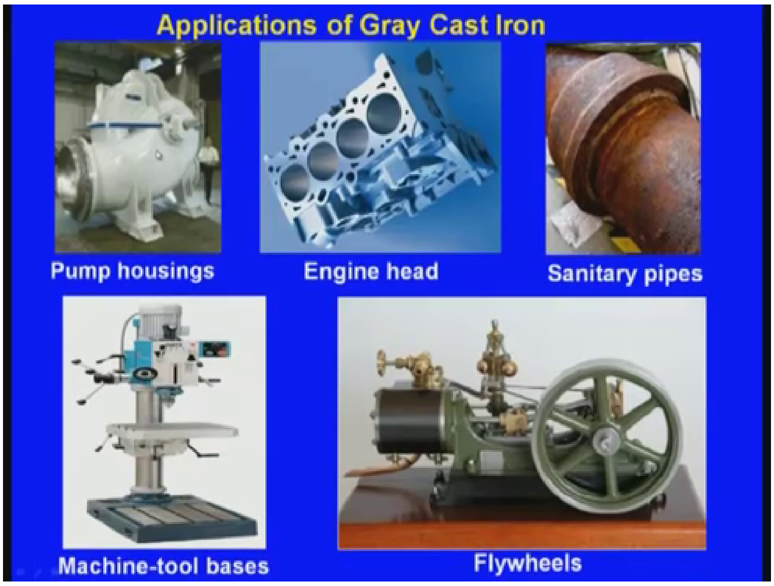
That is the high castability. Now these are the disadvantages or the limitations of the gray cast iron. Highly brittle right it has got the low impact strength, which severely limits is used for critical applications. Next one graphite acts as a void, and reduces this strength. Because graphite is soft it become acts as a void, and it reduces the strength. Next one changes in section size will cause variations in machining characteristics due to variation in microstructure. Next one higher strength gray cast irons are more expensive to produce right. So, because of the presence of the graphite flakes there will be voids. So, we have to overcome these difficulties we need to make certain treatments. So, that way what say if we have to produce gray cast iron with higher strength that would become expensive.

(Refer Slide Time: 06:23)



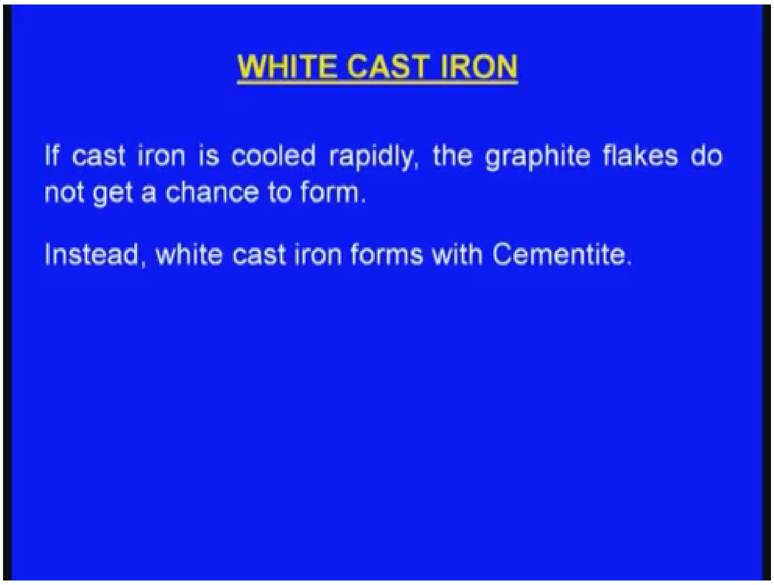
Now, these are the applications of gray cast iron. Pump housings, engine heads, crank shafts, fly wheels, machine tool bases, sanitary pipes. These are important applications in fact, there will be many more applications of gray cast iron.

(Refer Slide Time: 06:41)



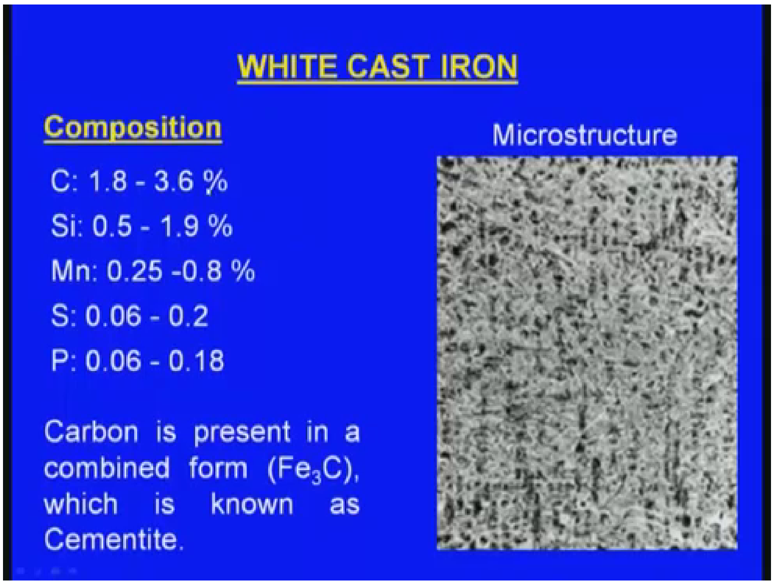
Now, here we can see, this is the pump housing. This is made up of gray cast iron. This is an in engine head made up of gray cast iron. The sanitary pipe and this is the machine tool structure, and this is a flywheel. All these are made up of gray cast iron. Next one let us see the white cast iron.

(Refer Slide Time: 07:09)



Now, what is the characteristic of white cast iron? If cast iron is cooled rapidly the graphite flakes do not get a chance to form. In the case of the gray cast iron we were cooling slowly; that is how graphite flakes were forming. Now here we cool the what say cast iron very rapidly so that there is no chance for the graphite flakes to form. Now when the cast iron is melted, the carbon will be present in the melt in the form of the in a chemically combined form; that is the iron carbide or the cementite. Now during that state, we are rapidly cooling. Means, we are arresting the chemical combination of iron and carbon. Now what will happen? When it is cooled down the white cast iron forms with cementite. The what say chemically combined form that is the iron carbide, or the cementite will continued to present even in the solid state; that is way white cast iron is more hard compared to other cast irons.

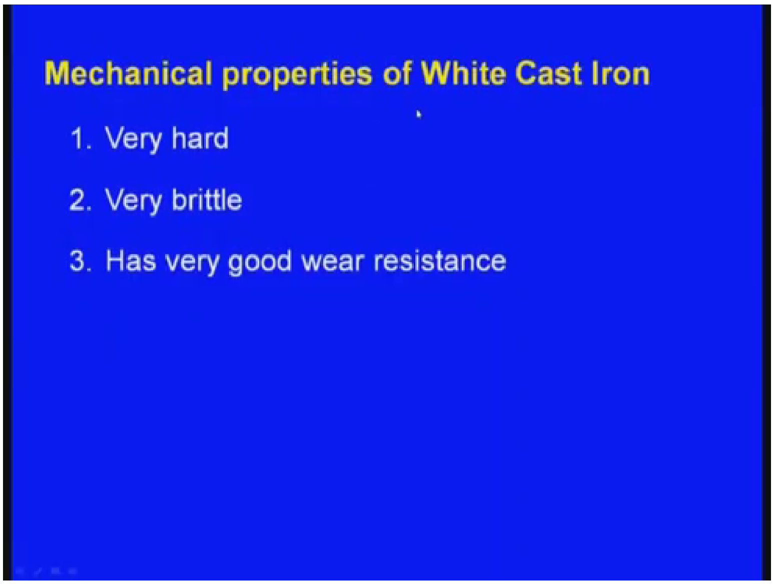
(Refer Slide Time: 08:12)



Now, this is the typical composition of white cast iron. Carbon will be present from 1.8 to 3.6 percent.

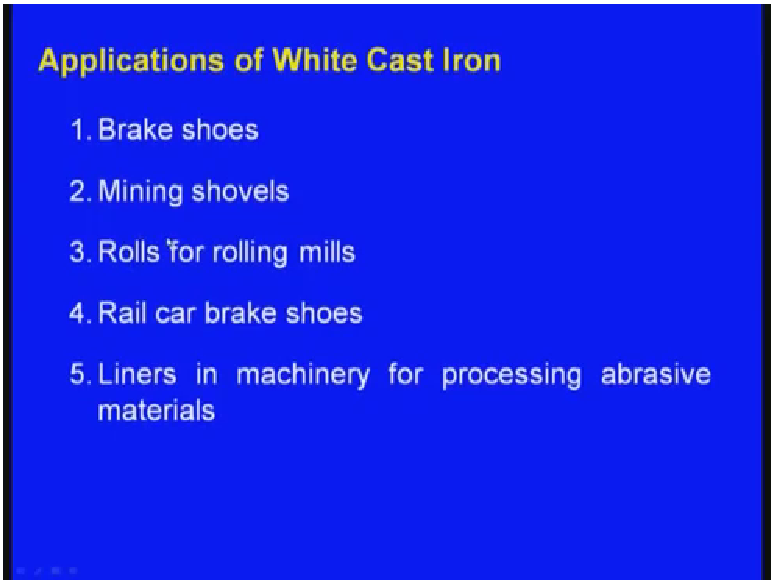
Silicon 0.5 to 1.9 percent. Manganese 0.25 to 0.8 percent, sulfur 0.62 to 0.2 percent. And phosphorus 0.62 percent to 0.18 percent. Again, we have to note that carbon is present in a combined form, that is the Fe 3 C right. And which is known as the cementite. Now this is the microstructure. We can see everywhere, we can see the cementite particles everywhere. So, this cementite is very hard. As hard as cementite. That is how the entire cast iron, the white cast iron becomes very hard.

(Refer Slide Time: 09:04)



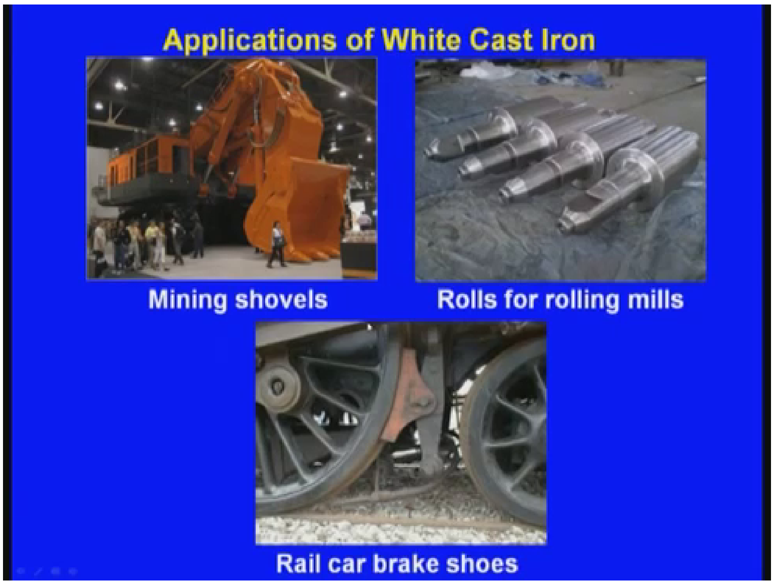
Now, these are the mechanical properties of white cast iron. Very hard why? Because cementite is present. Cementite is very hard, that is why the white cast iron is very hard. Next one it is very brittle, and it has got good wear resistance. White harder what say the cementite is very hard, because of that there is a good wear resistance.

(Refer Slide Time: 09:27)



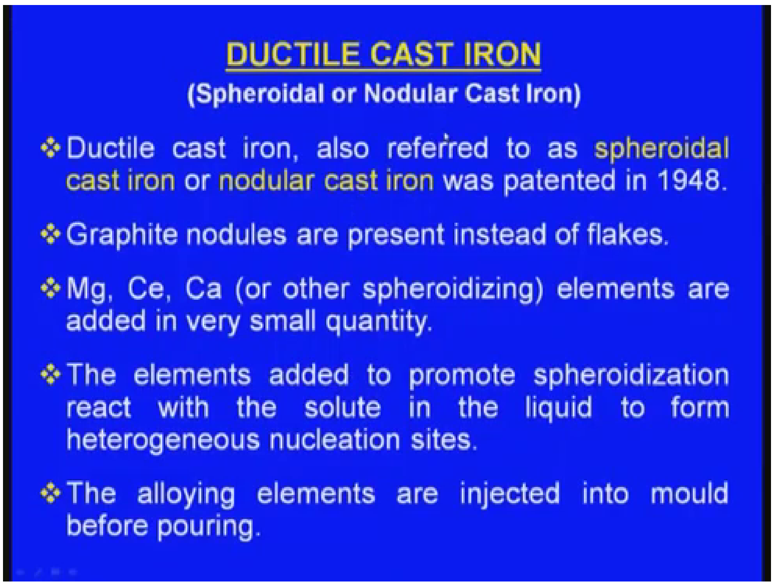
Now, these are the common applications. In fact, important applications of white cast iron. Brake shoes, mining shovels, rolls for rolling mills, rail car brake shoes, liners in machineries for processing abrasive materials. We will see few pictures.

(Refer Slide Time: 09:46)



So, these are the mining shovels. So, these are made up of white cast iron. These are the rolls for rolling mills. Again, these are made up of white cast iron. Now this is the rail car brake shoes. Here we can see this is the rail car brake shoe. Now if it is the ordinary cast iron what will happen? It will be what say undergoing the wear, but white cast iron has got the excellent wear resistance. Because of that nothing will happen, even when we apply the brake.

(Refer Slide Time: 10:28)



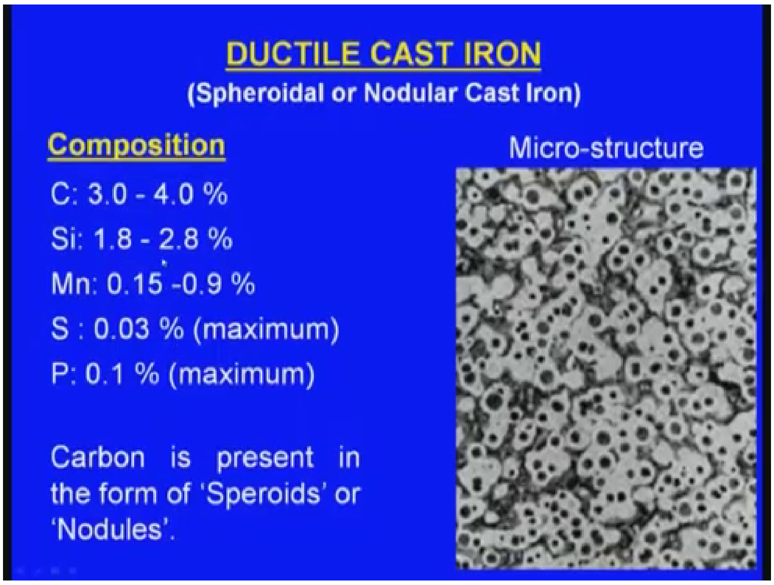
This brake shoe will be very good, it is condition will be very good. Next one let us see the ductile cast iron. What is the characteristic of ductile cast iron? Ducktail cast iron also referred to as spheroidal cast iron or nodular cast iron was patented in the year 1948. Now what is it is characteristic? Here in the case of the gray cast iron graphite flakes were present. And here graphite nodules are present instead of flakes. That is why we call it as the nodular cast iron.

Now how we are able to get these nodules? Magnesium, selenium, calcium or other spheroidizing elements are added in a very small quantity to the molten cast iron. Then what will happen? The elements that we are adding promote spheroidization, right? And with this solute in the liquid to form heterogeneous nucleation sites. Now what will happen? These magnesium or cranium or calcium elements that we are adding will be in a extremely small quantity.

Now they are spread all over, now these will be acting as the nucleating agents. Means, a small particle of magnesium will be present. Around that some cast iron will be solidifying. Another magnesium particle will be there somewhere around that cast iron will be solidifying. Likewise, there will be millions of what say magnesium particles, and there will be millions of what say nodules will be there. Now the alloying elements are injected into the mould before pouring. So, this is the simple characteristic or important characteristic of the ductile cast iron.

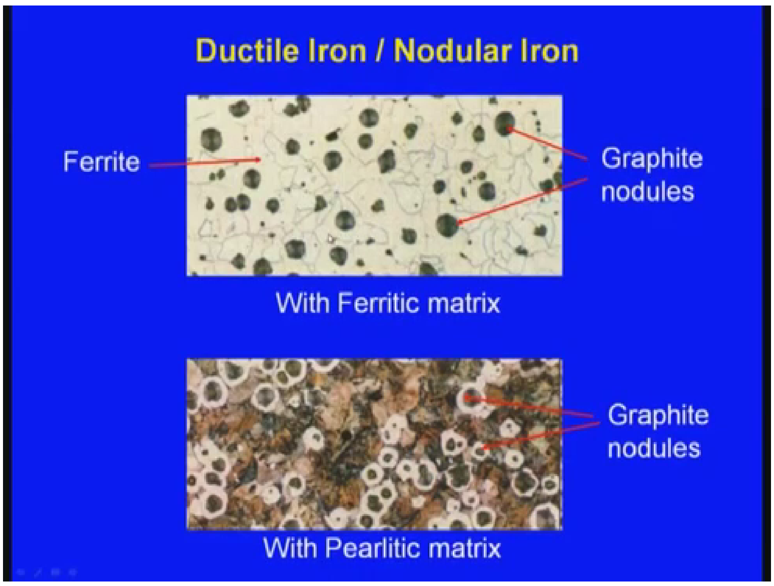
The graphite is present in the form of the nodules.

(Refer Slide Time: 12:16)



Now, this is the chemical what say typical composition. Carbon is present 3 to 4 percent. Silicon 1.8 to 2.8 percent manganese 0.215 to 0.9 percent. Sulfur 0.03 percent, and phosphorous 0.1 percent. And again, we must note that carbon is present in the form of spheroids or nodules. Now this is the microstructure. Everywhere we can see this is one nodule, and this is one nodule, this is one nodule, this is one nodule, this is one nodule. Means, at the centre of each nodule there will be one magnesium particle or cranium particle, around that cast iron is solidified.

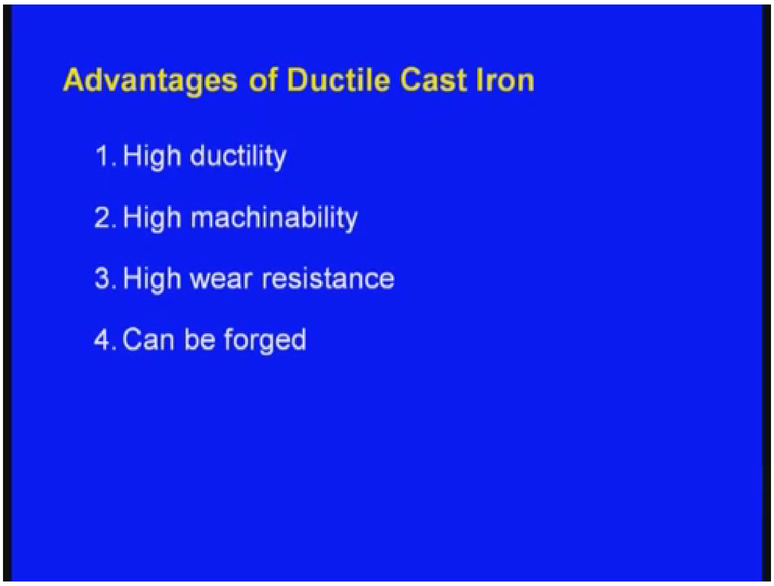
(Refer Slide Time: 13:05)



Now, here we can see again.

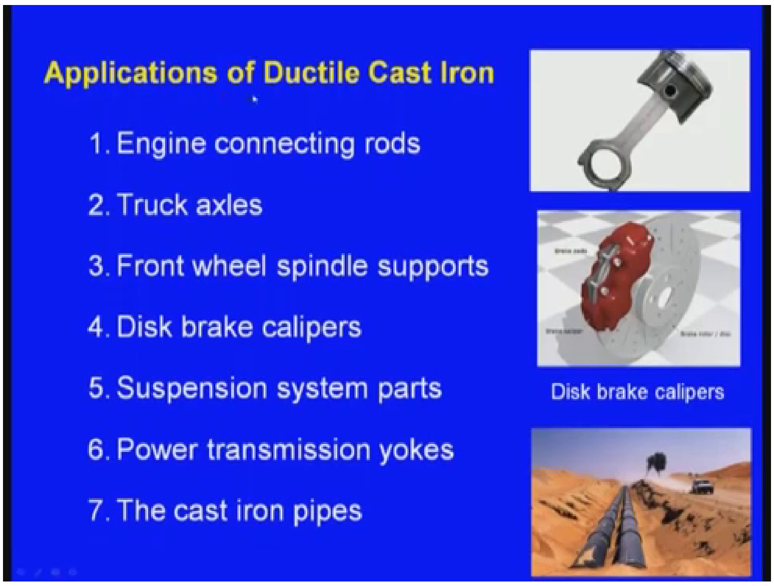
So, with ferrite matrix we can see these are the graphite nodules. Everywhere we can see graphite nodules. And this is the pearlitic matrix, and again here we can see these are the nodules. Now these are the advantages of ductile cast iron. High ductility as the name implies name is ductile cast iron it has got high ductility.

(Refer Slide Time: 13:34)



Now, it has also got high machinability. Next one it has got high wear resistance and it can be the forged.

(Refer Slide Time: 13:43)



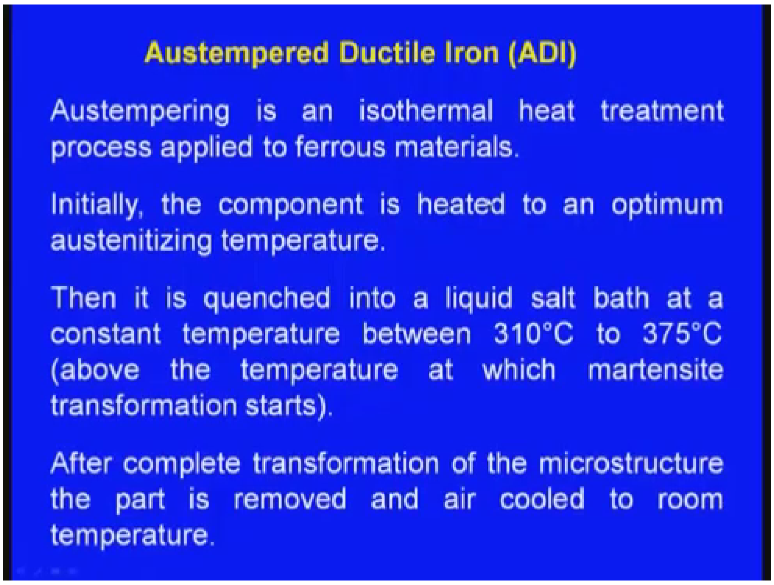
Now, these are the important applications of ductile cast iron. Engine connecting rods truck axles, front wheel spindle supports, disc brake calipers, suspension system parts power transmission yokes the cast iron pipes, and here we can see this is a connecting rod of in what say an internal combustion engine right.

Next one here we can see this is the disc brake calipers. Next one these are the cast iron pipes. All these are made up of ductile cast iron.

(Refer Slide Time: 14:14)

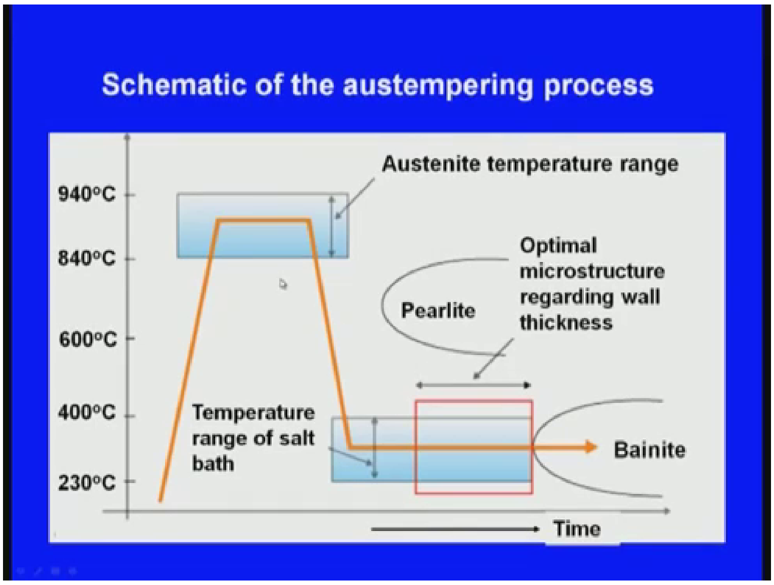
Now, you can see here this is the pump and valve components made up of ductile cast iron. So, all these are made up of ductile cast iron. Now there is another category of ductile cast iron; that is known as the austempered ductile iron ADI.

(Refer Slide Time: 14:33)



What is that? Austempering is an isothermal heat treatment process applied to ferrous materials. Initially the component is heated to an optimum austenitizing temperature. Then, it is quenched in to a liquid salt bath at a constant temperature between 300 and 10 degrees to 375 degrees centigrade. Means, it is the temperature at which martensite transformation starts. After complete transformation of the microstructure, the part is removed and air cooled to room temperature.

(Refer Slide Time: 15:09)

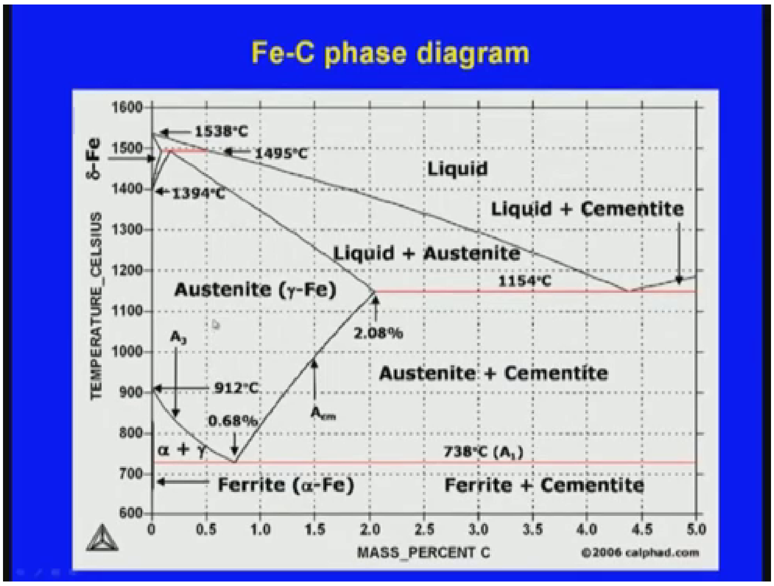


Now, we will see the diagram. So, this is the schematic diagram of the austempering process.

Now, what is happening? So, here it the component will be heated. So, this is the austenite temperature range. Now we will be heating the component to an optimum austenitizing temperature. Then what will happen? It will be quenched in a salt bath at this temperature. You can see at this temperature in this range it will be cooled down. And you can see here this line this is cooled down quenched at a constant temperature. So, this is the what say optimal microstructure regarding wall thickness. Now this is the temperature range of the salt bath. So, this is 400 degree centigrade, and this is the say 232. Something, something between that we what say quench the component.

Now, what is this what say austenitizing temperature range? Let us see the phase diagram. Yes, in the phase diagram you can see here the austenite will be starting at a temperature of 912 degree centigrade.

(Refer Slide Time: 16:11)



So, this is the starting what say temperature for the formation of austenite. Now you see here this is the austenite temperature range. Yes, 912 is somewhere in between in this range to that temperature will be heating. Then we will be quenching at a constant temperature. Then we will be getting the austempered ductile iron.

(Refer Slide Time: 16:44)

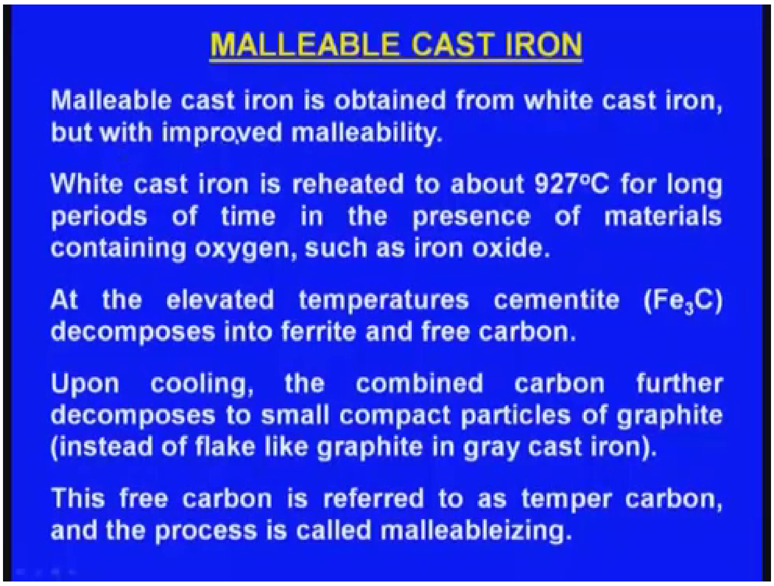
Now, what are the advantages of austempering or the austempered ductile iron? It produces a structure that is stronger and tougher than the structures produced with conventional heat treatments. Thin walled net shape components can be produced why?

Because within ordinary cast iron or with the gray cast iron if we produce thin walled sections they may not be strong enough to withstand. Whereas, the what say austempered ductile iron has got higher strength it is strong enough. So, even a thin walled section will be strong enough to sustain. Next one components possess high hardness and excellent wear resistance. Now ADI means it is the short form for the austempered ductile iron. It is much easier to cast than steel. It is approximately 9 percent lighter than steel given it is density is lesser nowadays what is the requirement for the castings we want lesser density. So, that is way austempered ductile irons density is lesser than the density of steel.

(Refer Slide Time: 17:58)

Now, this is a typical example of ductile, what say austempered ductile irons application a wheel what say cassette part made up of austempered ductile iron.

(Refer Slide Time: 18:15)

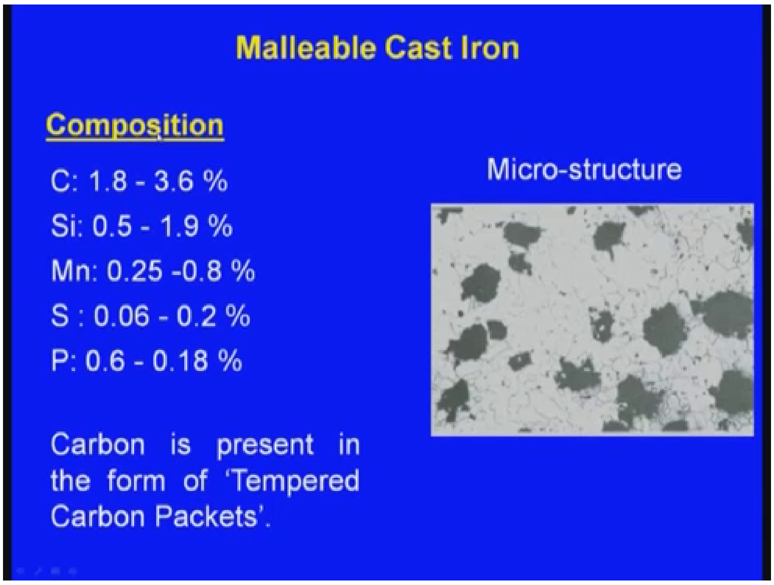


Now, finally, we will see the malleable cast iron. Malleable cast iron is obtained from white cast iron, but with improved malleability. It is obtained from white cast iron. What is malleability? Ability of the component to be made into thin what say plates or thin sections, that is the malleability. So, when we are making malleable cast iron from white cast iron, this property is improved, the malleability property. Next one the white cast iron is reheated to about 927 degrees for a for a long periods of time.

In the presence of materials containing oxygen such as oh what say iron oxide. Then what will happen? At the elevated temperatures cementite decomposes into ferrite and free carbon. Then what will happen? Upon cooling the combined carbon further decomposes means the combined carbon from the cementite further decomposes to small what say compact particles of graphite, instead of flakes like graphite in gray cast iron. So, in the case of the gray cast iron we have seen car what say graphite flakes. Were there where as in the case of the ductile cast iron there were graphite nodules were there. Now here what will happen there will be what say graphite or the carbon packets will be there.

This free carbon is referred to as temper carbon and the process is called malleableizing.

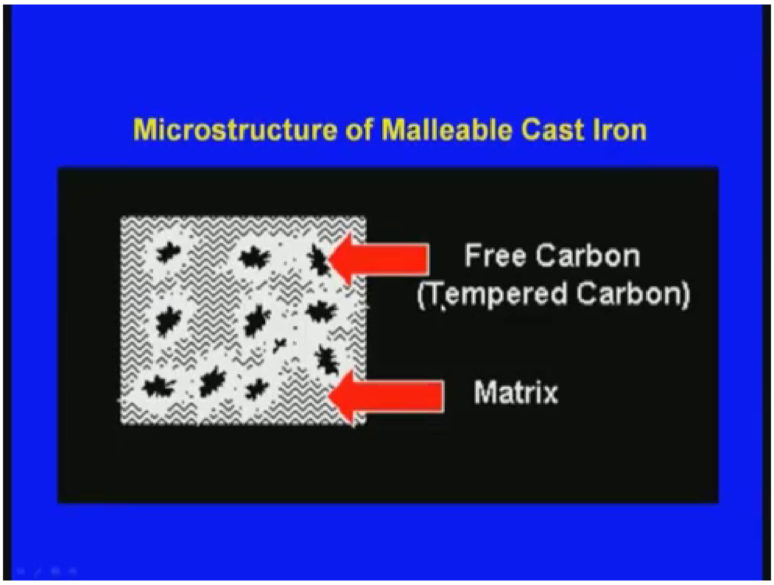
(Refer Slide Time: 19:48)



Now, this is the typical composition of malleable cast iron. Carbon it is proportion is from 1.8 to 3.6 percent. Silicon 0.5 to 1.9 percent. Manganese 0.25 to 0.8 percent. Sulfur 0.62 to 0.2 percent. And phosphorus 0.62 2.18 percent. Now we must note that carbon is present in the form of tempered carbon packets. Now this is the microstructure of malleable cast iron. So, this is a tempered carbon packet this is another such packet, this is another tempered carbon packet.

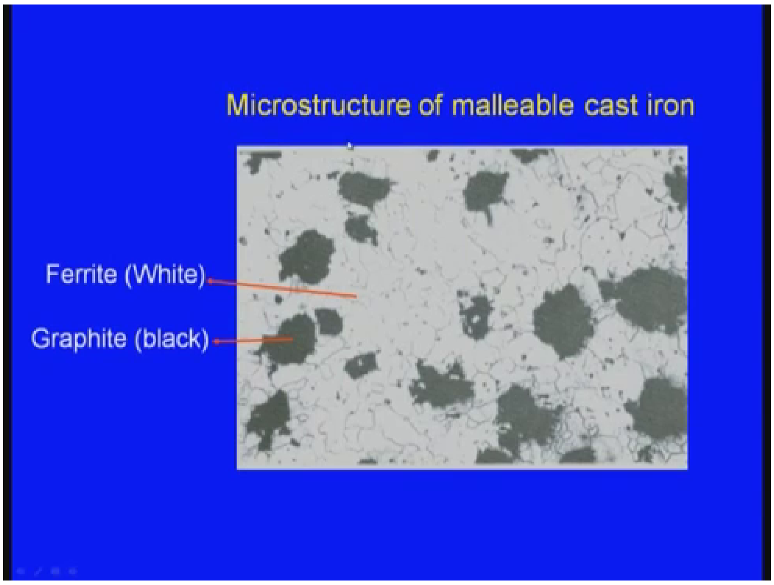
Likewise, there will be several such tempered carbon packets will be there. And because of that the malleability of cast iron is improved.

(Refer Slide Time: 20:41)



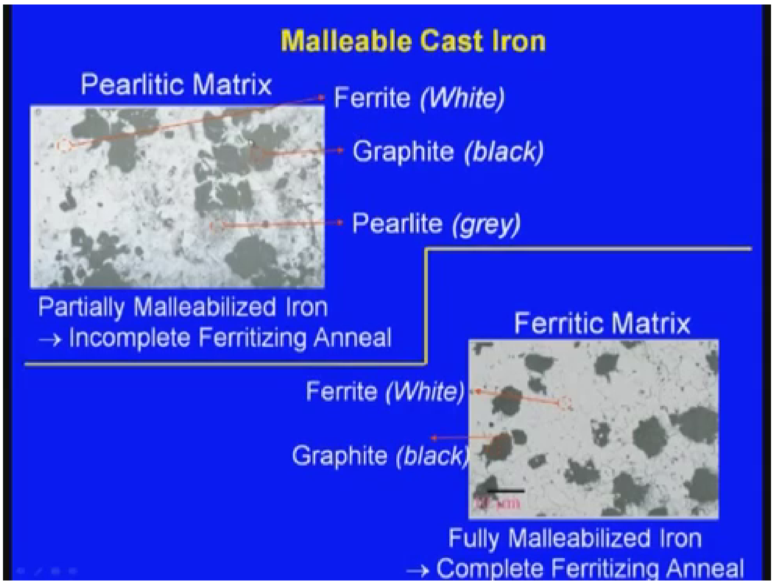
Now, we can see here again. So, this is this is the free carbon or the tempered carbon. Now again this is we can see the microstructure.

(Refer Slide Time: 20:48)



Here the matrix is the ferrite we can see here this is the ferritic may what say matrix, and this is the graphite packet or the carbon packet, this one.

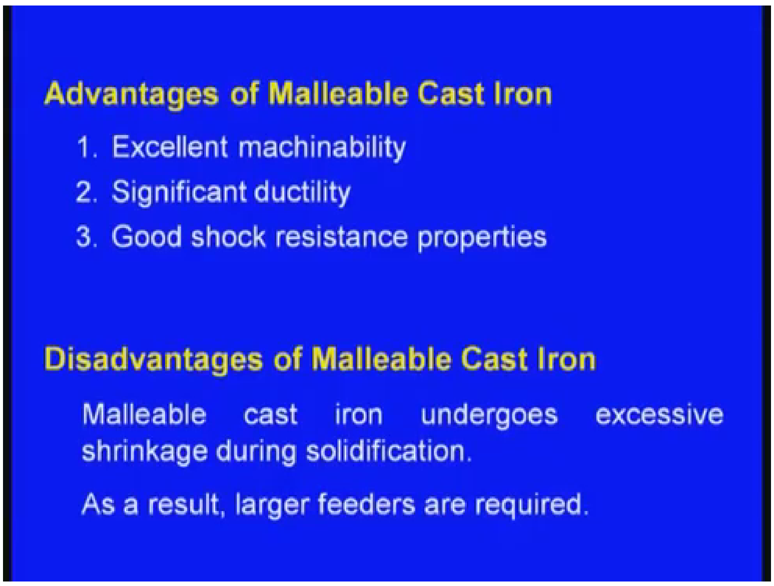
(Refer Slide Time: 21:02)



And again, we can see here we can see pearlitic matrix. And this is the this is the what the carbon packet. And again, here we can see this is the ferritic matrix, and this is the carbon packet or the graphite packet. And here it is partially malleable iron we can see and here we can see fully malleable iron.

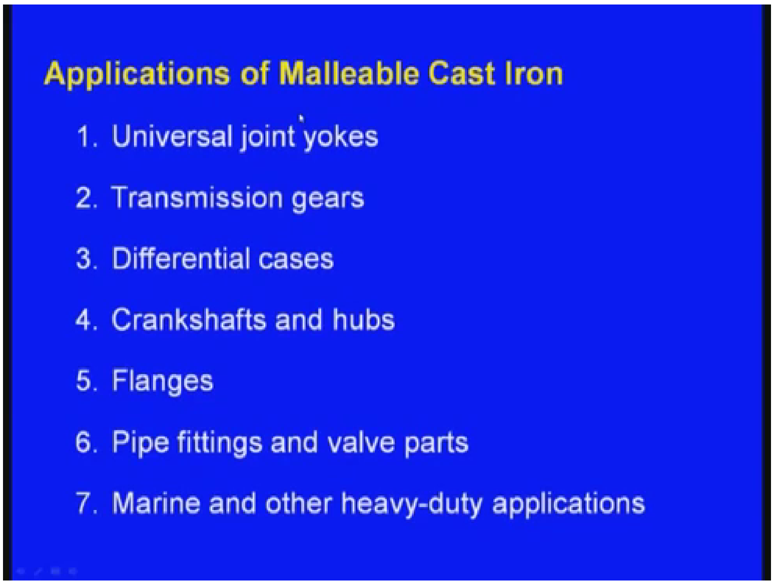
Now, these are the advantages of malleable cast iron. One is the it has got excellent machinability.

(Refer Slide Time: 21:38)



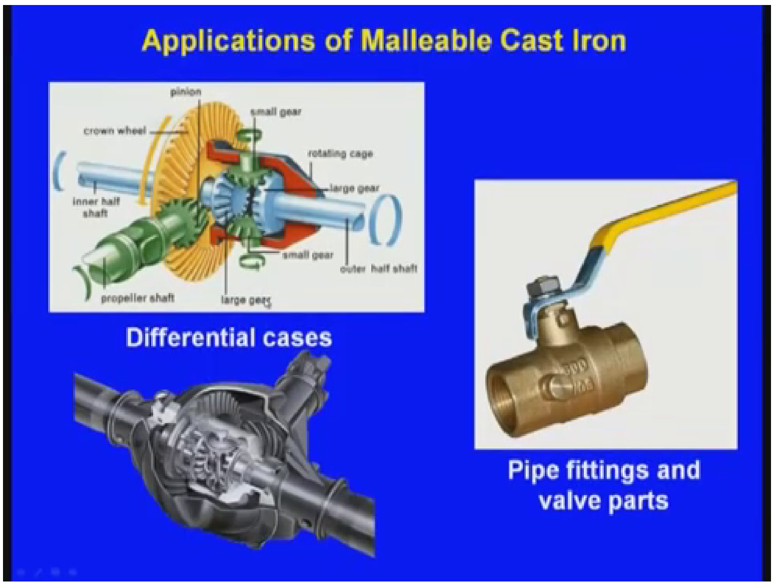
Next one it has got significant ductility. Next one good shock resistance properties. And these are the demerits or disadvantages of malleable cast iron. One is malleable cast iron undergoes excessive shrinkage during solidification. As a result, larger feeders or the risers are required.

(Refer Slide Time: 21:55)



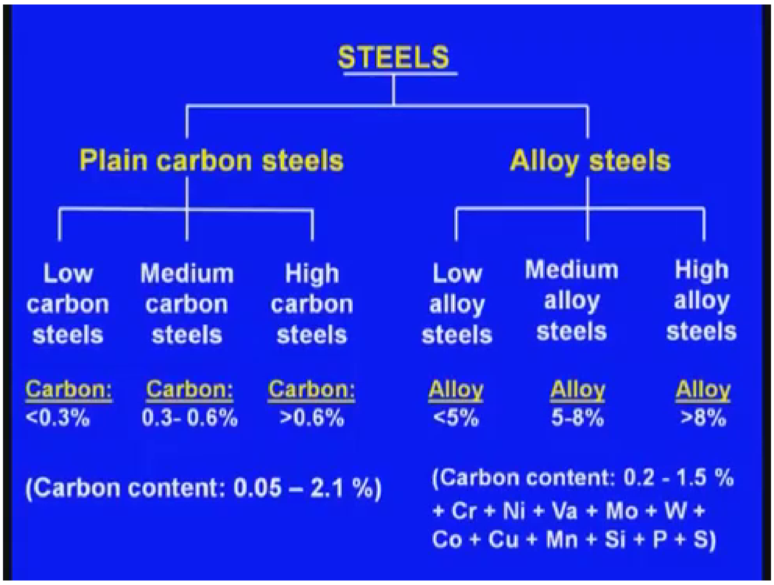
These are the applications of malleable cast iron. Universal joint yokes, transmission gears, differential cases crankshafts and hubs flanges, pipe fittings and valve parts marine and other heavy-duty applications. All these are made up of malleable cast iron.

(Refer Slide Time: 22:14)



And here we can see few what say pictures. So, this is a differential oh in used in the automobiles. So, this is made up of malleable cast iron. Differential case and he this is the pipe fittings and valve parts. So, these are made up of malleable cast iron. Next one so far, we have completed the cast irons. Now let us see the cast steels.

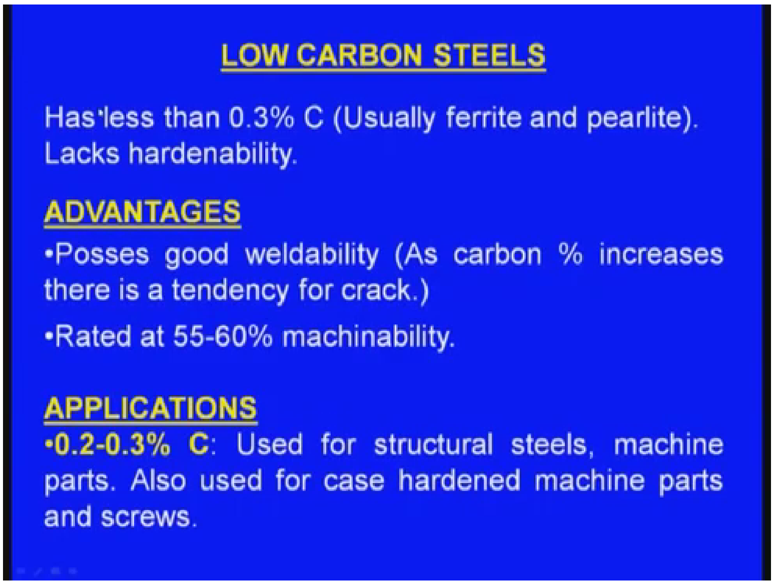
(Refer Slide Time: 22:37)



The steels can be broadly classified into 2 categories. One is the plain carbon steels and the other one is the alloy steels. Now in the plain carbon steels is several elements are present like carbon, silicon, manganese, sulfur, phosphorus are present, but carbon is the principle alloying element. Whereas, in the case of the alloy steels, carbon is also present. Along with carbon several elements like chromium, nickel, vanadium, molybdenum, tungsten, cobalt copper manganese silicon phosphorus sulfur. These are also present.

But what is the difference between plain carbon steels and the alloy steels is that; in the case of the plain carbon steels carbon is the main alloying element or the principle alloying element where as in the case of the alloy steels though carbon is present, some other elements like chromium or nickel and several such elements. One of these will be the principle alloying element rather than the carbon. That way there are 2 categories. Now first we will see the plain carbon steels. Next, we will see the alloy steels plain carbon steels.

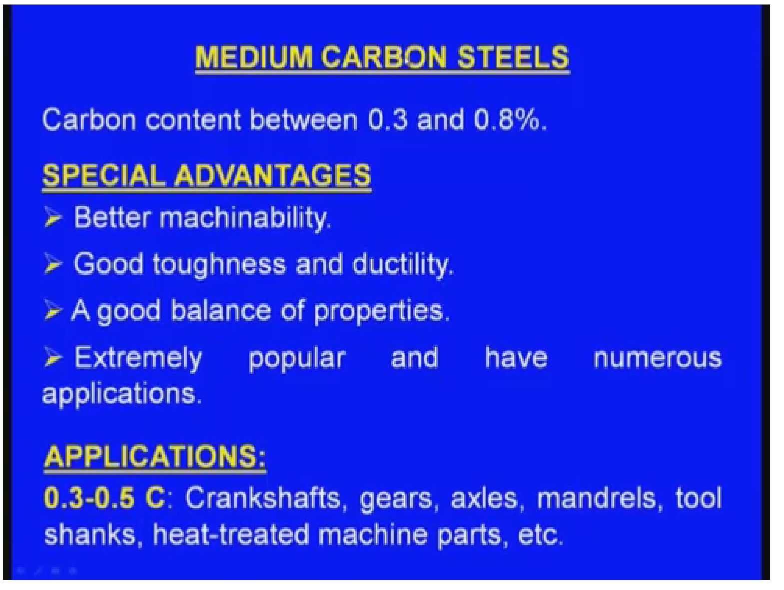
(Refer Slide Time: 23:56)



Plain carbon steels among them again there are 3 categories. One is the low carbon steels, right? And another one is the medium carbon steels and the third one is the high carbon steels.

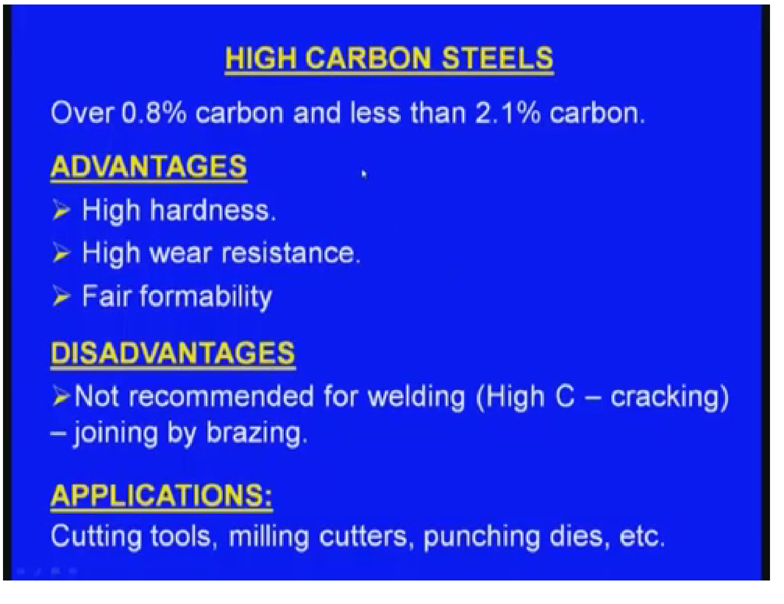
Now, first we will see the low carbon steels. It has less than 0.3 percent carbon. Usually ferrite and pearlite right and it lacks hardenability. What are the advantages? It possess good weldability as carbon content increases there is a tendency for crack. Here the carbon content is lesser. That is why the welding is good, but as the carbon content is increasing it develops cracking during welding. Now rated 55 to 60 percent machinability. Now what are the applications? Say, among them when the carbon is present from 0.2 to 0.3 percent, such what say low carbon steel is used for structural steels machine parts. Also used for case hardened machine parts and screws.

(Refer Slide Time: 24:58)



Next one let us see the medium carbon steels. In the medium carbon steels, the carbon content is between 0.3 percent to 0.8 percent. Now these are the special advantages better machinability, good toughness and ductility good balance of properties, and this is extremely popular and have numerous applications because the carbon content is neither less nor high it has got the moderate amount of carbon. Now what are the applications? When the carbon content is present from 0.3 to 0.5 percent, it will be used for making crankshafts gears axels mandrels tool shanks and heat-treated machine parts and many more. So, these are the applications of medium carbon steels.

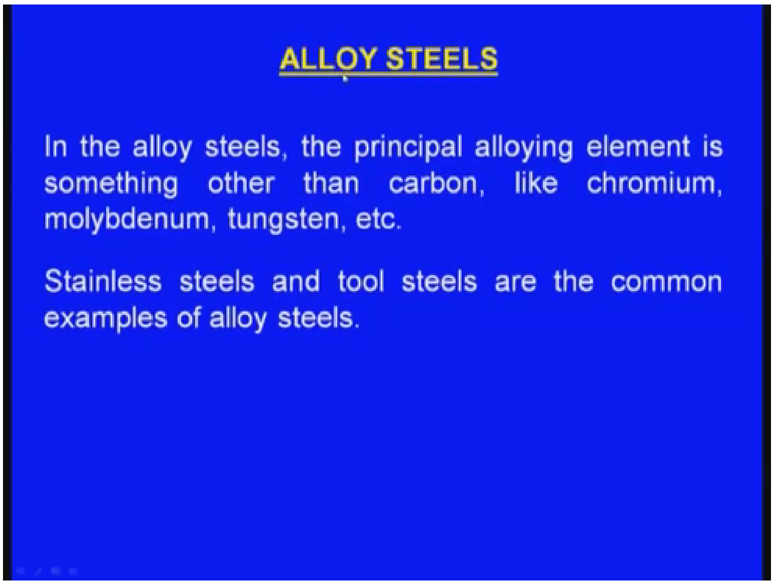
(Refer Slide Time: 25:46)



Next one let us see the high carbon steels. Now when the carbon content is more than 0.8 percent to up to 2.18 percent. This is the high carbon steel. Now what are the advantage? It has got high hardness, why?

Because carbon content is very high. Next one it has got high wear resistance, fair formability. Now what are the disadvantages? Because the carbon content is very high during welding it develops cracking. Now what are the applications? It is used for cutting tools, milling, cutters, punching, dies and few other few such applications.

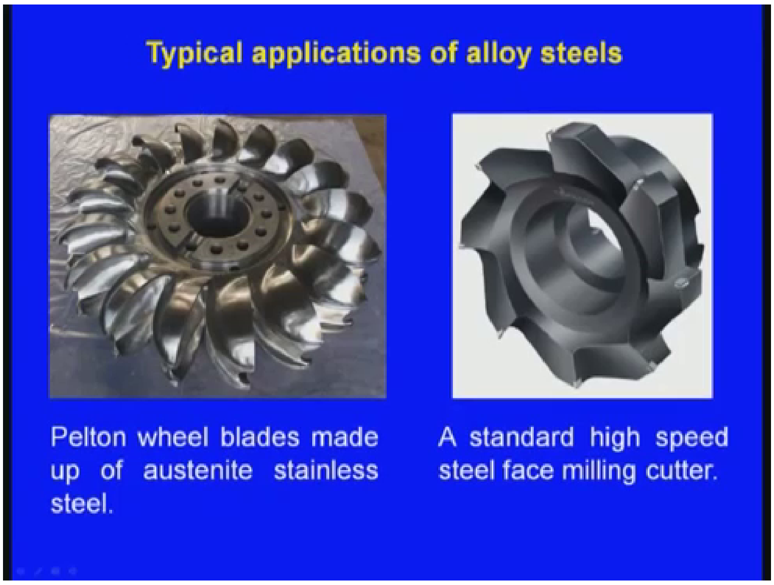
(Refer Slide Time: 26:34)



Next one let us see the alloy steels. Now what are the characteristics of alloy steels? In the alloy steels the principle alloying element is something other than carbon. Like, chromium, molybdenum, tungsten etcetera. It does not mean that carbon is not present. Carbon will be present, but or the rather than the carbon the influence of some other element will be dominating.

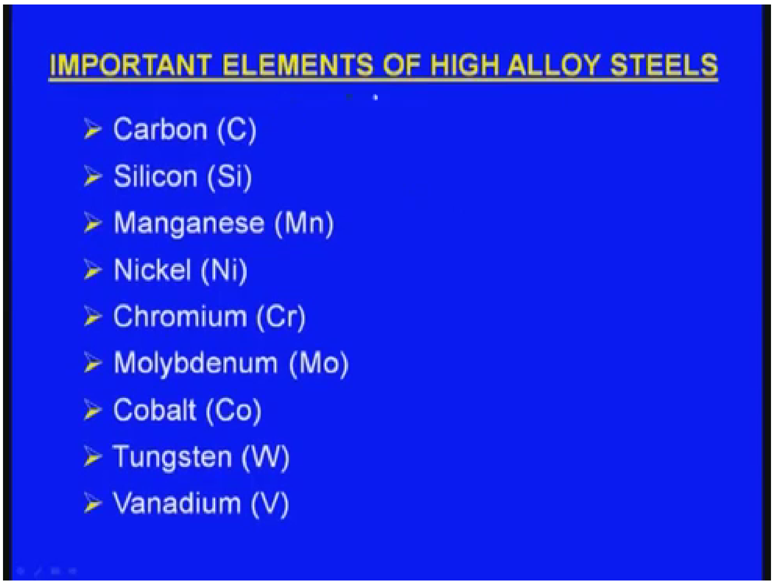
Stainless steels and tool steels are the common examples of alloy steels.

(Refer Slide Time: 26:59)



Now, we can see here these are the typical applications of alloy steels. So, this is a pelton wheel blades made up of austenite stainless steel. And here we can see this is a standard a high speed what say milling cutter made up of high speed steel. So, these are the applications of the alloy steels.

(Refer Slide Time: 27:18)



Now, important elements of high alloy steels. What are the elements or the principle alloying elements present in the high alloy steels? One is the carbon may not be the what say primary element or the principle alloying element, but these are present carbon is present. Silicon, manganese, nickel, chromium, molybdenum, cobalt, tungsten and vanadium.

Silicon is a principle alloying element, but carbon is not the principle alloying element in the high alloy steels. Now we will see the alloying elements of steels and their functions. One is the carbon.

(Refer Slide Time: 27:52)

ALLOYING ELEMENTS OF STEELS & THEIR FUNCTIONS

S. No	Alloying element	Functions
1	Carbon (C)	1. Increases solid-solution strength 2. Increases hardenability.
2	Silicon (Si)	1. Used as deoxidizer. 2. Alloy for electrical and magnetic sheet metals. 3. Improves oxidation resistance. 4. Strengthens low alloy steels. 5. Also prevents decarburization.
3	Manganese (Mn)	1. Counteracts effect of brittleness from sulfur. 2. Increases hardenability inexpensively. 3. High Mn and high C produce steels resistant to wear and abrasion.

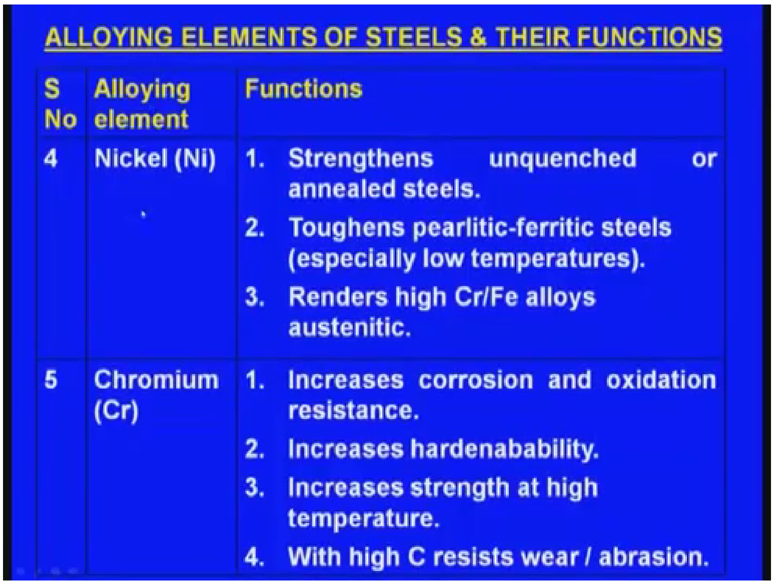
What is it is what are the functions of carbon it increases? Solid solution strength and also it increases hardenability. Next element is the silicon. It is used as a deoxidizer, means it prevents oxidation. Now it is an alloy for electrical and magnetic sheet metals. Improves oxidation resistance, because if you may what say metal is about to undergo oxidation; this silicon reacts with that oxygen and saves the metal instead this undergoes what say oxidation. That way what say it improves the oxidation resistance of the what say that alloy.

Strengthens low alloy steels also prevents decarburization. Now decarburization is another severe problem in the steels. In fact, even in the cast irons what is this decarburization carbon has to be present in a what say particular range is both in the steels and also in the cast iron. Now because of this carbon right the casting will get a what say particular amount of strength, but if this carbon content is reduced this is the decarburization. What will happen? The strength of the casting comes down. At such times when they what say decarburization is about to takes place silicon prevent such decarburization. Next one next element is the manganese. What are the functions of manganese? Counteracts the effect of brittleness from sulfur. Now sulfur has to be present in the both in the cast iron and also in the steel.

Now, it is sometimes it is intentionally allowed, but up to a extremely small amount may be 0.05 percent. That improves the machinability of the casting. Sometimes by mistake if the proportion of the sulfur crosses that limit may be 0.05 is the limit the casting becomes brittle. Now that casting develops cracking. At such times this manganese reacts with sulfur and forms the manganese sulphide. And preve counteracts the effect of the brittleness from the sulfur. Next one manganese increases hardenability inexpensively we do not have to spend so much, next one high manganese and high carbon produce steels resistant to wear and abrasion.

Because of the manganese and sulfur there will be wear and abrasion resistance.

(Refer Slide Time: 30:37)



ALLOYING ELEMENTS OF STEELS & THEIR FUNCTIONS

S No	Alloying element	Functions
4	Nickel (Ni)	1. Strengthens unquenched or annealed steels. 2. Toughens pearlitic-ferritic steels (especially low temperatures). 3. Renders high Cr/Fe alloys austenitic.
5	Chromium (Cr)	1. Increases corrosion and oxidation resistance. 2. Increases hardenabability. 3. Increases strength at high temperature. 4. With high C resists wear / abrasion.

So, these are the functions of manganese. Next alloying element is the nickel. What are it is functions? It strengthens unquenched or annealed steels. Next one it is toughens the pearlitic ferritic steels. Especially, at low temperatures. Next one it renders high chromium, high what say ferrous alloys austenitic. Next alloying element is the chromium. It increases the corrosion and oxidation resistance. That is why this is widely used in the stainless steel. Often, we say that stainless steel is what say it has got the highest resistance against corrosion why it contains chromium.

(Refer Slide Time: 31:36)

ALLOYING ELEMENTS OF STEELS & THEIR FUNCTIONS

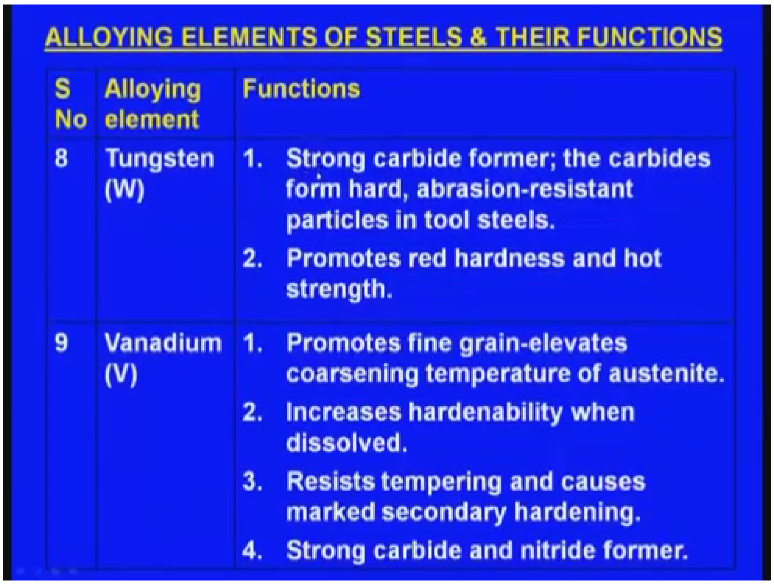
S No	Alloying element	Functions
6	Molybdenum (Mo)	1. Raises grain coarsening temperature of austenite. 2. Increases depth of hardening. 3. Raises hot and creep strength promotes red hardness. 4. Enhances corrosion resistance in stainless steels. 5. Forms abrasion resistant particles.
7	Cobalt (Co)	1. Contributes to red hardness by hardening ferrite. 2. Alloying element for HSS.

Next one it increases hardenability. It increases strength at high temperatures. Now with higher carbon.

It also develops good wear and abrasion resistance for the component. So, these are the what say functions of chromium. Next one next alloy increment is the molybdenum. What are it is functions? It raises grain coarsening temperature of austenite. It increases depth of hardening. It raises hot and creep strength and promotes red hardness. Especially, this molybdenum is used in the high-speed steel. Now what happens to the high-speed steel? During machining the high temperature will be developed at such times even the. Tool becomes red hot. Such times the tool should still possess the required hardness and because molybdenum is present in the high-speed steel even if the when the tool is eleva what say heated up to an what t say elevated temperature it does not loose the strength because of molybdenum.

Next one it enhances corrosion resistance in stainless steels. It forms abrasion resistant particles because of the molybdenum the what say abrasion resistance of the casting will be higher. Next alloying element is the cobalt. What are it is functions? Contributes to red hardness by hardening ferrite. What is this red hardness? Means hardness of the cast component when it is temperature is raised to an elevated temperature during it is use. For example, the best example is the what say a cutting tool made up of say high speed steel right next one alloying element for high speed steel it is an alloying element for high speed steel.

(Refer Slide Time: 33:16)



ALLOYING ELEMENTS OF STEELS & THEIR FUNCTIONS

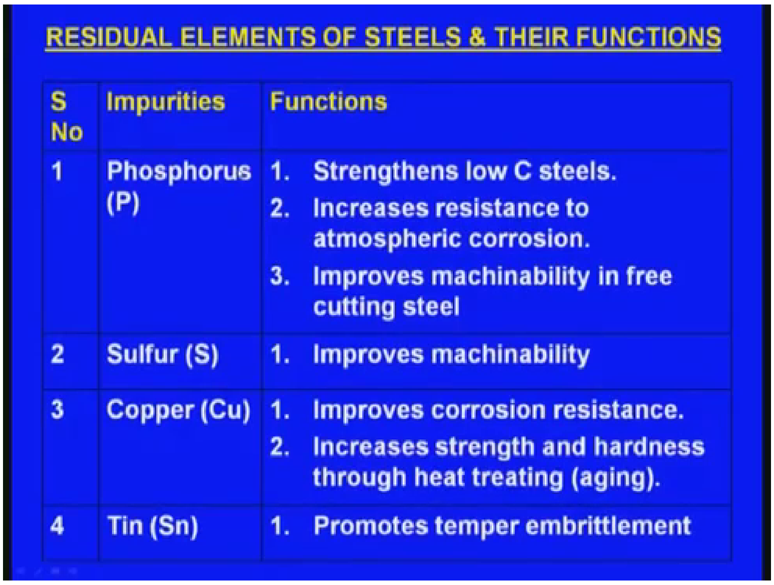
S No	Alloying element	Functions
8	Tungsten (W)	1. Strong carbide former; the carbides form hard, abrasion-resistant particles in tool steels. 2. Promotes red hardness and hot strength.
9	Vanadium (V)	1. Promotes fine grain-elevates coarsening temperature of austenite. 2. Increases hardenability when dissolved. 3. Resists tempering and causes marked secondary hardening. 4. Strong carbide and nitride former.

Next one is the tungsten. What are it is functions? It is a strong carbide former once there is carbide.

There will be good wear resistance will be there. The carbides form harden abrasion resistance particles in the tools right. In the steels so once there is carbon carbide formation there will be abrasion resistance to the casting. And there will be wear resistance to the casting. It promotes red hardness and hot strength again. So, this tungsten is again used in the high-speed steel tungsten. Say tungsten series the tungsten will be present 18 percent, why? Because it promotes the red hardness. Means, even when the tool is heated to a red state red hot state, the tool still contains still posses the hardness. So, that is the red hardness it promotes the red hardness.

Next one next element is the vanadium. What are the function? It promotes fine grain right elevates the coarsening temperature of the austenite. Next one it increases hardenability when dissolved. It resists tempering and causes mark what say secondary hardening. And it is a strong carbide and nitride former. Once it is a what say carbide former what is the advantage? There will be good wear resistance, there will be good abrasion resistance. Also, there will be it will be a nitride former. Now apart from these alloying elements, there will be residual elements in the steels what are these residuals elements and their function.

(Refer Slide Time: 34:59)



RESIDUAL ELEMENTS OF STEELS & THEIR FUNCTIONS

S No	Impurities	Functions
1	Phosphorus (P)	1. Strengthens low C steels. 2. Increases resistance to atmospheric corrosion. 3. Improves machinability in free cutting steel
2	Sulfur (S)	1. Improves machinability
3	Copper (Cu)	1. Improves corrosion resistance. 2. Increases strength and hardness through heat treating (aging).
4	Tin (Sn)	1. Promotes temper embrittlement

So, these are the residual elements. Phosphorus is present in the steels, right?

So, what do you what is the meaning of residual element. Means it comes into the what say cast metal or the alloy without our intention or without our knowledge. That is the residual element. Now it is strengthens low carbon steels. It increases resistant to atmospheric corrosion. It improves machinability in free cutting steel. That is why though it is a what say residual element, though it comes without our intentional knowledge, we allow it to a small proportion. Next one sulfur. Sulfur is another residual element, but what is it is use it improves machinability, but if the sulfur content is more it da it makes the casting brittle and cracking takes place. Next one copper is also considered as a residual element in the steel. Now it improves corrosion resistance, though it is a residual element means though it comes into the what say alloy without of knowledge and intention it does some favour to us what a what are they it improves corrosion resistance increases strength and hardness through heat treat treating edging.

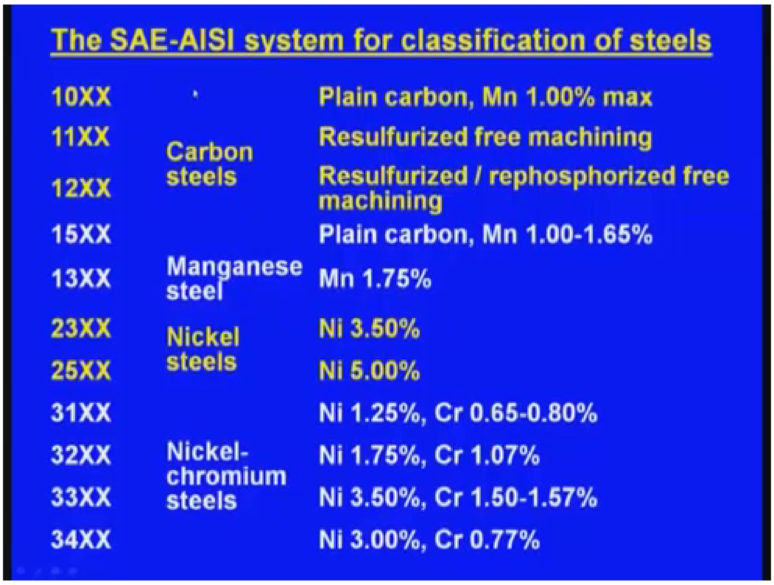
So, these are the advantages of copper. Next tin, tin is also considered as a residual element. Means, it comes into the alloy without our knowledge and without our intention, it promotes temper embrittlement.

(Refer Slide Time: 36:36)

Now, the SAE the society for automotive engineers and AISI, american iron and steel institute system for classification of steels the SAE, AISI system classifies all other alloy steels using 4-digit index as follows, right? One means one series, these are the carbon steels. 2 series means, nickel steels means nickel is the principle alloying element other elements also will be present 3 series means nickel chromium steels. 4 series means, molybdenum steels.

5 series means, chromium steels. 6 series means, chromium vanadium. Steels 7 series means, tungsten chromium steels. And 9 series means, silicon manganese steels. Now there will be 4 digits will be there, in this what say coding. The first digit indicates the principle allowing element. The second digit of the series indicates the concentration of the major element in percentile, right? And the last 2 digits of the series indicate the carbon concentration. Carbon is also present in all the steels. So, last 2 digits indicate the carbon what say concentration.

(Refer Slide Time: 37:57)



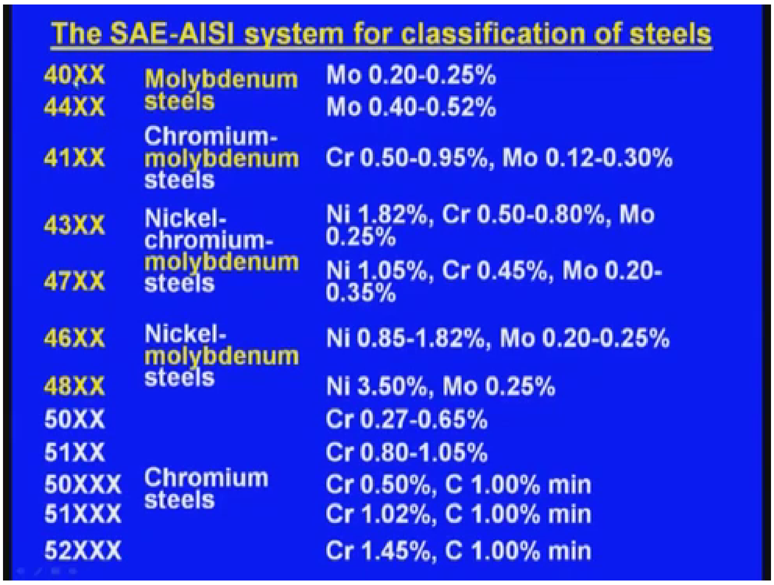
And this the we can see here SAE AISI system for classification of the steels.

And here we can see few series. One series, we can see one 0 and something. 1 1 and something 1 2 and something. So, these are all the carbon steels. Means, carbon is the principle alloying element. And in the first series if the second digit is 0, then these are the plain carbon steels and manganese maximum one percent. And if the second digit is one it is the resurlferized free machining. And if the second digit is 2 resulpherized or rephosphorized free machining. Again, in the one series if 5 is the second digit it will be plain carbon and manganese will be from one percent to 1.65 percent. Next one in the one 3 series when the second digit is 3 what will happen?

So, the manganese is 1.7 point percent. Now here we can see these are the 2 series. Means, the first element is the 2 means these are the principle alloying element is the nickel. Again, when the first second digit is 3 nickel proportion is 3.5 percent. When the second digit is 5, the nickel is 5 percent. Again, we see the 3 series means, the first digit is 3 means, it indicates the principle alloying elements are nickel and chromium. Again, when the first second digit is 1, it is nickel 1.25 per percent, chromium 0.65 to 0.8 percent when the second digit is 2 nickel is 1.7 percent. Chromium is 1.07 percent.

When the second digit is 3 nickel is 3.5 percent, chromium 1.5 percent to 1.57 percent. When the second digit is 4 nickel is 3 percent, and chrome is 0.77 percent.

(Refer Slide Time: 39:53)



And here we can see these are the 4 series. Means, what are they? These are the what say molybdenum steels. Means, the principle alloying element is molybdenum. Again, among them when the second digit is 0, molybdenum proportion is 0.2 to 0.25 percent. When that second digit is 4 the molybdenum proportion is point 4 to 0.52 percent. When the second digit is one chromium proportion is 0.5 to 0.95 percent. Molybdenum 0.18 to 0.3 percent. When the second digit is 3, we can see nickel proportion is 1.8 to chromium 0.5 to 0.8 and molybdenum 0.25.

When the second digit is 7, the nickel proportion is 0.18 0.05. Chromium 0.45. Molybdenum 0.2, to 0.2 to 0.35. When the second digit is 6, nickel 0.85 to 1.82. Molybdenum 0.2 to 0.25. When the second digit is 8, nickel will be 3.5, molybdenum 0.25. And again, we see this is the 5 series. Means, the principle alloying element is chromium. Again, the second digit can change. When the second digit is 0 the chromium content is 0.27 to 0.65 percent. When the second digit is 1, chromium proportion is 0.8 to 1.05 percent.

When the second element is digit is 0 again, 0 and there will be through 3 what say digits will be there, then chromium will be 0.5 to 1 percent. Again, when there is second digit is 1, and another 3 digits will be there means totally 5 digits. Again, chromium be 1.02 to 1 percent, minimum. Carbon, carbon 1 percent. When the second digit is 2 and 3 more digits will be there, chromium will be 1.452 percent. And the carbon will be 1 percent.

Friends, in this lecture we have seen the what say important cast steels and the cast irons. We have seen the cast irons are divided into broadly 4 types. One is the gray cast iron.

Second one is the white cast iron. Third one is the nodular cast iron. And 4th one is the malleable cast iron. And we have seen the applications of these types of cast irons. We have also seen different types of the steels. The steels are broadly classified into plain carbon steels and the alloy steels. In the plain carbon steels carbon will be the principle alloying element. Whereas, in the alloy steels though carbon is present some other element like chromium, nickel, molybdenum or tungsten such elements will be the principle alloying elements. And we have seen again in the principle what say plain carbon steels there are 3 types.

Low carbon steels, medium carbon steels, and high carbon steels. And we have seen the classification of the alloy steels according to the AISI. So, in the next class, we will be learning about the aluminium and magnesium cast alloys.

Until then goodbye, and thank you.