Materials Science and Engineering
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Lecture - 40
Alloy designation and processing

Hello friends. Today's lecture is it is kind of a general lecture on Alloys designation and some processing methods which we use for making or for processing bulk materials and that we will discuss today ok. So, in Alloy designation first, alloy which is utmost importance and widely used is steel ok.

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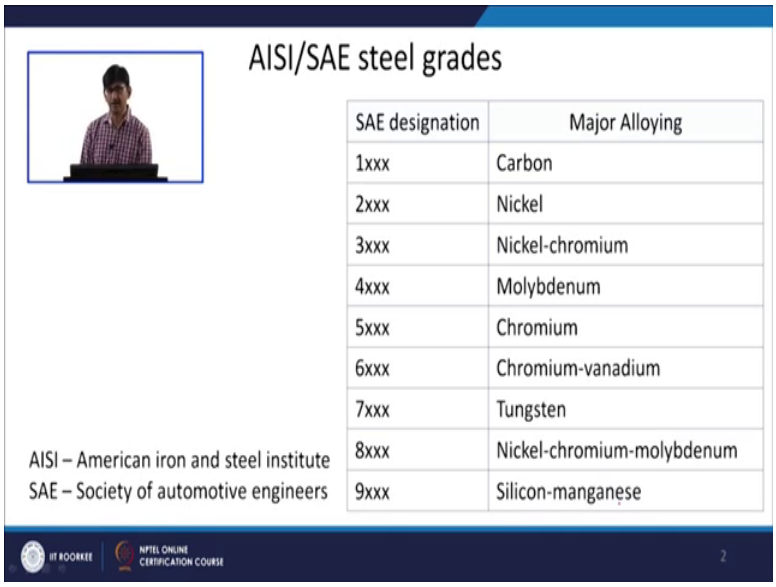

And in steel there are different grades of steel are available ok. These are given by designation provided by these 2 agencies ok. So, AISI is American Iron and Steel Institute and SAE is Society of Automotive Engineers because these 2 agencies are responsible for making the grades or making the designation for the grades for different materials ok. So, in this case steel, for steel it is given. So, SAE designation if you see, there are different numbers are given here.

And then, xxx is written. So, the first digit here actually specifies the major alloying element ok. So, for example, if it is only plain carbon steel, only carbon is added as an alloying element. Then, it will be having the first digit as 1 and then, there are 3 more digit remaining there ok. So, the first digit is specify if it is one, that means, it is going to

the Carbon ok; main alloying. If it is 2, Nickel will be there as a major alloying element ok.

Of course, carbon will also be there, but now the main alloying element is Nickel and which actually dictates the properties. Then, 3 series is Nickel-chromium. 4 series is Molybdenum and 5 series is plain only Chromium and 3 series it was both Nickel and Chromium were there 6000 series Chromium-vanadium. 7000 is Tungsten; 8000 is Nickel-chromium-molybdenum and 9000 is Silicon-manganese ok.

This is one of the important alloy for magnetic application as we discussed that silicon, steel are as one of the most important alloys for any transformer application or soft magnetic material application ok. So, in plain carbon steel we are not going into details of all this things because it is a very long list and each one has some variation in the composition and then their usage ok.

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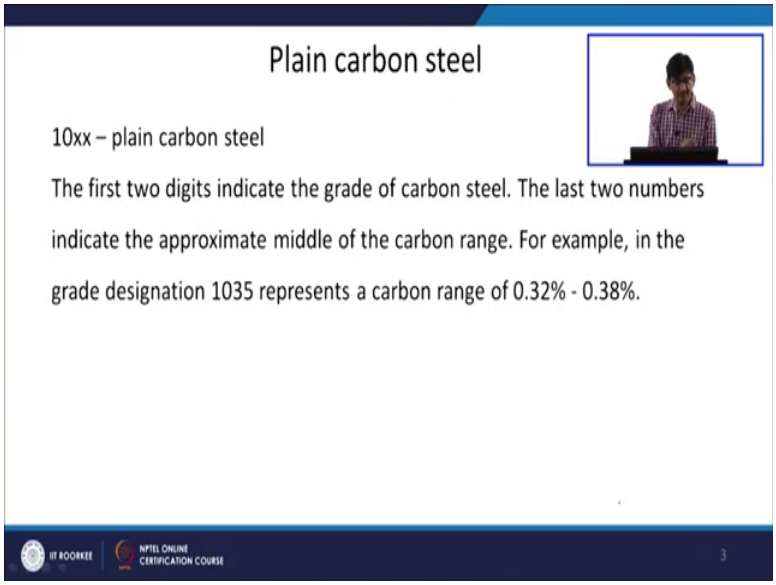

So for example, if you take plain carbon steel; now, you can see in that 4 number series another number is added here ok. Now it is 0. So, in this case, it is only a plain carbon steel in some cases you will have some other number also. So, these are depending upon what kind of another chemical treatment is given ok. In some cases it is kind of the de-frustize or disulphuric ah; it is added or removed and so on ok.

So, depending upon that this number will keep on changing. So, plain carbon steel also depending upon what type of treatment was given to the steel, the number will come in the second digit place ok. Right now, it is simple plain carbon steel that is a 0 here and now, still the 2 number are left here ok. So, if it is plain carbon steel, you are only dealing with Carbon. So, these last 2 digits will be responsible for telling us the composition of the alloy.

So, first 2 digit indicate the grade of carbon steel. What grade ok? And the last 2 numbers indicate the approximate middle of the carbon range. For example, in the degrade designation if it is written as 1035 ok. Then, it represent the carbon range of 0.32 - 0.38 percent. So, it is range and you should take average of that ok. It will come somewhere around 0.35 percent Carbon ok.

So, that is why in the designation it is written as 1035 ok. So, this is how you will get usually the if you want to go and buy plain carbon steel in the market ok, this type of designation you have to specify ok. Just to know just to tell the sailor that what type of material you want ok.

So, it is plain carbon steel. So, now, depending upon carbon percentage, it will be low carbon steel or high carbon steel and so on ok. So, you will know that what type of material you want for a certain application. Now, coming to aluminium; another very important material used in large number of engineering applications.

So, these are the widely used materials. These two class of materials in kind of daily product. So, Aluminum is another one very important alloy ok.

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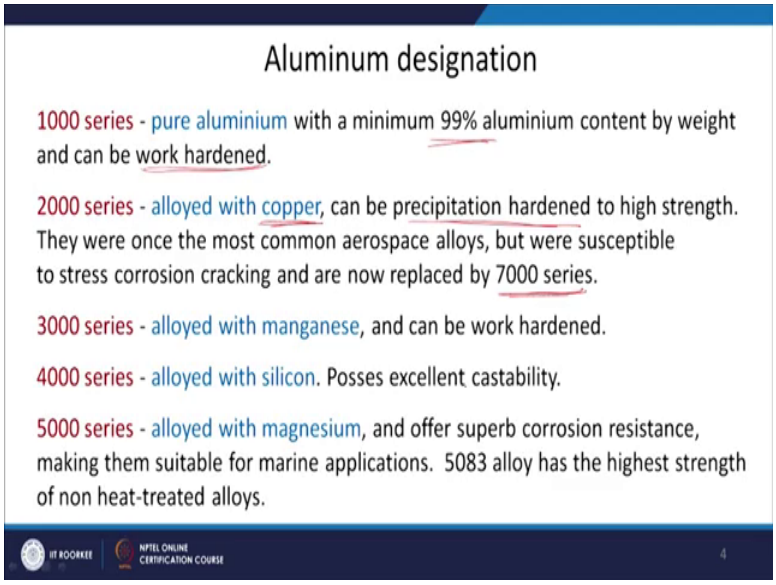

So, they also have large number of series depending upon what is the alloying element ok. If you remember the temper designation, we have already discussed when we were discussing hit treatment of Aluminum copper alloys that we can give different suffix to specify that what is the heat treatment was given to the materials ok, that is already discussed now.

The remaining numbers which are there will tell you about the composition of that alloy ok. So, the compotation will be there and the temper designation will be there. So, combined them, you will able to know that which material we are taking about and what is the composition that? What is the treatment given to that particular material or in your case whatever application you what that material for ok?

So, from your design purpose, you came to know that what you kind of strength you want, what kind of if possible some ductility should be there ok? So, from that you can go back to the that particular material and see that which material is able to satisfy your conditions and what should be the heat treatment given to that material to get those properties ok.

Then as an engineer, it is always important for us to understand that; what are the cost benefit analysis has to be there. So, what is the cost of that particular material and how much it is going to benefit for whatever application you want that material for ok. So, this cost benefit analysis will always be there for any engineer.

Because there are large number of material, some alloying elements are expensive ok. So, you will have to see whether you need that kind of composition or not or you can leave it with material which does not have these expensive element as alloying element ok. It can still it serves your purpose ok. So, in aluminium you have 1000 series aluminium ok. These are basically pure aluminium. So, nothing is added, commercially pure.

So some impurities will always be there. So, it will only 99 percent aluminium content will be there. Now depending upon the processing, it can be 99.9 or 99.99 for different from different manufacturers you will get different purity ok. Of course, cost will be also will be dependent on that on what kind of purity you want in a particular material ok. And since, there is no alloying element here. If you want to kind of change the properties of this material, it can be only done with work hardening.

So, basically you can do a court ruling or some working operation to introduce large number of dislocation in the material and thereby, you can have work hardening in the material ok. So, because there are no alloying elements, I can only do work hardening in these or if you possible, you can have grain size refinement. So, grain size strengthening can also be there.

Then next one is 2000 series, if the 2000 series is alloyed with copper, one of the important alloy initially people studied a lot to understand the aging phenomena in aluminium and that is why you can see it can be precipitation harden to very high strengths and they were used as aerospace alloys for a very long time because they had high strength due to precipitation and of course, aluminium is a lightweight material.

So, preferred for aerospace applications ok, but due to stress corrosion cracking problem, these susceptible it is where you can have stress concentration and under corrosive environment ok, you have stress corrosion cracking and that is why they were later replaced now by 7000 series alloys ok. We will see what this 7000 series alloys are there ok.

But, once copper alloys were very popular , aluminium copper alloys ok. Then, we have 3000 series, in this it is in this case it is allowed with manganese ok, again manganese will go into solid solutions. So, these alloys can be work hardened and so, next is 4000 series alloy, we which in which we add silicon into aluminium.

And these are some of the very important alloy, alloys because they give you very good casting ability ok; you can do casting very easily and these are now used for making cylinder head ok. You can understand they have a very complex shape with all these things around them for better cooling and they have to be casted.

So, you can understand that material has to flow in those complex shape ok, when you are doing the casting. So, since it has a good flow ability and to get into those mould shapes ok. That is why these kind of a alloy aluminium silicon alloys are used for making the cylinder blocks nowadays. The next craze for 5000 series allowed with magnesium ok. It offers superb corrosion resistance.

So, wherever you need a good corrosion resistance for example, in marine application ok, where the for example, ship is in saline water. So, corrosion will be very fast in these kind of conditions ah, there this aluminium magnesium alloy are very good. They have very good corrosion resistance and out of this 5083 alloy is one of the more popular alloy which is used in marine application.

And because it has the highest strength in non heat-treatable alloys ok; these are non heat-treatable; they do not show precipitate precipitation within the grain ok. So, either they are in the solid solution or if any precipitate is also forming, they will form at the grain boundary ok.

So, these are cannot be hardened using precipitation ok. You cannot do aging of these alloys. So, these are called non heat-treatable alloys, but they the 5083 alloy has the highest strength in non heat-treatable class of materials or in aluminium and then, they have a very good corrosion resistance that is why they are used in marine applications.

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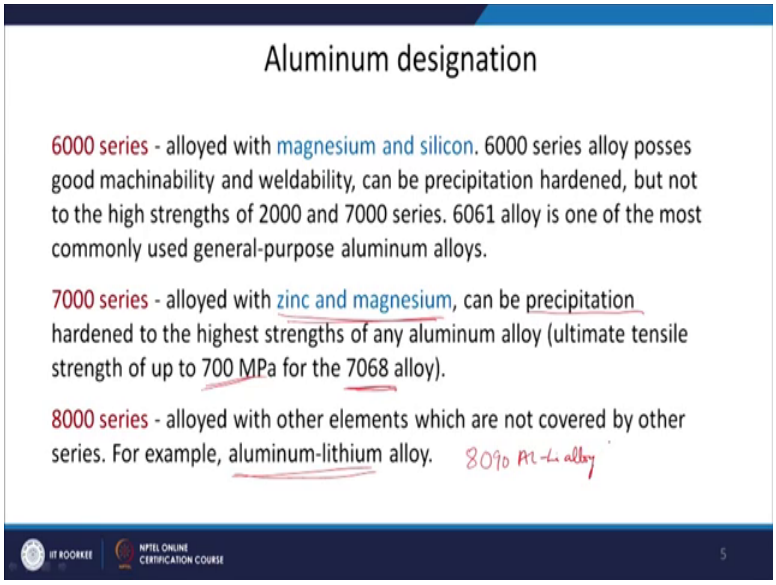

Then the 6000 series is there a alloyed with both magnesium and silicon ok. So, 6000 series alloy possess good machine ability and weld ability ok; can be precipitation harden what not to high strength of 2000 or 7000 series ok. So, it cannot be as good as aluminium copper alloys or 7000 series alloys. 606 is one of the most commonly used general purpose aluminium alloys ok.

So, if you see any you know general purpose aluminium, wherever it is used ok. Most probably, it will be 6061 alloy which contains both magnesium and silicon. Then comes the 7000 series is very important alloy because it is it comes under high strength category. These are called high strength aluminium alloys and these are now nowadays used in large number of applications.

Especially aerospace application, where you need high strength and because you have aluminium as the base material the density will also below the weight of the that particular component will be low ok. So, that is what is needed and coupled with that you have, you get a very high strength in this materials. For example, in case of some mobiles also when they were advertising that this are made of aluminium and the cover is made of aluminium. These are all high strength aluminium alloys which usually comes under 7000 series.

So, it can be precipitation hardened to the very high strength of any aluminium alloy ok. For example, in for 7608 alloy, the hardness which you can achieve is 700 Mega Pascal ultimate tensile strength which is fairly good strength, it is close to any steel normally.

So, this kind of strength you can achieve in aluminium alloys by doing very careful alloying zinc and magnesium.

Then, comes 8000 series alloyed with other element which are not covered by other series and in this class one of the most important alloys are aluminium-lithium alloys and the importance of these alloys is that lithium is a very low density material ok. The weight of the lithium per unit volume will be one of the very low in any structural material ok.

So, if you are adding lithium in aluminium the overall weight reduction is very good and this one of the very important alloys 8090 aluminium alloy, aluminium-lithium alloy ok. Again, used in aerospace applications because you want to reduce the weight of the weight of the body whatever whether it is airplane or any other aerospace body ok. So, aluminium lithium alloys are very important and in this 8090 is one of the most important alloy.

So, 8000 series, you will see in large number of different alloying with different alloying elements because it is given for kind of a general purpose alloys and where alloying elements are can be quite different type of alloying elements can be there. Then, will come to material processing just to give you a overall idea that how will you get different type of materials. So, we are not going in the processing back from over to the main material which you get.

So, we are not going into that processing right now because lot of processing is done in secondary processing also. For example, if you want to recycle steel or you really want to recycle aluminium ok. So, that is already been extracted refined and you have the material in useful composition ok.

So, these are again re melted and you do casting. So, lot of these industries are also there and some industries are there which starts from the over itself and then, do the refining and later on do the other processing ok. So, right now we are not going into that part ok, we will do starting from the casting so that my material is already refined or if you have a recycling already taken from a recycler and you know that we are segregated it into aluminium and steel scrap differently ok.

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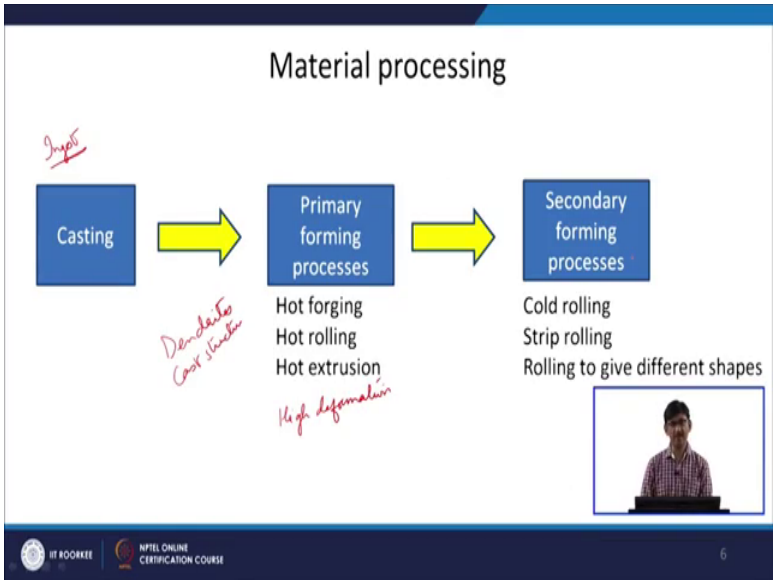

So, the first process by which we do is Casting. So, you basically melt the material and furnaces and then, you pour it into same ingots ok. So, we are not kind of concentrating here on different type of castings ok bulk material processing that you do casting in ingots ok.

Then, you will go to Secondary some forming processes ok. So, these are either primary you can divide into Primary forming processes or Secondary forming processes. The Primary forming process are usually done at high temperature. So, that is why they are called Hot forging, Hot rolling or Hot extrusion.

The purpose of this particular state after casting is if you remember when we were discussing solidification and what type of microstructure you get during solidification. We said that they contain dendrites and they sub dendrite cast structure basically they have ok. Then, they also have lot of heterogeneity in composition. So, heterogeneity in composition can be eliminated by doing a homogenization process, but to break this entity cast structure, I have to do processing where I can impose very high deformation ok.

So, that is why they are done at high temperature where you can introduce more deformation in the material at one go ok. So, in this case you want to have very high deformation. So, we either it can be done by forging or it can be done by rolling process or it can be done by extrusion process. Then, we go to the secondary forming processes ok, usually you do a lot of rolling at this stage.

So, cold rolling is going to be there ok. If you want strips of any sheet then strip rolling will be there, if you want different shapes of material; for example, you want a rail you want I beam. Then rolling to give different shapes are there. So, these are the final stages of processing. So, you have Casting and Primary forming process; then, Secondary forming process. This is a very broad classification here ok. You can have much more refined classification also in between different processes are done ok.

For example, after any forming process maybe there can be aniline in between to kind of do a stress relieving or to do in case of precipitation hardening to dissolve the precipitate and make a solid solution and so on and then, you have your may have heat treatment later on also ok. So, Casting if you see just you are concentrating here on the ingot casting because casting itself is a big subject and you can see very big Ingots are there ok.

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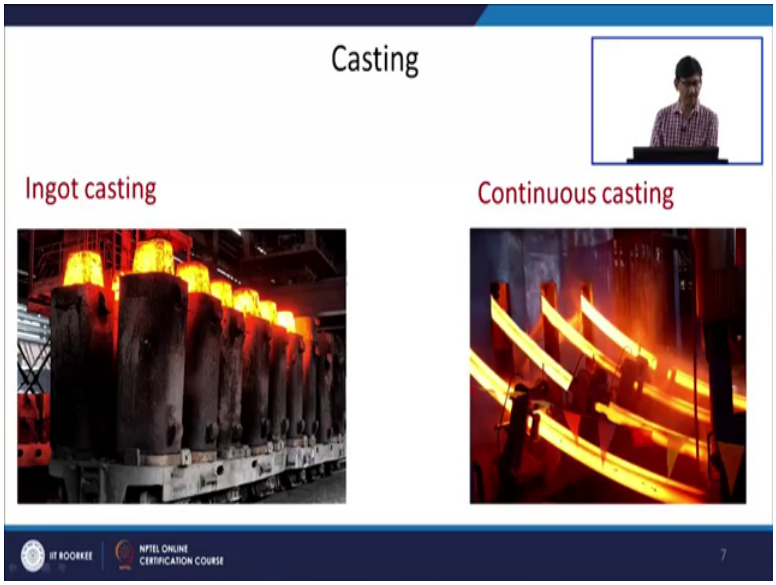

It is already lying on a rail and you can understand that the; what will be the dimension of this cast. So, basically from a big laden, where tons of molten metal molten metal is there it is poured into this kind of ingots where you get the shape of ingots maybe rectangular shape or round shape depending upon what processing you want to do later on ok.

And then, you do later forming operations if this is kind of a batch process, you can see single ingot will be there and then, it will be taken to for other processing.

Nowadays; another very useful casting process is called Continuous casting. So, you can see that in this you have a continuous metal is coming in form of different shapes of ingots and it is a continuous process. So, you put molten metal in some die and then, the molten metal will flow down by vertical force or by due to gravity and then, it will be when it starts solidifying it will be kind of taken out and taken on some rails to which will be cut in different shapes later on.

Then, you do the secondary processing by doing rolling or extrusion or whatever end product you want from that this is a continuous process. This is a batch process where as this is a continuous process. Then, after casting we do rolling one of the process. It can be other processes also ok.

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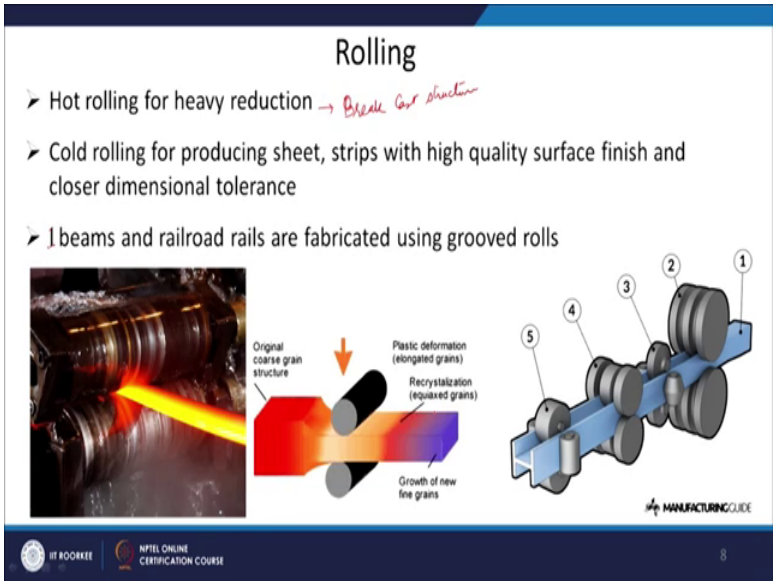

So, hot rolling is done for heavy reduction basically to break to break your cast structure ok. Once you do that in hot rolling the problem is because the material will be hot, there will be lot of oxidation takes place. So, you have scale on the surface.

Also when it cools down ah, it will have some distortion in the material the surface finish will not be very nice ok. So, we cannot do hot process as the last process after which the materials go to the customer. But we can do it as a intermediate process where we want very large reduction to break the cast structure ok. So, these are done in the initial processes and the later on when the material is supposed to go out to customer we do cold rolling ok.

So, for producing sheet strips with high quality surface finish, in this case you get very good surface finish and closer dimensional tolerances which is not possible with a hot rolling process. But, initial processing is required at higher temperature. We can also get I beam this is I beam and railroad rails are fabricated using grooved rolls. So, either you can do a groove rolling as you can see in this case; we want to have I beam ok.

So, you can see multiple rolls are there to make this particular shape; whereas, in simple strip rolling ok, you need only 2 rolls and the material will be taken through those rolls. It is like your sugar cane you must have seen, if you want to take out sugarcane juice, you put sugarcane between 2 rolls and that is squeeze with it and you take out the squeezed sugarcane from the other side ok. So, basically same process, 2 roll are there and the material will go through this rolls. So, initial material will have a higher thickness, after going through the role depending upon the separation between the roll the thickness will be reduced and because you are putting.

So, much strain maybe the strain will be enough to do to have some recrystallisation in the material. You will get very fine grain material after the reduction and these can be again processed using some grooved rolls to get a certain shapes depending upon your requirement. Forging is another very important process ok. So, it can be open die forging or closed die forging if you want a certain shape. Then, you can have closed die forging. So, die itself will have that shape and then, you are forging it and the material which will take the shape of the die or you can I have an open die forging has being shown here right now.

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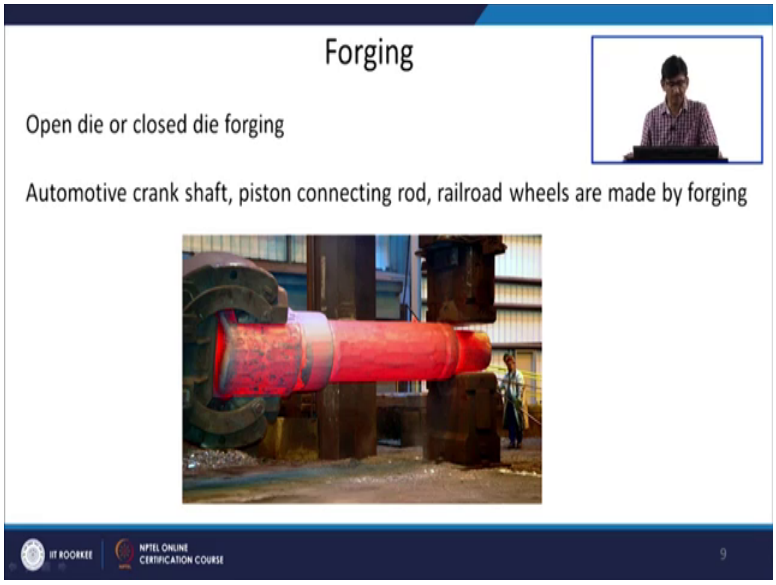

And you can see the size of the rolling size of the forge machine and the size of the material which is being forged ok. So, if you have Automatic crank shafts, piston connecting rods, railroad wheels are made by forging.

So, by forging because you are doing we are putting lot of compressive load on the material and already we have seen that the compressive stresses in the material are very good for their later on application ok. First thing is you kind of remove the defects, by forging if there are defects you are kind of closing those defects and you are imposing some residual stresses compressive stresses compressive residual stresses in the material and also the microstructure gets refined, you also introduce lot of dislocation density ok.

So, overall you have very dens material with minimal defects and very good micro structural a properties and so, this forging is a very important processes for any to make any product where you need very high very high stresses will be there ok. For example, crank shaft and piston connecting rod you can see continuously it is experiencing the fluctuating loads ok. Railroad wheels you can understand that. So, much load is there and they are rotating.

So, again continues fatigue loading is there ok. In all these condition, you need forged material ok. So, cast material will just break under the load ok. So, by forging we are breaking the cast structure, refining the microstructure, introducing lot of strain hardening in the material to get a very high strength material.

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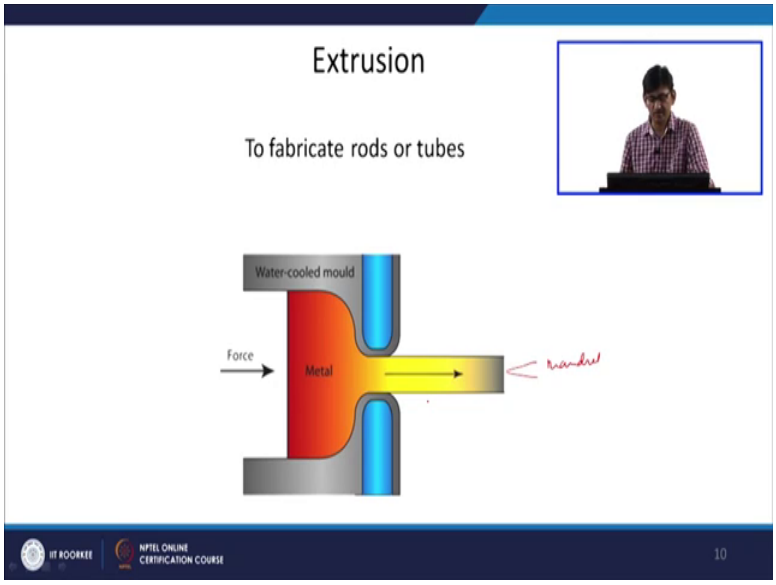

Extrusion is a another very important process to make rods or tube ok. So, if you put a mineral here this called a mandrel, you can get tube out of that.

There will be hollow section in the centre and the material around it or if you do not put the mandrel you will get it in rod shape ok. So, in this case you have a die here ok, it is a cross section is shown here and we are applying force from the other side; squeeze the material out from here ok.

A lot of in household we have this kind of technique to make certain what we call as [FL] to make using this kind of tools ok. It is similar to that. So, extrusion is basically you are putting force from the other side to squeeze the material out from the open and here in the die and the cross section is reduce during the process and also you are imposing lot of strain in the material.

So, it is getting work harden, if temperature and strain are sufficient you will have requested microstructure and so on. So, this is a axis symmetric process ok. So, to make a rod to make a tube, it is a very nice process to make tube or rod of through the extrusion process. Another very important processing is what we call is Powder metallurgy processes and usually in case of ceramics you cannot do any other processing like casting melting casting and then, other forming operations ok.

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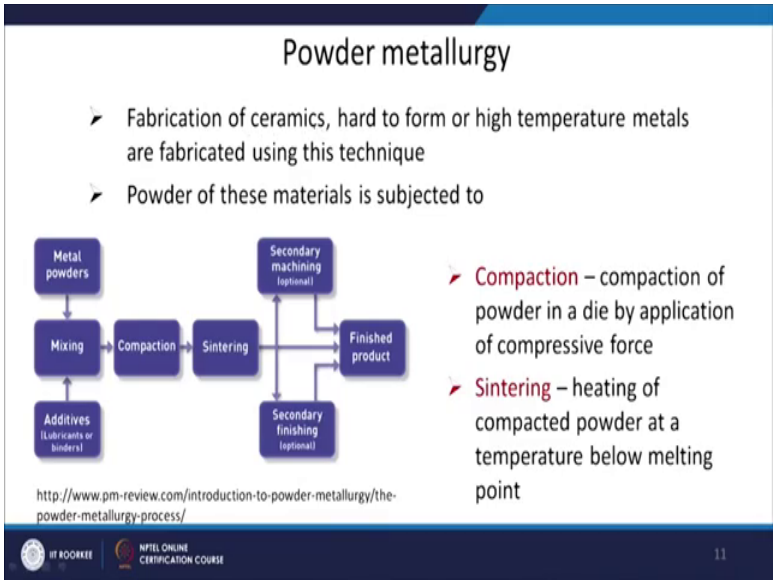

So, in case of Powder metallurgy alloys in this basically ceramics that can be processed only using Powder metallurgy processes or if you have material which are hard to deform or will have high temperature with their melting point is very high.

Then, it will be very difficult to melt it and take into a ladle; ladle will be of a low temperature material ok. How you are going to store a liquid metal into these ladles ok. So, it is very difficult. So, for a high temperature materials, ceramic for hard to form materials we have a very good technical Powder metallurgy. So, in this case you process the material in solid state.

So, you have powder you pour the powder or whatever shape you want final shape you want for the product; you make a die of that put powder there and you can consolidate it ok. So, basically you have metal powder for ceramic powders whichever powder you want you do a mixing, you can add additives also; lubricants and binder.

Then, you do a compaction ok. So, you make a compact of that and then we do Sintering. So, Sintering means you have to heat this compacted powder to some high temperature below melting point to increase the diffusion process. So, when you do the compact the powders are only in kind of a mechanical contact ok. There they are not metallurgically bonded to each other ok.

So, to have this metallurgical bond, we need to take it to high temperature. So, that diffusion is possible and then the powder each individual powder particle gets attached to the next one and the overall you get a product.

Then, depending upon the application you can have secondary processes either you can have machining or some other finishing operation and then, you have finished product ok; so, very important technique for some type of material where, it is very difficult to melt them or to form them.

Now, I just taking here 2 examples that how now material are being celebrated. Celebrated in the since I think in a importance of a certain subject can be gauged from if that particular product is advertised like that this is made by made of certain materials ok.

Then, material you know the material has come to a certain stage ok. For example, earlier if you want good sound system the advertisement will say that it is it Dolby sound system or it is a Stereo sound system or it has a high Fidelity sound system ok.

So, you know these are important things, when it is advertised ok. So, for me the importance of material comes when the materials or that specification comes in the advertisement of the product ok. So, I am just taking here 2 examples; where, the materials are celebrated because they are being advertised that because of this material you are getting some special properties or some special product we are getting; for example, Car bodies.

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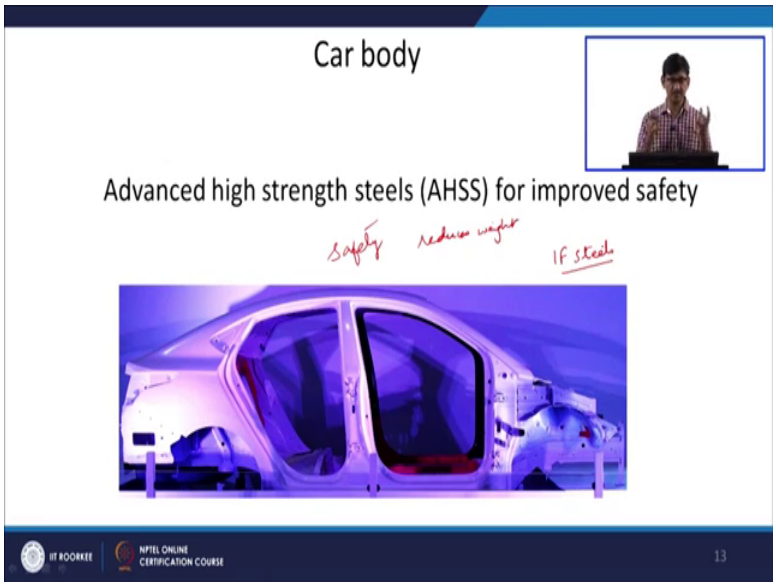

Now advanced high strength steels are being use in Car bodies ok. Recently you must have heard that in lot of this crash test none of the Indian cars could qualify ok; almost all failed in those crash test to see that whether any impact on the car whether the passenger will survive or not ok. So, now, all this new cars which are coming, they are coming with the material which is called Advanced high strength steels. So, they have very high strength ok.

So, by that you can also reduce the weight of the body car body and at the same time you have very high strength. So, both it is good for safety ok; because you have highest and material to take the impact load and also it reduces weight of the car ok. So, you have improved safety at the same time you have reduced weight ok. So, that is why this high advanced high strength steels are very important and the strength is there because of the alloying element ok, some alloying element are added to get very high strength in this material.

So, basically the structure is made by advanced high strength steels. The car body that it is the place which are covering the car, those are not very high strength as I told you earlier also those are interstitial free steels IF steels ok. So, the only the structure, the main structure of the body of the car that is that is a high advance high steels and the remaining which is like tenels which is covering the car, they are usually IF steels, another product Smart phones ok. So, one of the most important specification given in any Smartphone is that what type of glass is used.

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So, these are gorilla glasses, all their trademark of certain company ok. So, they are advertised like they have very high resistance to scratches. So, you will not have scratches on the screen and then, they are they are also now coated with nano silver ok.

So, they do not have any smudging will be there or a little bit antibacterial properties also or for certain product or certain company also advertise that the body which this auto and this phone has, it contain high strength aluminium alloy ok.

So, again as I told you that some of the highest strength aluminium alloys are used to make bodies of these Smart phones ok. So, these are actually advertised during the product launch that these kind of materials are there and that for me is a is a very good sign that and also now, you can also understand that the metallic materials are again coming into the 4 ok.

So, earlier we people started thinking that on that the plastic will take over the whole thing, but now we see that the metallic materials are again coming becoming popular and in this kind of very fancy product also you see that usage of metallic material is increasing.

One of the most important reason for users increased usage of metallic material is they are recyclable. Whereas polymers, plastic that they are not we are not able to recycle them and for environment it is not good; whereas, for any metallic materials it can be recycled ok. So, once you discard them, the scrap can be again taken to some secondary

processing units ok. There it will be again melted and you can again start getting a new product out of that ok.

So, with that this our courses is ended this is the last lecture just wanted to bring out the flavour of materials in different application and how they are processed, what are the designation of different alloys ok. So, I hope the course will be of benefit to you and I; it will satisfy your curiosity and also it will help you to decide when you are making any product that which materials to use.

Thank you.