Principles of Metal Forming Technology
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Lecture - 39
Powder metallurgy forming - I

Welcome to the lecture on Powder metallurgy forming. So, we are going to study about powder metallurgy first part in this lecture and the remaining part will be studying in the next lecture. So, that is powder metallurgy forming II; so, what is powder metallurgy forming? So, basically as the name indicates it is dealing about the use of powders. So, whenever we deal with the use of powders to make the components then we talk it as powder metallurgy and that has many use in varied kind of applications this powder metallurgy is used.

So material processing technology in which parts are produced from metallic powders; so that is that branch is known as the powder metallurgy a.

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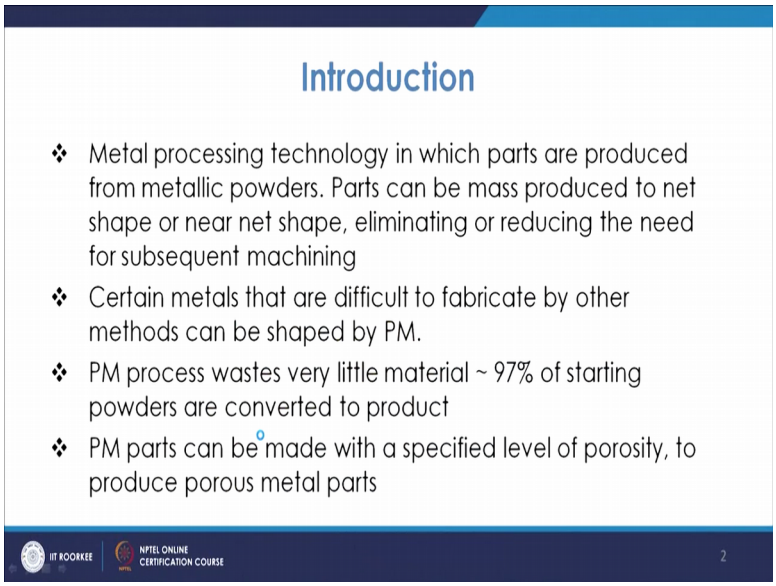

Parts can be mass produced to net shape or near net shape eliminating or reducing the need for subsequent machining. So, in this case we have the powder and from the powder after processing the powder through different roots; we are getting the product of the final shape. So, you do not have you know extra attachment to it or a wastage of the

you know material. So, basically you are getting the near you know net shape or the final shape of the product and you have a better yield; you do not have wastage.

So, you have not to go for subsequent machine in because you in the you know surface finish is quite good and it is near to the final shape of the material. So, that way it will be eliminating or using the need for the subsequent machining. Now why powder metallurgy is important that certain matters which are very difficult to be fabricated by other methods. Especially those metals which have very high melting points extremely high melting points; they I mean for them basically a you need you have the challenge to melt them.

So, you need a typically larger refectory you know large heat resistant refectories. And refract when you have to make the material from the refectory type of materials; in those cases when they are very you know having high melting point and also sometimes you cannot do by forming. Because while forming they if they are extremely brittle so, in that case you cannot go by forming.

So, basically what we have studied that is what we know about the different type of manufacturing methods like casting, but in casting you have limitation of the melting point. So, when the melting point is extremely high in that case that limits the cast ability behavior of the cast ability of the material similarly forming. So, when the material is not at all ductile even at higher temperature it is not sufficiently ductile to be formed into certain shape in that case you cannot do by forming for melting also you need a material of such so you know not very high melting point. So, that way weld ability may also be affected because of many properties may be because of its conductivity because of its other properties.

So, when all these type of you know manufacturing methods raise their hands; they are not you know suitable for making a material. And in the material you required that type of a you know and when you have to design some cast product, some product basically where you need to induce these elements which have which is expected to produce some specific type of you know properties; in those cases you need to use this powder metallurgy route and that is why this powder metallurgy is quite important. Then you have the wastes very very little and so, powder metallurgy process is wastes are very very little materials about 97 percent of the starting powders are converted to product.

So, you do not have to worry about the productivity of the process; you have a very less wastage of the material.

Then powder metallurgy parts can be made with a specific level of porosity to produce porus metal parts. This is another advantage of the powder metallurgy because you cannot very easily make the products with specific porosities; when you have to control the porosities. So, those things can be made only by powder metallurgy because you will certainly get certain level of porosity in casting; cast products and when we format then certainly we know that the porosity decreases as we found the material.

But you do not know the porosity where it will we have know be happening and up to what extend the porosity will be there and then and that uniform porosity cannot be maintained you cannot predict in the case of casting processes. But when you have to have the product with specific level of porosity and that also should be uniform throughout the domain; then that can be made by this powder metallurgy route.

Because when you are using the powders then powders are you know powders when they are loose powders you know that a there will be porosity in between them there will be wide spaces between them. And with the degree of compaction basically the that porosity decreases and ideally when the compaction will be quiet high; as you increase the compaction at one a level will come when the density will be same as the actual density of the material in that case post is 0.

But before that if you treat the material if you make the material from there then porosity remains and you can have the material with certain degree of porosity. So, that is how you can maintain the processing mostly used in case of bearing application or so. So, this is the only root by which you can make the materials with you know requisite degree of porosity. So, this is the treat of the powder metallurgy process; what are the steps in the powder metallurgy?

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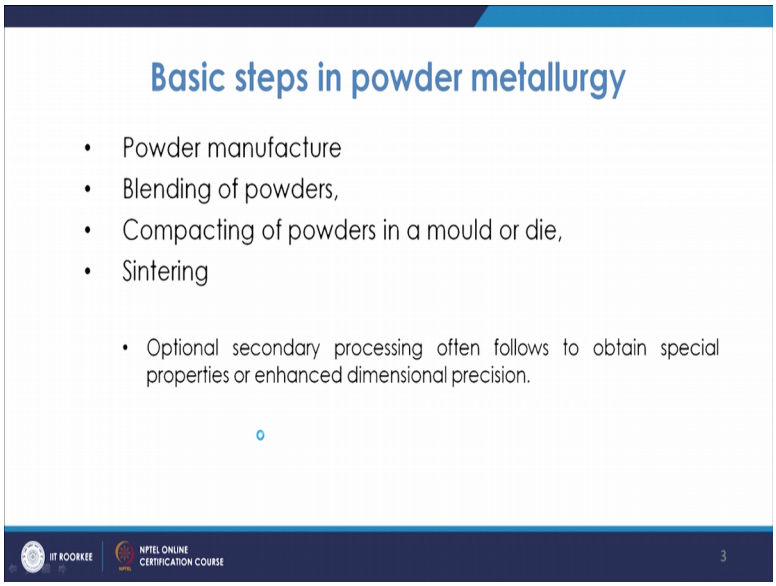

So, as we discuss that in powder metallurgy we use the powders. So, first of all we require powders; so powder manufacturing is important you have many methods of a manufacturing. You require basically powders of high priority you should not have the impurities with the powders. Because if they have they are impure they are going to be with the powders inside the when you are going to further you know treat them. So, you require you must use many methods you use we will discuss about those methods.

So, methods are used to generate powders to make powders of different materials and then use them or treat them further. So, once you have powders then you require the blending of powders. So, blending of powders means you have to mix the powders you know as in proportion desired. So, blending of powders means the they should be uniformly mixed, they should have the technology to mix them properly.

And then a for blending you required certain medium also you may have some binders which is required to blend them properly. So, that blending is very much required then after blending you require the compacting of powders in a mould or a die. So, once we mix the powders of different materials of different composition; then next is to make the compaction of the powders. So, the powders are compacted in a mould or die under pressure and when they are compacted and given a shape and the moisture is still there or binder is still present in the liquid form then they are known as green compact.

So, first of all I just like we make the green sand mould. So, similarly you have the green compact formation initially when we have the binders into the you know powders, we mixed with the powders and then blended and then you are having putting them in a mould or a die or in a press. And then you are making a compact of the powders now compaction is done basically to reduce the space between the particles.

So, as we know that when you have loose powders there is enough space between the powders; the density is quite less. But then once we start compacting then they come closer and closer and you have many methods of compaction basically you can compact from the top, you can compact from top as well as bottom.

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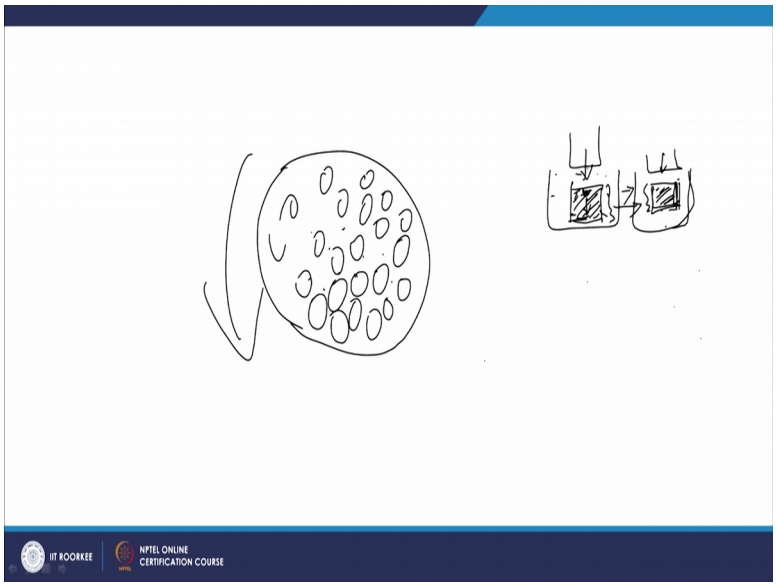

So, as we know that when we have a surface and you know when we compact; so basically when you have the powders and if you are compacting from here, so this you know material this you know powder which is there of this shape; so slowly that may come to this say. So, this will be coming to this smaller dimension; so this later dimension will be same, but this height will be reduced. So, this will be going to this dimension.

Now, the thing is that when we do the compaction from the a top then that case your complex and density will be decreasing as you go down. So, maximum compaction will be here and as we go down the compaction density is; so, density will be decreasing. So,

compaction methods are also important how we do the compaction we have to do from one side single acting or we have to double acting compaction.

So, that compaction on is very important to have the proper compaction is among the powder particles, because that will be you know talking about or that will be representing basically the density of the parts into various you know places of the component. Then the important stage is sintering now sintering is done basically sintering done stages, but the sintering is important in the sense that when we are compacting the material. Then still when you have the green compact then you have the presence of moisture or the lubricant is there also.

Now, this you volatile you know materials into it now they need to be drawn off and in fact, you know that is it is also required to have the strength now you have to increase the strength; so you have to increase the bounding. So, what it does is before the melting point, so it is heated below the melting point of the material. And in that process basically initially you have; so you have different stages in which basically the all these volatile materials they are going away then wanting develops and then you get basically a material with quite a good strength; so that is your sintering stage.

Then optional secondary processing and after that there may be secondary processing requirement which you know is required for the enhanced dimensional processions. You may go for other second procession secondary processing to achieve the desired type of properties in the material. So, that is what are the different steps are there in powder metallurgy you know products.

So, first of all as you were discussing that to you have powder manufacture and for powder manufacturing you have different methods and we will discuss about the different methods of powder manufacturing. So, the first process which is there for the production of powders is the atomising process.

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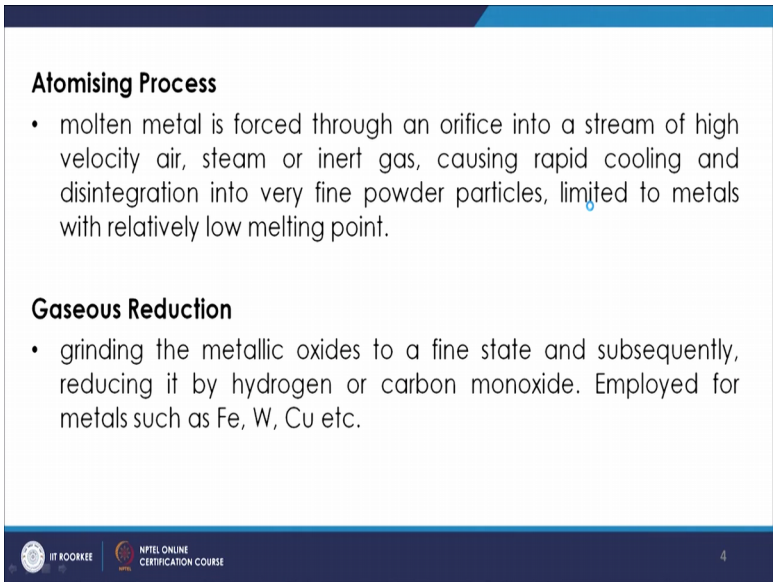

So, in that atomising process basically you have a the spray of the material atomized form.

So, molten metal is forced through an orifice into a stream of high velocity air stream or inert gas causing rapid cooling and disintegration into very fine powder particles. Now what happens in this case you produced the final you give fine atomisation of the metallic material. So, basically you have to have some means by which the atomisation of the metal is done and they are spread through certain type of nozzle.

And once they are coming then there will be you know rapid cooling of these you know fine droplets because they will be you know surrounded by the cooler medium and they have large surface area and they have very very small volume. So, there will be rapidly you know there will be subjected to rapid solidification and there will be converted to the tiny droplets of metal.

So, that is the process of atomizing atomization and this is normally limited to the metals with relatively low melting point. So, basically in this case you have to basically melt the materials. So, you require the temperature to be you know to be attained up to that level. So, normally we confine it to the metals with very low melting point.

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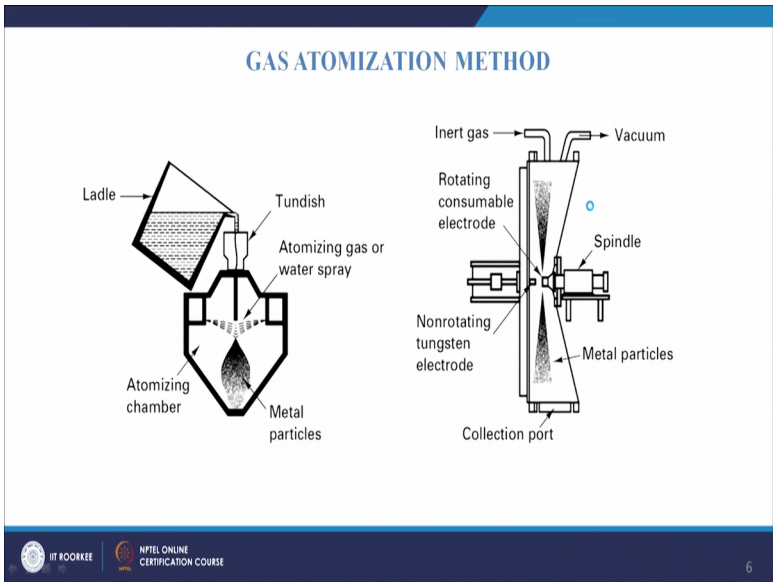

Now if you try to see the how these atomization is carried out you can see here that you have this is the atomising gas or water spray. So, this will be or a liquid metal which will be going through you know tundish and it will be coming here. And then you are basically you are atomizing it and then further you are; so this is a chamber and in this chamber there will be.

So, since they are atomize; so under the where is and this chamber is under vacuum you have inert metal. So, it is it will not be reacting with anything and be getting cooled. So subjected to very height heat transfer rate; so you get the fine metal powders which is. So, you go for this atomizing gas or water spray and because of that it is subjected to certain cooling and you have very fine droplet.

So, there will be converted to very small size of the metal powders. Similarly you have the you know gases; so you this chamber you have the; this is the electrode and you know this way you have the produce some production of the arch. So, because of the large centrifugal force is this arch will be going towards the upper side outer side.

And then they will be cooled because of the inert gases coming through here and then they will be cooled and inert gases there to maintain that atmosphere inside. And then they will be cooled and they will be you know solidified and there will be collected at the bottom and there will be taken. So, basically these are the methods by which you get ready pure metal powders using this atomization process. Then you have a gaseous

reduction and in the gaseous reduction process basically you can grind this metallic oxides to the fine state and subsequently reduce it why hydrogen or carbon monoxide.

So, many a times you have the availability of the gaseous oxides as compared to the pure you know metal. So, metallic oxides not gases oxides it is a metallic oxides are abundantly available and in that case you can use this metallic oxides and you can you know I mean a crush them to fine state and then further that you can reduce it.

So, the oxygen part will be removed leaving the pure metal part. So, that way you can get the pure metal powders for the use; so it is normally implied for metal such as iron tungsten copper where the metal is available in the form of its oxides. So, that oxide can be reduced to give you that you know pure you know; so pure metallic powders.

Another you know process is the electrolysis process.

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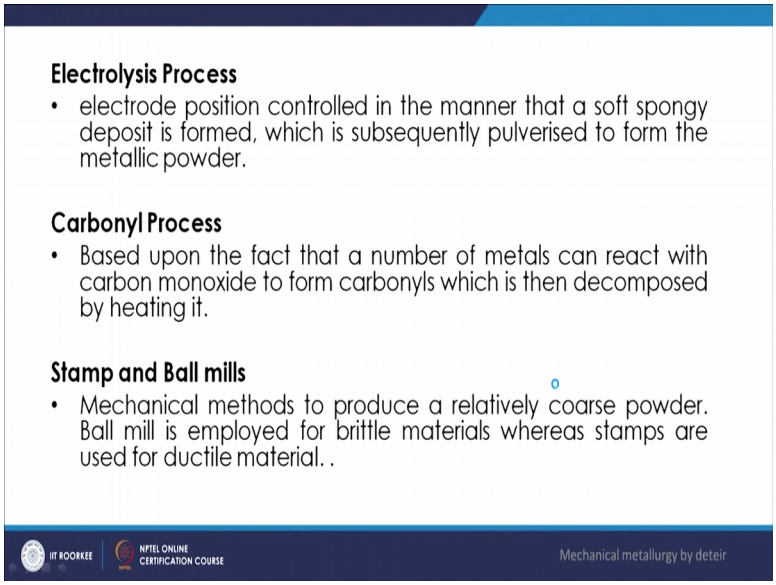

And you must have the knowledge about this process where using that electrolysis process; you know that you have 2 electrodes cathode and the anode. And you can have the deposition of the metal at one of the cathode and that is very pure you know impure form. So, basically you can also control these parameters for increasing the rate of deposition and that can be done. So, (Refer Time: 19:44) position controlled is controlled in such a manner that soft spongy deposit is form down one of the electrode. And then you can take that and then you can polarized it you can cross it to powders and use it. So,

this electrolysis process is a very important process to get you the pure metal you know you know production.

There is another process that is known as carbonyl process. So, here basically the metal carbonyl is there and that will be decomposed by heating it. So, so once you decompose it by heating then it will be forming to the pure metal form. So, it is based upon the fact that a number of metals what happens the basically react with carbon monoxide to form the carbonyl and then it is decomposed; so we will have some more study about it.

Then stamp and ball mills; so, this may process is about basically you know crushing the material and stamping for the ductile materials and you get the powders. So, you have the mechanism by which you basically crush it in the ball mills using ball steel balls or the hard balls. So, you are crushing the material especially the crushing is we used normally for the brittle materials and when it is ductile one you can use the stamping methods.

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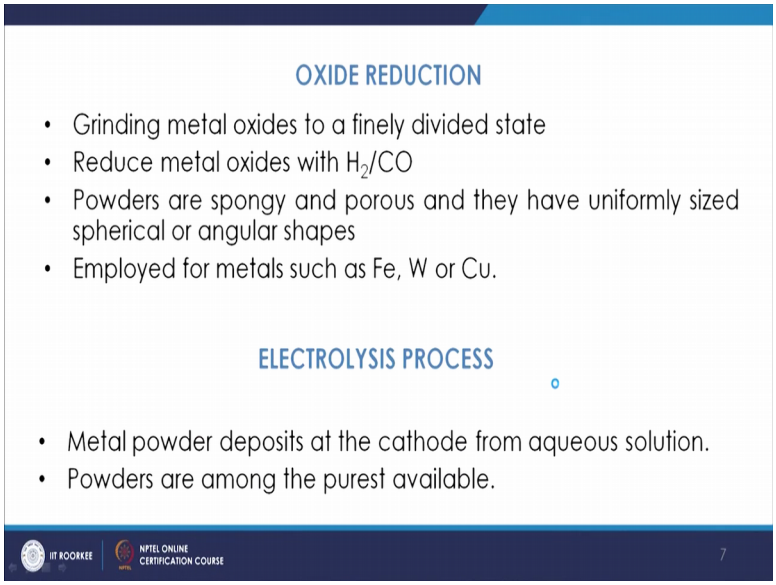

So, the we are discussing about the oxide reduction; so oxide reduction is normally you have the use of hydrogen or carbon monoxide ad we use that. So, that we are already studied you have you know deposition at the cathode and they are very pure.

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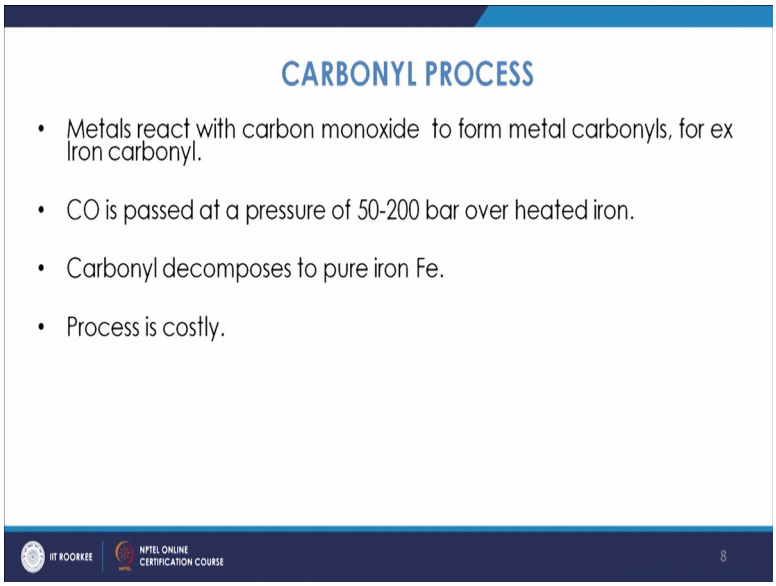

So, they are purest of the form and in carbonyl process what happens that CO2; carbon monoxide is; so, first of all metal will react with carbon monoxide to form the metal carbonyls. So, the metal will be reacting with carbon monoxide to form the metal carbonyls like iron carbonyl then the carbon monoxide will be passed at a very high pressure that is 50 to 200 bar over that heated iron and in that process the carbonyl will decomposed to pure iron. So, the process is costly all though it gives you pure you know powder and it is a costly process.

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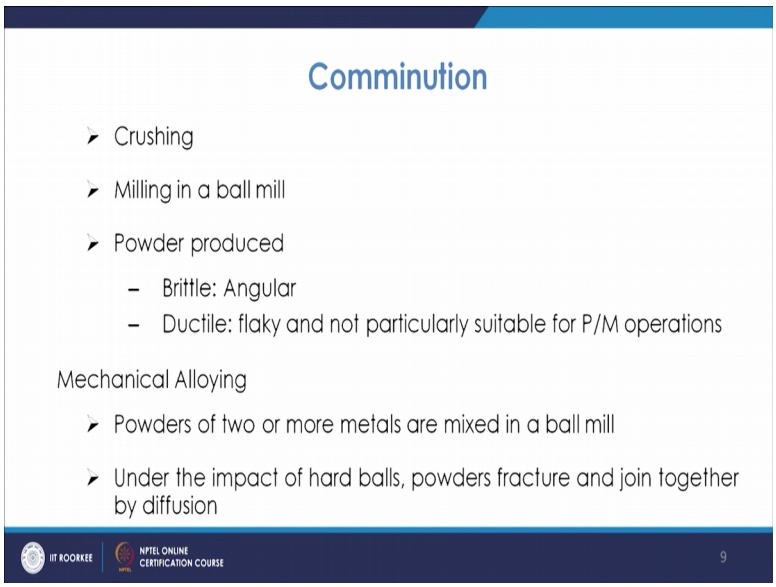

Another process which is important for making the powders is comminution methods. Now in that basically you have the crushing of the metal and that way you can get the powders. So, you have milling in a ball mill and powder will be produced. And for that what happens that if you have the powder which is of made of the brittle material; then you can get the angular type of powders. But if you have a ductile material you can have the flick which is not very much suited for the powder metallurgy operations.

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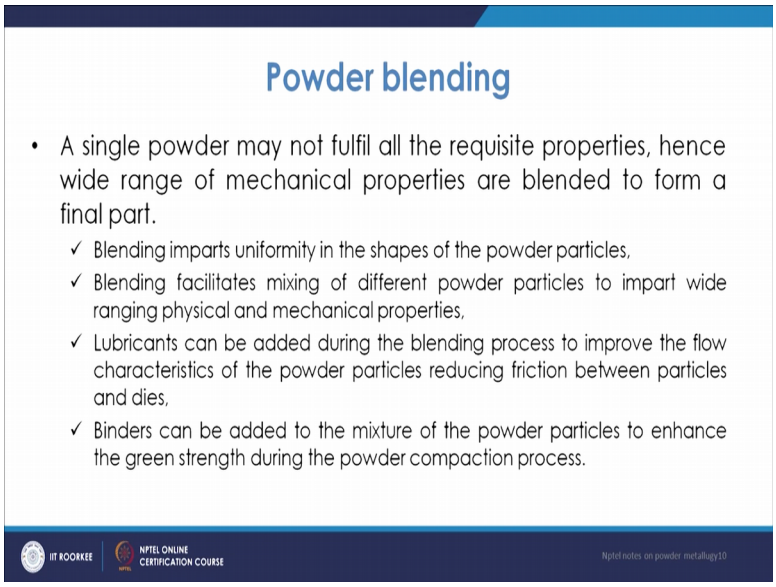

So, this is how you know we go. So, what happens that it normally in a you have a you know ball mill. So, you have a very large type of you know vessels in that you have these balls are you know refractory balls. So, hard balls steel balls or caped and they basically this is rotated. So, this will be basically rotated and then metal will be there inside and that basically comes under the impact you know of these balls that gets converted to the powders.

So, you must have the idea about this process before I visited certain steel plants or thermal power plants; there also you have a ball mill plant where you polarize the in cools and all that; so, you have that is the process. Mechanical alloying; so that is powders of 2 or more metals are mixed in a ball mill. So, if in the ball mill you have the powders of 2 or more metals or if you put 2 more metals then there will be crushed and then there will be alloyed also or mixed also.

So, under the impact of the hard balls this powders failure fracture and joint together by diffusion that also is possible under the action of this impact; so they join also by diffusion. Now powder blending, so what happens that you it is not always required that you can work only with the one kind of powder. So, basically you know a single powder may not fulfill all the requisite properties. So, you require basically the wide range of mechanical properties which will be available by the use of different types of powders.

So, you basically they need to be blended; they will need to be mixed properly in proportion. So, that you get the requisite type of properties like some may give you know better strength some may give you better you know resistance to corrosion and all that. So, did the different powders may have the different properties and that is basically attributing towards the final product preparation.

So, for that the blending is important and blending will be imparting uniformity in the shape of the powder particles. So, it will be giving you that in uniformity then it will be facilitating the mixing of different powder particles to import wide ranging physical and mechanical properties. So, as we discussed that when you have the mixing of the different proper; you know powders of different properties then certainly they are go you are going to achieve better physical and mechanical properties.

Lubricants can be added during the blending process to improve the flow characteristics of the powder particles reducing friction between particles and dice. Now while blending you require the use of certain type of lubricants; so that when you are you know blending the flow ability should be better. And in between the particle in the dice when they are you know having that relative motion between them there should be minimum friction so that the mixing process is more effective. So, for that the lubricant is added and also you add the binders which are added to the mixture of the powder particles to enhance the green strength during compaction process.

So, basically as we discussed earlier also you use certain binders maybe water based or even not water based. So, you can use the word these binders to; so, that they are you know they are corrosion develop corrosion between the powders develops or there is you know attraction between the different powders develops.

And basically from that way you increase the green strength of the compact and then further you are going to do the compaction. So, that time you will have more and more

increasing the compactness of the specimen. So, these binders are useful for the boarder blending.

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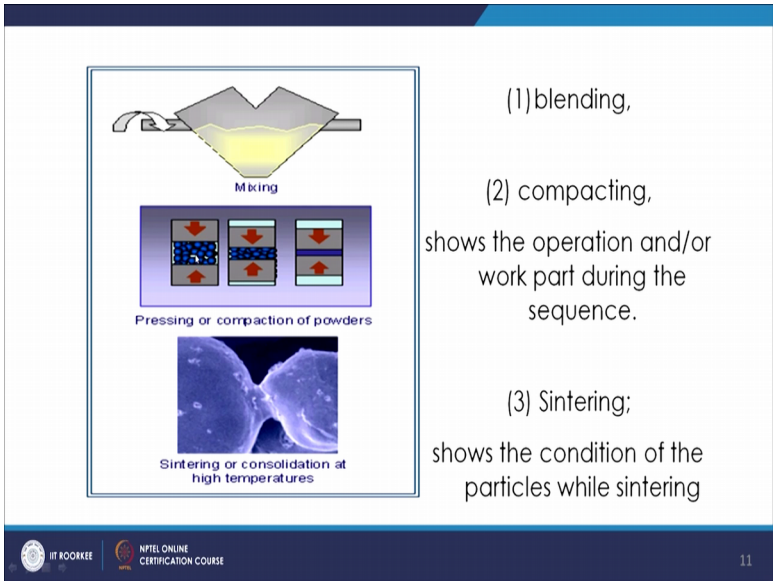

So, this process talks about the blending then once you do the blending; then you are going to compact its. So, compacting you apply this pressure and you; so, I will compacting you can see that the space between then is there that is decreasing and that is further decreasing.

So, that way you can change the spacing between the particles as the compaction is done and then you ultimately you go for the sintering. So, when it will be sintering then during the sintering or the consolidation when the high temperature goes there will be bounding developed initially. So, bounding will be developed and that way the material in between the material whatever porosity is there that is gone volatile materials will be coming out.

And porosity advise maintained whatever you have to maintain that way, but volatile materials will go out and then there will be consolidation there will be increase in the strength, there will be bounding you know fusion of the materials (Refer Time: 28:56) powders with each other. So, that way your strength is developed.

Now what is a powder compaction basically?

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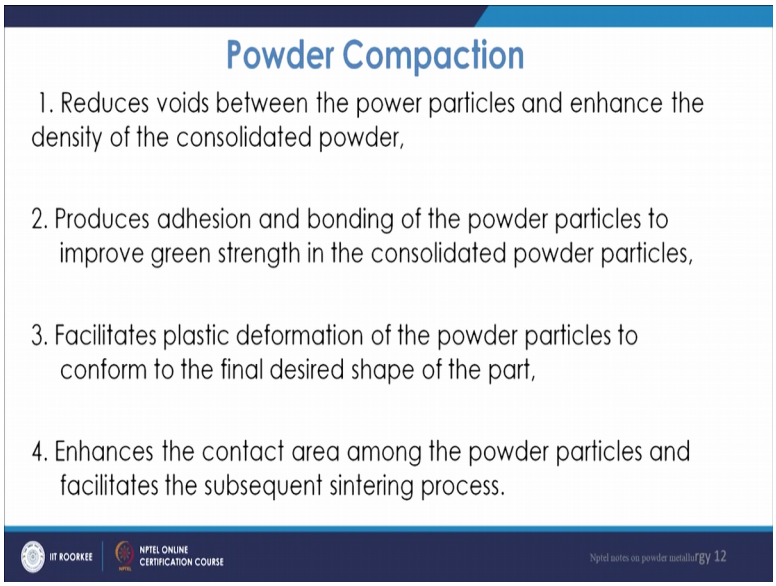

So powder compaction is required because it will be reducing the wide between the powder particles and enhance the density of the consolidated powder; so, once you have the powder then you and you have blended it and you have made the compact now you have to increase the density of the you know consolidated powder. Because otherwise you have a large you know interparticle spaces between them and that needs to be basically reduced. And it will be ideally coming to that when it is there is ideally distance as per their crystal structures. So, as you increase the compaction pressure as you increase the degree of compaction then their spaces between them is basically reduced. And the quite between the powder particles will be you know and the density will be increases.

Produces adhesion and bonding of the powder the powder particles to improve green strength in the consolidated powder particles; so basically again that is to for improving the green strength. Facilitates plastic deformation of the powder particles to confirm to the final desired shape of the products; so, what happens that when you do the compaction then there will be plastic deformation of the material and it will be coming to the final desired shape of the part.

Enhances the contact area among the powder particles and we facilitates the subsequent sintering process. So, the contact area between then will be increasing and that will be

basically be facilitating the subsequent sintering process. So, that is the about the powder compaction; so, if you can see this compaction sequence how it is done.

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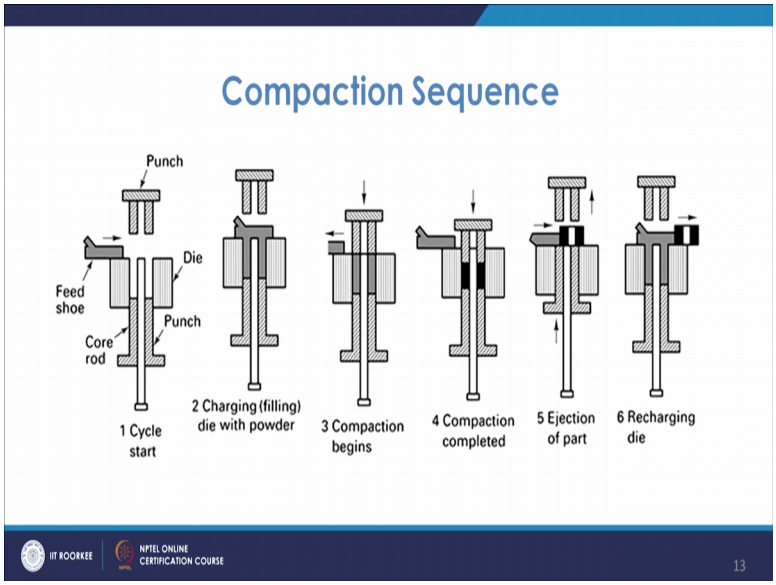

You see that you have the start of the cycle where you have this is the die and in that basically you have. So, this is a cavity in which this material is kept as a powder is kept and then from the top you will have the punch the top part will come and it will apply the pressure; so a dimension or height of this much.

So, here you have the start of the cycle then you have feeling the die with the powder; then the complex has started and once you have compaction started then the height of this is specimen will go on decreasing. And it will be decreasing to this level and then once you have gone you have reduced the height to certain level; then basically you have to take this punch out and then you are getting this final product with the height which is required for you.

So, that is how these you know compaction is done in sequence and then further after one sequence you are doing to further repeat the process. So, that is how the compaction is done and you can see that the dimension is reduced and the density will certainly be increasing in that time. So, that is the sequence of compaction which is you know done in the case of the powder metallurgy.

Now we also do the compaction maybe sometimes we are doing the compaction here, but what we see here in this case this person maybe you know this part maybe you know stationary or that part maybe you know acting from both the sides. So, basically it may be single action or double acting you know from both the sides either a working from both the sides or from the one sides.

So, that will be you know that will be more effecting as I discussed that once you have compaction only from top the compaction density decreases; as we go towards the bottom, but if you do the compaction from top and bottom both the compaction is more uniform in that case. So, this is about that compaction process.

Thank you.