Principles of Metal Forming Technology
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Lecture – 40
Powder metallurgy forming – II

Welcome to the lecture on Powder metallurgy forming II part. So, we had studied about the, you know operations which is there in powder metallurgy forming and we will continue from the last lecture. So, we are into the step of sintering. So, what happens in the sintering? Sintering in that are there is heating of the compacted powder perform to a specific temperature to allow diffusion between the neighboring particles.

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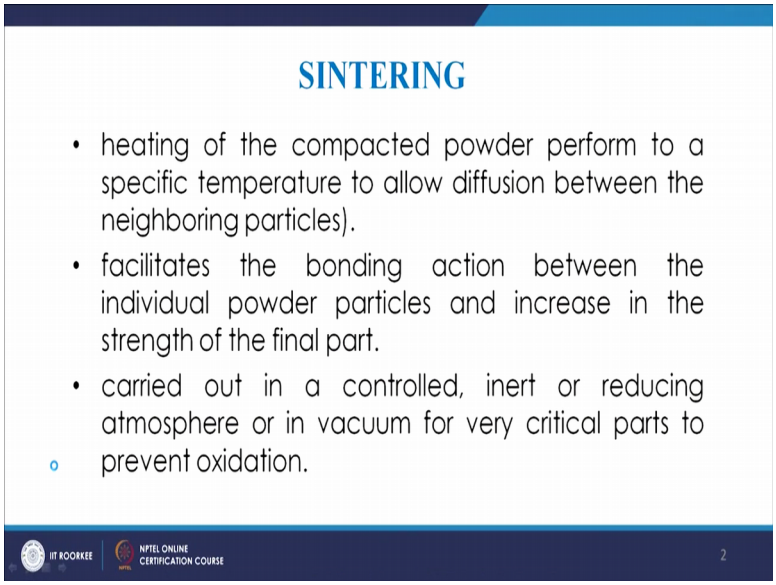

So, as we know that once you have blended the powders, mixed a powders; you have used basically the lubricants and also use binders, then you have put them under the compaction. So, you have made a green compact, but that bounded is not enough because that is not the type of metallurgical bound which is there in between the particles.

So, what we do is that now we are basically heating that you know compacted powder into a controlled atmosphere and we increase the temperature and we have to go to as high has temperature. But it has to be below the melting point of the temperature because it has not to attain the liquid state basically. So, we are and as the temperature goes on

and it is be below its melting point, then the diffusion basically between the particles increases it is at higher rate and that basically increases the bond strength between the materials.

So, basically that will be facilitating the bonding action between the individual powder particles and increase in the strength of the final part will be attained. So, that is what the, you know advantage of this sintering process is. Now this is basically carried out in a controlled inert or reducing atmosphere or in vacuum for very critical parts to prevent oxidation.

So, as you know that if you are heating in a normal atmosphere, if you have oxygen available in that atmosphere; then that may lead to oxidation of the material and basically if you have a critical part production, then that may you know interfere with the quality of the product produced. So, that is why you try to maintain the inert atmosphere in the case of the sintering. So, the atmosphere maintain you know maintaining inside the furnace is also important.

Now, what happens how this bonding develops in the Powder particles?

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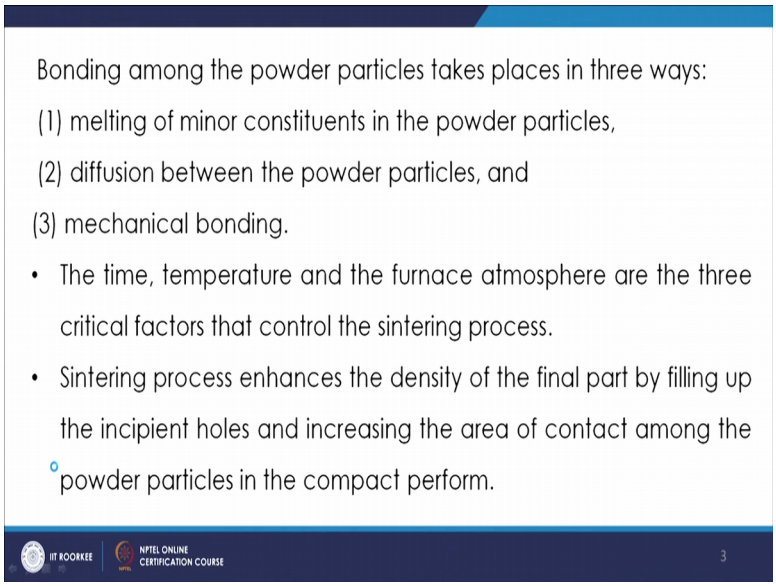

So, basically there are three stages in which the basically the bonding is developed. First is in the first stage you have melting of minor constituents in the powder particles. So, what happens that if you have minor constituents have lower melting point materials they

are melted, if you have volatile substance is they are driven off. So, that happens in the first stage. Then what happens that you go to the second stage and in the second stage you have a diffusion between the powder particles.

So, you have the diffusion starts between the powder particles you have making starts. So, they basically the diffusion between them will be starting the diffusion stage; so that second stage. And then and third stage, you have the mechanical bonding will be there in the final stage that mechanical bonding will between them will develop.

So, that time, temperature and the furnace atmosphere these are the three critical factors which are controlling the sintering process you know that how much time you have to put in that furnace sintering furnace; what should be the maximum temperature or minimum temperature because that will be affecting the property of the sintered product and also the atmosphere as we talked about the atmosphere should be such that it should not produce any kind of oxide or its not produce any kind of defect thereby. Because of the improper you know environment inside the furnace.

Now, this sintering process will enhance the density of the final part by filling up the incipient holes and increasing the area of contact among the powder particles in the compact perform. So, as we discussed that he will have lower melting point materials also, you have minor elements also.

So, what happens during that process when those melt and you have the pores in between that also will be filled up. So, that way ones that pores are filled up in that case your you know, so because of this filling of these recipients holes, the density will be going on increasing. And that basically will increase the strength of the material and also increase the area of contact amount powder particles. So, that even starts with the compaction process, but during this process of sintering also that increases in the compacted preferred.

Then, you have the finishing operation. So, after sintering there may be some finishing operation also desired like repressing that is to import the dimensional accuracy you do the further replacing of the material and also you can go for machining to improve the quality of the final part and part which is made for the powder metallurgy base processes are also subjected to you may also you know that may also undergo other finishing processes like heat treatment machining and finishing depending on the requirement.

So, if the you if you required to give certain type of heat treatment, heat treatment are of all though we have many types you may be required to give some surface hardness or you may required to have some toughness or maybe some hardness or whatever it be.

So, based on that you can have that specific type of heat treatment schedule which may be applied to the process; you can also go for the machining and finishing processes to have for the final appearance of the material to find to have the final you know surface finish of the material. So, based on the requirements you can have those things.

So, as we discussed the different you know stages how they go.

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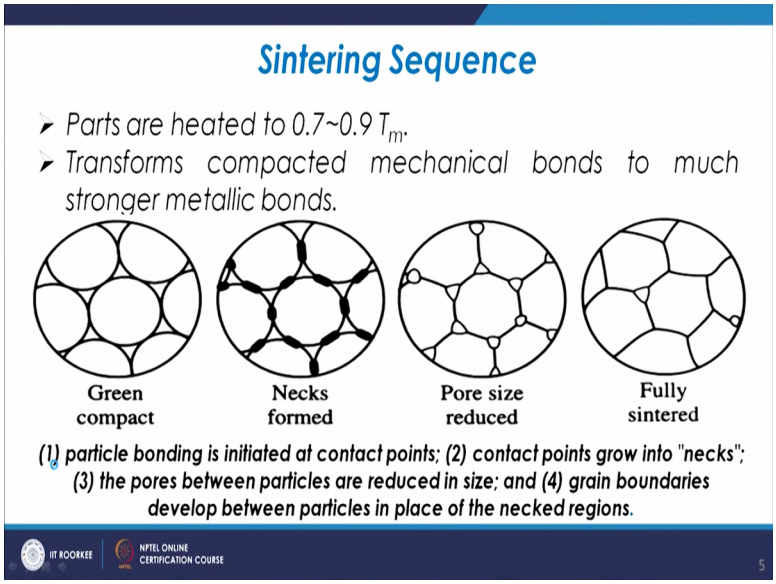

So, parts are normally heated to about 0.7 to 0.9 times the melting temperature of the material normally that is in the form of kelvin and then, so that way the compacted mechanical bonds to this you know much stronger metallic bonds you know they are converted to.

So, how you can see that in this stage you have a Green compact. When you are basically making that green compact, you are you are doing the blending of the powders; then you are contacting them. So, you are making the green compact first and then, there is formation of Neck and then the Pore size will be further reduced and then finally, when sintered you will see that very less pores.

So, second point you have contacts points grow into necks, then third point you have pores between particles reduced in size and then, you have grain boundaries development between particles in place of the necked regions. So, do you have those necked regions? So, there you have the bound development of the, you know a grain boundaries taking place.

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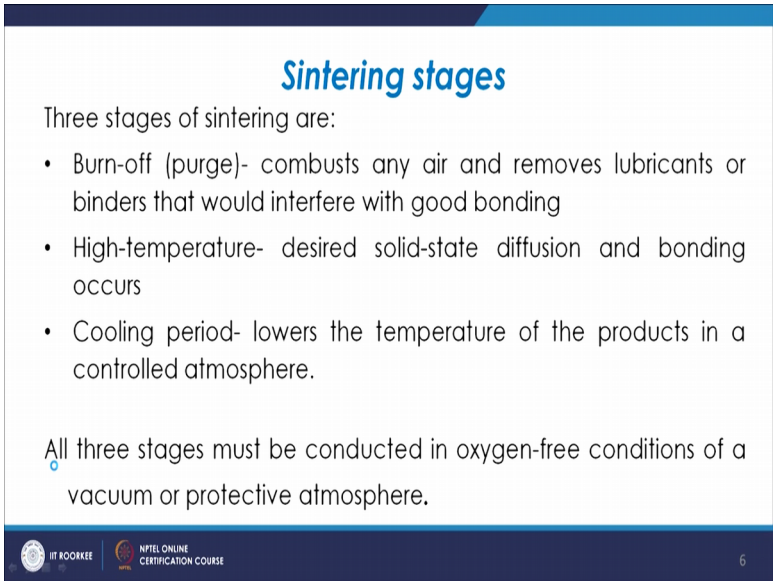

So, as we discussed that these three stages which are defined in case of a sintering. They are first stage is the Burn-off stage that is purge stage. Now, in this burn-off stage, when you are increasing the temperature in that case whatever gases are there inside in air or any lubricant which is there inside the green compact.

So, they or the binders which we are discussing that they were used. Now they are basically combusted, they are heated and they are driven off. So, they that is burn-off so, that is the first stage what happens in the sintering and in that case you are removing all these you know air or the lubricants or the firm you know those elements which have the lower melting (Refer Time: 09:40) they are volatile. So, they are removed.

Then you have the high temperature stage. Now in that basically you have the solid stage diffusion taking place and the bonding is developed and third stage is the cooling period where you are lowering the temperature of the product in a controlled atmosphere. So, all these stages must be conducted in the oxygen free conditions of vacuum or protective atmosphere. So, that is what the requirement of the sintering stage.

So, as we discussed that in the first stage temperature will be slowly increased.

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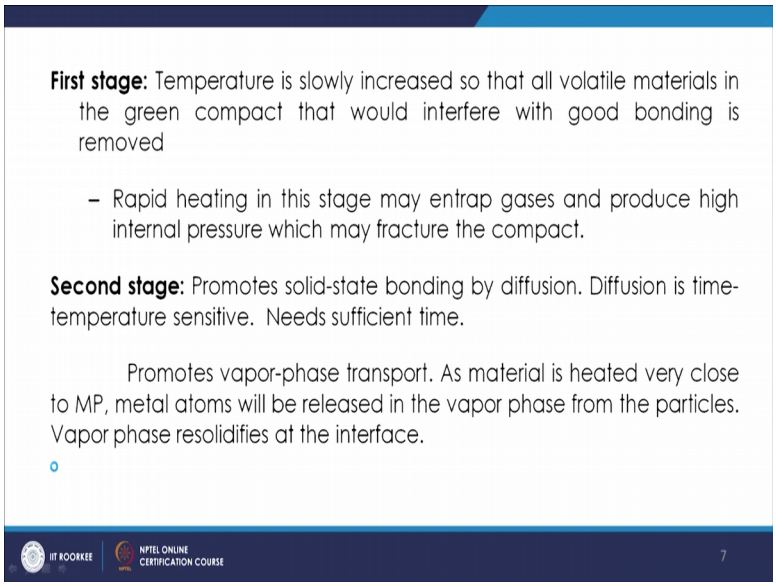

So, that all the volatile materials in the green compact that will be interfering with the good bonding is removed and rapid heating in this stage may entrap gases and produce high internal pressure which may fracture or the common the compact. So, you try to avoid that. Then in the second stage you have the formation promoting the solid stage bonding by diffusion is time temperature sensitive. So, you have to give a good time. So, that time taken in that stage is quite sufficient and it will be promoting the vapor phase transport.

And you know as the material is heated very close to its melting point. So, metal items will be released in the vapor phase from the particles and vapor phase will be further solidified at the interface. So, this process in that second stage you have the solid state bonding and then, all associated phenomena taking place. So, which develops the bond between the materials, then as we discussed that in the third stage you have the cooling in the controlled atmosphere.

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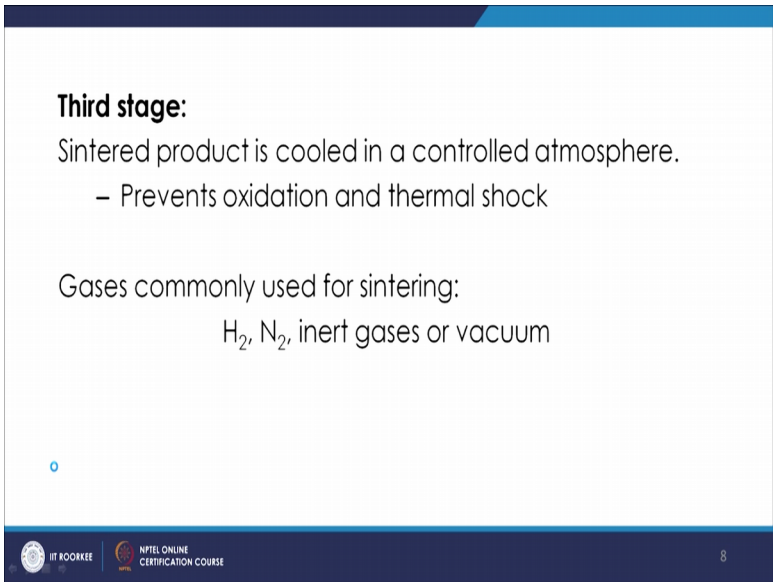

And it will be preventing the oxidation and thermal shock and the gases which are normally used for sintering is the hydrogen nitrogen inert gas or vacuum. So, basically you are doing that in a controlled atmosphere in the presence of the such you know inert gases in which the third stage three stages of the sintering is carried out.

So, then you have the stage of finishing now in the case of finishing. So, what happens that after sintering?

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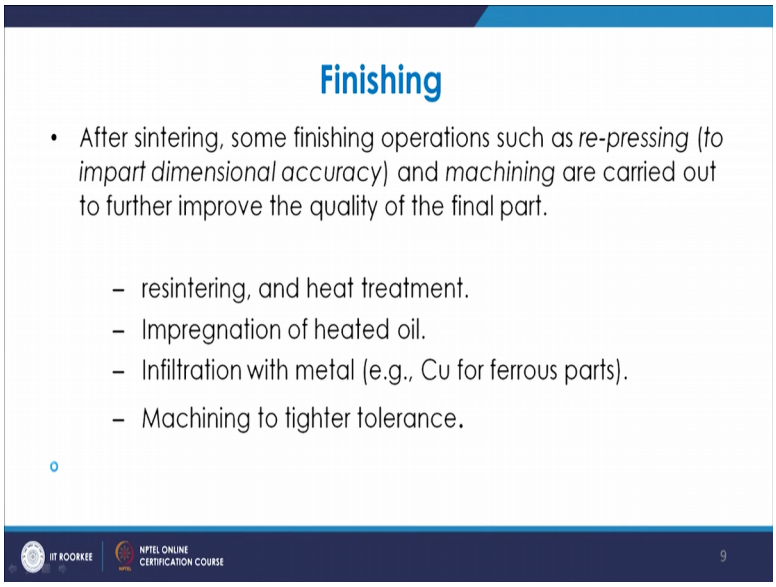

You may require certain you know finishing operations like refreshing to import this dimensional accuracy and machining also may be carried out to improve the quality of the a final part.

Now, as we discussed that you may go for the re-sintering and also you may go for the heat treatment that may be desired even after the sintering process. Now impregnation of the heated oil. Now, what happens that as we will discuss that you have a specific type of properties which are you know achieved in this ferrous which can be achieved in this ferrous by this powder metallurgy parts and one of them is the use of parts or making of parts which are used in the bearing applications.

So, the parts can be impregnated you know. So, impregnation of heated oil can be done you know after that so if you add to be used for you have to make the material of that particular type. .So, that way that impregnation you know process is carried out after the sintering process. Then you have infiltration with metal. So, you sometimes you have also you can have infiltration of one metal with other like you can use copper for the ferrous parts.

So, that that process is also carried out after this sintering process and then, machining to the tighter tolerance. So, after sintering if you feel that you have to do the machining. So, that a better tolerance is to be achieved. So, that also is done in the case of the. So, you say that will be in extension to this process of sintering and that is a under the, you know case of the machining you know processes.

Now, we will discuss about the, you know traits of this process. When to use this powder metallurgy process? So, as we discussed that we have many a times limitations with the kind of manufacturing process, we apply to make the products of different type. So, normally whenever your melting point is too high like tungsten or molybdenum. Now these materials cannot be made by the casting process because the melting point is very very high. Now in those cases its better it is economical to use you know this powder metallurgy route making such materials.

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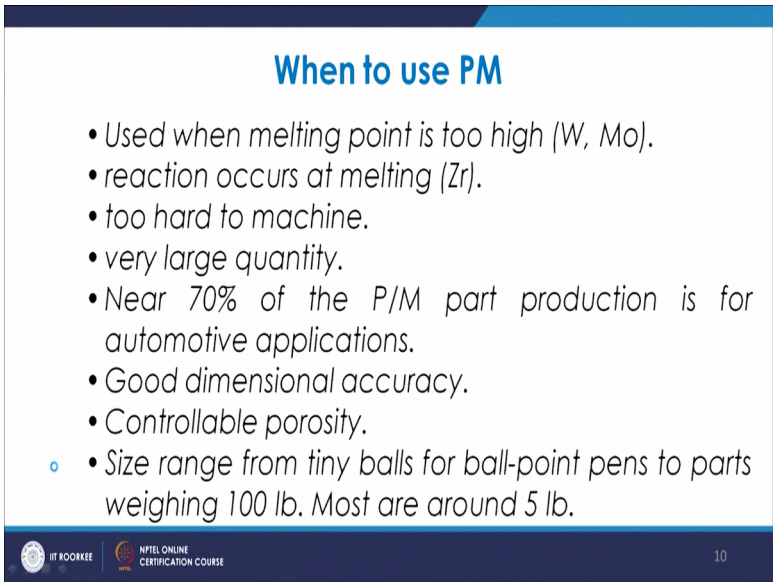

Then also for certain materials which are basically very very reactive. So, for very reactive materials like zirconium, which reaction makes you know oxide products like zirconium oxide, very quickly or so. So, highly reacting and it will be spoiled if it is done in normal atmosphere. So, in that case you can you know you can use this powder metallurgy route for making such a products..

Sometimes, some materials are very very hard to machine if and if you are making the machine, but it becomes so hard that is very difficult to shape it further by machining; you cannot shape it you cannot machine it. Now such materials when you have to have product of final shape you have to make. So, you since machining becomes very very difficult you have to make the final shape of the product final size of the product which has which need not be machine. So, the net shape product you have to make.

Now, in that case you can make it using the powders of those materials. So, you can have the, you know you know material using powder metallurgy route which is needs not further the machining. A very large quantity when it is require you can use the powders and you can make the materials.

Now nearly 70 percent of the powder metallurgy parts production is for automotive applications. Now in automotive applications many a times we requires specific type of materials; you require materials which otherwise cannot be you know. So, if the material

uses many you know materials alloyed and other than the alloying otherwise is not through conventional route of casting or so.

So, you can use such materials in the case powder metallurgy; then also you can control the porosity here. So, many parts can be used in that way. So, nearly 70 percent of the powder metallurgy parts production is for the automotive applications. Then good dimensional accuracy now in this case as you know that when we go for the compaction, then we are basically coming finally, in the final stage you are coming to the you know nearly the exact shape of the material.

So, basically the dimensional accuracy is quite high and that is the advantage of the product when we have to have that product at you know with very good dimensional accuracy you go for that then controllable porosity. Now this is the factor we discussed earlier also that in many parts you required the, you know control porosity you have to you want to have the part with porosity which you can control. So, that is not possible by other routes otherwise.

So, in this case depending upon the, you know degree of compaction you can basically control these porosities because you did the sintering stage all the void spaces from there you know the volatile materials will be going away. So, creating that spores in between.

And you can have the material with either less porosity or larger porosity. So, that way you can control the these porosities in that. Then size range from tiny balls for ball point pens to part weighing 100 pound most of.

So, basically you can have a very very small size part or and to every somewhat lagers part also; but normally you know about the 5 pound parts are normally most more common. Size limitation is there in the case of powder metallurgy because as you increase the size, then you need you know other attachments also accordingly; you need you know bigger vessel for blending and then a more importantly the press requirements for making the compacts.

So, that basically becomes more and more costly as the size you know grows. So, there is size limitation; otherwise for a smaller parts so you know this is quite suggested operation. Now where are its uses you know a like electrical contact materials where mostly you have you might be seeing that you have to use of these ceramic materials.

So, they are very difficult to be a fabricated with normal conventional operations. So, in that case you can make it to using that powder metallurgy applications you have heavy duty friction materials that also are used you know for using that also are made using this powder metallurgy applications.

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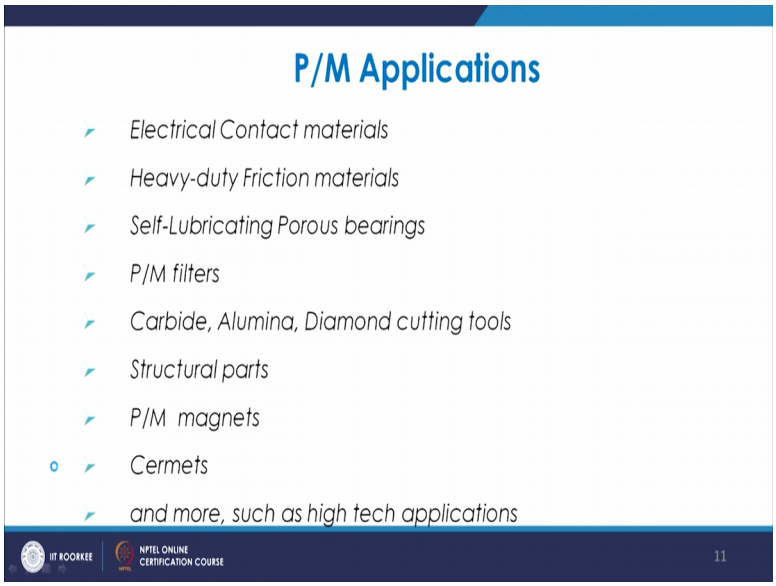

Self lubricating pours bearings as we discussed that for bearings which are self lubricating, why are we doing the impregnation with the oil and so there will be working as a self lubricating you know bearings and they are very much you know made by these powder metallurgy route.

Then Powder Metallurgy filters. So, these filters are also made by the powder metallurgy route. You have all these cutting tools as we discussed which have which are normally the you know ceramic materials and which cannot be made by other routes. So, they are like carbide alumina or diamond cutting tools the which are used as normally the insert materials; they are made by these powder metallurgy routes and have very wide used in the machining industries or machining of materials.

So, they are basically smaller inserts which are there available. They are made through this you know powder metallurgy route. Structural parts are also made by using this powder metallurgy. Then you have magnets are there cermets ceramic in metallic binders. So, they are also may used you know cermets. So, you have metallic binder that is used in with ceramics.

So, that is how you need cermets and many more high technology applications are there of these powder metallurgy materials. Now so it has many merits and the merit is that the main constituent need not be melted; you do not required to melt. So, basically that itself is a merit porosity product needs to be porous; you can control that for the self lubrication.

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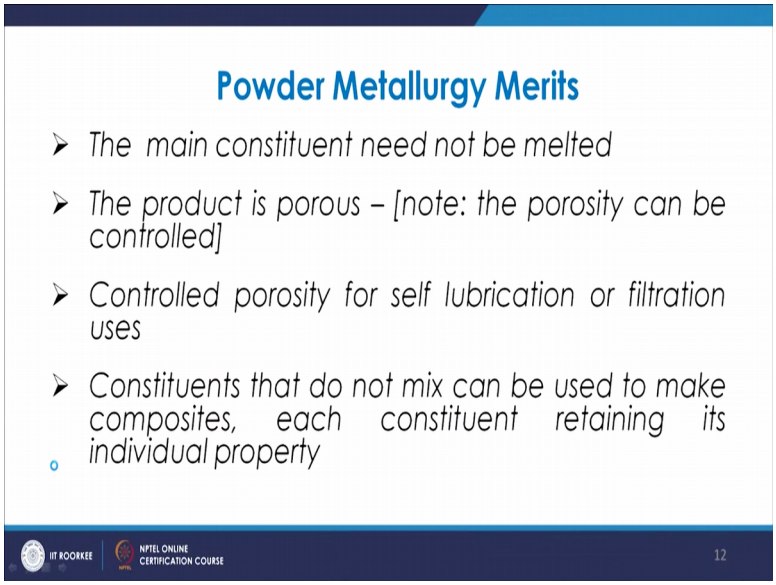

And also as we discussed that which the, those materials we do not mix with each other. Now, that there are many cases when you want to make a product with two materials, but otherwise you cannot mix, if you want to make that product through the normal conventional route by of alloying or y casting; otherwise you cannot make its alloy. So, their mixing is impossible. So, that can be when mixed using this powder metallurgy route. So, that is the merit of this powder metallurgy process.

So, you also you have the precision parts production.

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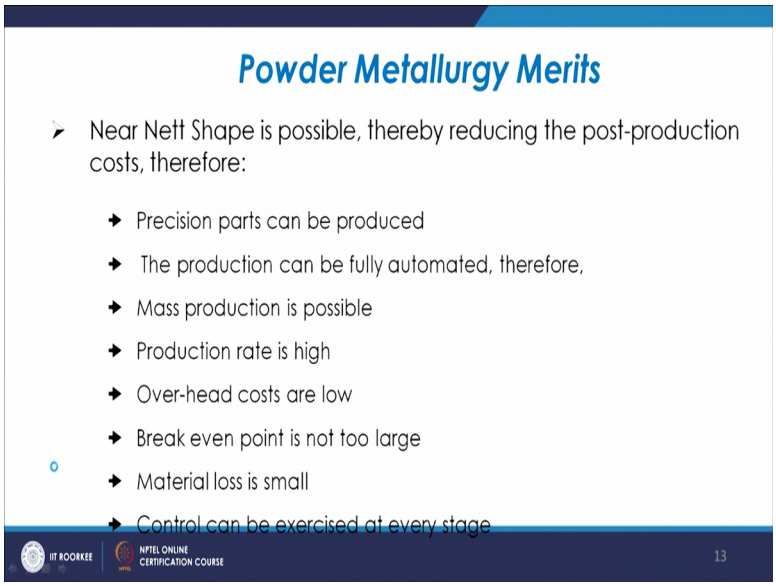

Then you can have the automation facilities in that mass production is possible; quite high you know production rate is possible. In this case the over head cost is less because you know that what are the process is involved.

So, there is not much of the overhead; in this cases break point, the even point will not be very large. Material loss is very very small as we discussed and you can have the control if you at any stage you feel that you need to control the you know you know that process, there is any defect coming out.

So, you can see that at in that particular stage suppose at the stage of sintering or at the stage of compaction or at the stage of blending. Wherever you feel that the output is not coming as per the specification as per the requirement in that case you can have the control of the process parameters. And you can have the quality check at that process. So, basically you can have the control at every stage of the process.

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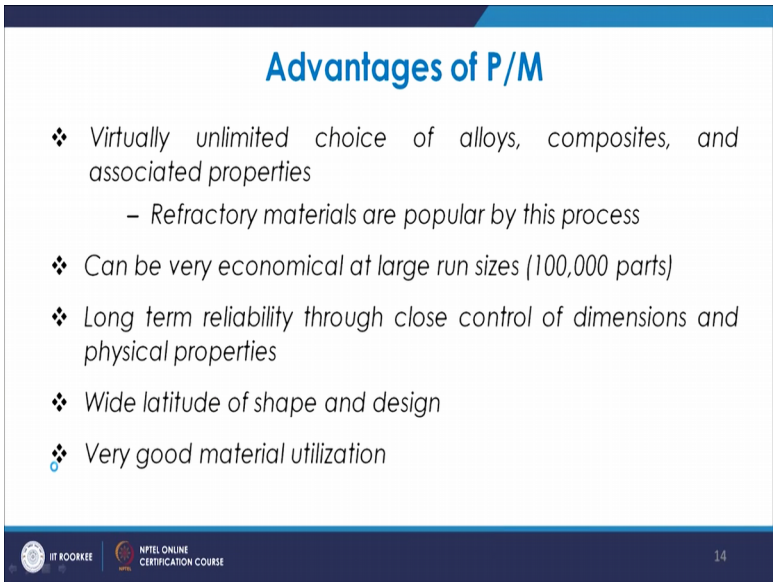

So, other advantages of the process powder metallurgy process is that you can have virtually unlimited choice of alloys, composites and associated properties and normally refractory materials are there among them. You can be have very economical for large run sizes long term reliability through close control of dimensions and you have wide latitude of shape and design and very good material utilization. These are the advantages of the powder metallurgy products.

Now, apart from that the advantages, you have also certain limitations and disadvantages of this process.

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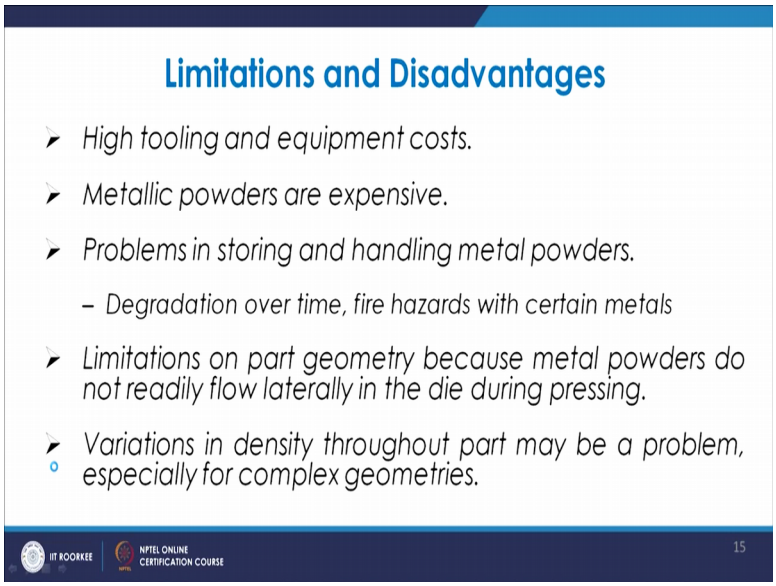

Now in this case you have high tooling and equipment costs. So, in this process as you know the you require specialized type of tools; you require the equipment suppose you want to have the powder productions. So, either you have to purchase the powder or you have to make the powder. So, for the powder production and that two of a larger purity you need a specialized type of equipments and also good tooling and that will be basically quite costly.

So, that cost for component is there in this cases. So, powder making is basically expensive and that is why when the powder making itself is expensive. So, the process becomes expensive especially for the short run applications then problems in storing and handling metal powders. So, what happens that if even if you have?

So, have to have the powders in a good quality and that should be fresh because if you keep for sometime, then many metals either may they may be contaminating getting contaminated or there maybe some issues of the safety also with some of the metals. So, ah there may be degradation of the material with time and there will be fire hazards also with certain metals.

So, you have to have you know that also you know aspect kept in mind and for that you have to have proper way to you know to tackle this problem of storing and handling of the metal powders, you have to make it.

Then limitations on part geometry because metal powders do not readily flow laterally in the die during the pressing. So, certainly the kind of geometry which you are making now that has to be relatively simple because many a times the filling of that die is very important.

So, and while also filling, you also need the compaction. So, in those case you will have to see that how. So, better the you know a size or shape is simple one; size is smaller shape is simple one because the otherwise in the complex shapes the filling of the those internal cavities or the complex cavities will be a challenge and also the you know getting the appropriate compaction in those you know shapes is a another challenge.

So, you need to have you know you have a look at these aspect that the normally the size is or shapes should be simple and size is should be smaller one. Now as we discussed that when you have the you know complex geometries; then you have the variation in the density and you know that you are not at all keeping as the desirable property because the density may be varying you know in parts. So, in some part the whereas, density may be more and in another part the density may be less.

So, that basically will be the you know challenge with such kind of you know materials. So, where you have the kind the geometry is quite complex and there is variation of the density. So, in fact, the there may be situation where you require that the density should be varying, but not always at in many places this density variation which is you know there that may be a negative point.

So, that is another disadvantage or limitation with this process. So, this is something about the limitation and disadvantage and as it happens that every you know process has certain limitations as well as disadvantage and it is not required to be you know seen that everything will be advantages for certain process, but you know there are many advantages with this.

Now, there are another you know there are many other applications of this powder metallurgy also you can have acid type of products you have powder rolling operation which is also possible where basically what happens that you know you have you have a you know containers. So, you put the powders into it and then you will have baffles.

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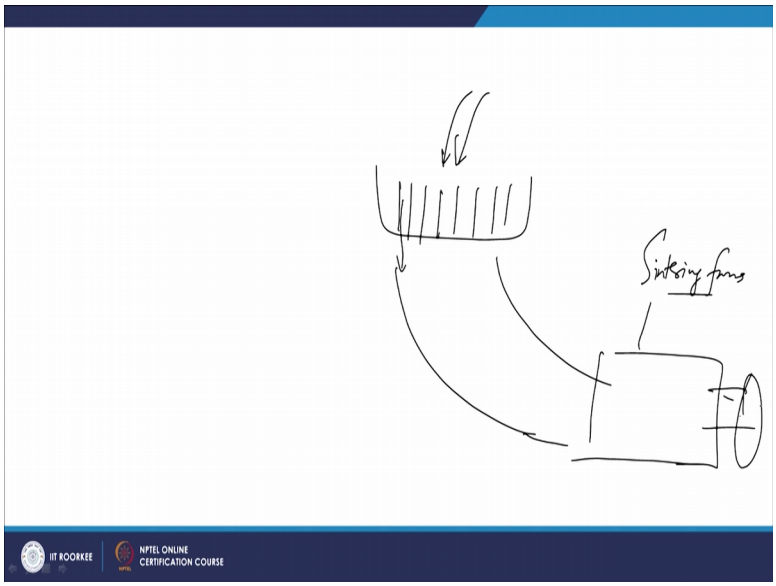

So, the powders will be there a in; so, powders will be coming and then once they are coming. So, there will be following through a route and then basically there is a furnace. So, there will be a sintering furnace. So, this sintering furnace is used so once there will come and in form of a sheet and then that is further you know under the application of a rollers, there will be further rolls that way you can get a rolled you know sheet even in the case of by using these powders.

So, you have the other applications also of these powder metallurgy that is what happening. So, this is the end of the lecture of the last lecture. This is the last lecture of this course. I hope you have been you have you have enjoyed this course you have got that regular understanding of the course and I suggest you to read you know the books like you have a book of Mechanical Metallurgy by Dieter; you have the book by you know Degarmo and other authors like Black and Koestler.

So, they are having also a book on this a manufacturing. So, you can have the reference of these books, which has been you know referred for the study of this whole courses and I hope that you have enjoyed it and you will continue to increase your knowledge by going more and more and by doing more and more interaction with books. So, I just wish you a good luck for the course.

Thank you very much.