Fundamentals of Materials Processing (Part–1)
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Lecture Number 26
Introduction to Powder Processing

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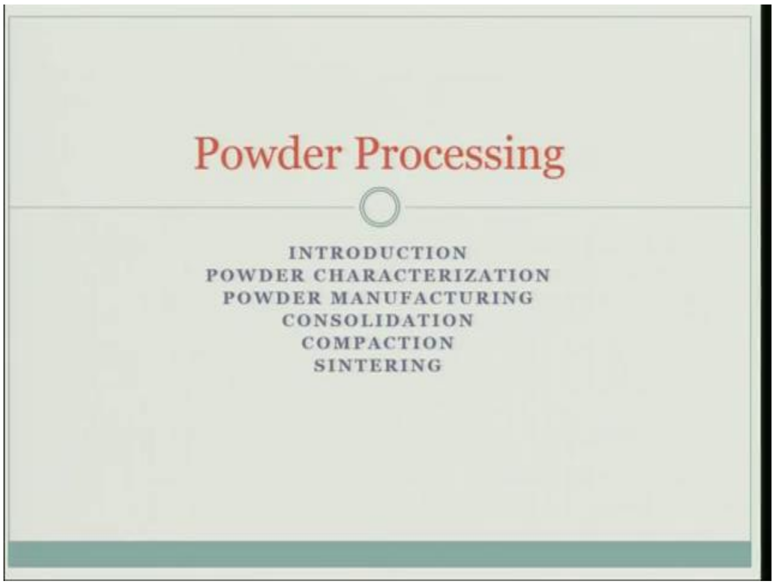

Okay. So, we are back to the other module for this course which is powder processing. So, the (())(0.24) of what are the topics that will be discussed in this module are given here in this slide. So, we will have a general introduction then we talk about powder characterization. What are the different ways to characterize powder theoretically and then few characterization techniques. What are the techniques available and then we will look at powder manufacturing then we look at consolidation, compaction and sintering which is usually the way this powder processing is actually carried out as we will see.

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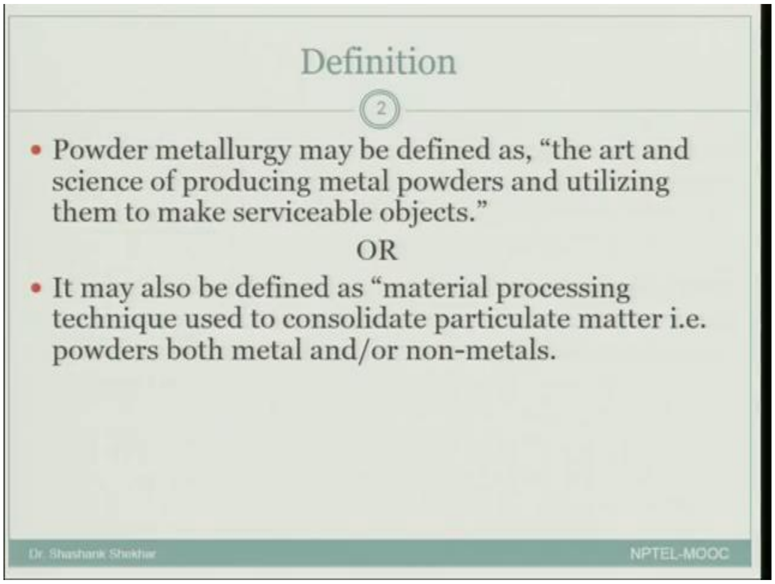

So, let us start with definition for powder metallurgy is the more common term although we are using powder processing because powder processing is for both metals and as well as ceramics. Powder metallurgy since like the term limited to metals or alloys. So, powder metallurgy is usually defined as the art and science are producing metal part powders and utilizing them to make serviceable objects.

So, this is the very (())(1:16) outline about powder processing is but in a particular about metals. So, this is talking about metals powders or it may also be defined as material processing technique use to consolidate particulate matters that is powders, both metals and or non-metals. So, (the) you see the second definition is a little bit more general in nature because it includes non-metals as well.

So, it is talking about to a technique that is use to consolidate powder particulate material generally powder which are both metals as well as non-metals and the most common non-metals that you will use are ceramics. So, ceramics are the most other common material class of material that are used for powder metallurgy or powder processing.

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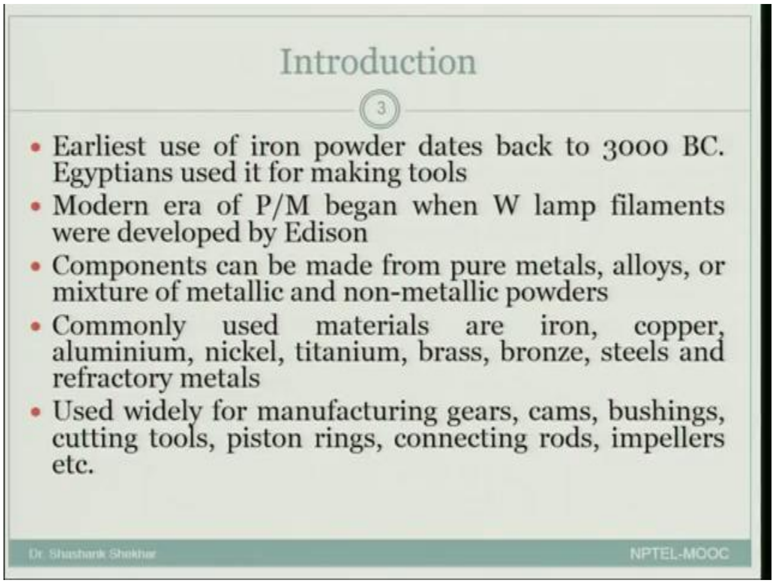

So, let us get some introduction about it. It is not that powder metallurgy is a very modern technique like solidification it has also been known to man for centuries not in centuries millenniums earlier. One of the earliest use of iron powder gets back to 3000 BC and Egyptians use to make tools and you will can you relies that we have still making use of powder metallurgy for making tools. So, in terms of the overall development we have although we may have seen from a so many a leaps and bounds but we are still using similar kind of knowledge base as as per as it comes to powder metallurgy or even solidification that we discussed previous to this.

Now, this modern era of powder metallurgy began when tungsten lamp were developed by Edison. So, this is another very common application of powder metallurgy. The filament that you see that is being used in the incandescent bulb is actually manufactured using powder metallurgy technique. So, you again take some powder of constraint and then press it and get required shape and the size and you can realize that solidification type of technique can be so difficult for constraint why because constraint is very difficult to a very high melting point temperature.

So, you will require immense amount of energy to melt to a constraint and then solidify it even you can for material metal processing technique would be little difficult because having high melting temperature also implies it has very high toughness and very high strength and high modulus. So, powder metallurgy is powder processing is one of the most viable routs for making these incandescent bulb filaments the constraint filaments. Of course now, we have switched on from incandescent bulbs to other forms of the light but incandescent bulb is still a very popular and widely available.

Components can be made from pure metals, alloys or mixtures of metallic and non-metallic powders. So, again this synthesizes the track that powder metallurgy is not powder metallurgy but it is powder processing, you can use metals, alloys, mixtures of metals and non-metallic powders. So, you that is in fact also one of the advantage because you are able to mix metals or alloys or in metals and powders. One of the most sited example of powder metallurgy is cermet's.

Cermet's is a mixture of ceramics and metals which is again used for making tools, cutting tools etcetera. Now, this is a combination of materials which is not possible through any other manufacturing technique. So, that is why powder metallurgy has again so much prominence because you can some other things that you can make through this is not at all possible using other techniques.

Commonly used materials for powder metallurgy or powder processing are iron, copper, aluminum, nickel. Platinum, brass bronze, steel and refractory materials. So, if we had mainly talking about here metals although ceramics are included. The ceramics are although silicate and carbonates or even other if you ceramics we are not going into that because overall the process with remains same but understanding the science of powder metallurgy will be easy or going a dealing with this metals because when you do not to worry about the inter metallic or the inter compound bounds and the all those things.

So, we are only concerned about metal powders and the bonding between the metal powders, bond between your metal powders from each other. It is used widely for manufacturing gears, camps, bushings, cutting tools, piston rings, connecting rod, impellers and the list goes on but these are some other most common and gears actually one of the most widely cited as wee as the cutting tools. These are the most widely used applications for powder metallurgy or powder processing.

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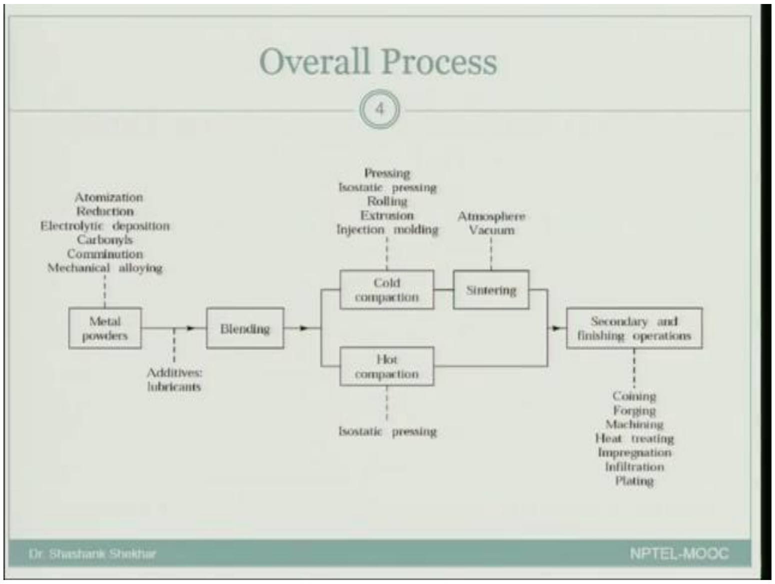

So, this slide gives you a brief summary of what is the overall process used and as we will see this is how our lecture will also proceed or (the) will also follow the same outlay. So, first is a metal powders or basically manufacturing of the powders. For. Example, you can make powders by atomization, reduction, electrolytic deposition, carbonyl method, mechanical alloying.

So, these are some other methods that are very commonly used to make metal powder because to begin with you need to make the metal powders which is it's not that in nature you get the metal powder as it is you have to make this very fine small products powders and when we say powder you should start thinking what is the size that we should be we should be talking about is it few nanometer, tens of nanometer, microns, few microns or even millimeter, which of these should be called powder.

So, you should start asking that question and will answer that may be towards the, when we start talking about the characterization. Now, once we have the powder you can it blend it, you can alloy it you can have simple pure material depending on you're the component that you want to make and the design that you want to followed. So, you can made it make it or blend it and you can also add some additives which will act as lubricants to make the process of a compaction is here. Which is the next process?

Now, in the next process you can do is either old compact and then sinterate, cold compact is basically done at very low temperature room temperature and an sintering is done at vary high temperature they have own purposes when we discuss about then in more detail but it is suffice to say now that in cold compaction you are bringing the metal powders or whatever the powders you have together in a desired shape. And in the sintering (you) what is happening is at the micro structural level (the powders part) the powder partials are getting bonded with each other to form grains.

So, these are two different steps but these can also be (compon) combined if you use the process like hot compaction. So, you have compaction even when we are doing the compaction you can actually do simultaneous sintering or basically both the process gets merge into one. So, you are doing a macro-structural compaction and the micro-structural compaction at the same time.

And after this process is complete when the sintering or the hot compaction is complete there may be its not very usual in powder material, there may be some secondary requirement secondary operation requirements to get it into the final check but most of the time powder metallurgy is called a near net shape process meaning we do not need to do a secondary process so which is again one of the advantages of powder metallurgy process, we do not need a secondary process. But if you need secondary process then how that is has to be done after sintering and some of the secondary finishing operation are listed here coining, forging, machining, heat treating, impregnation, infiltration, plating.

So, impregnation and the infiltration are processes which are probably required only in powder metallurgy because you will have some another porosity and in some examples some cases we may one to utilize that porosity is by putting some oil as a lubricant. So, you will impregnate oil into that porous pores and in the you will be able to utilize a lubrication properties for. example in the wall bearings or some piston. So, we do not need to have any additional mechanism of lubrication. So, that is again another advantage of powder metallurgy powder processing.

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So, like we said here is again brief description of the methodology that is followed to make fine metal powders and sorted and sorting is another important thing that you see when we are talking about characterization. Now you make powders but the powder may have range of distribution start for. example, if we are talking you cannot say we have only ten micron powders there may be five microns is also in their… even there may be hundred micron powder.

So, you have to sort it you have to for. example, if you have a particular application you have seen that your compaction is just achieved for a very narrow range of 10 to 12 microns then you have to ensure that you only get powders of those size range and not anything beyond that otherwise if your compaction suffers then the properties and micro-structural properties will also suffer.

Next step is to mix powders to get alloy. So, under again I like a set this mixing is another advantage of a powder processing because you are able to get alloys not only that common usuall alloy but also the alloys for which you would not be able to otherwise achieve that solidification. For, example, for something for which we do not have solid solution formation allowed so you those kind of alloys can be formed if you use powder processing by which just by mixing the two powders and of course even non-metals non-metals and non-metals. So, you can get something like Fe and Al2O3 kind of mixture or Fe and SiO2 kind of mixture.

So, those kind of alloys are also possible which we been which you will not think possible or not very easy to achieve by other techniques particularly for. example, solidification. Then what you need is compaction like I said you will compact it in the desired shape whatever is the shape that you have for the particle for the component you will have a die for it we will put the powder at powder particles together and put it in the die ends supply other in large pressure we are talking about on the order of 100 to 300 tons of pressure.

So, that pressure what it does is brings together the particles closer close enough to each other and there is some steps going for. example, if we are talking about metal powder and first rearrangement of metal particles are takes place to reduce the porosity then in the second case some amount of deformation of the powder particles takes place at the surfaces to bring the particles closer and to reduce the porosity but beyond that it cannot be done in compaction in fact even before compaction you need consolidation where you put the powders together to get rid of any air pockets inside it and get rid of and ensure that there is minimum amount of porosity to begin with.

So, consolidation which is not listed here is also a process after alloying and mixing. So, mixing then consolidation and then compaction, and in the compaction we will get density of the order of 70 percent as you can see it is very low density but in compaction this is as well the density you will get, and it will not have sufficient strength. When we put the material and if an apply a small amount of a let us a bending strength bending stress on it, it will break and it is called as a green compact meaning you have just put together it is just a structural component you have put it together but it does not have the final component shape and desired properties. It is just put together for the next step and the next step is sintering.

So, you use some controlled atmosphere for. Example, you are using very high temperature. So, you may desire no oxygen or some inert gas atmosphere and then you heat the material to 0.75 or fix melting temperature in kelvin. So, expose it to a very high temperature so that the diffusion process and other mass transfer phenomenon become very high active and it allows the mass to move from one point to another and here you will see when we discuss more about sintering that the pores to start to get filled because of this mass transfer phenomenon becoming active at such high temperature and it is because of them that the particles actually now start to bend blend together and they start form grains.

So, instead of being individual particles with your spores they becomes start to become grains. You will start to see grains boundaries at the interface and even the even the porosity is decreasing it also means that the part is shrinking and the parts will reduce to a some 10 to 15 percent reduction there were reduction in size. The density when the part showing and the porosity goes away but the also increases as you can realize.

So, the density increases up to 95 percentages remember in compaction we have density up to 70 percent but in sintering we may get up to 95 percent and this strength and parameters like toughness give a proportion to density. So, can get 95 percent, 96 percent, 97 percent those are very good density and it will give you provide you as much go strenght and ductility and toughness.

So, in usual or the traditional sintering processes you can get up to 95 percent but if use some unconventional means like spark plasma sintering you may get even up to 98, 99 percent of theoretical density and these are again some other powder metallurgy net shape parts that are formed and you can see almost common form is the gears but even other shapes like camp extra are available and the advantage is that it saves machining time.

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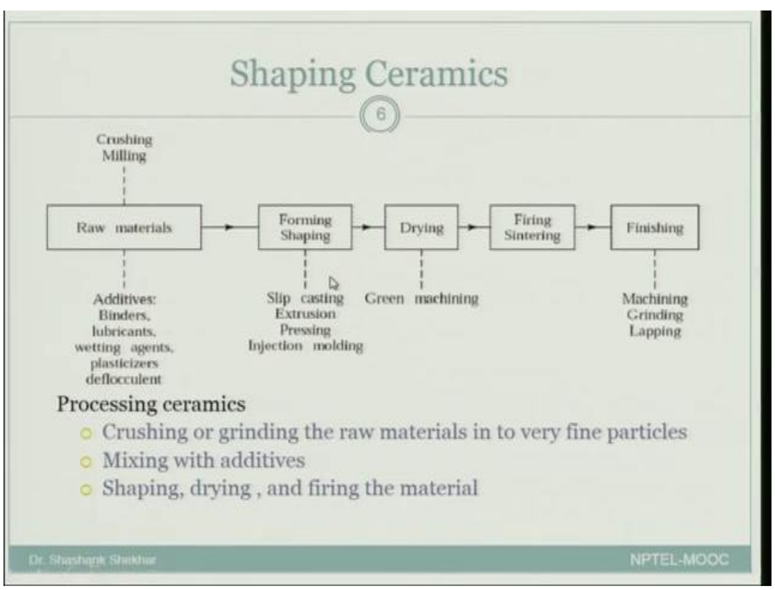

Now, when we are talking about powder processing we looked at the method or the steps involved in a powder metallurgy. So, it was also time to looked at the steps involved in powder same shaping ceramics. So, when you have using ceramics and you will see that the overall flow of the process is not very different. So, you have to first create raw materials for. example, like crushing, millings or extra and then along with some binders some additives which will add as lubricants general if you as binders, you put them together and you get a forming shape.

For. Example, it can be slip casting, extrusion, pressing or injection molding. So, this is a similar to our compaction method and then you do the drying. So, this is over here for not really a compaction this is a consolidation and drying is your compaction. So, this is consolidation and compaction that we observed in powder metallurgy process. So, when you dry it gets structural strength most of which structural strength that so that you can mold it on its own but it is not the final component and that move we as to final desired property and then you do the sintering which is again the sintering that we get in the metallurgy powder metallurgy process and over here the particles start to bind together with each other and then you may or may not require some other finishing operations like machining, grinding or lapping.

So, what are the processing of ceramics crushing or grinding, mixing with additives, shaping, drying and firing the materials firing the material that you want to get the shape to it. So, these are the steps in involved for ceramics and as if we see it is very similar to that we do for powder metallurgy.

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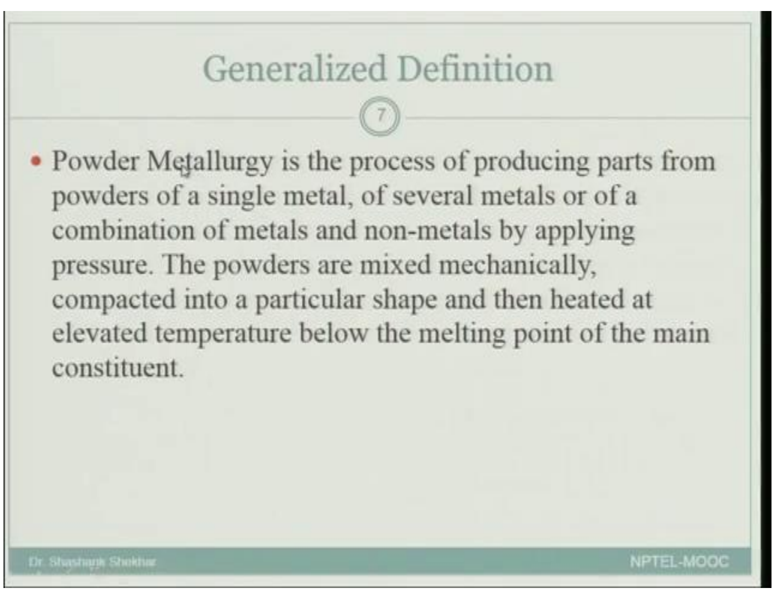

So, if at this stage it will be apt for us to have a more generalized definition which includes not only metals but also other classes of materials. So, powder metallurgy or let us say powder processing is a process a producing parts from powder of a single metal, of several metals or of a combination of metals and non-metals by applying pressure. The powders are mixed mechanically compacted into a particular shape and then heated at elevated temperature below the melting point of the main constituent.

So, very close to the melting point and at less than the melting point obviously. So, you will do the sintering operation of the main constituent to get the final desired component with desired properties. So, this is not only a generalized definition but it is also involve involves all the processes that (al) also discuss all the processes or a steps that will be involve in powder processing.

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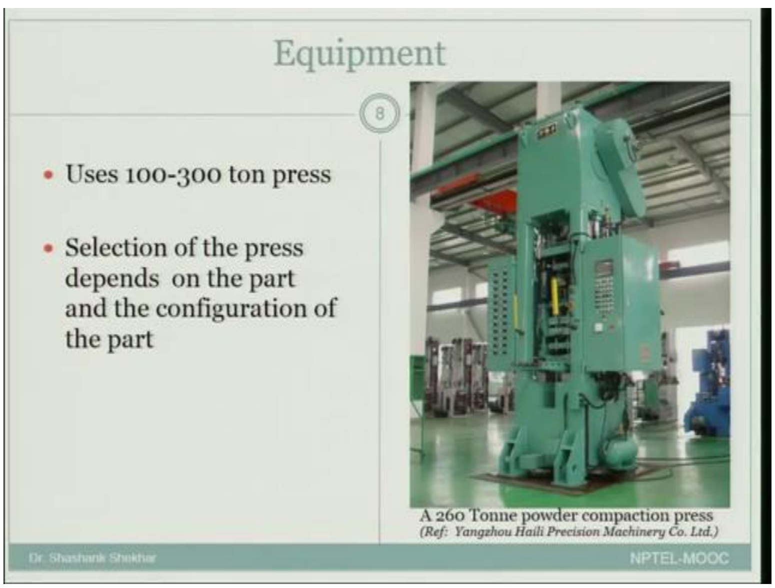

So, let us look at the kind of equipment that will be required when we are talking about powder processing. So, this is one equipment like I said, you will need I will need 100 to 300 tons size of press for compaction of the powder. So, you can see this is very very huge press and of course it will be very cost intensive. So, this is one disadvantage of powder metallurgy or powder processing that the initial investment cost is very large so you have to buy something like this to be able to compact or consolidate the powders powder particles together. So, this is a 260 tons powder compaction press. So, this is a from this particular company and it is a very huge and very cost intensive component and the selection of the press depends on the part and the configuration of the part.

So, if you have even larger component you may need to go to a even higher size can press. So, this is the usual 100 to 300 in ton but these are for user components small size components but if you are making for making the even larger component then you may have to apply or (may) you may need a press greater than higher than its capacity.

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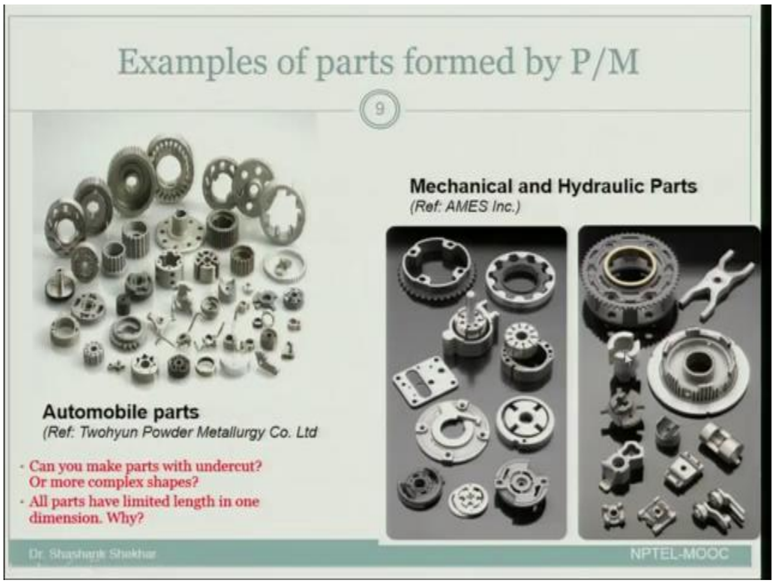

And this slide shows some of the examples of parts formed by powder metallurgy although we have shown a lot more but here it is shown you as classification. So, here are some of the automobile parts. So, these are various automobile parts that are manufactured using powder metallurgy technique and again you can see a lot of gear like parts gear and camp like a parts are formed and planar two dimensional parts and these are some (mechani) mechanical and hydraulic parts that are formed using powder metallurgy techniques. So, at this point you would start to know that they none of these have very high complexity as as per as under cuts or over cuts are concern will not see any part which has under-cut.

Under cut is something where are parts reenters into itself. So, those kind of to the shape we do not see over here and not only that you also see that most of the most of them have only two dimensions where basically most of them are flat in shape not any complexity in third dimension. So, whatever is the shape in the two dimension is what is carried in the third dimension and that is because you are applying a pressure.

So, you are applying a pressure from bottom and top. So, whatever shape (you) that you provide is like this and therefore, that shape that you obtain are two dimensional in nature, and it does not have any ability to provide complexity in this third dimension. You can get whatever complexity you want in the two dimensional but not in the third dimension. And that is why most of the time the parts obtained using powder metallurgy it's said to have 2.5 dimensions and in 2 dimensions in the plane and 0.5 meaning when in some limited amount of complexity or shape in the third dimension.

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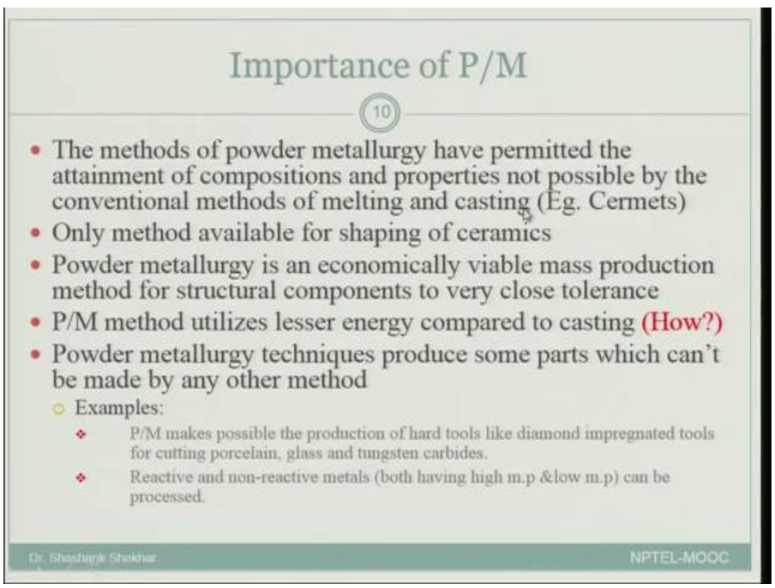

So, now that we have talked so much about powder metallurgy. Now, let us take a look at importance of powder metallurgy or a why is it so important? Some of these things we have already test upon earlier but it is a good idea put them together at one place. The method of powder metallurgy have permitted that attainment of compositions and properties not possible by the conventional methods of melting and casting and biggest example of this is Cermets.

So you are able to get ceramics and metal which combined together into one component which is not possible by any other technique it including the melting technique and you may even get like I said earlier you may even get mixing of two parts or two element, two components which have a very wide melting points.

So, for example, one may be metal, other may be ceramic or even two metals which do not have solid diffusivity or solid state (solu) solid solutionizing in each other, you can make alloys of those kind. Now, powder metallurgy is the only available method for shaping of ceramics, for metals we have seen solidification is one and in the part two of the lecture also you can talking about metal processing.

So, metal processing is another technique. So, metal have various techniques because they are ductile and malleable, but for ceramics powder processing is the only method that is available for giving them shapes and forming components out of it. Powder metallurgy is an economically viable mass reduction method for structural components to very close tolerance. So, one of the important things that are it has depend earlier was that it is an net set process we do not usually need a secondary finishing operation and not only that once you have got ton press like that have large ton press like that you can keep manufacturing large quantities of components of desired shape.

So, you have to just make new dies of required shape and you will be able to get the desired shape and any number of shape until the die wears out. So, this is a economically viable mass production technique for structural components and close to tolerance and very close to the tolerance because you do not need secondary operations in most of these cases you can actually credit how much shrinkage will appear and therefore, you know what will be the final shape and size of the component even though you will be getting some amount of shrinkage taking place.

Powder metallurgy method utilizes lesser energy compared to casting. So, now this is another advantage of powder metallurgy or powder processing. It will use lesser energy particularly when we are talking about metals or even ceramics and the best example was tungsten. So for. example, here you are not usually melting the liquid un unless you are a powder production technique itself required melting that’s why you are getting powder for using the powder size the particulates from some technique like attritions or mechanical attrition of some to them.

In those kind of metals you are not really melting. So, there do not have to take you do not have input energy to increase the temperature although to the melting point and then give it the heat of fusion to melt it and then again raise the temperature above well liquid melting point. So, you are giving much lesser energy for processing and therefore, it is a much utilizes lesser energy compared to casting.

Powder metallurgy techniques can produce some parts which cannot be made by other method and examples are like this powder metallurgy can make possible the production of hard tools like diamonds impregnated cutting tools. So, again you are diamond is your second phase (which is)which has properties very similar to ceramics and you can impregnate them in a metal phase. So, in the metal metal will have the ductility and (made) diamond will have the high gear resistance and high hardness.

So, you will be able to get good hardness and good gear resistance and at the same time good toughness because of the presence of metal matrix, and this can be used for cutting porcelain, glass and tungsten carbides. Reactive and non-reactive metals can be processed and that is again another important thing you would not be able to get this two or kind of materials like the reactive and non-reactive material metals together in solidification, they it start to react but using powder metallurgy you can put them together and not only that both having high melting point and low melting point that we have already discussed up on earlier that in metals we even though within have very large difference in melting point you can process them together.

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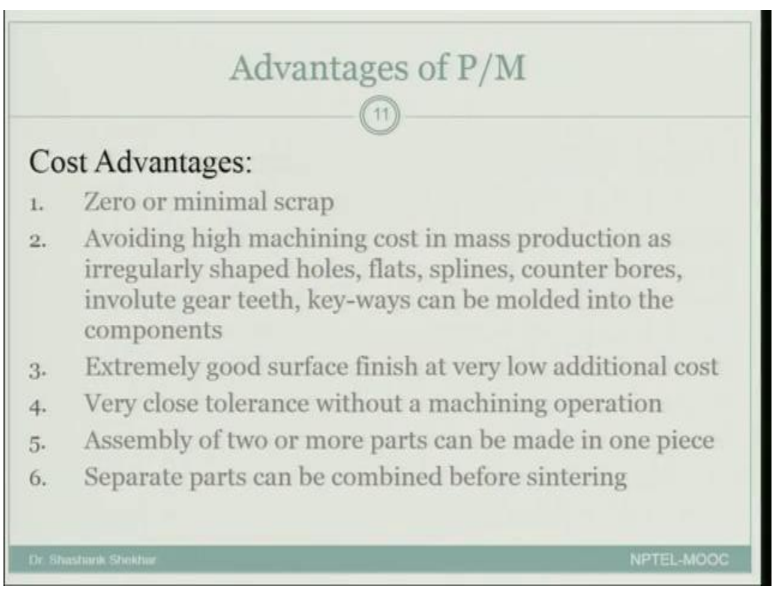

So, now it is time to compare what are the advantages of powder metallurgy compared to other some techniques available for manufacturing.

So, the one of the advantage in terms of advantage we can say is cost advantage and why are we getting cost advantage because here you do not have any scraps like we said that you put the die, you put the powder particles is together compact them and make the design.

So, you are not really wasting any thing, for. example, in metal processing particularly you have a lot of wastage even in solidification there is a lot of wastage although it is recycled but during the recycling a lot of impurity gets added on. So, the cost advantage is not as good as in terms of powder metallurgy when we are talking about minimal scrap. So, you here scrap is so small that it can be not small in fact it is zero but that is not true for other manufacturing techniques.

Avoiding high machining cost in mass production as irregularly shaped holes, flats, splines, counter bores, involute gear teeth, key-ways can be molded into the components. Now, let us take the example of gear which is the most common example that we know about powder metallurgy. So, the gears usually have taken. Now, if you have to do machining if you have to manufacture the machining the you will have to (machine) so many steps.

So, there will be a step by step so many steps involved for each step there will be machining and then we go to the next step the again machining. So, it will involve a lot of cost and the other hand if you are using powder metal powder processing technique then you have the die of the desired shape and then press it together and compacted. Now, then once you have compacted it you have got a die. You just open it you will take it off and put another for another set of powder particulates into that and you get another die or another gear out of it.

So, that becomes a very easy and easy to skill process but that is not the case when we are looking at some other technique like metal more processing. So, these kind things particularly the gears, holes, flats something where you have to do additional machining those kind of components which can be easily manufactured using powder processing. Now, you can see why these are the kind of components mostly preferred for powder processing. You wouldn’t see for. example a engine block be manufactured by powder processing one because it is very large and second because it does not involve so many operation in process.

So, that is why there the cost intensive is not as much as for other processes for other components. Another advantage is extremely good surface finish at very low additional cost. Now, when you are very close to the melting point. So, the surface also takes the contour of your die and therefore, you get a very good surface finish and that is without any additional cost meaning you do not have to do machining or even polishing or any kind of secondary operation on the surface, very close tolerance without machining operation.

Again this is what we have emphasized so many times that you can predict what will be the total amount of shrinkage and therefore, the final part can be produced very close to its final tolerance and therefore, secondary operations will not be involved. Assembly of two or more parts can be made into a one piece. So, some of the components which we are to be produced separately you can produce them together if using powder processing because now you can put them in one die, but die can have the shape or the overall component.

Separate parts can be combined to before sintering and even if you have manufactured them separately then you can still sinter them together that where you are able to avoid the cost. (So that) So, these are the some of the cost advantages of powder processing we will look at some more advantages and then disadvantages of powder processing in the next lecture. Thank you.