Powder Metallurgy
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Lecture - 01
Introduction to Powder Metallurgy

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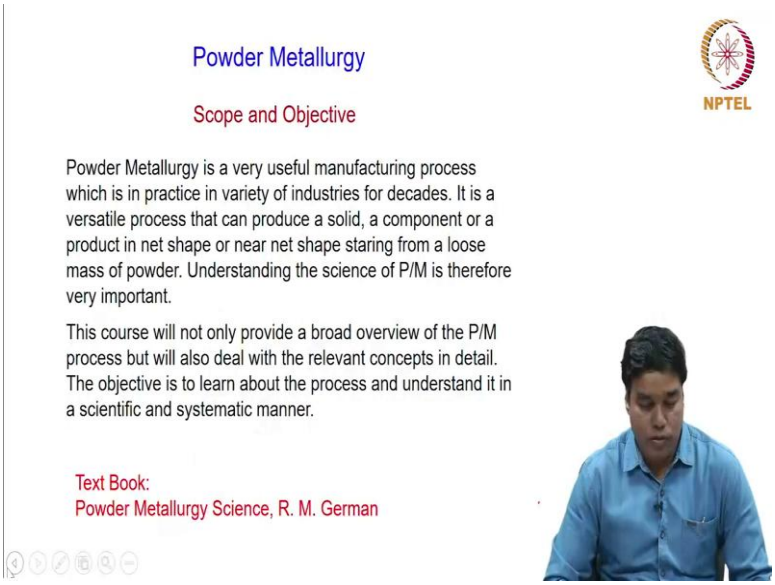

Hello everyone, I am Professor Ranjit Bauri from Department of Metallurgical and Materials Engineering at IIT Madras. Today we are going to start this new NPTEL course on Powder Metallurgy. So, to start with let me tell you what is the objective of this course and what is there in the syllabus of this particular course.

Powder metallurgy is a very useful manufacturing process which is in practice in various industries for a long time, it is a versatile process that can produce a solid, a component or a product in net shape or near net shape starting from a loose mass of powder. Therefore, understanding the science of powder metallurgy is very important.

This course will not only provide a broad overview of the powder metallurgy process, it also deals with the relevant concepts in detail. The objective is to learn about the process and understand it in a scientific and systematic manner.

So, in a nutshell the main objective of this particular course is to learn in great detail about the entire process of powder metallurgy as to know, how it is done, what are the

relevant mechanisms and concepts and all other details associated with this particular manufacturing process called powder metallurgy. And the reference book for this course is "Powder Metallurgy Science" by 'R. M. German'.

In fact, this book is known as the bible of powder metallurgy. So, you can refer to this book for most of the things which will be covered in this course.

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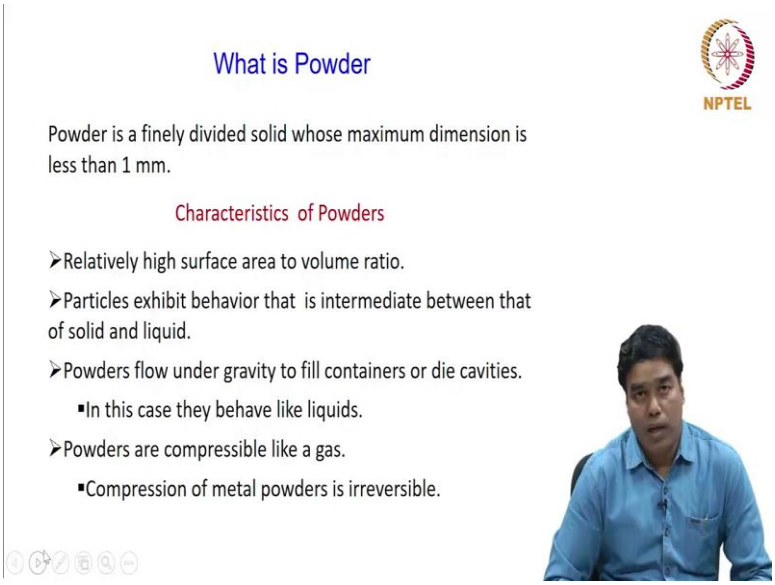

I suppose you have already gone through the syllabus and you have seen what are the topics which will be covered in this particular course and that the different categories or subtopics which are there under each of these topics. The first thing that you start with in a powder metallurgy process is the powder itself as I was mentioning. So, let me tell you what is a powder?

So, first you need to understand what is a powder right. So, a powder can be defined as a finely divided solid whose maximum dimension is less than 1 millimeter. In a broad term that is how you can define a powder. Furthermore, a powder should also have a certain characteristics which are listed over here as you could see and the characteristics that a powder should have are as follows.

It should have a relatively high surface area to volume ratio, the powder particles exhibit behavior that is intermediate between that of solid and liquid. For example, powders flow under gravity to fill containers or die cavities and in this case they behave like liquids

because they are flowing and they can go to different places inside the mold for example, when you are molding the powder.

So, like how a liquid flow the powder particles can also flow and that is why it is said that their (powder) characteristics is in between that are solid and liquid. Powders are compressible like a gas and compression of a metal powder is irreversible; that means, once you compress it or compact it you cannot get it back the powder to the initial condition.

So, these are the typical characteristics that a powder should have apart from the fact that the dimension of powder particles or the solid which can be called a powder should be less than 1 millimeter. So, that is about the powder.

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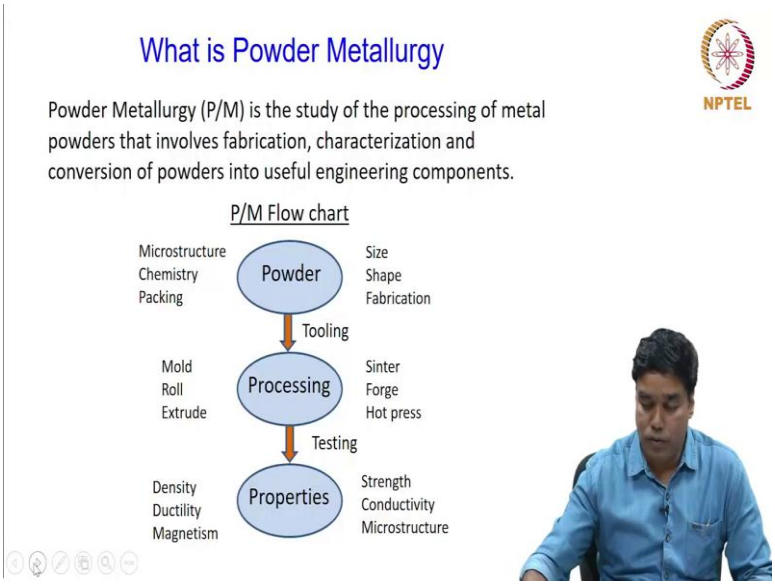

Now when you say powder metallurgy as I said in the beginning of the introduction powder metallurgy is a whole manufacturing process which can be used to make products and components. So, powder metallurgy can be defined as the study of the processing of metal powders that involves fabrication, characterization and conversion of powders into useful engineering components.

You start with the powder and then you can make components, or you end up with a final product. So; that means, the powder must go through certain steps or certain

processing for you to get a useful component or a useful product at the end of the process.

So, that is how you can see it is listed in the powder metallurgy flow chart (above diagram) as you could see over here, you first start with the powder and you have to process the powder to get a particular component or a particular product it is with required properties.

So, to process the powder you need certain tooling which can process it in a particular shape and things like that. Once you process the powder into a solid you need to test its properties. This is to know whatever the desired properties which you wanted in a particular component or in a particular product is there in the final part or in the final product which is coming out at the end of the powder metallurgy process.

To check these properties, you need to do some testing. So, that is how you can see how the flow chart goes over here powder then with the tooling you process the powder and then you want to get certain properties. So, you need to test it to get to know whether those properties are achieved.

In each of these steps you have a certain parameter that you need to consider. For example, when you talk about the powder itself, the powder has certain properties or certain characteristics in terms of the size and shape.

The fabrication process that is being used to make these powders and apart from that the powder also have certain properties like the microstructure, the chemistry of the powder and also the packing.

All these parameters will decide how the processing would be because the powder must be packed first in a particular shape. So, how that packing would be that might depend on one or more of these parameters which are listed over here like size, shape or microstructure, chemistry packing and so on.

So, before starting the processing these factors or these parameters must be evaluated. This is to know what kind of powder we are dealing with and what it might lead to when you process the powder for making a particular component of product.

Now, in the next step while you process the powder as I said before also you need certain tools. For example, you must mold the powder in a dye and then it has to be compressed. To do this job you need the dye and the punches which will compress it and also a press which can apply the pressure on this loose powder and give raise to a compact which can be further processed.

So, here the parameters or the process could be molding. The other process or the tooling other than molding, it can be rolling or extrusion of the powder to give it a particular kind of shape and compact it. And on the other hand, once you have the compact after either molding, rolling or extrusion you need to finally, close all the pores which are there in this compact.

Finally, at the end you come up with it fully dense solid. So, the final product that you need to produce would be fully dense and to achieve that you need to either sinter the powder, forge it or hot press it.

These are all known as high temperature processes (sintering, forging or hot pressing). These processes will make sure that whatever porosity is remaining after molding, rolling or extrusion after the compact is made through one of these processes.

These high temperature processes will make sure that the pores are closed and at the end you get a fully dense product. So, this is how the powder will be processed with the help of certain tools and certain processes like sintering, forging or hot pressing which happens at that high temperature.

Now finally, once you make a solid part out of it, you also look for certain properties which could be any of these for example, you look for strength, you look for conductivity or you look for a particular type of microstructure which can again give raise to certain type of property that you need in that particular component.

And, the other properties that you may look for is the density as I said at the end you have to have a product or a component coming out from the process which should be fully dense. So, you need to evaluate and measure the density.

And then when you talk about mechanical properties you also have to see what is the ductility of the final product and other properties like for example, magnetism. So,

depending on the requirement or what the property is that you are looking at, you do the testing and evaluate those properties.

To summarize, the powder metallurgy process it starts with the powder, the powder is processed into a compact or into a particular shape which could be the neonate shape also. And then it is densified with the help of a high temperature process like sintering, forging or hot pressing and then once you obtain a final fully dense product you evaluate the properties depending on what are the requirements or what are the properties that you are interested in it.

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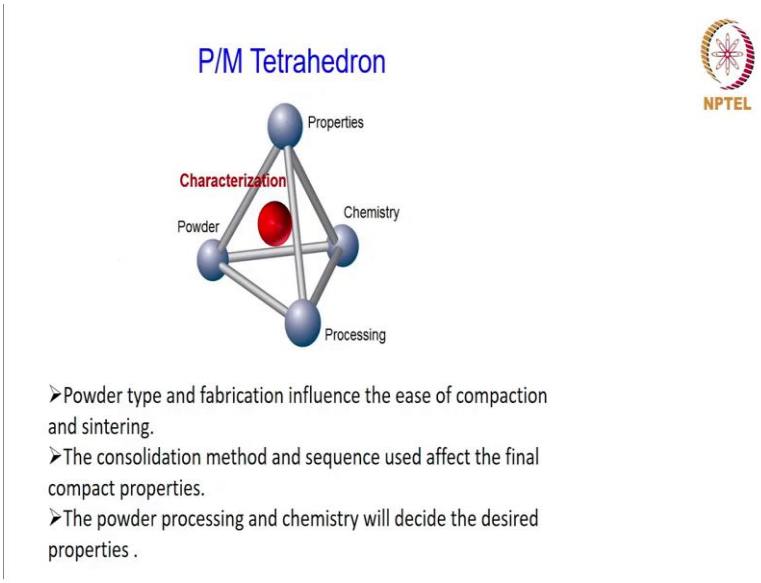

How this processing and properties are interrelated or correlated that can be understood with the help of a diagram like this with the help of this tetrahedron (above diagram) which is known as the powder metallurgy tetrahedron, where you can see in each of these vertices you have these four different parameters. Starting from the powder, processing, chemistry and the properties.

The way these things are correlated, you can easily see it from this diagram. For example, the powder is related to how it can be processed or how easily it will be processed or whether it will be difficult to process that would depend on the characteristics of the powder.

For example, the powder type and the fabrication that can influence the ease of compaction and sintering, because what do you do while making anything out of a powder you first compact the powder into a particular shape. So, you try and give it a shape in the beginning by compacting it and then you sinter that compact to close all the pores and come up with a fully dense product.

So, how the powder is in the beginning in terms of it is type or the fabrication process which is used to make the powder that will influence the ease of compaction and sintering. So, that is how these two this is powder and processing are related to each other.

Similarly, how the powder is processed will influence the final properties and in between you have chemistry because chemistry also has a lot to do with the processing and also the properties, if you change the chemistry of the material that will also change the properties.

So, this is how these vertices are correlated to each other, this is what we call it as a structure property correlation. Where you make something, you process something which will give raise to a particular chemistry or a particular structure and the properties that you obtain finally, that would depend on the structure.

On the other hand, the structure of the final product is depend on how the material is processed. As I said in the case of powder metallurgy in this case processing would depend on what kind of powder you start with. So, this is how with the help of this powder metallurgy tetrahedron you can see how these four things are correlated with each other.

Now when you look for the properties or you want to know the chemistry you will have to actually test the material, you have to measure it then only you can know a particular property whether it is achieved or not in that particular compact or in that particular component which is made out of the powder. So, to know that you need to characterize the processed material.

That is why characterization is at the center of this tetrahedron because for each of these that you want to know whether it is the chemistry or it is any particular property you

need to actually test it. And to test it, you need to characterize it, you need to measure that particular property using certain tools.

So, that is why you need to bring the process of characterization here at the center because for each of this you need to characterize for example, if you need to know what kind of powder it is, the type of powder then you need to actually see the powder under a microscope and look at the powder particles. So, that is a characterization tool in that case which you use to get to know about the product type. Similarly, if you want to measure any property you have to test it right using a particular instrument.

One may ask a question as to, why powder metallurgy and why not any other process? Or in other words, what is the advantage of a powder metallurgy over many other manufacturing processes which are available. So, let us try and understand as to why powder metallurgy and what will be the advantage of powder metallurgy over many other manufacturing processes.

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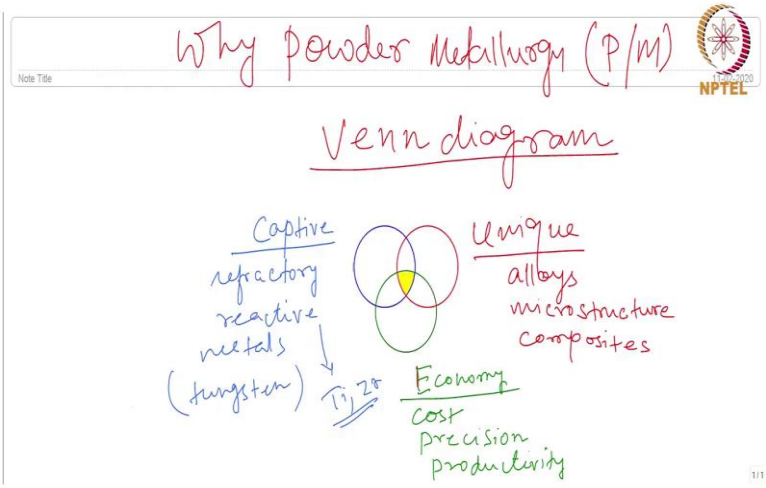

Why powder metallurgy? this can be understood with the simple Venn diagram (above diagram) which will show up the capability of a particular process. And, as far as the powder metallurgy process is concerned with the help of this diagram we are going to see what are those capabilities that powder metallurgy process will offer and how it is different or how its advantages compared to other processes.

So, this is how a Venn diagram (above figure) looks like and each of these circles can be associated with a particular property or a particular capability. Let us say for example, this first cycle (red color circle) that you have let us say that is talks about the uniqueness of the process which can be in terms of the material like the alloys or a particular type of micro structure that one wants to produce in a particular alloy or in a particular material and a particular type of material that somebody want.

Let us say for example, you want composites which are combination of two or more materials, so that can be done with this process of powder metallurgy. We can also make certain alloys; that means, we can have different chemistry and come up with you know different kinds of alloys you can also tail up microstructure and so on.

So, that is the uniqueness of the process and then when you talk about any manufacturing process the other aspects that you will have to consider is of course, the economy (green color circle). Because, when you are comparing this process with any other manufacturing process you also have to look at the cost whether it is cost effective or not compared to many other processes.

When you talk about cost use would also look at the precision and the productivity because these two are also related to that total cost of the process. For example, the data production or the productivity would of course, lead to you know how higher or lower costs depending on whether you have high productivity or low productivity.

And then the third circle (blue color circle) can be assigned to another capability of the process which is captive; that means, this process is capable of processing materials which are difficult to process by other conventional processing or manufacturing roots.

For example, refractory or reactive metals like tungsten which is a refectory metal, refectory metal means the melting point is very high so, it is difficult to melt. So, let us say you want to use a conventional manufacturing root like casting then you will find it difficult to melt because in casting process you have to first melt the material and then cast it and solidify it.

So, since it is a refectory metal if you want to use a conventional processing or manufacturing root like casting it is going to be difficult, but powder metallurgy can

easily handle that and overcome the difficulties that you might face while using a conventional manufacturing process.

Similarly, if you have reacting reactive metals for example, titanium, zirconium and this kind of metals which are prone to oxidation if you process them at high temperature anyway you will have to process it at high temperature.

These kinds of metals are prone to oxidation or other reactions and that is why this kind of reactive metals are difficult to process by conventional processing roots, but powder metallurgy can easily take care of that.

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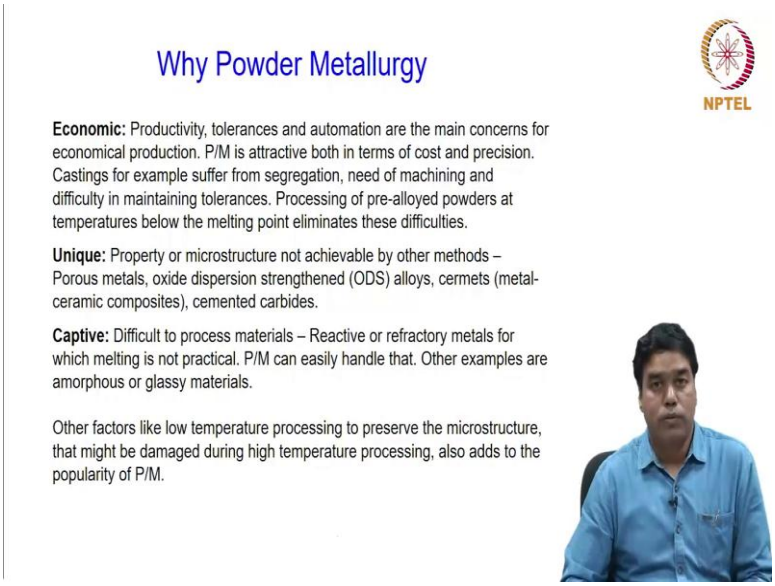

So, if I can elaborate on this, these are those three capabilities of this powder metallurgy process starting from the economy which also concerns the productivity, the tolerances and automations.

Hence, powder metallurgy is attractive both in terms of the cost and the precision because as I said in the beginning it can also make the product in net shape or near net shape. So, your requirement for machining and things like that is much lower so, it can easily make a product with high precision.

Other manufacturing processes for example, castings suffer from defects like segregation and there is also a need for machining and it is difficult to maintain the tolerances. So,

these kinds of difficulties are not there in case of a powder metallurgy and that is why this is attractive in terms of both economy, productivity and the tolerances.

Moreover, processing of pre - alloyed powders at temperature below the melting point also eliminates many of these difficulties which are associated with high temperature processing like you know this segregation porosity and so on.

Then, if you talk about the uniqueness this will come in terms of a property that you are looking for or a particular type of microstructure that you are looking for in the material for a particular type of property which will come out from that kind of microstructure.

Property or microstructure which cannot be achieved by other methods can easily be obtained by a powder metallurgy process. For example, a porous metal, oxide dispersion strengthened alloys which are much stronger, then cermets which is a combination of ceramic and metal that is how the name is cermet. It is a combination of ceramic and metals.

So, you also achieve a combination of properties of ceramics and metals in a single material when you combine them as a cermet. So, this kind of cermet materials can also be processed with the help of powder metallurgy. And other specialty materials for example, a cemented carbide which are again are difficult to process by conventional processing roots can also be processed easily by powder metallurgy.

That is how the process is unique and when you talk about the captive characteristic of this particular process, it talks about the difficult to process materials or the ability of this process of powder metallurgy to handle the materials which are difficult to process by other processing roots.

For example reactive refectory metals as we talked about which are difficult to melt and since you know they are highly reactive and melting temperatures are very high it is also not practical to go for melting and casting root. But powder metallurgy can easily handle that because here you do it in solid state itself and there is no need for melting to process this kind of materials.

Moreover, you can also get a kind of material which may be again difficult to process by other roots; for example, these amorphous or glassy materials which are not crystalline

because what happens in other processes. Like for example, casting, when you cool the material to solidify under equilibrium conditions which is most often the case during a particular process, when you cool it under equilibrium conditions it most of the time it will solidify into a crystalline material.

So, for some reason if you want an amorphous or a glassy material as we call them then it will be difficult to use those kinds of processes. But powder metallurgy if you take care of some of the process parameters you can easily handle these kinds of materials or easily produce this kind of materials.

Then you have other factors like low temperature processing to preserve a particular microstructure, because what happens when you process the material at higher temperatures the microstructure that you want it in the final product may be lost; for example, if you want a very fine grain microstructure.

So, that fine grain microstructure may be lost if you heat it to high temperatures because of grain growth. This kind of requirements can also be taken care by low temperature processing that powder metallurgy can do and this again adds to the attractiveness or popularity of powder metallurgy. So, you know these are the uniqueness or these are the characteristics of this powder metallurgy process.

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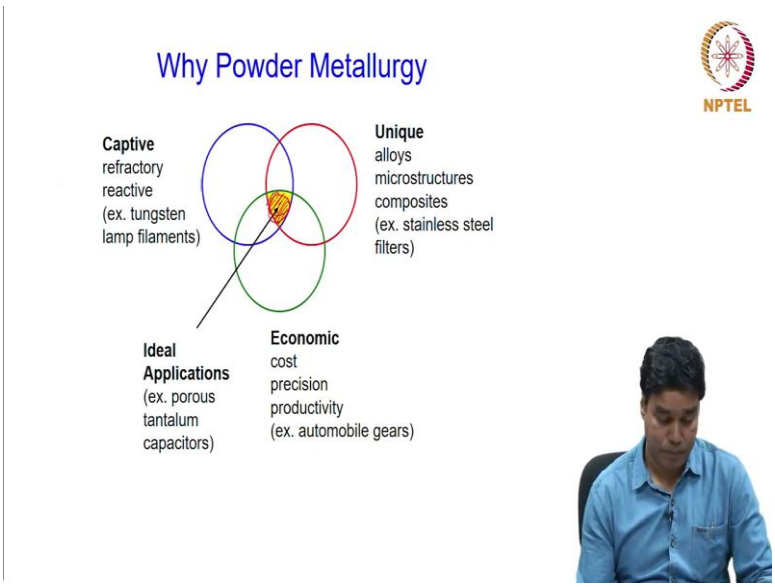

But the biggest advantage that you have in this process is what you can see in this junction (meeting area of the three circle) over here right in this place which is the meeting point of all these 3 circles. So, in this place you have all these three characteristics present so; that means, powder metallurgy can be an ideal application for making materials or making components products where you can combine all these characteristics in one process itself.

So, it could be ideal applications for specialty products for example, like a porous tantalum capacitors and things like that because it can combine as I said all these unique characteristics of a manufacturing process. So, this is why a powder metallurgy is so attractive and this is why people go for powder metallurgy, because of it is uniqueness and how it combines all these three categories or all these three different characteristics into one single process.

So, with this I will stop here for today and from next class onwards we are going to start all the topics which are listed under the syllabus of this particular course and you know talk about them and understand them in great detail ok. So, I will stop here today.

Thank you.