Processing of Non-Metals
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Module - 3
Glass: Properties and Processing
Lecture - 3
Ceramic Powder Preparation

I welcome all of you to this discussion on ceramic powder processing or ceramic powder preparation. As you are well aware that we are now discussing module number 3 in our course on processing of non metals. In module number 3, our focus is primarily on one of the non metals that is ceramics as the course title is processing of non metals. So, our focus primarily is on the processing aspects of the non metals and in this particular module, we have seven different lectures that we have to discuss. In the first two discussions, if you remember in discussion number 1 and discussion number 2, we have focused on the basic and the fundamental aspects of ceramics.

We have seen what are ceramics? From where have they derived their name? The historical perspective of in context of the ceramics, we have seen that how the ceramics can be classified on the basis of the composition. If you remember on the basis of the composition the ceramics can be broadly classified into four categories; that is silicates oxides, non oxides and glass ceramics. On the basis of the applications the ceramics can be classified into a number of different sub categories like advance performance ceramics or simple house hold ceramics cement and concrete bio ceramics and there can be the long list of ceramics on the basis of their applications, so that we have already discussed.

Then we have seen the type of bonding that is there in the ceramics. If you remember we have seen that ionic and covalent type of bond are present in most of the ceramic materials. Then we have try to co relate this bonding with the mechanical properties of the ceramics and we have seen that the ceramics as compared to the metals as well as as compared to the polymers have certain distinct mechanical properties, which make them are different type of a material suitable for processing. Because the processing techniques which are advisable or which are advocated for the use of metals and polymers sometimes may not be relevant or may not be faceable in case of ceramic materials.

We have seen that the melting points of ceramics is very high, the hardness of ceramics is very high, wear resistance is good, chemical and corrosion resistance is also good thermal conductivity in case of ceramics is poor, electrical conductivity is also poor. So, this is just a summary of the properties of ceramics and because of these distinct properties, there are special techniques which have to be used for processing of ceramics. So, this is just the summary of what we have already covered. Again I want to just revise that where this particular lecture fits in in our total course, as we are discussing the codes on processing of non metals, our focus is on different non metallic materials. And ceramics is one important non metallic material so we have divided the whole course of processing of non metals into different modules.

Now, we are discussing module number 3, in which ever focus is on ceramics. So, today's lecture would be focusing on the different aspects of ceramic powder preparations, because in order to formulate or in order to fabricate or in order to process a ceramic product, the powder is one of the most important raw materials, which this finally, blended and compacted sometimes entered also in order to get the final ceramic product. So, we will see that in which particular type of application what are the processing steps for ceramic materials?

But before going into that we should first address the main point, that is what are the various types of raw materials that go into the ceramic products and one of the important raw materials in the processing steps or the procedural methodology for making the ceramic products is the ceramic powder. So, we will see that how the ceramic powders can be prepared. If you remember or you have just heard to that particular lecture that was on powder metallurgy, which was recorded in the phase one, it is still available. In powder metallurgy we have seen that different types of methods are used for processing of powders.

So, today also we will focus on some important aspect of powder processing, but our focus would be that how to generate or create or process or prepare the powders. But in case of powder metallurgy if you remember, we have just focused our attention on the methods of powder preparation and then we have shifted our attention to the powder metallurgy as a technique and seen that what are the other steps which are used for processing of products by powder metallurgy? We have seen the mechanism of bonding

that takes place and certain design guidelines we should followed for processing of good quality parts by the technique of powder processing.

So, powders are an important aspect in some of the processing techniques, just I am giving you the reference of powder metallurgy, because there also powders are used powders are prepared and they act as the raw material in order to transform the raw material into the final products. So, we should have a raw material which can be transformed into a final product. So, in powder metallurgy process also powder metallurgy metallurgy technique also, we have the raw materials as the powder and these raw materials are then processed into a sequence of steps, so that we can get a product.

In that module as well as in that particular course on manufacturing process we have seen that what type of products can be processed by powder metallurgy. But today our focus is on preparation of ceramic powders. So, with this particular introduction, why powders are being produced in order to get the final product and which are the important powder preparation techniques? How the these techniques can be classified? Then, what are the important features of particular technique in case of ceramic powder preparation, that we are going to see.

We will try to understand with the help of diagrams that from where the raw material comes and what is the action taking place? From where the output or the ceramic powder is coming out and different mechanisms are there in an in operation in order to create or on order to process the ceramic powders. So, this is just an introductory a discussion of what we are going to discuss today and what we have already discussed in context of ceramics?

So, we have already discussed a number of things, but now actually the action is going to take place. That is action means now we are going to process the ceramic products. Though now the tangible product would be the output, but before making the product we have to do some preparations. So, today's lecture is focusing on the preparatory aspects, in which we are generating the raw material which would be later on used to process the composes the ceramic products. Now, with this particular introduction, let us start our discussion on ceramic powder preparation.

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So, ceramic powder preparation this is our main topic today. The processing of raw ceramics into ceramic products requires the preparation of ceramic powder. This point I have already highlighted in the introduction to today's lecture, that for getting a ceramic product we required the raw material. The raw material usually comes from the natural minerals they are a different types of natural minerals that exist in the environment and then they are processed. In some cases they may require a regress processing, so that we are going to get the desired characteristics of the powder.

In many cases depending upon the application, we may not require very sophisticated processing of the powders. So, the processing of the powders depends upon the final quality and the application for which the powder is being prepared. So, we can see in point number one, what does this address? The processing of the raw ceramics into ceramic product, so what is the final objective of this particular module? The module is focusing on ceramics and we have to learn various tools and techniques for making the ceramic products because this particular module is falling under the broad umbrella of our course processing of non metals. So, what is the broad objective or mandate of this particular course? To learn tools and techniques, which can be use for processing of non metals. Ceramics have non metallic properties and therefore, we should now the tools and techniques which can be use for processing of ceramic products.

We see in if you remember in our first two discussions ceramics once, ceramic one and ceramics two we have seen, that floor tiles, roof tiles, glassware, cookware, bio ceramics, space shuttle, tiles there are large number of applications of the ceramics. So, what are those? Those are the products which have been made by ceramic as the raw material. So, the processing of the raw ceramics into the ceramic products, so from a raw ceramic material which can be in the powdered form or which is a mineral which is existing in our environment.

So, we have a raw material and it has to be converted into a tangible product. For example, we have we are all of us use a pen is mostly these days are made up of plastic, so we have a plastic raw material, which has been in a way melted or it has been molded into the particular shape in order to get the final product. So, product is a pen, raw material is a plastic. Similarly, ceramic is a raw material and this ceramic product is the final objective of the whole discussion. So, processing of raw ceramics into ceramic products, so if we take step by step approach first step is there on your screen, that is the preparation of ceramic powders.

In order to convert the raw material into the final product, this is an important step. What is an important step? The preparation of ceramic powders. If we compare this with the other processing techniques, for examples for example, as an engineer everybody has discussed or has studied the casting process. So, what are the steps involved in casting process? In casting what we are doing? We are melting the metal and then that molten metal is fold into the mold cavity and it takes the shape of the mold cavity. So, why we cannot do casting of ceramics?

So, this is an important question, which all of you should be able to answer on the basis of what we have discussed in ceramics one and ceramics two. Already we have held two discussions on this particular module or in this particular topic. Why cannot we do casting of ceramics? Yes we do, but it is slightly different, because in casting process, we have to melt the raw material the raw material is a metal.

We are able to melt it because the melting point of metal is lower than the melting points of ceramic. So, we can do the casting of ceramic also, but we require very good or sophisticated instrumentation for that purpose. So, first in first and foremost we should try and learn to understand that why there are specific techniques for processing of

ceramic product? Why cannot the same techniques like the techniques which have been developed, age old techniques which are been use for processing of metals or for processing of plastics, why cannot those technique we use for processing of ceramics?

That is the first point we should be clear in everybody's mind. And the answer to this particular require your this particular, we can say question lies in the discussions that we have already done, that is ceramics one and ceramics two. If we just outline the properties that the ceramics possess, we will be very able very easily able to clearly distinguish that there are few additional, we can say characteristics that the ceramic possess. Therefore, they cannot be processed by the conventional processing techniques.

So, first important point is we should try to understand because in other cases, for example, in processing of metals we are not doing in any preparation we are directly taking the metal melting it or in case of machining we are taking the raw material, we are taking a cutting tool and machining it to get the desired shape. In casting we are melting the metal and pouring it in to the desired mold cavity and we are getting the final product, but here we are doing the preparation before going to the actual processing. So, what is the preparation of the raw material? The preparation of the raw material is that we are preparing the powder of the ceramic.

Why we are preparing the powder? Because the other conventional techniques of processing, for example, for metals and plastic cannot be directly applied, in case of ceramics. So, important point I want highlight here is that, we are going one step below in the processing steps, we are manipulating or we are fabricating or we are processing our raw material and the raw material in case of ceramics is the ceramic powder. So, the first point again whatever discussion we have done till now, I want to summarize it by reading the point the processing of raw ceramics into ceramic requires the preparation of ceramic powders.

So first and foremost requirement is that we should have ceramic powder. Second, the application and quality of the product. Now, whatever ceramic product that we want to produce, for example, we want to produce a cutting tool insert or we want to produce a tile which has to be fitted in to the space shuttle or we have to produce a product which has to be put has a decorative item in our drawing room. So, the application, application can be different. It can be bio ceramic, it can be in electronic industry, so depending

upon the application and the quality of the product, we have to do the powder preparation required.

So, we have to define the type of powder preparation required. So, we may somewhere require a very we can say defined or very fine preparation of the powder, so that we are able to achieve the quality for that the particular application. In many cases as we take the mineral we can process it slightly and bring in to that level that we can make a product out of it. So, we may require lesser processing of the powder or huge or number of steps of processing of the powder depending upon the quality of the final product and depending upon the application for which the ceramic powder is being processed or is being produced.

So, the application and quality of the product defines the type of powder preparation required. There are number of techniques which can be used for preparation of ceramic powder, which we going to discuses today. But first and foremost we should try to understand that depending upon the final application we have to decide that which process we should choose. Next step, the application spectrum of ceramics range is from house hold items to space shuttles. So, because the application spectrum range is from our domestic for decorative item to sophisticated to space shuttles application, we have to focus our attention on the preparation of ceramic powders that what type of powder would be suitable for a particular application?

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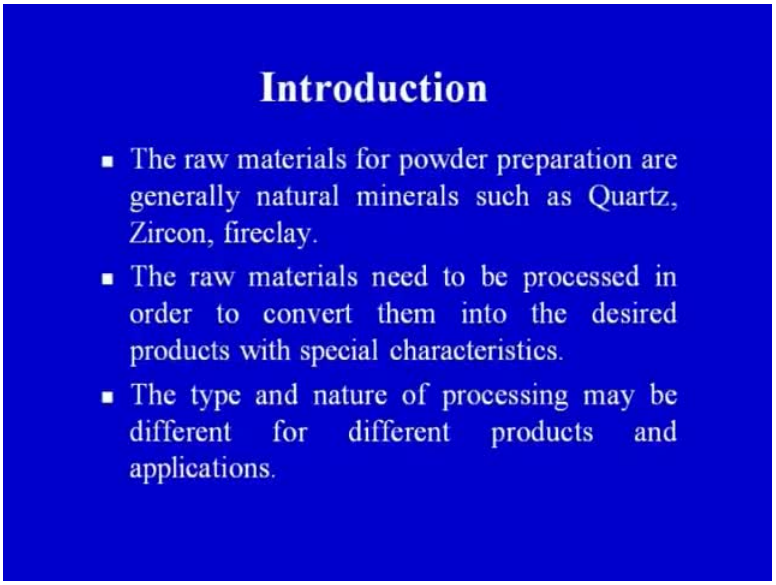

So, that is with this particular introduction let us now move on to other aspects regarding the preparation of ceramic powders. The raw materials, from where the raw materials will come? Because we need to have material, which we can process in to a powder. So, the raw materials for powder preparation are generally natural minerals. So, in most cases this would be natural mineral that is quartz, zircon or fireclay. So, there is a the list is a endless there can be number of types of minerals which can be used for processing in to ceramic powders. But this is just give you an example quartz, zircon, fireclay these are some of the example.

So, the raw the important point to understand is the raw material is available in the form of natural minerals. The raw materials need to be processed in order to convert into the final product or the desired product with special characteristics. Now, we have the raw material, we have to process it using different number of steps so that we get a final product and the product will have certain desirable characteristics. Now, the type and nature of processing may be different of different products and application. So, in previous slide one point was there, the type and nature of the powder processing techniques is different for different types of raw material.

Here the sequence of steps, if suppose if we have the powder we require five different steps to get the final product. So, depending upon the final product these step may vary. In some cases we may require different sequence of steps and other case we may require different sequence of steps. So, from the ceramic powder to the final product, the number of product require may vary depending upon the nature of the application for which the ceramic powder is being or the ceramic product is being produced.

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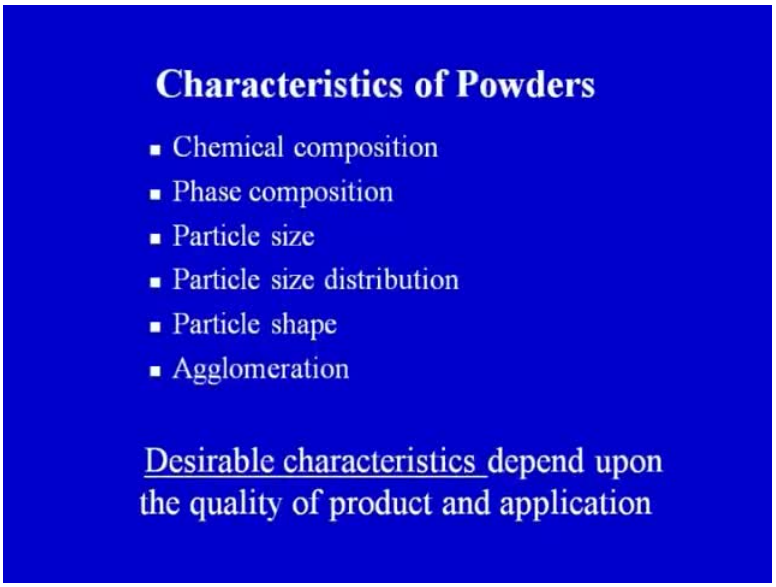

Now, coming on to another important aspect that is the characteristics of powders. Now, very raw materials should possess some desirable characteristics. Now, what are the important characteristics of powders that should be kept in mind? So, the first important, the chemical composition of the powder. Let me first read all these points; chemical composition of the powder, phase composition of the powder, than the particle size, particle size distribution, particle shape and the agglomeration of the particles.

So, these are some of the important characteristics, there can be other characteristics of the powders also, but these are some of the important characteristics which will define the quality of the final ceramic product. No one way, one we can see the cera depending upon the now final as I have already highlighted, depending upon the final product that we are going to make using the ceramic as the raw material, all these characteristics will alter or all these characteristics will vary. On the other hand we will say, that all these characteristics will defined the type of final product that we are going to produce.

So, if suppose the particle size is very large we will get a definite characteristics in the final product. If the particle size distribution is very wide, one particle is a very large size another particle is a very small size than also this will have veering on the final performance of the ceramic product. So, we can see let us take an example that we have to make a high performance ceramic product. So, for a high performance ceramic product, there should be certain characteristics that is there towards the end of the slide

you can see. Desirable characteristics, depending upon the quality of product and the application for which the product has been developed.

Now, these are the characteristics, but desirable depending upon the final requirements of the products or depending upon the quality of the product that we are making using ceramic as the raw material, all these characteristics will vary. Now, let us take an example, chemical composition. Now, in chemical composition we should have high purity chemical composition. If there are impurities, the final product that we may we will get may not be of very good quality. So, the chemical composition should be of high purity. Second phase composition, so in case of very high performance so not require many phases in the raw material.

So, we can chose a single phases system for high performance application. So, chemical composition I have already told that should be having high purity, if there are impurity is present than we may not get the desirable characteristics means we do not have the powders of high purity then we may not get the desired characteristics of the final product. So, first important point is the chemical composition. Chemical composition should be a high purity if you want a good quality product, the phase should be single phase. Then particle size, now particle size for high performance application should be fine. Fine means it should be smaller in size, so the particle size should be fine the distribution. What do you mean by… let us try to understand the difference between the particle size and particle size distribution.

Particle size refers to, suppose we are taking the spiracle particles should the particle size would referred to the dimensions of the spiracle particle or a individual spiracle particle. Whereas, particle size distribution will give us a distribution of the various sizes of the particles that are presents in the total bulk of the ceramic powder. Suppose there are ten different sizes that are available, that is there are particles will x size, there are particles with x plus delta x, then there are particles with x plus two delta x, so we have a wide range of sizes is of the particles in the ceramic powder.

So, particle size refers to the individual particle size and percale size distribution refers to the families of particle size is that are present inside the ceramic powder. So, we do not want very wide verity of particle size distribution. We want a narrow particle size of distribution in case of advance ceramics or high performance ceramics. We will just

revise for high performance ceramic, what are the requirement. Then the particle ship particle ship should also not very irregular. So, we should focused on certain standard shape of the particle.

Finally the agglomeration, we should not take agglomeration slightly. We should always focus that agglomeration should be minimum there should be no agglomeration of the particles, when we are the processing the ceramic powder. So, the powder should not agglomerate should not form lumps that is another desirable characteristics. So, these are the characteristics of the powder of all types of ceramic powder, but desirable for certain advance applications just one case we have taken. That chemical composition should be of high purity, phase composition we can choose a single phase system, particle size particle size should be fine, it should not be very large particle.

Then particle size distribution should be narrow, particle shape should be any regular shape and the agglomeration should be minimum or no agglomeration of the particle should take place. So, the desirable characteristics depending upon the quality of the product and application. So, whatever desirable characteristics I have told those are related to the advanced applications of ceramic or high performance ceramics or high performance ceramic product. But if we want to make a suppose poultry item or we want to make a table where for as decorative item, in those cases we may not be that much stringent with the characteristics of the powder as I have already discussed.

We may we little bit liberal in the choice of particle size or in the choice of particle size distribution, we may also liberal with the particle ship. So, depending upon the application if it is a decorative item, we may not be very stringent in our choice of the characteristics of powder, but if you are choosing a very high and sophisticated advanced application of a ceramic product in those cases, our focus would be on certain desirable characteristics. Now, the these are important, we should remember this characteristics.

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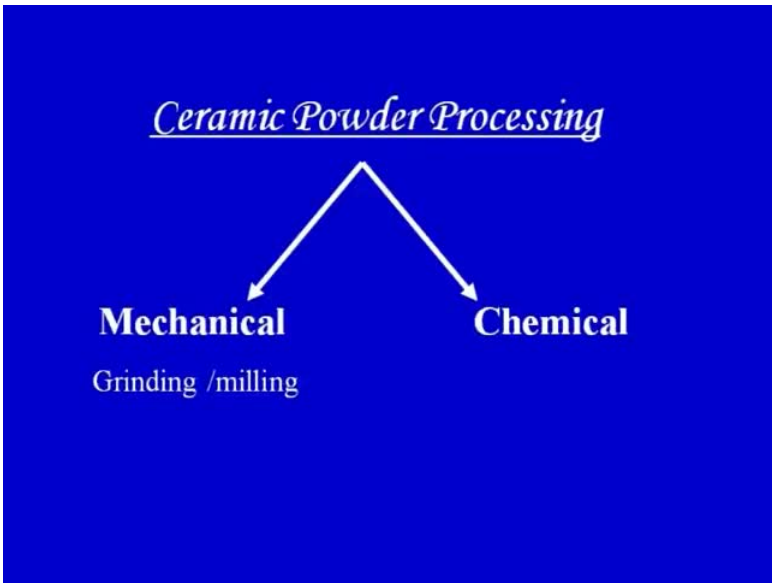

Now, coming on to the next point that is, we have seen till now, that why do we need to process the ceramic powder? I have I think given adequate discussion about the importance of preparation of ceramic powder because they are the tools and techniques that are use for processing of ceramic products is quite different from the processing of metals and polymers, therefore the raw material in case of ceramic is the ceramic powder, so that is a one important point. Then we have seen when we are able to fabricate or process the ceramic powder, what are the essential characteristics that should be taken into a account, that is the chemical composition, the particle size, particle size distribution, particle shape and agglomeration, these are the some of the points that have to be taken into account.

Now, this particular characteristics are variable, so they vary depending upon the quality and the application for which the powder is being processed. So, we have taken into two cases, at list one we have discussed in detail that if it is a advance ceramic or it is be using high performance then we can chose certain desirable characteristics, which has already being disused. Now, our focuses would shift in today discussion on the preparation of the ceramic powder. So, on your screen you can see the ceramic powder processing, which can broadly we divided into two categories; chemical processing of powder using the chemical reaction or the products of the chemical reactionsm, which are in the form of fine powders.

And the mechanical preparation methods, in which the direct contact of the particle with some agents would result into the agent. This would be some metallic balls or something that we will see in the subsequent diagrams. In case of mechanical we are doing grinding and milling and ball mill is an important apprentice which most of the engineers might have heard of. So, today we will see a simple diagram of the ball mill also. So, ceramic powder processing can broadly we divided into two categories, that is mechanical and chemical. Today our focus would primarily be on the mechanical aspects, in which the raw materials is coming and then some forces are acting on that raw material, so that it is being converted into a powder form.

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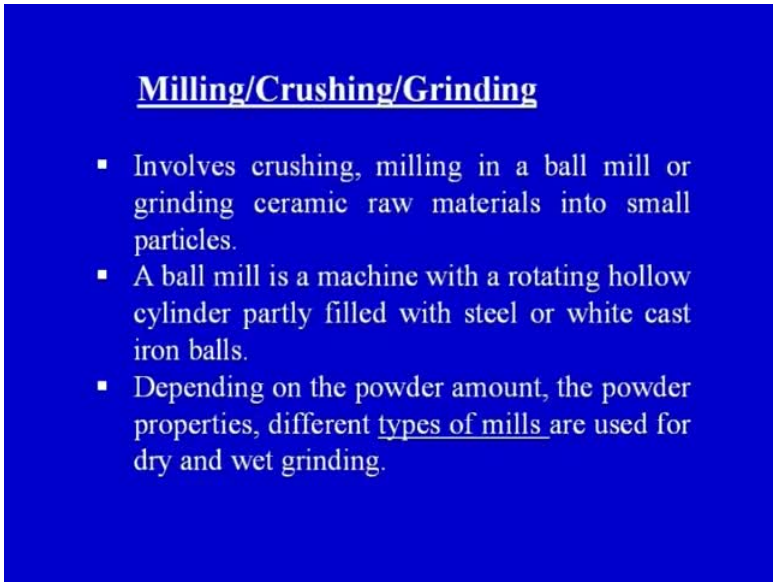

So, these are some of the techniques as which are highlighted on this particular slide at in milling, crushing or grinding. So, these techniques are use for getting the ceramic powder. So, it involves crushing, milling in a ball mill or grinding ceramic raw materials into small particles. So, we can do the milling, we can do the grinding and we can do the crushing of the particles to get the desired powders. So, these are some of the techniques which are used for producing the ceramic powder. Many of this the we will try to understand with the help of diagrams.

Now, first and foremost let us see a very important devise or instrument or machine which is used for making the ceramic powder, that is called ball mill. A ball mill is a machine with a rotating hollow cylinder partly filled with steel or white cast iron balls.

So, we can see there are broadly now till now two components here, that is one is a horizontal cylinder or a hollow cylinder second are the steel or the white cast iron balls. So, there are a hard balls and a cylinder. So, these are the two important note. Then depending upon the powder amount, the powder properties different types of mills are used for dry and wet grinding.

So, depending upon what type of final product we want, or product of these particular operations that is milling operation crushing or grinding operation in case of ceramic powder preparation is the ceramic powder. So, raw material is the kind of mineral or any natural acquiring mineral or any synthetically mid mineral, but output is a ceramic powder. So, that is the basic we can say step by step procedures for getting a ceramic powder, that there is a process. Process can be milling, crushing or grinding. The raw material is being pared into the process and the process gives you the ceramic powder.

So, now depending upon the powder amount, the powder properties we want that what should be the quantity of the powder that we should be able to produce on a hourly basis or on a weekly basis? What properties of the powder should poses? Based on that there can be different types of machine or equipment that can be use for processing of raw materials in to the ceramic powder. Now, let us one by one we can see, that what are the various process is?

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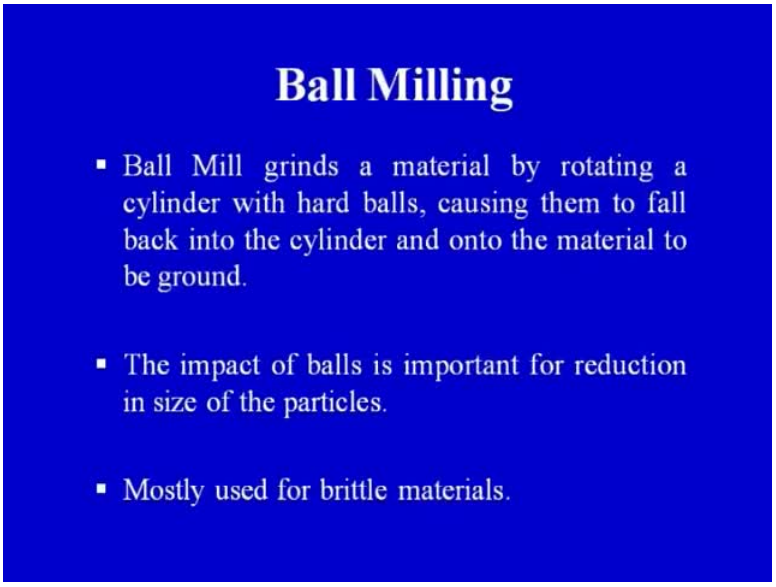

First one is ball milling, let us try to understand the basic principles of ball milling. So, ball mill grinds a material by rotating a cylinder. So, basically the words are being used interchangeably, so the operations are milling, grinding and crushing. So, the objective finely is to produce a ceramic powder. So, ball mill grinds a material by rotating a cylinder as we have seen in case of a ball mill, which is machine there is a cylinder and there are hard balls inside the cylinder.

So, it grinds the material, so raw material is put inside the ball mill. How it operates? It operates by rotating the cylinder, the cylinder continuously rotates with hard balls, causing them to fall back into the cylinder and onto the material into the ground. So, basically the impact between the two balls and two hard balls in between we may be having a ceramic particle or a ceramic raw material, which would be broken down or shattering shattered in to a ceramic powder.

So, ball mill grinds the material by rotating cylinder there is a cylinder which is continuously rotating. Inside it is a having the hard balls, the balls strike against the each other and the strike against the ball. In between there can be ceramic raw materials, we will try to understand with a help of diagram also. The ceramic would be processed into the ceramic powder. So, the raw ceramic would be converted into the ceramic powder with the help of ball milling. So, the impact of balls is important in reduction in size of the ceramic particles.

So, we as I have already discus that the ball would be hitting against the each other, balls would be hitting against the walls of the cylinder as well as the ball would be hitting against the ceramic raw material with the overall objective of reducing the size of the particles. So, basically we would be getting the ceramic powder after the ball milling operation. So, the impact ball is the very very important and it is mostly use for brittle materials. So, as we all know that ceramics are brittle in nature, therefore the ball milling operation is quite suitable for ceramic material.

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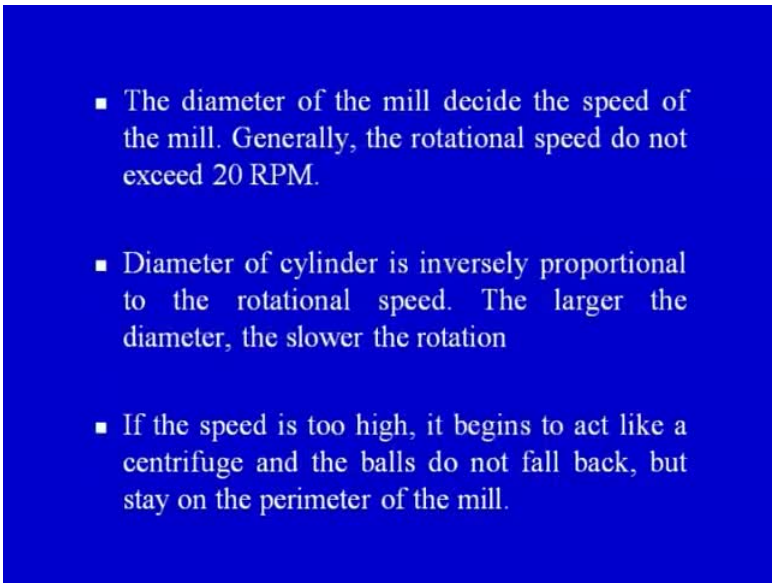

Now, another important point in contest of the ball milling operation is the diameter of the mill decides the speed of the mill. So, if we have a huge diameter of the ball mill and it has to be rotated we will rotate it at a slower speed, but if we have a smaller diameter ball mill we can rotate it at faster speed. So, the diameter of the ball mill or the cylinder decides the speed of the mill generally the rotational speed is less than 20 rpm, it may very within a particular range, but usually it is less than 20 rpm. As we have discussing, the working principle of ball milling, there are few things that we have to keep in mind, that we are discussing one by one.

We can see point number two, there the diameter of cylinder should be inversely proportional to the rotational speed, the larger the speed or the larger the diameter, the slower should be the speed. The smaller diameter of the cylinder we can go for larger speed. Now, why we should take care of this precaution? You can see in point number three, if the speed is too high that is the rotational speed of the cylinder which is getting the balls and the ceramic powder, if the rotational speed of the cylinder is very very large, then what is going to happen?

So, it becomes act like a centrifuge and the balls being a heavier and dense go towards the boundary or the periphery of the cylinder and we want and impact of the balls among themselves and with the wall of the cylinder as well as they should hit the ceramic powder, so that the ceramic powder gets settled. We get fine ceramic powder or they

should crush the ceramic raw material into the ceramic powder. So, the speed is if the speed is too high, then the balls would go towards the periphery and the effective coligence between the ball and the ceramic raw material would not be there. Now, we will try to quickly go through a number of diagrams and try to understand that how the ceramic powder is crushed by various mechanisms to get the ceramic powders?

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On your screen you can see the simplest diagram of ball milling, in this diagram this black sewers represent the balls, the material of the balls can be some very hard steel or it can even be a harder material than steel. So, basically we have hard balls and this green portion is representing the ceramic. So, this rotates continuously and because of the collagens or the impact of the balls against the ceramic raw materials we get the ceramic powder. So, this is just showing one particular position inside the ball mill. Here we can see, bigger balls represents the hard balls, which are acting as an hitting medium and other green portion shows the ceramic powder.

So, here we can see there are bigger lumps of ceramic raw material which has been broken down in to the smaller ceramic powder particles. Basically in ball mill this cylinder rotate continuously and the speed is not very high it is to the tune of suppose 40 rp sorry, less than 20 rpm and the balls are hitting the ceramic raw material to generate the ceramic powders. So, this is one of the simplest process of making ceramic powder that is the process of ball milling. Now, we will see some other process, I will draw few

diagram a simple diagram to just explain, that how the ceramic raw material or mineral crushed to make the ceramic powder?

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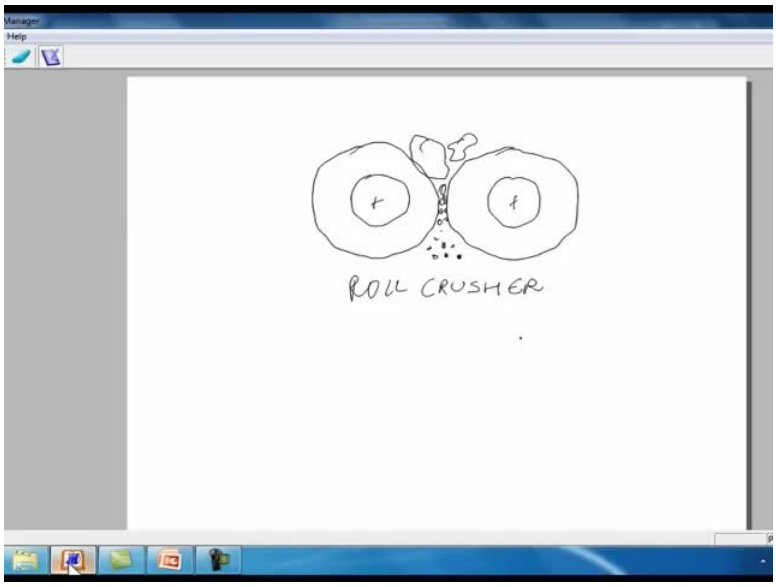

So, on your screen we can see, I am going to draw a simple diagram of a roll crusher that how roll crusher crush is the raw material. So, this is one roll and then we have insert another roll it is rotating. Then we have another roll, so on your screen we can see we have two rolls and in between we put the lumps of ceramic raw material. When it is pressed inside the two rolls rotating rolls we get very fine ceramic powder particles. So, this is a simple process it is called roll crusher or we can say roll crushing.

So, this is a simple, they are two rotating rolls in between in we are putting the bigger lumps of ceramic raw material and what we are getting? We are getting the smaller or very fine size ceramic particles. Now, the size of the particle that we are getting will depend upon the process that we have chosen. This is one of the process for producing the ceramic powder and we can see the diagram of this particular process also. Let us see, this is we can see schematic diagram of roll crushing.

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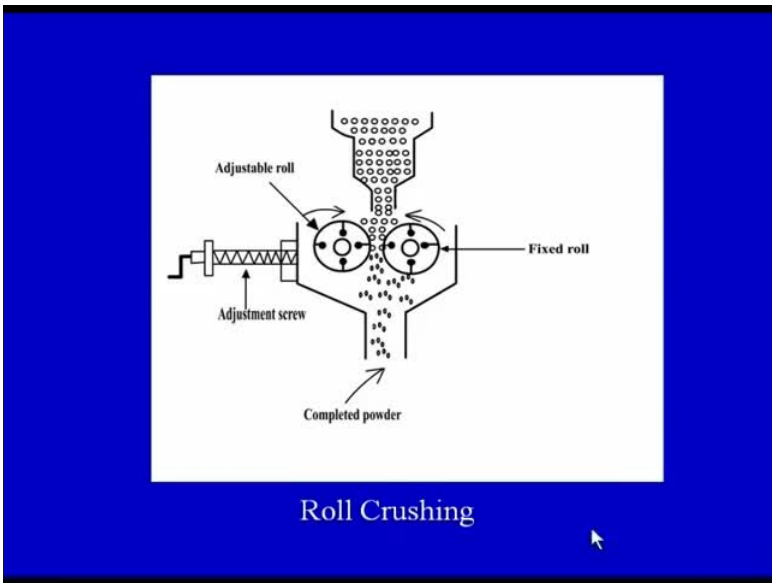

So, in this particular diagram we can see that this is a ceramic raw material hopper through which the bigger particles are coming, they are crushed inside the two rotating rollers and finally we have getting the completed powder or the crushed powder or very fine powder. So, there are these two roller and this is the adjustable roller, it is written clearly adjustable roll. This is the adjustable roll and this is the fixed roll.

Now, depending upon the size that we want to produce at the depending upon the size of the raw material that is coming from the hopper, we can adjust the center of this particular adjustable roll to get the particular size of the final ceramic powder. So, we can control the distance, center to center distance between the two rollers or the two rolls in order to get the desired size of the final ceramic powder. So, this is one process which we have seen that is roll crushing, but prior to the we have seen ball milling. Now, let us see another process I will just draw a very simple diagram for you for that process.

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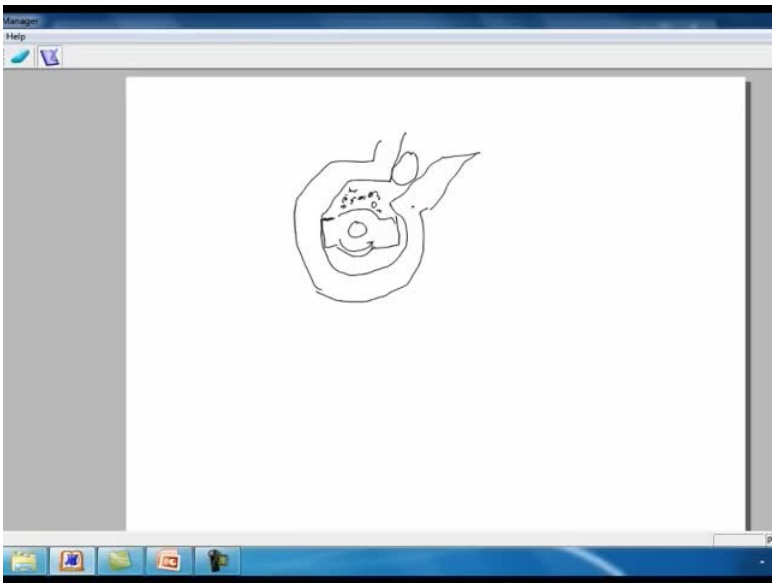

Let us see another process on your screen, I am going to draw another diagram in which we can see, this is we can say the schematic representation of the hammer milling process. On your screen you can see, now this is actually the hammer, which is we can say rotating. So, we have hammer and the raw material we can see becoming in a bigger lump form and here it is being hammer down into very fine size ceramic particle. So, the hammer inside the chamber is the rotating and it is crushing, we can say the larger size ceramic lumps into very fine ceramic powder. Now, let us see the diagram of hammer milling. On your screen you can see a schematic representation of the hammer milling process.

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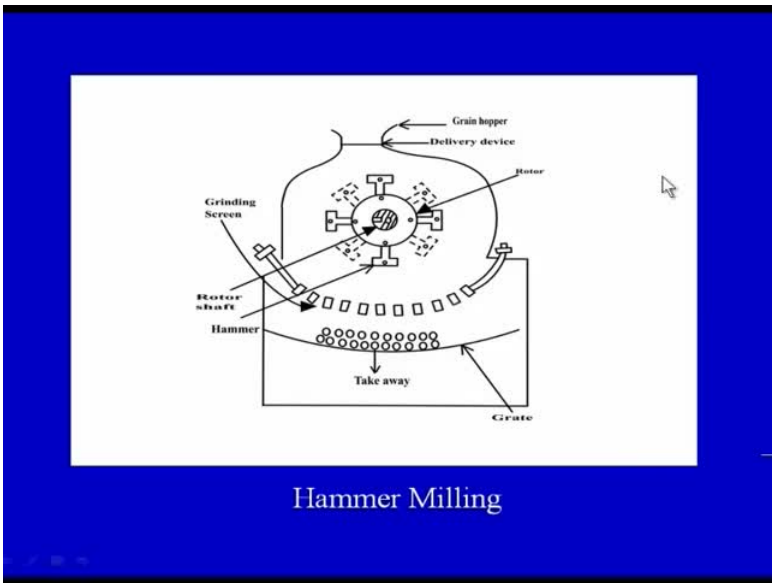

In this you can see, this is a grain hopper form the where the raw material is coming, this is a delivery device through which the raw material is coming. There in the previous diagram that I have drawn there were only two hammer, but here we can see there are 1, 2, 3 and 4 independent hammer. So, this is the rotor through which will rotate the complete assembly. Here we can see the rotation is shown, this is a next position and for this one, this is a next position. So, this is a rotating and the raw material is entering from this and the raw material would be hammer down and we will get the take way smaller size ceramic particle.

So, in this particular we can say the grinding screen through which the particle would be coming down and these are the hammers this is 1, 2, 3 and 4 and this is a rotor shaft to give the rotation, and this is the rotor. So, basically in this we are hammering down and we are shattering down the ceramic product or the ceramic raw material into the final product that in this particular process is the ceramic powder. We are having a ceramic raw material, we are putting it through the delivery device into the main chamber, where the hammer is are operating on the ceramic raw material and converting that into very fine ceramic powder.

This is another process which is use for making the ceramic powder and it is called the hammer milling. So, till now we have seen three process which are first one was the ball milling, the next one was the roll crushing and roll crusher in which two roll was

operating and they where crushing the raw material into the fine ceramic powder. And now we have seen third process which is the hammer milling operation in which the hammer are crushing or milling the material into the desired shape and desired size. Next we will see, one or two more process is which are used for processing the ceramic powder. So, on your screen we can see one more diagram, I am going to draw that is we can call it as gyratory crusher.

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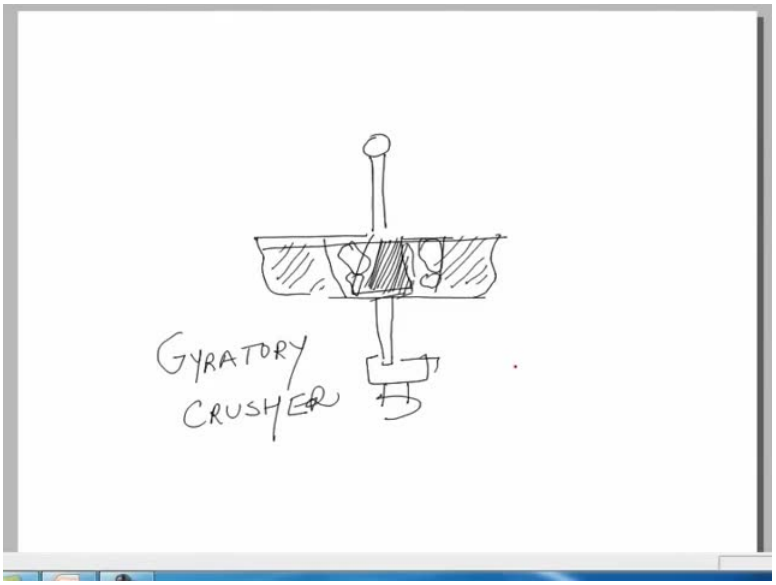

This is a simple representation of a gyratory crusher, this is a main acting member which gyrates and here this is the, we can say main area where the action is actually taking place. We can see the raw material is crushed here into smaller size particle. So, this is a whatever I am highlighting here, this is the solid section and it crushes is the material by the gyratory motion. So, the bigger size particles are put as an input and because of the gyratory action the bigger size particle or the bigger size ceramic parts which are put in to the system are crushed into the smaller size ceramic particle and this particular type of system is called the, as I am writing on your screen you can say this is called the gyratory crusher.

So, we have an another mechanism which is called the gyratory crusher. So, the word gyratory is coming from the movement of the we can say main crashing member, it gyrates to remove, to bring down the size of the ceramic powder. So, basically we have seen till now four process in which the use of this process is will help us to get the

ceramic powder. Now, what are this four process? First one is the ball milling, then we have seen roll crusher, then we seen in the hammer milling and now we have seen the gyratory crusher. So, last process that we want to discuses today is on your screen you can see, I am going to draw another diagram in which you will see that how a jaw crusher works?

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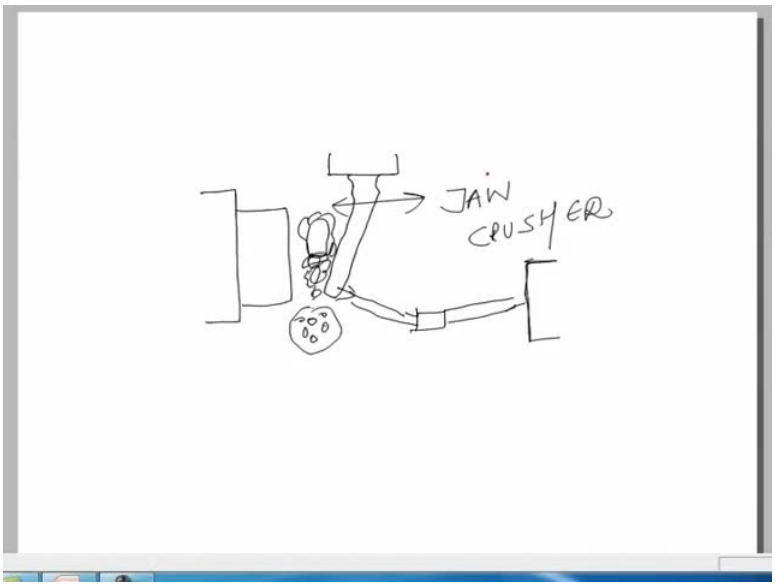

In a jaw crusher, quickly I will draw the diagram. This is the ceramic that we want to reduce into smaller size and where are the jaws, now this is the jaw and it is fixed here and this particular jaw will move and will crush these ceramic lumps into very fine size ceramic particles. So, the basically the movement is like a jaw as we chew the fruit that we eat. So, similar manner the two parts of the jaw would hit or two parts of the system would hit the particles and the size of the particles would get reduced. This type of the crushing mechanism is called the jaw crusher.

So, this is the jaw crusher in which the bigger size ceramic lumps are broken down into smaller size ceramic particle. So, the size of the particle can be controlled, so we can see that what is the final size that is desired and accordingly we have seen there are number of process which can be used for producing the ceramic powder in a mechanical manner. There are other techniques also for producing the ceramic powder that would be discussing, but this whatever we have discus today, those are this are mechanical techniques for producing the ceramic powder.

Here we can see there are number of techniques starting from ball milling, roll crushing, than we have seen the gyratory type of motion, which is used for producing the ceramic powder. and finally, the jaw crusher on your screen. So, different techniques can be used, now the final size the distribution of the size are some of the important decision that have to be taken of. Some of the process may give the very wide distribution sorry, some of the process is may give very wide distribution of the sizes, that few particles are very big size and the other particles are very small size.

So, we do not want very wide distribution than we will not go for that particular process. We will go for only that process, which would give a very fine size or which will give a narrow range of the particle size distribution. Similarly, if you want very fine very small size particle we will chose the process appropriately. In many cases because of the process mechanism there may be wear of the parts, which are use for example, in ball milling if the balls are not very strong or very hard, strong is not the correct word in case of wear, we should say hard. If they are not very hard then the wear of the balls even may take place and the the wear debris may we can say from in to the ceramic powder or may be react with the ceramic powder. In many case may get mix with the ceramic powder and we will not get a very good chemical composition of the ceramic powder.

So, we have to be very, very chose in the selection of the process, there are number of process is which can be use for producing ceramic powder, but we have to chose the process as per the requirements of the final product because according to that only we want the ceramic powder. In the very beginning of today lecture we have seen that what are the powder characteristics and what are the desirable powder characteristics for advance ceramic product? So, we this we come to the end of today's discussion in which we have seen, that why do we need to produce a ceramic powders? How in powder metallurgy, what is the importance of the powders? Then what is importance of the powder in ceramic product development?

Then we have seen that what are the desirable powder characteristics for advanced ceramic product? Specifically we have seen few important powder characteristics like the particle size, particle size distribution, chemical composition and the agglomeration, so there are few characteristics that we have discuss. Finally, we have seen that how the ceramic powder processing techniques can be classified, they can be classified into two; that is point number one is mechanical and next the chemical process.

We have today discus the mechanical processing methods for processing of ceramic powder, in which we have seen number of process is like ball milling, roll crushing, gyratory method of making powders and the jaw crushing. So, we this we come to the end of today's discussion and in the next discussion, we will discuss other important processing aspects of ceramics.

Thank you.