Processing of Non-Metals

Prof. Dr. Inderdeep Singh
Department of Mechanical and Industrial Engineering
Indian Institute of Technology, Roorkee

Module - 3
Glass: Properties and Processing
Lecture - 6
Processing of Ceramic Part – II

Good morning to all of you. We are going to discuss today the shaping of the ceramic part, which falls under the brooder category of processing of ceramic part, but before starting today's discussion, let us see where we are in our course on processing of non metals, as you are well aware that we are in the process of discussing the various aspects of our course that is processing of non metals.

Presently, we are discussing module number 3, module number 3 deals with the ceramics. In the beginning of this particular module, we have seen that ceramics have non metallic properties, we have seen the basic type of bonding that is present in the ceramics, we have also seen the basic properties of the ceramic materials, the physical, chemical, and mechanical properties of the different types of ceramic materials.

Although we have not discuss, the basic aspects of ceramics in much more detail, because our focus is on the processing of ceramic products, but we have discuss the fundamentals insufficient detail, so that we can discuss the processing aspects at a later stage. So, that we can understand the processing aspects, we have seen that how the ceramic powders are prepared. What are the different tools and techniques use for processing of ceramic powders, we have seen the a mechanical type of the root can be followed to prepare the ceramic powder and the chemical methods can be use to prepare the ceramic powders. Then we have seen that how we can give a shape to the ceramic powders.

Today also our focus is on the processing aspects of ceramic parts. So, I have just highlighted that what do we have covered in this particular module. In the beginning we have seen the properties of the ceramic materials, the basic definitions related to ceramics then we have seen the processing of ceramic powders. Then we have started our discussion related to the process of making the ceramic parts. In our previous lecture

that is processing of ceramic parts, we have seen that how we can make a shape of the ceramic part. If you remember, we have seen that there are different types of pressing mechanisms, that are use to give shape to the ceramic powders.

If you remember, the basic characteristics or the fundamental characteristics of wet drying, not the wet drying sorry wet pressing, dry pressing, hot pressing, and isostatic pressing. So, four different types of pressing techniques were seen with the relative advantages and disadvantages of all this techniques. And we are today going to see that what are the other processes, which are use for giving shape to the ceramic parts. So, basically as you well aware in our previous lectures, we have already discussed that there are three basic steps that are involved in making the ceramic parts.

Step number one is the preparation of the raw material, in the form of ceramic powders. So, first of all from the raw ceramics, which may be coming from the natural minerals or may be synthetically synthesized. So, depending upon the requirement, we have a type of raw material, which is available with us. Now, this raw material is crust or mild or grinded in to the ceramic powder. Even chemical synthesis root can also, we use to get the ceramic powder. So, basically our raw material in case of ceramics parts processing is the ceramic powder, once the ceramic powder is ready with us we mix it with certain additives, certain binders, in order to give it a desired shape or to make a green compact as in the case of powder metallurgy.

So we make a green compact by different techniques, that is we give a shape to the product and the last stage is the firing, or the cantering of the screen compact. So, that it attains the requisite density and the desired strength. So, basically three steps are involve step number one is the preparation of ceramic powders, or the preparation of the raw materials for ceramics parts processing. Second step is the mixing of the ceramic powder with additional binders or additives in order to in part certain special characteristics, and the third stage is the drying or shaping of the part in to the desired shape, drying and finally, the firing that is also called centering.

So, basically three steps are involved so, but before going to these three steps, we should first understand that, what are the various methods of preparation of ceramic powder and before going to the preparation of the ceramic powder, we should first understand that what are the ceramic material. What are the special characteristics of the ceramic

materials and why do we need to convert them in to powders in order to make ceramic parts. Why cannot we use the processes that are well developed, and commercially available for processing of metals or polymers. What are the distinct characteristics of ceramics were that make them a different class of engineering material. So, all this thing so, all these things, all this discussion has already being done.

So, now we have reach to a stage where we are in a process of understanding the conversion process from a raw material in to the final product. We know how to make a ceramic powder and we know how to mix the ceramic powder, with the various additives. Now, finally our objective is to give a final shape to the raw material. So, the different types of ceramic products you have seen. We have dining cook wear, we have different types of decorative items, there are bio ceramic, there are space shuttle, there are roof tiles, they are there are floor tiles made up of ceramic material.

So, different types ceramic products are there and they have distinct shaves and shape complexities, they have different types of sizes not depending upon the size and depending upon the shape complexity, we have to choose a process which would help us to give the ceramic raw material are desired shape. One of techniques, we have seen in our previous lecture that is pressing. In which we have seen that, we can go for dry pressing, we can go for wet pressing, hot pressing or isostatic pressing.

Today, we will see some other techniques like sleep casting, injection molding or exclusion, which can also be use to generate a green compact or to generate a ceramic part, which would further be subjected to certain secondary operations, in order to make it a usable product. So, with this introduction that, what we have already covered, what we are in the process of discussing, where this particular lecture fits in this lecture falls in which particular module, and the module is a particular module of our course on processing of non metals. So basically, we are discussing the course on processing of non metals, we are discussing module number three, in which we are discussing the processing of ceramic parts. With this introduction let us now start our discussion. First and four most, let us revise that what are the various stages involved making a ceramic product.

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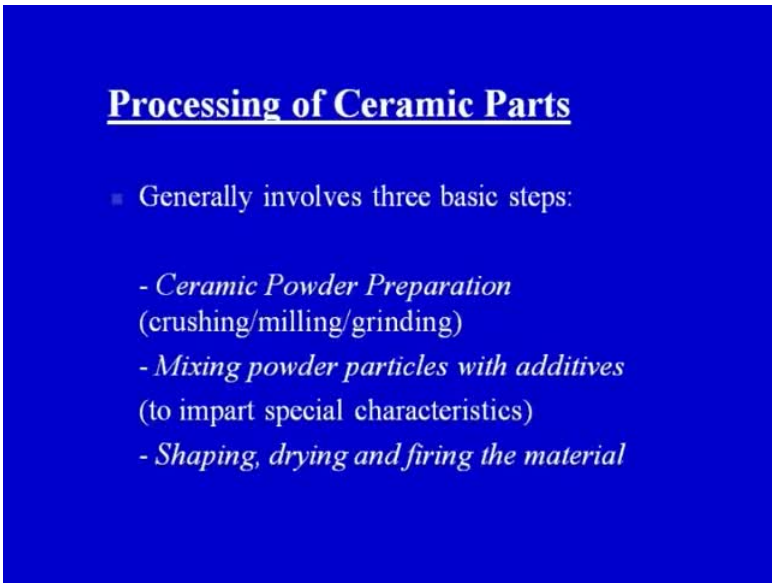

Processing of ceramic parts generally involves, three basic steps. So, all these three basic steps I have already explained. First step is ceramic powder preparation, some of the methods or techniques, which are use for preparation of ceramic powders is highlighted on the screen that is crushing milling and grinding. That we have already discussed with the help of diagrams, in our previous lectures. Crushing milling and grinding are the mechanical ways of producing the ceramic powder, if you know, if you understand, if you understood in our previous lecture, there are chemical methods also which are use for processing of ceramic powders like the precipitation method and the solid reaction method.

So, crushing milling and grinding gives us the mechanical root for processing of the ceramic powders and the chemical methods such as the solid reactions, solid solid reactions and the precipitation method gives us the chemical methods. So, basically first stage is or the first step is to prepare the ceramic powders, once the ceramic powders are ready. The second stage is mixing these powder particles with the additives. Why the additives are added? In order to impart the special characteristics to our final ceramic product, once the mixing has been achieved next, stage is to give a shape to the ceramic part. Now, for shaping we have seen pressing is one of the techniques, slip costing, exclusion, injection molding, jiggering. There are another methods, which are use for giving shape to the ceramic parts.

So, we will see one or two techniques today, which are use for giving shape to the ceramic part, we will try to understand these techniques with the help of diagrams and finally, once the shape has been made or the green compact is ready we will dry it and finally, do the centering or firing of that part in order to give it the desirable characteristics.

So, basically were today's lecture fit in, we are going to see that how the shaping of the part is done. That is the third stage of the total process of making a ceramic part. Step one or stage one is the processing of ceramic powders, or fabrication of ceramic powders. Step two is mixing or making the raw material, ready to be made in to a ceramic product. Stage three is giving a shape to the raw material and finally, drying and centering it or firing it.

So, today we are going to discuss that, how to give a shape to the ceramic raw material. So, one of the steps or one of the important process is slip casting, but let us before going in to the discussion of slip casting, let us try to understand that what are the various types of processes, which are use for processing of ceramic parts. So, the focus basically is on two aspects first is making the ceramic product and finally, doing the certain secondary operations on this ceramic product.

In order to make it more usable or more aesthetically relevant that is sometime, we may be interested in giving a particular type of glazing, or a particular type of surface finish or particular type of coloring arrangement to our ceramic product. So, all these processes of giving a particular coating or giving a particular surface finish, or machining a particular section or a feature in to the final product, falls under the secondary processing methods of parts processing or ceramic part processing. So, we will see that what are the important steps involved.

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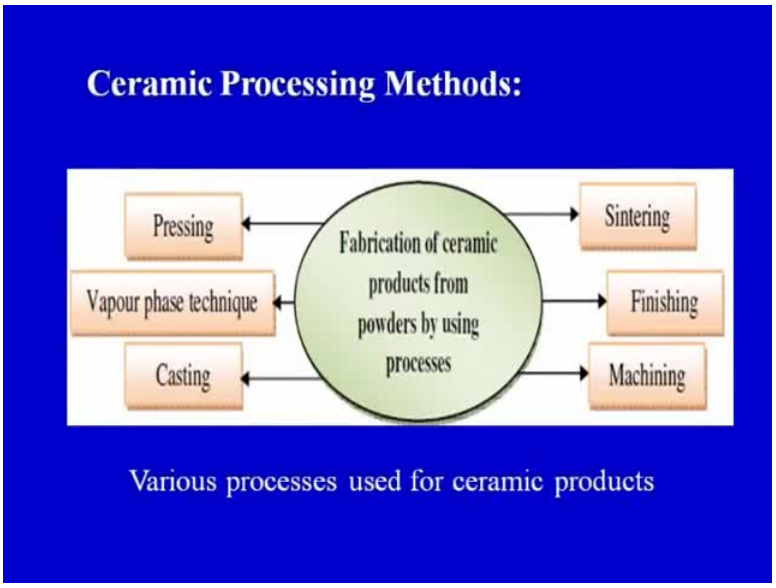

On your screen, you can see the different methods or techniques; that is used for making a ceramic product. We can do pressing that we have already seen, vapour phase techniques are also use for deposition of ceramic particles on certain substrates. This particular aspect, we would be focusing on in our last lecture of this module finally, casting that we are going to discuss today. Centering we will see in the next lecture, finishing and machining are the secondary operation, that are done on the ceramic part in order to make them more desirable or more user friendly or in case of improving their utility.

So, basically the all these processes can further be classified into two categories that is the primary forming of ceramic parts and the secondary forming of ceramic part. So, basically primary forming means, giving shape to the final product and doing the centering and all other operations. So, that the product is ready, but before the product is put in to use or sent to the market, there may be certain secondary operations like surface finishing or glazing that have to be done in order to further improve, the marketing aspects of our proud ceramic product or of our product. So, basically right now our focus is on the primary forming, that how to give a shape to the ceramic product. What are the secondary operations involve that we would we seeing in our next lecture. So, with this introduction let us now focus on one of the important processes that is used for processing or giving a shape to the ceramic part.

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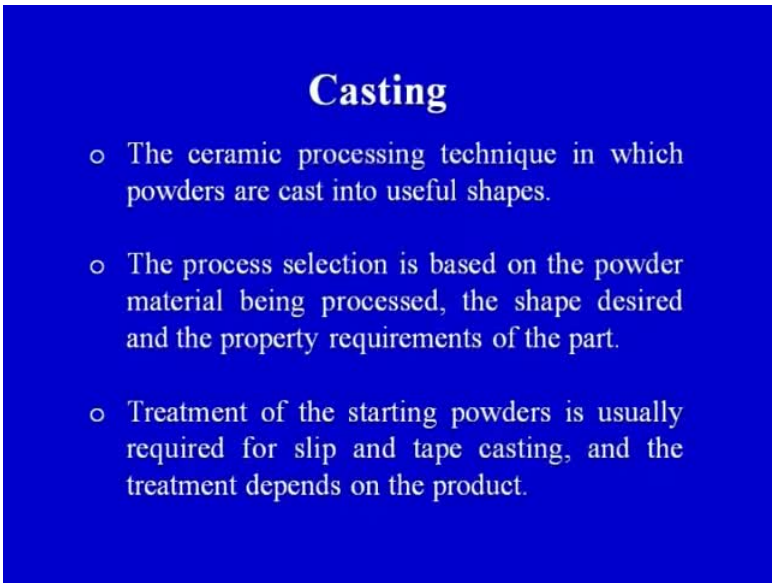

So, first process that we are going to discuss today is the casting process, out of which or in which slip casting is an important process. Slip casting is also, sometimes called as drain casting. Why drain casting? That we will try to understand with a help of a diagram. So, let us start our discussion with the first process that we are going to discuss today, that is use for giving shape to the ceramic raw material. The material which is having a additives or the binders as well as the ceramic powders. So, ceramic powder plus additive plus binder, this forms the raw ceramic, raw material and this raw material. We have give a particular shape depending upon the design requirement or depending upon the geometrical design of our final product.

So, the first point on your screen, you can see the ceramic processing technique in which powders are cast into useful shapes. So, before going to discuss this particular aspect in case of ceramics, let us first revise that what do we mean by casting actually. Casting is a very common process, which is used for metals or for making parts of metals and is one of the important, primary forming processes in case of processing of metals. So, what is done in casting? A mold is made usually a sand mold is in case of temporary molding technique, and in case of permanent mold casting metallic molds are also use.

So, basically in casting what is done. A mold is there, it can be a sand mold or it can be a metallic mold. The metal is melted in the farness, there are different types of farness that are use for melting the metal. The molten metal is broad to the mold in ladles and then

the metal poured in the mold. In case of sand mold it is usually gravity poring, and in case of permanent mold such as hot chamber or cold chamber, die casting, pressurized we can say metal is pushed in to the mold.

So, basically the technique is that we have a molten metal, which is somehow injected into the mold material. So, casting process basically there is a molten raw material and there is the mold, which has to gave a shape to the final product. The molten metal poured inside the mold and it takes the shape of the mold and finally, after solidification we get a final product, which we called as a cast product.

So, basically in ceramic processing also, the same aspect or the same mechanism is there, but here the raw material is not a metal. The raw material or the molten material or the liquid material in case of the ceramic casting is a ceramic slurry. So, basically the slurry is poured into a mold, the mold is not made up of a sand or the metal in case of casting in ceramics it is made of a plaster of paris.

So, there are some differences between the casting in case of metals, and the casting in case of ceramics that we will try to highlight with the help of the points, that are there on your screen, but first of all it is very important for us to understand that, what is the deference between the casting of metals and the casting of ceramics. So, first important point on your screen again I am emphasizing, the ceramic processing technique in which the powders are cast into the useful shapes.

So, basically this particular process falls under the third stage of the ceramic parts processing. Stage one is preparation of ceramic powder. Stage two is mixing up of the powder with additives to impart certain special characteristic. Stage three is the shaping drying and firing. Now, we are discussing how to give a shape to the ceramic powders. So, casting is the one of the important techniques and we have try to differentiate between the casting of metals and the casting of ceramics.

So, point number two the process selection is based on the powder material being processed, the shape desired and the property requirements of the final part. So, this we have discussed in our previous lecture also, if you remember we have seen that in order to choose a particular process for a particular application, we have to take in to account three or four important criteria that when we are choosing a process, we have to see that

this process is being used for which type of the raw material, what is the type of the powder or the characteristics of the powder.

Powder has got many characteristics or certain desirable characteristics, which also we have covered, when we have discussed the chapter or the lecture on ceramic powder preparation. If you remember there are just I will revise that, what are the important desirable characteristics. The important characteristics are the chemical composition of the ceramic powder, the phase composition particle size, particle size distribution, particle shape agglomeration; these are some of the important characteristics of the powder.

Now, depending upon the type of the powder, the process would be chosen next is the final shape of the product desired. Now, if the shape is very, very complex we have to choose the process accordingly and if the shape is very simple then a different process can be chosen for making that part. Finally, the final property requirements of the product or the part that what are the desirable characteristics or the design requirements of the part, which we are going to make by the process.

So, basically these three or four important criteria have to be taken into account, when selecting a process. So, we will see that slip casting in which cases, this slip casting process can be used in case of making or giving a shape to the ceramic raw material. Another important aspect is the treatment of the starting powders is usually required for slip and tape casting and the treatment depends on the final product. So, basically the raw material which we have prepared, that is the ceramic powders that we have prepared, in many cases they may be requiring certain treatment.

So, these treatments are given in order to make them more usable, for a specific process. If we are not doing a certain specific treatment then, the quality of the product that we will get may not be desirable. So, in many cases without even treatment, we can make the final product, but for certain specific requirements we may require to treat the ceramic powders before subjecting them to the next processing step. Basically, casting is a simple process, which is used for giving a shape to the ceramic part or for processing of a ceramic part in to a green compact.

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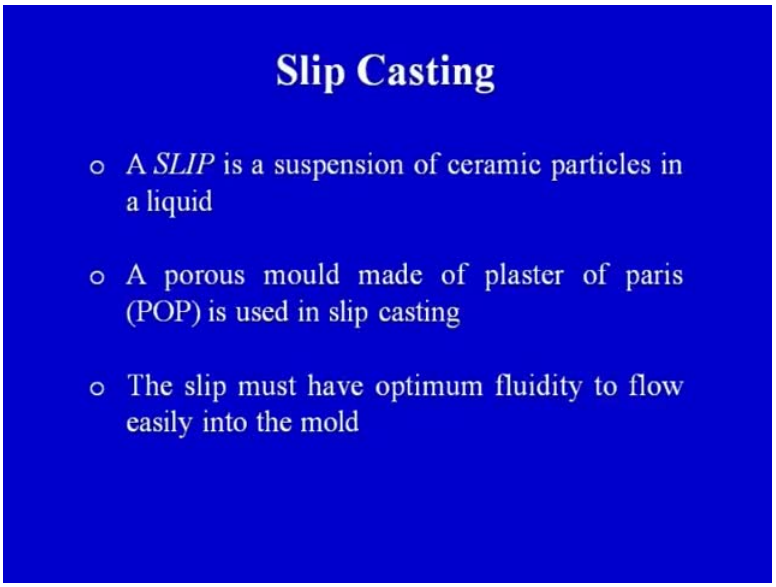

Let us further see a we can say certain important aspects related to slip casting. So, casting is a important process, which can be used for processing of ceramic parts. Slip casting is one of the you can say important casting types so, a slip basically why the word slip is coming in to picture. A slip is a suspension of ceramic particles in a liquid. Basically, the ceramic particles would be suspended in a liquid. So, liquid can be we can see simple example can be water.

So, ceramic particles can be suspended in water to make a slurry. The pores mold made up plaster of paris is used in slip casting. So, two important parts are there as I have told in the casting of metals also we have a mold and we have a raw material, the raw material is melted in the farness and the molten metal is then poured into the mold. The mold can be made up of sand, or the mold can be permanent mold made up of metal.

So, there are two important part, the raw material and the mold. And the raw material in the liquid form when it will go inside the mold, it will take the shape of the mold and after solidification, we will get our product. So, here also the two important parts that is a raw material that is going into the process is a slip. A slip is a suspension of ceramic particles in a liquid. So, the raw material is going into the mold in the form of a liquid and there for it will take the shape of the mold.

Whatever is the design of the product we will make a mold accordingly, then the porous mold porous is also important we will see why the mold is porous. A porous mold is

made up of plaster of paris. So, the mold here is not made up of sand or metal, but it is made up of plaster of paris and there for this process is a economy economical process, it is not a very, very costly or expensive process. So, a porous mold made up of plaster of paris is used in slip casting.

The slip must have optimum fluidity to flow easily into the mold. So, slip is a liquid so, it should have optimal viscosity. So, that it is able to flow into the mold of plaster of paris easily. So, basically we have try to understand in this slide that, why we are calling thus process as slip casting, what is basically a slip and what is the material of the mold that is used for processing of ceramic parts using the slip casting technique.

And finally, we have seen that the slurry or the slip should have optimum viscosity. So, that it is able to flow into the mold or it should have optimum fluidity so, that is able to flow is easily into the mold. So, next stage is the steps involved in the slip casting process that how actually, the slip casting process takes place. Now, let us try to understand, the steps that are involved in slip casting process.

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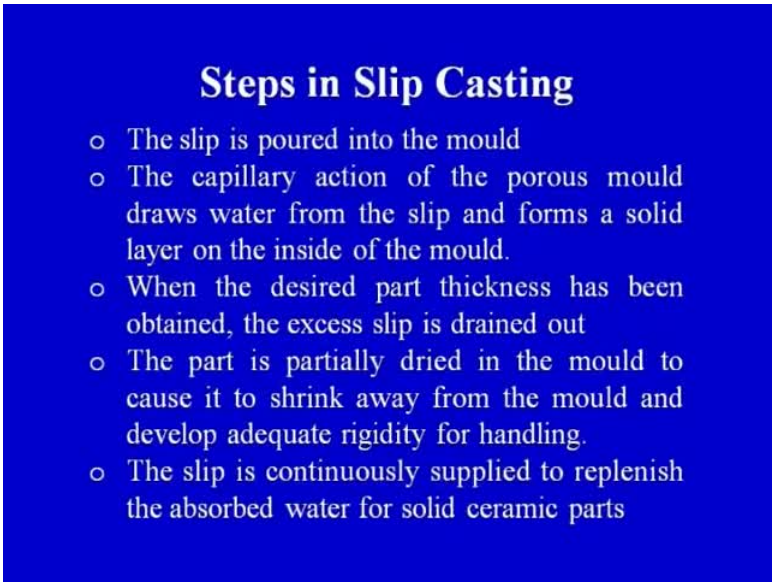

So, these are some of the important steps, there are five bullets or five points in this particular slide. So, the steps in slip, slip casting process are step number one, the slip is poured into the mould. So, the slip is prepared. What is a slip? It is we can say suspension of ceramic particles in a liquid, the liquid can be a simple type of a liquid like water.

So, we have a slurry in which we have the ceramic particles. So, slip is poured into the mould so, the mould of plaster of paris a porous mould of plaster of paris is prepared depending upon the shape of the final product. Now, whatever is the shape of the final product accordingly, the mould of plaster of paris is prepared and the slip or the slurry which contains the ceramic particles is poured into that mould.

Step number two, the capillary action of the porous mould draws water from the slip and forms a solid layer on the inside of the mould. So, you we have a mould we have poured, the slip inside the mould and because of the capillary action, in the mould because it is a porous mould that we have see in the previous slide also, because of the porous nature of the mould and the capillary action taking place, the water. Water because we are assuming that the slurry contains the water because the suspension of ceramic particles is suppose in water.

So, this water would be drawn into the mold by the capillary action and a solid layer is formed on the inside of the mold. So, this is suppose the mould on the inside of the mould a solid layer of the ceramic product would be forming. So, step number one is pouring of the slip into the plaster of paris mold. So, slip is poured into the mould the mould is porous in nature the capillary action of the porous mould, draws the water from the slip. The water we can say is absorbed into the plaster of paris mold, and a solid layer of ceramic product is formed on the inside of the mould walls.

Next, step is when the desired part thickness has been obtained, the excess slip is drained out. So, depending upon the thickness that we want to achieve or the part thickness or the section thickness that we want to achieve, when that thickness has been achieved the remaining slip is drained out of the mould. This process is sometimes analogues to the slush casting technique, which is sometimes used in case of casting of metals. So, slush in slush casting also we drain out the excess metal, and here also when we have achieved the desired thickness, the excess slip or the slurry is poured out through the nozzle opening. So, when the desired part thickness has been achieved, we will remove the excess slip or we will drain out the excessive slip.

The part is usually dried in the mould to cause it to shrink, away from the mould and develop adequate rigidity for handling. So, we will allow the mould to be in the closed position for certain amount of time. So, that the mould a is allowing the drying of the

ceramic part, which has been formed inside the mould. So, basically our objective is that it should dry to certain extent. So, that when the mould is open and the ceramic part is taken out, it is easy to handle if it is not easy to handle there is every chance that it may break.

So, basically we will allow the certain amount of time, depending upon the type of the abrasive or the type of the ceramic material and the type of the slurry that, we are using or the type of the we can say liquid that has been used. So, depending upon all these requirement depending upon section thickness, there are number of parameters that would be taken care of to decide on the amount of time for which the mould would remain closed. So, the mould would be allowed to remain close for a certain amount of time. So, that the material that has formed what the ceramic part that has formed inside the mould attains, the rigidity so that it becomes easy to handle that part after taking it out from the mould.

Next, step next stage is the slip is continuously supplied to replenish the absorbed water for solid ceramic part. So, the first four steps deal with the processing of hollow ceramic parts because the excessive slip is being poured out, or drained out of the plaster of paris mould, but suppose we want to make a solid part then what we should do? We should keep on replenishing or keep on pouring the slip or the slurry continuously. So, that to compensate the amount of water, which has been absorbed by the porous plaster of paris mould.

So, basically we want to highlight here that the slip casting technique, in case of ceramic parts cannot only be used for hollow parts, but can also be use for processing solid ceramic parts. So, basically there are four steps involved. Step number one is pouring of slip into the plaster of paris mold. Second step is the absorbing of the water by the porous plaster of paris mold, and the formation of a solid layer of ceramic on the mould wall.

And third stage is when the desired thickness has been achieve, the excessive slip is flushed out or drained out or is poured out from the mould. When we get the desired thickness and the last step is that, it is allowed to dry inside the or the ceramic part is allowed to dry inside the plaster of paris mould, so that it attains the adequate amount of rigidity so, that it becomes easy to handle and does not break, when it is taken out from

the mould. Finally, if we want to make a solid part then continuously we have to replenish the slip into the plaster of paris mould. So, these are the important steps that are followed in slip casting technique. We will try to understand this with the help of a diagram also.

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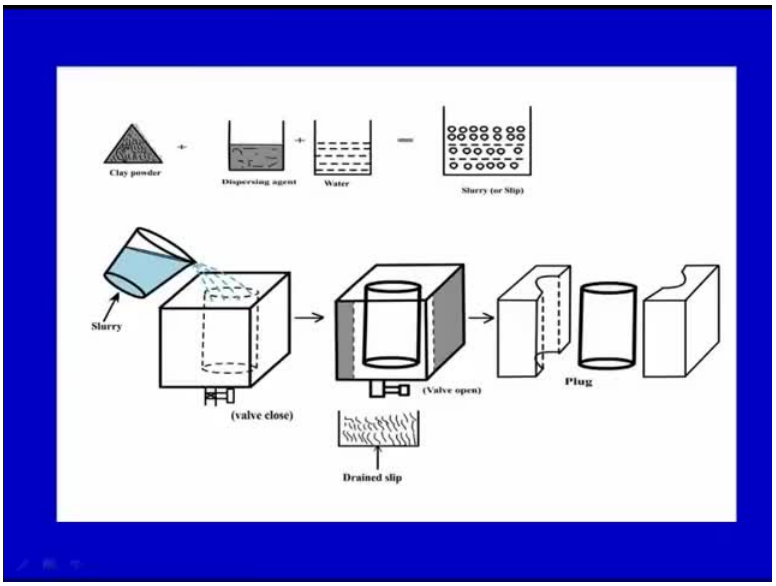

On your screen, you can see the diagram if you have understood all the four stages then it is easier to understand this diagram also. You can see I think the font size is not adequate, but I will explain this in detail this is the ceramic powder. For example, we can take it as a clay powder. So, this is a powder or a ceramic powder plus the dispersing agent plus water. So, this is our we can say the raw material, it forms a slurry this is our slurry.

So, this is the raw material which has been mix together, if you remember the three stages of processing of ceramic part first one is the preparation of ceramic powder, mixing with certain additives. So, additives plus the powder mix our raw material. So, the raw material in the form of a slurry or slip is poured into the mould, this is the mould, this is made up of plaster of paris. The mould is a made up of plaster of paris and then we have a wall this valve is closed slurry is filled inside the mould.

After certain amount of time when the desired thickness this solid portion, or solid lines indicate the desired thickness has been achieve. When the desired thickness has been achieve the valve is opened, here the valve is closed the valve is opened so, that the

excessive slip is drained out this is a container, which can be used for collecting the drained out slip or drained out slurry.

There for sometimes it is called as drain casting also, drained out slurry comes out from this valve, which is opened at a later stage. When the desired thickness or the desired valve thickness of the ceramic part has been achieved finally, the mould opens and we get the desired product or the cast. So, basically we can see there are three or four important steps that are involved, in the slip casting of ceramic parts finally, we get a desired shape.

So, once we get the desired shape we have to go for subsequent operations such as drying or firing or centering and finally, some holes are required machining has to be done in slip casting. We will see certain time flash is formed so, that flash has to be trimmed of it a wire brush can be used to remove that flash or certain times it can be trimmed of with the help of manual or hand tools. This is basically the simple representation of the slip casting process.

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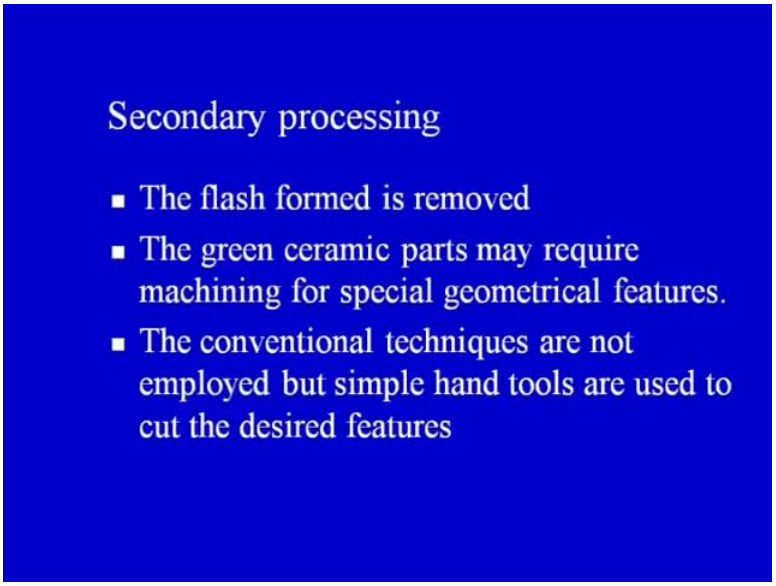

Now, let us see the secondary processing, we are we have been able to form a shape of the ceramic part. The flash that is formed like in forging operation, in forging of metals also many a times flash is formed. So, the flash formed is removed, we can use a wire brush to remove that flash. Secondly, the green ceramic parts may require machining for

special geometrical feature sometimes we may require a hole inside the ceramic product sometime some additional cut is required.

So, whatever are the geometrical features required that are cut into this green ceramic parts before subjecting them, subjecting them to the other secondary operations. So, this is not done by the conventional machining operation. Simple machine, simple hand tools are use and the operations are usually done manually. So, the conventional techniques are not employed, but simple hand tools are used to cut the desired features. So, basically the desired features are cut with the help of hand tools manually, there are other secondary operations also that are involved once, we are able to give a shape to the final product. If you see in case of slip casting, what has be, what is our final product, what was the objective.

So, the objective was to give a desired shape depending upon the final requirement to the ceramic raw material in the diagram. We have seen the raw material is the ceramic powder there a ceramic powder is converted into a slurry, with the addition of certain additives as well as the binder, as well as the dispersing agent or the liquid. Once a slurry is made we are inputting that slurry into a mould and finally, we are making the liquid into a solid.

So, solid part or green compact is prepared. So, the objective was basically to convert raw material into a solid part. Once, the solid part is ready it has to be subjective subjected to certain secondary operation so, that this part can be used desired for the application. So, basically we have seen that what is the slip casting process, but this process has got certain advantages on the contrary, it has got certain limitations or disadvantage is also. Now, we will try to understand that what are the important advantages and limitations of the slip casting process.

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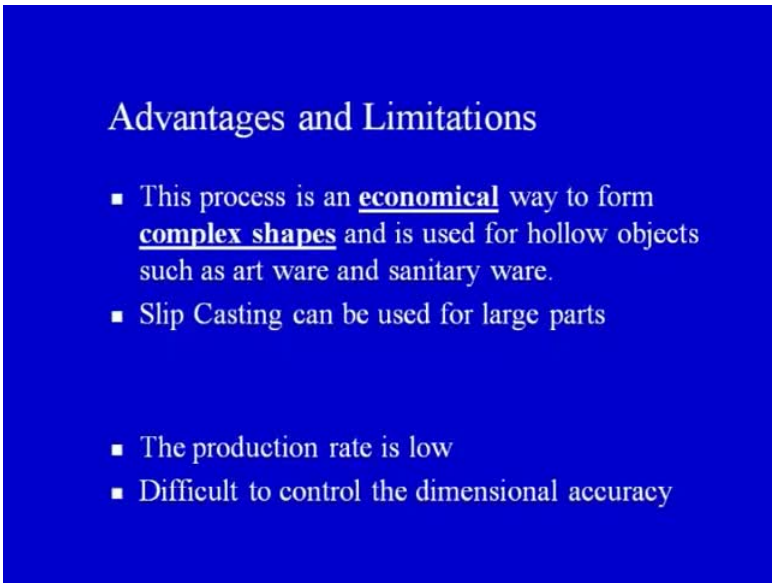

Now, the important advantages are the process is an economical way. So, first important advantage is that slip casting is economical why? Because the mould that we are using a plaster of paris mold, which is not very costly in place of plaster of paris suppose, we use a metallic mold then the cast may be relatively higher, as compared to simple plaster of paris mold. The raw material we are making and it is being poured as in the example, we have seen it is been poured under gravity.

So, there is no we can say mechanized way of pouring the slurry into the mould. In certain further advancements of this process for example, pressure casting many a times pressure may also be used to inject the slurry into the mould, but the process we have seen today simple or the fundamental slip casting, the slurry is poured under gravity into the plaster of the paris mould. So, all we can say technique involved or all we can say process in process is involved or the steps involved in this process are not very costly.

The preparation of the raw material, the pouring of the raw material into the mould, the preparation of the mould all these are the very economical stages or economical process that make of the total process of slip casting. So, the process is economical because we do not have require any expensive or any high and sophisticated instrument, or instrumentation for this process. So, the process is economical, this is again summary of whatever we have discuss.

Second is it can be use to make complex shape, another advantage is that the process of slip casting can also be use for processing of complex shapes. So, as we have seen in our previous process that we have discuss in our last lecture, that is the process of pressing for giving the desired the shape to the ceramic raw materials. One of the limitations what that it can be use simple shapes only, but in case of slip casting we can go for fairly complex shape. So, two important advantages are that the process are economical, the process can be use for complex shapes and it can also be used for large parts.

Point number two, the slip casting can be used for large parts. So, three salient or important advantages of using the slip casting technique, for giving shape to the ceramic parts are that it is economical in nature, it can used for complex parts and finally, it can used for large parts. So, in case of pressing we have seen that if the part is very large then pressing cannot be applied because sometimes in many pressing techniques, we get a non uniform density gradient.

So, have a high density in one particular zone of the product and fairly different density or lover density in the other zone sometimes, we have density on the outer purifier in the density is high, towards the core the density is non uniform. So, pressing can be used for making different types of ceramic shapes, but the density distributions sometimes is not uniform, but in case of slip casting technique we can make large parts wear the uniform density would be there, all along the bulk of the part all along the bulk of the material.

So, basically the three important advantages of our process of slip casting are the economical process, it is the economical process, it can be used for complex shapes and it can be used for large parts, but the part from these three advantages on your screen towards the and you can see the two important limitations also. Now, what are these limitations, the limitations are the production rate is low, because you can see first the preparation of the raw material.

Although it is required in all the process is that are use for processing the ceramic part, but then we have two pour it, give it certain time to for the thickness to form on the inside of the mould wall, then keep the mould in it position for a certain amount of time for giving the time for the thickness to dry up, so production rate is relatively low. And another important point is that it is difficult to control the dimensional accuracy. So, dimensional accuracy is also an issue, in case of the slip casting technique.

So, although it is economical process it can be used for the complex shape and it can be used for a large parts, but it has got two important limitations in the form of production rate and the dimensional accuracy, but still slip casting is use as one of the important process is for giving shape to the ceramic parts. Now, we will focus our attention on some other techniques quickly, we will see which are common techniques which are used for polymers also and they are also used to give shape to the ceramic part. So, till now we have discussed one of the important technique, that is slip casting the fundamental aspects only we have covered.

There can be other important aspects related to the process variables in this process that can be discussed in detail, but the objectives of this particular lecture to highlight the fundamental aspects of the process of giving shape to the ceramic raw materials, and for that we have been able to successfully see that slip casting is an important process, which can use for giving shape to the ceramic parts. Now, let us see some other process is which can use for giving shape to the ceramic part.

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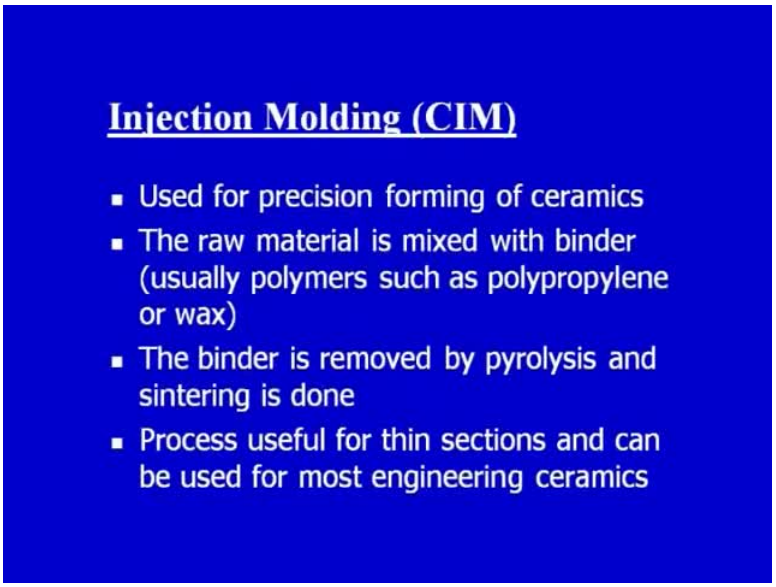

One of the important process is the injection molding, or we can say the name C I M or the ceramic injection molding. In case of metals it is called the metal injection molding and in case of polymers we simply call it, as the injection molding of polymers or in the simply injection molding. So, ceramic injection molding is used for precision forming of ceramics and this process is prolifically use for high and applications like, aerospace

applications or in many cases sometimes may be employed for making bio ceramic parts also. So, injection molding is a process, which is quit widely known or worldwide known for processing of plastics or polymers, but in today's lecture we are seen that it can also be use for processing of ceramics parts into the desired shapes.

So, it is used for precision forming of ceramics that is it is used for high and applications of ceramics. The raw material is mixed with a binder, which is a common process in all ceramic forming techniques. So, the raw material mixed with a binder, the binder in this case is usually a polymer, which can be polypropylene or wax there can be other types of polymers also or specific polymers, that can be used as the binding agents for ceramic particles.

So, the raw materials mixed with binder, the binders examples are given on that your screen that polypropylene or wax can used the binder is removed by pyrolysis and sintering is done. Once the part is ready then the pyrolysis and sintering is done and finally, the process is useful for thin section and can be used for most engineering ceramics.

Some of the important ceramics are alumina or silicon carbide and these particles can be used in a binder of poly propylene or wax. Some other polymer depending upon, we can say the characteristics of polymer or the ceramic material or the ceramic particle they can be mixed together, and can be injected into the mold cavity to give the desired shape.

So, injection molding we will just try to see understand with that the help of a diagram how the process takes place. Although this process, we are going to discuss in detail in case of polymers which is going to be an another module, in which we are going to see the processing of plastics, where injection molding exclusion rotational molding all these process is would be discussed in detail, but today we will just have an overview of the injection molding process.

That how the process actually takes place and in case of ceramics, there are few important points to be taken care of that is already there on your screen, that injection molding in case of ceramics is used for precision, for precision forming of ceramic that is for high and application only. The raw materials are mixed with the binders few examples of the binders are given on your screen and later on, the binders are removed to get a dense ceramic part after sintering. And finally, the process is useful for thin

sections and can be use for most engineering ceramic such as a alumina and silicon carbide.

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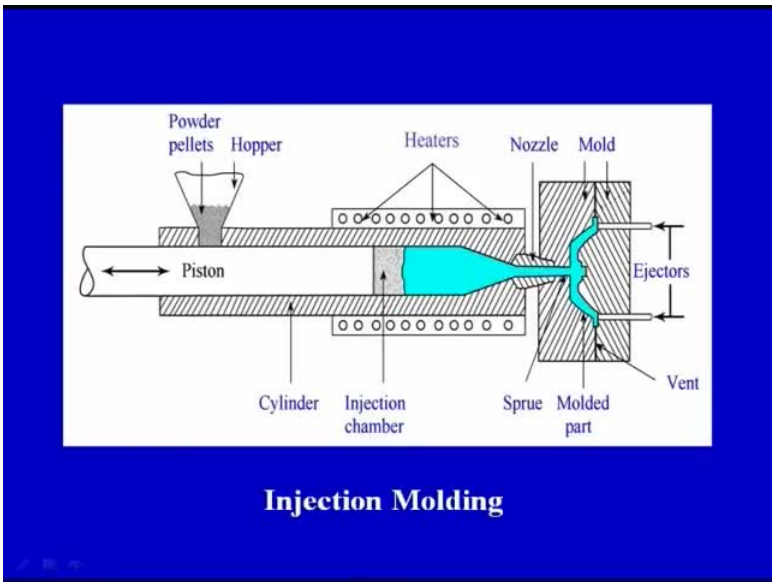

With this now, go on to the diagram of the simple injection molding process. So, we have the powder raw material this is the hopper, the raw material is captor it is mixed with the binder that are there we have already seen, what are the deferent types of binder two examples, we have seen for the binding agent. So, powder and the binder comes from the hopper and there is a piston there is a screen, which pushes mixer into the mold cavity. Now, this is the mould to halves of the mould one half is a stationary half another half is a movable half.

When the two halves of the mould combined together, we get this shape of the final product, this light green color shape is the final product that we want to produce. So, the two mould halves would combined together and would form the mould cavity, and the raw material in the form of ceramic powder, which is having the binder or which has been bound by the binders, or the polymer binders is posed into this mold cavity by this piston. And it is allow to take this shape and finally, the mould halves open and the shape or the green compact is taken out and is put to subsequent processing or subjected to the additional, the additional steps before it is brought in to the usable form for a specific application for which it has been designed and processed.

So, basically the process is fairly simple, the raw material comes. The raw material contains the ceramic powders and the binders, and the binders in this case are polymers different types of polymers can be used it is pushed into the mold cavity. The mold cavity has been generated into the two halves of the mold. One halves of the mold is of stationary half another half of the mold is the movable half and the movable half after the process is complete, the movable half opens and the final product is taken out.

So, this is the basic working principle of the injection molding process, and the ceramic injection molding also uses the same mechanism, and this process we would discuss in detail in our section or in our module of processing of plastics let, but this particular process can also be used for processing of ceramic parts, or for giving shape to the ceramic parts.

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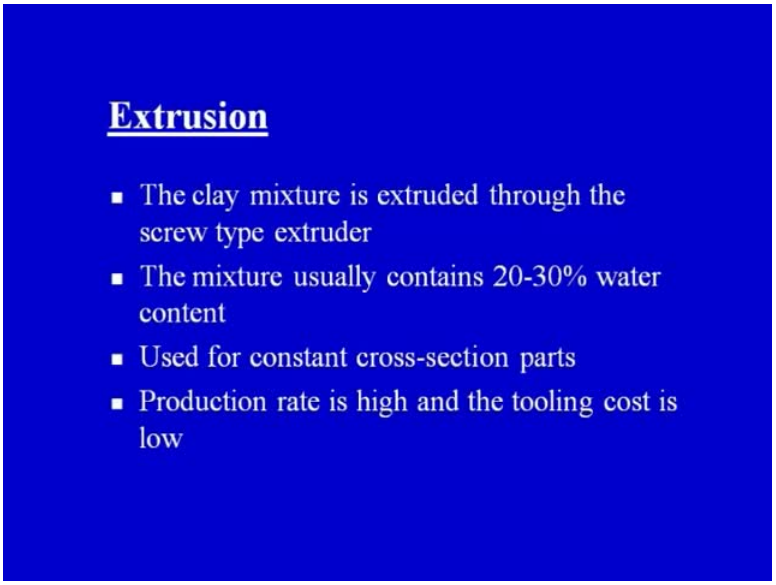

Coming on to the process of extrusion, in extrusion one example is taken the clay mixture, the raw material can be in the form of clay. The clay mixture extruded through the screw type extruder, there can be different types of extruder, you can ever ram type of extruder also, but usually a screw type of extruder is used. We will see the diagram of the screw type of the extruder.

So, the clay mixture is extruded through the screw type extruder, the mixture usually contain high mixture content to 20 to 30 percent of water content, it is use for constant cross section parts only and production rate is high and the tooling cast is low. So, some

of the important characteristics of the extrusion process, in case of ceramics is given with the example the clay mixture is a extruded through, the screw type of extruder mixture content is high it is use for constant cross sections only, and the production rate is high as well as the tooling cast is low.

So, for making the ceramic or clay parts, which can further be subjected to certain other operations to get the desired shape. So, in order to make a raw material of a ceramic part which can be having the binders in incorporated, into ceramic particle or the ceramic particle plus binder mix together extruded through, the extruder gives a sub part which can be further subjected to shaping operation to give a desired shape.

For example, extrusion in combination with jiggering can be used to give a design shape to the ceramic part, but extrusion is the primary step to give a shape to the ceramic raw material. The raw material can be clay as one of the example. So, we can make a clay part which can be further subjected to the other operations in order to give it, the desire designed shape.

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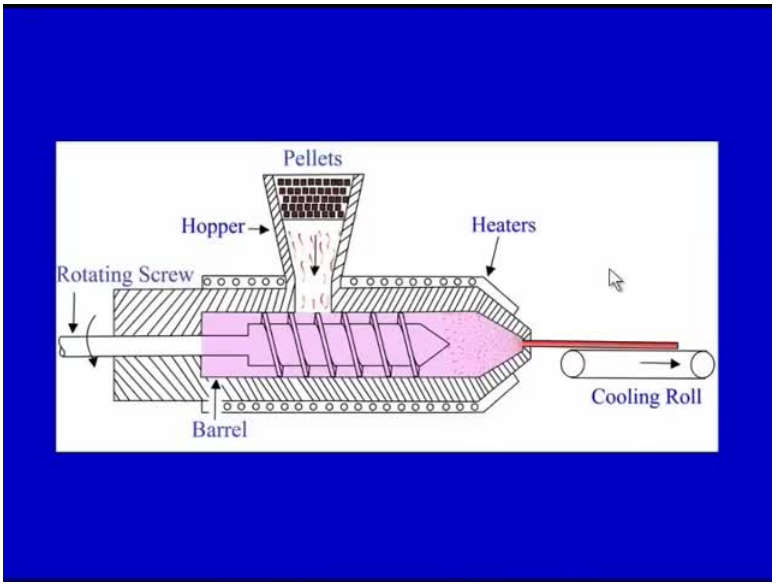

So, basically we can try to understand the basic working principle of the extrusion. This is the screw type of extruder, this is the final part that is coming out. So, depending upon the opening here, we can get the final ceramic part. Depending upon the shape of the opening we will get the shape of the final ceramic part, that part can be further be subjected to other operation, even shaping operations to give it the desired shape, but

extruder will help us to make the raw material ready for further operations, or to give a particular shape. Raw material which can further be subjected to other operations for giving it the designed shape.

So, we have a rotating screw here which is used to feed, or which is used to push the ceramic raw material out of the die opening, which gives it the desired shape. So, basically our objective in today's lecture was to understand, the various process is which can be used to give shape to the ceramic raw materials. So, basically three steps are involved in making the ceramic parts.

Step number one is the processing of or fabrication or the preparation of ceramic powders. Step two is the mixing of ceramic powder with the different types of additives, in order to in parts certain special characteristics to the final product. Step number three is shaping drying and firing of the part, in order to get the desired final product. Today's focus was on shaping in which we have seen that using the slip casting technique, we can give the shape to the slurry.

Using the injection molding technique, we can make a ceramic part or give a shape to the ceramic part. As well as using the extrusion process also we can give a shape to the ceramic raw material. So, we come to the end of today's lecture and in next lecture, that is the last lecture in this particular module on ceramics, our focus would be the secondary processing techniques, which are used for processing of ceramic parts or the technique which make the product, usable for the various engineering applications.

Thank you.