Manufacturing Guidelines for Product Design

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Lecture-03
Manufacturing Processes: Advantages and Limitations-I

Namaskar friends, welcome to session 3 of our course on manufacturing guidelines for product design. As you are well aware the product design process has number of steps and all these steps we have already covered in our MOOCs course on product design and development. We have seen that once we have a novel idea once we have a idea about a new product which can be developed once.

We have a idea which can satisfy the needs and requirement of a customer, we can follow a systematic step by step procedure and develop a product. Now in that step by step procedure the last 2 stages are related to the rapid prototyping and the product development or manufacturing. So rapid prototyping also we have covered in detail, also the development of the product by using the various manufacturing processes we have introduced only in that course.

But here our focus primarily is that when we are developing a product finally we reach to a stage where we have to see that how this product will be manufactured broadly we do 4 types of analysis in the product designer and development process. The first is related to the marketing analysis or the market analysis in which we try to understand the needs and requirements of the market.

What the customer actually wants, what type of products are already available, what is niche market in which we want to introduce our product, who are going to be the users of our products, we do all these analysis and then we can conceptualize idea that this product can be developed, then we do the product analysis we try to understand the functional aspects operational aspects durability aspects of the product.

We try to understand the aesthetic aspects of the product, how it will look like, what must be the colour combination, what must be the texture of the surface and finally we do by economic analysis of the product, we try to see that when we can break even at what quantity

we will be able to achieve all our investments, what will be the return on our investment and finally once we know that this business plan is going to be successful we have a idea, we have the detailed specifications of our product.

We start thinking that how the product will be manufactured and in that case we have to select the manufacturing technology, manufacturing processes, manufacturing techniques judiciously, so that the product is developed in the most cost effective manner as well as we are able to achieve all the specifications which have been laid out for the product and therefore the manufacturing attains or gains or archives are major role in the product design process.

So our understanding of the manufacturing processes in context of the product design becomes very very important and most of the times I have observed that this is particular aspect is not covered in detail. Most of the time focus is in our curriculum related to the process details, the process mechanisms, the technique how a material will be converted into the final product.

We do not focus primarily on the designs that suppose product has to be made by using this process what are the standard guidelines that must be taken into account. So here our target is to give you an overview of the advantages, limitations, applications, exceptions of the various processes. So that as a product designer I know that it is the product is suppose less than a particular size we cannot use this particular processes or a specific process for manufacturing that product.

Or if the product is very very very very large size the huge product we may also have some guideline that this particular product since the size is very large cannot be manufactured by using X, Y and Z processes, it can only be produced by the process P, so therefore what is this process p which is useful for large size products that we will try to see here. Similarly we may also try to understand certain guidelines that suppose the material that we have selected for making the production has a very high melting point.

So when the melting point is very very high we may not be able to use a particular process for example in casting we have to melt the metal, so the melting point becomes very very important. So if the melting point is very high we may not propose the use of the casting

process for making the product by that material which have the very high melting point. So we may propose a different process which can be used for that particular materisl which is having a very high melting point.

So today in the next may be 25 minutes of discussion we will try to have a glimpse overview of may be 3 or 4 processes and see that what are the advantages, what are the limitations of the various processes, so it is very very difficult to cover all the processes but we will try to see that there are certain guidelines we will try to suggest that there are few guidelines which are already existing.

And we can refer to these guidelines when we are selecting a process for manufacturing of our product. So let us just revise what we have already covered in the previous if you remember this diagram already has been shown in session number 2.

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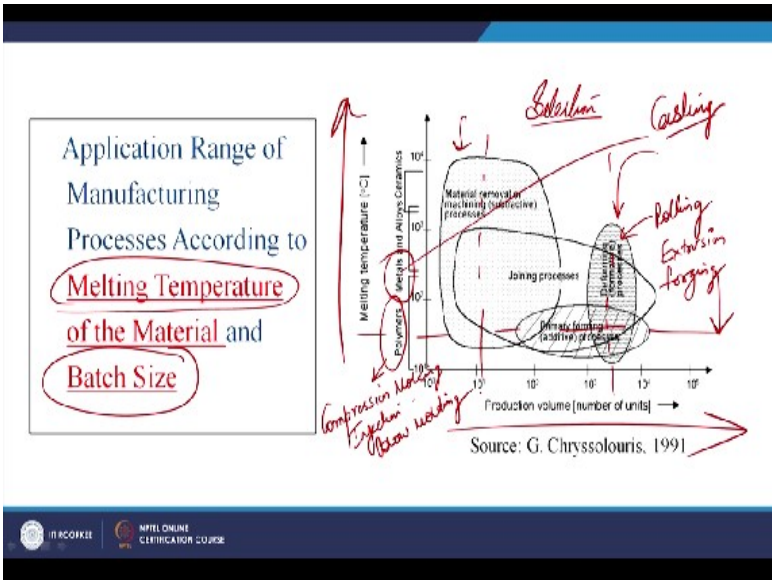

So this is showing the selection of a process based on 2 criteria, the criteria are the melting temperature of the material and the batch size. So the batch size is on x axis and the melting temperature is on y axis and this classification we have seen yesterday that we can classify the processes into 6 basic categories. So we are again revising that once we have to select a process we need to understand that which particular process is applicable under which type of circumstances.

So here we can see the deformity processes already we have seen are used for large volume, so if you see drop down from here so the volume is large, so that if the batch size is large then

only we must propose the use of deformative processes. Similarly the primary forming processes are used when the temperature is less or the melting temperature of the material is less and therefore you can see the primary forming processes are most commonly use for the polymers.

And some of the processes for polymers can be that we are trying to understand today also, one of the process can be compression molding, then it can be injection molding or we can also have a process called blow molding. So this primary forming processes what do we usually do we try to melt the plastic and then we try to deform it as a requirement of the product or as per the shape of the product.

So first thing is melting and second thing is deforming or the first step is melting, the second is deforming it as per the requirement. Similarly for metals also we undertake the process which is usually known worldwide as casting process. So in casting we try to melt the metal and deform it into the required shape of the product. So only possible for primary forming when the melting temperature is lower.

So this is one guideline that is melting temperature is lower go for primary forming processes, if the volume or the batch size is large go for deforming processes, what are the deforming processes, some of the examples cab be rolling, it can be extrusion, there can be other examples, may be you can have another example of forging, so once the batch size is large we can go for the y.

Now why do we need to go for large batch sizes for reformatting process because of the tooling requirement, the machine requirement, the set up requirement. So the setup is costly therefore it must be justified with large batch size for production activities. Similarly machining you can see it is for small batch size. So the batch size is small then we must go for material removal process.

So this way this diagram is an important diagram which gives us an indication based on only 2 criteria, now what are these 2 criteria, this is the batch size and the melting temperature. There can be classification based on other criteria also. Now what can be the other criteria, let us try to understand the other criteria is the properties of the raw material.

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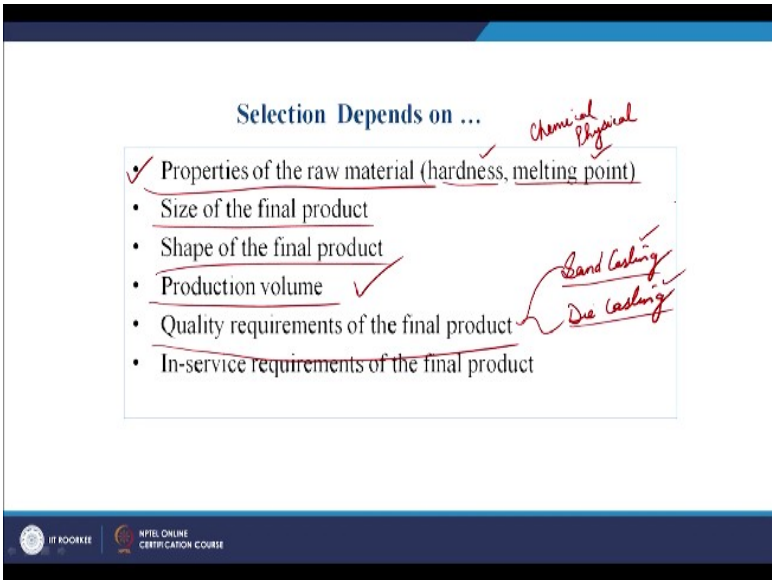

This is the first criteria, this also we have covered in the previous session, we are just again revising because when we are designing a product this is an important aspect that must be kept in mind that how to select a manufacturing process that will be used for manufacturing or fabrication or processing of the product. So one first and important property is that is the properties of the raw material and we have seen that there are different classes of engineering materials which we will be covering in the second week of our discussion.

So regarding the materials the properties are very very important, so the properties can be one of the properties melting point we have seen in the previous slide also, then the hardness of the material is also important there can be other chemical as well as physical properties of the material which may also define the manufacturing process or help us to select the manufacturing process that can be used.

So the properties of the raw materials are a very very important, the raw material means the material which we have selected for making our product. For example the plastic chair what is the material, the plastic or the polymer or thermoplastic is a material which we are going to use for making the chair. So that is a material. So properties of that material, the melting point of that materials.

The other things can be the in case of plastic there can be a glass transition temperature for polymer and their can we are the physical and chemical properties which may decide that whether we can select material for a particular process or not. So that is may be the first thing

is the properties of the raw material which will decide that which process we must choose. The second criteria is the size of the product.

And today we will see that we have taken 4, 5 processes and I will try to understand that advantages and limitation that where which particular process can be used. So there we will see size of the final product is very very important. So the size is very very large you can go for a casting process shape of the final product, so when the shape is very very complicated within casting also we have different types of casting process.

If large variants of the casting process now depending upon the shape if the shape is less complicated we will go for the simple type of casting process. If the shape is very very complicated we may go for advanced type of casting process. For example if you take the example of a jewellery items which is being used by the ladies. So for design of jewellery items we may not be able to cast the gold using a standard casting process.

So there for jewellery there is a separate process which sometimes we called as the investment casting process. So within casting also there is the large variety of processes which are specific to the specific applications. So for simpler shapes we may use the simple casting process and for complex shapes we may be advised to use a different type of casting process. But the summary is that a product designer must know that casting is a versatile process.

Simpler products can also be casted on a complex product can also be casted. Similarly the production volume which we have already seen in the previous slide on x-axis our criteria was production volume. So if the production volume is large what is advisable, the deformative processes are advisable, if the production volume is very very small the material removal process or machining processes are advisable.

Similarly the quality requirements of the final product suppose we take 2 examples here 1 is sand casting which we are also going to cover today and the other one is die casting. So both will give us different types of quality of the surface. So we can decide if the quality of the surface is very very or quality requirements are very very stringent we would like to go for die casting process.

If the quality requirement of surface finish required is not that stringent we may go for a sand casting process. So based on the quality requirements also we will decide that which process has to be used. Now within machining also we have turning, we can do shaping, we can do milling, we can do grinding. So all are material removal processes. So we will see that what type of or what quality of surface we want to produce.

And depending upon the quality of the surface that you want to produce we will select a specific machining process and there similarly in the case of casting. So for regarding the quality requirements of the product we have seen 2 examples sand casting and die casting from the primary forming processes and from material removal we may have to select between shaping, milling or grinding processes.

We will see one may follow the other, so may be first we do the shaping operation, then we do the milling operation on same surface and then we do the grinding operation on the same surface and surface finish will keep on improving. So the quality requirement will also decide the selection of the manufacturing process or the series of the manufacturing processes that we have to use to attain to achieve the desired quality of the surface.

And lastly in-service requirements of the final product will also dictate or also decide that which type of process must be used to convert or to convert the raw material into the final product or to manufacture the product. For example if we take part which is going to undergo cyclic loading. So we would definitely like to use a process which will induce a specific type of stresses on the surface. So that the crack do not propagate on cyclic loading.

So we will select the process such a way that the product performs its intended function as per the designed life or as per the design requirement and that is very very important. So we have to select the process which converts the material into the final form and allows it to perform as per the design life or as per the design requirement. So there can be number of example where the process defines the in-service performance of product.

So these are all the criteria which we must keep in mind, and I must advise you that since this course is only for 20 hours duration we may not be able to cover all processes and all requirements but certainly after going through the course you definitely will be able to

develop that kind of a thinking process, that once we are our design is ready how we can select a process for manufacturing this product.

And that is very important and relevant in today's scenario where we are manufacturing new and new novel products, new and new start-ups are coming defining or may be satisfying to define different types of needs of the society, different types of products are being developed every day. So once we know that the broad summary of the manufacturing processes we can very easily trying to differentiate that which process can be used under which circumstances.

And that is possible only if we have a basic idea about which process is applicable under which type of circumstances and with this background we try to address 4 to 5 processes today and try to see how these processes are applicable for different types of situation. So we start with the most common and that is the first in our list yesterday also we have seen primary forming process that is sand casting process.

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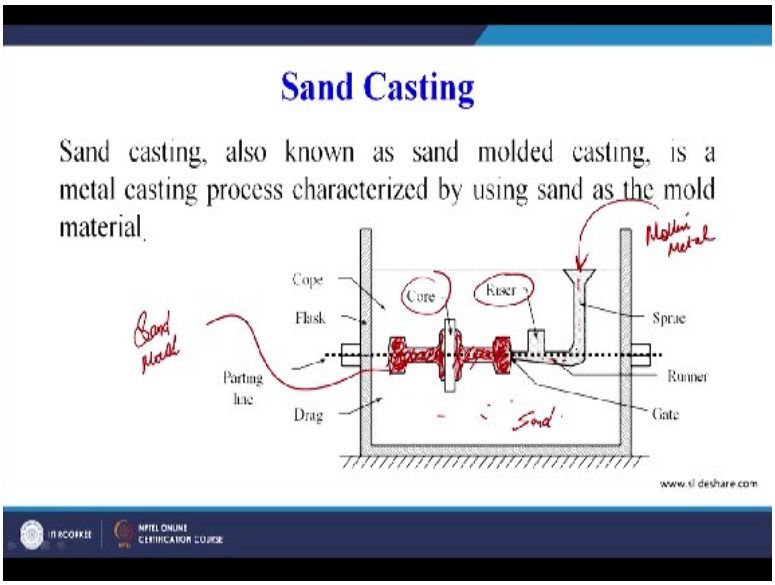

So we are not going to go into the design of the riser or the design of a core or the material required of the shape of the riser or how the riser must be placed in the casting process. So for that there are course which are already available. So in casting process what is primarily done is that we have a mild which we can see that we have a mold cavity which is here. This is my mold cavity.

And this is the core, the core is generally used to create the hollow sections in the casting. So this is the final shape that I am going to produce. So we usually pour the molten metal from

here that is true and the molten metal flows through this channel which is called the gating system and it fills the mold cavity. This mold cavity is created in the sand mold and the metal will come and it will fill this cavity.

And this will be my final casting, this core is taken out and this hollow section is produced in the casting. So this is we can say basic explanation of the casting process that we have a molten metal and this usually we call as the sand mold. So the molten metal comes it travels to the gating system and fills the mold cavity and after solidification the metal takes a shape of the product or the final product that we want to produce.

So sand casting also known as sand mold casting these are metal casting process characterized by using sand as the mold material. So all this is sand, so your the sand mold, so the basic point of sand casting is that we melt a metal there are different types of furnaces which can be used it will be depending up on the requirement we can cupola furnace, we can have rubber plated type of furnace, induction furnace, different types of furnaces are there.

We melt the metal, we bring it to the sand mould, in the sand mould we have already made the cavity which is exact replica of our final product and we pour the molten metal into the sand mold and it after solidification the metal takes the shape of the cavity and our final product is ready. So this is the sand casting process, where the sand casting process can be applied. Now what are the advantages of the sand casting.

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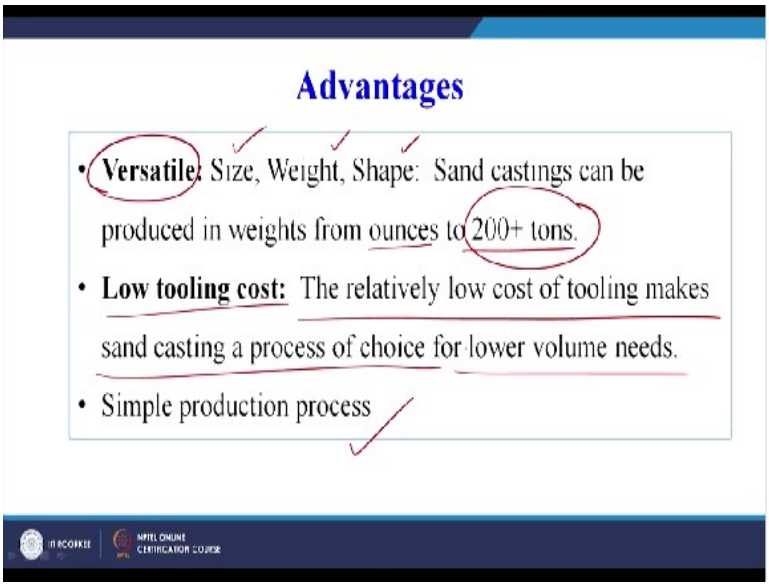

We will also understand the application areas also, but what are the advantages, now sand casting is a very very versatile process, so versatile means that if your product design changes what you can do, you only need to change the pattern which is going to create a mold cavity. So once you change the design of a pattern you can take it to the sand mold, the sand can be reused although with certain additives and modifications.

So sand is reusable, so you can again make the mold, but the pattern now changes, now the design has been changed for the product, so you change the pattern accordingly, now patter is the exact replica of the final product which can be made in wood, it can made in metal also, sometimes it can be made out of wax, it can be made out of cluster of pairs, so depending upon the situation you can make a pattern or pattern is an exact replica of the final product.

So once the product design changes you change the pattern, now you take this patter, put it in sand, complete the molding process, take out the pattern, your cavity is created. So it is versatile because you can do the design modification easily, you have to change the pattern and now the cavity is exact replica or duplicate of the modified design of the product, you have to melt the metal in the similar manner.

You have to bring the metal, the metal flows like water, so depending upon the viscosity of the metal that we have choosen, so the metal flows and it again fills the mold cavity, and it takes the shape of the mold cavity after solidification. So this sand casting process is a versatile process, so you can have you can use fairly complex shapes also can easily be made by the casting process which is difficult to make by the machining process.

Because in machining process you need to have a multi-access machine to create the complex geometry whereas in casting first you have to make a pattern, pattern can be made in wood, if it is a very very complicated pattern you can even make the pattern in wax, so once that pattern or a model or a duplicate or a replica of your product is ready very easily you can create that cavity in sand and the molten metal can be used to create that product.

So it is a versatile process, size is not a limitation from a small size to a very large size casting process can be used, weight is also not a limitation in this case, shape is also not a limitation, the sand castings can be produced in weights from few ounces to 200+ tons. So

you can see a large size products can be made using the casting process. So if your product size is extremely large, it is extremely bulky sand casting is the process.

You can have a sand pit of the size of this room and then you can create the mold cavity there and pour the molten metal on solidification, the metal will take the shape of the product. So if your product design necessities are very large size products or large size a sand casting is the process that you can choose. The tooling cost is also not that high as I have already told the pattern can be made out of wood.

And wood I suppose is not a very costly tooling material and one pattern can be used for making a large number of products because once the pattern is put in the sand it is the mold is ready to take out the pattern you use it the same pattern for other mold. So that way the tooling cost is not very high, so the relatively low cost of tooling makes the sand casting a process for choice for low volume needs.

So if the volume is also less or the volume that we are going to produce is also less, in that case also we can use the sand casting process, hence the process is simple not very very complicated. So from product design point of view you can see that large size products weight is not a constraint even the shape of the product is not much of a constraint. What are the imitation now as we can say there can be certain casting defects.

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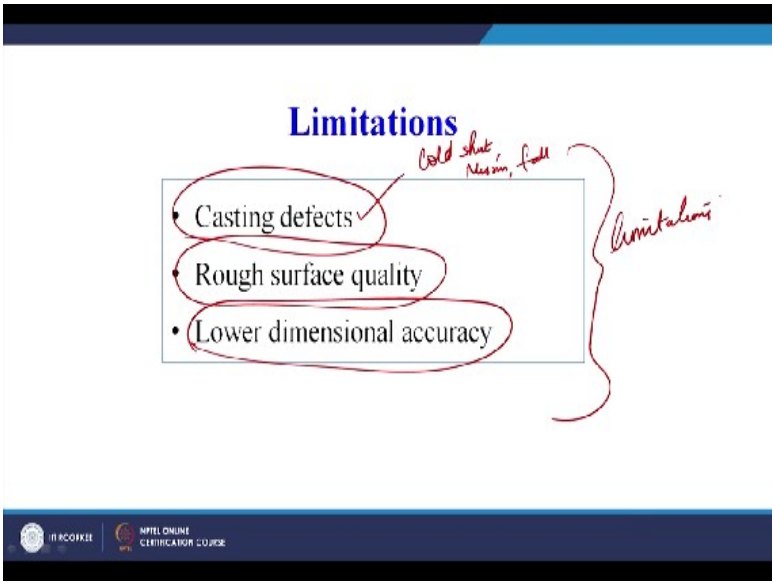

There are number of casting defect such as we can have a cold shut, we can have a miss run, we can have drop or fall, there can be different types, sometimes the metal flow that are very

high velocity it takes away some of the sand also into the mold cavity, sometimes the mold get damaged because of number of reasons, sand may fall from the floor of the or from the top of the mold cavity.

There can be number of defects, so first problem is casting defects, but these defects can easily be avoided with the proper selection of various parameters such as the speed at which you are pouring the molten metal design of the gating system can be helpful for avoiding these defects and then the use of riser, the use of screw can mitigate the effect of casting defects.

But yes once we are selecting sand casting process we must be careful about that casting defects, then the rough surface quality as I have told in one of the example that if the quality is the very very important parameters, so if you want a very fine surface finish die casting we must use because sand casting will produce a rough surface quality and the dimensional accuracy also is not very very good.

Because it is on solidification the metals usually change and when the metal shirks the shape slightly gets distorted. So for that in order to account for this kind of shrinkage we get if we can give different types of allowances. So what I mean to say is that all these limitations that we have pointed out here can easily be covered. So limitations can be covered but we need to have a basic understanding of the casting procedure.

So there are experts, there are courses which are available which explains the casting process in much more detail, in much more maybe detailed manner plus with examples and case study that how to avoid the different types of casting defects. But as a product designer we look at a casting process which is versatile, which can give us very from small to large size of products it can help us to produce from simple to complex products.

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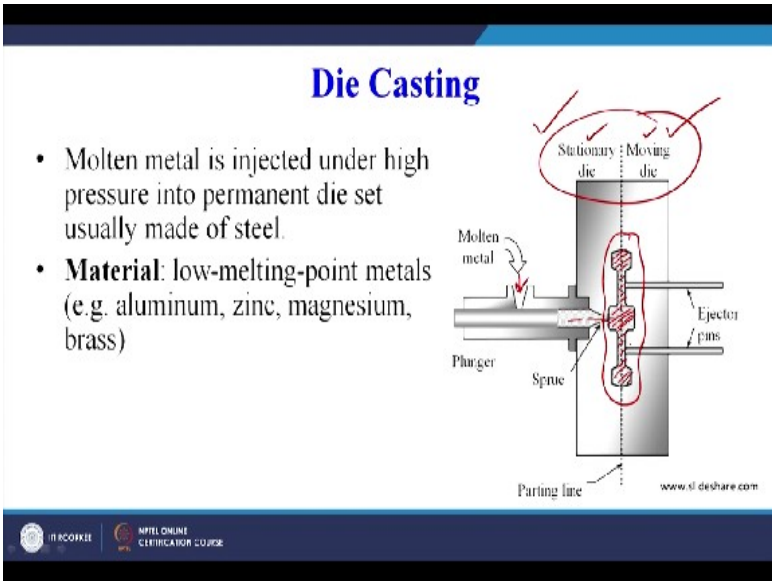

And we can avoid all these limitations of the casting process by proper optimisation of the various parameter that define the casting process. So this is one process let us now take the advanced version of the sand casting process that is the die casting processing, in die casting processing the molten metal is injected under high pressure into the permanent die set usually made of steel.

So there are 2 dies half one is the moving die another one is the stationary die and this is the same product you can see which we are trying to produce here. So this is a molten metal entering from here and this a plunger which will push this molten metal into the die cavity through this route. This is the cavity which has been created by the closing of the mold or the die half. This is the stationary die half, this is the movable.

So the movable die half will come and close with the stationary die half and we will have the complete cavity and when the metal is injected the cavity will be full and once solidification we will get the same product here. Now what are the advantages of the die casting process it will give us better surface finish, our product will have better surface finish as compare to the sand casting process.

Moreover the dimensional accuracy will also be good, so these are the ejector pins, these are used for ejecting out the part of the part, because there is a metal to metal contact the part may have a tendency to stick to the mold half. So this ejector pins will just be actuated and they will pick the part and the part will drop down from the moving half of the die. So this

type of process can be used for low melting point metal such as aluminium, zinc, magnesium, brass.

So the material selection is also very very important, so if we know that our product is going to be made of aluminium and this is going to be the shape of our product and this is going to be the size of our product very easily we can take a decision based on surface finish required, based on the number of parts that we have to produce that whether we must go for a die casting process or we must go for a sand casting process.

Depending upon the design requirements of the product the material which is going to be used for making the products we can select a month the sand casting or the die casting process. So die casting let us quickly see.

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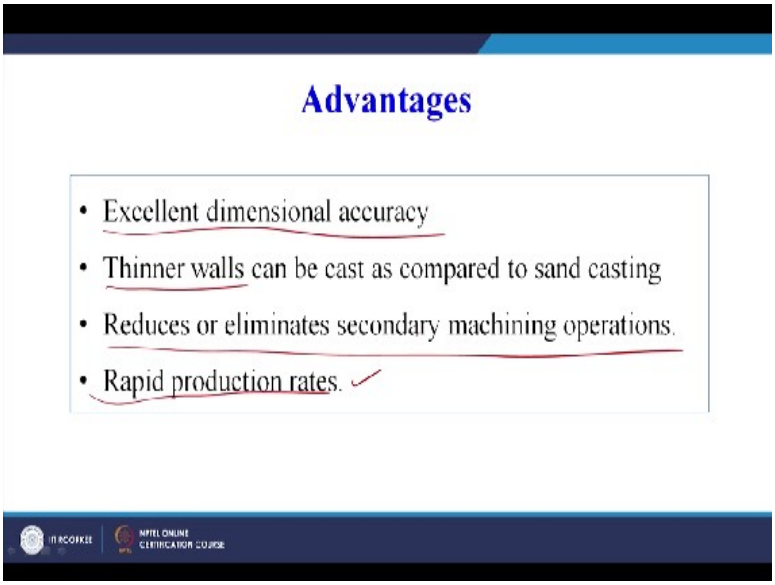

What are the advantages which has got you have seen in sand casting dimensional accuracy is not that good, but in case of die casting the dimensional accuracy that we can achieve is very very good, even thinner walls can be cost as compare to the sand casting. So in sand casting imitation is on the wall thickness. So thinner walls cannot be cast because of the problems associated with the casting defects.

And we can easily cast this thinner sections in case of die casting why because here we are pushing the metal inside whereas in sand casting the metal flows with its own gravity only. So therefore in die casting process we can cast the thinner wall sections also, then it reduces

or eliminates the secondary machining operations. So if you do a sand casting process surface finish is not that good we have to machine.

So additional process is added for finishing the surface of the sand casting product, but in case of die casting this machining is not required because the surface quality that we good we get is very very good and the production rates are extremely high in case of die casting process. Now what can be the limitation, the limitation here can be the high initial cost.

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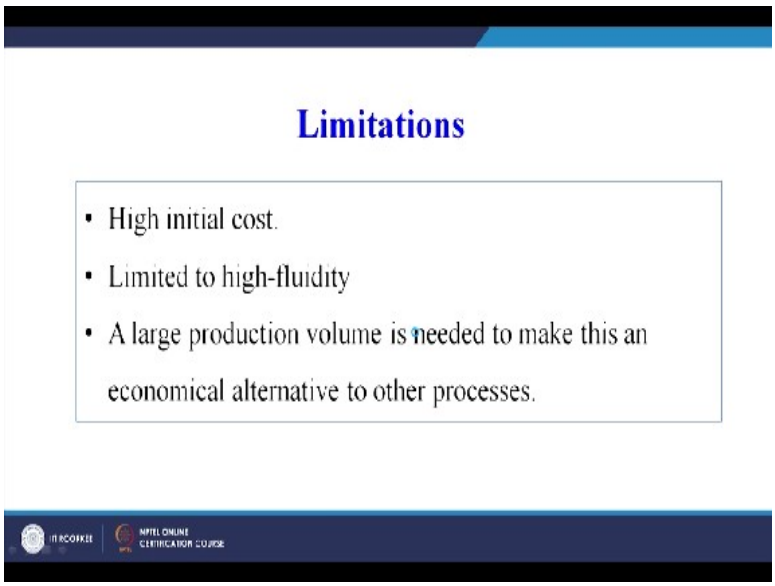

The cost of set up the cost of the machine is high in case of die casting limited to high fluidity metals only, the large production volume is needed to make this an economical alternative to other processes. So we cannot use die casting only for making 10 products or 20 products or 50 products we can use sand casting for that, but die casting is not advisable for small batch size or small number of product.

So die casting is advisable for a large volume, another limitation which is not mentioned here is the size of the product also, so the size of the product is very very large then die casting is not advisable, sand casting is advisable in that case. So with this we close the today's session, we will carry forward this discussion in our next session.

Thankyou.