

Manufacturing Guidelines for Product Design
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Lecture-04
Manufacturing Processes: Advantages and Limitations-II

Namaskar friends, welcome to the session 4 of our course on manufacturing guideline for product design, and if you remember what we are cover till now in the very first session we have discussed about the introductory aspects, why do we need to study this course, what are the benefits of going through the course and what are the contents to be covered in the course we have already discussed and highlighted in our introductory video.

Then in the session 2 we have covered about the basic aspects or the classification of the manufacturing processes, what are the board areas in which the manufacturing processes can be classified. Then in the last session that is session number 3 our focus was primarily on understanding the processes, what are the advantages and limitations, but our target is understanding the process from the product design point of view.

We have to understand that we have already designed the product, now we have to select the process which can be used for manufacturing that product. We are not going into the intricacies of the process mechanisms that how the process has to be done or what are the various control parameters that have to be taken into account while designing the process. For example if you see in the last session we have seen casting process.

So we are not bothered about how to reduce the casting defects or what are the casting defects, because there are other courses which deal with the intricacies of the manufacturing processes, our target is as a product designer to have an idea that yes there is a process which is called casting process, it can help us to make very large size product, it can even help us to produce small size products.

But in sand the dimensional accuracy may not be good in order to have a better dimensional accuracy we can go for die casting process. So that kind of understanding we are trying to develop that as a product designer I must know that when is the product is to be made by

aluminium or maybe to that any other low melting point metal what are the processes available with me which can help me to fabricate my product or to develop my product.

So this course is focused on those specific guidelines, now for example the size we know that this is going to be the size of the product, this much inches is the length or this much inches are the diameter for the product, it has to be made in aluminium. So that we will see certain cases study related to this when we go further into the details of the course. But today we are trying to understand that what are the advantages, limitations.

And what are the various types of processes that are used for making of products. So again I am emphasizing that once our product design is ready we have to select a manufacturing process and why a selection of the manufacturing process is important because we do not want to do the iterations again and again, we do not want to modify the design again and again based on the manufacturing limitations of the organization.

It may so happen that we have designed the product or a product designer has come up with design specifications and when if these are submitted to the manufacturing department for the final manufacturing there are certain manufacturing limitations which again call for redesigning or rethinking about the product design. So that easily be avoided that if product designer focus primarily on the guidelines that already exist which are we are not conducting any research.

But trying to establish any new guidelines for the processor, whatever are already existing if we are able to take into account those guidelines during our product design process our iteration or may be the time will be same and that is the most important parameter these days. Once we have a concept once we have a idea we can make a conceptual design, we can make a detailed design, we can do a prototyping and finally we want to launch the product in the market as quickly as possible.

And finally we want to launch the product in the market as quickly as possible and if you refer to the product life cycle of any product maximum advantage, maximum leverage of the technology can be taken during the initial stages of the product life cycle. So each company wants to launch the product as quickly as possible in the market and that is only possible if we do most of the things concurrently.

And use the concepts of concurrent engineering and similarly we are able to squeeze down the overall product development cycle, we do not want to even a single day. So therefore once we are designing the product we must keep all these manufacturing guidelines in our thought process. So that the product is developed as quickly as possible and therefore we must have a basic idea about the various types of manufacturing processes as a product designer.

So in the last class you have seen that we have covered sand casting and die casting and we have seen the die casting has certainly got certain advantages over the sand casting process, but there are few limitations also the limitations primarily is the high cost of tooling and the machine set up required in die casting. So it is only justified if we have to produce a large quantity or large batch size of the product.

So if large number of products have to be produced then only we can justify the high cost of tooling that is important in case of that is necessary in case of the die casting process. Similarly sand casting has also got its own advantages and limitation. So that is one of the important process which is used in industry for producing the products. Now let us see few other processes.


Forging is another process, so we have already seen a primary forming process which is casting and in casting also we have seen a variant which is die casting, there are other types of casting procedures also like we can have investment casting process, we can have a centrifugal casting process and then for moulding also there a different types of technique that are used for making the mould.

So casting is a very very versatile process but we have just seen that casting can be used for making the products wherever the melting point of metal is less and we can easily melt the metal and pour it into the mould and produce the shape that is required. Similarly forging is another process which is most commonly used for metals.


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Forging

- Forging is a manufacturing process involving the shaping of metal using localized compressive forces.
- The blows are delivered with a hammer (often a power hammer).





Red hot metal



Hammer

<http://www.dropforging.net/open-die-forging.html>
<http://www.mechanicalbooster.com/2016/08/forging-vs-casting.html>

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And forging is a manufacturing process involving the shaping of metals using localised compressive forces, so we might have seen the black smith they produce a fan hooks or to other product day to day product. So this is fan hooks are an important example of the forging process. The blows are delivered with hammer often with a power hammer. So forging also has got different types of modifications or variant we may have hand forging, we may have a machine forging, squeeze forging, press forging.

So different types of forging processes can be used, now what basically done as explained with the first 2 sentences on this slide, we take a metallic piece, we heat it till its red hot and then with the help of a hammer we give the controlled blows on this hot piece of metal and try to give it the desired shape.

Now this process is also important and gives number of products in industry and can be used for making different types of products. Now what can be the advantages and limitations of this process we can see and as you can see in the diagrams also 2 diagrams are there, this is you can see the forging process being done and this is the red hot raw material, or the red hot metal which is being deformed into a desired shape.

And here also you can see this is a hammer, which is being used to deform the shape of the metal. So we are not going to the details of the forging process, but let us try to understand that what are the advantages of forging process.

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Advantages

- Forging can produce a piece that is stronger than an equivalent cast or machined part.
- During the forging process the internal grain of the part changes its form and continuous forging for a few minutes strengthens the part's characteristics.



The forging can produce a piece that is stronger than an equivalent cast or machined part. So what important guidelines we can keep in mind that if we are using forging as a manufacturing process the part that we will get will be stronger as compare to the part made by the casting as well as the machining. So this is a very very general guidelines.

There can be certain exceptions to this guideline but generally as a product designer we can use this as a rule of thumb that is for a specific metal we are using a forging process, we can get a stronger part as compared to if we make the same part or product by casting or by machining process. So one general guidelines during the forging process the internal grain of the part changes or the internal grain structure of the parts changes it forms and continuous forging for a few minutes strengths the part characteristics.

So the internal microstructure of the metal also changes on the continuous forging operation and sometimes or in most of the times it imparts strengths to the part. So we can say that one of the major advantage of forging is that we can get strong metallic parts after the forging operation.

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Limitations

- Hot forging increases the difficulty of performing other machining operations on the part.
- Producing forged parts involves a lot of expenditure for the machinery, dies, tools and personnel.



Now what can be the limitations of forging, so hot forging increases the difficulty of performing the other machining operations on the part. So if we are doing the hot forging operation later on if we need to do the machining on the forced part it may press certain difficulties or it may cause certain difficulties. So that thing we must keep in mind when we are designing a product we must not suggest that first we will force this part to the desired shape.

And then we will machine it, so machining may have certain difficulties after the forging or on a forged part there will be certain difficulties for machining operations. So producing forced parts involves the lot of expenditure for the machinery dies, tools, and personal. So you can see skill is required, if you are doing manual forging suppose I have no skill in the forging operation.

And I start doing the forging, I may not be able to produce a good quality forged part. So therefore skilled personal are required if we are doing a machine forging we are using a die set for the forging operation yes, skill is not required the machine will be able to produce the part that we have designed or the product that we have designed. But yes one of the important limitations here again as was in the case of the die casting in the previous session we have seen is the high cast of that tooling.

Because we need to have fully control system which will be able to do the machine forging and will be able to produce a good quality product using the forging operation of the one of the limitations here again is the high cost of tooling which must be justified with a large

volume of production. So large volume of production means large number of parts that can be made using that forging setup.

If only 4 to 5 parts have to be made these parts will not justify the cost that we will incur on procuring a forging machine or a forging set up. So that is the common thing between a forging setup as well as the die casting setup. So hot forging certain will lead to certain difficulties in the machining of the part if that all it is required so it is advisable that once the part you are suggesting that it has to be made by the forging operations.

We must take into account that we must not prescribed machining after the forging operation. This is the rule of thumb which is followed. Then coming on to compression moulding. Now we have already seen 2 important processes which are used for making the products with metals. Now we are slightly moving our attention towards the products which are made by plastic.

So if we want to make a plastic part we can use processes such as compression moulding we can injection moulding, we can you blow moulding, we can you transfer moulding. There are number of processes rotational moulding is another process for making large exist symmetric hollow parts. So depending upon the requirement we can choose a process for plastics also. So why we are trying to cover both metals and plastic because when we see the product around us we see some products which are made out of metals.

We see certain products which are made by plastics. So our course is focused on a wide variety of products. So we are not only focused on metals as the material or raw material as a product material or not only focus on plastic as the raw material for the product. So basically the focus is on different types of products that can be developed and what are the manufacturing guidelines for different types of manufacturing processes.

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Compression Molding

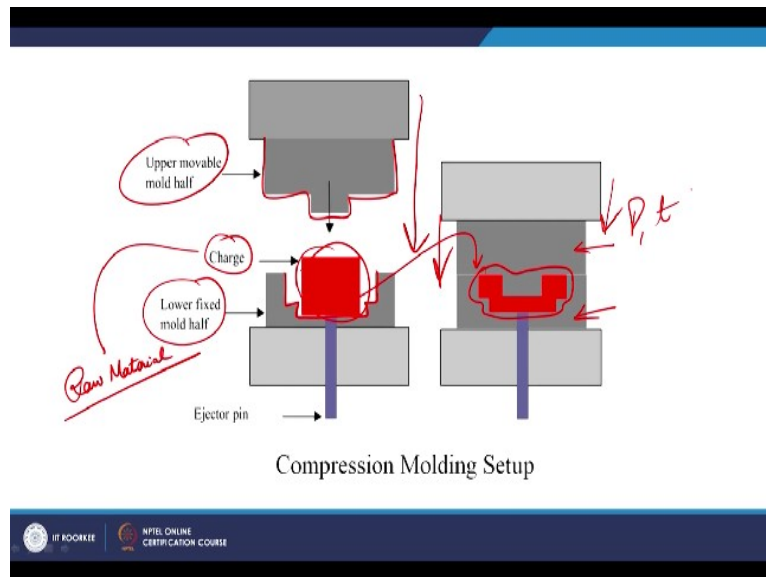
- Compression molding process is one of the low cost molding methods as compared to injection molding and transfer molding.
- It is a high pressure forming process in which the molten plastic material is squeezed directly into a mould cavity, by the application of heat and pressure to conform to the shape of the mold.

Now let us see compression moulding, what is compression moulding. Now compression moulding process is one of the low cost molding method as compared to injection moulding and transfer molding. So important point here is low cost molding as compare to injection and transfer molding. So suppose we want to produce a part where the cost of the part is very very important.

So therefore we though in that case we may like to go for the compression molding process. It is a high pressure forming process in which the molten plastic material, what is the raw material here, the plastic materials we have to melt that material it is squeezed directly into a mould cavity by the application of heat and pressure to confirm to the shape of the mold. So we can try to understand it with the help of a diagram.

In compression moulding if you see 2 words are there compression and molding, so we have to compress the raw material and it will take the shape of the mold and finally solidify as per the shape of the mold and we will get our product.

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Now let us see this is a simple diagram of a compression moulding process, this is a lower fixed mold half it is complained to a particular shape which I have highlighted and this is upper movable mold half. This is the shape of upper movable mold half and this is my charge which usually we call as the raw material. So we have a raw material, this movable half will move down as it is shown here, it moves down.



And this is upper half, the lower half when they will be in contact with each other, they will form a cavity here, this is a cavity and this charge which was earlier like this takes the shape of the product a very simple process which can be used for making of the plastic parts. So we are not going to go was already highlighted in the previous slide there an important control parameters here that important control parameters can be.

What is the temperature of the charge, what is the pressure that is being applied by the upper half of the mold, for half what is the pressure, what the time required for which you have to keep the 2 mold half together. All these parameters have to be controlled in order to make a good quality part using that compression molding process. But what are the advantages where this process can be applied that is what we need to understand.

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Advantages

- Low initial setup cost and fast setup time
- Heavy plastic parts can be molded.
- Good surface finish of the molded parts.
- Wastes relatively little material as compared with other methods.
- Thermoplastic composites with unidirectional tapes, woven fabrics, randomly orientated fiber mat or chopped strand can be manufactured.

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Now the advantages of the compression moulding process are initial setup cost is not very high, fast set up time, so we can vary quickly made the product, so when we have to produce large number of products we can go for a compression molding process. The charge can be made ready, the raw material can be made ready, out it into the mold half close the 2 half of the mold, keep it, keep the 2 half close for a particular period of time as decided by the product designer.

And then you open it your product is ready easy process, simple process, initial setup cost is not that high and the cycle time is also very very fast, heavy plastic parts can be molded, now suppose you have designed the plastic part which is large in size and is flat in nature. So the shape is also important, size of the products is also important as we have seen in the previous sessions when we have to select a manufacturing process there is a criteria that we have to address that we have to follow.

So thus if the size is slightly larger, if the thickness of the wall is not that high or the wall thickness of the product is not that high and is the shape is not very very complex, then in that case we can go for the compression molding process. so heavy plastic parts can be molded, good surface finish of the molded parts, why because on both side we have the upper half, upper mold half and the lower mold half when you compress the top surface is also very very good.

Because the metallic finish is transferred on the plastic part on the lower half of the mold also the metallic finish is transferred to the product. So top and bottom both side the surface finish

is good. So the good surface finish of the molded parts, large size, heavy parts can be made by compression moulding, waste relatively little material as compared to the other method. So whatever charge you can what is the quantity.

What is the volume of the material that is required for making the products it can be pre calculated, it can be pre decided and that decided amount of material is put between the upper half and the lower half of the mold and then you compress it under the temperature and pressure hold it for some time it will take the shape of it, wastage of the material is very very less in case of compression molding.

So it waste very less material thermoplastic composites with uni-directional tape or fabric randomly oriented fibre mat or chopped strand can be manufactured. Now this point is relatively difficult to understand because it talk about a composite material, all these points are relatively simple to understand because they only talk about the plastic material. But many times this plastic material maybe reinforced with certain fibers which may be available in the form of unidirectional tapes.

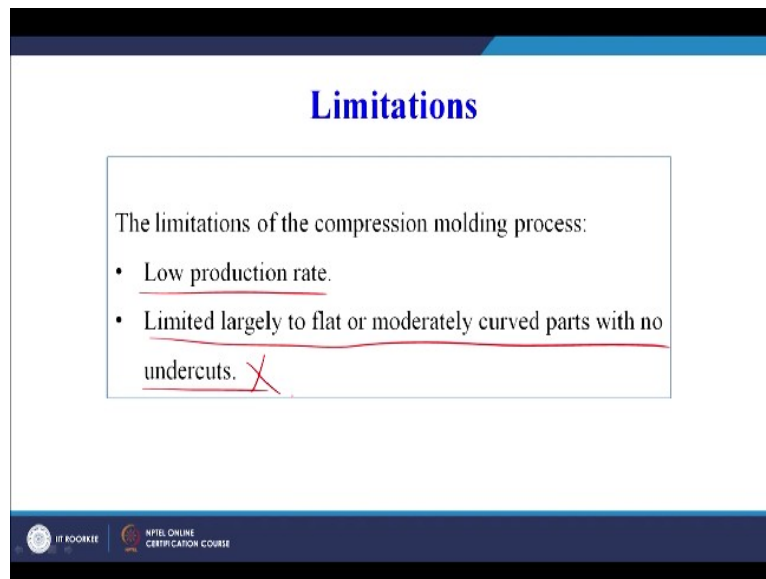
They can be available in the form of woven fabric or even they can be available in the form of randomly oriented fibre mat or maybe in the form of the last form also given in the form of chopped strand mats. So we can make simple plastic parts also using compression molding and we can even make composite products using compression molding process, in that case we will have 2 raw materials in the charge or as a raw material going into the upper and the lower half of the mold.

We will have polymer or the plastic also we will have fibre in the form of cloth or in the form of chop strand mat. So you put both these raw materials together in between the upper and the lower half of the mold and it will compress this product or this raw material to convert it into a product. Now in this product we will have fibres also, we will have polymer also. So we can make composite material or fibre reinforce plastic parts also using the compression molding process.

So that versatility that flexibility also is available with the compression molding process, we can make only plastic parts, we can make plastic reinforced with certain fibres also using the compression molding process. So we can see it is a very very versatility process can be used

for large size part, surface finish is good, can even be used for making of composite product wastage is also very very less.

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Limitations

The limitations of the compression molding process:

- Low production rate.
- Limited largely to flat or moderately curved parts with no undercuts. X

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So we can say it is a very good process that there has to be certain limitations. So what are the limitations, so limitations of the compression molding process are low production rate, so the production rate as compared to injection molding or blow molding is relatively less, limited to largely to flat or moderately curved parts with no undercuts. So undercuts in the product design have to be avoided.

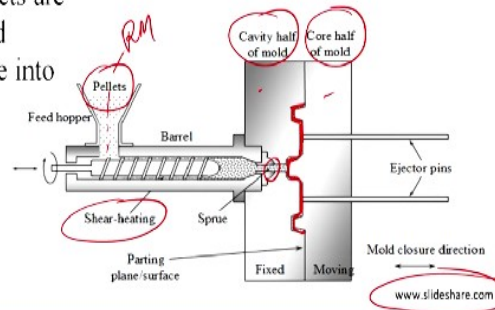
So this is the good guideline for product designers that if the product has to be this product is having a large number of undercuts, so there in that case compression molding process is not advisable. Similarly if the surface is very very complex three-dimensional in nature compression molding not be a good processor. Why because here we have upper half and the lower half of the mold from sides we may not be able to apply too much of pressures.

So compression molding process is broadly used for flat surfaces or slightly curved surfaces only, it is not advisable for very very complex 3-dimensional products. So limited largely to flat or moderately curved parts only. So we can see with no undercuts, so it give us a limitation in our product design that if our design has lot of may be three-dimensional feature which is having lot of undercuts we may not go for compression molding.

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Injection Molding

- Thermoplastic pellets are melted and injected under high pressure into a metal mold.



But yes as engineering we will never give up there are processes as you or we can see on your screen. We can use injection molding process, in injection molding you can see presentation is already available on slide share this diagram has been taken from slide share, thermoplastic pellets are melted and injected under high pressure into the metal mold. There number of presentation, good presentations available on injection molding on internet.

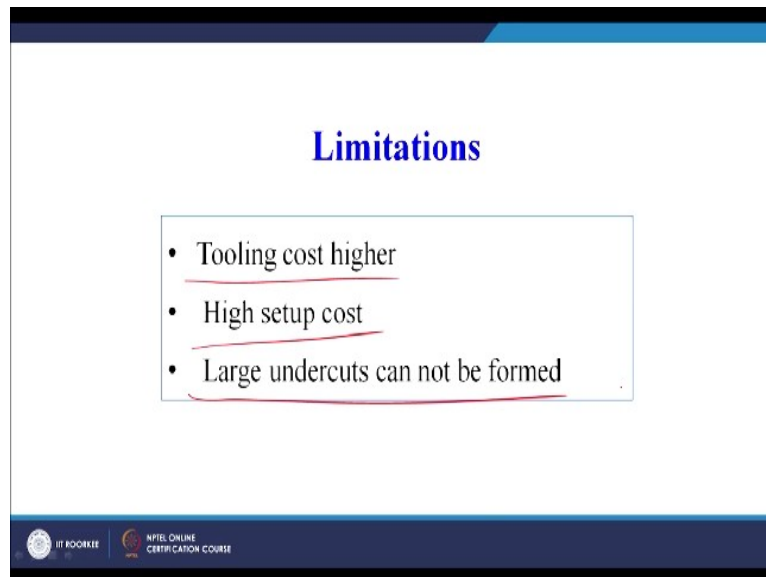
Even we have also developed a course on processing of polymers and polymer composites where we have discussed all the details related to the injection molding process with the help of certain videos also, we have shown how the process actually takes place. But here we can see that in compression molding the material is compressed between the 2 half of the mold and we get a final product.

What are the advantages and limitations, where the compression moulding process is good, we have already highlighted. Similarly in injection molding what we do this is the raw material here, this is the raw material it comes here and then shear heating takes place during this barrel, and finally this is a screw, it this is my final product here I am highlighting the product that we have to trying to make using that injection molding process here.

So this is our final product that I have already highlighted so again here there is a this is 1 half of the mold, this is another half of the mold, this is movable, this is fixed, so the movable half will come and it will close down with the fixed half in between we have a cavity we melt the molten plastic or we melt the pellets and the pellets are pushed into the mold cavity between the 2 half of the mold and finally we allow it to solidify.

Once it has solidified we take out the product. So this is slightly different from our compression molding process. So what can be the advantages here, we can see that make a slightly more complicated design or slightly more complex designs using the injection moulding process as compared to the compression molding process.

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The slide is titled "Limitations" in blue text. Below the title, there is a white box with a blue border containing three bullet points, each underlined in red:

- Tooling cost higher
- High setup cost
- Large undercuts can not be formed

At the bottom of the slide, there are logos for IIT Kharagpur and NPTEL ONLINE CERTIFICATION COURSE.

So where we can see the production rate is very high close tolerance is on small intricate parts, another good guideline intricate parts, if you have to make by plastic material which is the process injection molding is the process. Another guideline size of the product will not be too large in case of injection molding whereas in case of compression molding we have seen large bulky parts can be made.

So size of the product has to be small it can be slightly complicated, wastage is minimum here also, complex geometric can easily be produced. So we have seen we can see all around us if I can give you the first assignment for that course you can look around you and see and identify plastic products which might have been made by compression molding as well as might have been made by injection molding.

You can make a table compression molding these are the parts around you in your day to day life, similarly for injection molding these are the products which have might have been made by the injection molding process. Now what are the limitations, again the tooling cost is higher here because the mold design and fabrication is a tedious process the mold cost is the most important cost in the whole injection molding setup.

Setup cost is also high because we have to control we have to see the melting of the plastic and only that plastic molten plastic is pushed into the mold cavity. So we have to control that also, we have to control a number of parameters for making a good quality plastic part using injection moulding process. So the set up cost is high, so we must only recommend injection molding process where large number of products have to be made.

We must not recommend injection molding for a very small number of products for a very small number of product we can suggest rapid prototyping process such as 3D printing only 4, 5 parts have to be made we can make them using the 3D printing process, but if the large number of parts have to be made large number of products have to be made then only we must suggest the use of the injection molding process.

Here large undercuts cannot be formed, though may smaller undercuts can be form a large undercuts it is even difficult to make in the injection moulding process also. So in our last 2 sessions if you remember we can summarise that we have covered 2 processes which are used for making the metallic products and we have taken 2 processes which are used for making the plastic products

So we with these guidelines if we keep in mind these guideline during our product design process we can modify our design accordingly and suggest the process that yes this process can be applicable for my product design. Although these are not the only processes the list of processes is endless but our objective is to orient the thinking of the learner in that direction that such type of information is available.

And this information must be used while the product design process in order to minimise the time required for launch of the product with this we conclude the today's session, in next session we will try to wind up our first week of discussion by discussing the process capabilities, application and exception of certain processes by taking appropriate case studies, Thank you.