Manufacturing Guidelines for Product Design
Prof. Inderdeep Singh
Department of Mechanical and Industrial Engineering
Indian Institute of Technology-Roorkee

Lecture 17
Selection of Processes-II

Namaskar friends, welcome to session 17 of our course on manufacturing guidelines for product design. As you were well aware that currently we are in the fourth week of discussion, we have already completed 3 weeks. And in 3 weeks our broad focus was on manufacturing materials and design. The various design tools that are used that must be used in fact by the product designers were discussed during the third week of our discussion.

We focused on the concept of robust design, we focused on design for X, we focused on DFMA guidelines, we focused on ergonomics as well as we focused on product design guidelines based on the products which have to be assembled manually. So, we had a overview of the concept of manufacturing as well as materials and how it is applied or how the information related to manufacturing and materials must be used by the product designers.

So, that is the overall summary or maybe synopsis of this course that we need to bring together the information related to manufacturing which is handy which can be used by product designers during your product development process. And in that context we started the discussion for fourth week in which we have already seen 1 session on selection of processes which was selection of processes 1.

And in that line our target is selection of processes 2 today and we will try to see certain charts some of them we have already seen in the previous class the remaining we will try to cover today. And with these 2 sessions that is session number 16 and session number 17 I am quite sure and clear as well as confident that every product designer can make use of this information and this information will be handy for product designers in the long run.

So, this information not only talks about the manufacturing aspects it talks about the limits it talks about the boundaries within which a particular manufacturing process will operate based on the various attributes. Usually in manufacturing for any manufacturing course whenever we take a course on manufacturing we try to learn that how the process will work, how the process will work means how the process mechanism is there, how the raw material will come.

Then it will go through the process then it will get converted into the final product. So, these lectures are not related to the manufacturing of the products it is related to the guidelines, the boundaries, the limits for the various attributes. Such as the mass that a particular process can be used for a minimum mass of this much kilograms or a process can be use for making products which can run into tons of mass.

So, that is the limit, limits of attributes similarly related to the surface finish, similarly related to the tolerance, similarly related to the shape as well as the size. Size I have already told can be in terms of dimensions in terms of meters or centimeters. So, we have different attributes and these 2 sessions give us the limits for the various attributes in context of the processes. And if you remember in the previous session we have of material matrix process, material, matrix.

So, there were 2 important things that the processes, so the processes were broadly classified as if you remember the shaping processes, the joining processes, the finishing processes. And the materials were as we have discussed in the week second of our course the materials were like metal which are ferrous, metals which are non ferrous, alloys, polymers, thermosets and thermoplastic type of polymers, ceramics, composites.

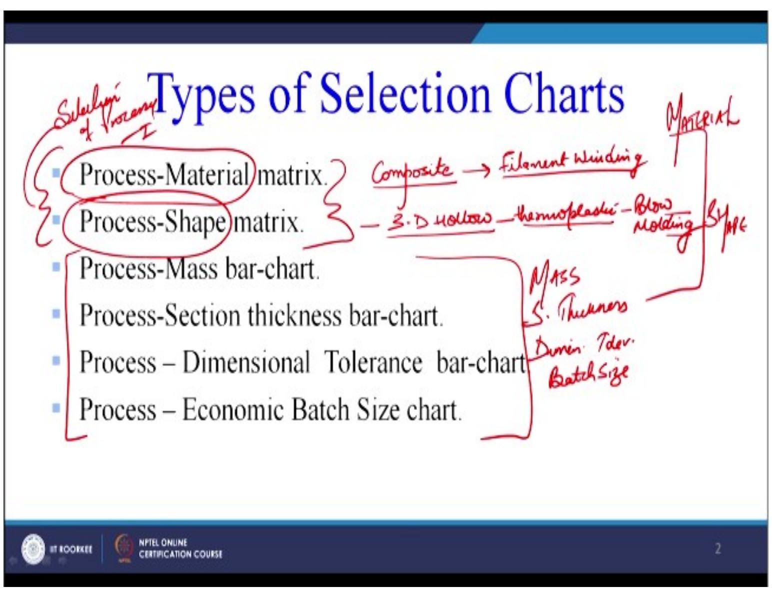
So, there was a long list of materials, there was a long list of processes as I have already and then points were given or maybe the circles were made that this process is compatible to this material, this process is compatible to these 3 materials, this joining process is compatible to these 4 materials. So, the process-material matrix we have already discussed in our selection of materials 1 that is session number 16.

Similarly we have seen the other matrix also in which we have tried to correlate the shaping process with the maybe the shapes, the process and the shape. And we have seen that how the various shaping processes, we have 3 classifications for these 2 sessions for the manufacturing processes the first one is the shaping processes, the joining processes and the finishing. Now for giving any shape the joining and finishing is not that relevant only relevant are the shaping processes.

So, the shaping processes and the different types of shapes that is circular shape, prismatic shape as well as maybe continuous profiles, long continuous profiles, we have seen 3D hollow, 3D solid. So, different shapes and then the processes that which process is relevant to which type of shape, maybe for example we have seen a 3D hollow shape can be produced in thermoplastic material using the blow molding process.

So, that can easily be deciphered that can easily be observed, that can easily be seen from the process shape chart which we have seen in the previous class. So, today we will carry forward our discussion from these 2 type of charts which we have already covered. And then we will see the other types of charts which are available on internet as well as in E-resources and we must make use of these charts as product designers and make use of the information which is easily available in the public domain. So, let us now try to see that what we have covered till now and we are going to cover today.

(Refer Slide Time: 07:05)



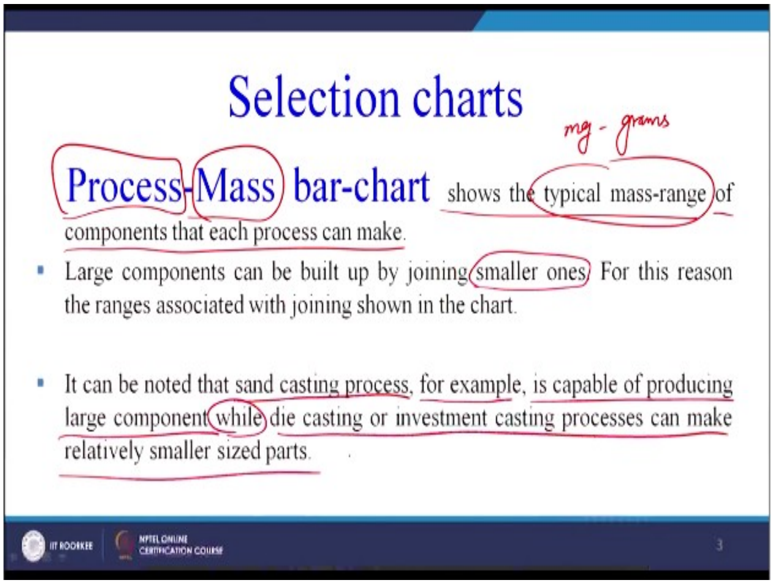
So, these are the 2 things which already we have covered the process material already I have taken an example, the process shape already taken an example. So, process shape we have already seen that a 3D hollow shape this is a shape then the material is maybe thermoplastic and the process is blow molding 1 example. So, such information is easily available similarly the process material also we can take any example that we can take a composite material let us see a composite material and the process can be filament winding.

So, this is the process and this is the material, this is the shape, this is the material and this is the process. So, such type of information is already available and we have already covered these 2 in our first session on selection of processes 1 and today our target is to cover these 4 types of charts process-mass bar-chart, process-section thickness bar-chart, process-dimensional tolerance bar-chart and process-economic batch size bar-chart.

So, 2 attributes already taken care of which are if you summarize 2 attributes for process selection first one is the material already taken care of in the previous session the shape already taken care of and today our target is mass, section thickness, dimensional tolerance and the batch size. So, the how the processes can be selected or eliminated as we have seen in the previous session that there is a broad family of processes we keep on eliminating which do not satisfy the design requirements.

And then finally we select the best process which satisfies our design requirement, so these 2 attributes already done these 4 is the target today, so let us take them one by one.

(Refer Slide Time: 09:40)



The process-mass chart as the name indicates there will be a process and there will be the change or maybe the mass or the variation in the mass that process X can be use from this much grams to this much kilogram, process Y can be used from this many kilogram to this many tons. So, this is going to be setting up a relationship between the mass and the process that for this particular mass this process is advisable.

So, as a product designer we can very easily calculate the mass of our product and once we know the mass very easily we can try to look at these charts and locate that which are the possible or the plausible alternatives available with us in context of processes that can manufacture this much mass. So, let us now try to see that process mass bar chart what is it, it shows the typical mass range of components that each process can make very very simple English language.

Shows the typical mass-range already I have told you maybe from milligrams to grams or from grams to kilograms. So, this is going to show a typical mass range for the components or the products which can be processed by various processes. We will be able to better comprehend it once we see the chart large components can be built up by joining the smaller ones.

So, for smaller ones we must know that which process can be used for how much mass of a product or a component. Obviously there is no process which can make the complete airplane or a aeroplane in a single shot. So, for aeroplane to be developed or to be made it will always be made in parts, components, sub assemblies and these will then be put together to make the complete product which is a aeroplane.

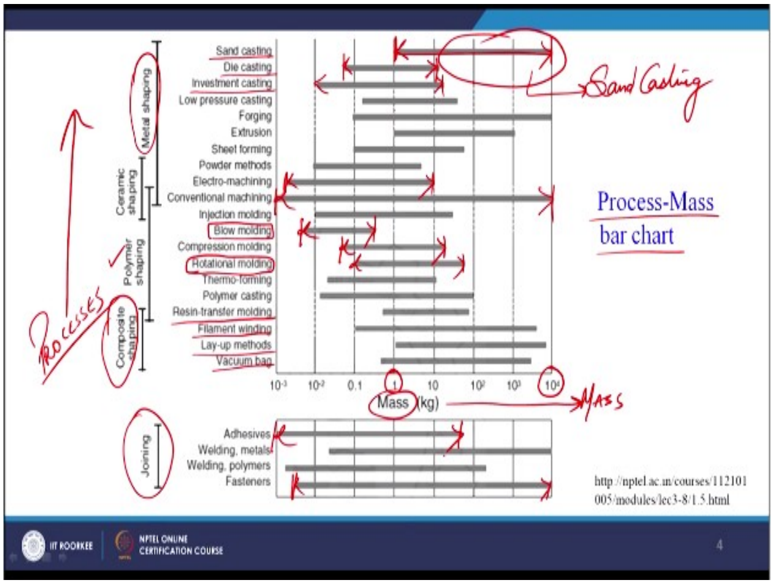
Similarly for making the individual parts of a aeroplane also some parts will be very bulky whereas some parts will be very very light. So, depending upon the lighter parts and depending upon the bigger parts we have to choose the appropriate processes that this process is maybe suitable for this size of component, size in terms of mass here. So, we have already seen shape, we have seen process material relationship, we have seen process shape relationship in the previous session.

Today we talk about the process mass relationship, so for each and every range of mass different processes are applicable. So, we can see for this reason the ranges associated with joining are shown in the chart it can be noted that sand casting process which is already we have seen sand casting. It can be noted that sand casting process for example is capable of producing large components while die casting or investment casting processes can make relatively smaller sized part.

So, as a product designer such types of thumb rules must be known to us before we start our design process that if the part size or the product size is large or it is heavy we can go for obviously sand casting process. But if the size is very very small for example the jewelry items which are usually warn by the ladies.

So, for jewelry item we will not go for sand casting process, we can go for investment casting process for making the jewelry designs. So, therefore these type of information must be easily available with the product designers, so that they can select their processes accordingly.

(Refer Slide Time: 13:47)



Now on your screen you can see a process mass bar chart different processes are given here and as we have seen that bulkier parts like an aeroplane can be made by joining processes also. So, the joining is also listed here as we have seen in the previous slide also and then we have sub categorization of the shaping processes. So, we have metal shaping, we have composite shaping, so obviously for composite shaping we have different processes.

Such as the resin transfer molding, filament winding, lay-up methods, vacuum bag molding, so that is for shaping the composite parts. Similarly for metal shaping 2 examples already we have taken sand casting and die casting also we have mention the term investment casting. So, for each one of these the size is clearly mentioned, on our X-axis on this axis we have mass which is already written.

So, this is mass in kgs, so on x-axis we have the mass, on y-axis we have the processes, now we have to establish a relationship between the 2. Now let us take an example we have already mentioned in the previous slide for sand casting you see the range is range starts from here and it goes till here. And if you drop this down we can see from 1kg we can go up to 10 to the power 4 kg.

So, this is the working range for sand casting process whereas we have seen in the previous slide that if we have to make smaller components we can make use of investment casting and die casting or not smaller but lighter component where the mass is less. Now let us see that die casting you can see the range for die casting considerably lower than the sand casting process and for investment casting also you can see the range is further narrow.

So, the range is wider for investment casting but it can make very light or very less weight products. So, as I have already take an example the jewelry items worn by the ladies usually are made by the investment casting process. So, we have a range here you can see for shaping of metals where die casting and investment casting are not advisable. So, for this range if we have to make a very heavy part or a component or a product only sand casting is advisable.

So, these type of charts give us a clear indication that which type of process must chosen for which type of product. So, if it is a very very bulky product very very heavy product obviously it has to be made in metal another condition obviously the sand casting is the choice. Similarly we can see here that for electro machining this is the mass range and for conventional machining very wide range.

So, we can see that we can do the ceramic shaping conventional machining very large range. Now coming on to the polymers we can see blow molding you can see this is a process blow molding of previously also we have seen this is the mass range for blow molding. So, blow molding is not advisable for very heavy part, so the plastic 3 dimensional hollow plastic bottles are made by the process of blow molding.

Similarly compression molding for plastics even heavier parts can be made then blow molding similarly rotational molding large axis symmetric parts can be made. For example overhead tanks of plastics are usually made by the rotational molding process for shaping the polymers. So, therefore we can see that there is a relationship between the mass and the process that we choose and this type of charts are really helpful for the product designers when they decide on the material.

Now first thing has to be decided that what is going to be the material and therefore we have already emphasized on the importance of the materials in the second week of our course. First week was dedicated towards basics of manufacturing, classification of manufacturing processes, selection of manufacturing processes. All these attributes we have highlighted there also but not in much detail.

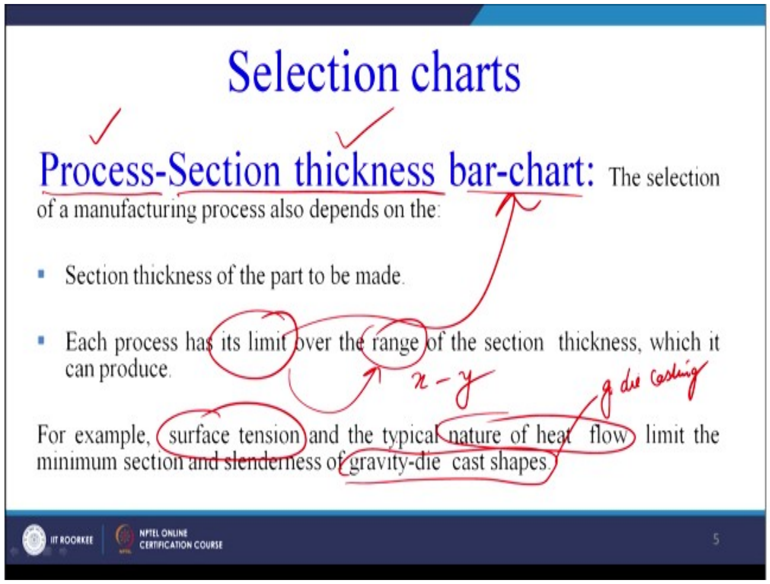
So, we have seen manufacturing basics then materials basics we have seen in week 2, design approaches or the various design tools we have tried to focus with manufacturing and materials as our focus area in week 3 and week 4. Now we are going into the depth we are trying to understand how the information is available and how this information can be used by the product designer.

So, 3 types of process attribute relationships are now clear to all the learner, the first one is the process material relationship. The second one is the process shape relationship, the third one is the process mass relationship which is there on your screen. So, we can see for joining also wherever the fasteners have to be used very wide ranges there where the adhesives have to be use this is the range.

So, which means that for very very heavier parts or heavier components when the joining has to be done adhesives are not recommended. So, there is a range where the welding this is a range where welding or the fasteners either in this range we must go for welding or we must go for mechanical fasteners wherever the lesser weight is there in those cases maybe we can even use the adhesives.

So, that is we can say from joining point also there is a relationship between the mass of the assembly as well as the fastening or the not the fastening but the joining technique that we must use. So, adhesive joining is not recommended for very heavier parts welding and mechanical fasteners are obviously the big choice or the right choice for heavier assemblies. So, therefore these type of guidelines usually help the product designers to take the judicious decisions related to the selection of the processes.

(Refer Slide Time: 20:49)



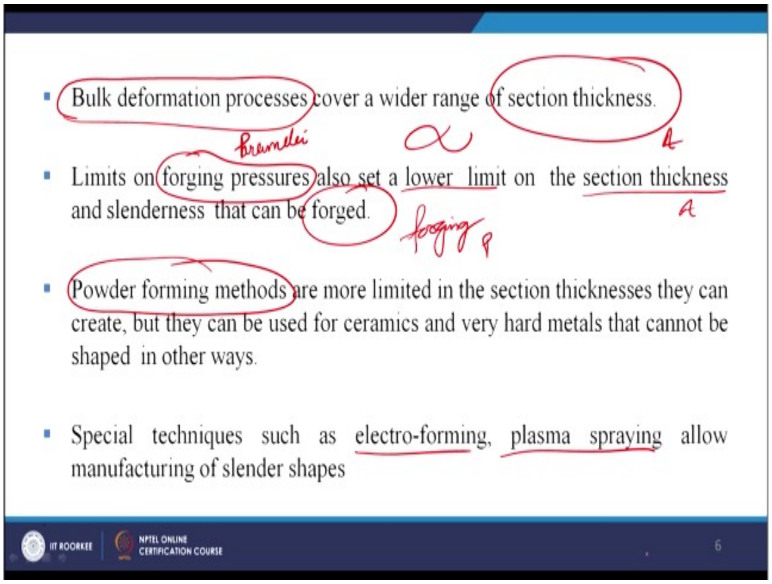
So, 3 attributes already covered, the fourth attribute is the process section thickness bar chart. So, the process remains same, we are trying to study the selection of processes in context of the various attributes. So, the section thickness is the another attribute, so see we can there are ribs and bosses in different products. So, what can be thickness minimum section thickness which can be produced by a process that can be seen from these charts.

So, the selection of a manufacturing process also depends on the section thickness of the part to be made. Each process has it is limit and this limit is given in the chart each process has it is limit over the range of section thickness. So, limit is in the form of a range it can be from X to Y, so that is a range of the section thickness which it can produce. So, each process has the limitation or has a range up to which it can produce the section thickness.

For example surface tension and typical nature of heat flow limit the minimum section and slenderness of gravity die cast shapes. The process is gravity die casting, now what are the limiting factors, the limiting factors are the surface tension and the nature of heat flow. Now these 2 parameters that is surface tension of the metal and the nature of heat flow they limit the minimum section thickness that can be produced by 1 process which is that process gravity die casting.

Now we know that gravity die casting can produce a section thickness within this range, so we must not propose the use of gravity die casting for a section thickness which is beyond that range and all that information is already available in the form of charts. So, let us take few more examples before going to the chart.

(Refer Slide Time: 22:54)



Bulk deformation processes cover a wide range of section thickness, so there another bulk deformation processes which is the process and what is our attribute that is the section thickness. So, P we have to see the relationship between the process and the attribute, so bulk deformation processes cover a wide range of section thickness another process is limits on forging pressures also set a lower limit on the section thickness and slenderness that can be forged.

So, the forging pressure acts as a limiting factor, so on setting up the lower limits of the section thickness which is our attribute in which process in the process of forging. So, this is the process and forging pressure is a we can say a parameter which influences it is a process parameter which influences the what does influence the section thickness and the slenderness which can be produced by the forging process.

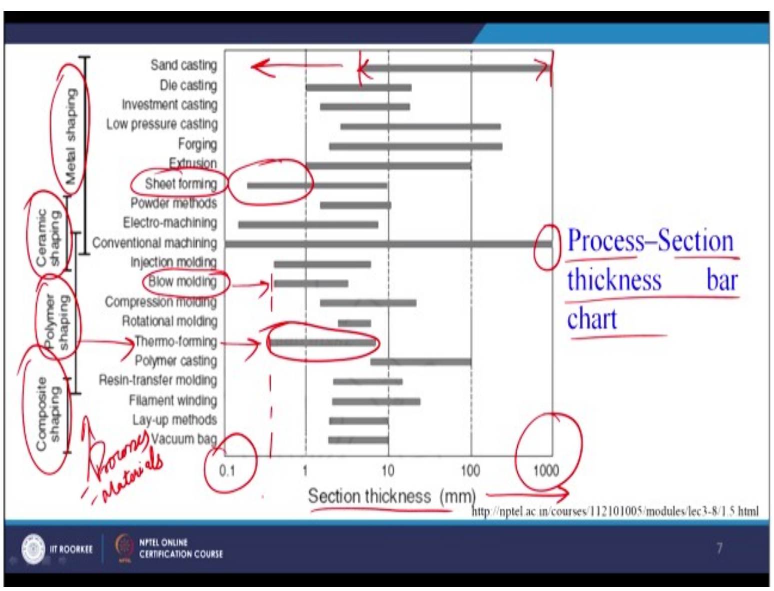
So, similarly the powder forming methods again this is a process powder forming method are more limited in section thickness they can create but they can be use for ceramics and very hard metals that cannot be shaped in other ways. So, powder forming methods cannot produce very we can say very thin sections but they can be used for materials which otherwise are very difficult to shape.

So, there are materials in which have very high melting point, so they cannot be made by casting. They may have very very high hardness, so they cannot be machined, so there are materials which you can first process them into powder and then you can compact that powder to produce a particular shape. But the problem is with the section thickness that you can acheive with this powder processing method, so that is also 1 limitation.

But then if there is no other choice then we have to use the powder processing methods or for powder forming methods for making the products out of these materials which are otherwise difficult to shape. Special techniques such as electro forming, plasma spraying allow manufacturing of slender shapes, so these are the processes electro-forming, plasma spraying and if we have a very very stringent requirement of a specific section thickness.

We can go for these advanced processing techniques which can provide us that kind of section thickness or slender shapes, so quickly see the process section thickness bar chart.

(Refer Slide Time: 25:34)

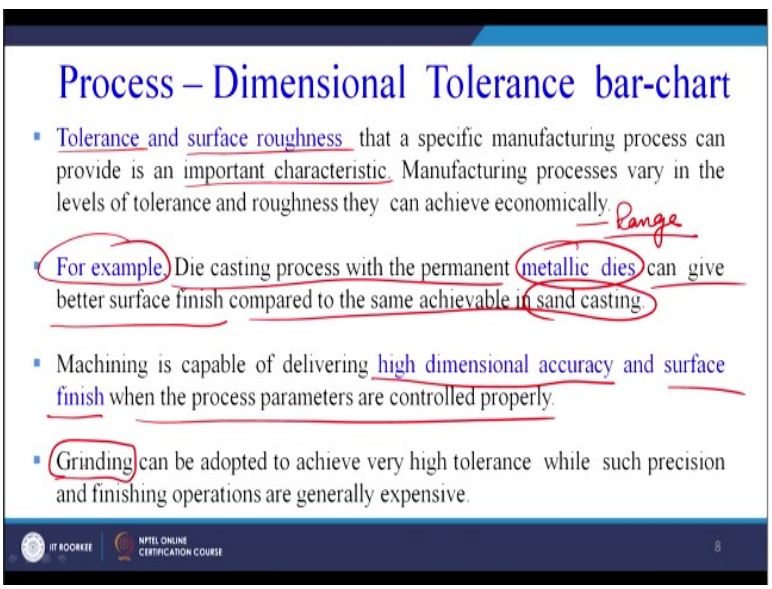


Again the processes are given here on the Y-axis metal shaping, composite shaping, polymer shaping, ceramic shaping, so the it is related to the processes. As well as you see the materials also are specified and therefore we have already discuss this classification in the first and second week. So, the processes are listed as well as specific to the materials it is listed, so we can see the section thickness is there on our X-axis.

So, it is in millimeter from 0.1 millimeter to the highest is 1000 millimeter, so we can see conventional machining there is no limit it can go up to 1000 millimeter. For sand casting also there is wide range for the section thicknesses that we can achieve. But if we want on the lower side the section thickness to be on the lower side sand casting is not recommended but if you want a section thickness on the lower side sheet metal forming is advisable sheet metal forming here.

So, for very thin section thicknesses we should go for sheet metal forming, similarly thermo forming. In case of polymers is it polymer shaping thermo forming process can also provide us less section thickness similarly the blow molding process again and again I am referring to blow molding it can also provide us very less section thickness. So, we can see that based on the section thickness also we can very easily select the processes that when the section thickness is low which process can be chosen.

(Refer Slide Time: 27:23)



Now the next attribute is the dimensional tolerance bar chart, tolerance and surface roughness that a specific manufacturing process can provide is an important characteristics. Because this surface roughness and tolerance will directly affect the quality of the product that we are producing. So, this is an important characteristics manufacturing processes vary in the levels of tolerance and roughness they can achieve economically.

So, therefore there has to be a range for each and every manufacturing process range of tolerance and surface roughness which it can produce. For example it is given to better explain the concept die casting process with the permanent metallic dies can give better surface finish as compare to same achievable in the sand casting. It is well known every mechanical engineer knows this that a sand casting will produce a poor surface finish as compared to the die casting process which uses the metallic dies.

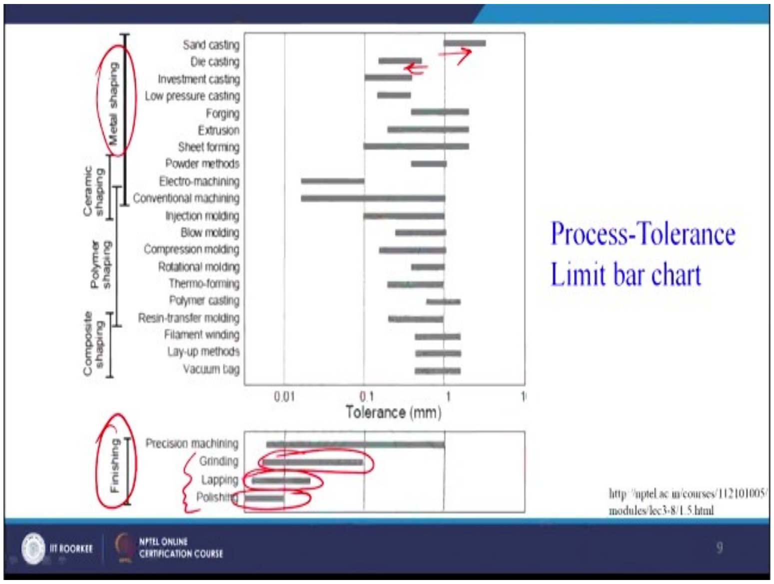
Machining is capable of delivering high dimensional accuracy and surface finish when the process parameters are controlled properly. And all of us know that after sand casting we normally give the machining allowance on sand casting why because later on we need to machine the casting in order to produce the desired surface finish. So, which clearly indicates that machining will provide us a better surface finish as compared to the sand casting process.

So, grinding can be adopted to achieve very high tolerance while such precision and finishing operations are generally expensive. So, we have if we want a very high surface finish we can go for grinding also there another processes such as super finishing processes. We can polishing, lapping, honing different types of finishing processes are there but they do add cost to the cost of the or to the price of the product.

So, we have to be very very judicious as product designers to see that what kind of surface finish we want to put on our product or what kind of surface we want to offer to our customer. Sometimes we may offer a very high surface finish which the customer may not be appreciating that much but that to produce that kind of surface finish we are spending lot of money in producing that.

So, therefore we have to be very very cautious judicious as well as intelligent in specifying the surface finish that is to be provided on the product.

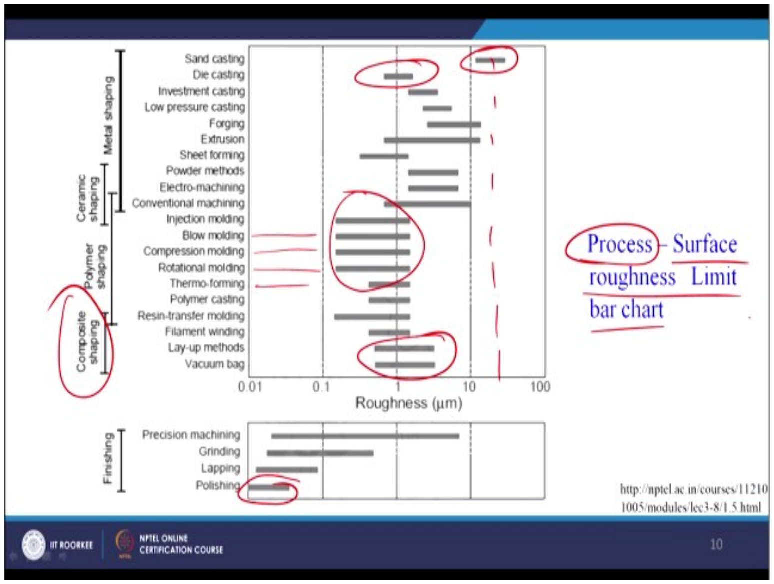
(Refer Slide Time: 29:55)



Now this is the process tolerant limit bar chart we can very easily see again there are finishing processes here which can provide better tolerance. Then there is metal shaping processes here we can see for different processes what kind of tolerance we can get. For sand casting you can see it is on the higher side whereas die casting it is comparatively lower as compared to sand casting.

So, this type of chart can help us to select the process based on the tolerance limit bar chart that which process can be use for which type of tolerance levels. Similarly we can see polishing can give us better tolerance, lapping can give us better tolerance, grinding specifically is used for as a finishing operation. So, if when we go for finishing we can choose any of these processes, so very easily we can now select that which process will be able to give us the kind of surface that we want to produce in our product.

(Refer Slide Time: 30:58)

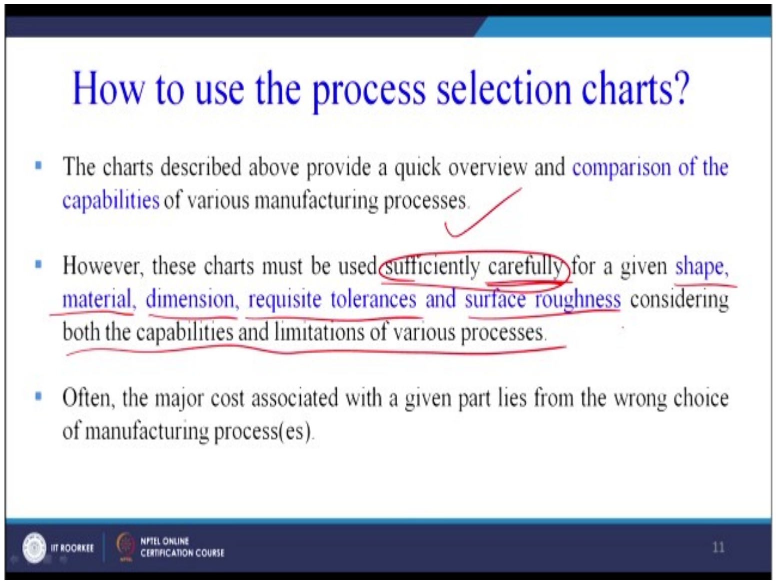


Then this is the process and surface roughness limit chart again we can see it is in the previous one was in terms of tolerance that is achievable, this is in terms of roughness which is achievable. So, we can sand casting high surface roughness whereas die casting lower surface roughness previous one was related to tolerance. So, tolerance also similar trend is there, similarly the polishing will produce lower surface roughness or better surface finish.

And similarly for grinding and lapping, the processes for composite shaping also we can see produce better surface finish as compared to sand casting. Here we can see sand casting produces a poor surface finish as compared to the other processes. So, similarly we can see most of the polymer shaping processes, blow molding, compression molding, rotational molding, thermo forming almost similar type of surface finish is achievable.

Or all or maybe good surface finish is achievable in case of the polymer shaping of product. If you see the kind of mineral water bottles or the soft drink plastic bottles that we use they have very good surface finish. So, the roughness or the surface roughness values are lower, so this is a process surface roughness limit bar chart. So, we can easily see depending upon the surface roughness requirements we can select the process. Now how to use the process selection charts quickly we can see in the next 3, 4 minutes.

(Refer Slide Time: 32:40)



The charts described above provide a quick overview and comparison of the capabilities of various manufacturing processes. And I totally agree with this sentence that we can very easily compare the different processes based on the range for which a different attributes can be taken care of. We have seen the different attributes by now if we go in the reverse order just now we saw regarding surface roughness what kind of surface roughness will be produced by the different processes we have seen tolerance.

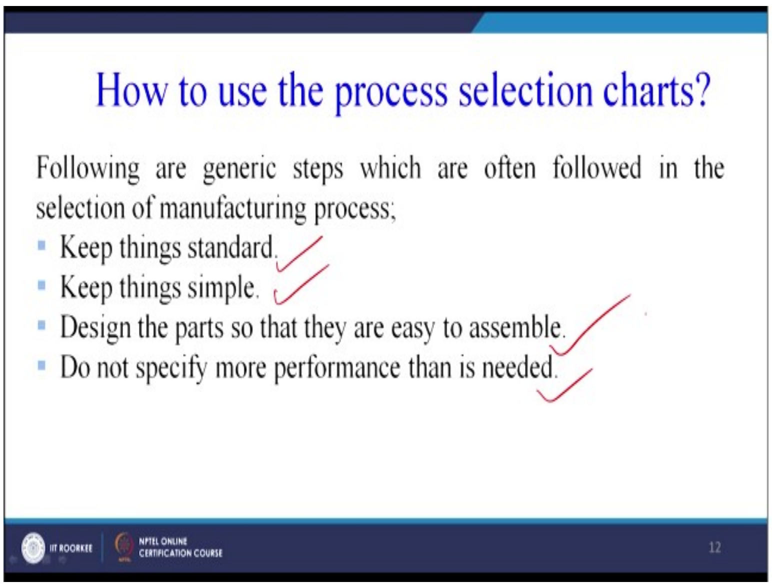
Then we have seen in today's class maybe mass then another parameter we have taken related to in the previous we have taken shape also we have taken the material. Now depending upon the material, the shape, the mass, the surface roughness, the tolerance we can very easily categorize the processes and select the process accordingly. So, the charts described above provide a quick overview and comparison of the capabilities of various manufacturing processes absolutely correct.

However these charts must be use sufficiently carefully for a given shape material already we have seen dimension, requisite tolerances and surface roughness considering both the capabilities and limitations of the various processes. We must try to trade off among the various attributes and then select the best process which satisfies all of the attributes often the major cost associated with the part lies from the wrong choice of the manufacturing processes.

So, many times the products are costly why because we have not selected or we have not judiciously selected the right process which could have given us a cost effective solution for manufacturing our product. So, the wrong choice of the process can lead to escalation in the cost of producing the part which may make the part non competitive or maybe the product may not be able to compete with the competitors product.

Because the competitor may have chosen the best process the most economical process for producing the product. So, we have to be very very careful while selecting the manufacturing process.

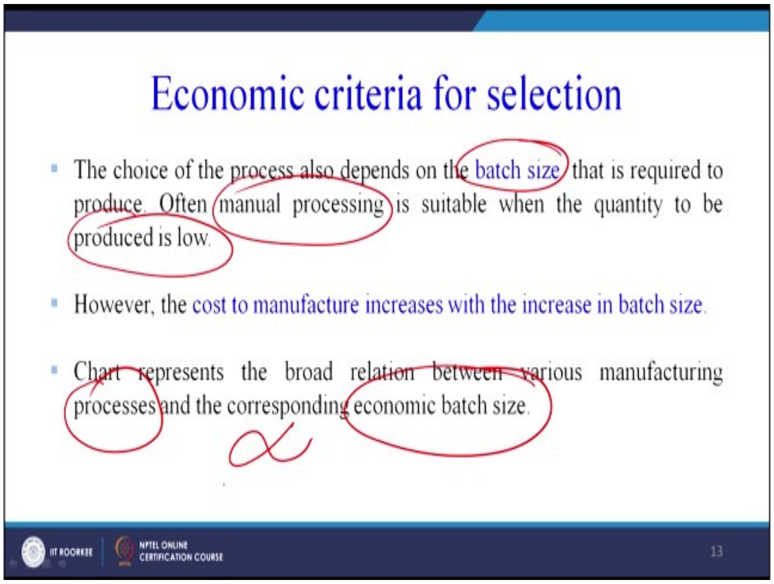
(Refer Slide Time: 35:01)



Now how to use the process selection charts just very very simple rules of thumb following are the generic steps which are often followed in the selection of the manufacturing process, keep the things standard. Keep standard means when we are designing our product we must make use of the standards keep the standards in our mind. So, that standards are set as per the manufacturing process, so therefore we know this standard can be achieved using x process.

So, therefore we will be able to make the product in a more effective manner in a more cost effective manner, keep things simple, design the parts. So, that there easy to assemble already in the third week we have seen design for manufacturing, design for assembly DFMA guidelines do not specify more performance then needed just now I have told please do not specify a very very high surface finish requirement for the product if it is not required. Because it will add to escalation in the cost of the product, now therefore last criteria is the economic criteria for selection.

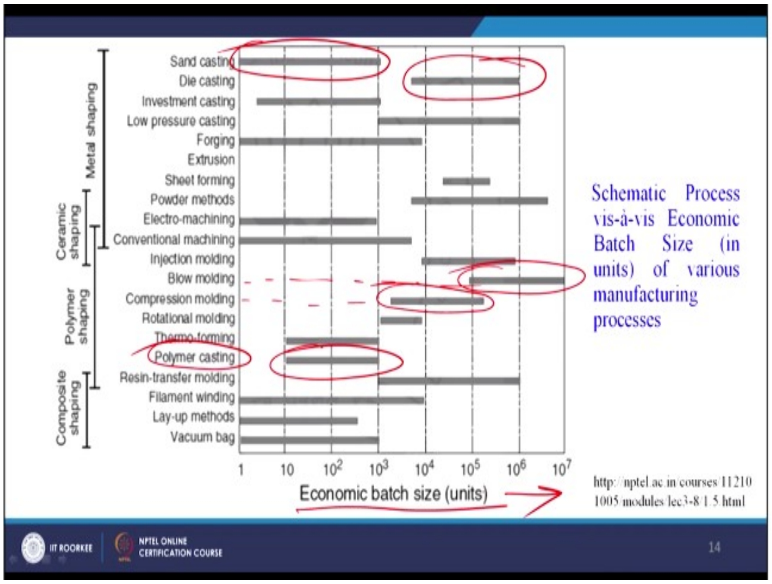
(Refer Slide Time: 36:07)



The choice of the process also depends on the batch size, the number of parts to be produced that is required to produce often manual processing is suitable when the quantity to be produced is low well known common sense. Manual processing when number of parts are low, however the cost of manufacture increases with the increase in batch size. So, manually if you are doing and the batch size is large the cost of manufacturing may increase.

Chart represents the broad relationship between various manufacturing processes and the corresponding economic batch size. Again process in relationship to the economic batch size, so this chart we are going to see now.

(Refer Slide Time: 36:49)



The schematic process vis-a-vis economic batch size of various manufacturing processes, so we can see sand casting. The batch size is from 1 to maybe 10 to the power 3 die casting because the die casting machines are very very costly, so we cannot use them for less number of products or parts. So, therefore die casting for larger number of parts, similarly we will see for polymer shaping also simple processes polymer casting for lesser number of parts whereas we go for compression molding, larger number of parts, blow molding even larger number of parts.

So, as per the economic batch size which is given on the X-axis the number of units we can select the process. If we are talking of the polymers if we want to do blow molding of polymers the economic lot or batch size or the economic lot size has to be bigger. Whereas if we want to do compression molding maybe comparatively less number of parts even can be made by compression molding.

So, therefore we have to justify the cost of the equipment as compared to the size or the number of parts that we are producing or the volume of parts that we are producing. So, therefore this is also very very important to take a decision that what is the quantity of products that we are going to produce and that sometimes maybe based on sales forecasting. And different sales forecasting techniques qualitative, quantitative, time series different qualitative techniques, quantitative techniques can help us to arrive at those numbers.

And once we know those numbers which have been forecasted we can use those numbers which is given here on X-axis and select that this process is best suitable based on the numbers that we envisage, that we forecast, that we predict will be made for this product. For this product to be launched in the market, so therefore all these criteria all the criteria all the attributes that we have seen will help us to make a judicious choice of the process which can help us to achieve our target of economizing our overall product development process.

So, with this we come to the end of these 2 sessions that is selection of processes 1 and selection of processes 2. In our next session we will try to see the process capabilities maybe the general process capabilities for some of the most commonly used manufacturing processes that every product designer must keep in mind while designing a products.
Thank you.