**Manufacturing Guidelines for Product Design**

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**Lecture-16**
**Selection of Processes-I**

Namaskar friends, welcome to session 16 of our course on manufacturing guidelines for product design. Today we are going to start the discussion for week 4th already 3 weeks of discussion we had and we have by now understood the importance of 3 important aspects in product design, the materials, the manufacturing and the design. I have deliberately taken the names in the reverse order otherwise first the design will come.

Then we will see how it can be manufactured and finally we will see that what are the materials that can be used. So, these 3 things are interrelated, sometimes we will first fix the material then do the design accordingly and find out the ways to which we can fabricate the product. So basically the 3 things are interrelated or intervened or inter related to each other interconnected to each other.

So the 3 things we have already discussed but only the fundamental parts of the 3 important issues or 3 important parameters or 3 important characteristics or 3 important constituents of a successful product design. Now these 3 things are the materials, the manufacturing and the design, with all these information our target basically in this course is the manufacturing guidelines for product design which means that as a product designer.

I must have a handy tool or information base or a data base or expert system maybe which is a very higher end version of what we can try to develop. So that when the design is ready I am able to select the process which is going to be use I am able to select the material that is going to be used for finally the fabricating the product. So, the point is that we have to have off hand information, we have to have a firsthand information, we have to have a basic information or a source of information which we can make use of not only after the design is ready.

But also during the design stage, so that our product does not have or the design does not have go through the design iterations again and again. So, whatever manufacturing guidelines we know whatever basic information that we have related to the various processes. Those processes if selected for a particular product design we must take into account the process capability. We must take into account the number of products that process can make per hour.

We must take into account the surface finish the process can produce, we must take into account the tolerance the process can produce. So all that basic information must be available as a single source, so that we can do our design iterations during the design stage only and finally we give a compact well thought of, well informed design, so, that the design it is selected manufactured and the product pushed into the market.

So that is the purpose, now we are going to discuss regarding the processes that can be used and what are the capabilities but before going to the processes already we had 1 week of our discussion on the very first week that was on manufacturing the fundamentals of manufacturing, the process capability, the selection of processes. But that was quite generic in nature now we are going to be very very specific related to the specific processes.

But before going to the specific processes we will like to have 2 sessions, that is session number 16 and session number 17 dedicated towards the developing our knowledge related to the selection of processes or what are the various criterion that have to be kept in mind when we are selecting a process for a particular design during the design stage. And sometimes maybe after the design stage an important decision has to be taken that the design is ready.

Now how to manufacture it, many times we have seen in our labs also we have a design we have thought we put into a paper then we make a rough sketch of the design. Then finally we make it in auto cad we have the complete drawing a detailed of our product. But when we go to manufacture it we find that there are number of issues related to the manufacturing why?, because we have not taken into account the manufacturing guidelines during our designing process.

The design was made without any consideration for manufacturing and that is one if issue in industry. And this course basically aims at addressing that issue. Now let us quickly see that what are the various criteria that can be used for selection of processes, so there are large number of processes as all of you know how to classify the process is already we have seen in the first week of our discussion.

We have seen that processes can be classified as primary forming processes, deformative processes, material removal processes, finishing processes, joining processes as well as sometimes the bulk property enhancement processes such as the heat treatment. So, we have a wide variety of manufacturing processes each one of this family has got certain design limitations, has got certain process capability which can be taken into account when we select a manufacturing process.

So thought, discussions, decisions, related to the manufacturing process must be taken into account during the design stage of our product. So that we are able to design the product which is successful in the market. So there are number of we can say selection charts which are available which we can make use of in our decision making related to selection of a particular process for a particular requirement or a particular design.

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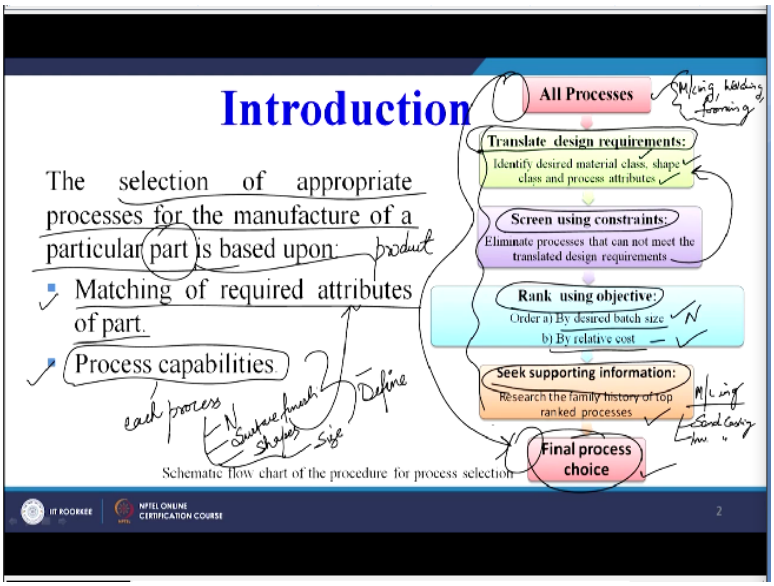

So, let us first see that how the selection process takes place or how we have to do this selection. So the selection of appropriate process that is our target today that we are going to discuss, so the selection of a process for the manufacture of a particular part. So this part can be part of a product or the product itself, so the selection of appropriate processes for the manufacture of a particular part or a product is based upon matching of the required attributes of the part.

Now we first need to know what are the required attributes of the part and then we have to see the process capabilities. Each process will have a process capability, now process capability can be in terms of number of parts it can produce per hour or per day it can be in terms of the surface finish. It can produce it can be in terms of shapes it can produce, it can be in terms of size is the process can produce.

So all these parameters are basically going to define the process capability of any process, so what we have to do we have to matching of the required attributes of the parts and the capabilities. Now the attributes can be anything one of the attributes can be say surface finish. So, we know that in our final part we require this much surface finish or in our final product this is the surface finish requirement.

Now we have to see that which process has the capability to give us a surface finish as is required in the design requirement. Similarly one of the attributes can be a particular shape for example it is axis symmetric cylindrical job. Now we will see that which are the processes available with us which can help us to produce this axisymmetric cylindrical job. So we may have a long list of processes which can help us.

Then we will do the screening there maybe suppose 5 or 6 processes which can produce axissymmetrical cylindrical job. We will see that what is going to be material of the job based on the material there can be screening there maybe few processes which are only applicable for metals. There are few processes which are only applicable for polymers, so we will further screen out the processes depending upon the material that is going to be use for making the product.

Then maybe the further screening can be based on the number of parts or the number of products that are thought of or that is forecasted. So, depending upon the batch size also few processes may get screened out, so depending upon the criteria we will keep out screening out the processes. And finally we may be left with 1 or 2 processes and final decision then can be based on the cost for component that we can calculate that which our process is more economic.

We can go and select that processes, so basically in any process selection scenario what has to be done we have to first see that what are the desirable attributes. And then we have to list out the processes which can match this desirable attributes and some of the examples I have already shared some of the attributes which can be taken into account. Now let us see the step by step procedure for selection of this is the flowchart procedure for process selection.

Now first we have all processes we can have here I can write may be in brief we can have machining, welding, we can have forming. So, this is a combination of all the processes which are available to us. Now first thing that we need to do is given here matching of the required attributes of the part or the product. So, first thing is translate the design requirements identified desired material class as I have already told we have to select shape class.

The shape I have already taken an example axisymmetric cylindrical job that is a shape class material maybe a polymer or a metal another thing and the process of attributes that what are the process attributes desired. Now based on these 3 things we can screen using the constraints, eliminate the processes that cannot meet the translated design requirements. So, the translated design requirements are here and we have to screen out the processes.

We will leave out the processes, we will eliminate those processes from our list which do not satisfy the translated design requirements. Then once we further screen out these processes we rank using the objective, the order can be by the desired batch size, the number of products to be produced by the relative cost. So you can see the cost is coming towards the end before that we have to see the material, we have to see the shape that has to be produced.

We have to see the process attributes that we need to for example surface finish can be one process attribute. So, first we do the screening based on these translated design requirements and then further we come to the desired batch size and the relative cost. Now finally we can seek the supporting information research the family history of the top ranked processes. Now suppose we are left here with machining.

So we will see that only one process is left we will try to do the research related to the top ranked processes. Here we are selecting one only one process maybe is coming as the top ranked process there can be another situation where 2 or 3 processes are among the top rank, so then we have to see the relative advantages, disadvantages and the history of these processes. For example in some other case we may get 2 processes we can make it by sand casting as well as we can make it by investment casting also.

So we will see that which one of the 2 we must finally select depending upon the history and the specific application spectrum for those processes. And finally we will be left with one choice of our manufacturing process for which we have done this step by step elimination. So, from all processes at the top we have reached the final process after doing the step by step elimination based on a certain set of criteria.

Now some of you may be wondering that it is a very very difficult process how it can be done? But it can be easily done based on the step by step procedure as well as using the information which is already well documented and is available in the public domain in the form of different books. So we have that kind of information that is available which can help us to take these decisions.

So we can quickly now rush through the different types of selection charts that are available with us. So, even in e-content also this type of information is available. Now we have seen that from the large number of manufacturing processes we can boil down to a single process which we are going to use for manufacturing our product. And all the important criteria which we have seen in the very first week of our discussion is coming into picture here.

The shape of the product, the size of the product, the surface finish desired in the product, the number of products to be manufactured, all this is coming into our decision making domain is coming into our decision making process when we are going to select or when we are train to select a single process from a large family of processes.

Now such type of selection charts are available, based on the individual attribute and their rank the do not exactly rank. But fix the limiting condition for the processes, for examples sand casting, surface finish achievable can be in this range, die casting surface finish achievable is can be within this range. Similarly the number of products to be produced or the batch size sand casting can be used for the batch size of this number to this number.

Similarly investment casting can be used for a batch size of this number to this number. So, all that data is available in the form of selection charts and each product designer must have the information related to these process charts. So that he can use this information during his or her product design process. So now let us quickly see what are the set of attributes?.

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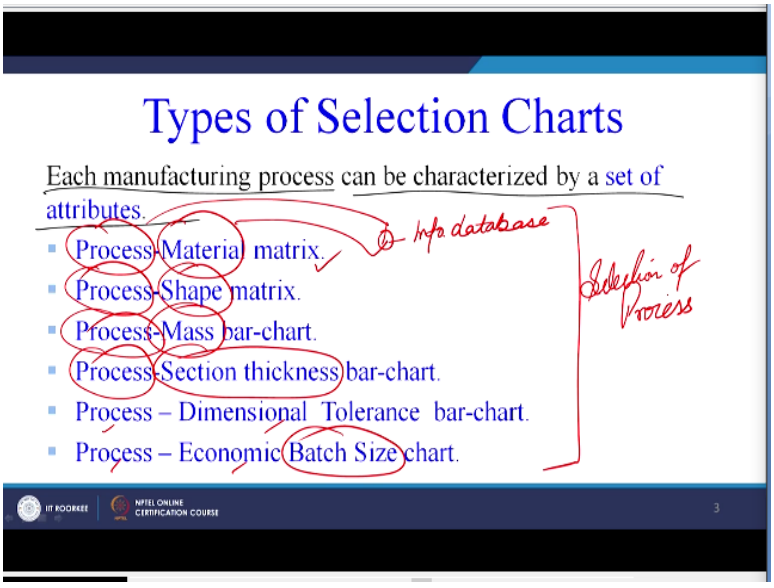


Now each manufacturing process can be characterized by a set of attributes, now the types of charts that are available, the process material charts. So, here they you can see there are 2 things here one is the process, another one is the material. And therefore we had our discussion about the fundamentals of processes and materials in the very first and second week of our course that

we must know the classification of the processes the term, process capability, the selection the problem of section of manufacturing process.

The types of engineering materials, their basic application areas because here we want to now come down or boiled down into a very very compact set of information which can be directly referred to. So first thing is the process, second is the material. So, we have to have a information database or a chart which can help us take the decision related to this process and material. Because now we can see that there can be processes which are dedicated towards processing of polymers.

There can be processes which can only be used for certain alloys, there can be processes which can only be used for glasses. so therefore material and the process and their compatibility there has to be a chart. And such type of chart is available in the form of a matrix and we are soon going to see example of a such a chart which can help us in taking the decision. Then the other thing is process and the shape charts, what type of shapes can be processed by the different processes.

So these type of charts are also available process and mass charts, if you remember in the very beginning in the very first week we have seen. And we have discussed the sand casting can be use for making very large size of products. So that is the mass of the product in context of the manufacturing process whereas the die casting can only be used to make smaller size products. Because the product is solidified or product is casted inside the mould or the die.

So therefore the mass which process can make heavier parts which process can make lighter parts. So all that type of information has been discussed it has been compiled, it has been collected and compiled I must say and is put in the form of the charts. Similarly the process section thickness that which process can give us smaller section thickness which process can be give as larger section thickness.

Similarly the process in context of the dimensional tolerance, process in context of the economic batch size. Batch size as I have already discussed that is also the information is available, so in

our discussion now we want to see an example of each one of this. So this the broader topic that we are currently discussing is the selection of process. And in the previous slide we have seen the step by step by step procedure for selecting the process from a wide variety of processes.

In between what is required to be done we have to translate the design requirements into our matching with the process capabilities. So there are few design requirements, there is a process capabilities for each process, we have to match that this design requirement can be satisfied with this capability of x-process or y-process or z-process. So that matching has to be ensured and how we can do that if we make use of all these matrix and charts. Let us quickly see an example of 1 or 2.

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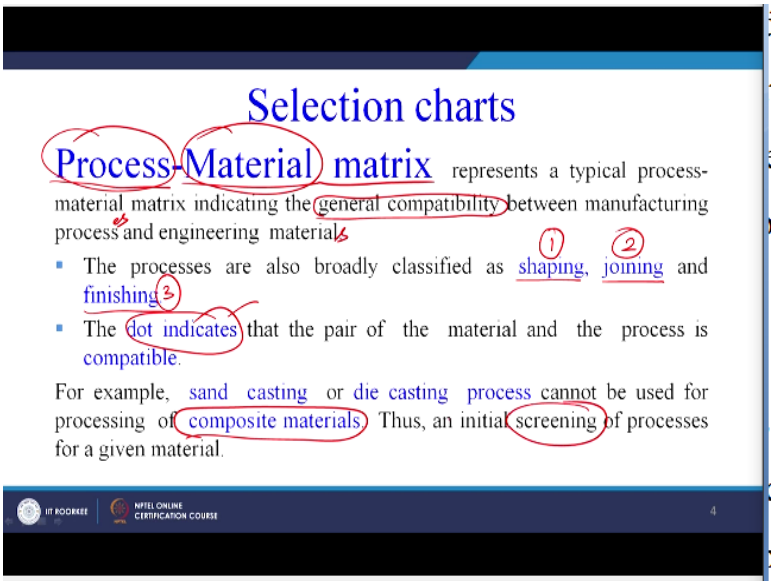


So, the first one is the process which we have to select and the material matrix that which process is capable of processing which type of material. So, the process material matrix represents a typical process material matrix indicating the general. It will show a general compatibility between manufacturing process and the engineering materials. We can say manufacturing processes and the engineering material.

The processes are also broadly classified as we can say shaping, joining and finishing. In our previous discussion we have classified the manufacturing process as primary forming processes, deformative processes, material removal processes then joining process. But here another kind of

classification of manufacturing processes is done in context of matching their capabilities with the engineering materials.

So, we have 3 types broad categories process which give shape, processes which are use for joining the different parts and processes which are used for finishing the parts. The dot indicates that the pair of the material and the process is compatible, so we will try to see how the dots have been placed. When we see a process matrix or process material matrix. Now the example is given here for example sand casting or die casting process cannot be used for processing of composite materials.

So we will see this example when we go to the process material matrix, thus an initial screening of processes for given material can easily be done. So, our job is to do the screening process and this chart can help us from the material perspective that for these materials suppose we decide that the product is to be made by x material. Now we can see the process material matrix and see whether for x material which are the processes which are available.

There may be some processes which cannot be used for processing the material x. So, automatically those will be screened out, so now let us quickly see this is the process material matrix on your screen.

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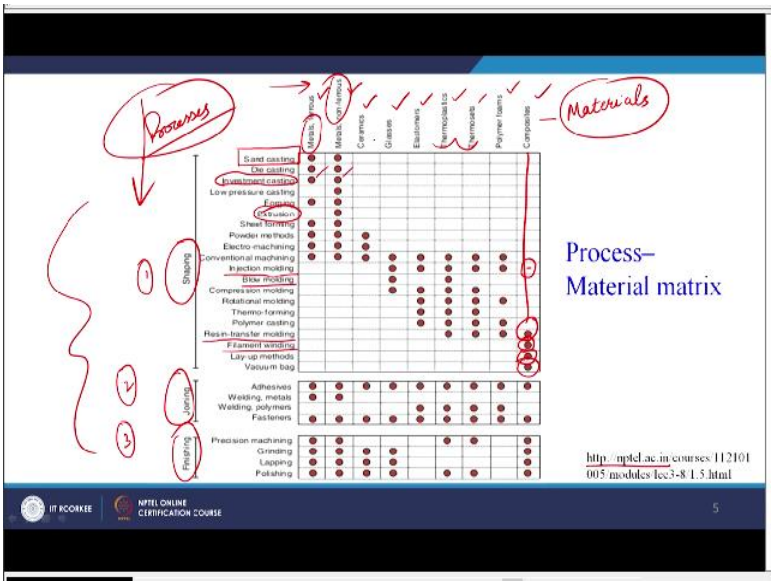

The source is also given NPTEL it is available in the e form this matrix is available. Now we can see here we have already classified the manufacturing processes as shaping 1, joining 2 and finishing 3. So, these are the 3 broad categories of processes and for giving shape to materials. One example is first one is sand casting, then for polymers one of the processes injection molding, for polymers only blow molding for making the mineral water bottles.

Then another for composites there is resin transfer molding, filament winding, so for different types of materials. There are different types of processes now I have take an example on in different columns we have the materials and in this direction we have the processes. So we have processes which are broadly classified into 3 categories and materials and for materials as we have already done the classification.

There are metals, non-metals, metals which are non-ferrous metals the non-metals such as ceramics, glasses, elastomers, thermoplastics, thermosets which are broadly polymers, polymer foams and composites. Now let us see here resin transfer molding process very well use for composites, filament winding used for composites lay-up methods handle up used for composites.

So, here we are not finding that injection molding can also be use for composites. But in research it has been proven that injection molding can also be used for composites. So may be this type of information database can help the designers in taking their decisions related to the materials and the processes in such a way that later on you need not do the design iteration. Because for a particular material the particular process is not possible very easily it is possible to look at these charts or this matrices and take the decisions judiciously.

We can take a large number of examples maybe this only one can be explained into 2 to 3 classes with lot of information. But the basic idea about discussing this topic is that a designer must have an idea that such information in a concise form in brief form in a very very compiled form is available and must be taken care of while designing the products. So, there are processes which are there for metals both ferrous and non-ferrous for example.

Because most of the designers make use of metallic parts, so sand casting is there for metals as well as for non-ferrous metals. Similarly extrusion can be done for metals for example investment casting can be done for metals, ferrous and non-ferrous metals. So, we can very easily see that if we look at this graph lot of decisions can be made in context of matching the materials and the processes. Similarly there can be a chart related to the process shape matrix, now process shape matrix as we can see 2 things are there for process and the shape.

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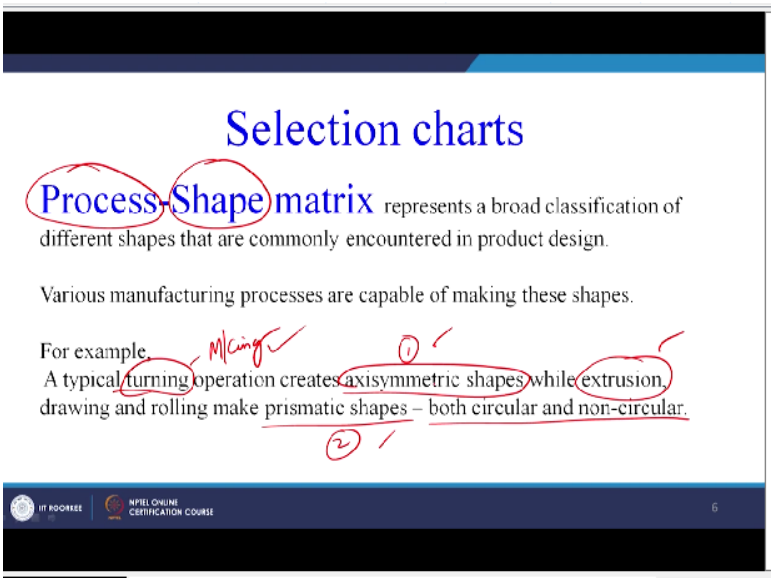


Now here the processes will be listed down in context of the shapes that they can process. In the previous matrix we have seen the processes were listed out in context of if you are listening it carefully in context of the materials the process can process or the materials were given a combination that which process can be use for which material and a dot indicated that yes it is possible.

So here the process shape is similar in the previous case only indicates interrelationship between the processes and the various processes shapes they can process represents a broad classification of the different shapes that are commonly encountered in product design, various manufacturing processes are capable of making these shapes. For example a typical turning operation turning operation which is one form of machining operation creates axisymmetric shapes.

While extrusion drawing and rolling make prismatic shapes both circular and non-circular the 2 processes are listed one is which is an example of machining another process is extrusion. And 2 different shapes are mentioned one is the axisymmetric and the another one is the prismatic shape. So, 2 processes turning extrusion 2 shapes axis symmetric and prismatic. So, this can be put in the form of a matrix how the matrix will look like going to come in subsequent slide.

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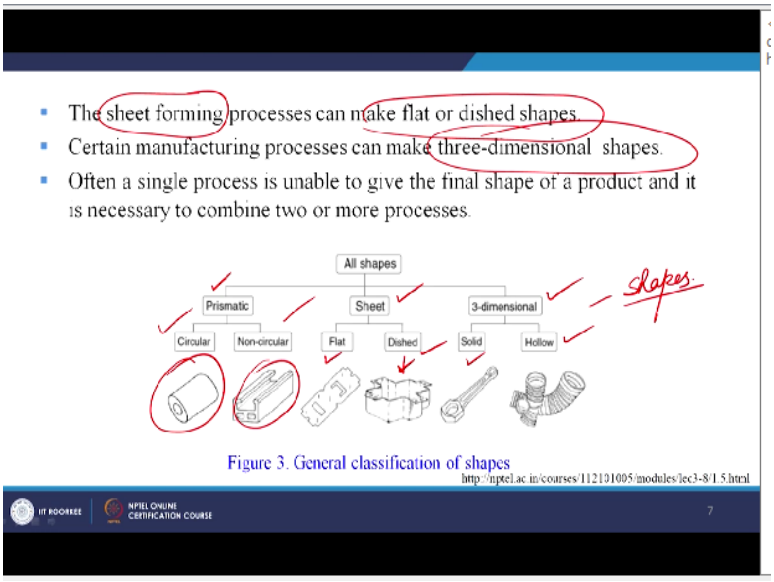


The sheet formation processes can make flat or dished shapes another process sheet forming shapes flat or dished shapes certain manufacturing processes can make 3 dimensional shapes also often a single process is unable to give the final shape of a product. And it is necessary to combine to or more processes, many a times it may so happen that with single process we are not able to attain the final shape of our product.

In that case we may require a combination of 2 or 3 processes to give the desired shape to our product and classification is given here you can see all shapes are there. We can prismatic shapes, sheets as well as 3 dimensional, 3 dimensional can be solid shape it can be hollow shape. Similarly sheets can be flat or they can be dished one example is shown here, prismatic can be circular example is given.

It can be non-circular this is the example, so this is a classification only of the shapes that usually we use for making our products. Now how these shapes are related to the manufacturing process we can see here.

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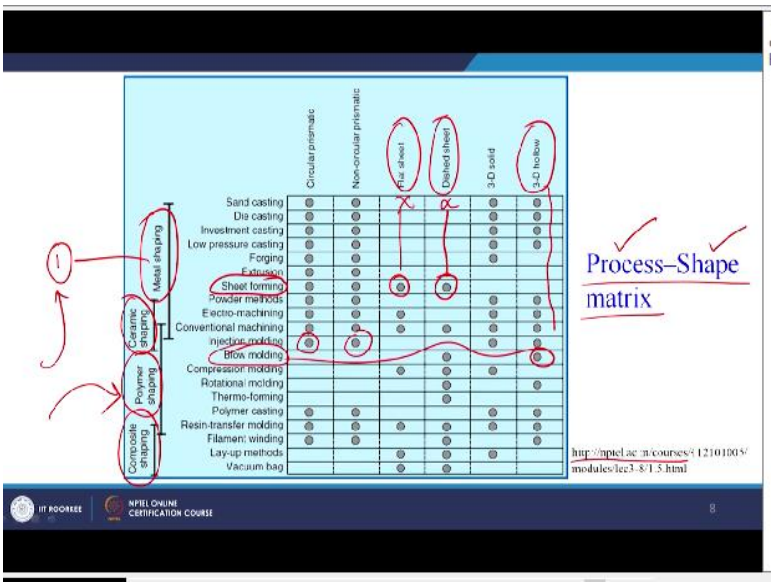


The process, shape matrix, here we have again the processes we have classified them metal shaping, there is this is related to shaping only, shape polymer shaping, ceramic shaping. If you remember we have classified the processes into 3, first one was the shaping, second one was the joining, third one was the finishing. So, here for the shapes only we have to give the shape to the products, so only the shaping processes are mentioned here.

So let us quickly see sand casting circular prismatic shapes it can be non-circular prismatic shapes it can make. But if we want to make a flat sheet our sand casting process is not recommended. Similarly for dished sheet sand casting is not recommended but yes we have to make the dished sheets we see so many products of sheet metal. So, which are the processes that can be used.

So, here is a process called sheet forming, so sheet forming can be used for making the dished sheets, sheet forming can be used for making the flat sheets. So, sand casting is not recommended for flat and dished sheets where a sheet forming is applicable for making those

similarly the ceramic shaping also processes are mention that for ceramic shaping injection molding can be used for non-circular prismatic parts also injection molding can be used.

Similarly we can see that there can be other processes for example our plastic bottles basically that we use for mineral water or soft drink or 3D hollow shapes. Now which process is relevant maybe we conceive for polymers most of the bottles are polymers. So for polymers we have a process here blow molding can be see blow molding here yes you can see. Blow molding process is recommended for making 3D hollow shapes or the example taken is or 3D or a hollow plastic bottle which is used for mineral water.

So we can see a relationship between the shape and the process and the source is again the NPTEL lecture which is already available in the e-form on the NPTEL website. So, gives the very good idea to the product designer that when he is selecting the shape he can very easily have an idea that which manufacturing process can be use for creating such type of a shape. So, that is you can say a basic information that can be used by the learner or by the designer.

In such a way that later on you need not change your design, in the very beginning of the design stage only you can keep in mind that this is the shape that we are going to make this is the material that we are going to select for our design. So, this is the manufacturing process which is capable of producing a shape with the given material. Similarly there are other things also which we will come to in the subsequent lecture.

So, may be in today's lecture we have only focused on 2 important attributes the first attribute was the material the second attribute was the shape, still we have to come to size dimensional tolerance, batch size. So, all these matrix or charts are also available and we will cover this in our second session for the same topic that is selection of processes, maybe I think the first part is absolutely clear the second part will even make the things more clearer and we will be able to use this information for designing our products in a more efficient manner.
Thank you.