**Manufacturing Guidelines for Product Design**

**Prof. Inderdeep Singh**
**Department of Mechanical and Industrial Engineering**
**Indian Institute of Technology-Roorkee**

**Lecture-05**
**Process Capabilities: Basics**

Namaskar friends, welcome to session 5 of our course on manufacturing guidelines for products design. Just to have a quick review of what we have cover, we have tried to establish manufacturing guidelines or establish the basic fundamentals of manufacturing in context of the product design. So we have tried to address an important issue that when a product designers designs a product he undergoes or he takes a step by step procedure or he conducts a step by step approach or procedure for a study to design a product.

And towards the end of the product design procedure or a product design cycle, 2 important points emerge, and those are the rapid prototyping and the manufacturing consideration. We have to see that how the prototype can be developed and then further we have to see how the product will be manufactured and when the manufacturing of the product has to be a certain a product designer must have some basic information related to the manufacturing processes.

He may not be an expert of manufacturing but he must have a basic idea of manufacturing and that is the bride or the gap that we want to address with this course, many a times a product designer designs a very good product which is functionally excellent is easy to operate but difficult to manufacture. Now why it is difficult to manufacture because the product designer has not considered the manufacturing guidelines or the manufacturing aspects during the project product designer process.

And many a time these days a product design team is created in which they are experts from the manufacturing division also, but there can be exceptional circumstances where a student comes up with the product, he may be from civil engineering background, now civil engineering background student comes up with the novel idea of developing a product for example for cleaning a water.

Now when the product has to be develop he may not be knowing that how the product can be manufactured or what can be the intricacies during the manufacturing of this product or he

may have a problem in selecting a particular design because he does not know that whether it is a type of a design can be manufactured easily or not.

So it is not required that he knows all the nities and grities of the manufacturing processes but at least he can have a basic idea that yes this type of a product can be developed using this process or these are the manufacturing processes which can be used for converting my idea into a final tangible product. So with this basic consideration we have attempted to develop this type of a course in which any product designer from any background can undergo the program or undergo this course or may be learn this course.

And may become acquainted with the basics of the manufacturing processes and use this basic manufacturing guidelines during the product designer process and in that context today our topic is process capabilities we are just going to see the basics, must I again address this point that there are 100s of manufacturing processes and each process has got its own capability.

So there can be different processes with the same name with little variation. For example casting in the last session we have seen we can do the casting by making of mold in the sand or we can make a permanent mold of metal and then pour the molten metal into that permanent mold and get our final product. So that basic concept is casting where a metal is melted and it is poured into the mold.

But the molds are different, in one case it is a temporary mold that we make in sand, in the other side it is a permanent mold which is made in metal or which is made by metal, so the casting principal remains same but the variation is in sand casting and the die casting and both these processes which fall under the broader umbrella of casting have got their process limitations, their process capabilities.

As well as the application areas also vary for these 2 processes, within casting only we can have investment casting, we can have slush casting, we can have within die casting, we can have hot chamber die casting, we can have cold chamber die casting, so we are not going to study the process details of these manufacturing processes but we are going to study the capabilities of these processes.

So the most commonly used among casting are the sand casting and the die casting processes, the other ones are also used but are use for very very specific type of applications. For example centrifugal casting process can be used for for making axisymmetric large size casting products. So we will see that what is the process, we are not going to the intricacies of the process but what are the capacity of the process.

That for example we have seen the criteria based on which we will select the processes if you refer back to our discussion in the second and the third session for this course we have tried to identify a criteria. So what was their criteria, the criteria was that we will select a manufacturing processes based on the raw material or the material which needs to be transformed or used as a raw material for converting into the final product.

It can be wood, it can be a ceramic, it can be a metal, it can be a alloy, it can be a plastic, so you can have different types of materials which you will use as a raw material and then convert this raw material into the final product. So the process will depend upon the type of the material, the mechanical, physical, chemical properties of the material, then it will depend upon the shape of the product that we have to produce.

Accordingly we will select the process for example if we have to do an large axisymmetric product we may go for centrifugal casting process if it has to be made in metal. Similarly the size of the product will also decide which manufacturing process we must choose the quality that we are planning or which has been designed during the product the design specifications we have to select the process accordingly.

So that we are able to get the quality that has been that has been designed by the designer during the process. Then there are other parameters number of other parameters that will dictate our choice of the process that we will use for converting our idea into the final product. So process capabilities basically means there are 2 words here a process and a capability like I as a person may have certain capability.

I am recording a half an hour session I may speak for 1 hour at a stretch I may attempt speak 2 hours at a stretch but I do not have a capability to speak for 24 hours continuously, I can speak by the quality of speech will deteriorate the you can say the pitch at which I am speaking may not audible if I speak continuously for a long period of time. Similarly each

and every system for example a battery we are using, will have its own capability, if we are using an internal combustion engine it will have its own capability to produce power, so depending upon the equipment, the process, the human being, there is a capability defined for each one of these examples. So here we are talking about process capability, so capability word I think I have tried to explain process means the manufacturing processes that we have discussed.

We have seen sand casting, we have seen die casting, we have seen injection molding, we have seen compression molding. So different process we have seen and each of these processes have got certain capabilities. Now we will try to understand today what are the applications where sand casting can be used because most of the time if you talk about a process and see the mechanism that how this process is done.

We usually do not go to the application side, so basically in examination point of view also we try to prepare that how the process will look like, how to draw the diagram, what are the various elements of the gating system in for example in sand casting process, but we usually do not focus on the application areas. So today we will try to see that what are the standard applications of the casting process.

And we will try to see that what is the process capability, so the criteria I have already explained now what is the criteria, criteria again I am listing out I will not take examples now the criteria can be the raw material that is used for the properties of the raw material, the shape of the product, the size of the product, the quality that we want to produce and finally the number of products that have to be produce, if only 5 products have to be produced we will definitely select a process which is suited for less or may be a lower batch size.

And if a large number of products have to be produced we will select a process which is suited for a large batch size. So basically these are the 4 or 5 important criteria which will help us to decide that which process we must choose and important point also is that we must know that which process is suited for which type of production or which type of manufacturing or which type of product and that is what I will try to see.

The only thing again I am emphasizing is that we will not be able to cover all the process capabilities of all the manufacturing processes, but our focus will be to align the thinking

process of the learners that such type of information or this type of concrete very very crystal clear information is available about the processes and we must take advantage of this information while we are designing our products.

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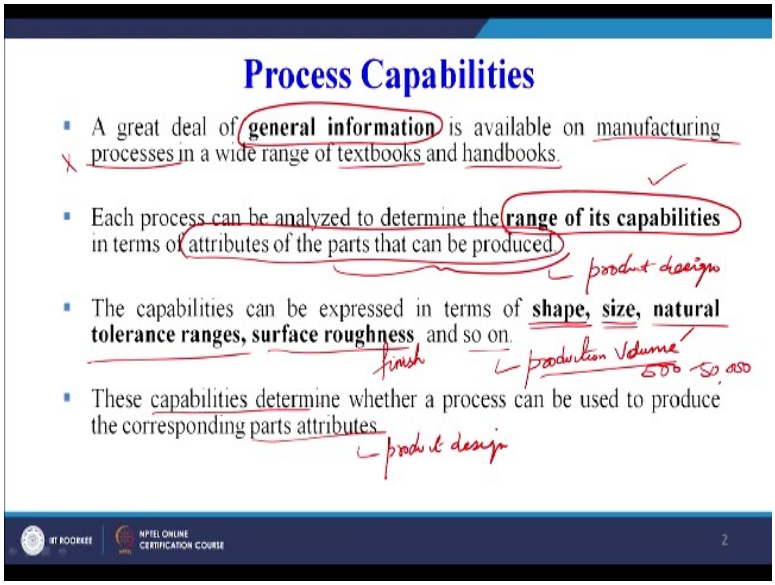


So let us now quickly go through at least 3 or 4 processes today and see the application areas of these processes as well as what is the process capability of these processes. So let us quickly now go to the presentation and try to see the process capabilities of some of these processes. Now we can see what do we mean by process capability. so quickly I have already try to explain but let us now quickly try to formalise or may be standardized the definition of process capability.

So the great deal of general information is available on manufacturing process in a wide range of textbooks and handbooks. So this general information is our target, we are not going to the specifics of any manufacturing process. So that is not our target, we want to have a general guidelines for each and every manufacturing process, whatever possible in our 20 hours of discussion.

If you go if you have gone through the syllabus that we are going to cover in these 20 hours you will see that we have identified the most important processes which are used in industry and we will try to establish the basic thumb rules or guidelines that must be kept in mind while we are designing a product. So lot of information is available, so if we refer to the textbooks and handbooks we can get lot of information related to manufacturing processes.

Each process can be analysed to determine the range of capabilities, so this is what we will try to just highlight today with the help of certain examples, in terms of attributes of the parts that can be produced. So this is very very important, so parts that can be produced is related to our product design approach. So when we know this particular part has to be produced we will certainly have a design for that part.

And that design we need to understand that how it can be produced in the most economical as well as in the most productive manner and that is what where the range of capabilities will come into picture, we must know that casting is capable of producing this type of a product or machining is capable of producing such type of a surface finish or forging is capable of giving me this much strength in my final product.

So that capability we must be able to understand we must be able to highlight, we must be able to keep in our mind while we are designing a product. So the capabilities can be expressed already I have told the capabilities can be expressed in terms of shape, shape of the product, size of the product, natural tolerance ranges for the product, surface roughness, or we can say surface finish of the product.

And so on may be in the so on we can write the production volume, may be it can be 500 or it can be 50000. So depending upon the production volume also we will decide that which process has to be used why because every process will have a capability some process may have a capability of producing only 500 parts in a day whereas there can be another process which has a capability of producing 50000 parts in a day.

And satisfying all other criteria, so if our production volume is large we will certainly go for a process which can produce 50000 parts in a day. So the production volume is also an important decision criteria when we have to select a process and process we will select based on the process capability, that this process has got this list of capability, this process has got this this is the list of capability.

Then we will match or we will do the matchmaking what are the requirements, what is the capability of the process and then we will try to match that two and then we will start our production process. These capabilities determine whether a process can be used to produce

the corresponding part attributes. Now depending up on the part attributes will come from the product design.

And this design can be manufactured or not that will depend upon the capability of the process, so we have a product design with us, for example this pen, I am using this design is ready, now we have to see how many of such pens have to be produced, what is the shape intricacy of this pen, what is the material of which this pen is to be made of, what are the type of slots required.

So we have the design ready with us, now we have to see how this can be produced, now how we have to find out answer, when we know there is a long list or there is plethora of or there is a spectrum of processes available with us which can help us to produce this product. we have to choose the most economical the most productive, the most efficient, the most effective as well as the most important process from the quality point of view.

Sometimes it may so happen that is the process which is giving us the best maximum productivity or the maximum efficiency may not produce with the desired quality. So the quality is an important parameter which will also help us to decide the process, many a times it has been seen that there are processes which will produce at a very fast rate, but will produce may defective items also.

So those type of processes may be if the production quantity is very very large and we can effort some defective items we will go certainly for those processes, but wherever we are very very conscious about the quality of the product we will discard these processes and we will go for a process which may produce at a lesser rate but the defective items are minimum or may be sometimes we talk about the zero defects also.

So we do not want a defective item to be produce, so quality is important parameter, cost is important parameter, shape of the product, size of the product, tolerance range of the product, so there are different criteria which will help us and another point is the process capability, the process capability we must know then only we can select the processes, if we know that for example the weight of the product.

Now we know the weight of the product is very very very small, so we cannot say that casting can be used for this particular application. So there will be a range in which casting sand casting is possible or the range of the weight for which the sand casting is possible, sometimes the weight maybe so high, we cannot use the die casting process there. So we must know that the die casting is suitable for a specific rate range.

It is possible for a specific surface finish, sometimes we may require a super finished surface and in die casting that kind of surface finish may not be achievable so how we can select die casting, we cannot select but the decision will be better decision it will informed decision if we know that die casting has the capability to produce this much surface finish or a surface finishing in the range from this much micron to this much micron.

So that is the importance of process capability, so once we know that this is the process capability for casting process, this is the process capability for forging process, this is the process capability for machining process, accordingly we can select our process. So let us take few examples.

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So capabilities of a range of manufacturing processes, quickly we will try to go.

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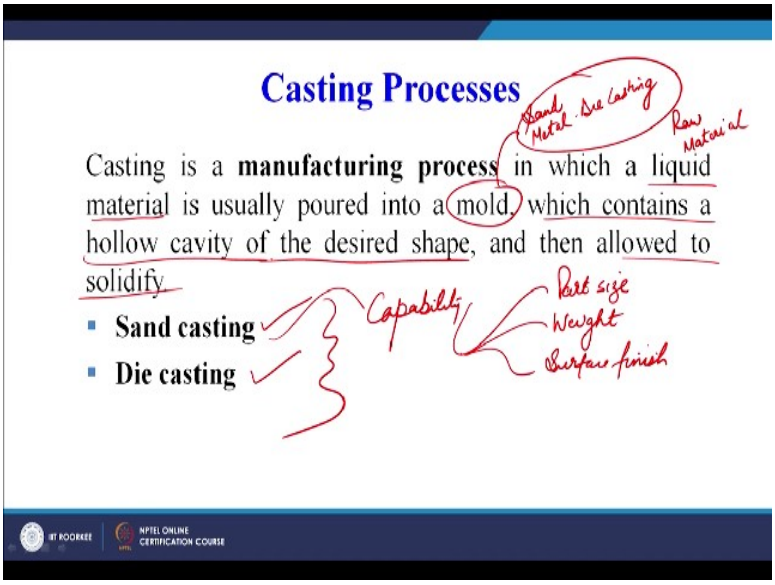


So this process already we have seen casting, so casting is a manufacturing process in which a liquid material is usually poured in a mold, so the mold as I have already told one thing is the liquid material which is which we can call as the raw material, so we have a raw material which his in the molten form and the mold can be a sand mold, or it can be a mold made in metal specially in case of die casting process.

So we have a molten metal, we have a mold, the mold is prepared as the exact replica of our final product which contains a hollow cavity of the desired shape. So the mold is exact replica or it is a cavity of the desired shape of the product and then the materials that is poured into the mold is allowed to solidify. Two examples already given sand casting and die casting which I have already highlighted here.

So this is the basics of the process, now we want to see make a decision we must know what is the capability or the process capability of sand casting and similarly for die casting, in terms of what we want to see it in terms of the part size, or the size of the product we need to understand the capability in terms of the weight of the product which it can produce, we need to understand the surface finish which can it produce and we need not memorize all these information.

We can have standard textbook we can refer to those textbooks and see the capability and that is important we must know that this type of information is available and we can make use of this information. So now we can go for the capability and try to categorise or classify the sand casting and the die casting process in terms of part size, weight, surface finish or

sometimes it can be the number of products produced per hour or sometimes it can be per day also depending upon the size of the product.

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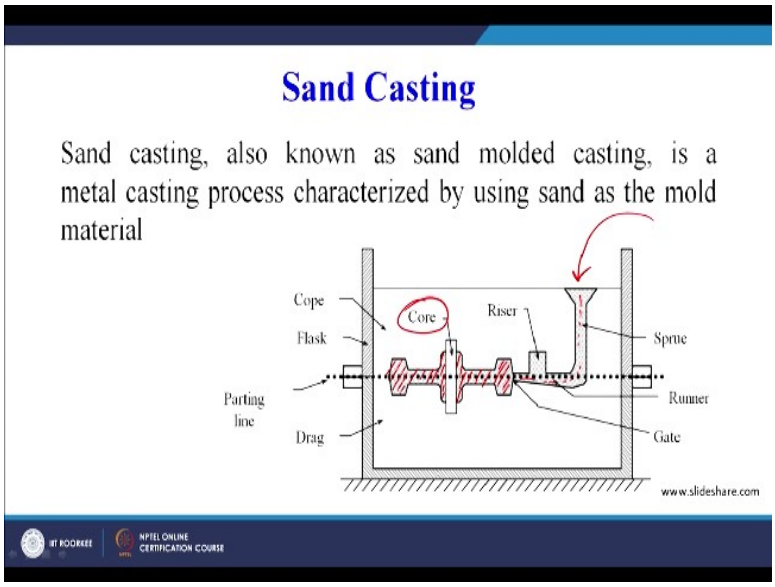


So these are the criteria are which will help us to make a tabular arrangement of the capability for sand casting as well as for die casting. So this is the basic sand casting process which we have already seen and there are number of very good lectures available on sand casting process in MOOC's as well as the other courses of NPTEL. So we are not going to go into the details of casting process here.

So this is an example of the sand casting process, we make a sand mold here, and this is our product as I have already highlighted in one of the previous lectures also. This is the final product that will come out and this is the core which is used for creating a hollow section in the casting. So the important point is we bring a molten metal and we pour it into the screw the metal moves through this gating system and enters the mold cavity.

And after solidification we are able to produce our final product. So sand casting also known as the sand mold casting is a metal casting process, characterized by using sand as the mold material. So this is the sand, and we make a mold in the sand. Now this process has got certain capabilities.

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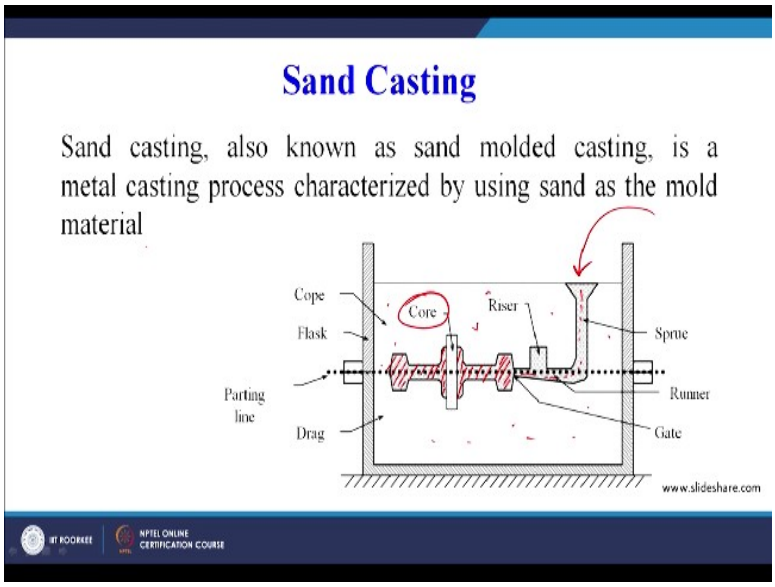


Now let us see what are the capabilities, this is the source for this information product design for manufacture assembly by Geoffrey Boothroyd, Dewhurst and Knight. So form this book this data is available, there can be additional data which is available so we can see one of the criteria that is parts size, from part size point of view the weight can be from 0.21 0.2 on to 459 tons. And minimum wall is 0.125 inch.

So this is the minimum wall thickness which is possible using the sand casting process. Similarly the surface finish can be the second criteria which will define sometimes the quality of the surface produced. So that is also in the range of 500 to 1000 micro inch, then the shapes produced competitively we can see here large parts which is giving the size of the product size which we can produce.

The sand casting is capable of producing large parts with walls and internal passage of complex geometry, this is another from the complexity of the product point of view, so fairly complex products can be produced requiring good vibration damping characteristics. This is from the application point of view. So if we see now where to use sand casting process, so the weight is also specified 450 ton is on the higher side on the larger side.

The large size castings can be produced minimum wall thickness is given below that you cannot go because during solidification there will be a problems and there can be certain types of casting defects. But as a product designer we can keep in mind that when we are designing a product which has to be made by sand casting process we must not specify a wall thickness less than a specified value.

Similarly the surface finish also the values are given and the shapes produced are also given, this type of process capability tables are available and we must make use of these tables when we are designing our product. Now let us see the applications for sand casting.

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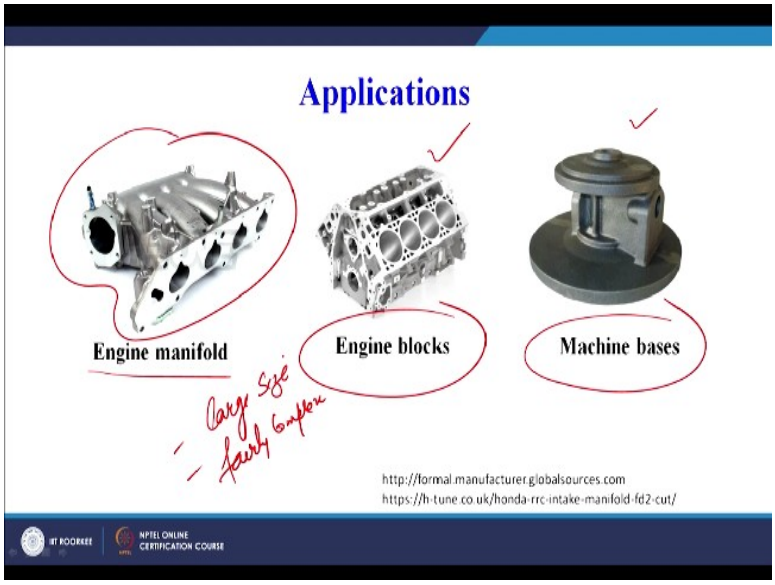


We can see the engine manifold, you can see the complexity of the product here, and this can easily be made by sand casting, engine block can also be made, machine bases can be made by casting. So here if you look at these 3 things all of them are large size and fairly complex geometries. So we can say the casting sand casting specially has a capability to produce large shapes with fairly complex geometries.

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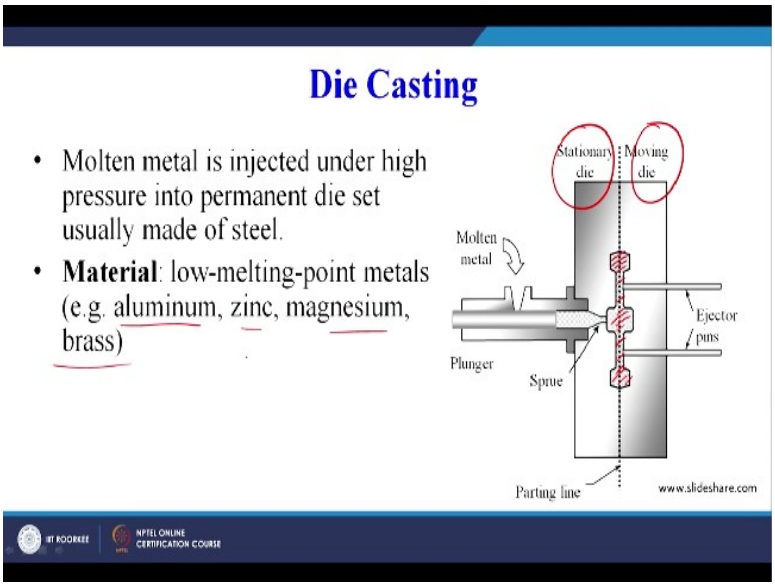

Now the die casting this diagram already we have seen, this is the final product that is going to be developed here, there are 2 die halves one is moving and another one is stationary once they close they create a cavity between them and once we pour the molten metal inside it solidify and takes the shape of the product. So the molten metal is injected under high pressure into the permanent die set usually made of steel.

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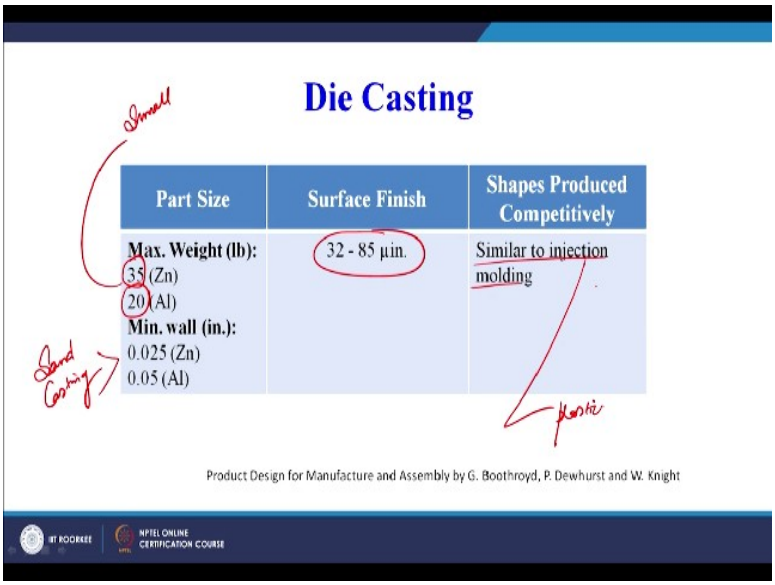


Material can be low melting point metals like aluminium we have already seen this in one of the previous sessions. Now let us see what is the die casting, here we can see surface finish 32-85 micro inch maximum weight you can see 35 here and it is 20 for aluminium. So the weight is not that large, so weight is small only, similarly minimum wall thickness is also smaller as compared to the sand casting process.

So it is we can say smaller than the sand casting process and this is the shapes produced competitively this is similar to injection molding. So whatever we can produce in the plastic using the injection molding process similarly type of shapes can be produced or fairly complex shapes can be produced in case of the die casting process. So we can see the surface finish range, so we can get better surface finish in die casting process as compare to the sand casting.

The range is mentioned here, part size also we can make smaller size parts with the die casting process with complex geometries. So we can see that within casting also we have 2 different processes let us take some example.

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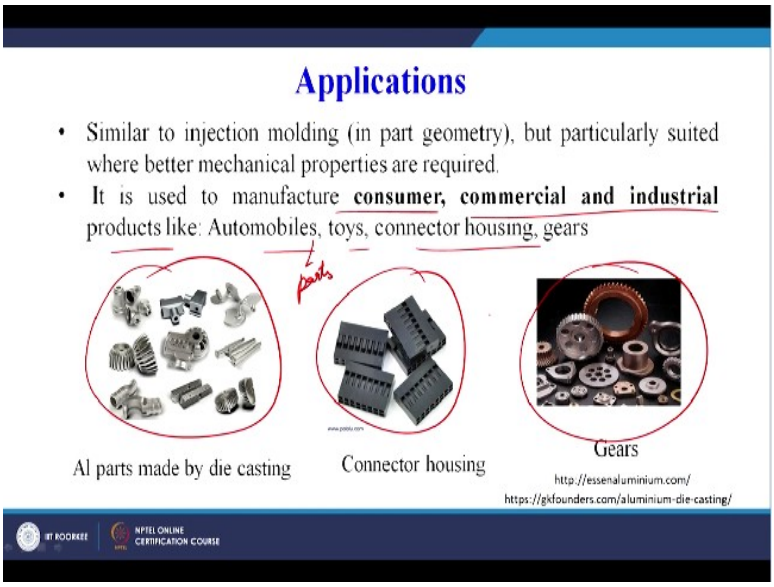


So here we can see similar to injection molding particularly suited where better mechanical properties are required. So in die casting we will get better mechanical properties as compared to the sand casting process. So what kind of products can be made, we can make consumer, commercial and industrial products like automobiles, toys, connector. So automobile we can make different parts, different smaller parts or components which are used in the automobile industry.

So these are the aluminium parts made by die casting, you can see the size is not very large, small size parts are made by the die casting process, principle remain same, the metal is melt it is poured into the mold in case of due casting we inject it at pressure and it goes into the metallic die and it the metal gets solidified there, but we are not able to make very large parts in die casting.

Similarly the connector housings are given here these are the gears which can be made using the die casting process. So we can very easily differentiate between the 2 now where sand casting has to be used and where die casting has to be use. So when we are designing a product we must keep this process capability in mind that where we are going to if I am designing a product which is small in size has to be produced in large quantities we require very good surface finish, we must up for a die casting process.

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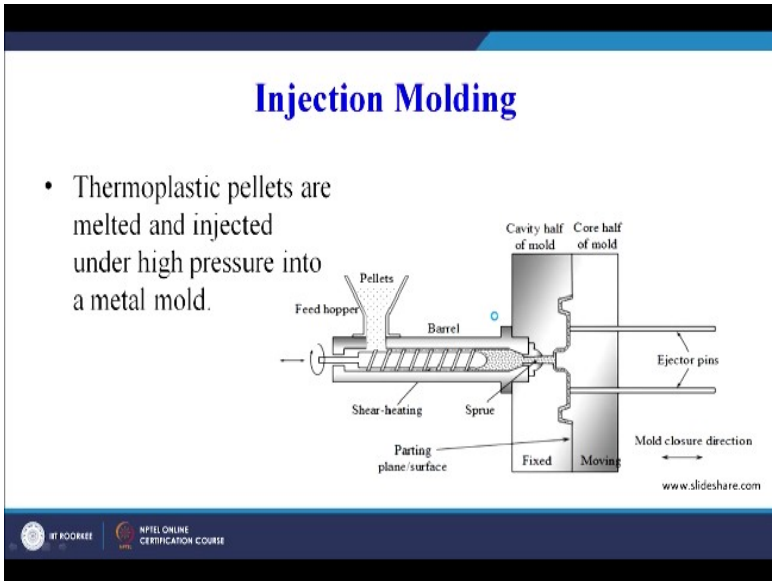


Now similarly injection molding process also we have seen in the previous slide.

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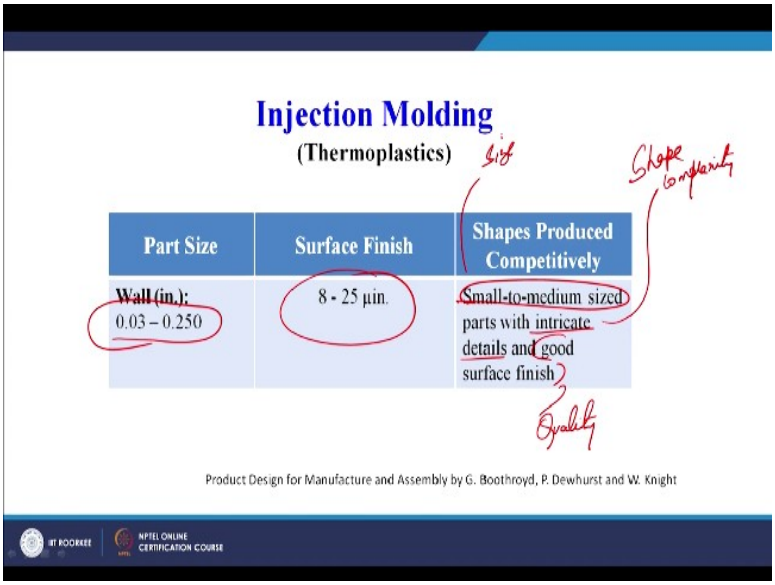


I will skip this and go to the injection molding which is normally use for thermoplastics, we can see the wall thickness range here, which is available the surface finish is better and shape complexity small to medium size parts with intricate details and good surface finish. So good surface finish is from the quality of the product that we are producing intricate details from the shape complexity point of view.

And small to medium size is from the size point of view. So we can see that size is an important criteria, shape of the product is an important criteria and the quality of the product that we are desired of the quality of surface finish that we desire is an important criteria. So

we can see where injection molding can be used small to medium size complex parts where we require a very good surface finish.

Surface finish range is also given which can be easily attained using the injection molding process even the when we are designing our part the wall thickness also is range is specified that it is we injection molding process has the capability to produce the wall thickness in this range.

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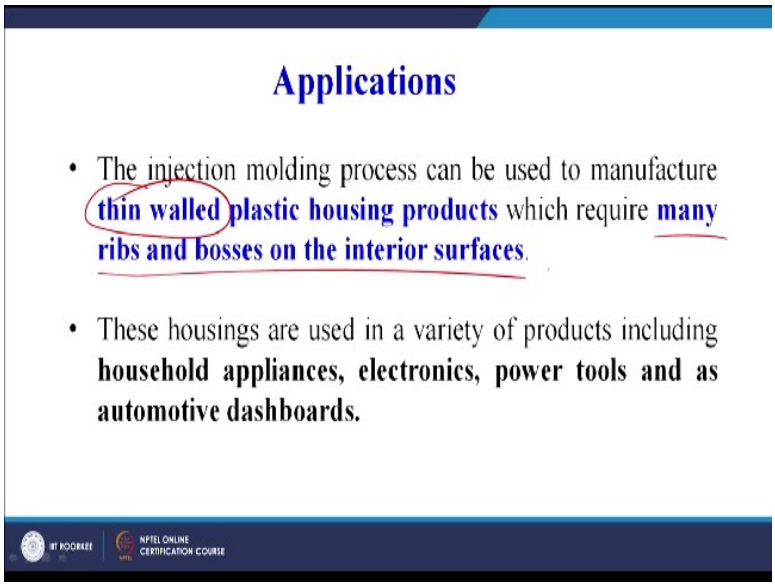


So the applications the injection molding process can be used to manufacture thin walled the because the wall thickness is given plastic housing products which require many ribs and bosses on their interior surfaces. So there if there are ribs and bosses on the interior surfaces injection molding is the process that has to be used. These housings are used in variety of products including household appliances, electronics, power tools and as automotive dashboard.

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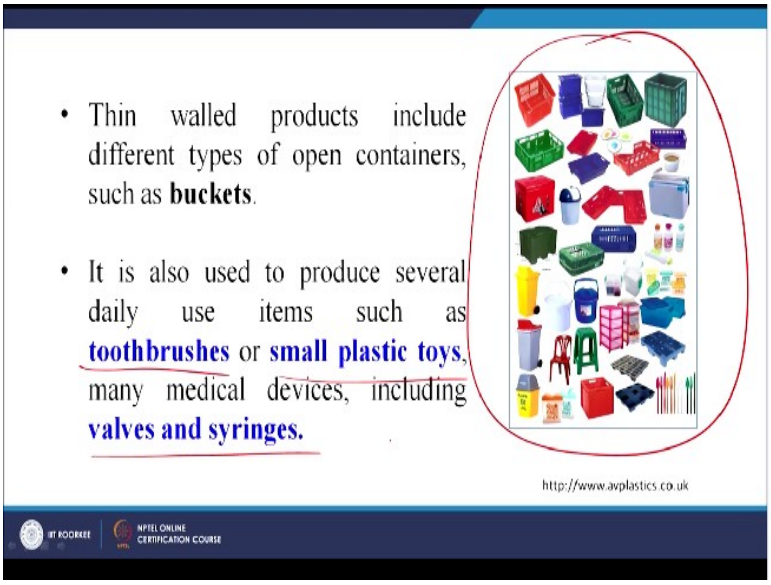


And you can see a lot of range or parts which are made by the injection molding process, so thin walled products include different types of open container such as buckets, it is also used to produce several daily use items such as toothbrushes or small plastic toys, many medical devices toothbrushes, small plastic toys, medical devices using valves and syringes. So you can see injection molding is a very very versatile processes and can produce a wide variety of products which are small in size which have very good surface finish which are fairly intricate in shape.

And when we have to produce in large quantity, so that this you can see is the capability of the injection molding process. Now similarly let us finish our today's session with the very important process for plastics that is the blow molding process.

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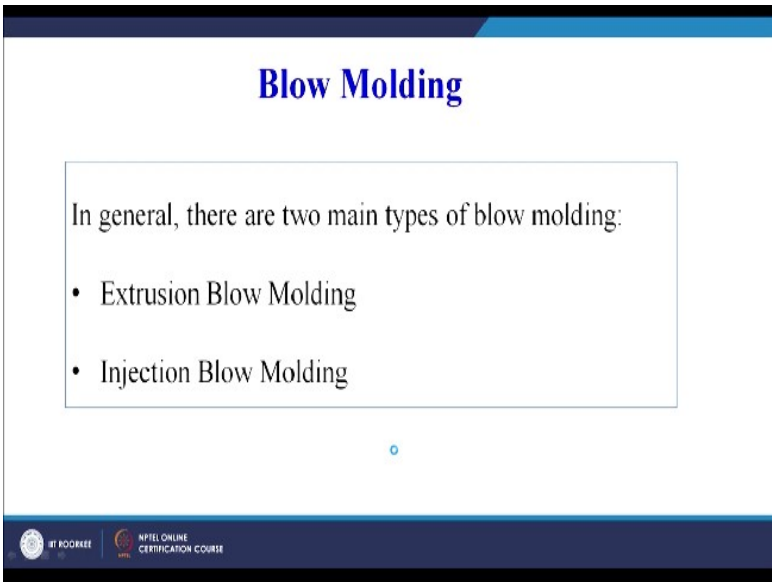

So blow molding is a manufacturing process that is used to produce hollow plastics parts by inflating a heated plastic until it conforms to the mold shape and forms the desired product. I think the definition slightly may not be very very clear in the first reading but let us try to understand it with the help of a diagram in general there are 2 main types of blow molding processes extrusion blow molding and injection blow molding.

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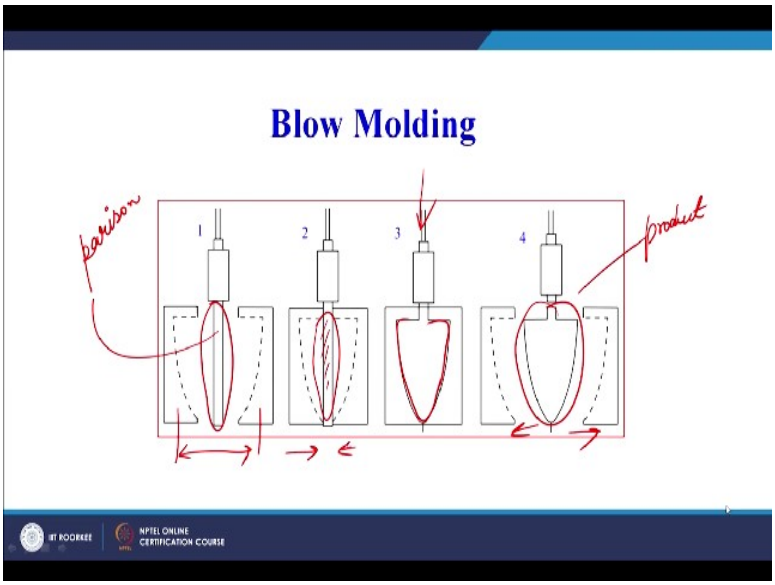


And this is basically the diagram which will make it very very clear, this is the raw plastic part which is sometimes called as the parison also and then this is the first stage these are the 2 mold halves they will close here the 2 mold halves have closed this is the raw raw plastic part then we blow hot air inside it inflates this plastic part and it adheres to the shape of the mold when we blow the air.

Then the 2 mold halves will open and our product is ready, this is our product, just a basic introduction of the blow molding process, now what is the capability of blow molding let us see.

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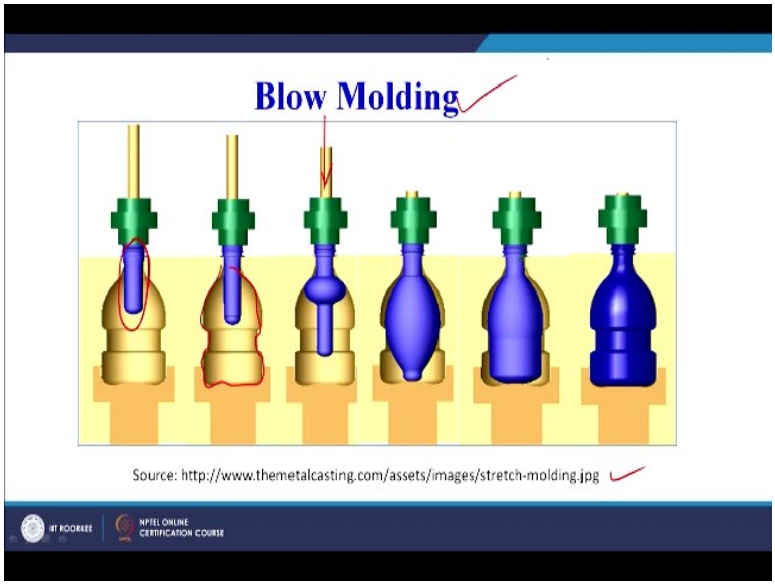


This is another diagram of blow molding which is a 3 dimensional this is the raw plastic part, this is the die half, this is the final product, so if the hot air is blown in from here it inflates the raw plastic part and it takes the shape of the part of the sources is also given, number of good videos are also available on youtube depicting the blow molding process.

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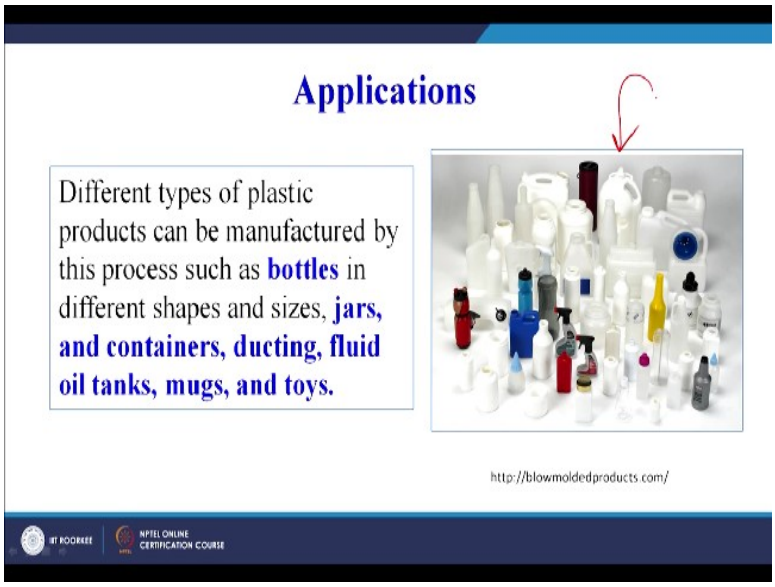


Now what is the process capability wall thickness size is specified, surface finish range is specify 250-500 micro inch. Now what type of shapes can be produced, it can produced hollow, well rounded thin-walled parts with low degree of asymmetry. So we have to have a symmetric part or axisymmetric part only in case of the blow molding. So it is advisable that we use this process for axisymmetric parts only.

So hollow parts have to be made well round thin walled parts can be made and all almost all plastic bottles are made using that blow molding process, surface finish range is specified wall thickness range is also specified. So we can see certain examples. So we can see a wide variety of plastic bottles are made by the blow molding process. So different types of plastic products can be manufactured by this process such as bottles in different shapes and sizes jars and container, ducting, fluid, oil tanks, mugs, toys.

So large number of parts can be made using the blow molding, the most of the parts you will see are symmetric in nature. So with this we come to the end of today's session, the important thing that we have learnt today is that each process has got certain capacity, some capability in terms of the surface finish it can produce, in terms of the parts it can produced basically the geometry of the parts it can produce.

The size of the parts it can produce, the tolerance range it can adhere to the dimensional accuracy it can produce and there is information available under wide variety of sources some of the information we have collected from one standard book on design for manufacturing and assembly and we have tried to show that this information is available which a product designer can use during his or her design process.

And select the designs ribs or bosses or wall thickness accordingly during the design process only so that when the product is manufactured no problem is encountered from the manufacturing point of view. So with this we conclude our first week of discussion our focus primarily has been to introduce the basic concepts of manufacturing the classification of manufacturing processes.

Then the process capability and applications of the most important manufacturing processes that are used for making different types of product. In our 2nd week our discussion will focus on the engineering materials and how they can be used for producing the parts and as a product designer how we must use the information related to the engineering materials in our product design process.
Thank you.