Manufacturing Guidelines of Production Design

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Lecture-20
Design Guidelines for Die Casting

Namaskar friends, welcome to session 20 of our course on manufacturing guidelines for product design. So we are at the midway of our course as you were well aware that this course is a 20 hour course. So, we have to have a 20 hours of discussion of 40 sessions half an hour each and today we are going to discuss the 20th session. So just to have a brief review of the last 10 hours of discussion, in last 10 hour our focus has been on understanding the importance of manufacturing.

The engineering material, the design tools in product design process, then we have identified the most important processes which are basically used for making the products. As you were well aware we have the discussion regarding the selection of processes and in those processes we have categorized the processes into different classifications. And then those processes we have seen that what is the criteria, what are the attribute, what are the design requirements based on which we will select a specific process for a specific product.

And in that we have seen 2 sessions, selection of processes 1 and selection processes 2, then we have seen the process capability and we have tried to list down the kind of information the kind of table, the tables the kind of complied databases which are available in very or various good books which can be made use by the product designers when they are going to specify a manufacturing process for a particular product.

Finally we have shifted our attention towards the manufacturing guidelines for specific processes. Now suppose the product has to be made by sand casting process, then as a product designer if I know the basics of sand casting I may not be knowing that what are the precautions, what are the design guidelines that I must keep in my mind when I am designing my product, although as a mechanical engineer I may understood the casting process, how casting is done.

But I do not have an idea that what are the guidelines that must be kept in mind for a product when it has to be manufactured using the sand casting. So in the previous session we have focused on the design guidelines for sand casting process, today our target is design guidelines for die casting process, if you remember towards the end of the previous session we have discussed that sand casting is expandable mold casting process whereas the mold is made in sand.

So, sand is used as the molding material and then we use a pattern we put the pattern in the sand ram it properly take out the pattern in the sand we will get the exact replica of or exact mold cavity representing the product that we have to make. And then we fill that mold cavity with molten metal which solidifies to give us a product, so that is the **basics** of sand casting process.

Now the product that is coming out of sand casting, what are the guidelines that we must keep in mind when we are designing that product that we have seen in the previous session. There are different types of attributes related to the product that we have to keep in mind, for example the kind of surface finish that we are going to get. The shapes that we can get the size of the product that we can make using sand casting process.

The tolerance that is achievable in sand casting process, the number of parts that we can make economically using the sand casting process. So, there are different attributes and we have seen an example of each of the attribute that where sand casting process is applicable and we have seen certain applications of sand casting process also. So sand casting is a expandable mold casting process where the mold is broken down after the casting is ready.

But in die casting process we make use of permanent molds and what are the design guidelines for the products that have to be made by die casting that is the target of our discussion today. And in die casting because the metallic molds are being use there has to be certain specific guidelines which are different from the sand casting process. So, today maybe in the next 25 to 30 minutes we will try to highlight what are the design guidelines for the products which have to be made by die casting. Within this short span of 25 minutes we may not be able to address all the design guidelines related to the die casting process.

For each material for example aluminum can be made by die casting or the aluminum products can be made by die casting. There can be specific requirements which are specific to the material for zinc there can be certain requirements which are specific for zinc castings made by die casting process. So therefore we cannot go into the detail of each and every material at each and every variant of the die casting process also.

Because in die casting also we can have hot chamber die casting, we can have cold chamber die casting the design requirements may vary. But we will try to discuss what are the basic things that must be kept in mind in case of die casting of the products. So, we will try to understand and see what kind of information is available in the public domain which can be made use by the product designers when they are designing a product or designing a product or designing a spectrum of products which have to be made by the die casting process.

So, before going to the die casting let us have a idea about the die casting process, we have just 1 slide just to give you overview that what casting is because there can be many learners who do not have the basic idea about die casting. So, let us first see die casting, then we will see that what are the design guidelines for the products that have to be made by die casting process.

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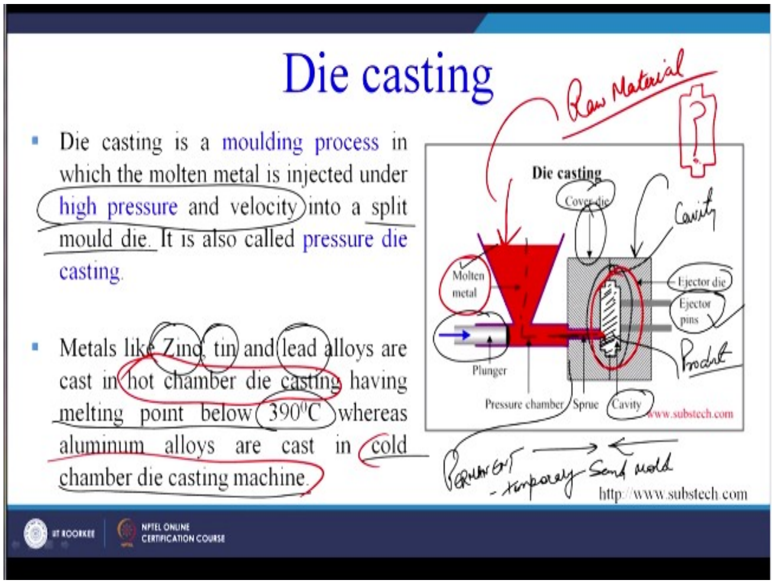

So, on your screen you can see this is the molten metal or we can also call it the raw material which is going to be use for making the product. So, this is the raw material it is coming here it is molten, so this is a raw material it comes here then using this plunger it is pushed into the die this is 1 half of the die. Already pointed out with the arrow and this is the other half of the die, so these 2 die halves will close to form the die cavity and this is the die cavity.

It may be written somewhere also this is the cavity already written in the diagram, so this is the cavity. So, this red color molten metal will enter from here you can see it is entering and it will be filling this die cavity and this is going to give us the product using this process. Now this is molten metal, so since it is molten it will solidify in the die cavity and take the shape of the die cavity and we will get our die cast product.

So, this is a very very very important manufacturing process in any industry or metal working industry and number of products are made using die casting. So you can see here the cavity that we have got in the die, the die is a permanent die here. We have a permanent die whereas in sand casting we had a temporary mold which was made in sand. So temporary sand mold we used in case of sand casting but here we are using a permanent mold.

So, therefore casting can be divided into 2 categories sand expandable mold or sand casting and the permanent mold or die casting process. So this is the simple diagram of a die casting process, there are 2 halves of the die.

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The 2 halves of the die will close in between there will be ca cavity which will exactly be replicating the final product. So, this cavity has to be filled by the molten metal and the molten metal will enter into the cavity and it will solidify there and the 2 halves of the die will remain closed. So we will get our final product after solidification, now how this product will come out the die halves will open and the product will be sticking to 1 half of the die which is shown here.

So, this is the ejector die once the metal has solidified it will be sticking to 1 half of the die and there are ejector pins here. These are the ejector pins which will give a slight it may this is suppose the we can say the ejector part of the die or the ejector die. And the product is struck here, the product is struck here like this.

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And it is moving like this.

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So here there will be ejector pin, the ejector pins will just hit it slightly and the product will fall down. So, these are this is the role of the ejector pins to help the product to move out of the ejector die or push the product away from the ejector die in the most simplest language. So, therefore we can see the die casting is a molding process in which the molten metal is injected under high pressure and velocity important.

High pressure and velocity into a split mold die it is shown here 2 halves of the die are shown it is also called pressure die casting process. Metals like zinc, tin, lead alloys are cast in hot chamber die casting having a melting point below 390 degree centigrade. Whereas aluminum alloys are cast in cold chamber die casting process, so 2 processes are show here we 2 processes are there 1 is the hot chamber die casting and the other one is the cold chamber die casting.

So, we are not going to distinguish between the 2 one of the examples shown what the data is shown here, the temperature of the alloys which are used for cold chamber die casting and for hot chamber die casting that is 1 differentiating factor between cold chamber die casting and hot chamber die casting process. So, this is basically what we talk about die casting, we have a molten metal which is pushed into using a plunger or using a piston type of arrangement.

The molten metal at high pressure and velocity is pushed into the die cavity there the die is into 2 halves the metal enters into the die cavity and solidifies there. Then the die halves open after solidification and the ejector pins push the final product the solidified product, the solid product out of the die cavity. And it is a cyclic process again the cavity will close the metal will be pushed inside metal will be allow to solidify the die halves will open, the ejector pins will push the product out after solidification, so this is die casting.

Now what is our target, why we are studying this course, our target is this product has to be designed. In this case what is the shape of the product in this case the shape of the product that we will get will be something like this. Now how it has to be designed, what are the design guidelines when the product is going to be die cast that we must keep in our mind. So, those guidelines is our target, so quickly let us go to those guidelines.

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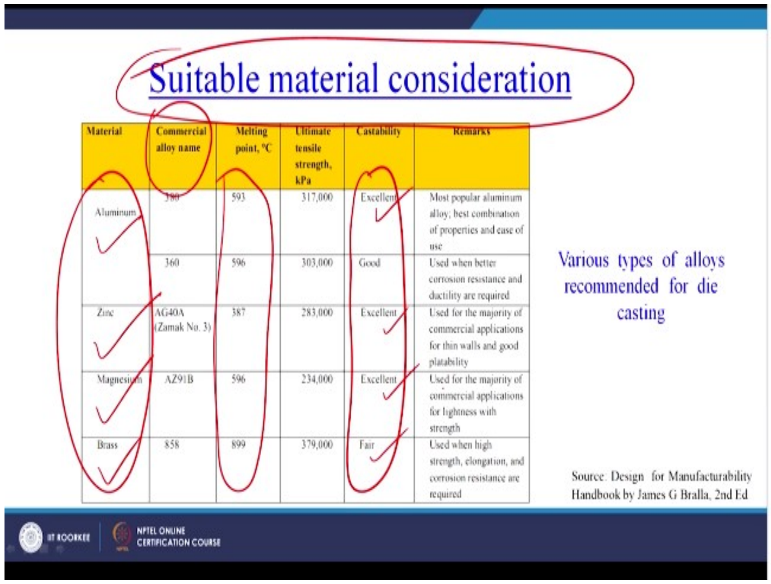

Material	Commercial alloy name	Melting point, °C	Ultimate tensile strength, kPa	Castability	Remarks
Aluminum	380	593	317,000	Excellent	Most popular aluminum alloy; best combination of properties and ease of use
	360	596	303,000	Good	Used when better corrosion resistance and ductility are required
Zinc	AG40A (Zamak No. 3)	387	283,000	Excellent	Used for the majority of commercial applications for thin walls and good platability
Magnesium	AZ91B	596	234,000	Excellent	Used for the majority of commercial applications for lightness with strength
Brass	858	899	379,000	Fair	Used when high strength, elongation, and corrosion resistance are required

So, first thing is suitable material consideration, so first we have to select a process if you remember in the very first week of our discussion we have talked about the manufacturing the second week we talked about materials. And then in the current week if remember session number 16, session number 17 we have discussed about selection of processes based on different attributes and then we have seen different types of charts.

And in one of the charts we have seen the process material chart which means that each and every process cannot be applied for each and every material. So, there has to be some difference that this process can be applied to this category or this family of materials. And the other process can be applicable for some other family of material, so that is the first thing the suitable material consideration.

So, when the product has to be made by die casting these are the important materials which can be easily cast using the die casting process. So you can see aluminum, zinc, magnesium and brass and the commercial alloy name is also given and you can see the melting temperature is in 3 digits only. So, different alloys different melting temperatures are there, the ultimate tensile strength is given, it is given kilo pascal it can be represented the mega pascal also.

And then the castability part aluminum excellent, zinc excellent, magnesium excellent, brass fair, so we can use the die casting process for a wide variety of engineering materials like aluminum, zinc, magnesium and sometimes under limited conditions for Bras also. So we can use the die casting process, so these are the various type of alloys recommended for die casting, the source is also given design for manufacturability handbook by James Bralla second edition.

So, this is you can say the material consideration for the product design, now suppose we have made a product it can be made using aluminum, it can be made using zinc. So we can choose that yes we can choose both the materials they can easily be made or the product can easily be made using zinc and aluminum by the die casting process. But then this is only the decision based on the material there are other things that have to be taken into account.

The other things can be the shape complexity, the size of the product, the surface finish that we desire, the number of products that we have to produce because the number of products will directly reflect on the cost of the die that we have to spend. Because here in this case die casting we need to have permanent metallic die which is certainly going to be very very costly as compare to a sand mold.

We cannot decide the material of the process to be chosen only based on the material it has to be chosen based on a wide variety of attributes. And then finally we have to select the process and if you remember in the selection of processes we have already seen that there is a flowchart and step by step approach that we must follow and screen out the processes which are irrelevant and go finally from a wide variety of processes we will boil down to a single process or maybe 2 processes which can be use for making our product.

But certainly die casting has application in terms of different types of alloys. Now the second part is the wall thickness when we are designing a product maybe of aluminum, the second criteria can be we have already decided aluminum is going to be my material for the product. Now we will see wall thickness, now sharp changes in sectional area and heavy sections over 6 millimeter thickness should be avoided if possible.

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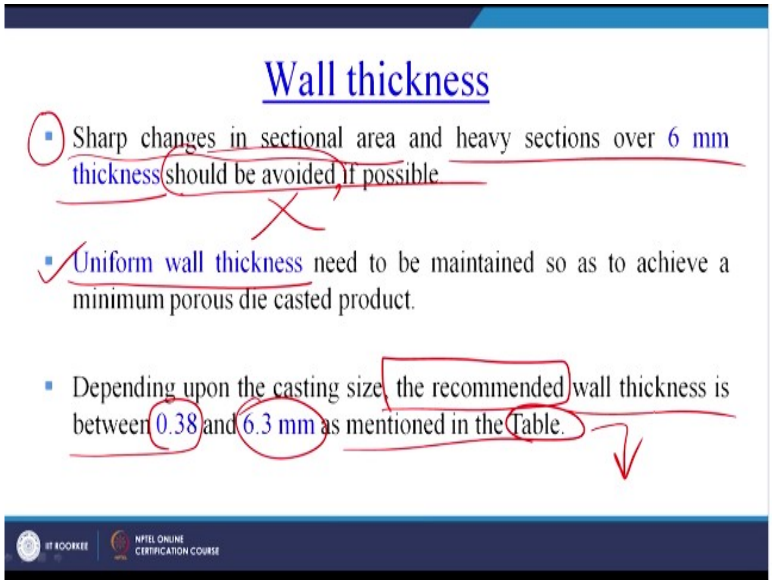

So, these should be avoided sections over 6 millimeter thickness why because there can be thermal gradients the cooling rate maybe different at the inside and then at the outside. The outside skin is in contact with the metal, the inside skin maybe in contact with the molten metal outside skin is in contact with the die. So, there can be thermal gradients in the sections, so therefore we must not recommend a very large wall thickness when the product has to be made by the die casting process.

So again I will read this important point for you sharp changes in sectional area and heavy sections over 6 millimeter thickness must be avoided if possible. Another recommendation is uniform wall thickness need to be maintained so as to achieve a minimum porous die casted product. So wall thickness must always be uniform and same guideline we have seen in case of sand casting also that we must try to maintain a uniform wall thickness.

Otherwise there can be issues related to the quality of the product that we are producing using the die casting process. Depending upon the casting size the recommended, so we must not worry there are already recommendations we which we must follow. But most of the time the product designers do not have excess 2 or information about these type of recommendations. So, the course basically is designed, the course is planned with this type of information only that the designers can access this information.

This is not the only information there is a wide variety of information which is available, so we can see that when we have to make a product in aluminum using the die casting process when we have to decide the wall thickness there is a recommendation, what is the recommendation, depending upon the casting size the wall thickness is between 0.38 to 6.3 millimeter as mentioned in the table, so table is given on the next slide.

So, let us try to see that what are the various wall thicknesses that are allowed and for which type of material and for how much dimension what amount or maybe what value of wall thickness we must select.

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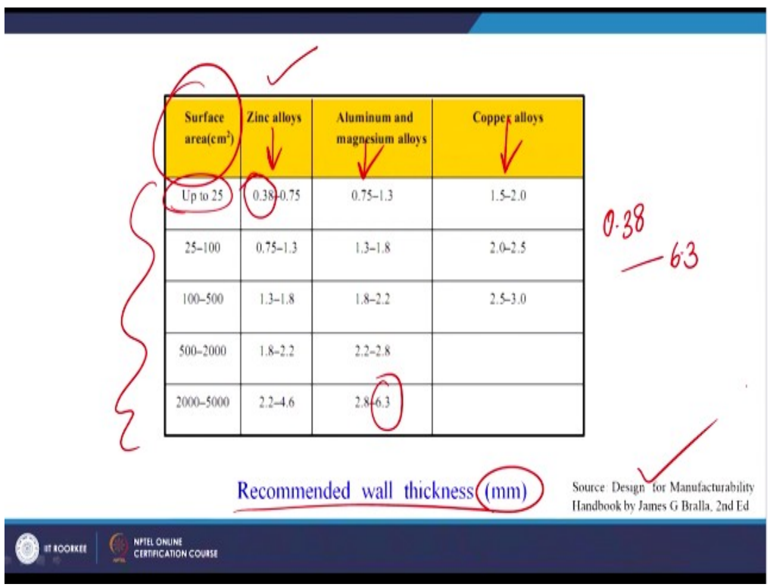

Surface area(cm²)	Zinc alloys	Aluminum and magnesium alloys	Copper alloys
Up to 25	0.38–0.75	0.75–1.3	1.5–2.0
25–100	0.75–1.3	1.3–1.8	2.0–2.5
100–500	1.3–1.8	1.8–2.2	2.5–3.0
500–2000	1.8–2.2	2.2–2.8	
2000–5000	2.2–4.6	2.8–6.3	

And you can see the table here the surface area for the casting this is given here then for zinc alloys this is the wall thickness, so you can see the minimum 0.38 surface area up to 25 centimeter square. And the maximum value is given for aluminum and magnesium alloys **0** 6.3 though from 0.38 to 6.3 is the wall thickness which is given and this is the recommended wall thickness the units are in millimeter.

So, for copper alloys also the range is given for aluminum and magnesium alloys the range is given and the source of this information is also given. So, when we are designing a product and there has to be maybe a minimum wall thickness we must decide that what is the material of the product and what is the recommended value of the wall thickness that we must keep. Otherwise the result will be that we will not get a good quality product.

So, we can see 2 things we have seen we which we must keep in mind, first thing is the selection of the material which has to be made by the die casting process, the second thing is related to the wall thickness, the third thing is related to the ribs.

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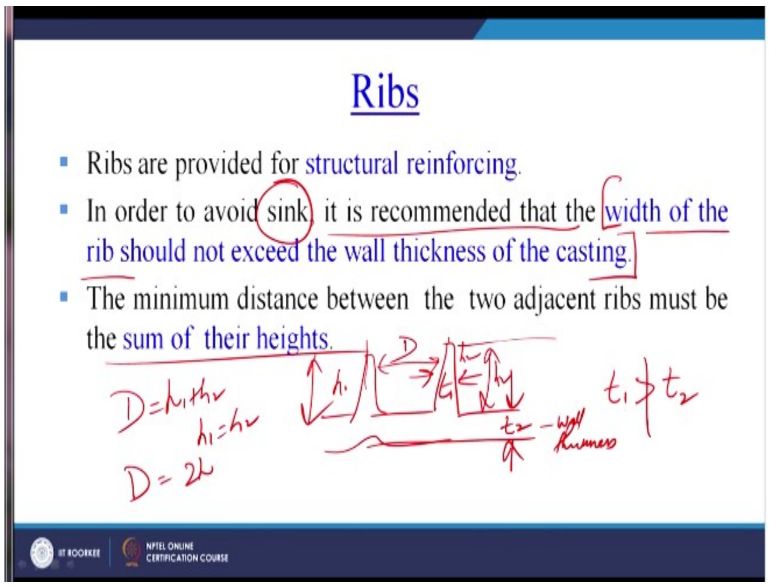

So ribs are provided for structural reinforcement in many products you will see there are ribbed structures also. In order to avoid a sink, what is a sink we will try to see in the next diagram with the help of a table or with a help of a figure. So, in order to avoid a sink it is recommended that now this is a recommendation which a product designer must keep in mind, width of the rib, so suppose this is my rib what is the average width of this rib should not exceed the wall thickness of the casting.

Now suppose this is my wall thickness, so this thickness t_1 must not exceed t_2 not exceed the wall thickness of the casting. So, t_1 should not be greater than t_2, the minimum distance between the 2 ribs, now we can see there is another rib suppose here. Now the minimum distance between these 2 ribs must be the some of their heights, so suppose this is h_1 and this h_2 the height here is h_1 and here it is h_2 or they can be of the same height also.

So, the minimum distance between the 2 adjacent ribs must be some of their heights, so this suppose this we see the capital D distance between 2 ribs. So, D must be equal to the sum of their heights which is $h_1 + h_2$ and if $h_1 = h_2$ we can easily write 2 times the rib height. So, that is basically the guideline that we must keep in mind. So, again these are important guidelines I am reading the guidelines again for you, so that you can keep in mind.

In order to avoid sink, what is sink that we will see a sink is something like this, so in order to avoid the sink it is recommended that the width of the rib the width should not exceed the wall thickness of the casting. So, t_1 should not be greater than the wall thickness that is t_2, the minimum distance between the 2 adjacent ribs must be the sum of their heights, so the distance between the 2 capital D must be equal to the sum of the heights of the ribs that is $h_{1+}h_2$ and if the ribs are of same height equal to 2h.

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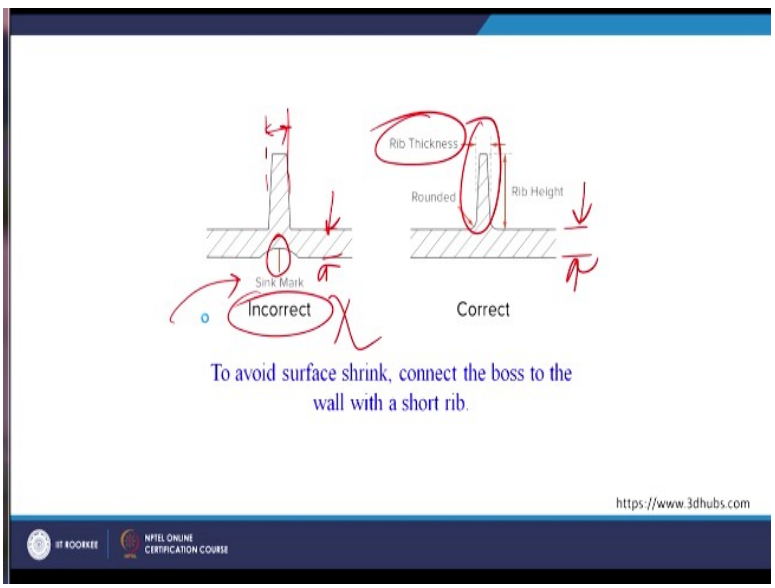

Now this is the example, this is incorrect, this is a sink mark which was mentioned the previous slide and you can see that what is the thickness average thickness of this which is shown here. Now this thickness maybe equal to this thickness which is incorrect and what we have seen in the previous slide the thickness of the rib, rib thickness must be less than the wall thickness which is mentioned here.

To avoid surface ring connect the boss to the wall with a short rib, so this is given to avoid the surface shrink which is this given here surface ring connect the boss to the wall with the short rib. This is a guideline that we must follow and let us see go to the previous slide this is the basically what we have taken as the wall thickness. So we can see that there are standards that we must follow. So, this is related to the ribs which are there in the product design in case of die cast products.

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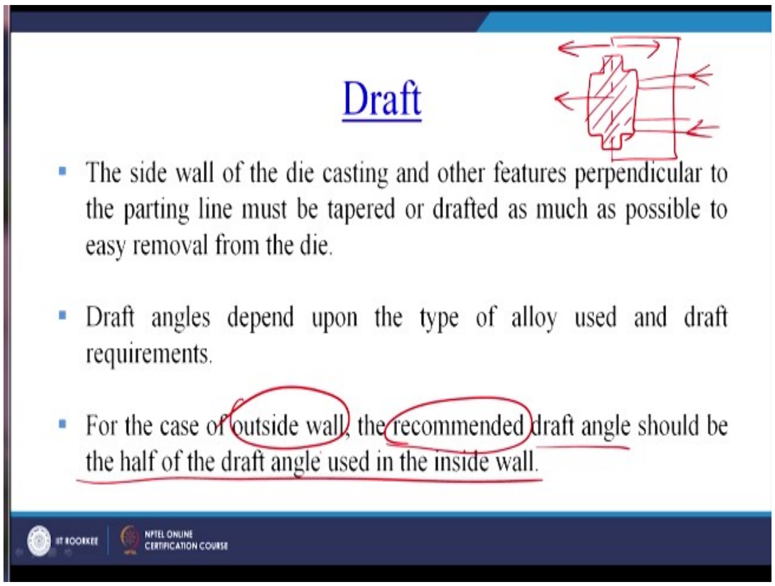

Now coming onto the draft what will happen if the product is inside the die we have to extract it we have seen in the ejector die there are ejector pins. So, ejector pins will hit and it will remove the product from the ejector die. But sometimes the even the ejector pins maybe difficult to incorporate, so therefore we must incorporate a kind of draft which can help us to extract the product from the die.

So the sidewall of the die thickness and other features perpendicular to the parting line. Now suppose this is the parting line as we have seen this was the product that we were producing there. So perpendicular to the parting line means this action and we have seen that this part was there in the ejector die and there were ejector pins here. So, perpendicular to means in this direction, so sidewall of the die casting and other features perpendicular to the parting line must be tapered or drafted as much as possible to ensure easy removal from the die.

So, this part has to be removed after the solidification, so the metal will be poured here it will solidify and the part has to be ejected out. These 2 ejector pins will act and they will push the part out, but in order to ensure easy ejection of the part from the ejector die we must provide the draft in the direction perpendicular to the parting line, draft angles depend upon the type of alloy used and the draft requirements.

In many cases we may not have a draft requirement, so no need to provide the draft in the product or the during the product design. For the case of outside wall the recommended draft angle again there is a recommendation recommended draft angle for the outside wall should be half of the draft angle used in the inside wall. So, if in the inside wall we have taken a value of the draft angle suppose x then for the outside wall it must be x/2.

So, let us see it is for the case of the outside wall the recommended draft angle should be half of the draft angle on the inside wall, so this is again we have seen.

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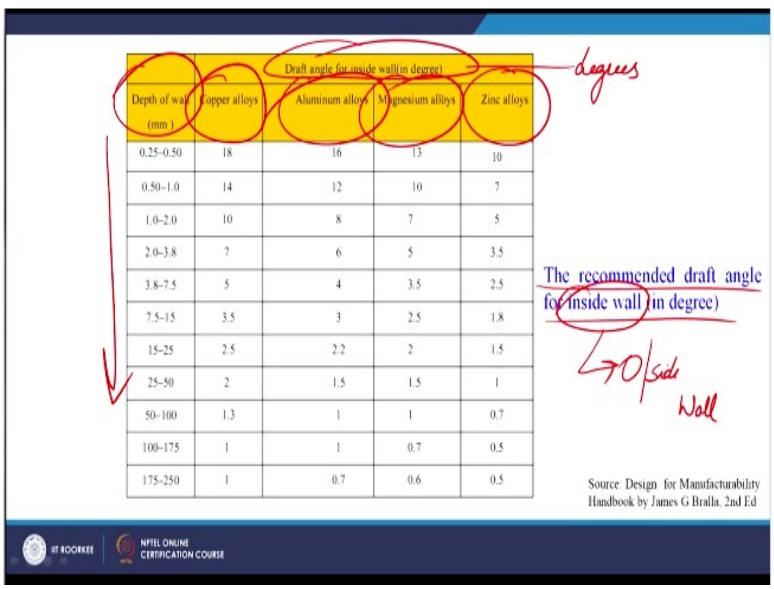

Depth of wall (mm)	Draft angle for inside wall(in degree)			
	Copper alloys	Aluminum alloys	Magnesium alloys	Zinc alloys
0.25–0.50	18	16	13	10
0.50–1.0	14	12	10	7
1.0–2.0	10	8	7	5
2.0–3.8	7	6	5	3.5
3.8–7.5	5	4	3.5	2.5
7.5–15	3.5	3	2.5	1.8
15–25	2.5	2.2	2	1.5
25–50	2	1.5	1.5	1
50–100	1.3	1	1	0.7
100–175	1	1	0.7	0.5
175–250	1	0.7	0.6	0.5

So, this is the recommended this type of tables are recommendations are available and this is if you see this is for the inside wall and based on this we can also select for the outside wall. So, the draft angle for the inside wall it is given in degrees and you can see depending upon the depth of the wall in this direction we can see for copper alloys, for aluminum alloys, for magnesium alloys, for zinc alloys what must be the angle which we must provide on as a draft.

So, we can seen that for ribs there are standard guidelines for providing the draft in order to ensure the easy removal of the part there are guidelines for the selection of the material based on the melting point there are guidelines. So, therefore if we take all these things into our mind when we are designing a part our product will come out easily and the manufacturing will be easy. So, this is a select related to the radii.

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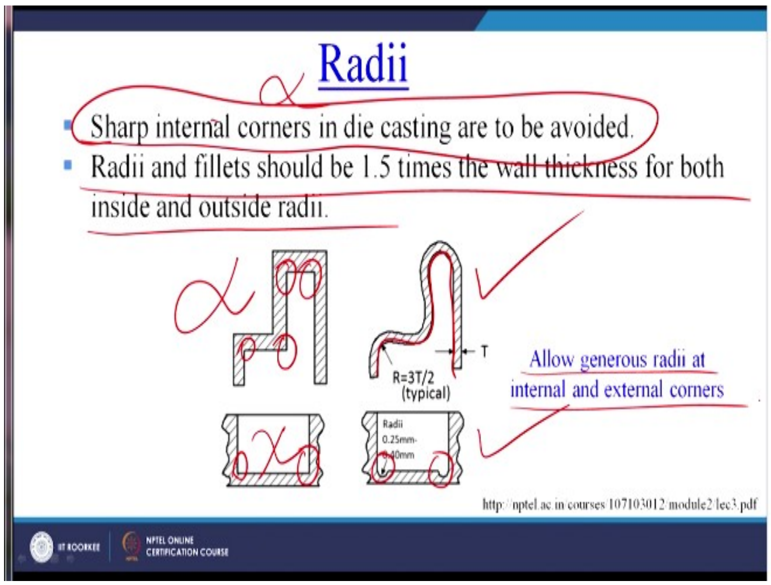

Sharp internal corners in die casting are to be avoided, what has to be avoided, sharp internal corners. So, this is sharp internal corner, so these have to be avoided, how we can avoid them we can avoid them by giving a fillet radii or maybe making them curved. So, that can be given radii and fillets should be 1.5 times the wall thickness for both inside and outside radii, there is a guideline for providing the radii also.

So therefore this is certainly not recommended, this is recommended similarly here also we see this is a internal sharp corner this is not recommended in product designed for made to be made by die casting process. So therefore a internal radii here the range is given 0.25 millimeter to 0.40 millimeter, this is recommended. So, allow generous radii at internal and external corners for the products to be made by the die casting process.

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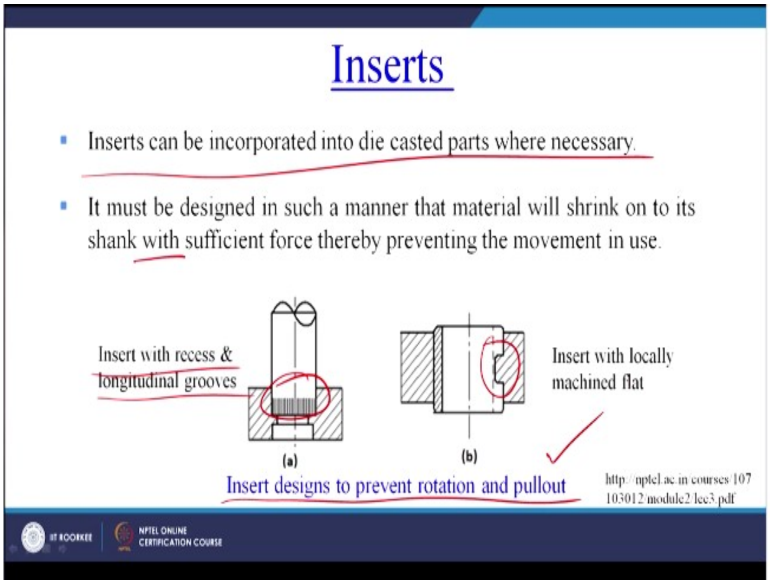

Then once we have to put the inserts inside our product, inserts can be incorporated into die casted parts wherever necessary. The inserts must be designed in such a manner that material will shrink onto it is shank with sufficient force thereby preventing the movement in use. So, we have to ensure that the insert is properly jammed inside the metal when the metal solidify.

So, this is an insert with recess and longitudinal grooves these are the grooves shown here, this is the insert with locally machined part. So, we have ensure that the insert fits in the metallic part or the metallic product properly, so that there is no movement at any latest stage, this is a another flexibility in die casting process where we can use inserts or we can pre-incorporate inserts during a casting process.

In the mold in the die cavity we can place the inserts and push the molten metal inside metal will go and solidify outside or at the periphery of the insert and insert will become a integral part of our final product. So, this inserts design to prevent rotation and pull out, so this will prevent the rotation of the insert inside it will prevent the pull out of the insert during use. So these type of insert design modifications can be done when the insert has to be put inside the product which is to be made by the die casting process.

Then the machining allowance we have as in the case of sand casting we sometimes make our products slightly bigger why because the product that we get is not of very high surface quality or not of very high surface finish. So, we have to finish the casting using the machining operation whatever type of machining is required depending upon the shape and size of our cast product.

In case of die casting also we get a better surface finish I must address here the surface finish that we get in die casting is much better as compared to the sand casting process why because here we are using metallic dies. But still sometimes the machining maybe required to get the desired surface quality or the surface characteristics.

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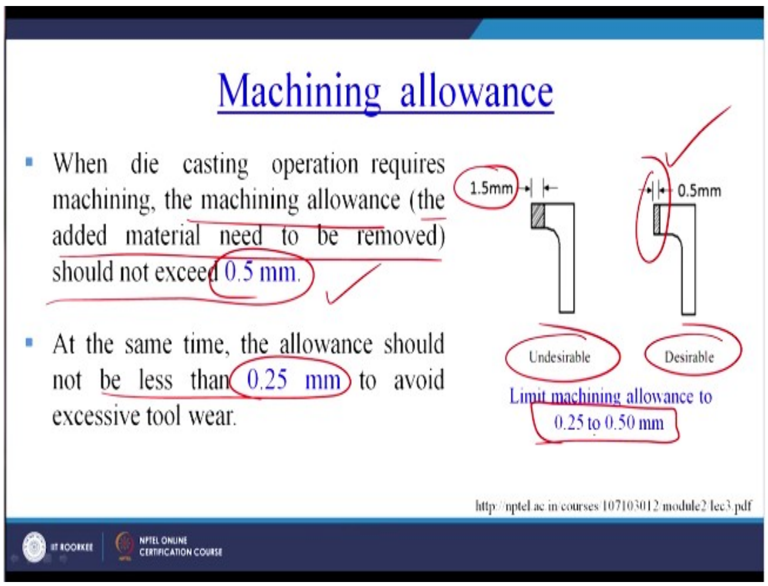

So, when die casting operation requires machining, the machining allowance what is the machining allowance, the added material need to be removed. So, we add some additional material we make the castings slightly bigger, so that we can remove the material later should not exceed 0.5 millimeter. Now this 0.5 may also depend on a large number of parameters but this is just 1 rule of thumb which we can apply.

At the same time the allowance should not be less than as I have already told 0.5 is not something which is the only value we have to use, the lower will limit is also given 0.25 to avoid the excessive tool wear. So, we can see here this is undesirable very large machining allowance is given yes 0.5 millimeter is desirable. So, limit machining allowance tool this is the range which is given for the products to be made by die casting process.

So, this is the dimension and tolerances the main cause of dimensional variation in die casting are due to the thermal expansion.

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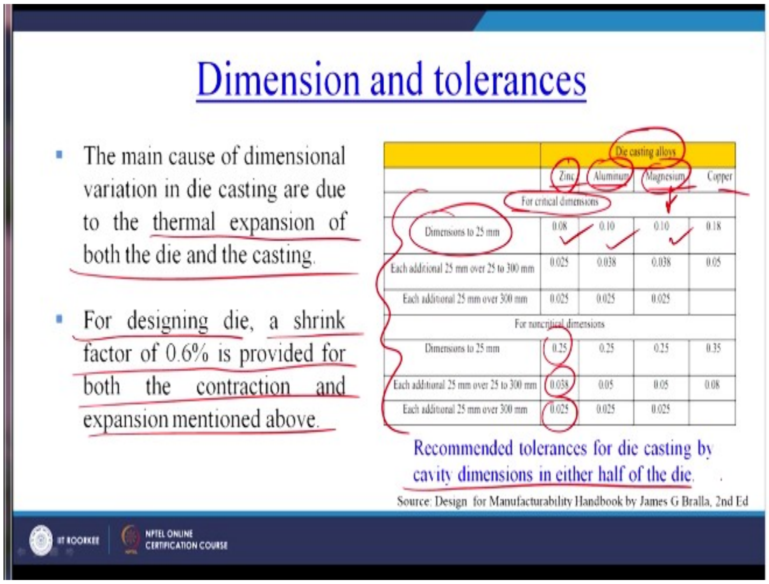

Definitely thermal expansion of both the die and the casting, so when the metal is being pushed into the die cavity which is made between the 2 die halves. So, when the metal will solidify certainly there will be thermal expansion for both die and the casting, so that has to be taken into account some dimensional tolerance has to be provided for designing a die a shrink factor of 0.6% is provided for both the contraction and expansion as mentioned above.

So, there may be dimensional changes in the metal when you pour it inside the mold cavity and the die also because it is in contact with the hot metal. The molten metal there are chances of dimensional variants, so therefore that kind of dimensional variations can be accounted for if we provide the tolerance in the beginning of our process only. So, that is what is given here die casting alloys, zinc aluminum, magnesium, copper and dimensions up to 25 millimeters.

Only for the critical dimensions we need to provide the tolerances, the tolerance values are given here 0.08, 0.10 for magnesium 0.10 and for non critical again it is given what type of tolerance we can provide. So, depending upon the size which is given here we can as well as depending upon the alloy that we are using we can choose our tolerance value. So this is the recommended tolerances for die casting based on the cavity dimensions in either half of the die.

So depending upon our product design depending upon the metal that we have selected depending upon the size of the product or the cavity that we have we can very easily select the kind of tolerance or the value of tolerance that we must provide in order to make a good quality die cast part. So with this we conclude the today's session as well as we conclude our discussion for the 4th week of our course on manufacturing guidelines for product design.

We will start our discussion on a different topic in the 5th week and our focus will be now to focus on 1 manufacturing process in maybe every session and try to see what are the guidelines that we must keep in mind while we are designing our products.
Thank you.