Design for Quality, Manufacturing and Assembly
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Lecture – 20
Estimation of Mold Cost for Injection Molding (Dixon & Poli's Method)

Good afternoon. In the previous lecture we saw the design process associated with plastic parts, and one of the important design consideration is the design of the mold because, that determines the cost of the plastic part as well as the quality of the part that will be created using those molds.

So, in today's lecture mainly we will look at the how to design these molds how to arrive at an estimate of these mold cost, so that we can design a different configuration. As we have seen we can make these parts with multiple cavities. So, one can design or desired on how many cavities to go forth and what kind of surface finishes can be obtained, what kind of machining cost will be involved in making the mold. So, all these can be estimated so that we have an idea about the and the final unit cost of the plastic component. We will understand few terminologies, before going ahead with estimating the mold cost.

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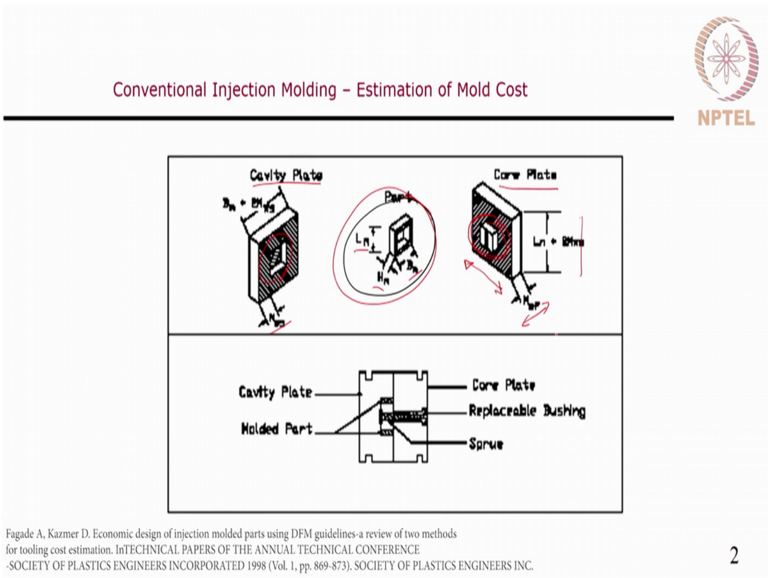

So, this is a part. These are the dimensions like height width and length of the part. These dimensions decide the wall thicknesses and other dimensions of the core and cavity plate which are the two halves of the mold. The cavity plate is the side of the mold where the part gets injected and core plate has features for creating the features on the component. So, the dimensions of these plates like the length or the width or the thickness of the plate these are intern dependent on the part dimensions.

And once we know the dimension of the plate we know the material cost that is the mold material cost as well as rough machining cost. The machining cost depends upon what is the details of this cavity and core features, the more the features to be machined more is the cost. And are there any side action features like we saw some side action holes which will also increase the cost of the manufacturing of the mold. So, we will see one by one how are some of these attributes can be used to estimate the mold cost.

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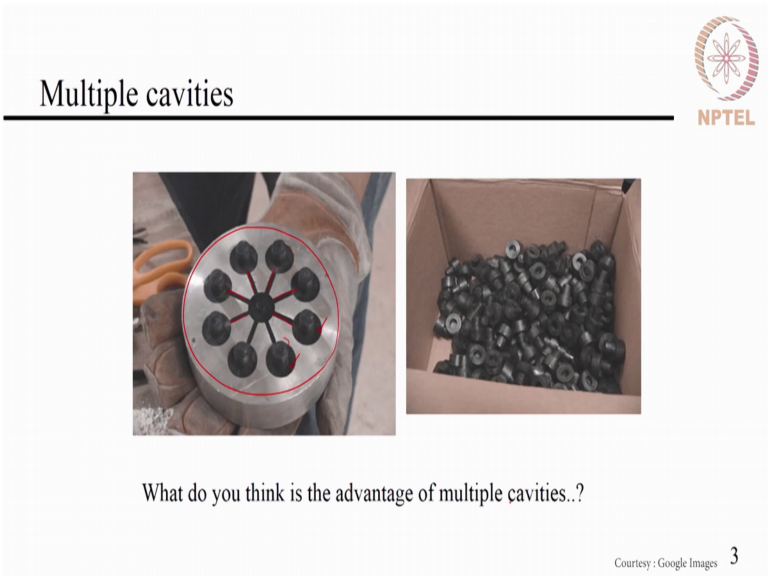

This is an example which shows multiple cavities. So, there are several cavities there is a gate to allow material flow into all these cavities. So, instead of making a mold for single component here you see that in one mold cycle we are going to get several components. So, what are the pros and cons? Obviously, because we have gone for an multiple cavity the mold size has increased the clamping force that is required to hold the mold will also increased and thereby the cost of making the mold will increase, but the cycle time that is associated with making one single component reduces. So, this gives a trade off and one has to decide on how many cavities to go, so that itself becomes an optimization problem.

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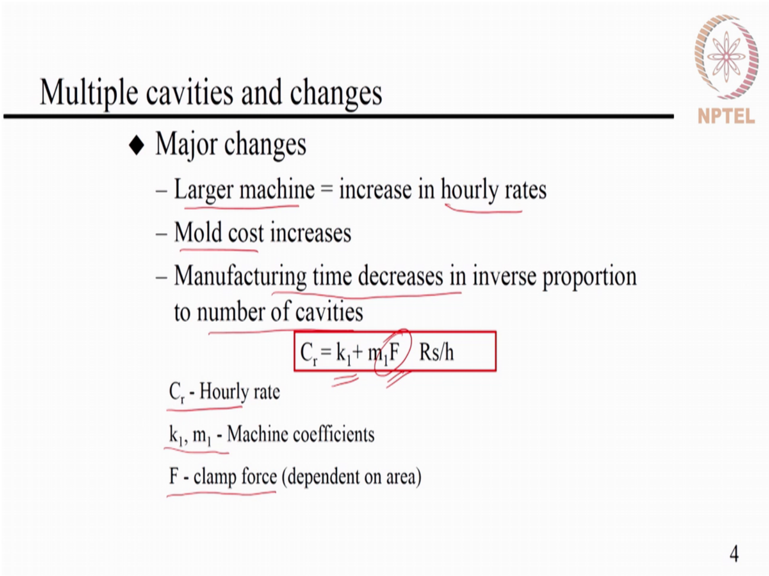

So, some of the criteria's as I have described. We need a larger machines to handle a bigger molds and thereby the hourly rates for having the machine and as well as operating the machine increases. The mold manufacturing cost increases the manufacturing time decreases because we are increasing the cavities.

A simple linear relationship between the hourly cost and the clamp force and the different machine component coefficients are given in this equation. So, one can see that the cost per hour is determined by the amount of mold holding force or what we call as the clamping force that the machine has to generate, and there are some overheads or some you know cost associated with making the machine. So, the hourly rates increase with number of cavities because I need more clamping force to hold the mold. So, this is one cost element.

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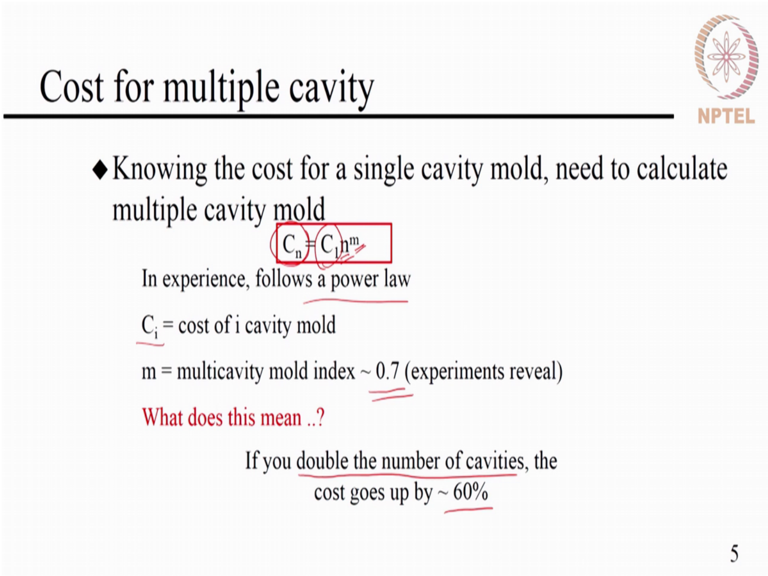

And the cost associated with single cavity can be calculated based on the cost for n number of cavities which is not a linear relationship it follows a power law. So, cost of an i, cavity mold if it is C i then the cost associated with n number of cavity molds can be given from single cavity mold based on the number of cavities power, mold cavity index which is typically 0.7 based on some experimental data. The implication is that if the cavity is doubled the cost goes by about 60 percent; the cost of making the mold goes up by 60 percentage.

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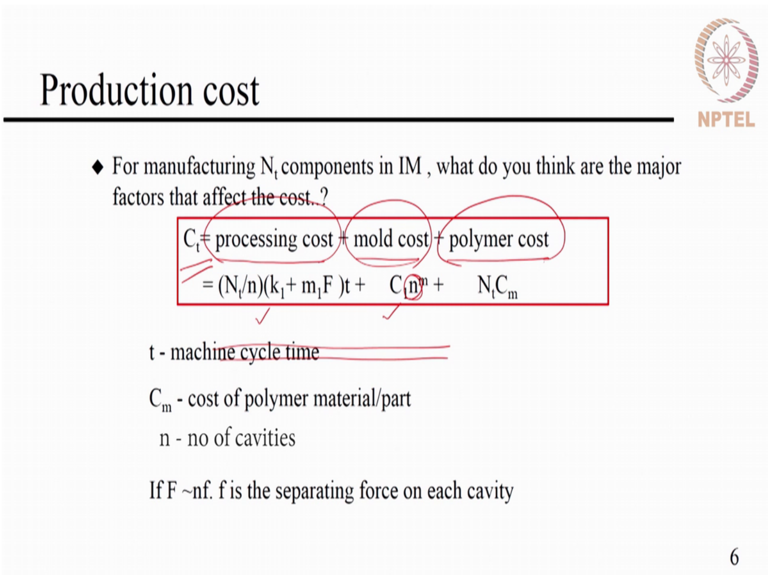

But the production cost is the total the cost since the number of components that are being made is more it will come down with multiple cavities. So, the total cost is processing cost, the mold cast and the material cost. So, the material cost is determined based on the material that is selected and it is not dependent on the number of cavities that are there in the mold, but number of cavities determines the mold cost and also the processing cost which is the hourly rate.

So, these two elements will form a the trade off for coming up with optimum costing. So, one can pose optimization problem using this formulation to determine the number of cavities that one can go ahead for minimizing the cost.

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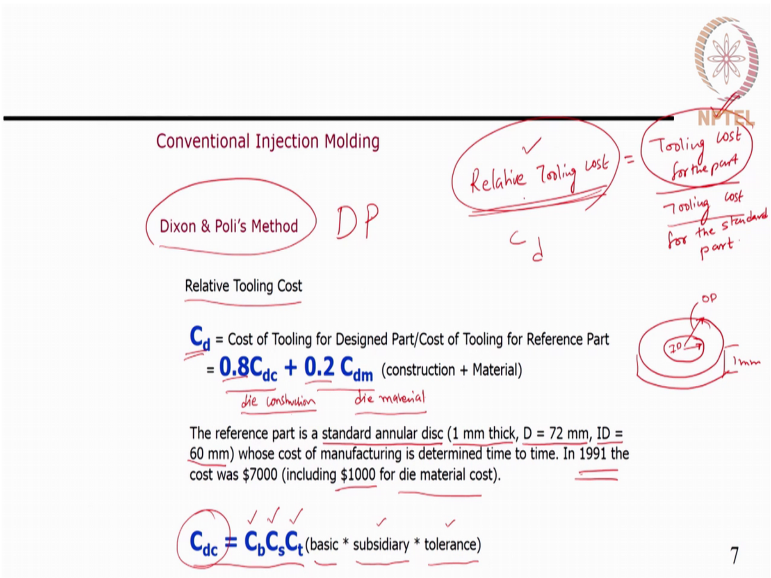

The mold cost estimation has been studied and documented based on several studies. We will look one such a method which is called as the Dixon and Polis method or in short as DP method. So, the cost of the part or the mold part is computed using a term called relative tooling cost. The relative tooling cost is given as tooling cost for the part divided by tooling cost for the standard part.

The standard part is an annular disc is 1 mm thick with an outer diameter of 72 mm and inner diameter of 60 mm. So, this is 1 mm, this is ID and this is your OD. So, this is a standard component which is an annular disc, the mold cost for a single cavity mold which can make this annular disc so that is taken as the tooling cost corresponding to the standard part.

We need to estimate the tooling cost for the given part. So, to do this estimate we estimate this relative tooling cost, instead of estimating the tooling cost. And once this relative tooling cost is obtained the tooling cost for the part is relative tooling cost multiplied by the tooling cost for the standard component. The tooling actual tooling cost itself keeps changing over time because the material cost change the hourly machining rates the skill the cost associated with the skill levels, all these things are variables with change over time.

So, by decoupling this method can be applied at any period of time. As an example in 1991 the cost of manufacturing this standard part is 7000 dollars which includes 1000 dollars of die material cost, but today's costing may be different. But one can still use this method to determine the cost because I can ask the mold maker to give me the cost associated with making this standard annular disc part and based on which I can compute the tooling cost of the part once I know this relative tooling cost.

So, in this method we determine this relative tooling cast to determine the tooling cost of the part. So, this relative tooling cost is called as C d, or what is called as the cost associated with making the tool. These cost components is further decomposed into two elements which is die construction cost and die material cost. And it has been found that the total relative caste is 0.8 times of the die construction cost plus 0.2 times of the die material cost based on the past you know experience and data.

The die construction cost we will look first and then we will move onto see the die material cost. The die construction cost is further decomposed into 3 relative cost components namely C b, C s and C t. So, C b is a basic die construction cost and C s is subsidiary die construction cost and C t is tolerance cost associated with the die construction. So, we will see each one of them. The basic cost determines the maximum the cost component and based on additional features this subsidiary cost and the tolerance cost will increase the die construction cost. So, we will see one by one how these cost components namely C b, C s and C t can be determined.

So, the basic cost is determined. So, I will show like based on the mold size and the cavity features the basic cost will be decided. The subsidiary cost maybe decided based on the number of features that need to be machined in the cavity. And tolerance cost comes from the fact what kind of finish we are looking at on the part the whether some additional finishing based on you know like processes like you know diamond buffing are required, so that will increase the mold cost which will increase the you know the cost of the mold. So, we will see one by one, ok.

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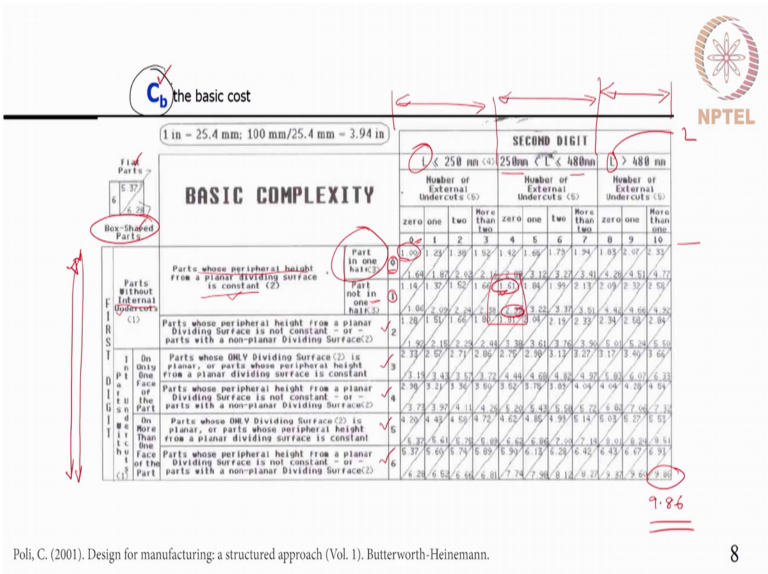

So, the basic cost C b is determined by several mold features like the largest dimension and whether the part is in one half or it is in a multiple halves and so forth. So, I will back to the stable little later.

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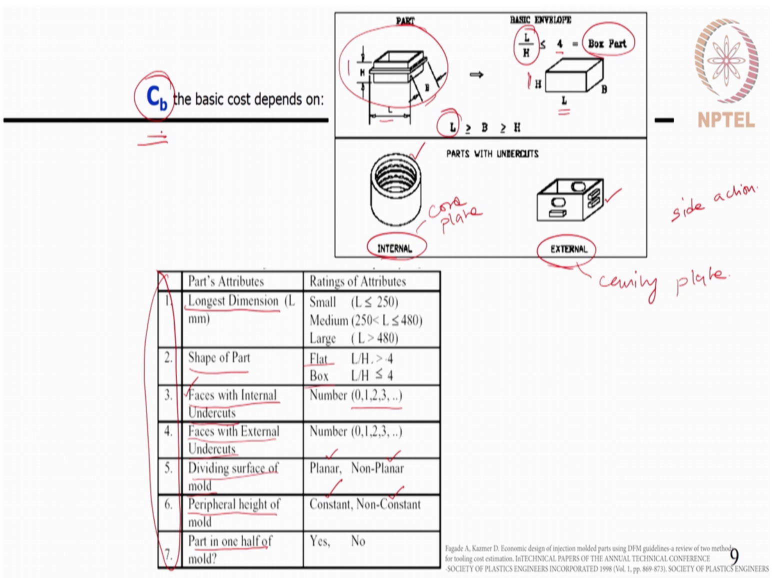

So, if I have a one part L, B and H are the dimensions of the part the largest dimension, L is a critical attribute so that is one of the first part attributes that we need to consider. So, all these part attributes are used with the table that we saw earlier to determine C b. The next attribute that we need to compute or infer is whether the part is flat or whether it is a box part so that is computed by seeing the aspect ratio of the basic envelope.

So, if L by H, L is the largest dimension and H is the smallest dimension, if L by H is less than 4 then it is categorized as box part otherwise it is considered as a flat part. Like if I am preparing a mold for making this the plastic component associated with this monitor it will be a flat part. And the next feature is faces with internal undercuts; this picture shows an example of internal threading. So, if internal threads are available one has to see on how many faces such internal threads are or internal undercuts are available. So, they are typically numbers like 0, 1, 2 and 3.

The other attribute is the external undercuts; undercuts are geometries which need special machining on the mold cavity surface so that these can be obtained. Undercuts may also require side action, because these undercuts will prevent the mold part from being ejected out the holes or other features on the transverse direction needs to be obtained by side action components in the mold. If this is a mold opening and closing direction any feature that is transverse to that cannot be obtained unless we have side action. Small features can be obtained because a plastic components have flexibility, so while ejecting maybe you know the part can be slightly flexed and it can be taken out of the cavity.

But big features through holes in the you know lateral directions they cannot be taken out. So, we need side action pins or side action mold components so that will increase the mold cost and that is why the number of faces that containing internal and external undercuts are important. The external undercuts are machined on the cavity side and internal undercuts are typically machined on the core side core in the sense core plate and this will be done in the cavity plate. So, number of faces with internal undercut and number of faces with external undercuts are important.

The next important feature is the parting surface whether the parting surface is planar or non planar, and whether the parting surface height is changing that is whether it is constant or not constant, another the part is in one half. So, these 7 features are used to determine C b. If I come back to this table this L if it is less than 250 mm I will be using these set of values, if it is between 250 and 480 I will be using these set of values, if it is greater than 480 I will be using these set of values. So, this L is my first parameter that decides which column I am going to look at for taking my C b cost.

Then I will see this aspect ratio L by H which is a box or flat part. In each of the cell I will take the top number if it is a flat part I will take the bottom number if it is a box part and based on the internal and external undercuts I will choose the row. So, here there is a coding. So, it is a two digit number. So, this is a first digit and the second digits are in the column. So, the first digit is decided based on the features like the internal undercuts. So, parts without internal undercuts and parts whose peripheral height is constant and part in one half means I will choose this number.

So, I try to classify to make a choice for my first digit. If the part is having no internal undercut and it has planar dividing surface, but part is not in one half then I will be coming to the second row. Like that I will choose the different rows thereby deciding the cell and then based on whether it is a flat part or it is a box part I will choose either the top or bottom number. The least complexity as you can see is 1 so C b can be 1 the maximum complexity could be 9.86 so that means, the basic cost could be equal to that of the standard component which is the annular disc or it could be roughly about 10 times the cost of the annular disc that is the meaning of this table.

The basic cost of making the mold could be same as that of making the mold corresponding to the standard part or it could be as large as 10 times or 9.86 times of the standard part. So, we will see little more in detail about these features so that we know which of these rows one has to pick for taking the relative tooling cost die construction cost, the C b component of that. So, we have fair understanding that we have to get the 7 parameters from the part design and use this table to compute C b. These are with pictures illustrating that.

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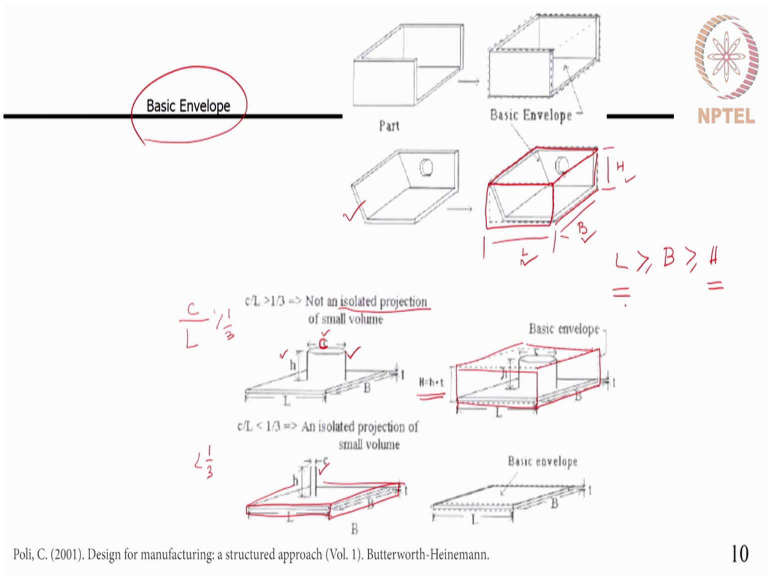

So, to determine the basic envelope if we have different designs how we come up with a basic envelope. So, the basic envelope is the convex hull or cuboid that is placed on the part. So, if this is a part design then this becomes my envelope of the part based on which I will be deciding L, B and H. So, if the part has different types of features like this boss is there whose height is H and whose diameter is C. So, whether we should consider this feature to form a part of this envelope or not is decided based on the aspect ratio or the dimension of this feature to the dimension of the say the larger component.

So, if there is an isolated feature like a projection as is shown here, then its dimension say C here it is the diameter or it could be one of the dimension if it is a square projection it could be the side of the square divided by L which is the largest dimension of the other dimension. So, if this ratio is greater than 1 by 3 then this is not an isolated projection and thereby I should consider that part to compute my envelope if this is less than 1 by 3 then this feature can be considered as an isolated feature and I can choose this as my envelope.

So, in this case the envelope is L B and t and in this case it is L B, H plus t. So, one has to decide whether some projections are isolated projections or not to come up with proper estimation of the basic envelope. So, once we decide the basic envelope our L, B and H are decided. So, we arrange them in the descending order. So, L is the largest dimension and H is the smallest dimension, both are used in the in choosing C b.

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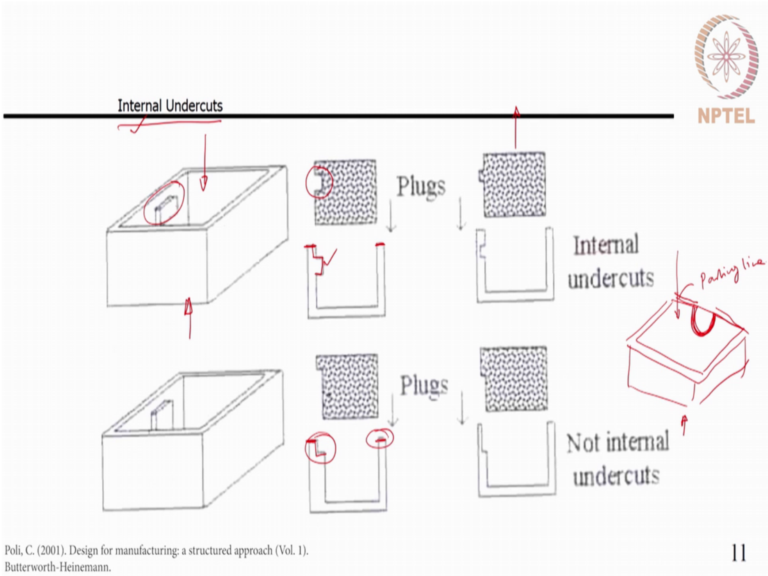

These are some pictures showing how to understand whether a feature is an internal undercut. So, if in a box you have this feature this is the mold opening and closing direction. So, this feature is in the transverse direction and thereby this is an undercut and this is on the cores side that is in the inner side of the part. So, such features will form internal undercuts. In a cross section you can see that this feature when it is available one cannot pull out this part when such you know internal undercuts are available.

By appropriately placing the parting line one can get some internal undercuts so that is why the mouse hole in an component like this if this is a wall and I have a whole feature this is a component let us say. So, this is a, this is a side this is a feature on the side wall, but this is not an internal undercut because in the mold opening and closing direction I can still obtain this feature when I place this feature along the parting line. So, this is the parting line I have placed entire component on one half of the mold and thereby this feature is available on the parting line so that is what is shown here this feature is exactly on the parting line and thereby this does not forms an undercut.

But in this case when I place my parting line here the same feature will become a undercut. So, to decide whether a feature is a undercut or not you need to also look at where this parting line is placed.

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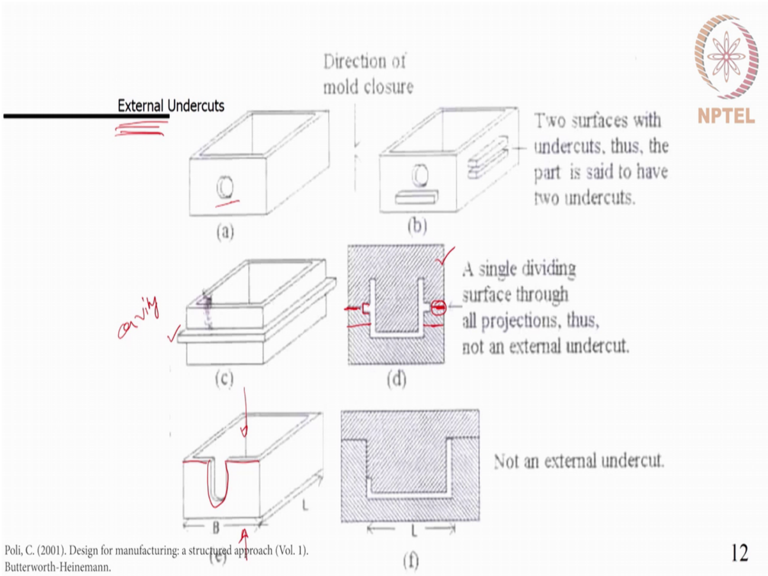

The external undercuts are these kind of features it could be either holes, it could be protrusions. This is not an external undercut as again we can see this is placed along with the parting line and thereby it can be made with the mold feature in the mould opening and closing direction itself. So, such features needs to be machined on the cavity side and thereby they are external undercuts.

This cavity the feature if it is placed along the parting line, then this does not becomes an external undercut if the same parting line is kept here then this feature will become an external undercut on this mold plate. So, the choice of parting line the location of the parting line is important and can change the number of external undercuts or number of internal undercuts.

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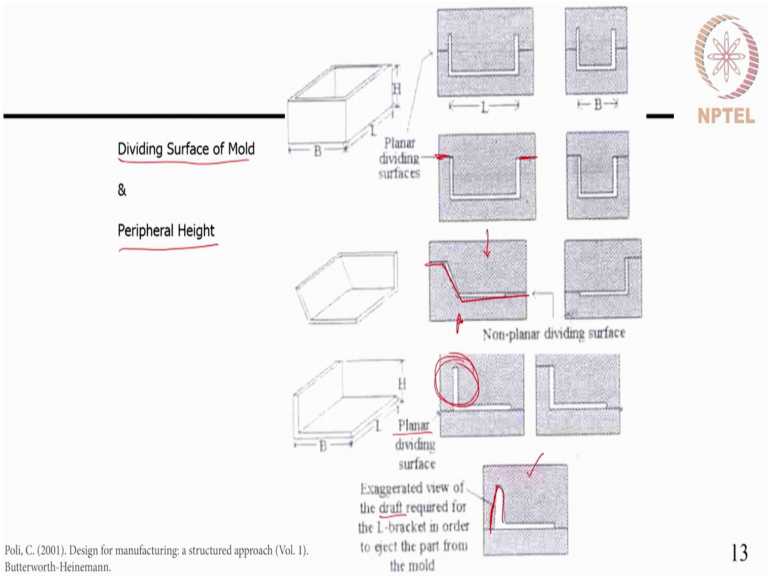

The next feature is the parting surface or the dividing surface of the mold whether the peripheral height is constant or not and what is the a type of the surface determines the mold cost. Planar dividing surfaces are most preferred because they can be matched across the mold plates, and thereby machining cost associated with planar dividing surfaces are less. If this surface is not planar then matching the two plates having non planar dividing surfaces becomes a challenge in terms of manufacturability and thereby the mold cost will increase. Like here we can see this is a non planar dividing surface I have the dividing surface going like this.

So, I have to match the two plates along this line thoroughly or very accurately otherwise I cannot obtain the you know the complete closure of the cavity and thereby filling will not happen, the mold the injection pressure will not developed. We can also have the planar dividing force kept on one side, but in this example you can see that the part depth increases on can remove still this part by providing a paper or what is called as a draft. So, depending upon the design if the dividing surface is kept planar then the cost of making the mold is less, but one has to also take care of the implications of keeping a planar dividing, surface like in this case to get this feature you need to additionally provide a draft so that this component can come out of this mold plate.

So, based on the design the cost elements will change and the purpose of these examples are to show the implications of each choice. Like here we can see that part is in both halves, here the part is in one half and in order to achieve the same component.

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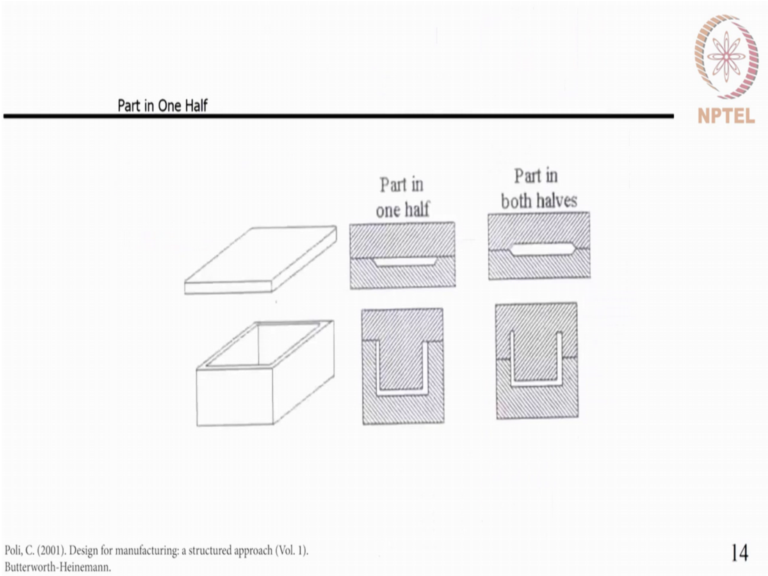

So, part is in one half and part is in both halves this is example. So, here the part depth increases whereas, here the part depth in each cavity is less. So, depending upon the choice of where we place this parting line the cost of manufacturing the core plate and cavity plate will change.

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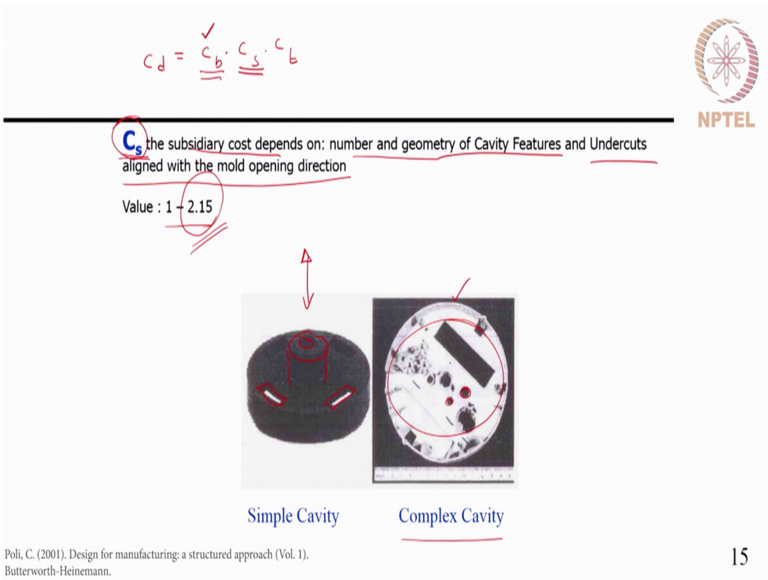

The next cost element that determines C d, if you remember C d is C b times C s times C t. So, we have seen the basic cost. So, now, we can look at what are the elements in the mold that determine the subsidiary cost. The subsidiary cost depends on the number and geometry of the cavity features because the cavity features are needs to be machined in the faces which are transverse to the mold opening and closing direction. So, the features are undercuts aligned with the mold opening direction. So, in this case this is the mold opening and closing direction. So, whatever features that we have like these are the bosses, let us say these are some slots all these are features that needs to be machined on the cavity and core plate.

So, such features which increase the manufacturing cost contribute to the subsidiary cost the value of which is typically 1 to 2.15 that means, the subsidiary cost need not change the basic cost if it is 1, the subsidiary cost can increase the basic cost as much as twice or 2.15 times depending upon the complexity of the cavity features. If we have too many holes and bosses and other features in the mold opening and closing direction as shown in this picture where you know the cavity complexity is high the C s value could be as large as to 0.15. Let us see how we determine the C s.

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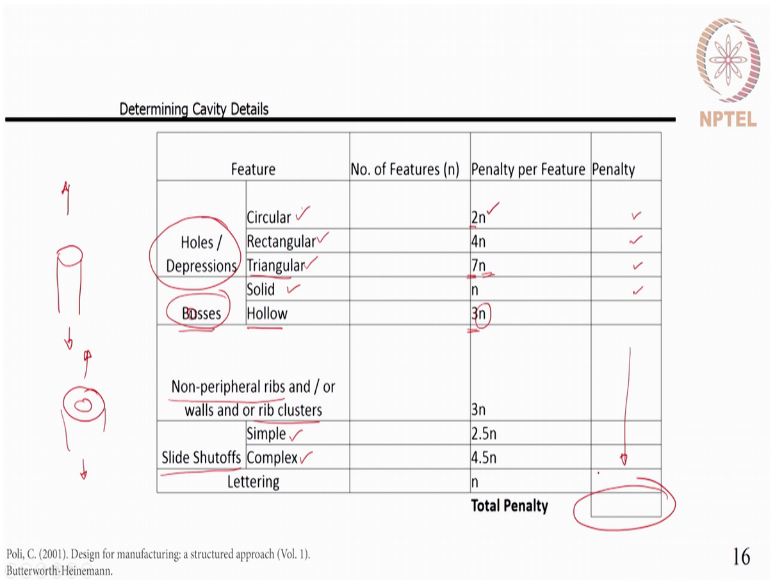

Feature		No. of Features (n)	Penalty per Feature	Penalty
Holes / Depressions	Circular		2n	
	Rectangular		4n	
	Triangular		7n	
Bosses	Solid		n	
	Hollow		3n	
Non-peripheral ribs and / or walls and or rib clusters			3n	
Slide Shutoffs	Simple		2.5n	
	Complex		4.5n	
Lettering			n	
			Total Penalty	

So, to determine the cavity details we need to understand how many cavity features are there and their types. So, we need to understand how many holes and depressions are there, how many bosses are there and how many non peripheral ribs or rib clusters are there, and how many side shutoffs are there. So, if it is a hole and if the shape of the hole is circular or rectangular or triangular see these features have to be noted and if it is boss, whether it is a solid or hollow, boss a solid boss is something like this in the mold opening and closing direction. This is a hollow boss along the mold opening and closing direction, these are the types of holes in the mold opening and closing direction.

The ribs are the stiffness depending upon their numbers and whether they are simple or complex, the penalty associated with the feature changes. So, we note down the number n of such features the penalty is computed based on these numbers like if I have a circular hole then the penalty is two times the number of such features. But, if I have a hollow boss then it is 3 times the number of such features and if I have to make a triangular hole then it is 7 times the number of such holes that I have to make. So, like this I compute the penalty associated with each feature and I sum this up to get my total penalty.

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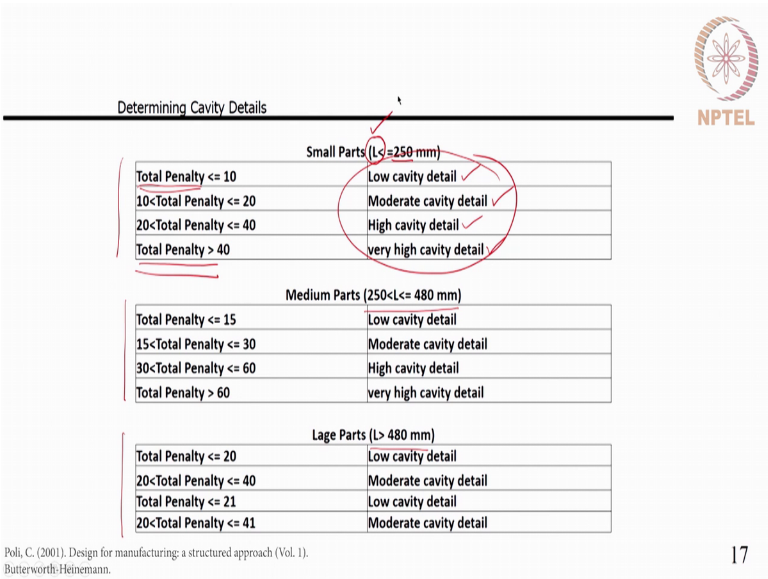

Small Parts (L<=250 mm)

Total Penalty <= 10	Low cavity detail
10<Total Penalty <= 20	Moderate cavity detail
20<Total Penalty <= 40	High cavity detail
Total Penalty > 40	very high cavity detail

Medium Parts (250<L<= 480 mm)

Total Penalty <= 15	Low cavity detail
15<Total Penalty <= 30	Moderate cavity detail
30<Total Penalty <= 60	High cavity detail
Total Penalty > 60	very high cavity detail

Lage Parts (L> 480 mm)

Total Penalty <= 20	Low cavity detail
20<Total Penalty <= 40	Moderate cavity detail
Total Penalty <= 21	Low cavity detail
20<Total Penalty <= 41	Moderate cavity detail

Poli, C. (2001). Design for manufacturing: a structured approach (Vol. 1). Butterworth-Heinemann.

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This penalty value is then used to determine: what is the cavity detail. Depending upon the largest dimension of the mold the L that we have already computed if L is less than 250 mm then we use this data if it is between 250 and 400 mm we use this and if it is greater than 480 we use this. And in each category based on the total penalty we decide whether it is a low cavity detail or it is a moderate cavity detail or it is a high cavity detail or very high cavity detail. So, once we come up with this classification the subsidiary cost can then be computed. So, it is based on the total penalty and the largest dimension of the mold.

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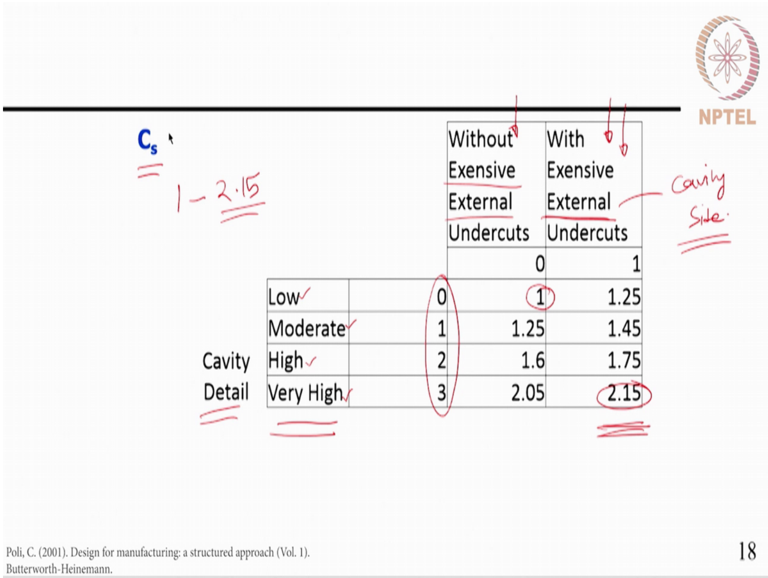

So, once the cavity detail is obtained either as low or moderate or high or very high which is the first digit in this table. If the mold does not has extensive undercuts then we choose the first column and if it has extensive undercuts then we choose the second column. So, as I said earlier the C s value itself can be as low as 1 to maximum value of 2.15 that means, the basic cost may be retained or the basic cost can become as high as 2.15 times of the originally computed cost because of these additional cavities details to be machined.

So, if the cavity details are very high and we have very extensive external undercuts and because external undercuts are machined also on the cavity side only. So, the manufacturability of the cavity plate goes up tremendously and thereby increasing the cost of manufacturing. So, the second element of the costing that is the C s is computed based on the cavity details and the presence or absence of the external undercuts. So, we will see the tolerance cost and complete costing in the subsequent class.

Thank you.