Manufacturing Processes – Casting and Joining
Prof. Sounak Kumar Choudhury
Department of Mechanical Engineering
Indian Institute of Technology Kanpur

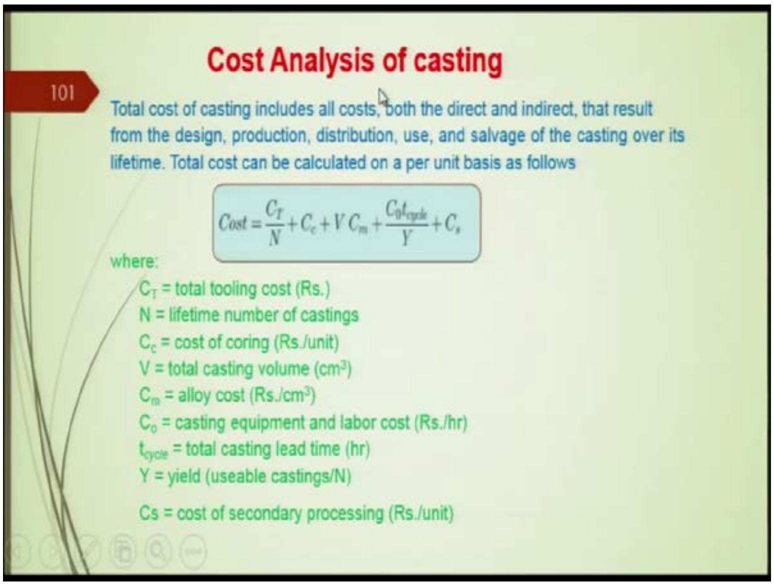
Lecture – 13
Cost analysis, Casting Defects & Product Design

Hello and welcome back to the course on Manufacturing Processes – Casting and Joining. We are discussing the casting processes, and the characteristic features, analysis of the different processes. Today we will discuss the remaining part of the casting, and then we will start discussions on welding in the series of manufacturing processes lectures.

Let me remind you that we were discussing the cost analysis. In the cost analysis, what has been told to you is that we have to consider all the costs which are incurred in the casting process to find out what should be the final cost of the casting, that means the product that we are getting, what should be the cost of that product. It is not only to compete in the market like how much you will be selling it for but to have the control over the economics, control over the cost.

If we know how the cost analysis can be done only then we can find out the means to reduce the cost of the product. And then it will be, of course, easier to compete in the market, because each of these parts will be going for an assembly and the entire assembly as an unit or as a machine will be sold in the market.

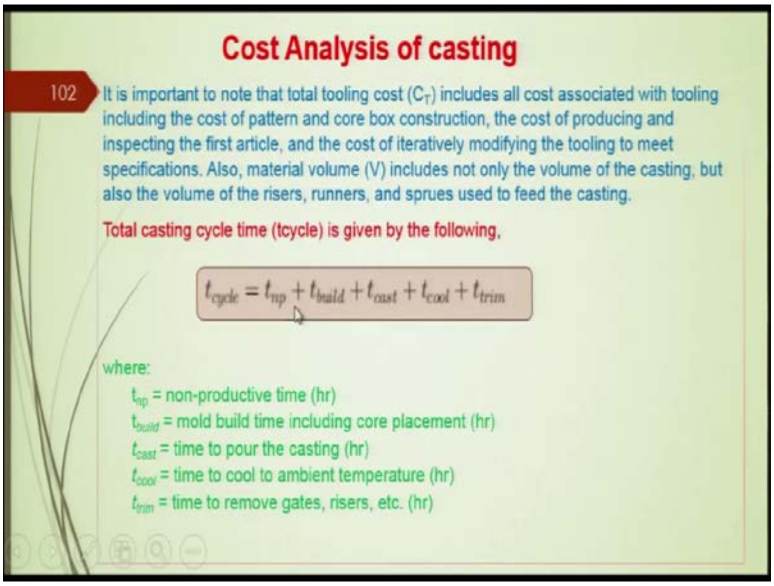
(Refer Slide Time: 02:13)



Now, if we see this slide - the cost analysis of casting, I will just have a recap. We said that the total cost of casting includes all costs – both the direct and the indirect. All these that is direct or indirect that comes from the design, production, distribution, use, salvage of the casting over its lifetime etc.

Now, the cost will be there for considering the total tooling cost, the cost of the coring,the total casting volume and the alloy cost, and then the casting equipment and the labor cost, and finally, the cost of secondary processing . So, as you can see that here all the costs are involved, and that summing up of all of them will give you the total cost.

(Refer Slide Time: 03:13)



In the cycle time, to find out what is the production rate, we have to sum up these five different times which are required for making the casting; this is the non-productive time. I explained to you what are the non-productive times when you are preparing for the casting process, but the casting process as it is not taking place.

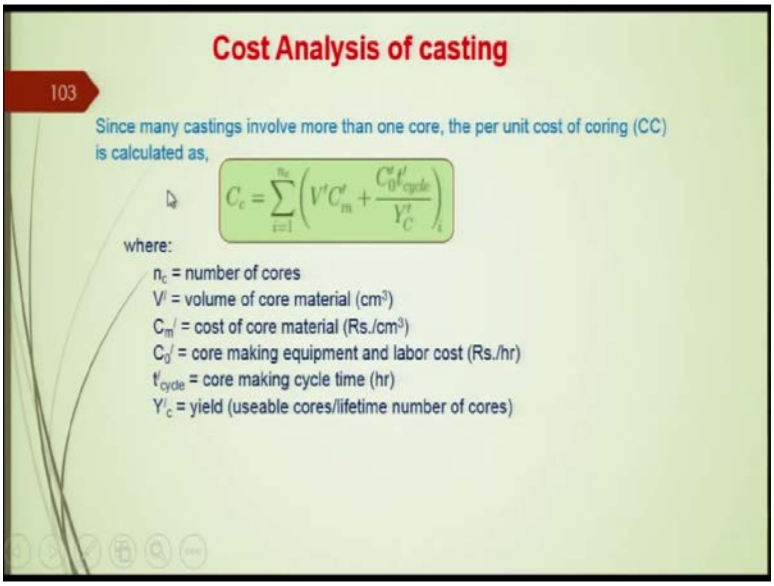
And I told you in my last lecture session –that this is equivalent to the idle time in case of machining when the machine is to be prepared for the process. Here also the same thing, the set-up has to make ready, so that the casting process can be performed.

So, that is a non-productive time. Second is the mold build time including the core placement that mean how much time you are making the mold that includes drag and core, then putting the sand, ramming, putting the core in the pattern and the core and so on.

Third is the time to pour the casting; molten metal is poured in the mold cavity. And the time to cool, so you are keeping that for sometimes for the metal to cool down up to the room temperature, so that also needs time, and for that time we are actually paying. Now, finally, after we get the casting, we have to trim it. Because as we said that casting normally does not give you the net safe products except very few, and we have to trim them.

So, we normally keep the allowances - machining allowance, shrinkage allowance, draft; so all those things I talked about in my earlier lectures. All these five times have to be taken care, so that the cycle time could be found out. And $\left(\frac{1}{CycleTime}\right)$ is the production rate.

(Refer Slide Time: 05:33)

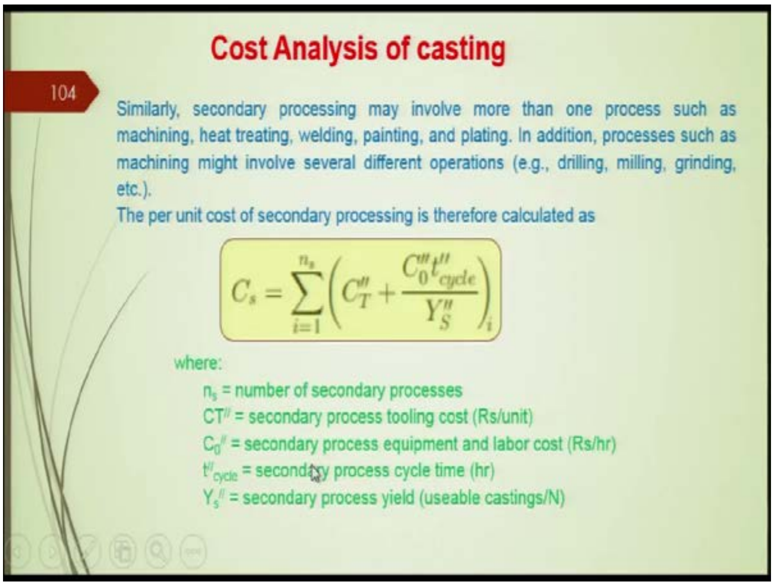


Now, many castings involved more than one core. The per unit cost of coring is very important. What is the number of cores? From one to that many numbers, let us say there are 5 different cores there may be small cores or part by part the cores are being placed because the internal shape is very intricate.

So, one core will not do, one core will do only when there is a straight internal hole, you have seen that. But suppose the internal shape is very intricate, very complicated, in that case the core may be in several pieces.

Let us say n_c is the number of cores. 1 to n_c summing up of the same that is the volume of core material into the cost of the core material plus the core making equipment and labor cost, like we have seen it earlier. And, this is divided by the yield that is what is number of usable cores.

(Refer Slide Time: 06:39)



And the secondary processing also may be more than one, such as machining, heat treatment, welding, painting, plating. All these numbers, let us say n_s number of secondary processes. And these remain almost the same, that is summing up of the secondary process tooling cost and the secondary process equipment, and the labor costs, and suitably multiplied and divided by the secondary process yield usable castings.

I mean trend is the same, but you have to consider the number of cores and in here you have to consider the number of secondary processing.

(Refer Slide Time: 07:27)

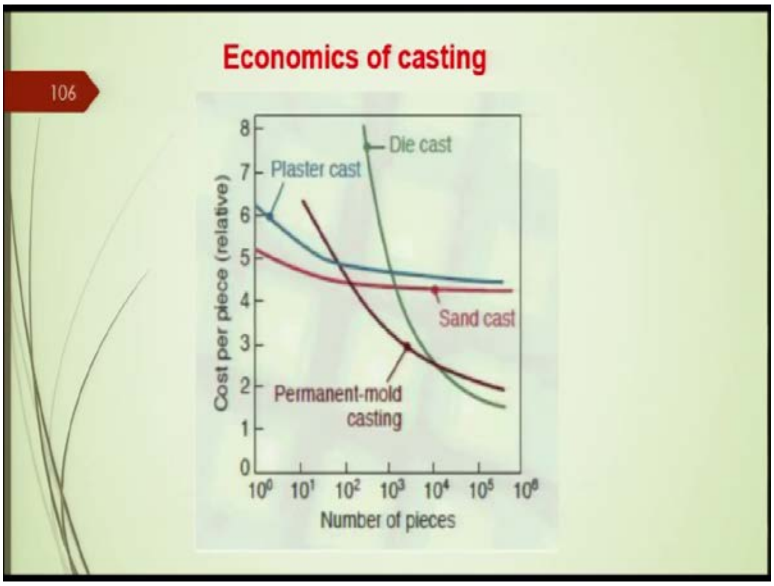
Let us see those equations that indicate that the following measures are to be taken to reduce the per unit production and the design cost, because we are doing the cost analysis. And as I said that the basic purpose of the cost analysis is to get the optimum cost, to get the minimum cost. Now, these are the five points or five measures that we have to take care.

Design to minimize the tooling cost, of course, design to minimize material cost design to minimize process cycle time, design to maximize the yield, and minimize the number of cores and secondary processes. As you can understand that all these measures are coming from these three equations.

That is the total cost of the casting,including the cost involved in the core and cost involved in the secondary processes . These are the conclusions that we have to draw.

Now, just look at it what we are saying - designed to minimize the tooling cost. During the design procedure, we have to actually make effort to minimize the tooling cost, material cost, process cycle time, and so on. This is the design criteria . If we can actually take care of that, in that case, the cost will be minimum. And we can say that at that optimum cost we can actually produce the casting.

(Refer Slide Time: 09:27)



Here is the economics of casting. And here different kind of casting processes are compared. Along the x-axis, we have the number of pieces 10, 1, 10, 100 and 1000 and so on. And here cost per piece. This is the relative cost per piece. Now, the most important as we said is the sand casting or sand mold casting, and this is how the curve goes, meaning that as the number increases initially the cost becomes less.

For small numbers of course, the cost is the maximum. And as the number of pieces increases initially it reduces, and after that it the slope of the reduction rate of reduction rate is much less. It is understood because the process remains the same if we take 10, 15, or 20.

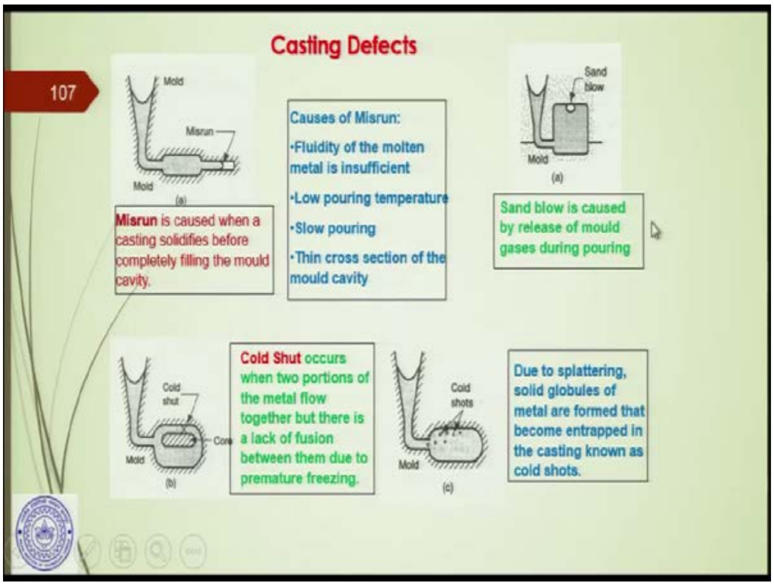
Therefore, in case of sand casting particularly this remains almost the same. Similarly, we also have for the kind of plaster of Paris. For example, if you are taking as a shell, there also we will have a similar tendency like this sand mold cast, because basically the casting procedure is more or less the same.

Whereas, in case of permanent mold casting, see the trend is very different more the number of pieces, less will be the cost per piece. This is understood because in that case production rate will be very high, and we do not have to break open the mold.

Therefore, the number of parts, when it is increasing the cost will be reduced. Similarly, in the die casting also because die cast uses the permanent mold. Permanent mold casting and the die cast is a subset of the permanent mold cast.

This shows the trend of different casting processes, particularly sand molding plaster cast or shell molding die casting, permanent mold casting, how the cost behaves with the number of pieces. More number of pieces will be economically feasible for permanent mold casting, die casting like that. And for sand mold and plaster cast it does not matter much because initially it actually decreases to some extent, but after that it almost remains constant.

(Refer Slide Time: 12:21)



Next, which is very important part of the casting, because basically our aim is as I said to get the casting process with the minimum cost, but the cast itself has to be an useful one meaning that this will be usable, not with defects. Because when it is defective, in that case, it has to be rejected.

Now, one thing that we understand is the advantage of the casting, let us say vis a vis machining. Suppose in a machining process one part is rejected, that part may be actually thrown out. It may not be able to be melted and the metal cannot be reused.

But in case of casting, if the part is defective, in that case that can actually be reused like we reuse the waste material like gating system, riser, and so on. That we cut off from the casting, and then it is again re melted. Similarly, once the casting is defective in that case that can also be reused. So, that is an advantage of the casting.

Let us see what kind of casting defects are there in practice, and why they happen. Now, the advantage of knowing that and why we should know that is that if we know what kind of casting defects are coming and know the reason, then we can actually prevent from getting such kind of defects in the casting.

One of the defects is called the misrun. Here, it is a part of the gating system which is the gating system and the cavity as shown. Here is a sprue. And then the molten metal is coming it is getting into the mold cavity, but it is not able to fill up the mold cavity. This defect is caused due to molten metal getting solidified before it fills the entire mould cavity.

It is not the desired quality. Misrun is caused when a casting solidifies before completely filling the mold cavity. It had to go up to this it had to fill up the mold cavity completely, but before that it is actually solidifying. I told you during our previous discussion that it may so happen that the temperature is not enough or in some cases the mold is cold.

In some cases, the mold is normally heated up, so that this kind of misrun does not take place. Causes of misrun is that the fluidity of the molten metal is insufficient. It is not fluid enough to flow. Low pouring temperature, slow pouring, thin cross section of the mold cavity. You can see that these may be the causes for the kind of misrun that may happen. And misrun is a serious defect.

Second one is the sand blow. And you can see in the diagram, the molten metal is flowing to the cavity through the sprue. And here you can see that there is a sand blow, there is a kind of bubble formed. So, sand blow is caused by a release of mold gases during the pouring. When we are pouring, the gas inside the mold, and I said to you earlier that gases evolve because of the burning of the additives in the mold sand.

We purposely add additives, so that the mold can be properly made. And those additives may burn at the very high temperature of the molten metal as it goes into the inside the mold cavity. Those evolved gases have to be escaped. If they cannot escape or if there is no possibility of getting escaped, in that case this kind of sand blow may happen.

Next defect is the cold shut. There is a core here inside the mold cavity to get a hollow inside the casting. So, we have to appropriately place a core as shown. Now, this is the kind of cold shut, that means, the molten metal will flow from the left side as well as from the right side.

Sometimes they are not able to meet properly. This is called the cold shut. So, the cold shut occurs when two portions of the metal flow together, but there is a lack of fusion between them due to the premature freezing.

Once again, because of the core the molten metal is free to flow from this side or from this side. The molten metal, obviously, will be flowing from both sides. But before these two streams of molten metal meet, they freeze prematurely. This defect is called the cold shut.

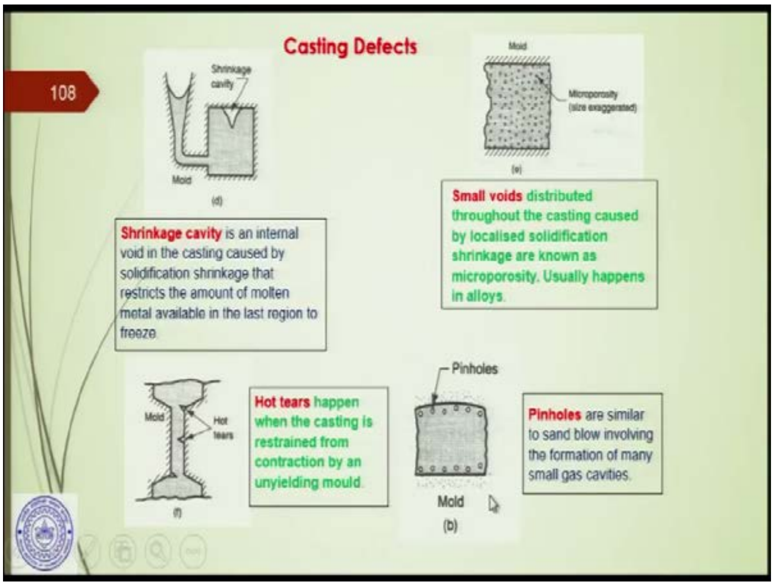
Next defect is called the cold shots. These are the cold shots. These are the splattering solid globules of metal. These are formed that become entrapped in the casting, these are known as the cold shots.

Now, if you remember when discussing the gating system, I told you about the well. From the cup through the sprue, the molten metal does not really go to the runner directly, but it actually flows to the well. There are basically two reasons - one reason I already told you that it should prevent the splattering.

And of course, second reason is because it is changing the direction of the flow, so that has to be smooth so that there is no aspiration of the air to the molten metal. Splashing also may happen even sometimes in spite of having the well because of higher flow velocity.

Those solid globules occurring due to splashing remain in the molten metal. Those are called the cold shots. After the solidification also they remain there as the solid globules, and they are known as the cold shots.

(Refer Slide Time: 20:39)



Next is the shrinkage cavity. Why it happens? This is the mold cavity and this is the sprue, and here is the gating system, runner, and so on. The molten metal flows into the mold cavity. And let us say it had solidified. After the solidification, there will be a shrinkage cavity because of the shrinkage in the metal.

This is an internal void in the casting caused by solidification shrinkage that restricts the amount of molten metal available in the last region to freeze, meaning that molten metal was not available, so that it could actually fill up or the riser was not properly designed to fill this cavity.

These defects do not happen always. Some of these defects or all of them or none of them may actually happen. But overall, these are the types of defects that are normally seen in the casting process.

Next is the small voids, these are called the micro porosity, very small voids; however, they remain inside the solid casting after the molten metal is solidified. Distributed throughout the casting caused by localized solidification shrinkage and known as the microporosity, usually happens in alloys because there are different kind of alloying elements.

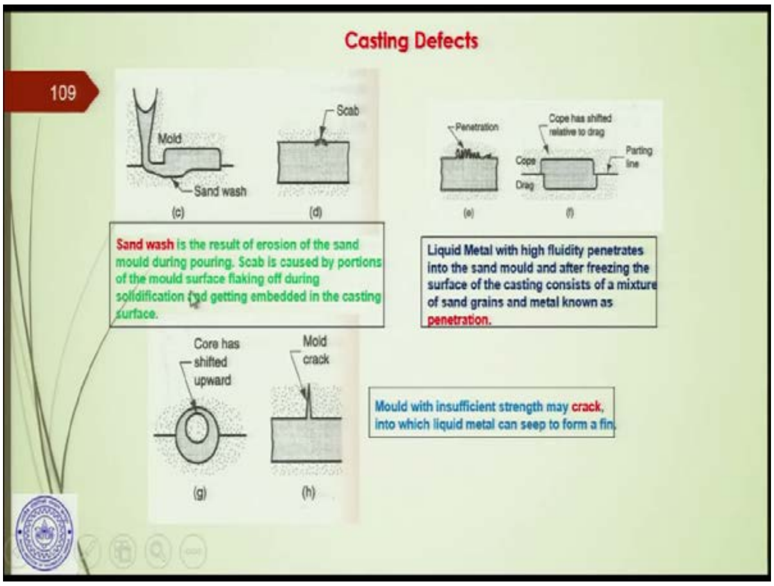
The next defect in the casting is the hot tears. You can see in the diagram that there is a kind of a notch these are called the hot tears that happen when the casting is restrained from contraction by an unyielding mould. What does it mean? I told you that in mold we add different kind of additives, namely wooden floor or the organic compounds. This is for the mold to give way and to prevent such kind of defects.

When the casting is expanding or it is contracting, mold should give way. Now, this kind of hot tears may happen when the casting is restrained from contraction. Casting is being contracted, but mold is not able to give way to that. Then the hot tears will happen. This is basically because of the inappropriate additives in the mold sand.

Next is the pinholes. This is the part of the mold, and pinholes are similar to sand blow. Sand blow if you remember, this is the sand blow that we have shown. Pinholes are much smaller in size. These are similar to sand blow involving the formation of many small gas cavities. Those are thus small gas bubbles which are not able to come out, and they are staying after the solidification. Metal has been solidified and the gas could not be escaped.

This is kind of the sand blow, but it is smaller in size. These are called the pinholes. And those pinholes will be either pinholes or microporosity, they are actually not desirable in the casting because they reduce the mechanical properties of the casting. So, we should avoid them.

(Refer Slide Time: 24:47)



Next is the sand wash. Sand wash is as shown in the figure. It should have been straight. But it became irregular as you can see, and there is this kind of a scab.

So, the sand wash or it is a scab. Sand wash is the result of erosion of sand in the mold. During the pouring of molten metal, because of the low strength or inappropriate strength of the molding material, the sand may actually get destroyed locally in some places.

And the molten metal will go in and it will form such a shape after the solidification. It may so happen that there is a scab and this scab is caused by the portions of the mold where flaking off happened during the solidification and getting embedded in the casting surface.

It may so happened that part of the mold can actually flake off. It can come off, it can be eroded. And it is falling on that pattern, and then the molten metal goes above that or around that and it is making a kind of small protrusions.

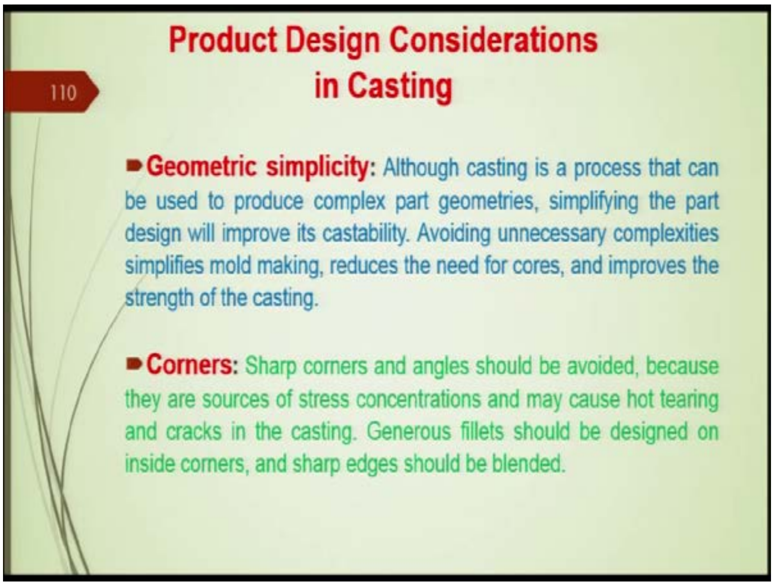
The next is the penetration. Liquid metal with high fluidity penetrates into the sand mold and after freezing the surface of the casting consists of a mixture of sand grains and metals.   This is kind of a irregularity on the surface that you can see because of the inappropriate strength of the mold or inappropriate preparation of the mold, i.e. inappropriate ramming of the mold.

There could be different other types of defects. For example, cope has shifted relative to drag as shown here. The parting lines are not meeting. This is the cope, and this is the drag – that is the upper portion of the box and the lower portion of the box. They are not meeting, and therefore, the casting is defective. You can see this.

Or it may so happen that the core has shifted upwards. It should have been at the center to make the center hole, but this has been shifted upwards. As you can see that it has become eccentric. Or it can have mold crack – mold with insufficient strength may actually crack into which the liquid metal can seep in, and they will form a kind of a fin.

All those kind of defects that the casting process may have, we can actually prevent them because we know what is the reason behind this. And most of the reasons as you can see is because of the inappropriate preparation of the mold. So, while preparing the mold, particularly in the sand mold, we have to take care of all those things, so that such kind of defects do not occur.

(Refer Slide Time: 28:13)

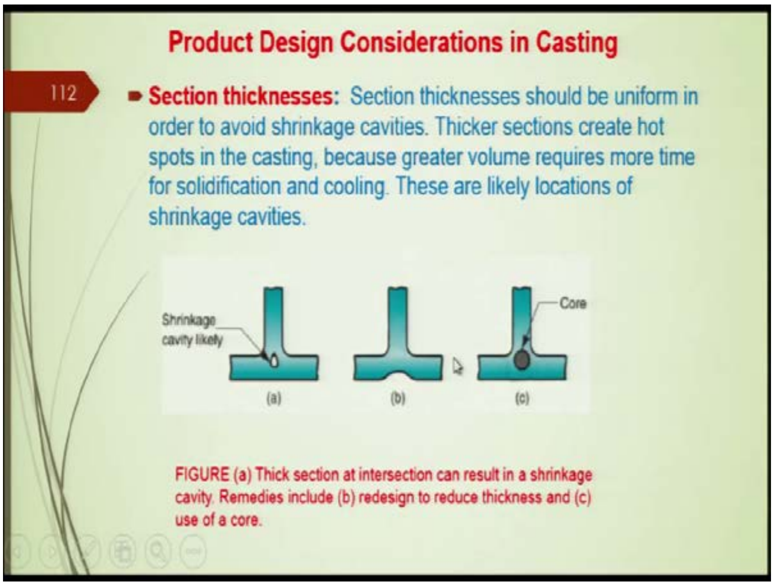


Now, let us discuss few things about the product design consideration in casting because we have seen that the design is very important. Geometric simplicity; it has to be simple in geometry. It is explained in the text shown in the slides. Corners have to be removed because sharp corners will have a lot of stress concentration.

(Refer Slide Time: 28:39)

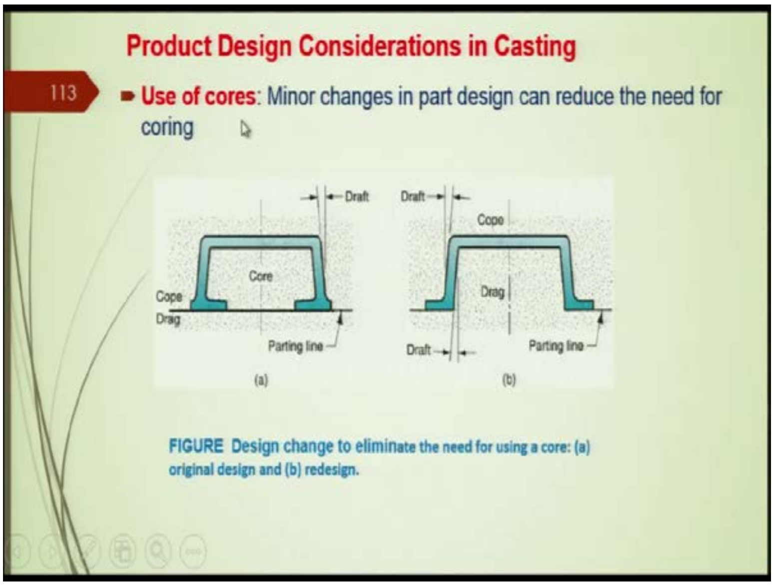
Draft: draft is provided so that the pattern could be taken out.

(Refer Slide Time: 28:49)



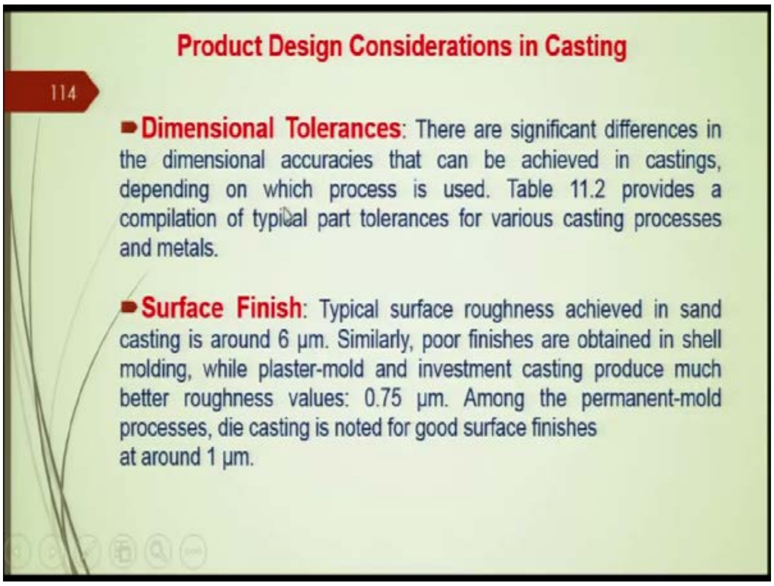
Section thickness - it should not be thicker in one place because in that case that portion will be cooling down at a slower rate. Therefore, the sections should be more or less uniform.

(Refer Slide Time: 29:09)



Use of cores: minor changes in the part design can reduce the need of coring, you can see as it is clear from the diagram shown. This is a very interesting design. If you see here, the coring is not required in this case, and we have simply changed the design.

(Refer Slide Time: 29:27)



Dimensional tolerances should be accurate, surface finish should be in high.

(Refer Slide Time: 29:35)

Machining allowances should be there. As we already mentioned earlier that there should be some kind of allowances, so that we could actually keep those portions for the removal after the casting process by machining. That is all I wanted to tell you about the casting. Thank you for your attention. And in the next session, we will start discussing the welding process.

Thank you.