Basics of Mechanical Engineering-2

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Week 03

Lecture 11

Basics of Casting (Part 3 of 3)

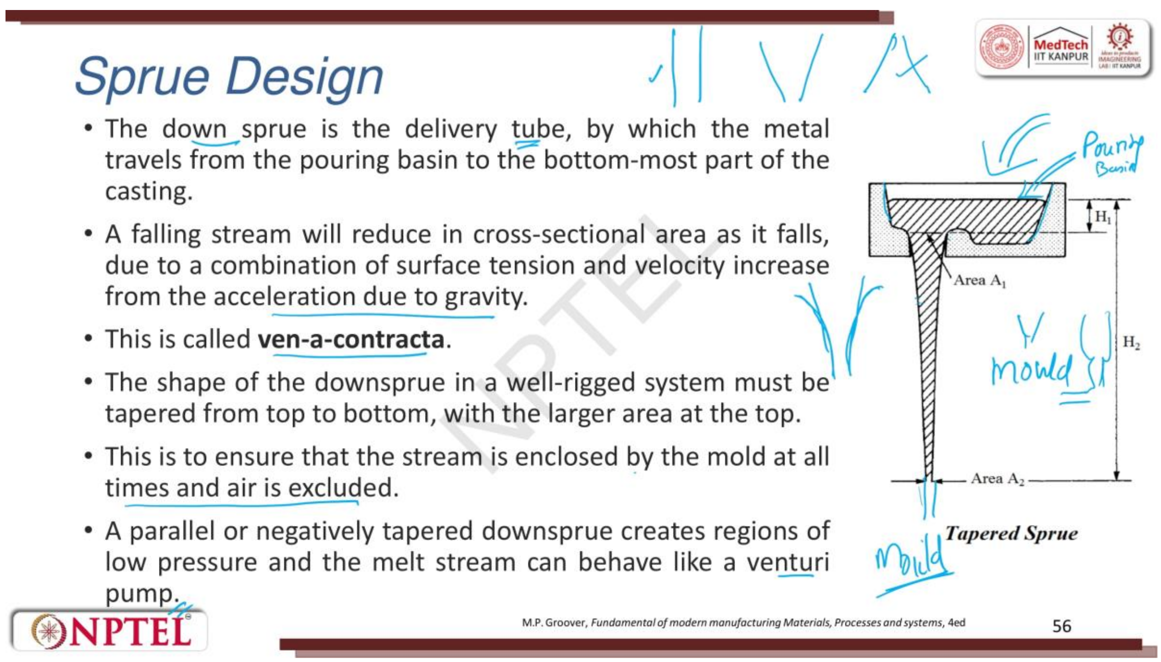
Welcome to the next lecture on casting.

Till now, we have gone through the fundamentals, and in this lecture, we will continue with the fundamentals. Plus, we will also try to understand different parts involved in casting and their design considerations. For example, sprue, design of a sprue, riser, design of a riser. So, these are some of the things we will be doing. And I am sure you would have done the three exercises I gave you in the last lecture.

At the end of the lecture, I gave you three assignments. Please try to do them. So, when you do it, you will start appreciating and understanding all these things. And when you analyze fluid flow through a pipe, you have to keep the continuity equation in mind. So, A1 V1 = A2 V2. So, keep that formula in mind.

And then, when you design for whatever I said—L by D—you should have that in mind and then plan it. In this lecture, we will try to see sprue design, riser design, more information about casting, sand casting, then mold design, and finally, we will try to have a recap. Let us first try to understand sprue design. As you know, when I try to pour liquid into the sand casting to go toward the mold, to go toward the mold, I pour the hot liquid into a funnel. So, this funnel is called a sprue.

It has a wide opening which is called as Pouring Basin. From the pouring basin, the hot liquid will flow down towards the mold .



So, this portion is called the sprue. The down sprue is the delivery tube by which the hot metal or the metal travels from the pouring basin to the bottom most part of the casting. So, if you have a mold, you can try to have the sprue here at the top, or you can try to have the sprue here, right.

So, both are possible, but here, we are trying to talk about, a downspout. So, from the pouring basin to the bottom most part of the casting, a falling stream will reduce in cross section. Why? Because of the Continuity Equation. A falling stream will reduce in cross-sectional area as it falls. "As it falls" means as it moves down, due to a combination of surface tension and velocity increase from the acceleration due to gravity, and then, this phenomenon is called Vena Contracta.

The shape of the down sprue in a well-rigged system must be tapered from top to bottom, with the larger area on the top. This is to ensure that the stream is enclosed by the mold at all times and the air is excluded because, finally, the mold is like a box. The box is filled with air, and as the liquid enters, the air should go out. This is to ensure that the stream is enclosed by the mold at all times and that air is excluded. A parallel or a negative taper. This is a positive taper. This is a negative taper. You can also have a parallel tube.

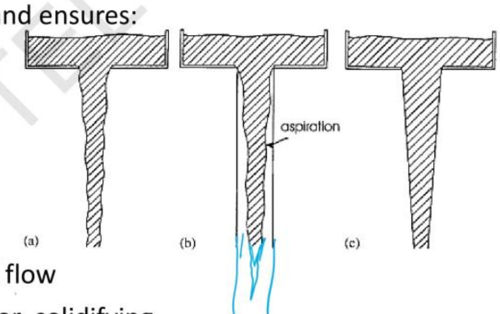
This is what I have given the exercise for you. A parallel or a negative taper-down sprue creates regions of low pressure, and the melt stream can behave like a Venturi pump. So, if it is like this or like this, it can behave like a Venturi pump. So, we will always have the sprue. In fact, if you try to solve the equation and see, you should have a sprue like this.

So, a sprue of this kind is the best, but manufacturing with this exponential curve is difficult. So, we always prefer to have a tapered one.

Sprue Design

Why is a sprue tapered shape?

- ***Reason:*** The **sprue** is needed to guide molten metal into the mold cavity during casting.
- It serves as the entry point for the metal and ensures:
  - ➢it flows properly
  - ➢Avoiding air pockets
  - ➢Ensuring uniform filling.
  - ➢Helps control the flow rate
  - ➢Preventing turbulence and splashing.
  - ➢It also aids in maintaining smooth metal flow
  - ➢Minimizes the risk of metal freezing or solidifying prematurely.



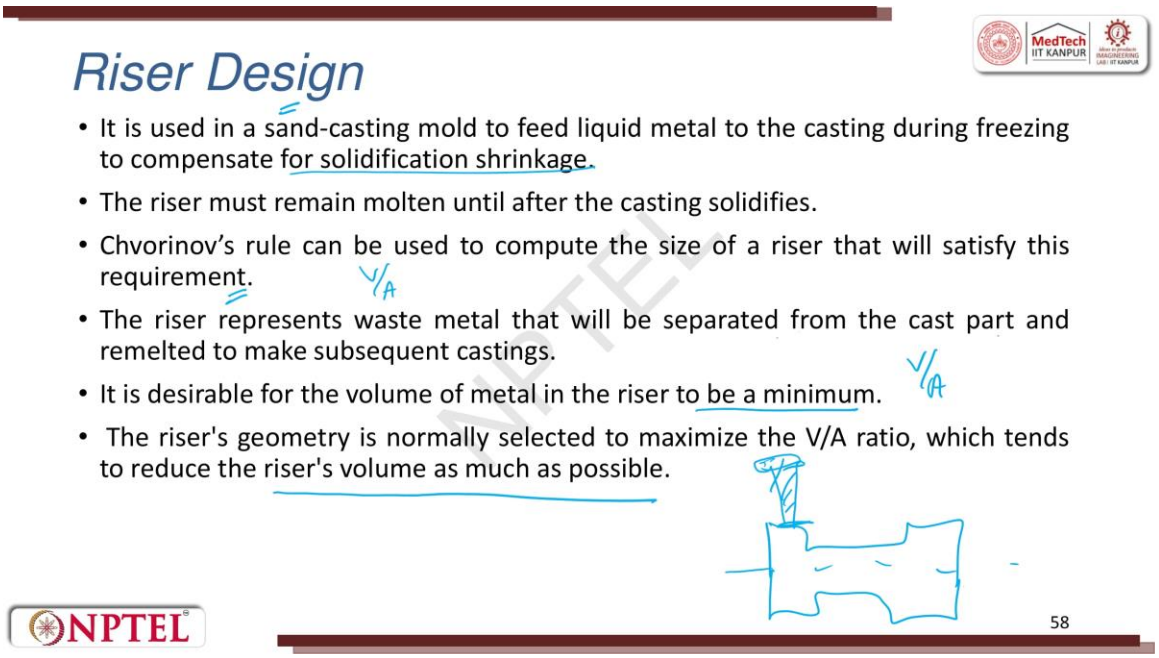
NPTEL

https://www.sciencedirect.com/topics/engineering/downsprue

Why is the sprue shaped tapered? The sprue is needed to guide molten metal into the mold cavity during casting. So, it serves as the entry point for the metal and ensures proper flow.

It avoids air pockets. It ensures uniform filling. So, you see here, if it is not tapered, you will have it like this, and then you will have aspirations, which are the air getting in if it is parallel. So, that is why we always keep it tapered. It helps with flow control, prevents turbulence and splashing, aids in maintaining smooth metal flow, and minimizes the risk of metal freezing or solidifying prematurely.

So, for all these things, you need to have it tapered. Is that clear? If you have a parallel one, the air can go inside. And then, it can fill here. So, the solidification will happen slowly, and this will get closed. If the distance is long, at some point, the taper on both sides will meet, and you will have a shut-off of the flow happening. So, that is why we always try to keep the sprue tapered.



Now, let us look into the riser. It is used in sand casting molds to feed liquid metal to the casting during freezing, to compensate for solidification shrinkage. The riser must remain molten until after the casting solidifies. The Chvorinov's rule can be used to compute the size of the riser that will satisfy the requirement V/A ratio. See, if it is a straightforward cylinder, V/A is good; but if you have a complex shape, then this becomes a little difficult.

The riser represents waste metal that will be separated from the casting part and remelted to make subsequent castings. What we are trying to say is, suppose you have a part like this, and then you have a riser which is attached. The metal flows through the riser also, right? So, what we are saying is, once the part is solidified, we trim it here. Now, this portion will be remelted, and we will use it again for filling the mold.

So, it is considered as a scrap which can be reused. So, the riser represents waste metal that will be separated from the casting part and remelted to make subsequent casting. It is desirable for the volume of the metal in the riser to be a minimum because, anyhow, you are going to cut it. So, though you say you are recycling it, but still it needs energy to first of all cut it and then you have to melt it. So, it all takes energy.

So, that is why what we do is we always try to keep this volume as low as possible. So, in V/A, we try to keep V as minimum as possible. But friends keep it in mind that once the volume goes low, the area goes high; then the solidification happens. So, you have to hit a trade off. The riser geometry is normally selected to maximize V/A ratio which tends to reduce the riser volume such as much as possible.

Riser Design

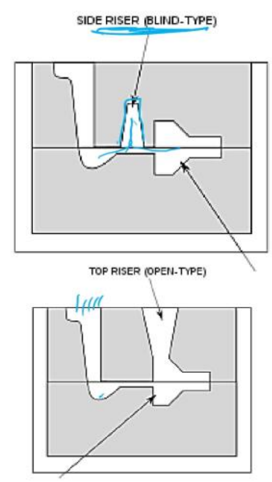
Risers can be designed in different forms:

Side Riser

- It is attached to the side of the casting through a small channel.

Top Riser

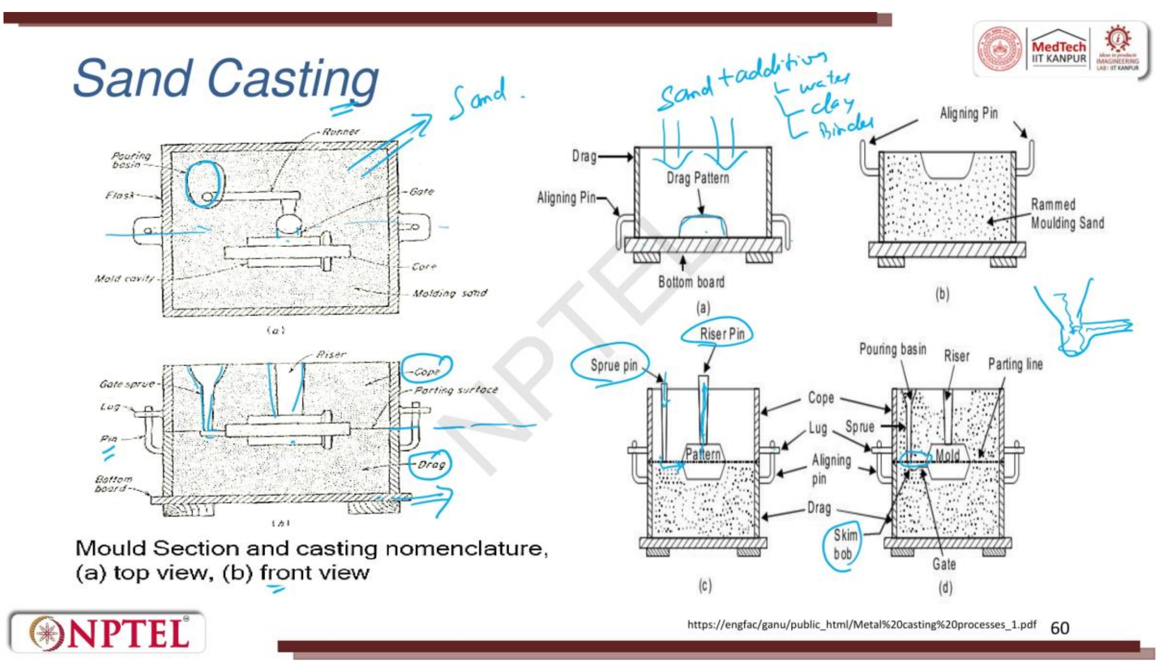
- It is connected to the top surface of the casting
  - **Open Riser:** It is outside at the top of the casting
  - **Blind Riser:** It is entirely enclosed within the mold



The riser can be a top, a side, or a blind riser. The riser can be designed in different form; One is side riser; the other one is top riser. The side riser, it is attached to the side of the casting through a small channel. The top riser is connected to the top surface of the casting. There are two types: one is called an open type or open riser, and the other one is called a blind riser. The open riser is outside at the top of the casting. (This is generally preferred.)

We can also have blind risers, but it is very difficult for us to control the surface and quality of the product, though it is followed to a large extent. The moment you have optimized the process, it is entirely enclosed within the mold. So, you see here the mold. This fellow sits inside the mold and fills here, here, and here; then it starts feeding here. So, blind risers are good.

Why? Because here you have heat extraction which happens here; it does not happen. It is good, but fabricating it is difficult. So, we always prefer to have top risers or open risers.



So, when we talk about sand casting, as I told you, it will be made of two portions. The A portion shows the top view, and the front view is seen in the B figure.

So, what we do is, we can see here very clearly the pouring basin, and then it has a taper. So, that taper is seen here. It is attached to a runner, which goes here. Then it is fed into a gate here. This gate, and then it is going into a mold.

You can see the mold here. So, now when I see the on top of the mold, what do I see? I see the riser and then I see the mold and there is a core. This core is used to give us the internal geometry. So, front view, you can see here there is a parting line which divides top and bottom which is cope and drag.

The cope and drag are attached because they should not move. They are attached by using a lug and a pin. So, this entire dot black portion is the sand. Here the top view and the side view you can see which clearly says that it is a square or the cross section area is a square. So, what you are trying to generate is a hollow part.

The hollowness is brought in by the core. The core can be removed or it is expendable. So, you may take the part out, you break it open, or you can try to have something to just release it out. Both are possible. So, this clearly says what are all when you see the top view and the front view you can see very clearly visualize what are all the parts of a sand casting.

Now, let us see how this is made and what we try to take is the bottom board. So, this board is the bottom board here. We try to keep the drag, the pattern, and keep it here. What is the pattern? From the pattern, what you get is the mold.

So, we have a drag pattern, and then we try to have the drag portion. We keep the pattern, and then we pour the sand. Once we pour the sand completely, we try to invert it. So, when we pour the sand—'sand' means it is not plain sand but sand with additives. The additives can be water, clay, or any other binding agent—whatever it is, all these things.

So, it gets mixed, and they try to dump it into the drag pattern. So, once it is done, it is also rammed so that we get a solid consolidation of the sand, then it is flipped, so the bottom here goes to the top. So, you see, the aligned pin, it goes to the top. Now, the pattern that you kept here has come to the top. Now, what we do is place the cope part on top of it.

We lock the pin and again, we start filling the sand. When we fix the pattern, we also fix the sprue and the riser. The sprue is for pouring the hot metal, and the riser is for infeeding when solidification happens. So, basically, what happens is the metal flows from here, goes into the pattern—which, once removed, becomes the mold—and then it gets into the riser. While filling itself, it goes up to here. Then, when it solidifies, the liquid metal starts coming down as solidification happens in the pattern.

So, now you can see here the pin, whatever is there, the aligned pin, which is attached to a lug. So, it is locked sand is poured pattern is kept and on top of a pattern you keep the riser and the sprue. This can be made out of wood. Sprue and riser design pins can be made, or they can even be made out of thermocol, right? You pour it, and then it becomes possible. You can pour it, and then you can try to have the sprue. Later, once the consolidation happens fully, we remove the sprue and the riser.

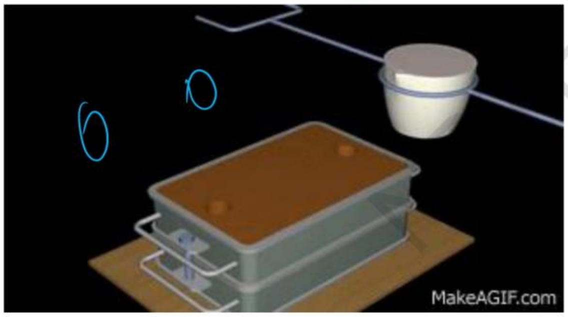
So, the profile is retained right. So, you see here the pouring basin and the other parts, and you see the parting line, okay? Now comes the question: how do I do the gate here and the runner here? So, as soon as you place the pattern here, before placing the pattern on top, what we do is try to make the profiles on the cope itself. So, then, what we do is remove the sprue, remove the riser, and then also remove the pattern.

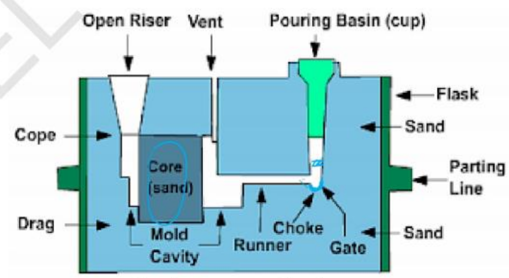
After that, we make the gate, assemble everything together again, and then we start pouring. So, the pattern, sprue, riser, and sand pour—everything is done. Then, once consolidation is done, we try to remove the pattern, the riser, and the sprue, and in the core portion, we try to make the gate and the runner. So, here, you can see the skim bob is made. So, as the sprue comes, we are trying to make a profile like this.

So, what happens? The liquid that comes here tries to fill, and then a uniform flow happens to the runner. So, this is how your animation looks. You can see here how interestingly it is made. So, your liquid metal is poured. You can see the sprue is there, and the riser is there. Then, you remove the cope portion, and you have the part. Now, whatever extra portion you see in the figure, those portions will be trimmed off. These portions will be trimmed off. You can see here, whatever comes in these two portions, the component will be trimmed off.

Sand Casting

Sand casting is one of the most popular and simplest types of casting, and has been used for centuries. Sand casting allows for smaller batches than permanent mold casting and at a very reasonable cost.



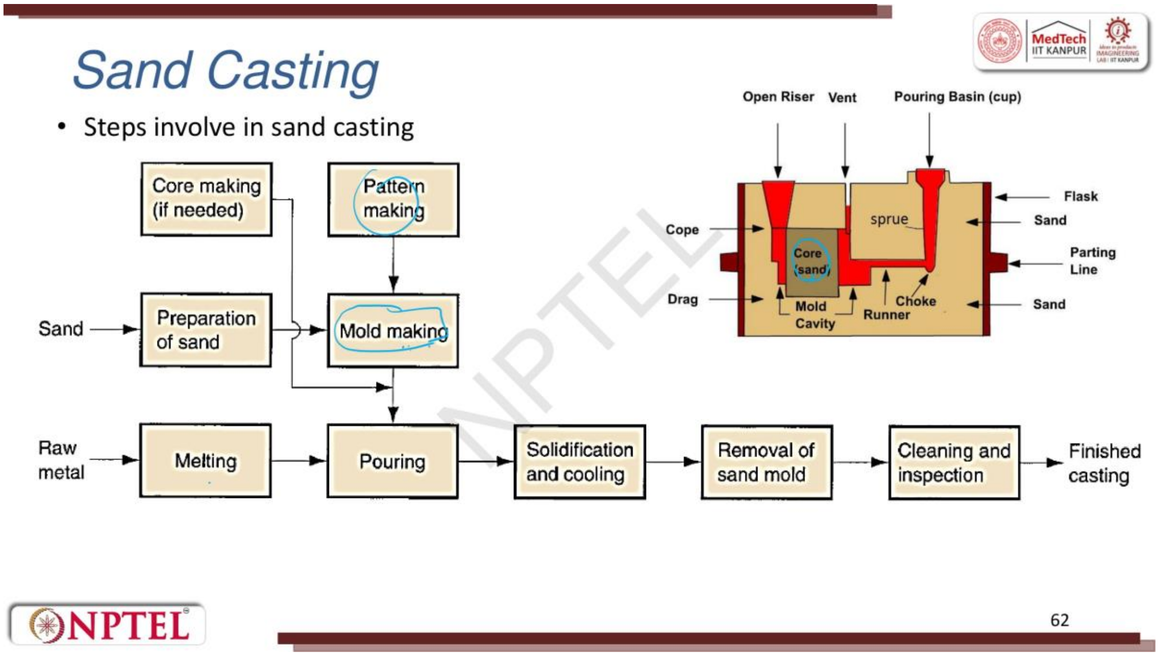


showing some casting terms

Sand casting is the most popular and simplest type of casting. It has been used for centuries. Even today, if you have a very large component, we always go for sand casting. Sand casting allows for small batches compared to permanent mold casting, and it is very cost-effective when the batch size is small, especially when the component is very large. So, this now clearly tells you all the things. The pouring basin comes to the gate, the gate to the runner, and the runner to the mold cavity. The liquid flows and then tries to fill the riser.

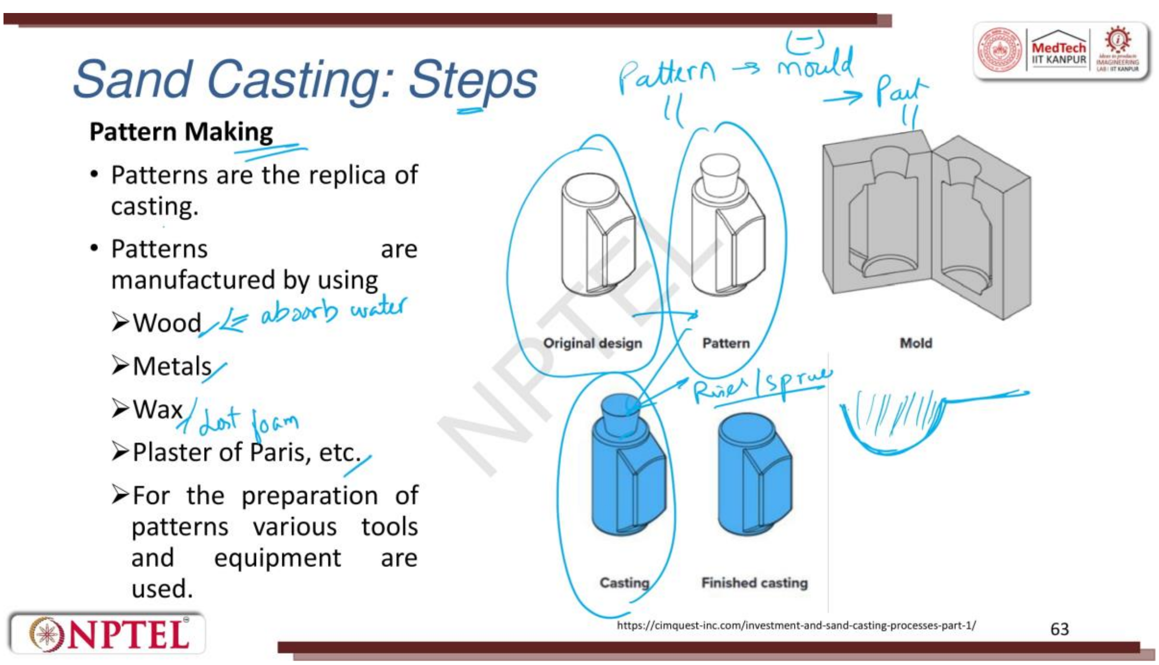
When the liquid flows in, the air gets through the vent and tries to escape. So, the core is used to give the internal geometry, right? And here, you have a choke. So, the choke will try to retain the sand particles, or you can have a filter here that tries to filter out all the sand particles and allows the liquid to flow. And this skim bob is also used.

These are all ceramically made. So, any sand particles will deposit here, and only the liquid metal will flow.



So, the steps involved in casting are: core making—the first step—this is the core. Then, we try to make a pattern for the mold to be kept. We make a pattern, and from it, you try to make a mold.

So, in the mold, you try to pour sand. The pattern is kept, and the mold is made. Now, in the mold, you try to melt the metal. In a crucible, you melt the raw material, then pour it into the mold. It is allowed to solidify and cool, then removed from the sand mold. After that, cleaning, inspection, or finishing—whatever is required—is done, right? These are the steps typically involved in sand casting.



So, in sand casting steps, first is pattern making. Why do you need to make a pattern? We need to make a pattern because the pattern will be a negative of the mold. Patterns are the replica of the casting. So, if you take pattern, mold, final part, this and this will be similar.

The mold will be negative of the pattern. So, the pattern is replica of the casting. Take an example, I have a vessel like this, right? This is how the pattern is. Now in this pattern, what do I do is, I fill up liquid metal as a mold , right?

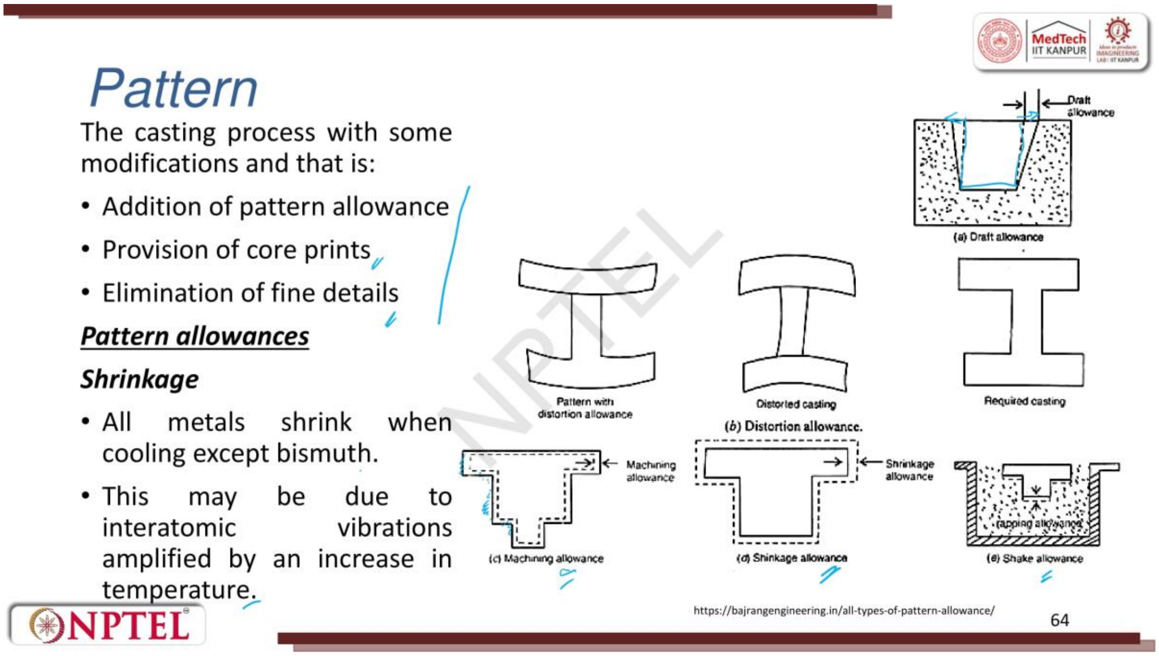
And then when I take it out, I get the final part, whatever I want. Patterns can be manufactured from wood, metal, wax, or Plaster of Paris, right? Wood and metal are generally preferred. Wood has only one issue—it can absorb water, so it can swell up. If it swells up, then the wood pattern will create a larger size for the mold. And wood has its own wear and tear attached to it, so we replaced it with metal. However, metal is expensive. And in metal, if you want to make intricate patterns, it is difficult.

For example, if you want to make Lord Ganesh's face or a human face, where it is a scaled-down version, it becomes very difficult. If you want to try to make frog skin or fish skin, it is very difficult to create in metal. It is easier to make in wood, so we still go for wood. But with metal, there is no absorption and no wear and tear. It can be used for mass production. Then there is wax, which is on the other side, where we make a wax pattern.

Now, with liquid wax, you can try to shape it, which is very easy. And then, when hot liquid metal is poured, the wax pattern will melt and disappear. Or you can try something like lost foam casting, where thermocol is used—it burns away and then disappears. You can also use plaster of Paris. It is ceramic, and it is easy to shape because you can mold it by hand. So, for the preparation of various patterns, various tools and equipment are used.

This is the original design. This is the pattern. This is the mold. This is the cast. You see here, the original design, pattern, and cast will be the same; the mold will be the negative of it.

So, once it is done, the top portion can be a riser or a sprue, whichever is required. So, you trim it off, and then this will be remelted, and then this will be the final part. So, in the casting process, the pattern undergoes some modifications, such as the addition of pattern allowances, provision of core prints, and elimination of fine details. These are some of the things which you should keep in mind when you are trying to make a pattern.



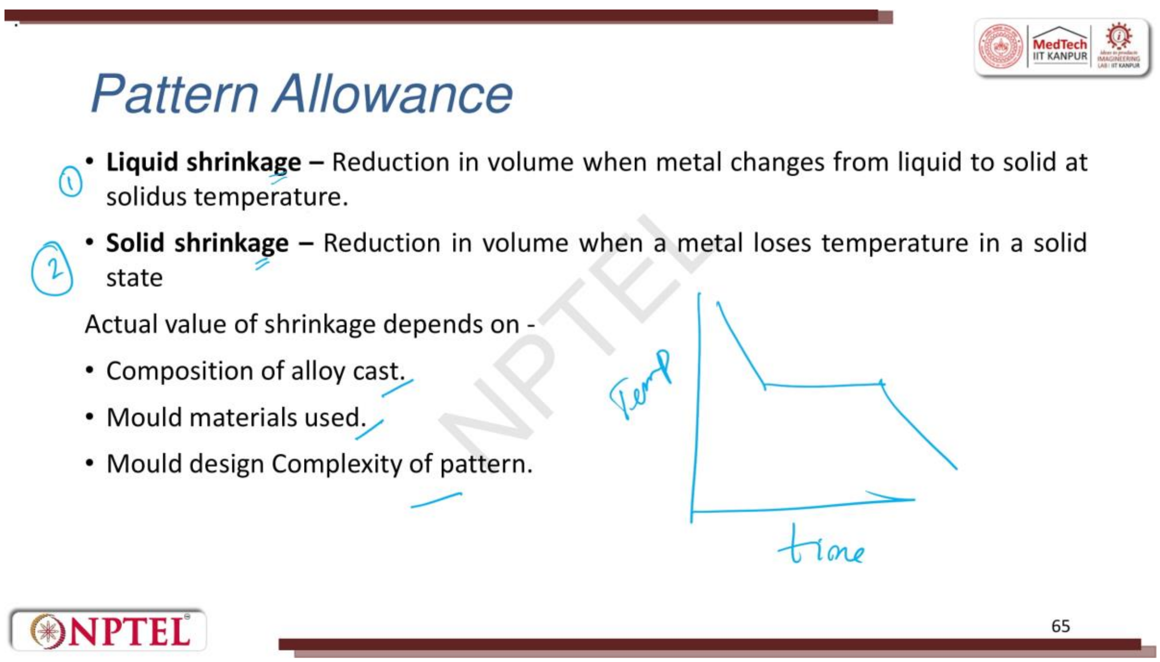
Additional pattern allowance will be given. Why do we give additional pattern allowances? Suppose you have made a pattern like this, a sharp-edged pattern. When you try to remove it from the sand mold, it will damage the surface. So, once it damages the surface, it is very difficult to remake the sharp edges. So, what we do is intentionally give a taper and a slightly larger allowance so that when the pattern is removed, it does not damage the mold.

So, this one is called pattern allowance. Next, if you want to have intricate shapes, then you will try to have a core. So, for holding the core, you will have a core print. And fine details have to be avoided. For example, if you want to take the skin or you are trying to cast my hand, and then you have skin there, and then on the skin you have hair.

These are very fine features. So, you generally try to avoid these features. These are some of the modifications we do. These are patterns with distortion elements. This results in a distorted casting. So, because of the pattern mistake, you see the component is also affected.

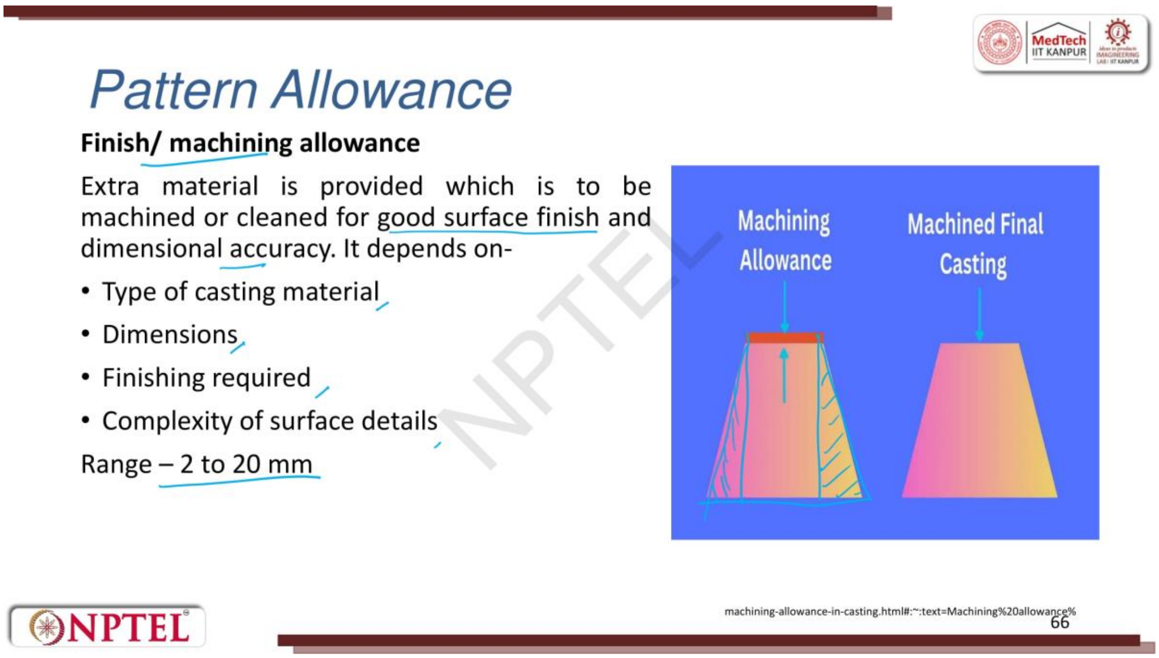
What we do is try to compensate for the distortion and get the best possible casting outcome. So, these are small machining allowances because sand can get into the surface of the casting. So, there is a machining allowance to remove it and produce the final part. Then, there is a shrinkage allowance, and there is also a shake allowance. So, these are some of the allowances which are given to the pattern. All metals shrink when cooling except bismuth, which has a negative expansion.

This may be due to the interatomic vibration amplified by the increase in temperature. So, the volume is always larger in the liquid state. As it solidifies, it shrinks. So, that is called Shrinkage Allowance.



There are two types of shrinkage: liquid shrinkage and solid shrinkage. Reduction in volume when the metal changes from liquid to solid at the solidus temperature is called Liquid Shrinkage.

The reduction in the volume when the metal loses temperature in the solid state is called as Solid Shrinkage. There are two types of shrinkage: liquid shrinkage and solid shrinkage. Then, when you go back to the diagram we studied, this represents temperature versus time. You also have a unit volume. The actual volume of shrinkage depends on the composition of the alloy, the mold material, and the complexity of the pattern design.



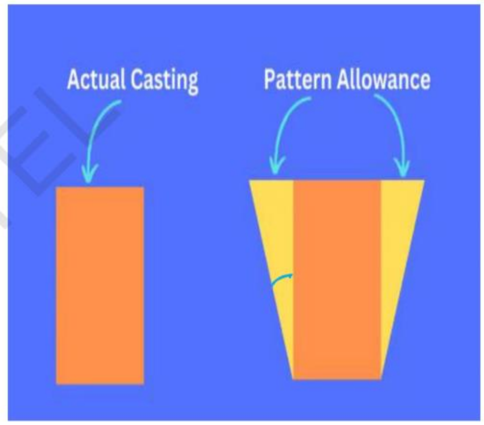
So, there is also a machining allowance which is given. So, the machining allowance is you have now made a taper in the pattern. So, in the mold, you will get a taper. Now in reality it might be a straight part. So, we have to remove this material. When we have to remove this material, we should also have some holding mechanism for the part.

So, those factors are considered and incorporated into the pattern itself. So, once the mold is made and the casting is done, we remove all the extra material and also remove the taper to meet the required specifications. Extra material is provided when machining or cleaning is required for a good surface finish and dimensional accuracy. Depending on the casting material, dimensions, required finish, and complexity of the design... A machining allowance of 2 to 20 millimeters is provided in the pattern itself.

Pattern Allowance

Draft allowance

- Vertical faces of the pattern are to be made tapered to reduce the chances of damage to the mould cavity.
- It varies with the complexity of the job. Inner details require more allowance than outer.
- This allowance is more for hand moulding than machine moulding.



The draft allowance, as I mentioned, means that the actual casting cannot have a perfectly straight pattern. Instead, a taper is added, which is called the draft allowance. This is called a draft angle. The vertical faces of a pattern are tapered to reduce the chance of damage to the mold cavity. It varies with the complexity of the job—inner details require more allowance than outer surfaces. So, this is for the outer, but if I have a hole, this is an inner detail. So, this portion, if I try to take, is called outer details. This allowance is greater for hand molding than for machine molding.

Pattern Allowance

Shake allowance

- Shake allowance compensates for dimensional changes due to mold movement or vibration during casting.
- Applied to dimensions parallel to the parting plane to account for shrinkage and distortion.
- Ensures the final casting retains its intended shape and size after cooling.

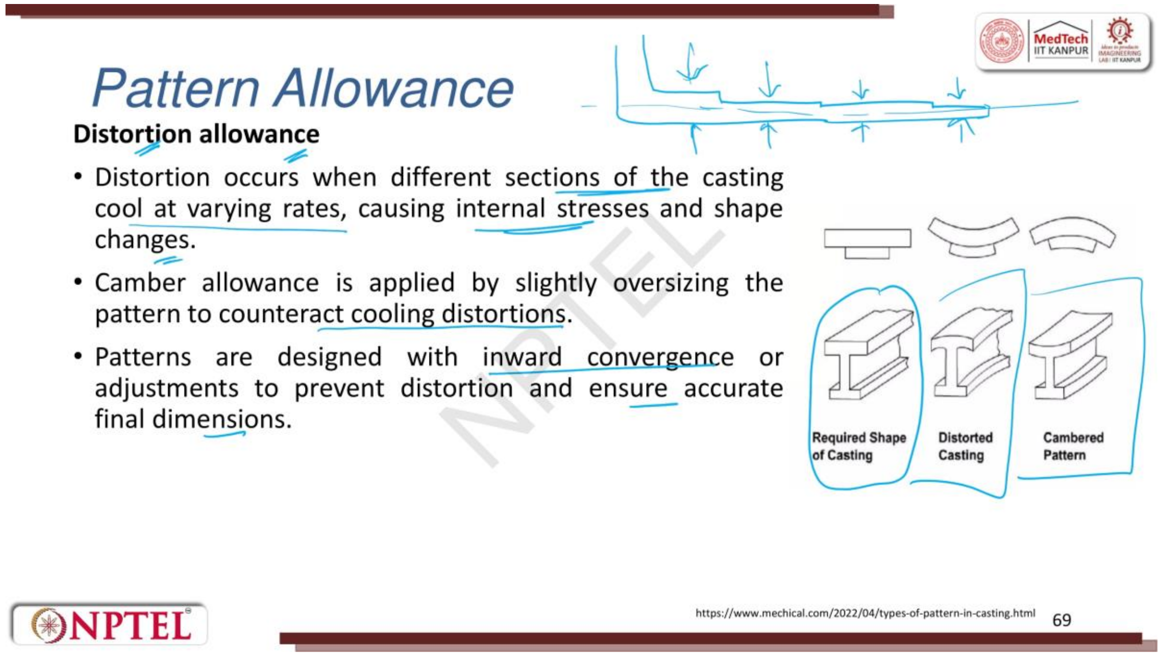
Shake allowance: See, draft allowance is for easy removal. Shake allowance is generally given because we shake the pattern before taking the part out.

So, the shake allowance compensates for the dimensional change due to mold movement or vibration during casting. See, when you try to remove, we shake and then remove, right? So, it is applied to dimensions parallel to the parting plane. The parting plane is where you have the cope and the drag—this is the parting plane. Identifying a parting plane for the part is very difficult because and it is very crucial. The moment you decide your parting plane; the overall strength of the part depends on it.

Applied to the dimensions parallel to the parting plane to account for shrinkage and distortion. It ensures that the final casting retains its intended shape and size after cooling. We give a shake allowance. So, what are all the elements till now we have discussed? Shake allowance, draft allowance, machining allowance, and shrinkage allowance.

So, the four allowances we have talked about are all given to the pattern to ensure the quality of the cast component. This means the mold size will be slightly larger than the expected final part. There can be tapers, sharp edges, or flat projections, all of which will be removed during the final finishing process. So, the distortion element occurs when different cross-sections of the casting cool at varying rates. For example, if I have Something like this, right?

So, here there are different cross-sections. So, at different cross-sections, now what is happening? The solidification happens at different periods of time. Because of this, it introduces residual stress in the component. Because of the residual stress that is induced, you will always get a distorted component.



So, in order to remove this, we give a distortion allowance. Distortion allowance occurs when different sections of the casting cool at varying rates, leading to internal stresses and changes in shape. So, this is what is needed. The surface area, we play with the volume and surface area. It gets distorted like this or like this.

The camber allowance is applied by slightly oversizing the pattern to counteract cooling distortion. So, this is the required shape of the casting. This is the distorted casting, and this is the camber pattern. So, now I can get this. Camber allowance is applied by slightly oversizing the pattern to compensate for distortion during cooling, ensuring the final casting retains its intended shape.

The patterns are designed with inward convergence and specific adjustments to prevent distortion and ensure accurate final dimensions in the casting process. So, this we have seen in detail.

Sand Casting: Steps

Molding and Core making

- Prepare a mold cavity by using patterns and use the core for making hollow parts in casting.

Melting and Casting

- Melt the metal in the furnace and pour it in the mould cavity.
- Wait until it solidifies.
- As the casting gets solidify, remove the casted part from the sand.

Cleaning of Casting

- After removing the casting from the sand cut the runners and risers, also trim the flash appears at parting line of the mould.

Testing of Casting Test the casting for various defects.

Just a quick brush through mold and core making. Both the mold cavity is created using a pattern, and a core is used for making hollow sections in the cast. Melting and casting involve melting the metal in a furnace and pouring it into the mold cavity.

Wait until it solidifies. As the casting solidifies, remove the cast part from the sand. Cleaning of casting: Remove the casting from the sand, cut the runner and riser, and trim the flash that appears at the parting line and other places. Testing of casting is done for various defects.

Sand Casting

Advantages

- Wide range of metals
- Sizes and shapes
- Low cost

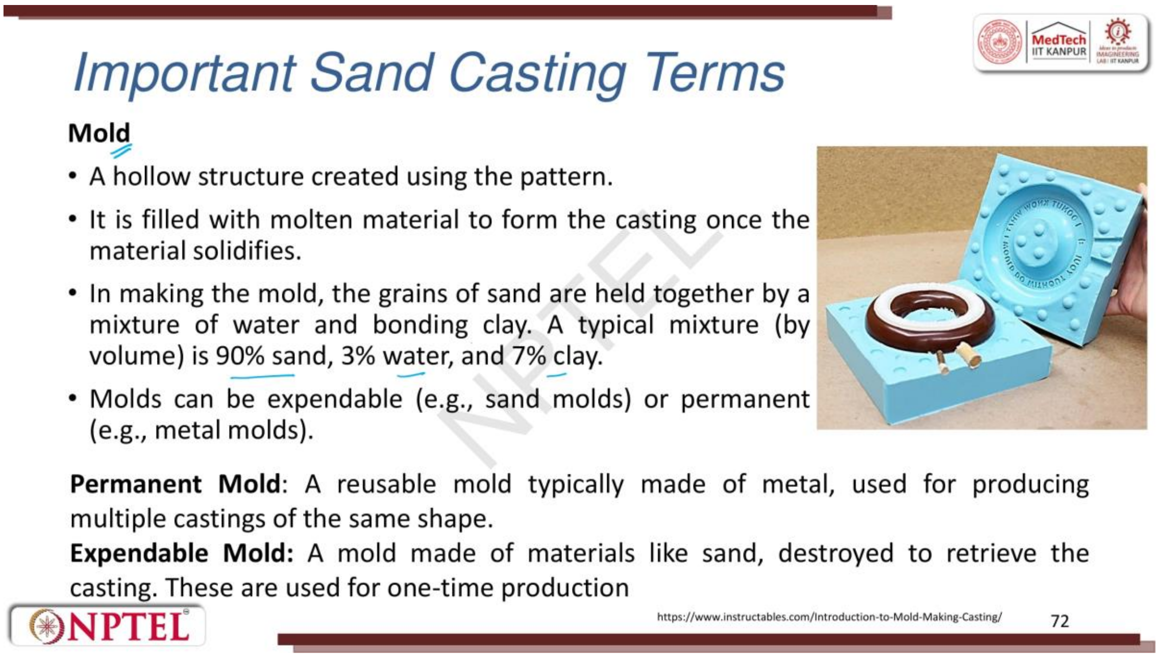
Disadvantages

- Sand casting-poor finish
- Wide tolerance

Examples Engine blocks, Cylinder heads

https://engfac/ganu/public_html/Metal%20casting%20processes_1.pdf

So, the advantage of sand casting we have seen is that a wide range of metals can be sand cast. The shape and size play an important role. It is low cost when there are large sizes; sand casting is the only option. When we talk about the disadvantages, sand casting leads to a poor surface finish and has wider tolerances.



Now, let us try to see the important sand-casting terms. Mold: A hollow structure created using a pattern is called a mold.

It is filled with molten material to form the casting once the material solidifies. It makes the mold, and the grains of the sand are held together by a mixture of water and bonding clay. A typical mixture by volume will be 90% sand, 3% water, and 7% clay. The molds in sand casting are expendable; they break and are thrown away. Yes, permanent molds are reusable and made of metal, allowing for the production of multiple castings of the same size.

For expendable molds, the mold is prepared each time, and the sand is discarded. Maybe you do a preparation, and the sand can be reused.

Open Mold

- They are simple, inexpensive, made of sand or basic materials.
- The liquid metal is poured directly into the cavity
- Making them suitable for low-precision parts but with less control over metal flow, leading to a higher risk of defects.

Closed Mold

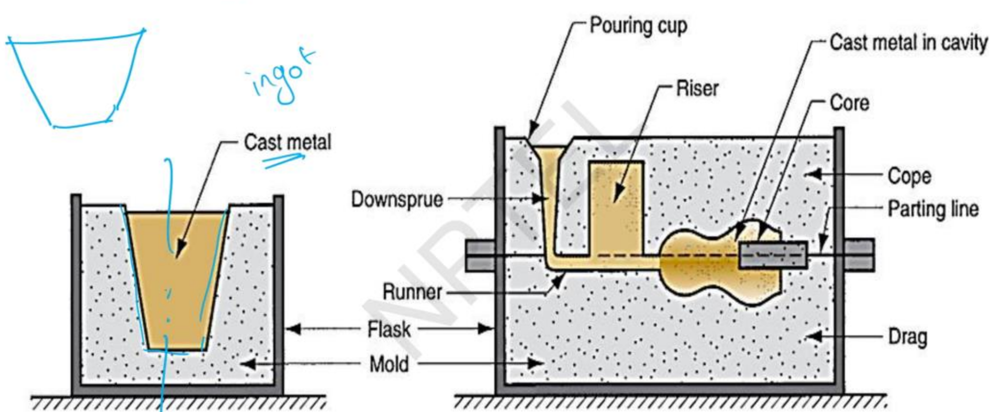
- Closed molds, made of metal, ceramics, or alloys, feature a gating system for controlled metal flow.
- It offering high precision, better dimensional accuracy, and surface finish.
- It ideal for complex castings despite their higher cost and complexity.

There is an open mold, and there is a closed mold. Open molds are simple, inexpensive, and made of sand or basic materials. The liquid metal is poured directly into the cavity, making it suitable for low-precision parts.

Open molds offer less control over the metal flow, leading to a higher risk of defects. Open mold. So, this is a closed mold. If you see here, this is a closed mold. Closed molds made of metal, ceramic, or alloy feature a gating system for controlled metal flow.

They offer high precision, better dimensional accuracy, and an improved surface finish. They are ideal for complex shapes despite their higher cost and complexity.

Mold: Diagrams



(a) Open mold (b) Closed mold

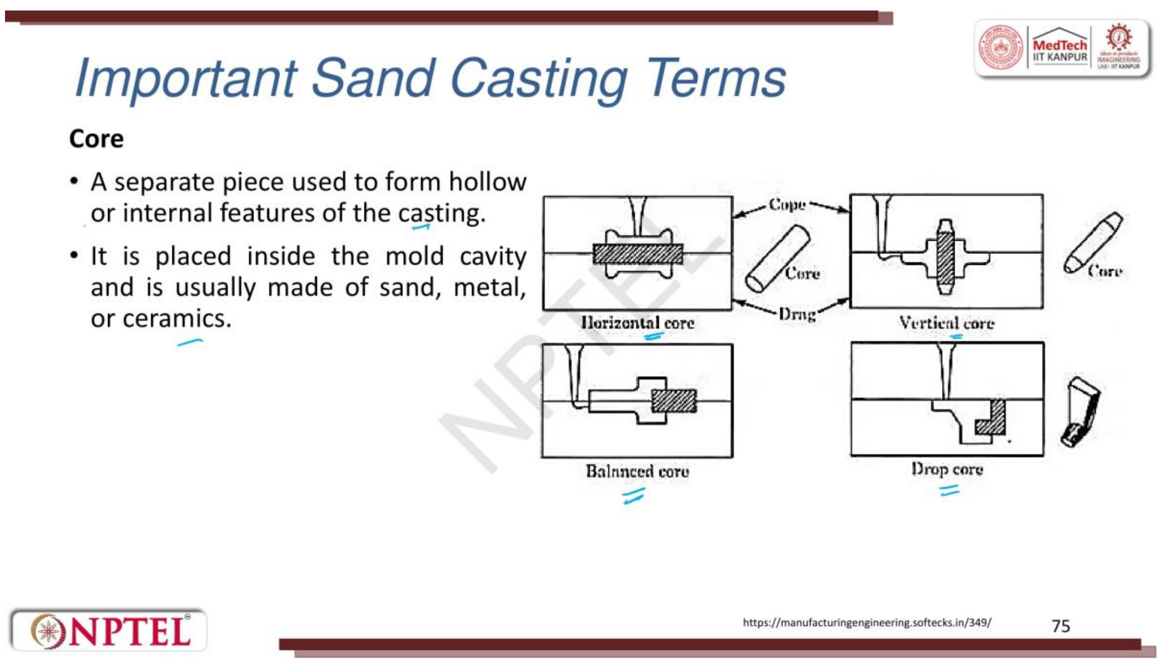
M.P. Groover, *Fundamental of modern manufacturing Materials, Processes and systems*, 4ed

This is the open mold. So, you just pour it in. For example, if you have liquid metal and want to make ingots, you just pour it and shape it into ingots.

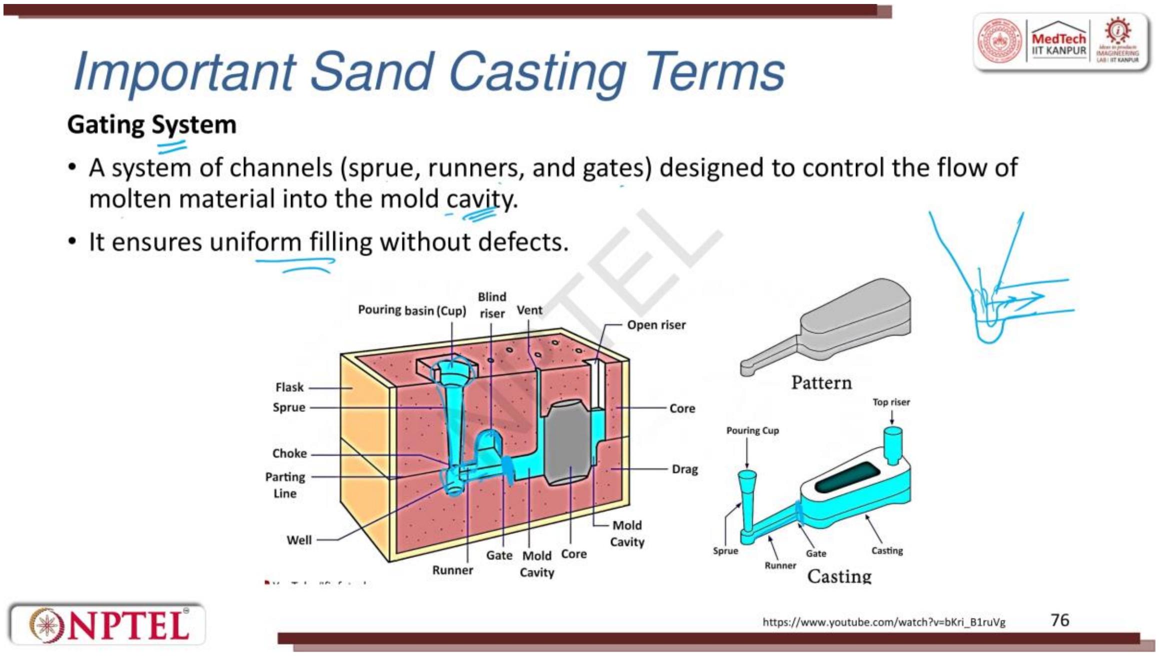
For example, think of sugarcane jaggery being formed. The sugarcane juice is heated, the viscosity changes, it is poured into a dye, and then they take the jaggery block out. Today, you also get small injected jaggery. So, those things are called closed dyes. So, this is open, and this is only an ingot.

Most of the time, this will never be used for the final output. If you want an analogy from everyday life, think of ice cubes extracted from an ice tray—they are all open molds. There is no intricate shape, nothing. It has a taper, so you just turn it and do it. So, if you look at ice cubes, they will always be tapered. You will always have an ice cube like this. See here.

So, if you see this today, you will understand. The other way around is that you pour it inside, ensuring a precise shape, so you get a closed mold. We always talk more about closed molding, where it forms the final part.



Core: these are the most important one. These cores can be horizontal, vertical, balanced, or drop cores. There are multiple types, but primarily core are used to give hollow features in the final part. A separate piece used to form a hollow or an internal feature of the casting is done by core. It is placed inside the mold cavity and is usually made of sand, metal, or ceramic. It can be sand, metal, wood also can be thought of. Sand is most probably used.



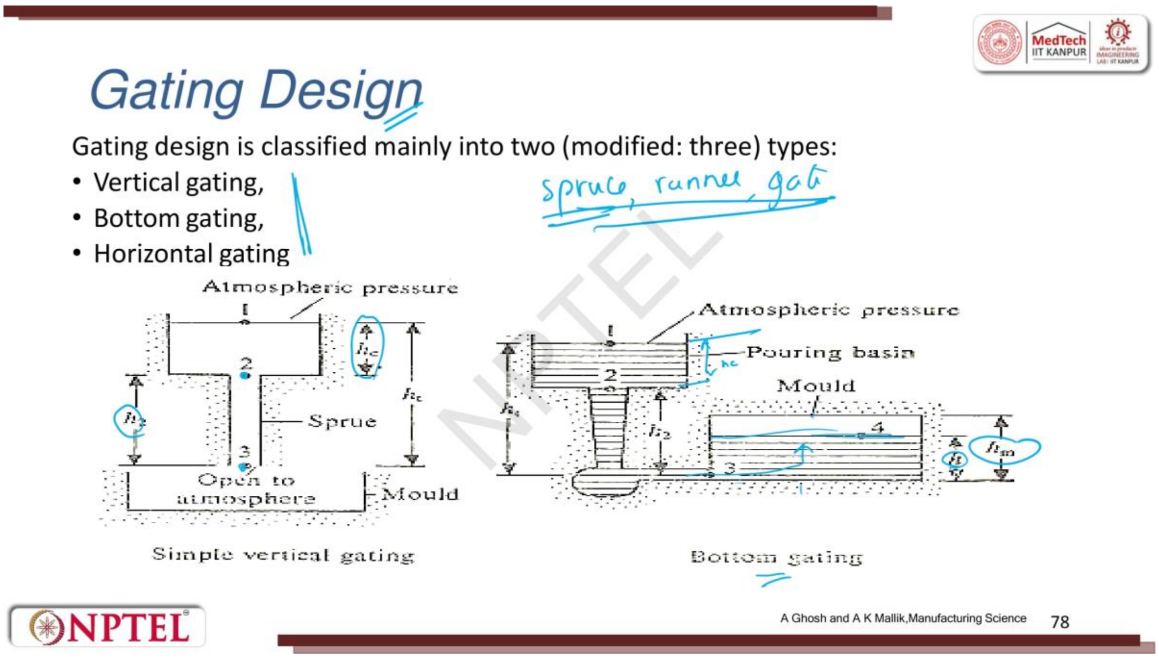
Next, Gating system. So, what is part of the gating system? So, pouring basin sprue is done. So, from here, the sprue is attached to a well. From here, there is a runner, and at the entry to the mold, you can have a gate.

This is the gate. A gate is like the entrance gate of a house. The gate is where the material enters the mold. In this example, you have given a blind riser, right? A system of channels—sprue, runner, and gate—designed to control the flow of molten metal into the mold cavity is called the gating design.

You should understand that the runner also needs a taper to maintain continuity. It ensures uniform filling without any defects. So, this is a top riser and pouring basin. This is your runner, and at the entry of the mold, it is called a gate. This is your runner, and at the entry of the mold, it is called a gate.

Slow pouring may lead to early solidification before the cavity is filled. Fast pouring can erode the metal. So, that is why we always talk about the pouring basin, a taper, and a well. Because from here, you can immediately change the direction. But when you change the direction, there is a possibility of the vena contracta effect, which can lead to solidification.

So, what you do is create a well where the liquid metal collects and slowly starts filling the mold. So, fast pouring can erode the mold. So, what you do is create a well where the liquid metal collects and slowly starts filling the mold. Gating design depends on the metal and its composition, such as aluminum, which is susceptible to oxidation.

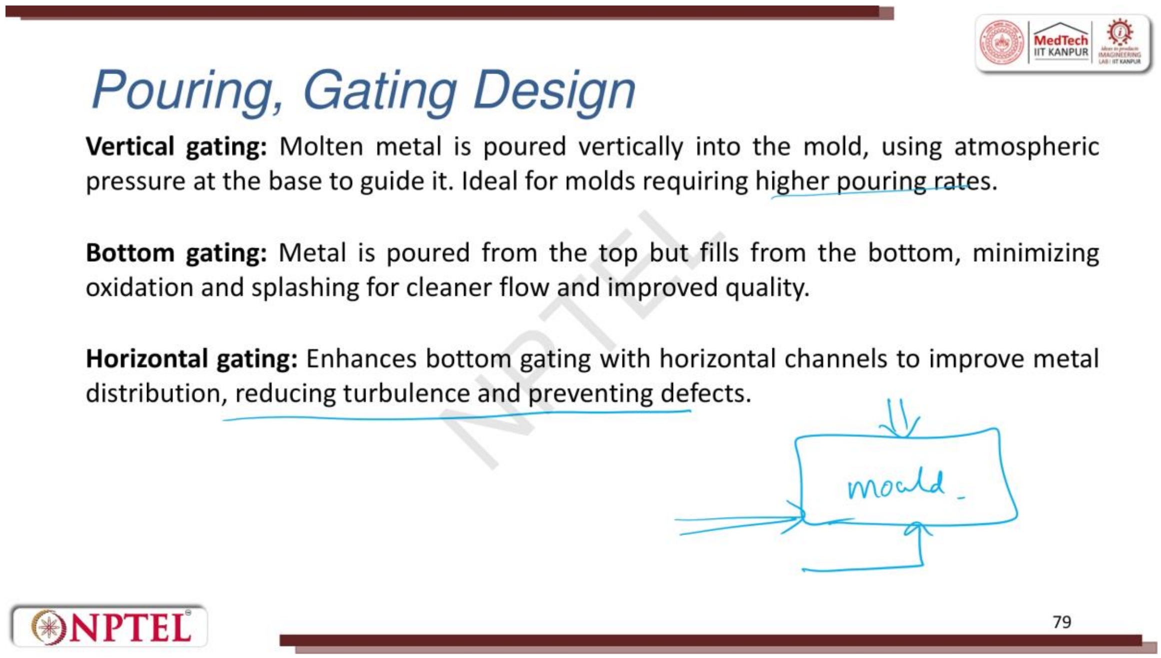


The gating system can be classified into three types: vertical gating system, bottom gating system, and horizontal gating system.

When we talk about the gating system, gating design means the sprue is also included. Sprue, runner, and gate. If you have an open gating system, you have a pouring basin, then you have a sprue. So, here whatever is there, it is at atmospheric pressure. At the change where the sprue starts, it will be 2, and at the end of the sprue, you will have point number 3.

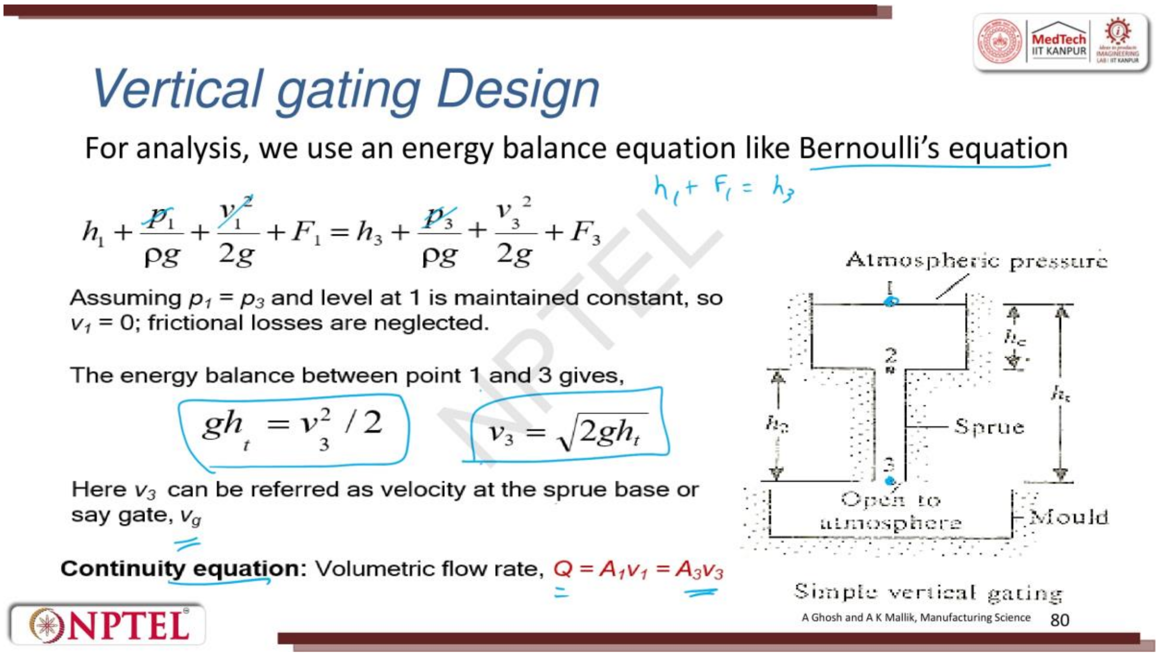
So, the heights are defined. hc is the height of the pouring basin. h2 is the sprue height. he is a combination of hc plus h2. And from point number three, it is exposed to the mold, so it is open to the atmosphere, right?

It is like an open mold. So, when we talk about a closed mold, this is called hg, which is h2, right? h2, and this is hc. This is the mold height, and as the liquid flows, the top level of the molten metal at this height is called H. This is for bottom gating. Bottom gating systems always give you very good results.

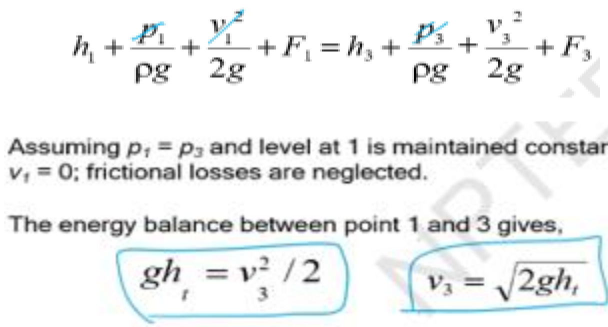


Vertical gating: Molten metal is poured vertically into the mold, using atmospheric pressure at the base to guide it.

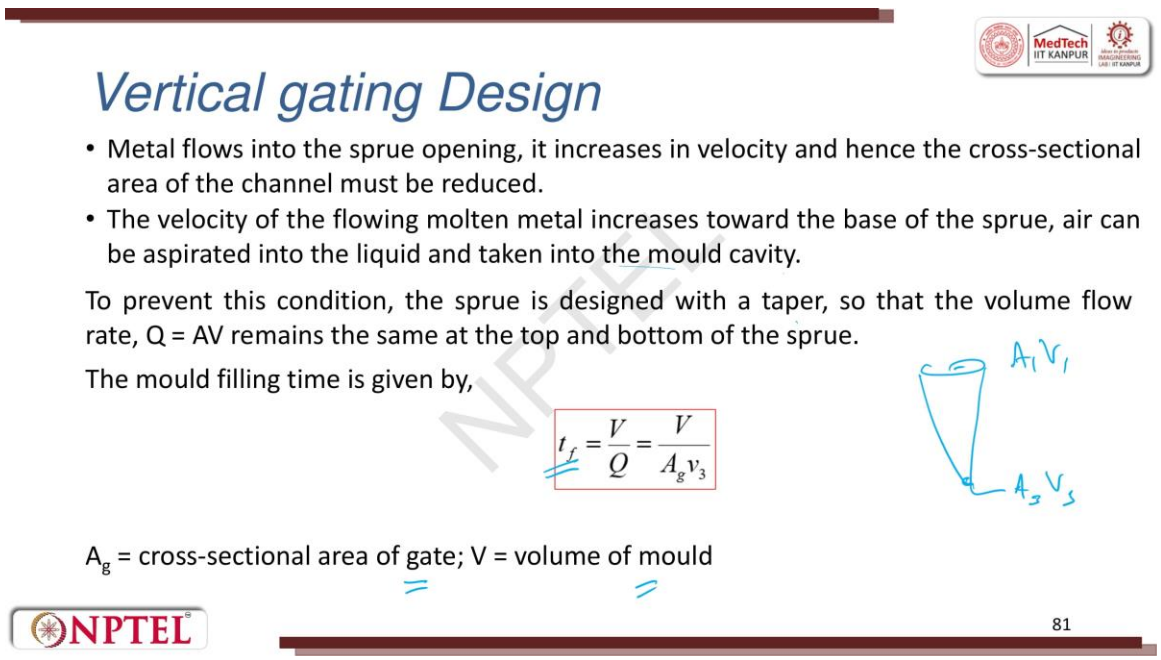
Ideally, molds require high pouring rates. Bottom gating: Metal is poured from the top but fills from the bottom of the mold. Minimizing oxidation and splashing ensures a clean flow and improved quality. Horizontal gating enhances bottom gating by using horizontal channels to improve metal distribution, reduce turbulence, and prevent defects. So, in bottom gating, the metal flows upward; in horizontal gating, it flows sideways. In vertical gating, it comes from the top, right?



So, for a vertical gating system, let us now try to determine the velocity at which it is done. So, for a vertical gating system, let us now try to determine the velocity at which it is done. So, we always use two simple equations: Bernoulli's equation and the continuity equation.



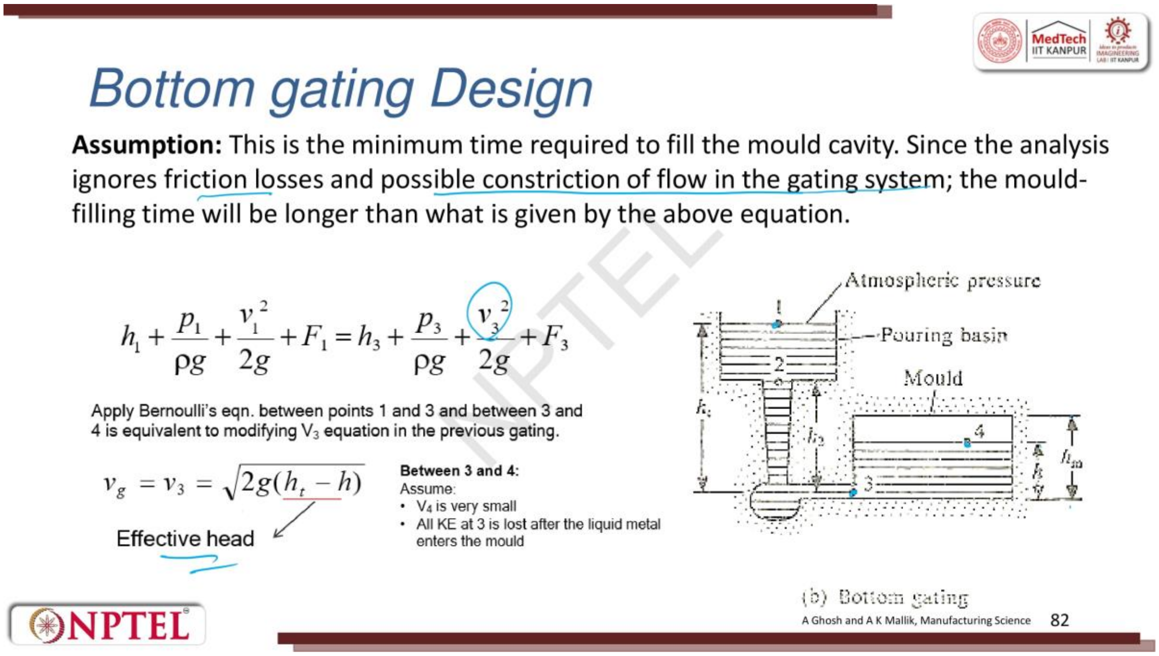
Here, v3 is referred to as the velocity of the sprue base or the gating vg. The continuity equation Q will be A1 v1 = A3 v3.



So, now substituting all, we try to get the mold filling time as $V/A_g v_3$. As the metal flows into the sprue opening, its velocity increases; hence, the cross-sectional area of the channel must be reduced. So, this is A1v1 = A2v3.

The velocity of the flowing molten metal increases as it moves toward the base of the sprue. The air can be aspirated into the liquid and taken into the mold cavity. So, you should be very careful. So, you cannot reach infinitely high velocities. Please, be careful.

To prevent this condition, the sprue is designed with a taper so that the volume flow rate Q = AV, remains the same at the top and bottom of the sprue. The top and bottom of the sprue are the same, so we try to have A1v1 = A3v3. So, the time for filling is nothing but V/Q, where Q is the flow rate. So, the flow rate is determined by the velocity. So, the cross-sectional area of the gating system is Ag, the velocity is v3 at the end of the sprue, and V is the volume of the mold. So, we can try to find out the mold filling time for a vertical gating system is going to be this.



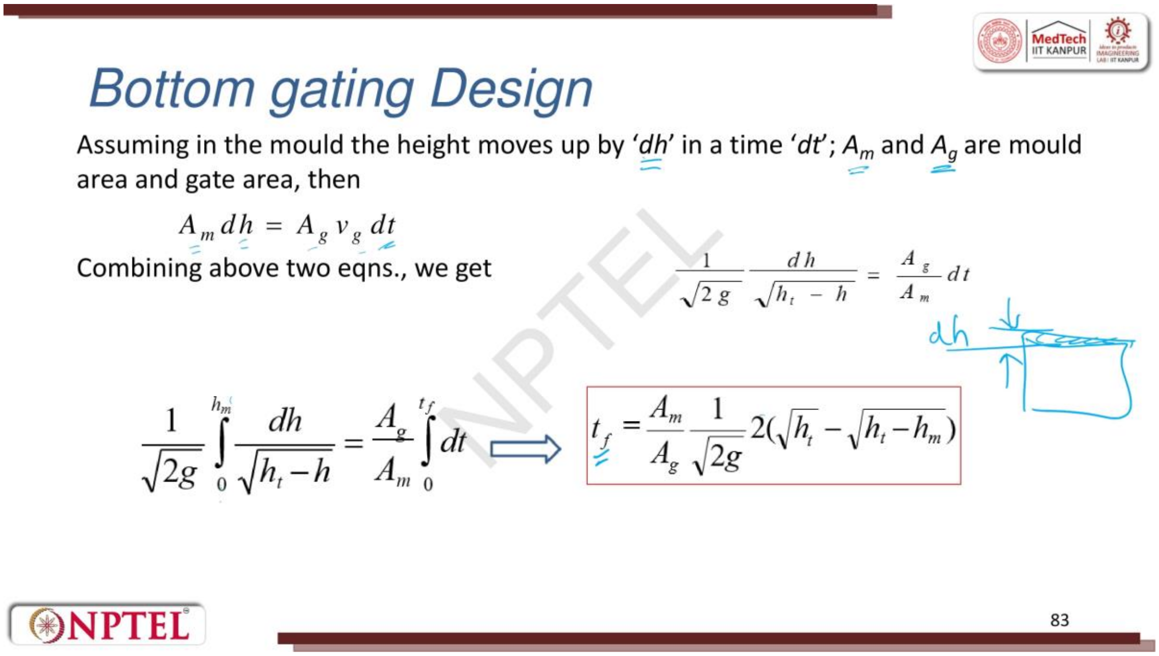
Now, let us take the option of a bottom gating system. In the bottom gating system, the assumption is that this is the minimum time required to fill the mold cavity. Hence, in the analysis, we ignore friction losses and possible constriction of the flow in the gating system. The mold filling time can be calculated using Bernoulli's equation, the continuity equation, and related principles.

So, it can be written as

$$v_g = v_3 = \sqrt{2g(h_t - h)}$$

So, applying Bernoulli's equation between points 1 and 3, and between points 3 and 4, we modify v3 in the previous gating equation. So, we try to get this. Between 3 and 4, we assume v4 is very small.

All kinetic energy at point 3 is lost after the liquid metal enters the mold. So, these two are the assumptions. Based on these assumptions, we try to determine the velocity at the gate.



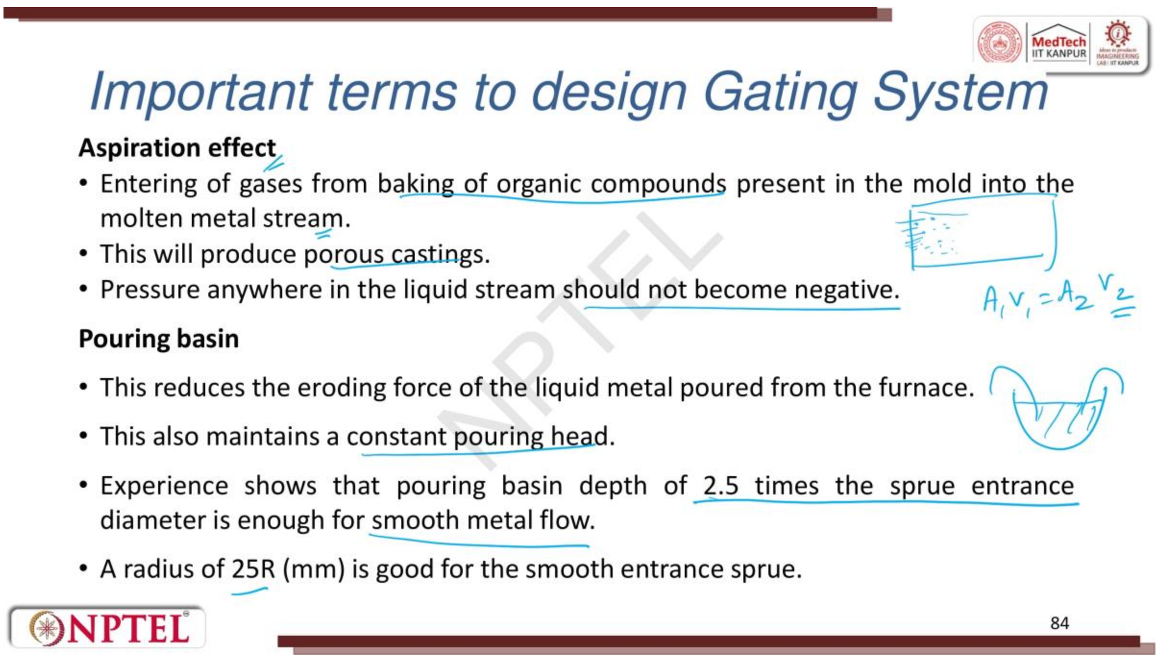
So, assuming that in the mold, the height moves up by Δh, this is the one that rises by Δh. Assuming that in the mold, the height increases by Δh in a time Δt, Am and Ag are the mold area and the gate area, respectively.

So, $A_m\,dh = A_g\,v_g\,dt$. Now, what we do is we combine the two equations, and we get this form. So, now we integrated between 0 to hm and we have 0 to tf, mold filling time. So, this can be rewritten and after solving the equation it can be

$$\frac{1}{\sqrt{2g}}\int_0^{h_m}\frac{dh}{\sqrt{h_t-h}} = \frac{A_g}{A_m}\int_0^{t_f}dt \Rightarrow t_f = \frac{A_m}{A_g}\frac{1}{\sqrt{2g}}2(\sqrt{h_t} - \sqrt{h_t - h_m})$$

Where is hm? hm is the mold height minus ht. So, with this, we will determine the mold filling time for the bottom gating system. In the top gating system, the mold filling time is straightforward, whereas in the bottom gating system, it needs to be derived and calculated.

So, please work it out. We will have one or two problem sessions where we will go through the steps in detail.



Continuing with the important terms of the gating system design, we have the aspiration effect. This is very important. The aspiration effect occurs when gas enters the molten metal stream due to the burning of organic compounds present in the mold.

So, what happens is that air enters from the walls. This is the mold. From the walls, air enters into the mold. Where there is molten metal. So, you have molten metal, and this air enters into it.

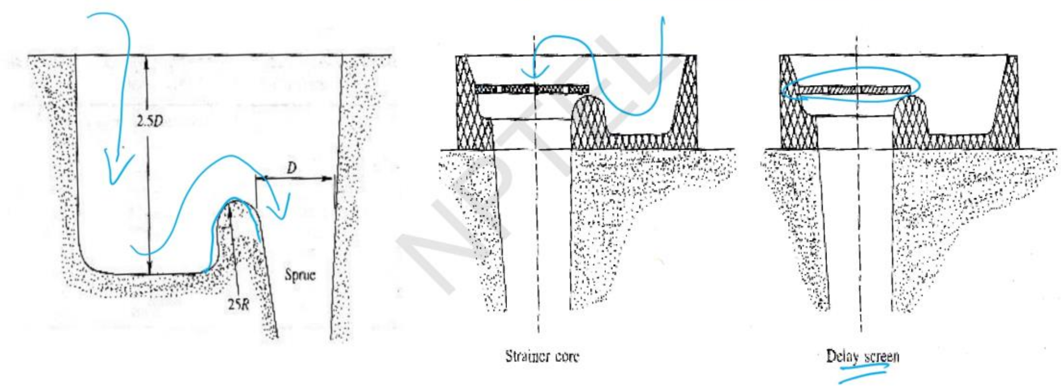
So, when the air goes there, it will lead to defects, which will produce porous casting. The pressure anywhere in the liquid stream should not become negative. So, what happens when, you remember, A1 v1 equals A2 v2, as we were seeing. v2 is the velocity at the gate and other things. Make sure this velocity is always high.

It should not go negative. The moment there is negative pressure, it will start drawing air back into the stream. The moment it sucks back, it will prevent the formation of a solid part. Pouring basin—we have covered it enough. This reduces the eroding force of the liquid metal poured from the furnace.

This also maintains a constant pouring head. This also maintains a constant pouring head, so it should have a constant head. Experience shows that a pouring basin depth of 2.5 times the sprue entrance diameter is sufficient for smooth metal flow. So, they have also derived some empirical values, such as 2.5 times. A radius of 25R is good for a smooth entrance sprue.

Important terms to design Gating System

The items provided in the gating system to avoid impurities and turbulence are:



P Rao, *Manufacturing Technology: Foundry, Forming And Welding* 85

If you look here, this is 2.5D, this is 1D, and here is the radius. So, the metal fills here first and then flows from here into the next section. So, now it will ensure a smooth flow as required. So, when we do that, there is a possibility of oxide formation or soil erosion. So, we always place a strainer core. Strainer core is there. So, the liquid flows in and then moves through like this.

Important terms to design Gating System

Delay screen: It is a small piece of perforated screen placed on top of the sprue.

Strainer core: It is a ceramic-coated screen with many small holes and is used for the same purpose

Splash core: provided at the end of the sprue length which reduces the eroding force of the liquid metal

Skim bob: this traps lighter and heavier impurities in the horizontal flow

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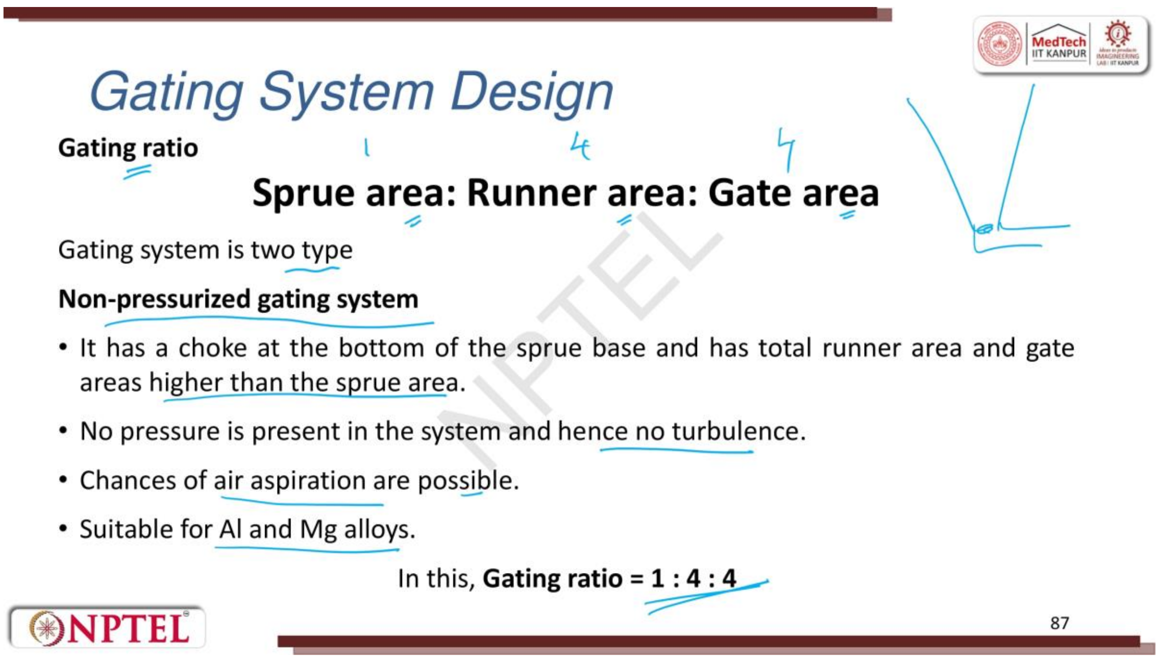
You can also have a delay screen. So, this strainer core and delay screen have similar functions. The items included in the gating system to prevent impurities and turbulence are used for this purpose.

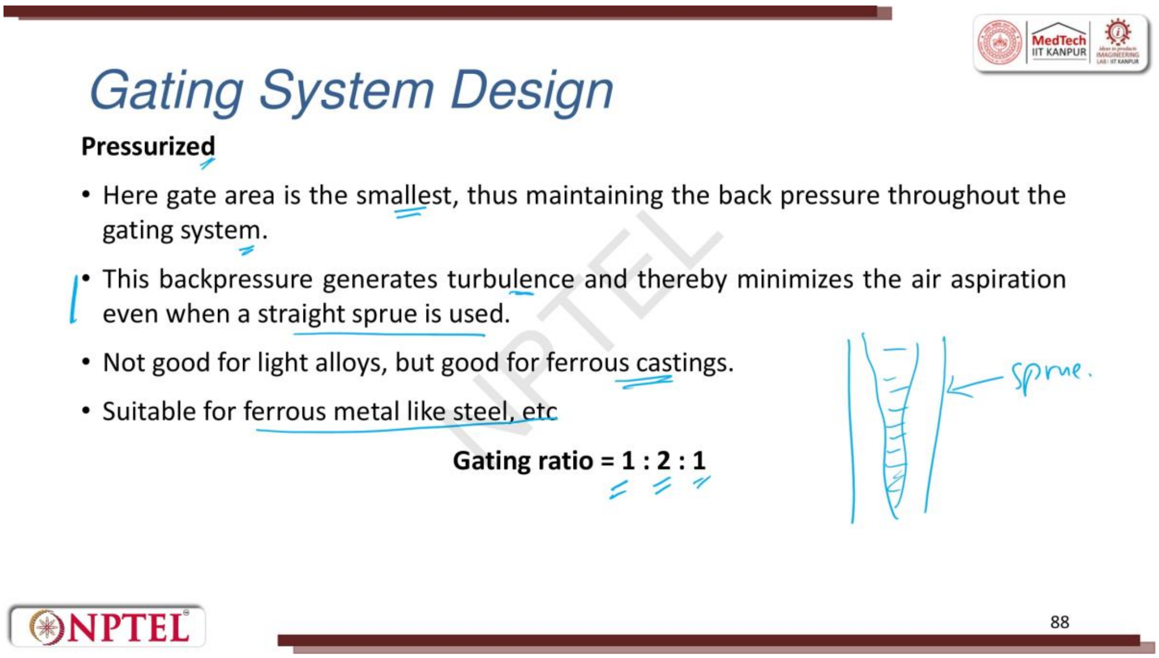
So, the important terminologies here include the delayed screen. It is a small piece of perforated screen placed on top of the sprue, called a delay screen. Strainer core is a ceramic-coated screen with many small holes, used for the same purpose of stopping small pieces. Splash core helps in reducing splashing by controlling the flow of molten metal. Splash core is placed at the end of the sprue length to reduce the eroding force of the liquid metal.

We also have skim bob. Skim bobs are used to trap both lighter and heavier impurities in the horizontal flow. So, all these components serve a similar function by ensuring a smooth flow and preventing unwanted elements from entering. And it also helps maintain a uniform flow.



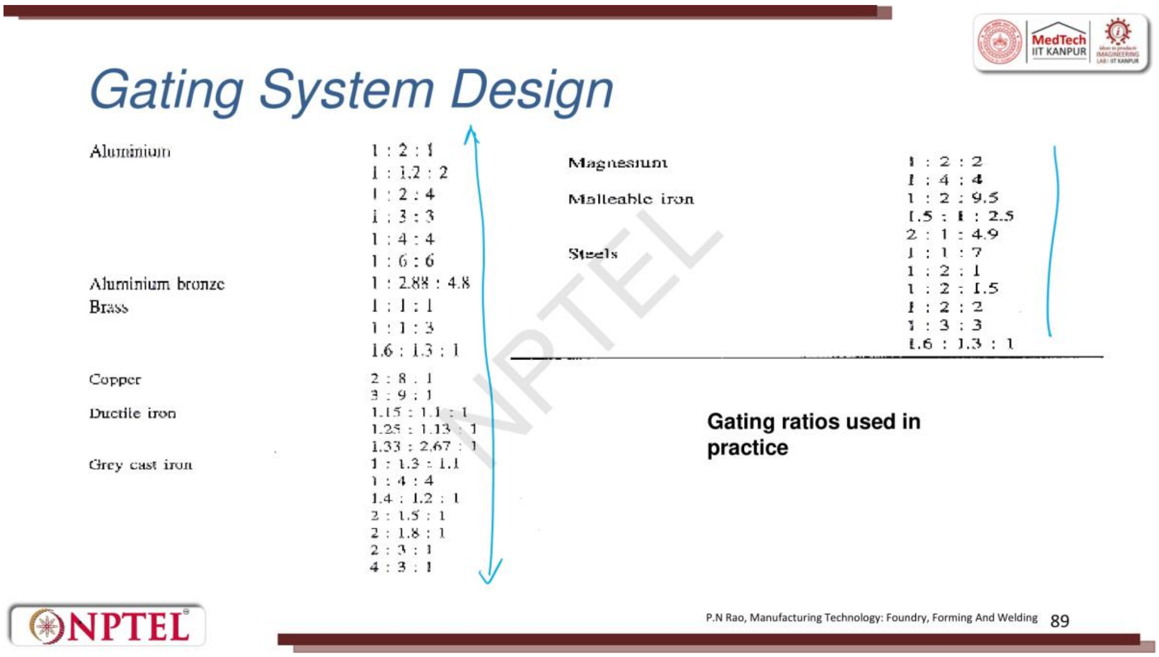
So, there is something called a gating ratio. The gating ratio is always written as sprue area : runner area : gate area. The gating system is of two types: non-pressurized gating system and pressurized gating system. In the non-pressurized gating system, there is a choke at the bottom of the sprue base, and the total runner area and gate area are larger than the sprue area. I repeat, it has a choke at the bottom of the sprue. What is sprue?

The bottom of the sprue base has a total runner area and gate area larger than the sprue area. So, no pressure is present in the system, resulting in no turbulence. So, the chance of air aspiration is possible. Generally, the non-pressurized gating system is used for aluminum and magnesium alloys. The recommended gating ratio is sprue 1 : 4 : 4.

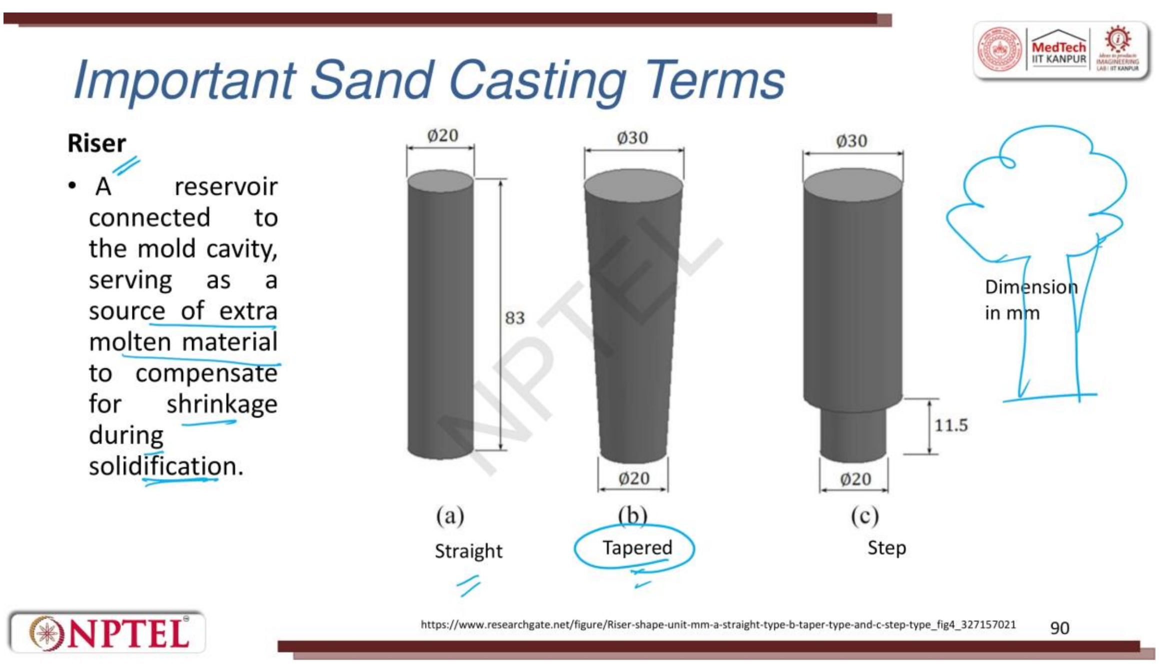


Now, pressurized system. Here, the gate area is smallest. The gate area is largest. The gate area is smallest. Thus, maintaining back pressure throughout the gating system. This back pressure generates turbulence, thereby minimizing air aspiration even when a straight sprue is used.

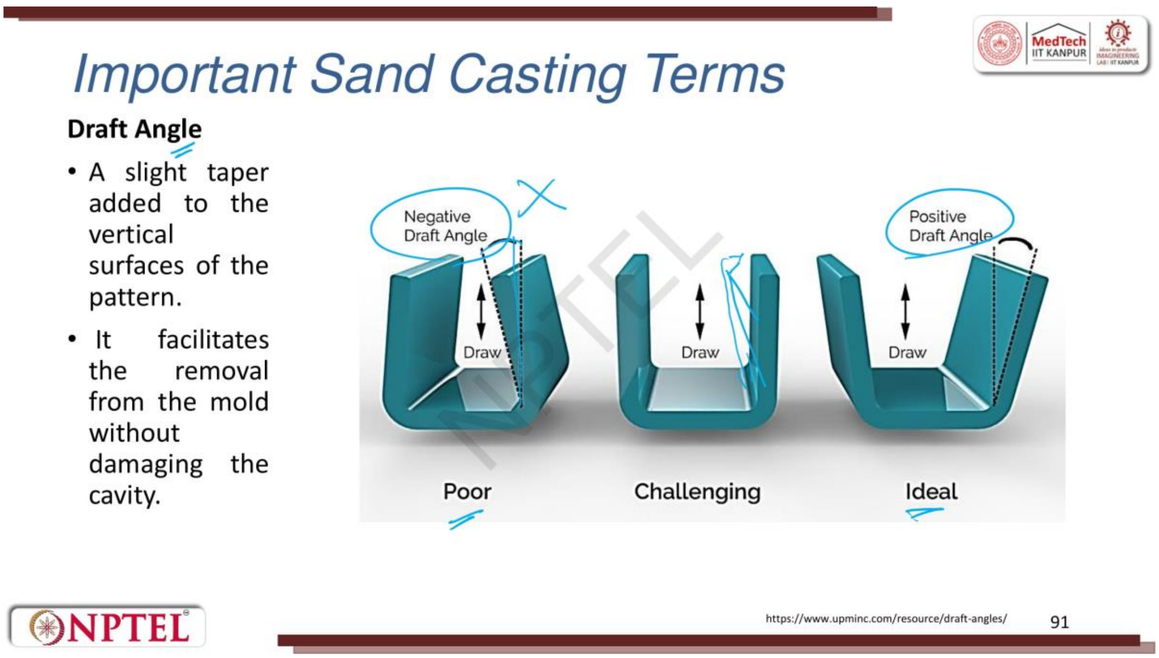
This is a very important point. The back pressure generated during turbulence helps minimize air aspiration. Air aspiration, you remember, we have seen, right? So, here there will be curing, and these are all metal, while this is the sprue, where air aspiration can occur. Even when a straight sprue is used, the pressurized system is not suitable for light alloys but is good for ferrous casting and die casting. Pressure die casting. Suitable for ferrous metals like steel, the gating ratio is 1:2:1.



So, here we have presented all different gating design ratios for aluminum, aluminum and bronze, brass, copper, ductile iron, and grey cast iron. We can also use it for magnesium, malleable iron, and steel. So, you can have a pressurized gating system or a non-pressurized gating system.



Riser: A reservoir connected to the mold cavity. It serves as a source of extra molten metal to compensate for shrinkage during solidification. You can have a straight riser, a tapered riser, or a step riser. The shape can be any, including a mushroom-type riser, depending on your requirements. You can also have blind risers. Straight riser, tapered riser, and step riser.



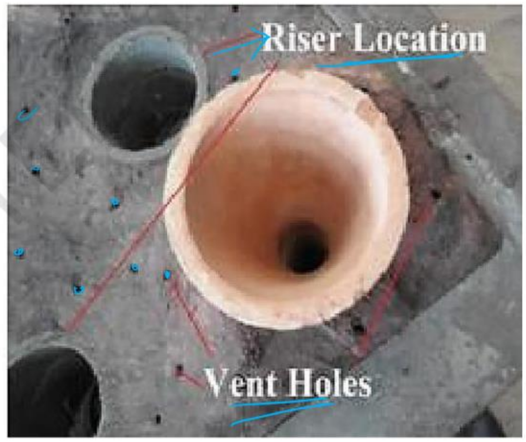
Predominantly, we use a tapered riser. So, there is something called a draft angle. A slight taper added to a vertical surface of the pattern is called the draft. It facilitates removal from the mold without damaging the cavity. You can have a poor or ideal draft.

This is a positive draft, and this is a negative draft. We avoid negative drafts. Draft means a small taper given so that the part can be removed from the mold. It facilitates removal from the mold without damaging the cavity.

Important Sand Casting Terms

Vents

- Small openings in the mold that allow
  - ➢ Trapped air and gases to escape
  - ➢ Ensuring the molten material fills the cavity completely.

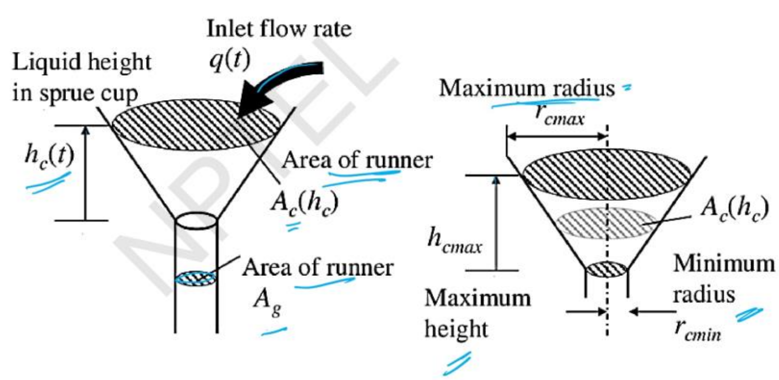


There are vents. These are all vent holes which are there. These are small openings in the mold that allow trapped air and gases to escape, ensuring the molten material fills the cavity completely. So, you can have these riser locations and small vent holes, which are there. Vent holes, riser locations.

Important Casting Terms

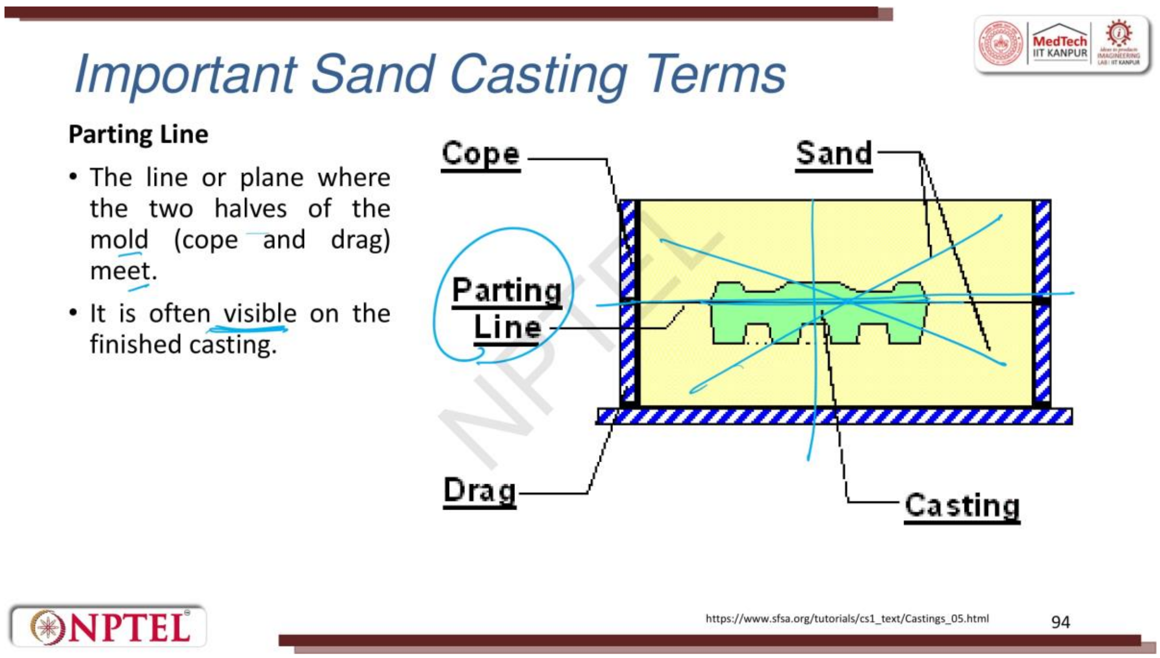
Pouring Cup

- A funnel-shaped structure at the top of the gating system that minimizes turbulence and directs molten material into the sprue.



When we talk about a pouring cup, the pouring cup will always be something like a funnel shape. The funnel-shaped structure at the top of the gating system minimizes turbulence and directs the molten material into the sprue. So, you have liquid height in the sprue cup, which is hc. This is hc, which you have already seen, and the area of the runner is ac.

So, the input flow happens, and then you have the area of the runner as ag at the gate. So, the maximum radius will be rcmax, and the height will be hcmax. Maximum height, minimum radius, and maximum radius for the pouring cup.

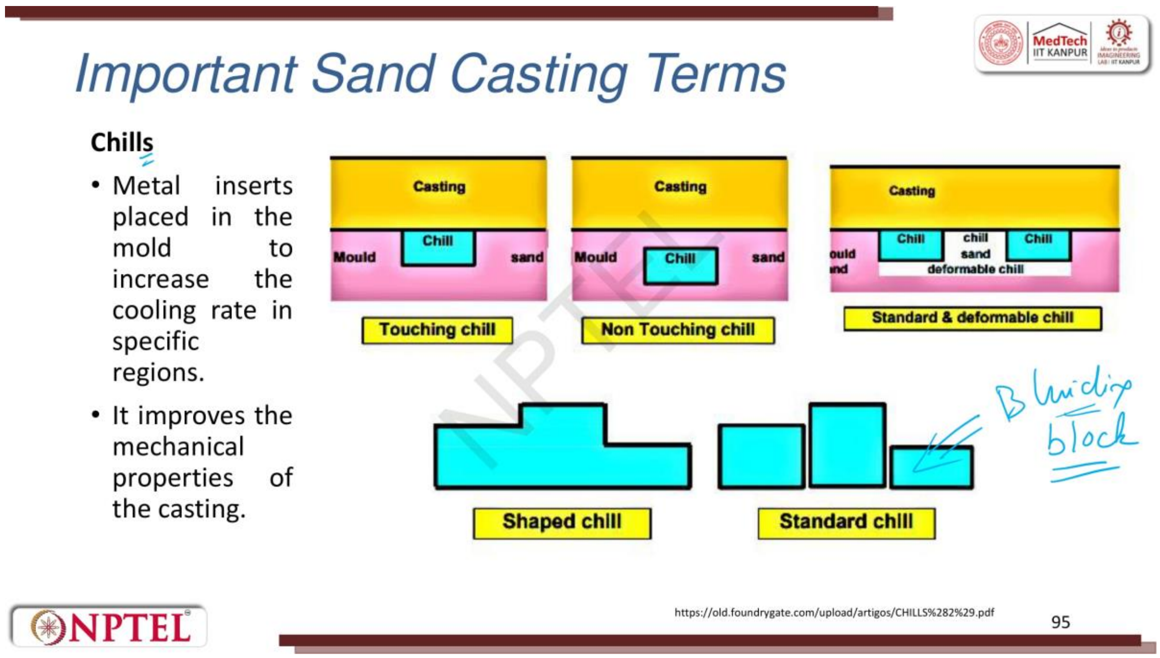


Parting line—we have seen the parting line. One of the toughest and most difficult tasks is identifying a parting line for any given component.

For any given component, identifying the parting line is crucial. The parting line dictates the mechanical behavior. So, you can make the component like this, you can make the component like this, you can make the component like this, like this. These are all parting lines. It is left to you to decide. There are software tools that can help identify the parting line because the parting line divides the cope and drag parts.

In sand casting, the cope and drag parts are used, but in metal casting, you can also have molds that move horizontally. Here it is vertical; there it can move horizontally. The line or plane where the two halves of the mold meet is called the parting line. It is often visible. So, when you see even your pencil box, you will notice a straight line running along it.

If you look at a plastic bottle sometimes, you will see a parting line. When you see a cast piece like a bell, you can observe a straight line. So, those are all parting lines. It is often visible in the finished casting.



So, we have already discussed chills. Metal inserts placed in the mold to increase the cooling rate in a specific region are called chills. So, this is the mold, this is the casting, this is the chill, and this is the mold. You can have casting, you can have mold, you can have chill, and then you can have this. So, the casting is touching the chill. In this casting, the chill is not touching the casting, and here you can have standard and deformable chills.

So, the chill sand, deformable chills, improve the mechanical properties of the casting. These are all shaped chills. These are all standard chills which are available. Chills are nothing but something like a building block. Like your jigsaw puzzle, you have a building block. With this building block, you can try to make multiple chills, to join together to meet the requirements. So, with this, I am sure you will now appreciate and understand sand casting.

How is sand casting made? In sand casting, what are all the parts? Cope, drag, mold, core, core print, sprue, riser, vent. These are the things we saw. We saw the pattern. Pattern, what are all the allowances? In the pattern, you have shake elements, machining elements, taper elements, distortion elements.

All these things are given such that you always try to get a solid part. And while going through the discussion, we also saw what the pouring time is when we use a top gating system and a bottom gating system. I am sure you will now have a good understanding of sand casting and the processes.

These are the references which we have used in this lecture.

Thank you very much.