Manufacturing Processes – Casting and Joining

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Lecture – 01
Metal Casting

Hello and welcome to the course on Manufacturing Processes, Casting and Joining. This is a new course that I am going to offer; my name is Dr. Sounak Kumar Choudhury, I am a professor in the Mechanical Engineering Department of IIT Kanpur. You must have attended, or you must have gone through different kind of courses, which are offered through the NPTEL, through the SWAYAM PRABHA, particularly in the area of manufacturing processes.

In these courses, it was told that, to get the final product from the raw material we need to go through different kind of manufacturing processes. Those processes include material removal process, that is the mass deletion process, where you have to remove the additional, the extra mass from the blank, from the raw material to get the shape, size, finish, and accuracy.

Or it can be a constant mass operation for example, casting or metal forming, where the mass of the final product is the same as the mass of the initial blank or the raw material. Or it can be mass addition process, where the final product that you are getting will be through adding mass to the initial blank or the raw material.

For example, the welding process or the rapid prototyping process whereby layers you are adding the mass to the blank or to the initial material and you are getting the final product. So, these two chapters we will be studying here in this course, namely the casting and the welding.

In casting, as I said in my introductory lecture, we will be looking into the process characteristics of different kind of casting processes; these are the new processes and the processes which are already being used. The casting process is one of the oldest manufacturing processes and it is dated back to 6000 years BC, that I will discuss in the historical aspects.

So, as you can understand that, this is one of the very important and one of the probably most important manufacturing processes among all the manufacturing processes.

Next in the welding, we will be studying process characteristics of different welding processes. Among new modern welding processes it will be tungsten inert gas welding, metal inert gas welding processes, ion beam processes, laser beam welding processes, ultrasonic welding processes and so on. We will be looking into this one by one. First let us consider the metal casting.

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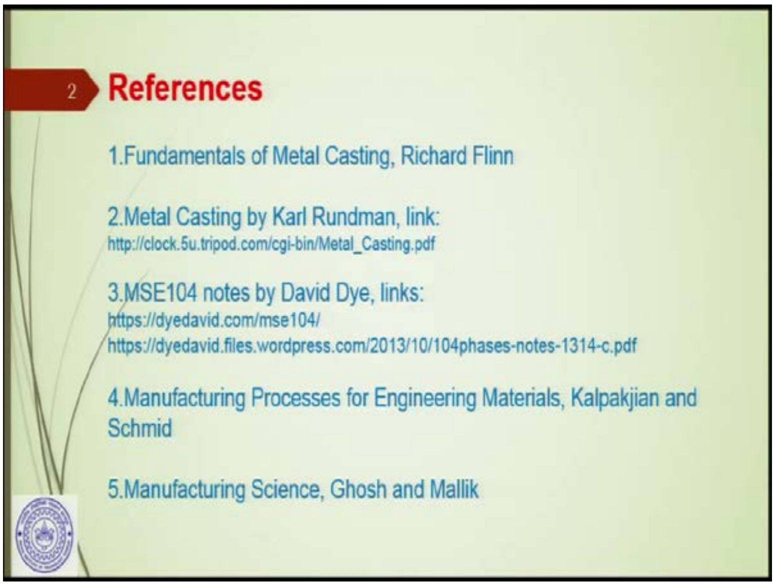

Before I go into the details of the course, let me point out the references. So, you can use these books. Out of this, the first one as you can see is the fundamentals of metal casting by Richard Flinn. This book is quite popularly used, and whatever we will be looking into, you will find the material in this book.

Second book is metal casting by Karl Rundman and the link is given here. By the way, if you click on this link, you can actually download the PDF format of this book. It is an open-source book.

Now, there are some notes, like note by Professor David Dye and the link is given here, two links are here. From these two links, you can download the notes and you can go through the notes; this will be the additional information apart from what we will be discussing in this course.

Fourth is a good book. This book is by Kalpakjian and Schmid. It is called the Manufacturing Processes for Engineering Materials. Here of course, you will find along with the casting and welding, other manufacturing processes as well - about the unconventional machining, about the NC machining and so on.

So, you can get that book. There is an Indian edition of this book and you can go through that. And finally, this is the book written by our ex colleagues, Professor Ghosh and Professor Mallik; this is quite a classical book on manufacturing science you can go through. A part of this book is about casting along with the other manufacturing processes.

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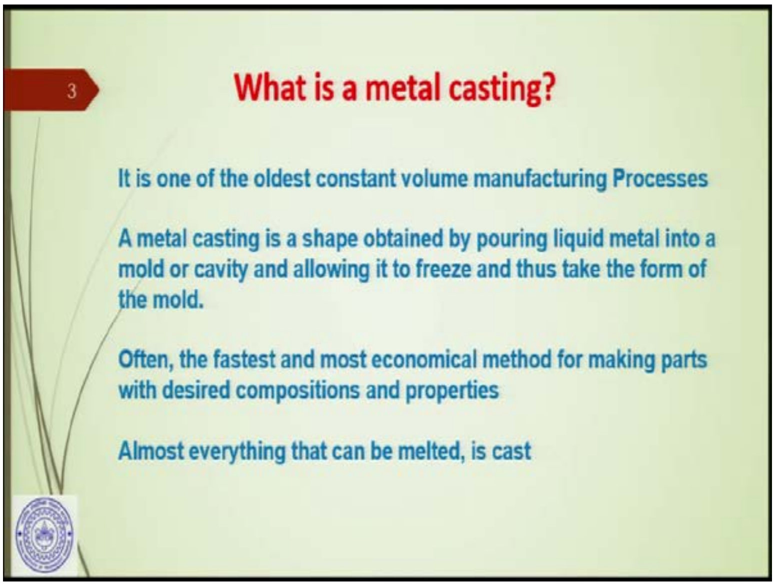

Now, let us see what is metal casting? How we can define casting? It is one of the oldest constant volume manufacturing processes where, as I said, the volume remains the same for the final product and the initial blank, there is no change in volume, A metal casting is a shape obtained by pouring liquid metal into a mold or a cavity and allowing it to freeze, after which it takes the form of the mold.

So, as you can see that, this is one of the most simple processes; that is you melt the metal, pour it into a cavity and after the molten metal gets solidified, it takes the shape of that cavity. That cavity, as you know, is called the mold. So, if you remember and if you have done that during the holi, holi mela - that is you take a big potato, cut it off into two pieces, and scoop out the entire inner material.

So, what you will get is two hollow pieces of big potato that can be separated out. In one of the hollow parts, you pour the molten wax, cover it by another part and then shake it, and put it into the cold water. After about half a minute or so, these two parts will come out and what you will get is a shell of wax.

So, what children used to do or you may be still doing they take a syringe and inject different kind of colours, liquid colours into that shell and then, that small hole through which the colour has gone into that shell will be sealed. So, what you are getting basically is a shell filled with liquid colour. This we used to call as colour bomb. You throw it to a person and the shell will be broken; it will not be painful. The colour will be splashed on the person.

Why I am describing this is because this is the principal of casting. Because imagine that this colour is the molten metal; in this case it is not solidifying, but it is taking the shape of that cavity in which it is poured.

Similarly, in casting also there is a mold, two halves of the mold, and the mold has a cavity. So, in one half you pour the molten metal, cover it by another half. After it completely takes the shape of that inner cavity, it can be allowed to solidify, and the final product is obtained.

Now, although it looks very simple that you pour molten metal and finally, within few minutes may be within a couple of minutes you are getting the final product; but actually the process has lot more things to be considered, if we have to get a final product which is casting, which should be defect free, which should be of high quality. For example, let us consider the sand moulding, where we are making that cavity out of sand, which is very popular and you must have heard about it, you must have read about it.

Now, you are pouring, let us say aluminium. into that cavity. First of all, when you are making that mold, it has to be in a box and as you know that those are called the cop and the drag. We will look at it after some time.

Now, what kind of material of that box you will be using? Whether it is a wooden box or it is a metal box? You have to consider that, after pouring the very hot molten metal, the mould will expand, the sand will expand and the box should allow that expansion; if it does not, then the whole thing collapses - that is one thing.

Second thing is, the sand that we will be using - whether that sand is very fine or that sand is coarse sand? When you will be using very fine sand and then the glue will be added, clay will be added to that along with water, then what will happen? Between the sand particles, there will be no space, or the minimum space will be left.

And then the gas, which is being generated inside that the mould cavity after the molten metal is poured, that gas cannot be escaped. So, porosity will not be there. In that case what will happen is that either the mold will collapse, mold will break because of the pressure from the gas or the casting will have porosity, casting will have defect. Those castings will be rejected; I mean they will not be of high quality.

Next consider that when you are pouring the molten metal, you have to heat up the metal up to a particular temperature. Now, what is that temperature? If the temperature is very high then of course you are wasting money on the oven, because it is very expensive of course to maintain an oven. And if the temperature is not sufficient, in that case what will happen is that the mold may not be covered. Before the molten metal covers all the parts of the inner cavity, it will actually start solidifying.

So, there will be defective castings or defective parts. So, it is not as simple as it looks like that you pour molten metal and after solidification you will get the final product; because during the solidification as well what you will have is that, as you know, when the molten metal solidifies, it will actually shrink.

So, you should have some provision for compensating those shrinkages and there are difference shrinkages. Now, when you will have the casting made, normally the casting process is not very precise; I mean the quality of the casting is not as good as the quality of machining.

Therefore, after casting, we always use the machining process to remove the extra material and to add the good surface finish and the quality. For that we have to consider some sort of allowance for removing that extra material; if you do not keep it, in that case again after machining the dimensions will not be adequate and so on.

So, there are many such factors that have to be considered, without which the high-quality casting cannot be obtained. All these things we will be discussing in this course one by one. Next, often it is the fastest and most economical method for making parts with desired compositions and properties. Casting is done very fast of course, and it is economical.

More economical than machining; because in case of machining what happens is that, we are removing the extra material that we are wasting in terms of small chips. In case of casting it is not the case; in case of casting, the volume remains the same.

So, we are not removing any extra material. That is why we are calling it as more economical method; at least than the manufacturing through the machining. Almost everything that can be melted is cast; any metal that can be melted and any metal from which you can get the molten metal that can be poured in the cavity and the casting can be obtained,.

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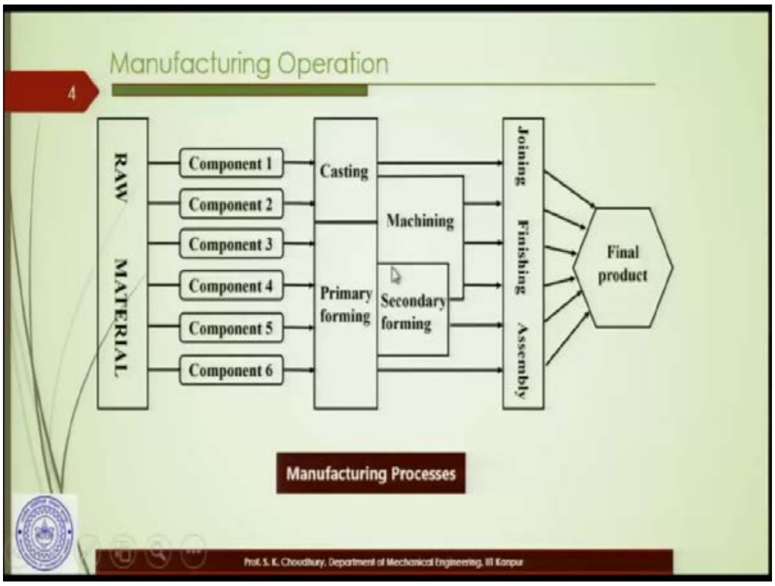

Next let me show the position of casting in the manufacturing operations. This we have seen earlier in machining courses, in other courses as well; so these are all manufacturing processes through which the raw material can go. For example, here if you see - all the raw materials; from the raw material you are getting the components 1, 2, 3, 4, 5, 6. Now, these components will go through different kind of processes; be it the primary forming or casting or machining or secondary forming.

Now, after going through these processes, some other manufacturing process like joining, finishing, assembly they will go through and then we will get the final product. Here when the components are going through the manufacturing processes, not all components need to go through all the manufacturing processes.

For example, here in this diagram, the component 1 has been seen to be going through the casting. Now, there are casting processes which are very accurate; I just now told you that the casting process surface quality is not very good; dimensional accuracy is not very good. And after the casting, we have to use machining process.

In general, it is true. However, there are casting processes which are very precise operations. For example, investment casting is one of them, where you can get the final product of very high quality; dimensionally or accuracy-wise very high quality of the casting you can get. So, in that case after the component has gone through the casting, it can directly go for joining, finishing, assembly and so on and it will be ready for the final product.

Component 2 can go through the casting, and after the casting it will go through the machining and then it may go through the joining. Similarly, component 3 as well. Component 4 can go through the primary forming, secondary forming, machining and then joining, finishing and assembly and so on. So, what I mean to say about this diagram is that, not all components need to go through all the manufacturing processes.

And all of them like casting, primary forming, machining, secondary forming, joining, assembly - all are considered to be the manufacturing processes. Here is the place of casting. And as you can see, casting takes a very primary position in the manufacturing processes to get the final product from the raw material.

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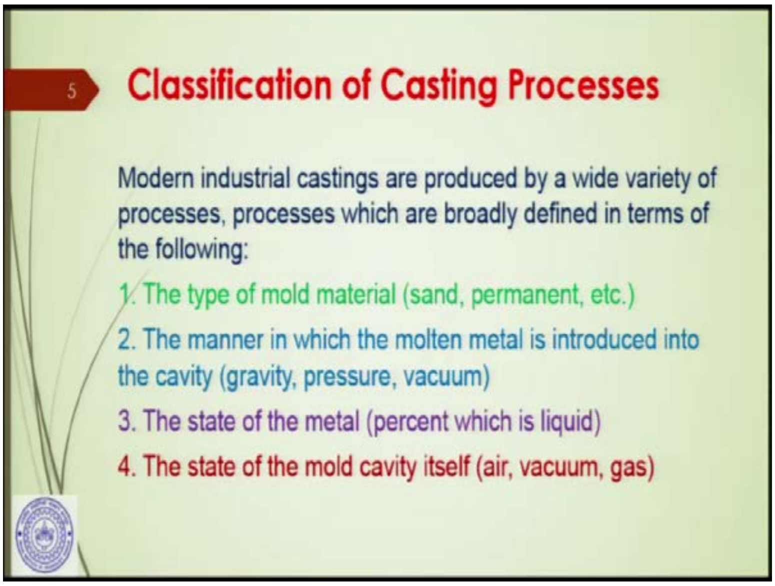

Let us see how the casting processes are classified. Modern industrial castings are produced by a wide variety of processes, which are broadly defined in terms of the mold material first of all. By mold material we mean to say that, what kind of sand materials, sand we are using; whether the mold will be permanent, or the mold will be once used type?

Like for example, if you are using the sand for the mold then after pouring the molten material when the metal will be solidified, to get the final product, you have to break the mold. The mold cannot be used again; whereas in case of the metal mold, there are permanent molds, where one and the same mold can be used several times.

So, the casting processes are classified depending on what kind of mold you are using; either it is a sand mold, or it is a permanent mold, like metal mold etcetera. The manner in which the molten metal is introduced into the cavity. It may be that you are pouring the molten metal manually. In that case, the pouring will be by gravity, it is just by gravity the molten metal is getting into the mold cavity.

Or you can use high pressure when you need the very intricate shape for example. You want the molten metal to cover all the intricate shapes of the cavity; in that case you have to force the molten metal into the cavity by means of some kind of external pressure. Or it can be vacuum, you create vacuum inside the cavity, so that the molten metal can be sucked; those processes also exist.

So, depending on the way the molten metal is introduced into the cavity, we can have different types of casting processes. Now, the next is the state of the metal; that means the percent, which is liquid, it may not be very liquid. In the sense that the temperature may not be very high.

So, it depends on how much percentage of the liquid, liquefied material that you will be using; I will come to that later. Fourth is the state of mold cavity itself; whether it has air, whether it has vacuum, or it may have the gas inside, depending on that the casting process can be classified.

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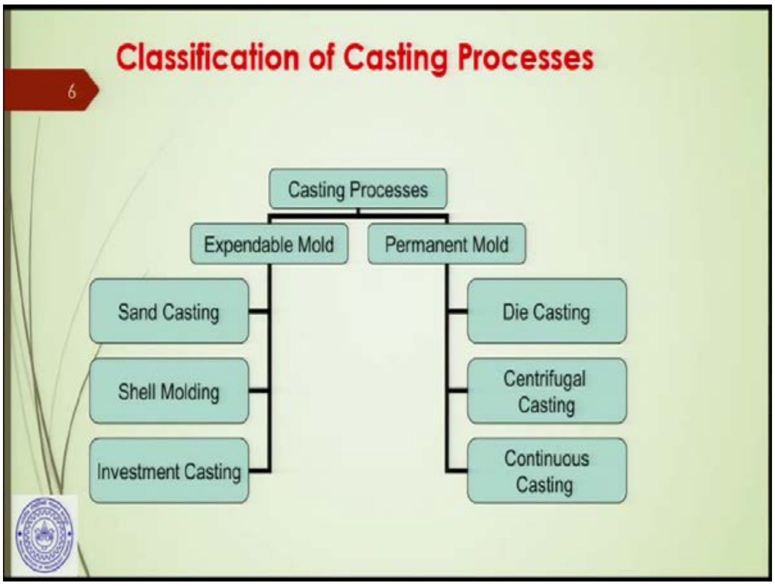

Here is the full classification. This diagram shows that casting processes are basically classified into two groups; one is the expendable mold and another is the permanent mold. I just told you about the expendable mold that, this is expended, that is, it cannot be used more than once.

For example, sand casting. Once again, I repeat that after you get the final casting, you cannot use the mold again; because you have to break the sand mold to get the casting. Same thing about the shell molding; you have a shell and you are pouring molten metal inside it. So, when the molten metal is solidified inside the shell, the only way to get it is to break the shell.

We will discuss the investment casting for example, there we have to actually take out the casting by breaking the shell and therefore, the shell cannot be used more than once. Therefore, this group of casting is called the expendable mold casting. Another is the investment casting, just now I told you about this. So, there also we have a shell and the shell is broken to get the casting. So, in this group, the mold can be used only once and the only way to get the final casting is to break the mold.

Second group is the permanent mold and I already told you about this that, permanent mold can be used more than once and using one mold, you can actually get more than one final casting. And in this group, we have the die casting, centrifugal casting, and the continuous casting. We will discuss each of them in great details at a later stage.

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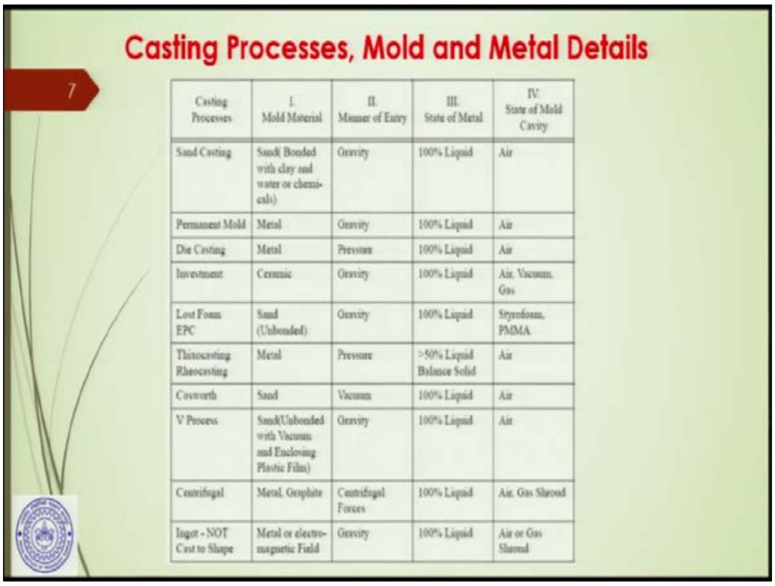

Casting Processes, Mold and Metal Details

Casting Processes	I. Mold Material	II. Manner of Entry	III. State of Metal	IV. State of Mold Cavity
Sand Casting	Sand(Bonded with clay and water or chemicals)	Gravity	100% Liquid	Air
Permanent Mold	Metal	Gravity	100% Liquid	Air
Die Casting	Metal	Pressure	100% Liquid	Air
Investment	Ceramic	Gravity	100% Liquid	Air, Vacuum, Gas
Lost Foam EPC	Sand (Unbonded)	Gravity	100% Liquid	Styrofoam, PMMA
Thixocasting Rheocasting	Metal	Pressure	>50% Liquid Balance Solid	Air
Cosworth	Sand	Vacuum	100% Liquid	Air
V Process	Sand(Unbonded with Vacuum and Enclosing Plastic Film)	Gravity	100% Liquid	Air
Centrifugal	Metal, Graphite	Centrifugal Forces	100% Liquid	Air, Gas Shroud
Ingot - NOT Cast to Shape	Metal or electro-magnetic Field	Gravity	100% Liquid	Air or Gas Shroud

Here we have the casting processes and for each of these processes, what kind of mold material is used, what is the manner of entry of the molten metal, what is the state of metal and what is the state of mold cavity is given here.

This is for your reference; you can see. And here of course, the main casting processes are the sand casting, permanent mold casting, die casting, investment casting, lost foam, EPC and so on. And you can see that, in sand casting, the mold material is sand; for permanent mold it is the metal.

And for die casting also the mold material is the metal where the molten metal is poured inside themold cavity under pressure. Therefore, it has to be 100 percent liquid. Now, there are some casting processes like thixocasting or rheocasting process. Here only the 100 percent liquid is not used; only 50 percent liquid and the balance is solid, these are very special type of casting which are rarely used.

Apart from that in all other processes, the 100 percent liquid is the state of the metal. And for the state of mold cavity you can see that mostly it is the air. In the investment casting, it can be either air or vacuum or it can be the gaseous medium. As I said that in lost foam EPC, we have the Styrofoam inside the cavity instead of air, which actually gets destroyed as the molten metal at high temperature is poured, that we will discuss at a later stage.

In centrifugal casting we have the metal mold or the graphite mold. Centrifugal forces are required or they are used to get the molten metal inside the cavity. Stae of the metal is of 100 percent liquid and the air gas shroud inside the cavity is the state of the mold cavity and so on. So, you can have an idea of what kind of casting processes are there and for each of them what kind of mold material, manner of entry, state of metal and so on are used.

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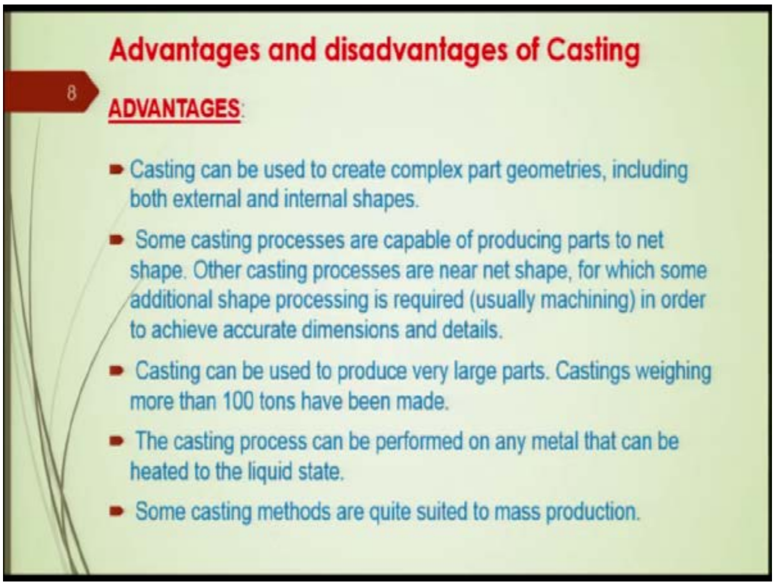

Next let us see what are the advantages and disadvantages of casting? There are lot of advantages that I already told you; the first of all if you compare with the machining, almost not at all wastage of material; that means, the volume of the end product, of the casting is the same as the volume that you started with. So, there is no waste. Like in case of metal machining, you are wasting metal by removing the extra material in terms of small chips.

And as you know that, those chips cannot be reused; of course in casting, you will see that there is some material which has to be cut off from the final product like the gating system as you know or sometimes the flanges. But that material is again remelted, it is not wastage; whereas in case of machining, the chips are waste, you cannot reuse, remelt the chips, because as you know that those are strain hardened.

Those chips cannot be reused as the metal; whereas in case of casting, even the gating system that you are cutting off from the final casting can be remelted. So, there is no wastage that is the first advantage.

Next, the casting can be used to create very complex part geometries, including both external and the internal shapes. Now, why we are saying that? In machining it is difficult, because of the difficulty in producing the relative movement between the tool and the workpiece, if the workpiece is of a very complicated shape.

Particularly when the internal shapes are very complicated; because normally we get the internal shapes in machining by milling and then you have to grind, we have to polish them and so on. But in case of casting it is easier; because you can make one pattern of that complicated shape, one core for the internal intricacies and you will get the final product, whatever intricacies that we are having in the casting.

Therefore, the casting can be used to create very complex part geometries and that includes both external and the internal shapes. Now, some casting processes are capable of producing parts to net shape. About this I already told you; like in case of investment casting, you do not need to have the machining process or you do not need to have the allowance kept for the machining to remove the extra material to get the final dimensions and you can get the final product in the net shape.

There are only few of them, few of the casting processes through which you can get the final product in the net shape. Other casting processes are near net shape. By near net shape we mean that, for which some additional shape processing is required, for example, machining.

In most of the cases it is machining, it can be turning, it can be grinding, it can be milling depending on what kind of surface finish you want to get, what kind of tolerances you want to get in the dimensions and so on in order to achieve the accurate dimensions and the details.

Now, next point, in the advantage is that the casting can be used to produce very large parts. Let me give you an example of the Spring Temple in China. There we have a Buddha statue the weight of which is 1000 tons. That Buddha statue was obtained through the casting process. Several other advantages and disadvantages we will discuss in our next session.

Thank you very much.