Theory of Production Processes
Dr. Pradeep Kumar Jha
Department of Mechanical Engineering
Indian Institute of Technology, Roorkee

Lecture - 01
Introduction to Theory and Practices of Casting

Dear friends, good morning. I am Dr. Pradeep Kumar Jha from mechanical and industrial engineering department of IIT Roorkee. So, we will have together the course that is theory of production processes. So, you must have gone through the introductory video of the course and this course is normally for those students or for those learners who have the basic understanding about the production processes.

So, in this course, we are going to discuss about some of the theoretical aspects, how the things are done? What is the theory behind it? So, as you know that, this course has basically 3 sections 1 is casting, another is forming and then we are discussing about the welding.

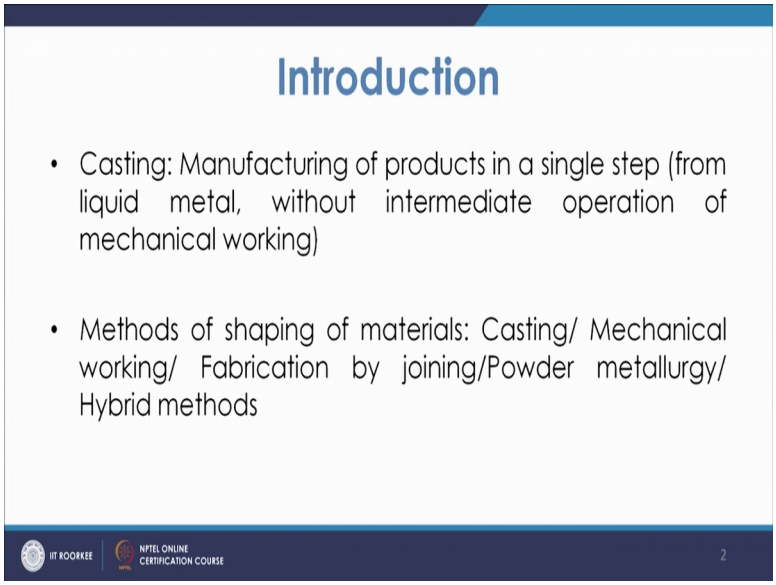
So, as you know we have already formulated those syllabus and in that in casting we are going to discuss about the solidification, getting, rising, type of foundry methods, then you have type of materials melting and all that. Similarly, in the forming we will discuss about different kinds of forming processes, their analysis, then before that we will also discuss about the critical aspects like about the stresses, then the rules of deformation plastic deformation or so, then we will go to welding. In welding, again we will discuss about the theoretical aspects of welding, metallurgical effects of welding, different types of welding processes and then, this is how we are going to learn together in this course.

So, I am quite confident that this course will be interesting to you and you will be able to utilize the knowledge which you have gained earlier for further enhancing your skills in the area of theory of production process.

So, coming to the first lecture, that is our lecture 1 and this lecture is basically for the introduction to theory and practice of casting. So, now, coming to the topic of casting, so in this lecture we will have the introduction, the theory about the casting theory and practice of the casting processes and we will also know that what are the different shaping processes available and further we will see some what history about the casting

processes and then what is the process in which this having to be followed for making a cast unit.

(Refer Slide Time: 03:09)



So, coming to the definition of casting, basically casting is defined as the manufacturing of products in a single step from liquid metal, without intermediate operation of mechanical working.

So, let us see, why casting is so much important? Now, there are many kinds of shaping methods of materials are available. Why shaping is required? As we know, that as an engineer we are required to exploit the available raw material of the nature, which the nature has supplied to us. So, we are going to exploit these raw materials and we are going to get something in a form which is going to satisfy our needs. So, that is what the role of an engineer is and for that basically as we know that we have different principles based on the science and mathematics.

So, we use those principles, we have other resources, so based on that we shape the material. As you know, that most of the natural materials we have in terms of results, we have the mineral deposits. So, we take these mineral deposits they cannot be used, so as you know that we had all these all the items buried, then they are in certain other form then they are to be extracted I mean you have to extract from it, the material which you need. So, that is how you extract the metal, so you have the iron ore, you extract I mean you take the iron ore from there you process it, get the pure iron.

So, then the thing is that once you have the iron ore and you convert it to the iron. Now, during the conversion basically you will have to see that you can shape it. So, for that as you know that since it is in solid state you cannot shape in the way you want, so you are converting it into the liquid state by heating it.

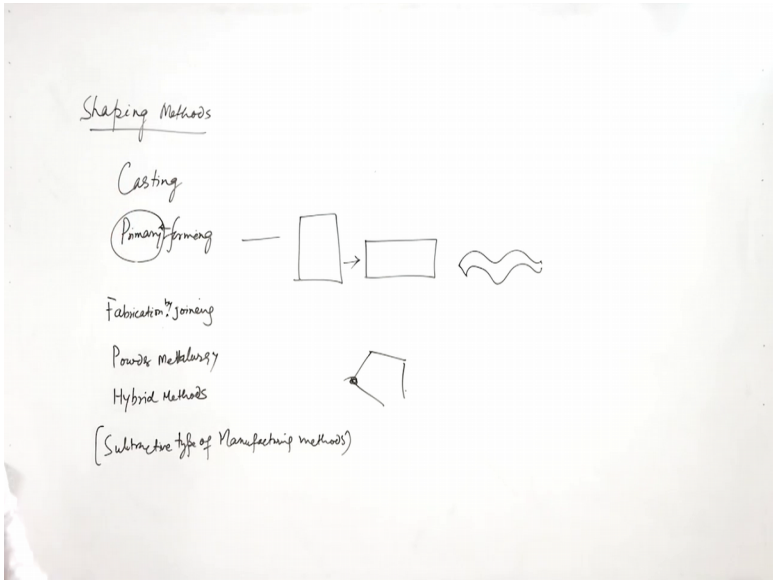
So, once you heat then that comes into a liquid state or you have other extraction processes by which you take it in a different form. Now, in casting what we do is, you are basically using this liquid state material directly and then you are getting final cast product. So, that is what the definition tells that you are manufacturing the product in a single step from liquid metal, out of the available shaping processes you have process like casting, you have processed like mechanical working, you have joining, you have powder metallurgy and then you have hybrid methods.

So, in casting as we discussed that you are, in 1 go itself you will get the final product. The only thing is that, you have to have that shape and group somewhere you have to have that shape which is called a mold. So, you have to put the liquid metal into it because we know that the liquid metal wherever it is poured or by enlarge a liquid wherever it is poured it will take that shape. So, the material is converted into liquid state and then it is basically put in that cavity.

So, once you take that material from that cavity, you know that you have the final product with you. So, you do not need to go for any intermediate operation. So, that is what the advantage of casting is.

Now, if you take 2 other methods of shaping like mechanical working. So, in mechanical working you work on the materials.

(Refer Slide Time: 07:26)



So, let us see you have the shaping methods in that you have the casting first. So, we will discuss about it, we have anyway discussed little bit, but as you know that in casting you have the cavity, which is to be filled by the liquid metal and once this cavity, the liquid metal which is there in the cavity that gets solidified because you have given the energy into somewhere or in the solid state, so that it converts into liquid state and then that energy is extracted, so again it will go into it is solid state. So, that, so directly you get the final product.

Now, other product are in methods like 1 is primary forming processes or you can say that forming processes mechanical working primary or secondary forming processes let us say forming basically. So, in that what we do is, we are applying the pressure or the force to deform the object. So, for that you need an object and that object must have a certain shape. So, you may have any object in any shape. Now, this shape you can not get as, but your will. So, you will have to make it and that you make by casting.

So, once you cast then you bring that stock material and you go for further forming it. So, you can form it and you can make it to this shape, you can have the different kinds of dyes, you can have different kinds of walls and you can apply the pressure on it and you can make any shape of material. So, whatever you feel depending upon the type of forces applied, depending upon the type of equipments used, you can have different kinds of products, you can have you know flat products, you can have hollow products, you can

have bars, you can have wires all that. So, that comes under the forming primary or secondary forming processes.

So, you can have it as the forming process is basically, you can leave it and then go for following processes mechanical working processes. Then comes, fabrication or joining; now, fabrication or joining is also a method of fabrication, so fabrication by joining basically. So, anyway normally whenever we talk about the fabrication term, we commonly refer to the term joining. So, now in that case the joining is as we know that you have to join the components.

So, you have 2 components and certain part is to be joined. Now, these things are required, when you feel that the whole component cannot be manufactured in a single run. Although, there are different methods of joining, but then for that again just like as we have seen that in forming you require a stock. So, similarly in welding also or in joining also you need a stock or you need a material in certain shape which is to be joined.

So, for that again you need some cast unit or some force unit or so. So, ultimately you need a material which is to be cast. Then comes, the powder metallurgy; now, powder metallurgy it is a new method or it is a good method, where you use these powders. So, these powders of different materials can be used now, because of the requirements in a different sense of varied nature. Nowadays, you require many a times the material, which should have many type of properties, you should have good lubricating properties; we should have very good porosity, we should have good strength, so all these properties.

Now, the thing is that in casting basically you are melting the material first. So, while melting you will have to see that the materials which are melted are normally of comparable you know melting points or so, but many a times and also they should have the gelling tendency with each other they would mix with each other at macro structure level.

Now, many a times that is not possible, you may think of having something some material, where you should have metal as well as ceramics that is not possible when you melt. So, when you will melt the ceramics will be different and that way the casting itself will be different, I mean difficult because once you cast, you cannot ensure the homogeneity of these ceramic, particles throughout the container or throughout the mold.

So, these are the challenges which basically are to be faced. So, they are basically taken care of by adopting this process of powder metallurgy, where you have the powders of different materials, you have the powder, you mix the powder blend them properly then further you go for heating it. So, you do not go to melting stage, but before that you come to sintering stage, use the pressure and then compact it. So, that the bond develops between the particles or the materials.

So, this way you get the powder metallurgy products, so this is 1, new method which is used, but this is used for, I mean do you have a limitation that you have the size limitation like you cannot make very large size products because you need the compaction, you need powder, for that you need a die keeping that lubrication and all that all this is a challenge. So, very large sized products cannot be made by powder metallurgy.

Then, you go then last is that you have the hybrid methods. So, in hybrid methods you have the mixture of these methods, you can have different kind of non conventional methods by which you can shape, apart from that you have other, if you try to classify you have this is known as additive type of manufacturing methods. Further, if you specify that way you have subtractive type of manufacturing methods like you go for machining. So, if you have a product and certain part is to be and remove lot of it you are going to use the machine for removing this material.

So, this way you are basically bringing the material into certain shape. So, you are removing that is why it is additive type further you have this is formative type where you apply the forming pressure and get the material in certain shape, then you have these joining methods another you know non conventional methods also. So, this is how the different shaping methods are there and casting basically is 1, which is again the most important of these processes because it does not have any intermediate step required. If you look at the other methods, you have many intermediate steps required in many cases like if you go to forming, the forming is in most of the cases does not happen in 1 go, you have to form there is a limit up to which degree you can form it in 1 pass.

So, in 1 pass you have certain deformation ratio further you go and further you go you here to heat in between. So, like that you have many 20 to 30 is many a times, if you go for forming processes in large steel plants or so, in earlier days when you have the ingot

kind of ingot steelmaking process was going on, still it is also going on, but many a times in many of the industries now we have the continuous casting setups.

But if you go to and visit any of the plant like that and if you see the forming setup you will see that you have to the material has to undergo I mean large number of passes. Then, the reduction suppose this reduction is there large thickness and it is to be reduced to plate may be more than 20, 30 or so, then more passes are there because it depends upon the temperature conditions, depends upon the properties of the material because that governs that how long and how much you have to form it. So, you cannot get the product in 1 go.

Similarly, you go to joining. So, in joining also you may have different passes, you have to go and then you have to otherwise you have many work to be done initially, then you have to get, further you have to see that the passes are right also. So, forgetting that shape, you have many controls required and then may be that once you are you have to attach a different place then you have to go and further do it. So, you have to further put in a different set up and different at a different position you have to further weld. So, if you have to weld at 3 places, so here, here and here. So, first of all you have to do welding here, then here, then here or so or else you have to put 2 mis or 3 machines.

So, like that. So, it means you cannot get the product in 1 go. Similarly, in powder metallurgy you have different stages, you will have first of all the powders of different materials, you have to blend them, then you have to mix and properly see that the porosity is not there mixing is properly then porosity is to be removed further compaction is their heating sintering all that, there are many stages and then you get the product.

Similarly, in machining also, as you see that you have to machine many a times and then you have to. So, you cannot machine large number of large quantity of material. So, there is a limit that how much material can be removed. So, what we see is, out of all these methods this method is a 1, where you get the material in 1 go itself. What are the major characteristics of casting process?

Now, let us discuss about the advantages of casting process. So, you have the weight range, as you know that in casting the advantage is that you can get very large size products whenever you require very large frame material. So, you can have that, so

weight ranges from very small, many few grams or so to large products which are made like star wine setups so and very heavy casting the streets are there, like a etsy is there, bell there, the sell is there, sale is there. So, like that you have many industries are large foundries so.

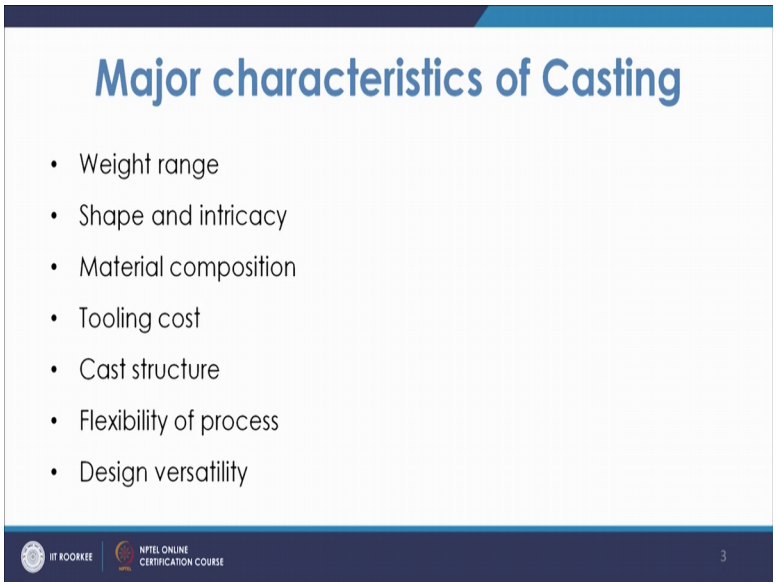
So, they use large foundries and because in that sense you can have the mold in the ground itself and you can so, there is no you do not have to do much, you do not have to take it to somewhere, you bring the liquid metal from somewhere and pour it here, all you can have any container and in there or mold and you can put it.

So size, in that you have the flexibility of weight from this small ornamental casting to very large size of lost tons of tons of casting I mean weight is possible in this case, shape and intricacy. So, in casting you can have any shape, you see depending upon the, so once you have any design in mind you will have to see that how to make the mold.

So, mold will be made or cavity will be made and this cavity will be made by making a pre replica of the product which you are planning to make and then you are doing in such a way that you remove this replica and get a cavity. So, this way you can have any shape of the material and since you have the development of newer and newer materials, newer and newer processes the intricacies also, the complex details can be achieved.

So, you have some you use finer materials, finer sands you use different kinds of binders or so, so this way the intricacy also can be achieved.

(Refer Slide Time: 22:09)



Material Composition, so this tells that you have the material of different compositions, I mean any material can be cast. So, material is there you see that the, this composition of materials basically can match. So, you just bring them, you just see that you can have the material. So, you use these materials put in the oven and you put in the furnace melt them and get, so do the cast product. So, any composition; varying composition of materials can be cast, tooling cost is normally less, you do not require very sophisticated kind of tooling in the case of casting.

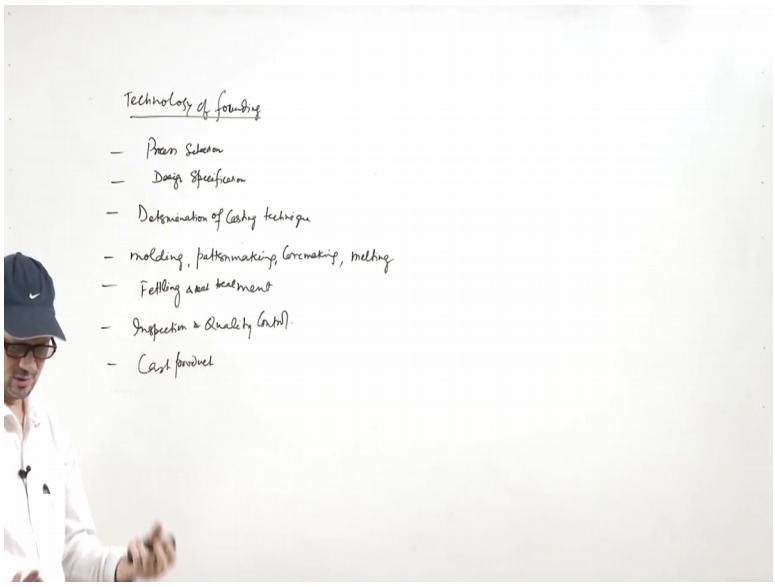
So, you have basically to see even in normal foundries you may have the foundries, foundries are the units, where the casting take place. So, in the foundries either it can be semi automatic foundry, manually you also be you can do the work or you can have the automated foundries. So, depending upon the requirements you can have different kinds of foundries and even if you work I mean if there is 1 of order, there is only 1 order for some unit is only possible by casting.

So, it is advantageous to get it by casting because you can have, you have the level requirement which is not required to be very, very skillful unless otherwise specified. So, this is the advantage in case of casting. You have the cast structure, if you get the casting normally you say that you have uniform properties in the cast unit.

So, that way you get a good structure and if you control the processes you can have defect free cast unit. You have the flexibility of the process, you have the flexibility

available with you that makes the process even more versatile further you have the design versatility, you can have different kinds of designs you have. So, these are basically the characteristics of a casting process.

(Refer Slide Time: 24:45)



So, if you talk about typical forming processes, so in the technology of founding or technology of casting, what you see is, initially you have basically some design in mind. So, you have the process selection, design specification, you have determination of casting technique, further you have molding pattern making, core making. Then once you have also the melting units, 1 after that you have see product ready then you go for fettling and heat treatment, inspection and quality control.

So, this is how and you get the cast product. Now, what happens in the case of casting that you have first of all you have to have in design that what you have to cast. So, and then you have also to see that what kind of requirement you have, what kind of accuracy you need, what kind of surface finish you need. So, that basically tells you that which kind of process you are going to use, whether you need a process where the surface finish is given very high quality.

So, accordingly you have to take that process, you may think of going for die casting where you use the metallic mold or you may go for the sand casting where you use the sand as the molding material. Certainly, when you go for die casting the surface finish will be better as compared to those in the sand casting, but if the requirement is such that

you need to have the product at a lower cost in those cases and also that you do not have to go for a very large number of units and the product size is larger in those cases you go for the sand casting methods.

Then comes that you have design specification is there. So, based on that design depending upon the intricacy or size you have to decide the process selection, then you have the casting technique. So, ultimately that helps in discussing about the casting process selection, which talks about the molding methods, the pattern making, the core making and then you have a separate section as the co I mean melting unit.

So, basically you have a probe a section, which talks about making the molds, the cavity in which the molten metal is to be poured for that you need a pattern. So, there will be a section known as pattern making. So, this pattern may be made of a wood or metal or so, so this pattern may be, so in that we will have designers and they will make the patterns giving do allowances so and then that pattern is to be brought to the molding section and make the mold.

You will have a separate core making section, so that, they will make the cores. So, that in the casting if you require the hollow projections, cavities then you need a core making section, once that is ready, once your mold is ready you need to put the liquid metal into the cavity for that you have a melting unit, where you have furnaces available. So, you melt the material and then pour into it.

Once, you are pouring the material into it, then basically they are to be extracted out of the mold and then you have many unwanted attachments with the cast unit. So, they are to be broken out like risers or runners or so and then also you do certain heat treatment, if you need to have or in any way sometimes some requirement is there that you need to have the surface to be little more hard or many a times you do the treatment for the removal of the residual stresses which are developed and then goes to inspection and quality control and finally, you get the cost product.

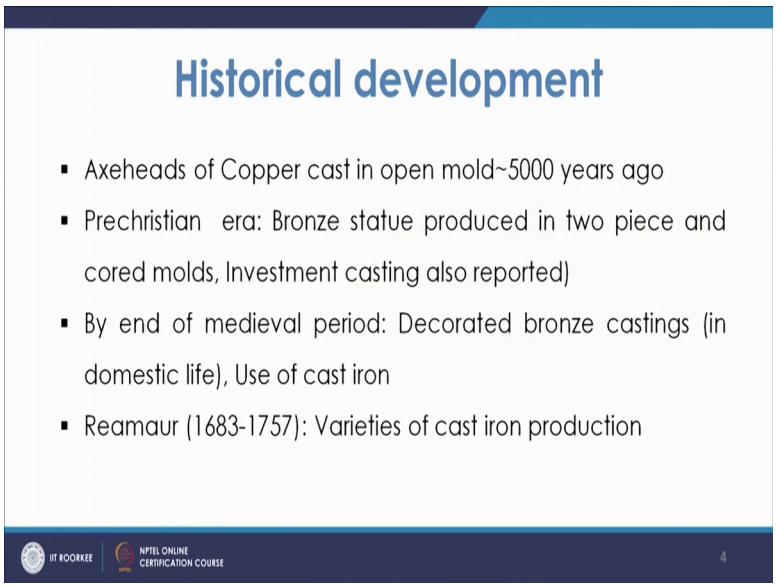
So, this is how the technology of casting works. Now, this is all about, so we will discuss in our coming weeks the topics like what are the molding methods? How the pattern making is done? How the core making is done? What are the melting units? So then, about these methods like, what are the fettling and heat treated methods so?

Now, let us see something about the history of this casting. So, as you know that this casting is coming from long ago as we see in the history. So, excess of copper were cast in open mold and these are these are reported maybe about 5000 years ago. So, this method of casting like putting, so earlier you had no such furnaces available. So, you have, but still you have pierce so.

So, earlier the process was that you melt it put in the pit and get the material in certain shape. So, it has been seen that this it has very large history and this was a very practiced method of making or shaping the material in certain for, even in the pre-Christian era, the bronze statue are produced in 2 piece and even core molds.

So, that has been reported even about the investment casting which we call now, it is kind of process also has been reported in the pre-Christian era. By the end of medieval period basically, that decorated bronze castings in I mean they are used in the domestic life, so that has been reported, use of cast iron was reported. So, these are the reported literature in the earlier period, but then you have seen the, I mean the rim or that is he had a life span from 1683 to 1757. So, he has done the pioneering work in the area of cast iron production. So, earlier iron means cast iron, even now we talk whenever iron means it is cast iron.

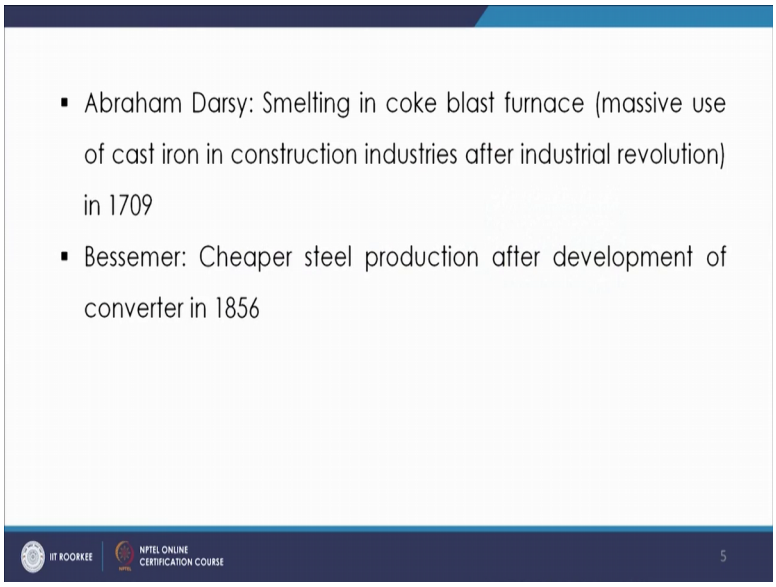
(Refer Slide Time: 32:27)



So, for the cast iron mainly he worked for the malleable iron, he talked about different kinds of cast iron, in motor iron and white iron or so, so he was the 1 from where, I mean

in the earlier literatures, we see that his work is very much referred from there the more good and good works started in the area of this casting or so and typically in the area of cast iron.

(Refer Slide Time: 33:06)



Then another name which is very popular, which is very famous is Abraham Darcy. So, at his time, basically from his time the smelting in the coke blast furnace that started. So, basically it was started in the allow period after the industrial revolution and when it was seen that large amount of cast iron was basically used in the construction industries.

So, that was in the year 1709, then further the revolution started and it is 1 of the most important revolution that is you have the use of cheaper steel production, with the development of converter that by Bessemer is done in 1856.

So, after that you see that 1 steel came, it has basically revolutionized the whole story, you have the steel which has very good qualities I mean if basically you have lot of work which was done after some of the tragic incident of the failure of the cast iron bridges or so, then once the steel came after that as we see, now we have every day we have the development of these processes, newer and newer materials are coming and this way what we see is the, now we talked about different kinds of improvement in quality, productivity how can we make cheaper and cheaper I mean the product are cheaper and cheaper rates with good properties, with tailor made properties or so, so this is how this curve we can say that casting process is gaining momentum, it will, I mean try to gain

momentum, it will continue to get momentum and will be useful for the development of mankind.

Thank you very much.