Welding Metallurgy
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Lecture - 01
Introduction to Welding Metallurgy

Hello friends, very good morning and very warm welcome to this course on welding metallurgy. So, it is my pleasure to be associated with you all. We will be studying this course welding metallurgy, hopefully you might have seen the syllabus of the course and I will be glad to be with you. So, this is the first lecture of the course and we will have the overview of the course as well as the introduction of the topics like welding metallurgy, how it will be useful for us.

As you know, let me give you some brief information that this is a 12-week course, so we will have different topics that we will discuss later and in that in every week we will have one assignment. So, that assignment will be you know visible to you, you have to solve the assignment questions, you have to submit it. So, ultimately it will carry certain weightage and then you will have the final examination towards the end.

So, many of you I hope have taken this course as a credit course and depending upon how you perform in this course, you will be able to use these you know marks or the grades for the academic purpose or for other purposes. So, I hope that you will be getting a full benefit and I will be also giving my best to make you understand to you know to make you, you know fully you know be aware about the contents of the welding metallurgy course.

So, as we discussed that it is a 12-week course and we will have different you know topics which will be covered.

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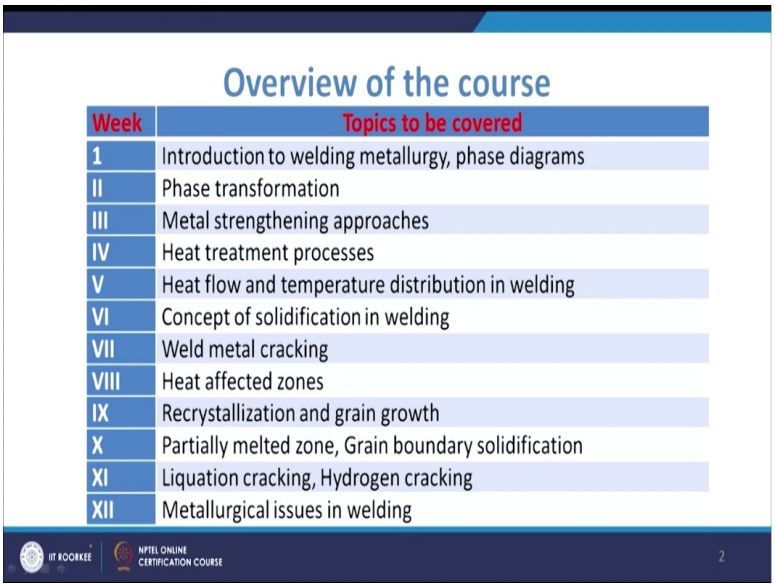

Now, the topics which we see that as we go week wise. So, in the first week, we will talk about the introduction to welding metallurgy and then we will talk about the phase diagrams, we will slowly come and discuss about the importance of the various topics, how they are going to be used you know in context with this course. Then, you have phase transformation, so phase transformation you might have also the introductory you know knowledge about the phase transformations.

So, we will talk about the phase transformation processes. Metal strengthening approaches that is another you know topic where we will talk about the different approaches; how to strengthen the metals and alloys, so will talk about it. Then, you have heat treatment processes; we know that we try to enhance the mechanical properties of the material by different types of heat treatment processes, so that will be covered under that you know in that week.

Then, heat flow and temperature distribution in welding. So, in that basically, we will talk about you know how the heat flow is there during the welding process, how the temperature distribution is at different places and then how the temperature varies with time, so that will give you an idea of you know temperature gradient, then depending upon that there will be microstructural changes so that will be discussed.

Then, you have concept of solidification in welding in the week 6. We will talk about the different types of welding you know solidification processes especially in casting and welding normally when we talk about solidification we normally cover you know or relate

that with the casting processes but the similar type of concept is there in the case of welding also, so that we will have certainly today we will be having some light over that.

Weld metal cracking will be in week 7, heat affected zones week 8, week 9 will talk about recrystallization and grain growth phenomena, then week 10 will be partially melted zone, grain boundary solidification. Then, week 11 is liquation cracking, hydrogen cracking and in the end in the 12th week, we will talk about the metallurgical issues in welding. So, overall you will have these 12 weeks and in all these 12 weeks we have 5 lectures each of approximately 30 minutes of duration.

So, you know all together we will have a very good you know time in between where we will discuss in detail about the different topics we will have it later. We will talk about it little bit in detail. Now, talking about you know the welding metallurgy course as you know, so welding metallurgy has two you know terms; one is welding, another is metallurgy and I hope that you are aware of these two terminologies. So, as we know that welding you know which is also one of the joining processes.

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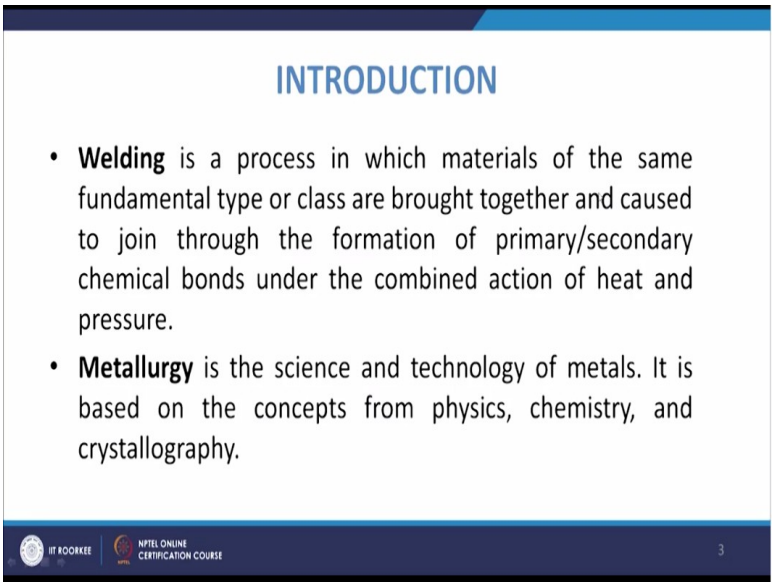

So, it is a process in which materials of the same fundamental type or class are brought together and caused to join through the formation of primary or secondary chemical bonds under the combined action of heat and pressure. So, if you try to look at the different type of welding processes or joining processes as you know, so we know that you have different type of joining processes that is one is mechanical joint where we use these rivets, we use the you know nuts and bolts, so they are basically.

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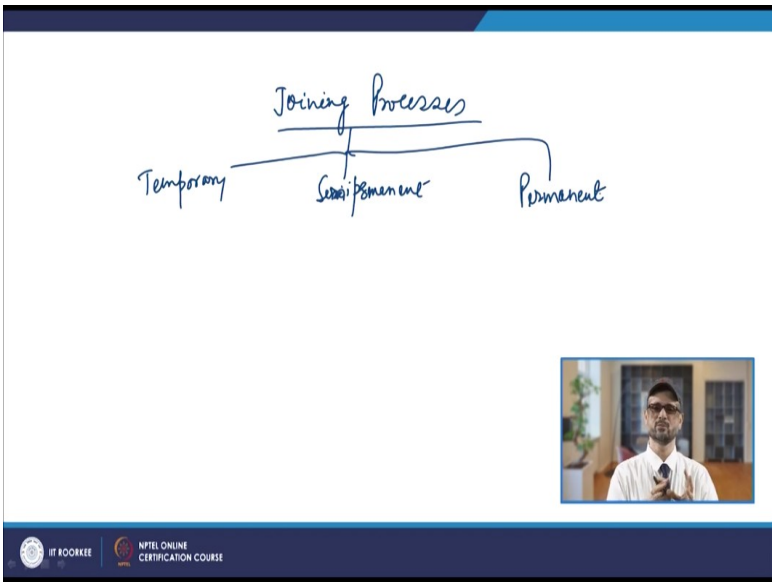

So, if there may be permanent or you know so once we talk about the you know if you talk about the joining processes. So, joining processes typically when we talk in a very broad manner, you may have the temporary type of joint, you may have semi-permanent type of joint and you have permanent type of joint. So, as we know that when we are trying to join you know for engineering applications many a times you have to join two materials.

Now, their joining can be either temporary or semi-permanent or permanent. In temporary means you have you know metal which is two parent metals which are to be joined. So, in the case of temporary, whenever you feel you can dismantle them, you can take them apart and both your you know the parent metal as well as the metal with which you are joining, the medium with which you are joining they are intact like you have nut and bolt joints.

So, that is the example of temporary joint. Similarly, you have a semi-permanent joint where whenever you try to dismantle them you have to take them or separate them, in that case your parent metal is not at loss, you are not losing but certainly the medium with which you are joining that is lost. So, that is your semi-permanent type of bond and joining and that is the typical example is rivets.

Because when you remove these plates which is riveted then the rivet material is gone and then comes the permanent joint. So, in that permanent joint basically we are concerned with those you know processes where it is a permanent type of joint or if you try to you know

remove them or separate them in that case there is loss, I mean loss to both because the joining is at you know molecular level.

So, you have then both of them are to be altered again for further you know application. So, in this case when we talk about welding metallurgy, so this is basically the welding classification of welding process in that and then in this case we are going to talk about the processes which are coming under these permanent type of joining processes and again in permanent type of joining processes, you may have classification based upon the type of heat source.

So, whether you apply you know pressure or you are not applying pressure your type of source may be based on electric, based on chemical that is fuel. So, you will have basically fusion type of welding in these cases and when you fuse the material and when you do the joining in that case because of the high temperature there is likelihood and there is certainty also on the changes in the microstructure of the material in a zone.

So, that zone basically has the changed structure, changed mechanical properties. Now, that is to be understood how that is changed, then while joining also what kind of you know changes take place, what needs to be taken into account so that ultimately you are getting a good weld. So, basically when we talk about temporary joint or semi-permanent joint now we are thinking of you know in temporary you are simply thinking of joining.

So, we are not going into that metallurgical aspect whereas when we are going to permanent type of joint especially the fusion welding processes, now in those cases, you are melting a zone and then that zone gets solidified. So, during that process whatever changes occur typically in a casting process like you will have you know solidification. Now, most of the defects which are coming, you know apart from the defect which arises due to moulding material they are separate.

But the defects which are coming because of the weld metal I mean cast metal, so those kind of defects are likely in this case because this is also a type of solidification. So, you know in these cases, you need to look into those aspects to ensure that your weld metal ultimately your aim is to have a sound weld so that you have better mechanical properties towards the end.

So, what we see that in this case, your purpose is to join them for formation of the bond under the combined action of heat and pressure. So, both the actions are there, under that basically your aim is to have you know the best mechanical properties, defect free product. So, you are thinking of having such you know you have to analyze on many aspects what way you know the properties may change, what way the properties may be affected, how the you know how the physics can be interpreted basically while doing that process.

So, all these things we will have certain you know session or lectures. So, we will have these lectures in a continuous manner and we will talk one by one about all these processes. So, in that we will see that we have to discuss about the metallurgical aspects, material science aspects. So, in that we are talking or going to talk about you know phase diagrams where we will see that how the two metals which are going to be welded.

Now, if or filler metal which is there in the weld pool, so how they are going to make the compounds whether we are not going away, whether we are likely to have any you know undesirable intermetallic compound formation or how good gelling will be there. So, those aspects will be you know studied, then we are going to also talk about the strengthening approaches and all that.

So, metallurgically you must be able to you know better understand so that you are able to give a good weld joint. So, as we discussed that welding we know that welding that is a type of process. Then, metallurgy; what is metallurgy that also we know, it is the science and technology of metals. So, in that we are talking about the science and technology of the metals, how you know that concept is coming from the physics, chemistry and crystallography.

So, basically we talk about the material science aspects. In that, we talk about the metals, different type of metals, their behaviors, then how they can I mean how they can interact with them with each other when they are molten, so that will be based upon the phase diagram principles that you know we will see that what type of phases are formed at what temperature and in that also we can discuss further about the phase transformation processes.

We will talk about the solidification mechanisms, we will talk about the different phases which are formed and by undergoing the different kind of atmosphere like if you have different type of cooling mechanism, if you have different type of heat treatment, then how the different phases are formed and how their mechanical properties will be different. So, all these things we have to understand in that and then you know different way of, different types of you know processes will also be you know studied to understand it better.

Now, coming to know more about the metallurgy, so it is the science that explores why metals behave the way they do, so in metallurgy normally that is what we are you know trying to understand that why metals behave in a certain manner, why certain metal will be you know giving you more strength when you edge (15:49) or why certain metals will give you more strength when you cold deform them.

So, basically in the case of science of metallurgy you know we are going to talk about you know the behavior of the material and it will also explain the properties behavior and internal structure of metals. So, in that we try to understand that what is the internal structure, we go from crystallography, we talk about you know how the crystal structure is, how it is going to have the different properties when combined with other material. I think these things you must have studied in the course of material science.

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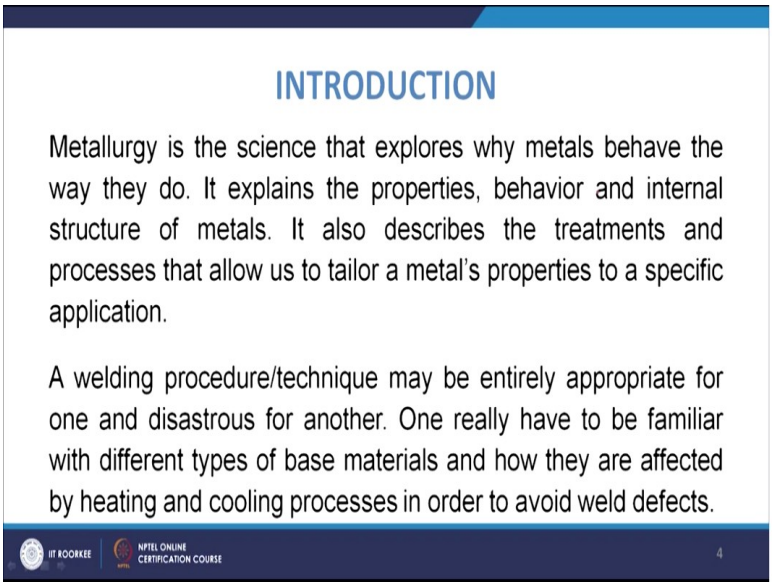

Then, this from there you will be able to explain the properties, behavior and structure of metals. It will also describe the treatments and processes that allow us to tailor a metal's properties to a specific application. Now, when you know that what will be the behavior of

the material when subjected to a certain kind of treatment, then depending upon the need, upon your need you can try to you know tailor the material's properties.

You can have the different type of treatment you can give to materials and in that you will get the tailor-made you know properties that can be used for a particular application and that way it will help you to come up with new and new materials which are used for, which have to be used for you know different type of advanced applications. So, nowadays we certainly need you know we have the need of welding.

And for that you know at many places and for that we must understand that when you have the tailor-made materials with tailor-made properties, then how to again further weld them because you see once you have the material, the challenge is that how you can increase the longevity of you know component because many a times they fail. So, rather than bringing the new material, you can use them by you know welding.

And then further use it for large you know amount of time. So, that will increase the productivity of the organization. So, that will be the metallurgy. Then, welding when we talk so that is basically kind of procedure or technique which is entirely appropriate for one and disastrous for another. So, that is what you know we needed to discuss that if suppose you have one metal and you have come to a different type of a process, you have fabricated or you know you have devised.

So, you cannot say that that will be used for another metal too, so many a times if you use the same thing then that may be disastrous for other. So, you must have the proper understanding you know you must be very familiar with different types of base materials and how they are affected by heating and cooling processes. So, basically when we talk about welding, so it is nothing but when we talk about fusion welding, so you are heating and then you are cooling.

Now, the way you do for one metal, another way you do for second metal that may be may have a different effect, completely different effect. So, these things need to be kept in mind so that you get the best properties.

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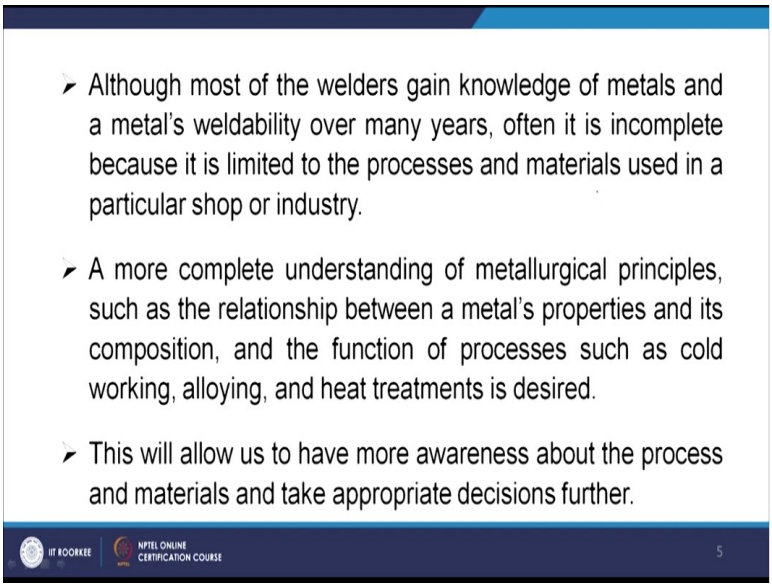

Now, certain issues like although most of the welders gain knowledge of metals and a metal's weldability over many years, often it is incomplete because it is limited to the processes and materials used in particular shop or industry. So, as we discussed that many a times some person may be working on a certain process or on a certain material for many you know for large amount of time.

But that does not mean that he is expert in all these all other processes because you know that the mechanism is different, the result which have to be obtained they are different. So, you need to have a more complete understanding of metallurgical principles, so that is required. You must know the metallurgical principles, you must know the metallurgy behind it so that like the relationship between metals, properties and its composition.

So, you know if the metal is having different composition what will be the properties, like many a times you are welding two metals of same composition with and you do not have a filler material, so you are using filler material of different composition, you must be able to know that if you are using the filler material of different composition, then what way it is going to affect the mechanical properties in certain area especially in that weld pool zone.

So, that composition and then the function of the processes such as cold working, alloying, heat treatment, all these things will have what kind of effect on the material properties that needs to be understood. So, for that you need to study the welding metallurgy in you know detail. Now, this will allow us to have more awareness about the processes and materials and take appropriate decisions further.

So, once you have a better understanding about you know the metal's properties and depending upon its composition, so basically many things will be clear from you know concept of phase diagram. So, from there you will have a proper understanding that which of the materials have you know better gelling, they can have they can make you in compound or better you know properties.

So from there and then also the phase transformation processes or the different you know processes like CCT or you know TTT curves will let you know that what kind of you know heat treatment process will give you which kind of phase which will be more useful. So, these things can be better understood when you study these welding metallurgy course.

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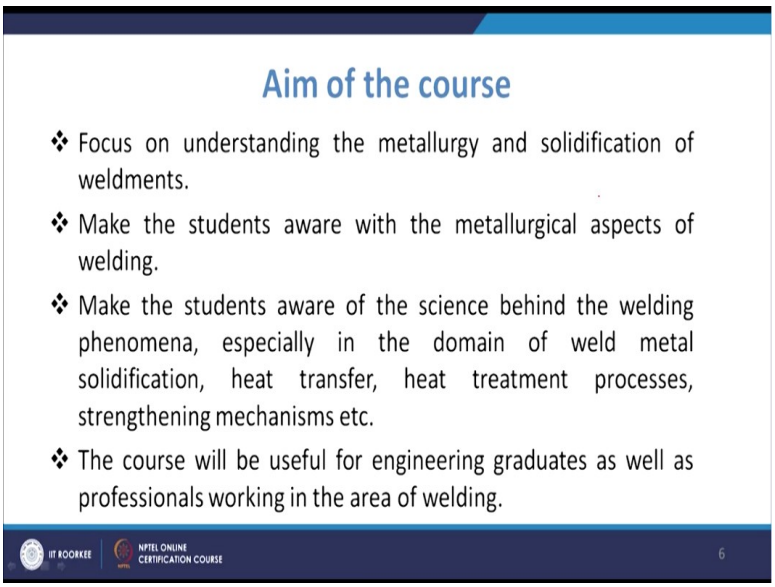

So, finally what is the aim of the course? So, as we know that we have to focus on understanding the metallurgy and the solidification of weldments. So, first of all, we must understand the metallurgy as well as the solidification of the weldments. Then, make the students aware with the metallurgical aspects of welding. There are many issues; many metallurgical aspects are there in welding.

You must be able to judge the weldability aspect also, how when you are welding two materials whether how weldable they are, how good bond can be developed between them. So, that is you know these aspects need to be understood. Then, you have the to make the students aware of the science behind the welding phenomena especially in the domain of

weld metal solidification, heat transfer, heat treatment processes, strengthening mechanisms, etc. will have one eye over there.

And it can be used for engineering graduates as well as professionals working in the area of welding and as we discussed earlier, so now we can see that these are the you know topics which are going to be covered, so in the first case, we will have introduction to welding metallurgy and we will talk about the phase diagrams where you will try to have the overview of the metals and its composition, its effect on the properties.

And different type of phase diagrams for ferrous as well as non-ferrous materials. So, what is the concept behind you know use of phase diagrams and how that can be useful when we are studying the welding subjects. Then, you have phase transformation, in that phase transformation; we are going to talk especially about the solidification you know aspects you know how the different type of heat treatments are you know.

So, in the phase transformation basically we are going to talk about the CCT or TTT curves, so how the different phases which are transformed, how they are different when you have the different type of treatments given, different type of you know heating or cooling given, how they will give you different phases, so that will be under phase transformation. Then, you have metal strengthening approaches.

In that, we are going to talk about the different mechanisms because we know that we do not use normally the pure metals for the engineering purposes because they are either too soft or too ductile, too much ductile many a times and we have to compromise on strength in many cases. So, you have to strengthen them and strengthening can be based on many principles you may have.

The strengthening you know by giving proper treatment or you may go for you know the precipitation hardening. So, there are different types of strengthening approach that needs to be discussed and basically that also will be useful while doing the welding. Heat treatment processes we know that these processes are used to enhance the bulk properties of the material, many a times the surface properties of the material.

So, different types of heat treatment processes are there which are to be used. In the case of heat flow and temperature distribution in welding, now in this case as you know that in the case of welding if you take the example of welding, it is nothing but when you talk about the fusion welding, it is nothing but the movement of a heat source in a particular direction and you have the heat dissipation on the sides.

Now, as these sides on the both side you have parent metal and that is normally a very small dimension. So, the heat transfer rate is quite high normally and how the heat transfer is going to be, how much fast it is and how it is going to affect the properties, how the you know the speed of the welding is going to affect the properties. So, these you know different things will be discussed in the case of heat flow and temperature distribution in welding.

How the temperature will, in which area temperature will be more, how it will decrease in the nearby zones, so that will be studied in that. Then, you have concept of solidification in welding. So, in that basically solidification in welding is somewhat different simply because in the case of you know solidification we know that normally you have heterogeneous and homogeneous type of nucleation and that is basically further.

After nucleation, you have growth so that is normally the mechanism of solidification. Now, it is a kind of heterogeneous nucleation where you have one you know layer which is available and from there, there will be further growth. So, in the case of welding normally epitaxial type of growth and depending upon the rate of solidification or the degree of temperature gradient which you are getting in that case that will be deciding how much brittle will the metal be or how much ductile the metal be.

Whether you need to give further any treatment to reduce the brittleness which you have achieved by the sudden cooling of the material, so all that you know weld metal cracking, so that is cracking is another issue because when you do the welding, so because of the heat flow because of large temperature gradient because of the stresses involved, you have the you know examples of cracking.

Cracking is very common in the case of weld metal. So, that needs to be understood what type of cracks are there, what are the reasons for these cracks and how they can be avoided. So, all these things studied. Heat affected zone, as we told that heat affected zone is required

to be understood because when you do the welding in certain zone, the microstructure is affected.

Now, there the properties will be affected. So, how to reduce that zone, what are the methods by which you can have the reduction of those zones and how they are going to affect the properties. So, basically based on that you can decide what way these materials can be used, so that will be in the heat affected zones. You have crystallization and grain growth because of the high temperature which you are going because we are going to the melting zone.

In this case, you will have recrystallization and grain growth and how that is going to affect the properties, will study different aspects of that. Then, you have partially melted zone, grain boundary solidification that is another issue which you know partially melted zones are there because at the fusion boundary zone you will have the partially melted zone and then you have the grain boundary solidification also.

So, these aspects will be studied. Cracking, hydrogen cracking that is cold cracking, so that is another way, another challenge in these cases and then further we will talk about the metallurgical issues. So, what are the different challenges which we face in the case of the welding and I mean from metallurgical point of view. So, this will be the normally the course overview.

We will be having the lectures, so in continuation and we will be having more and more interval. We will have also some live interaction about the different you know if you have any kind of you know clarification required, so we will have also you know interaction in between and hope that you will enjoy the lectures and you will enjoy this course and do good by scoring more and more in this course. Thank you very much.