Aqueous Corrosion and its Control
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Lecture – 30
Forms of Corrosion: Stress Corrosion Cracking (Part – II)

We shall continue to discuss the chapter on Stress Corrosion Cracking. In the last class, I started giving the historical perspective of stress corrosion cracking and then we also highlighted the importance of the stress corrosion cracking for the industrial component safety how it can impact the safety of the components. And, then we looked at the characteristics of stress corrosion cracking especially in terms of the cracking behaviour.

And, about the characteristics we said that these cracks are brittle in nature as compared to ductile failures happen in metals due to mechanical loading and these brittle fractures can be intergranular type or it can be transgranular type of cracking. Of course, sometimes you can also have a mixed mode of failures it you know partly intergranular and partly transgranular cracking can really happen. In all these cases they are brittle and mostly cleavage kind of cracking they appear.

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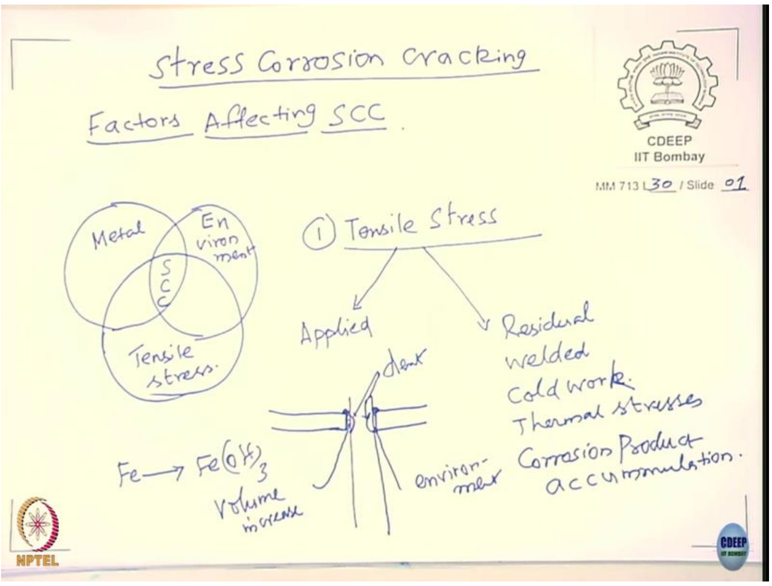

So, continuing on the same direction the next important thing that you like to know is what are the factors affecting stress corrosion cracking. If you recall I have given you the Venn diagram right wherein we discussed what is stress corrosion cracking. This is SCC, the phenomena that happens and the factors involved are the metal or the material, the environment the third are the tensile stresses.

So, if you need to understand what are the governing factors, we need to understand in relation to the metals the metallurgy of the material that we used for a given application, the environment that the material will be exposed to and the nature of the tensile stresses ok. So, all these are going to govern the susceptibility of a material towards stress corrosion cracking.

And, if you start with let us start with the tensile stress. Please notice that we are not talking about fatigue or we are not talking about the compressive we do not talk about the torsion right. We talk about the tensile stresses.

The tensile stresses acting on the material can be classified into two categories; one it is applied, the other residual stresses, right. The applied stresses are it know a process specific right what kind of load you are applying externally in a chemical reactor you know it can come out of the pressure of a reactants and products involved ok.

And, the residual stresses they reside in the material because of let us say the welded component. You weld it and the weld zone as you could have a tensile component and somewhere in the weld component you can also have a compressive component we have. So, there is a the residual stresses acting even you remove all the external loading or stresses on to a component ok. It could be a cold work.

You have done a wire drawing, you have done you have done some kind of sheet metal you know formed by rolling operations. It can be thermal; can be the thermal stresses acting on the material or it can also be related to corrosion product accumulation in the system, right. The corrosion product accumulation can come depending upon the situation. I give a illustration. You guys have some exposure heat exchangers we have seen, right.

In heat exchanger you would have tube and a tube sheet. You weld it right you weld you weld it or something expansion joint actually you know mostly is an expansion joint right, you expand it and sometimes you know you weld on one side you know normally they weld you know where it is facing outside they welded and this side is not welded right.

Assume what happens the liquid goes inside; the liquid goes inside the environment penetrate what can happen? For example, you have iron the iron can convert into what it can convert into various corrosion product one of the product could be iron hydroxide it get form right. The volume of the iron hydroxide is more than the volume of the iron where it corroded right. So, volume increase so, volume increase right.

Now, there is a corrosion products here and volume increases what will happen to this tube? The tube will dent right it could be dent it can happen a dent; stresses will start acting on that ok. It can be very high tensile stresses. Now, these stresses can add to the applied stresses you can add to applied stresses. So, when you consider the material against you know stress corrosion cracking you need to take care of both the applied stresses and the residual stresses acting on the structure.

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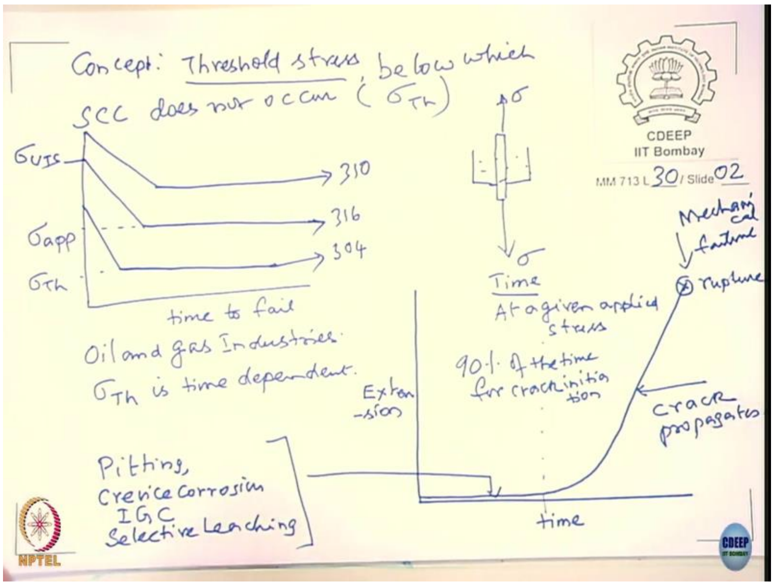

Now, there is a kind of I will say concept; I will say concept called as threshold stress below which stress corrosion cracking does not occur called sigma Th there is a symbol sigma Th. So, that this arises out of the fact that if you carry out a test in the lab, time to fail versus the applied stresses right you apply a stress you can conduct a simple test right. I can take a tensile sample and I enclose it you know in the cell I can take the environment here I can apply a stress on the sample right.

This is environment here and I can find out the time to failure simple test you can do and if you notice that something like that you know you get like this. When I apply a stress it fails instantaneously, right? What should be the stress at which the metal component fails a metal fails instantaneously what it is called? Fracture stress or what you call in normal term it is called as is called as ultimate tensile stress right.

But, if you lower the stress level in an environment the time to failure increases right is it not? As you lower the stress the time to failure increases and there is a there is a limit ok. And there is a limit and this is called as threshold stress below which metal is not failing. Now, this is used in some cases you know especially in oil and gas industries, they use this concept of that ok, but you notice that the threshold stress that we talk about is time dependent, right.

What do you mean by that? Suppose, you know here it starts failing so, you know that here it does not fail what is the time you wait for right. So, generally the time is say 1000 hours or 720 hours, if you wait for more it may start failing ok. So, this is not an ideal parameter, but it is used as engineering parameter to determine the you know applicability of a particular material especially in the oil and gas industries.

You come back to this later right and this concept is not used in the nuclear industries and again I will talk about it later why it is not used in the nuclear industries. But, nevertheless the literature as you know you see lots of materials you know people give this as a property of course, it depends upon the environment. You keep change the environment the sigma threshold could change its not a material property alone it is also an environmental property that I think you should you should be aware of that.

Now, in our example I would say this is your 304, 316 and with 310 something like that you know we can see that it can change, if you are going to use a duplex stainless steel things can still go up and the threshold stress interestingly sorry, threshold stress does not I mean remain constant for all the materials it can change.

Now, this particular thing is very important to understand from the concept of what happens in the stress corrosion cracking. Suppose, I apply a component and for a you know industry application how does stress corrosion cracking really work actually? Let us look at the time. With the time what things are happening? What will really happen with the time right?

This is the time and this is you can say extension you take a material and you apply a load you know and then expose it to the environment and you observe you see that you know the extension does not happen long time after takes place at a given load at a given a given stress applied stress. So, the curve change if the load is I was stresses you know increasing or decreasing, it could move left and right kind of thing right.

If you look at here what happens is you see generally between 90 percent of the time generally 90 percent of the time for initiation for crack initiation. So, this is where crack initiates and this is a the crack propagates, and this crack initiation it is a very interesting thing ok. This initiation time the initiation here involves it could be a pitting assisted pitting corrosion assisted one, it could be a crevice corrosion assisted or intergranular corrosion assisted one, it could be selective leaching.

They re all can be they are called as a precursors and they are involved in the processes. A pit turns into a crack an intra granular corrosion turns into a crack into a intra granular stress corrosion cracking right. A crevice attack can lead to stress corrosion cracking within the crevice can happen, selective leaching also can happen. So, these are the factors can assist stress corrosion cracking and since these are relatively slow processes and quite a bit of time is involved in the crack initiation.

So, when you talk about stress corrosion cracking control you should also understand that you can controlled by controlling the pitting corrosion, controlling crevice corrosion, intergranular corrosion, selective leaching all these stuffs. Of course, the metal can leak just with pitting only, it need not be SCC you know. Crevice corrosion can be standalone failure can happen, but if they are loaded and if the stress levels are beyond threshold stress levels yes, they can undergo stress corrosion cracking at a later time.

So, this is a very important and very interesting thing when you talk about materials development and materials design, actually the other thing that you like to notice is that please notice that the crack initiate and grows and finites a rupture right and this rupture is a mechanical failure; failure of the remaining portion of the specimen or component right.

Suppose, I have taken let us say about 1 centimetre thick component it is possible that stress corrosion crack exists up to 70 percent of the thickness remaining 30 percent of thickness it fails by over load I come to the point later ok. So, it is not necessary that entire sample entire component fails by stress corrosion cracking. This is very important because when you talk about investigation, when you take a failed component you would not see completely intergranular cracking or transgranular cracking, you will see yes there are brittle cracks, but we also see some part of sample having a ductile fracture.

The ductile fracture is coming out of the fact that it is a over load failure. The crack advances right it means the crack advances and then it leads to it leads to finally, over load failure you know see look at this here right. What is this actually? This one leads to ultimate tensile strength, right? Yes, if you lower the cross section you keep the same applied load, the stress increases and ultimately that comp that particular segment leads to a mechanical failure can happen in practice and it indeed happens in most cases actually ok.

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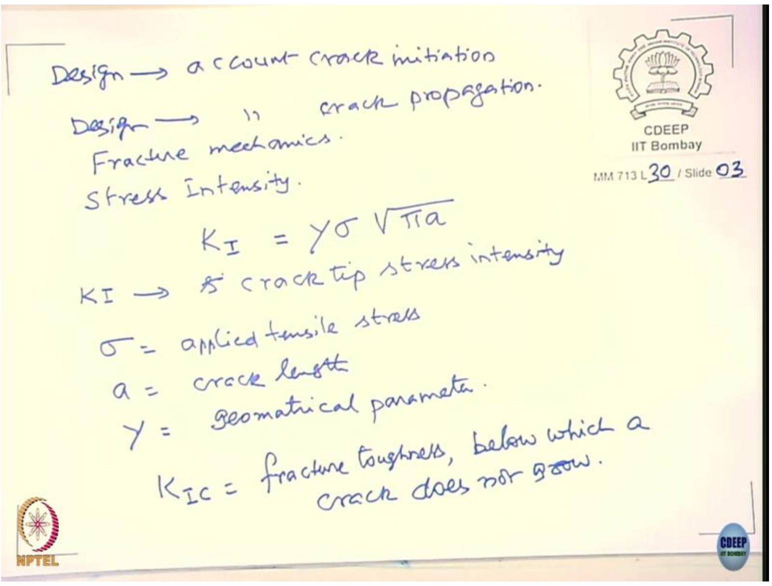

Now, that means, the two types of the two types of the two types of design people talk about the design that takes into account crack initiation and the design that takes into account crack propagation right. So, what do you mean by a design that takes into account crack initiation? I simply do not accept even a small crack the component because the metal is considered to be brittle and a small crack is there and it is going to fracture. So, there is a problem right there is a problem.

So, the design that takes care of crack you know initiation account they use the threshold stress as a concept, right? But, those design which takes care of the crack propagation they use the fracture mechanics as a concept as a criteria for that right. So, that is what they use it. Now, so, let us look at how the crack propagates again I am not going to deal with the fracture mechanics you know in details, but a bit of exposure to that is useful to see how stress corrosion cracking can affect the crack growth in any given component, right.

So, if I you know what is you know what is called as stress intensity factor, ok. What is stress intensity? You know and you of course, have different modes of you know loading that you have and mode I of loading K I is given by what given by Y sigma and square root of pi a right you might have again you know again studied in may be in other courses ok.

And, K I corresponds to crack tip stress intensity and sigma corresponds to applied tensile stress and a corresponds to crack length and Y is a complex factor anybody recognize? It depends upon the geometrical factors it depends upon the geometrical you see it is a geometrical parameter. So, we are not getting into too details about it, but it is you know it is I think sufficient for us to get a feel for stress corrosion cracking and crack growth in a given material.

Now, it is now look at here depends upon the applied stress and it depends upon the length of the crack which is related to K I value right. Now, you know very well that there is something called as K IC what is this called? Anybody? Yeah, it is toughness, it is a material parameters right below which a crack does not grow, fracture difference right, critical stress intensity factor or the fracture difference and below which the crack does not really propagate.

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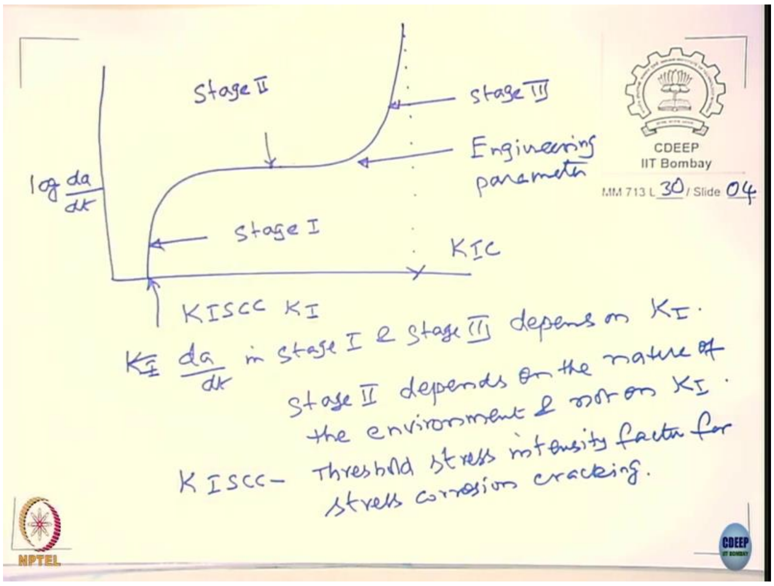

If I carry out a test to measure the crack growth rate versus crack tip stress intensity ok. So, if I plot a is the length of the crack and. So, da by dt corresponds to crack growth rate and versus the crack tip stress intensity, if I do that in a given environment of course, you will see that it goes like that this is called as stage I crack growth rate, called as stage II crack growth rate and this is stage III crack growth rates. What is special about it?

What is special about it? The stage I and stage II the crack growth rates depend upon the crack tip stress intensity whereas, the stage II does not depend on the crack tip stress intensity. Now, it depends on what? So, the stage II that K I no da by dt in stage I and stage III depend upon and so on applied stress intensity or cracked stress intensity.

Stage II depends on the nature of the environment and not on crack tip stress intensity factor. Again a lot of you know understanding there we will not get more details above this you know those who really want to do there are good papers available and so, we will not right now get into that discussion.

Now, let us look at the plot and this corresponds to what this corresponds to K IC and this corresponds to K I SCC ok. What is K I SCC? Threshold stress intensity factor for stress corrosion cracking. Please notice that if you have environment look at this plot we have an environment the crack can grow at a much lower stress intensity level right, much lower than K IC right. The K IC is here it goes much lower than that and in fact, this is they called as subcritical crack growth right and you know.

So, in the intensity of environment you can have subcritical crack growth that taking place in the material. That is a disadvantage of the environment actually that is something is used to be. So, the people use these factors and also people use this is another factor and this is also please look at this here the crack growth rate now does not depend upon stress intensity and this also is used as an engineering parameter to design the life of the component.

So, K I SCC and stage to crack growth rate in fact, there are designs just takes care of or used as only the stage II crack growth rates. They do not worry about all other things because if I know what crack growth see below K IC you are not supposed to have any crack growth rate at all. Why is that the crack is growing here? Because of the environment ok. Here of course, you have a combination of quite a bit of stress intensity and environment, but the role of environment here is much more here.

Because see there are two things happening: the stress intensity drives the crack first of all. The environment drives a crack more. When you lower the stress intensity the driving force for crack growth is decrease or increased?

Student: Increased.

When I lower the stress intensity of the crack tip driving force for the crack is decreasing or increasing.

Student: Decreasing.

Decreasing, right? So, it is so, if you move over like this the driving force for crack is decreasing crack to grow is decreasing, but what keeps up? The environment keeps up. The environment is making the crack to grow. If there is no environment in this case the crack growth rate has to be almost the crack is not supposed to grow at all actually right it is not supposed to grow at all. So, that is the meaning of this particular plot.

Student: How did the (Refer Time: 34:41)?

Student: How it will be without the environment actually?

Environment without environment is start from here only right. It does not start from here, it will it will start somewhere here only. It will go from here, it start going here, is it not? Without the environment the guy will start here only. In fact, this whole thing will not come into pictures it will start going somewhere here. Above K I is only the crack will start even growing at all it does not even grow. The crack is there, but does not does not grow if it is less than K I C if there is no environment ok.

So, crack will start you know you will see inside it will go like this only it will go like this or like this depends upon (Refer Time: 34:32) you know other things now ok, but it start from here only. Yes, did I answer the question?

Student: Yes.

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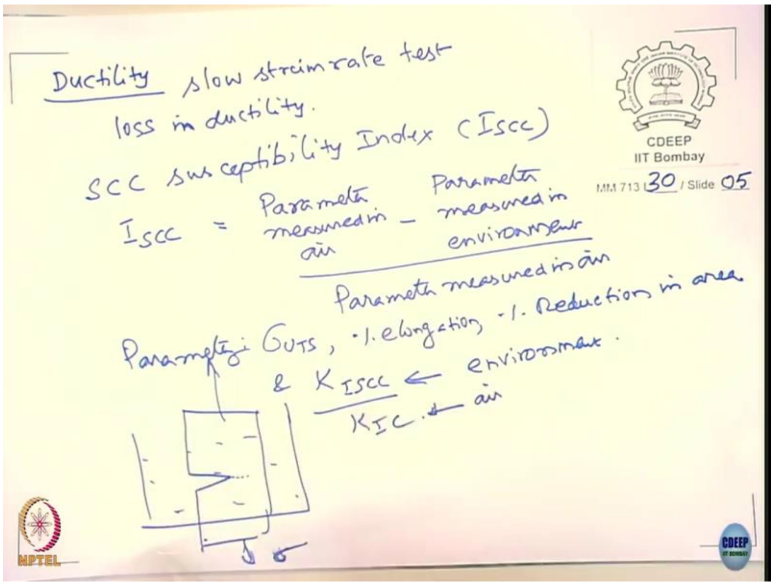

The other parameter that also counts the stress corrosion cracking in general of material is the ductility. The measured ductility especially on in a slow strain rate machines in a slow strain rate, I am not discussing right now strain rate test they use a concept called a loss in ductility. Please again notice all this again time dependent parameters you know. If you are going to do the experiment at a very low rate very slow pulling then the ductility might even decrease quite significantly.

So, it is again SCC is a time dependent process much like creep; only thing is creep occurs at higher temperature, but here this occurs at the it can happen at the ambient temperatures. It is very similar to the key process and but happening at the ambient temperatures. SCC can occur at higher temperatures I am not confining this to that what I am trying to see an analogy of SCC versus (Refer Time: 36:03) it is somewhat similar to (Refer Time: 36:03) which means they are all time dependent phenomena you should take into account ok.

So, we had; so, we had some idea about so that means, when we have this then people use a term what is called as SCC susceptibility index the term that is used. And, you might have if you attended other course as I might have discussed in details is given as a parameter measured in air minus parameter measured in environment upon the parameter measured in air.

This parameter can be anything you know it could be ultimate tensile strength measured there, it can be elongation reduction in area and it could be and it can be if you want to called yeah you can call it as K I SCC versus K I C, yeah. It is it is a K I C it is in air right, it is in air it is in the environment measured here. So, that is about the role of tensile stresses and how the material is going to behave in terms of the you know these mechanical parameters in presence of the environment we saw this you know briefly.

What ah yeah from the fracture feature of that also we if you if you can recollect the we said yes it is brittle you know and we also said that you know in a failed sample in SCC whether you do it in a laboratory test or in the field you also have a ductile fracture component in the specimen ok. That is happening because you know see let us just look at like this.

Suppose, this is notched sample right now sample notched and I have the environment here and apply that at the applied stress is constant you keep it like that, but as the crack propagates what happens? The stress increases right the stress the actual stress increases on the load bearing member of the specimen right. And as it moves then what happens? Stress can be equal to it could be K I C in this case in a smooth sample it can be UTS value and so, metal can fail in a ductile manner.

So, the last ligament that fails would have a ductile component in the in the material actually you can see that.

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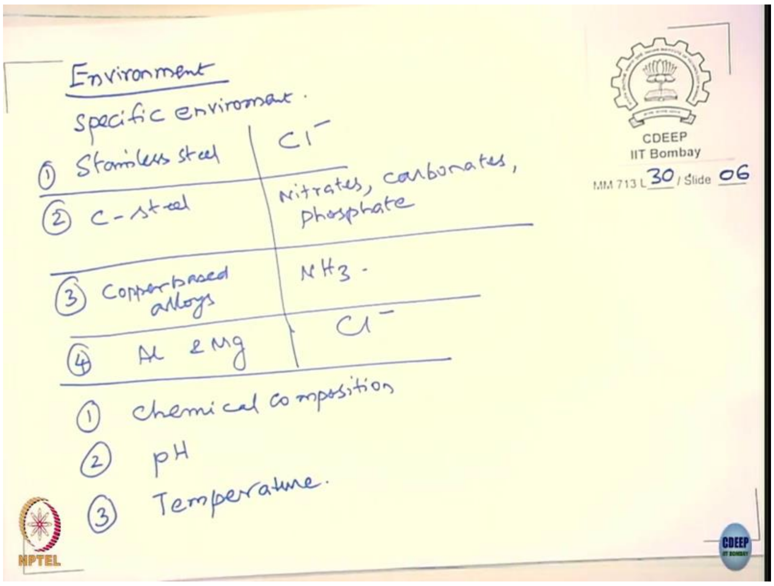

The next important thing that we should talk about is the environment when you see environment you know this always some kind of general you know feeling that it is specific to an environment is generally that kind of you know the concept provides. And, say you know to give an example stainless steel take that it could fail in the chloride medium ok.

In carbon steel it could be nitrates carbonates like that you know nitrates carbonates and even phosphates. So, what I am giving is just illustration not an exhaustive list and you are talking about let us say copper based alloys, say the ammonia solution is a problem. Similarly, when you talk about in aluminium and magnesium – chloride medium ok.

So, there are you know some kind of you know there are experimental observations right, but it appears that SCC need not be confined to a specific environment. The list of environments they keep adding with the time ok.

In fact, you know in a nuclear industry you know that SCC is observed in stainless steels in pure water. The water quality that they use in nuclear industries you know extremely very high quality, even then stress corrosion cracking occurs, but then the time taken for SCC to occur is more. But, the pure water can induce stress corrosion cracking on stainless steels at that temperatures at that pressure and over a long period.

So, the specific environment though people overall talk about it you know if you are going to be more technical I think this may not be totally correct ok. It can happen in many kinds of environments, but nevertheless environments play a significant role in terms of the life actually you know. What are these environments you say?

1 – chemical composition of the environment right say chloride, sulphates, phosphates all the stuffs. 2 – the pH of the environment. 3rd - the temperature. So, I have given a broad picture right and broadly you can you can say this chemical composition and pH and the temperature they can influence the stress corrosion cracking susceptibility of the metals.

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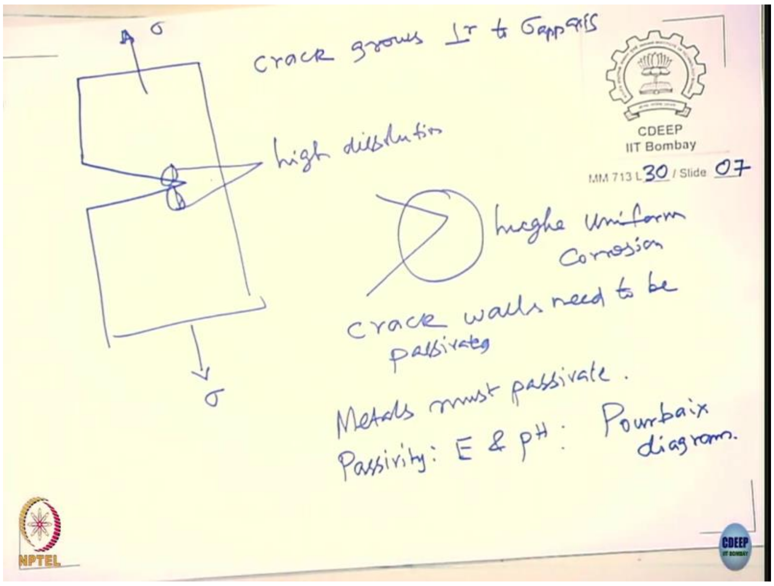

Now, when you look at this broadly speaking again let us look at you know our understanding of stress corrosion cracking; right now I am not go into get into mechanisms.

Let us look at the our understanding of the stress corrosion cracking. Now, when I apply a stress tensile stress you have a crack here pre-crack is formed here. The crack grows perpendicular to the applied stress right. The crack grows perpendicular to the stress axis. Stress axis is perpendicular to the stress axis it this as propagates you know it grows.

When you have an environment the crack has to grow the crack tip. If the crack grows for example, if the crack grows in sideway like that side way like this the stress has to be concentrated at the crack tip. Assume that there is a huge dissolution here right assume there is a huge dissolution, high dissolution, on the crack front the dissolution rate of the metal is very high. So, what will happen? What do you think will happen? I magnify this and here the huge uniform corrosion right it corrodes so much. What will happen there? The crack tip will blunt crack is no more sharp blunt stress concentration could be significantly reduced from that.

So, what it means for stress corrosion to cracking to occur so, for stress corrosion cracking to occur the crack walls need to be passivated. The film has to be there so that only the crack tip the corrosion occurs the crack starts from getting along the directions, otherwise the SCC will not occur. Assume that I want to use very strongly corroding acid SCC will not occur. So, the one criteria is that the metals must passivate. If they do not passivate, they would do not undergo stress corrosion cracking. The film has to be there on the surface.

And, say when you take a passivation right, when you take a passivation passivity depends on what? You guys already studied right it depends on what? It depends upon it depends on the environment it depends upon the potential and depends upon the pH and what is this diagram called? The Pourbaix diagram forms certain kind of broad you know indication where the stress corrosion cracking can occur for a metals.

So, when we when you said that the nitrates the carbonates and phosphates when you talk about it they are the ones they passivate the carbon steel and so, they are the ones they also promote stress corrosion cracking. If there are no applied stresses I mean they will be very happy the corrosion rate may very small and because there are tensile stresses the stress corrosion cracking occurs am I right ok. So, the passivity is a very important one. Is the passivity is a very important one? Yes.

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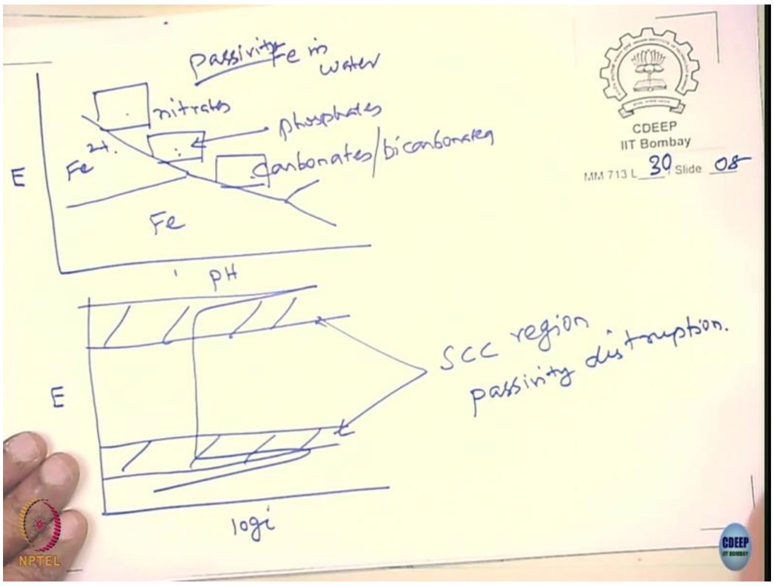

But, then if you look at so, then I want to draw this now. Say, it is your potential the pH something like that I think I hope you know this is for iron diagram right; it is for iron in water. So, you have carbonates and bicarbonates right and bicarbonates you have nitrates and you have phosphates.

So, these are the ones they the phosphates; that means, what does it mean? When you take a steel and have water and put a carbonate bicarbonate, the potential of that solution automatically goes this particular place and starts passivating and phosphate it goes here and passivates, put a nitrate it goes here. So, these environments maintain certain pH and the potentials and so, these are the places where you get stress corrosion cracking happening in these steels.

People also have shown that in the polarization diagram SCC region right is a polarization diagram you see this. They also found that stress corrosion cracking occurs very close to the pitting potential and very close to the active passive potential. These two potential region they are happening. So, how would you imply from this? What do you imply from this? Passivity is important, but if it is going to show absolute passivity there will be no stress corrosion cracking. The passivity so, it has to be an unstable passivity or something will should disrupt the passivity ok.

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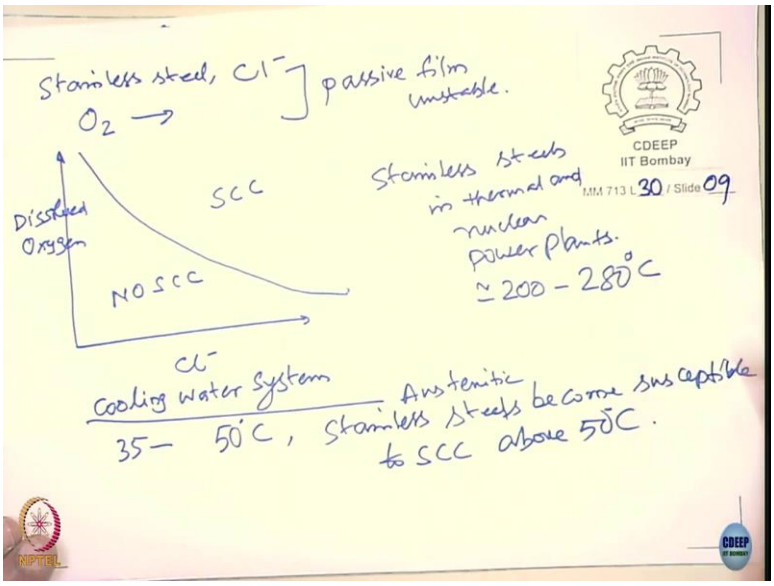

So, so the passivity disruption has to be there. So, you take a stainless steel what does chloride do? The chloride disrupts. What does oxygen do? Oxygen will take the potential towards a higher noble potentials, right. You have chloride, you have oxygen both of them they become they make the passive film unstable.

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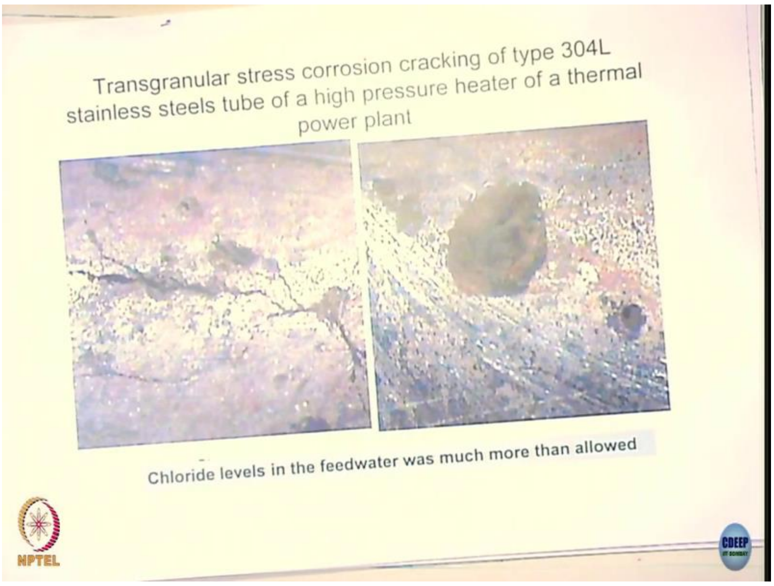

You can see that you know there are pits and the pits they become the place of the crack initiation the pitting occurs. So, the chlorides they do help to damage the film and then and when you are form a pit they become stress rises and lead to stress corrosion cracking. You know we discussed earlier that stress corrosion crack involves initiation right. And the initiation process involves we say pitting is one of the precursor event; you see the pits they are responsible for this corrosion cracking. It can happen and, so, they are they are they are the problems.

If this is the case they found a very nice relationship between stress corrosion cracking and the oxygen content. They call dissolved oxygen versus the chloride level SCC, no SCC. This we are talking about stainless steels in thermal and nuclear power plants. So, when you use so, what how do they how do they generate power? They use water, they create steam, the steam is used to turn the turbine.

So, the water should contain as low as chloride and the oxygen content so that they do not undergo stress corrosion cracking it is very critical ok. And, you will see that the oxygen content is in the PPB levels the chloride also is very very untraceable levels of chlorides ok. So, this are very important things when you talk about the material stability is you know in SCC.

Similarly, you also see this in the cooling waters systems the heat exchangers at the ambient temperature; see these temperatures are what? These temperatures are all around about 200 to 280 degree Celsius on very high temperatures ok. In cooling water systems the temperatures are all in the range of what? In the range of 35 to about 50 degree Celsius and you know cooling water is used you normally use a drinking water.

As the chloride content there may be 100 ppm from 200 ppm are going to be there, but then if you are going to use chlorides and then what happens? The stainless steels become prone to when I say stainless steel I mean austenitic; please make this change austenitic stainless steels become susceptible to SCC above 50 degree Celsius.

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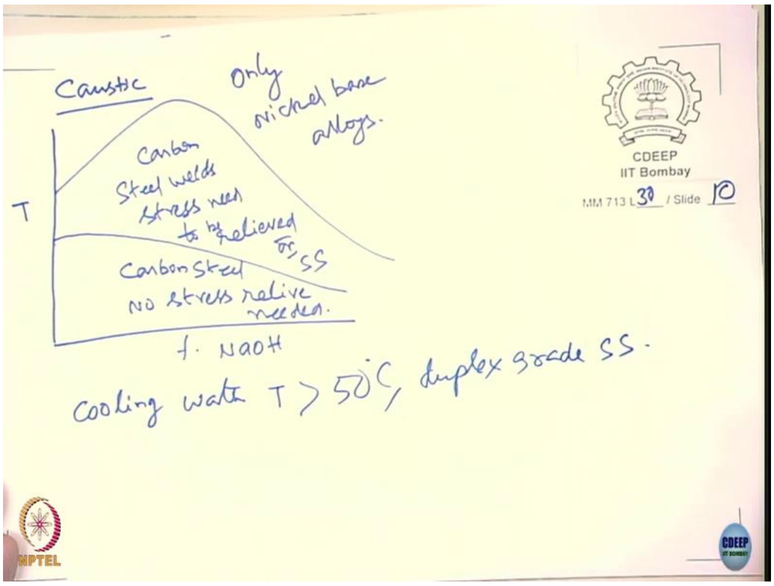

The other example I just give and then move on because you know there is several kind of you know cases we can discuss is illustration ok. When it comes to caustic and how you can promote stress corrosion cracking temperature carbon steel no stress relieve required and carbon steel welds or whatever stress need to be relieved or use stainless steels. Here only nickel base alloys.

So, put it in simple terms it is necessary for us to understand the environment you know before we have talk about what will be the right material when I say environment I would mean the pH chemical species temperature all the stuffs are to be known, so that you make right material selection.

Going back we talked about let us say you know cooling water, right? The cooling water the temperature goes if the temperature is going to be greater than 50 degree Celsius how do the people tackle? Tackle using duplex grade stainless steels they use that ok. So, you could find a solution right. Where you cannot use it you what you do? You bring down the intensity of the environment you know in boiler water you know 280 degree Celsius you cannot use to duplex stainless steels.

So, what happens you get rid of chlorides; you can get rid of the oxygen content. So, you can have SCC. In the nuclear reactors what they do in fact, they add even hydrogen, so that the potential comes down because of the presence of hydrogen in the system. So, you can modify the environment also in order to bring down these stress corrosion cracking tendency of the metals.

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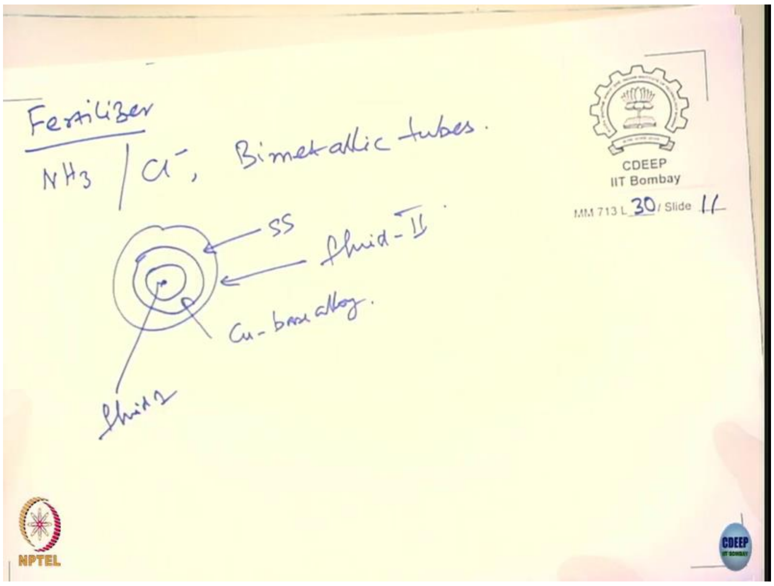


There are sometimes you get into a very difficult situation in the material selection it happens in the some industries like a fertilizer industry for example. The fertilizer industry say in a heat exchanger you use ammonia on one side and the chloride on the other side of it right, how do I choose a material? Right. If I have a chloride then I can choose a copper based alloy, it does not undergo stress corrosion cracking whereas, ammonia I would go for stainless steel because it is free from stress corrosion cracking in ammonia right.

But, I have streams one side you know maybe in the tube let us say ammonia goes in and cell side water goes in and water has got chloride. So, how do I do that ok? So, what people do in this case is they use bimetallic tubes. So, these are all tubes and in you have two different metals bonded actually right. One surface will have brass and inside you will have stainless steel, they are bonded and so, that kind of things are being used.

So, what you are trying to look at is if you know the problem you can find an engineering solution to the problem right. So, this is an engineering solution to the problem right. So, you can overcome the issue without any problems actually at all ok. And of course, they are expensive bimetallic tubes are expensive, but that is a solution that you have, so that you can overcome the problem of stress corrosion cracking in the fertilizer industries ok.

Student: Are these bimetallics bonded together?

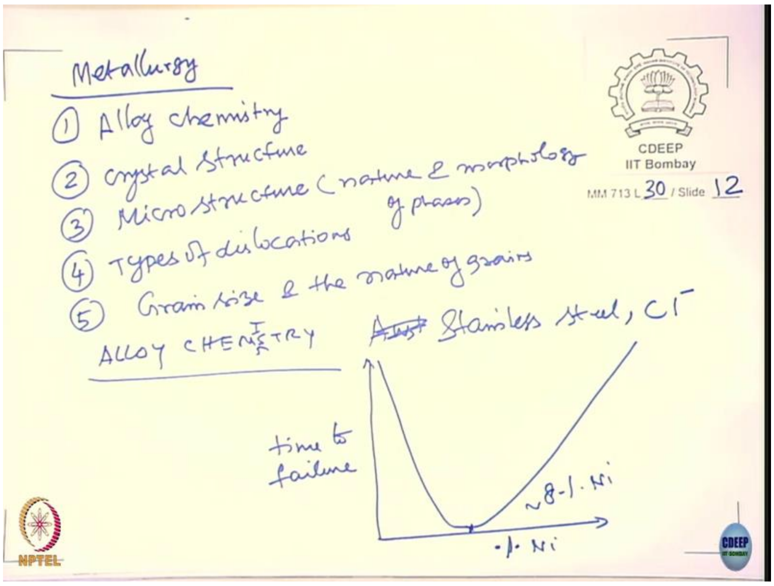
Yeah, they are just yeah they bonded.

Student: If the copper (Refer Time: 63:08).

You can do whatever; I mean it depends upon how the stream looks like, right. You can have copper outside steel inside depending upon of course, the technology that is available you can do that, but they are simply bimetallic tubes right.

What does mean know it is what it is right this may be your stainless steel; this may be your copper base alloy. Yeah, I will go inside this is one fluid here fluid I, here is a fluid II and so, what happens in this case I will send the ammonia outside right and the chloride containing one inside. So, I do not have any stress corrosion cracking issue at all. Any questions so far?

(Refer Slide Time: 64:26)



Let me go to the next subject which is and that is the metallurgy of that ok. It is of course, (Refer Time: 64:33) is very difficult to cover a huge amount of things here and I just give a very broad outlook and move because the metallurgy that you deal with stainless steel is different from than one you deal with aluminium alloys and with copper alloys. So, everything goes ok.

So, let us make a very broad discussion, so that you get a feel for what we mean by the metallurgy in relations to the stress corrosion cracking. It could mean the alloy chemistry could mean the crystal structure, microstructure when you say microstructured means the nature of phases nature and morphology of the phases. The types of dislocations in the system grain size and the nature of the grains. So, they all can happen.

Let me start with the alloy chemistry one example I will give to do that and I would take here the austenitic stainless steel or stainless steel I call it. And, it is stress corrosion cracking in chloride environment. Time to failure versus the percentage of the nickel content ok, goes like that. You know what is the nickel content of this? 8 percent nickel almost the one we use as a workhorse right 304 has 8 percent nickel and its worst.

Actually it is very difficult to separate out alloy chemistry, crystal structure, microstructure dislocation they are all intertwined it is not possible just to separate out actually you know not possible to do that because if I would add nickel and what happens the crystal structure changes from BCC to FCC. If you take if you add nickel then what happens? You will see that the stacking part of energy decreases. So, they are going to have different dislocation structure.

So, they are all quite intertwined, but still you can try to make you know you know some component of you know what really happens you know to the SCC from that perspective that point of view. So, the chemistry of the alloy can happen because you know at one point of time you said that passivation is a very important one right.

If you are going to add a very high chromium content if it is going to make the passivation very very strong then the stress corrosion cracking can come down as well actually ok. It is possible can happen you know from 304 to 316 and in some cases this they do see marginal improvement in the stress corrosion cracking of the alloy they do see that thing.

I think we can continue in the next class.