Aqueous Corrosion and its Control
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Lecture - 17
Forms of corrosion: Crevice corrosion (Part-1)

Today, we shall look at the another important form of corrosion called as Crevice corrosion. It is also called as under deposit corrosion. Sometimes called as waterline corrosion if you want to call it, a gasket corrosion. All these different names are given for this forms of corrosion.

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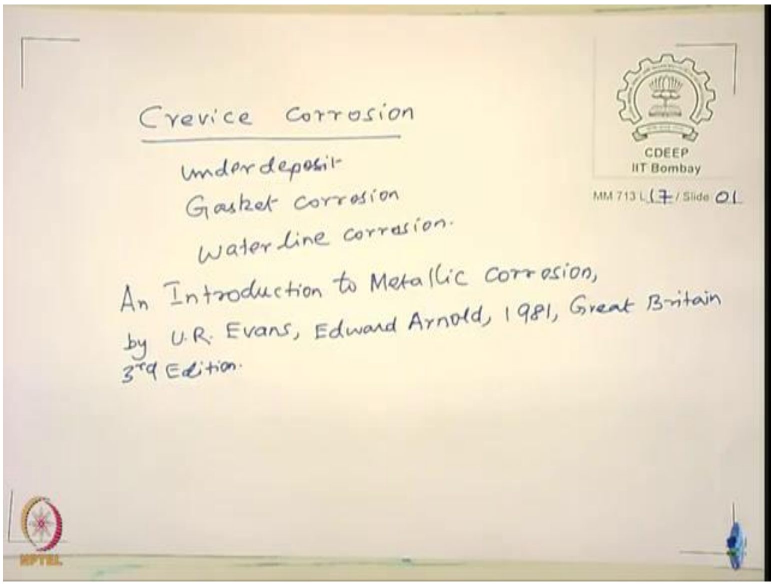

Crevice Corrosion

Underdeposit
Gasket corrosion
Water line corrosion.

An Introduction to Metallic Corrosion,
by U.R. Evans, Edward Arnold, 1981, Great Britain
3rd Edition.

So, crevice corrosion is a common name. So, it is called as also as under deposit. Some time called as gasket corrosion and is of course, similar to that is called as waterline corrosion. In all these cases there is something very common. It is a common mechanism. This particular type of corrosion problem is industrially very important ok.

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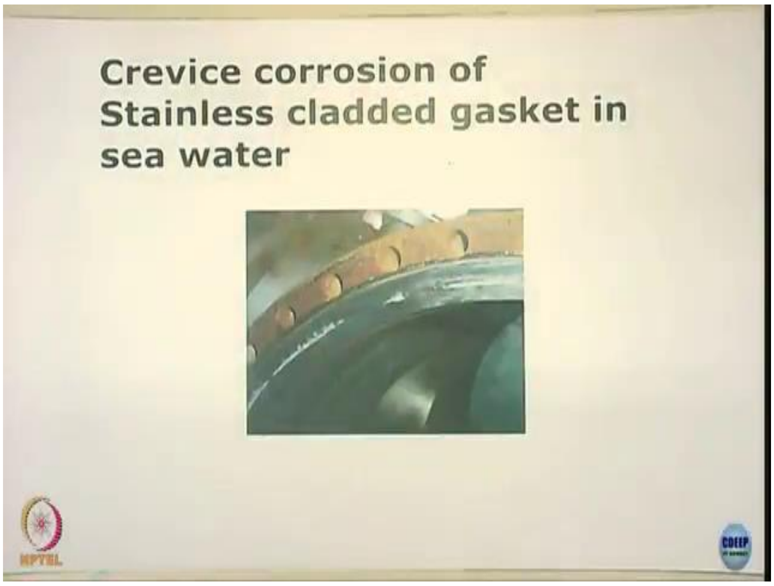

Crevice corrosion of Stainless cladded gasket in sea water

I show some examples of how the crevice corrosion will affect the performance of a component. What you have seen here is a flange joint of an heat exchanger ok. The heat exchanger is made up of the carbon steel you can see this and the carbon steel inside was clattered with a duplex stainless steel.

So, it is a stainless steel and it is a flange joint and use a gasket here right use a gasket here and the medium of exposure in this case was seawater. Now, you can see the corrosion right. The exposure is inside here. The attack is slightly inside see this is inside it is not at the mouth of this joint.

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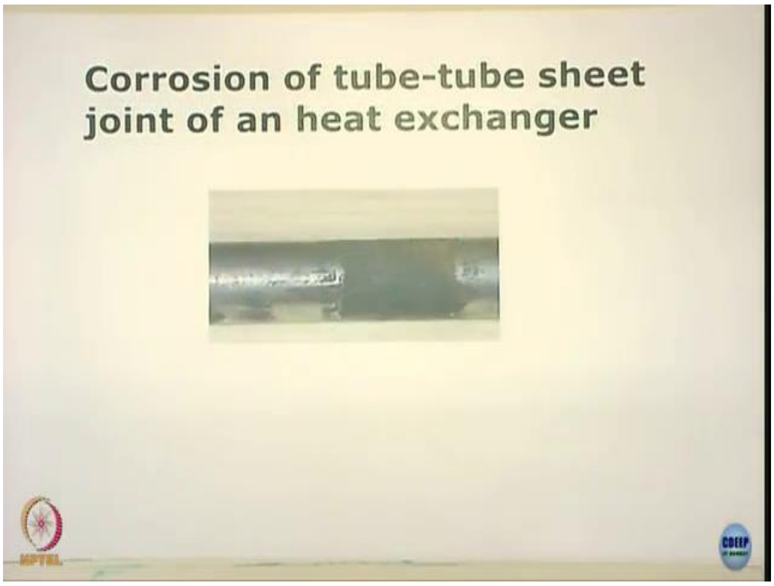
Corrosion of tube-tube sheet joint of an heat exchanger

So, these are the typical you call gasket corrosion or crevice corrosion joint corrosion problem. You have the other kind of joint you will see in the case of a the heat exchanger we probably brought out this heat exchanger in one of the previous classes.

Now, you have the tube and tube sheet joint right tube and tube sheet joint and this location is the tube and tube sheets joint here just expanded. See please look at it is a mechanical joint it is just expanded. You have a tube; you have a tube and surrounding that is a tube sheet.

You join them by expanding it this should bites actually and there is an airline gap. Now, look at this only the place where it is joined there is undergoing corrosion. It is a stainless steel it is used in the one of the high pressure heaters in a boiler operations actually there are no thermal power plants.

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Under-deposit Corrosion-
Stainless steel tube of a high pressure heater

These are joints. What you see here it is something I call as under deposit corrosion right. I hope you will able to see this spots here ok. These are the spots the fouling occurred. What does it mean by fouling occurred? Some kind of you know organic film or products accumulated on the surface of this. When they accumulated look at this below the deposit only more corrosion and the surrounding area there is no corrosion at all actually. Inside you can see that you know inside the steel you see there is no corrosion here ok.

So, wherever there are deposits and below the deposits it can cause corrosion of in this case the stainless steel ok. This is a common industrial problem and it can cause prematured failure of the industrial component actually it can happen. And I just want to introduce a new book and if you people you know can have a look at that.

This book is An Introduction to Metallic Corrosion by U. R Evans. I think you know all the name is very familiar to you right the Evans diagrams and it is published by Edward Arnold 1981 Great Britain. It is actually is a 3rd edition. I just introducing this book to you because you will see quite a bit of industrial illustrations importance.

Not much on thermodynamics and kinetics the way other books of dealing with, but it is a nice illustration exposures you see. There are some typical experiments in the laboratory to simulate the various forms of corrosion. So, when you people have time I think you can look at this book actually. I will give some nice illustrations as given in this book to show how this crevice corrosion can occur.

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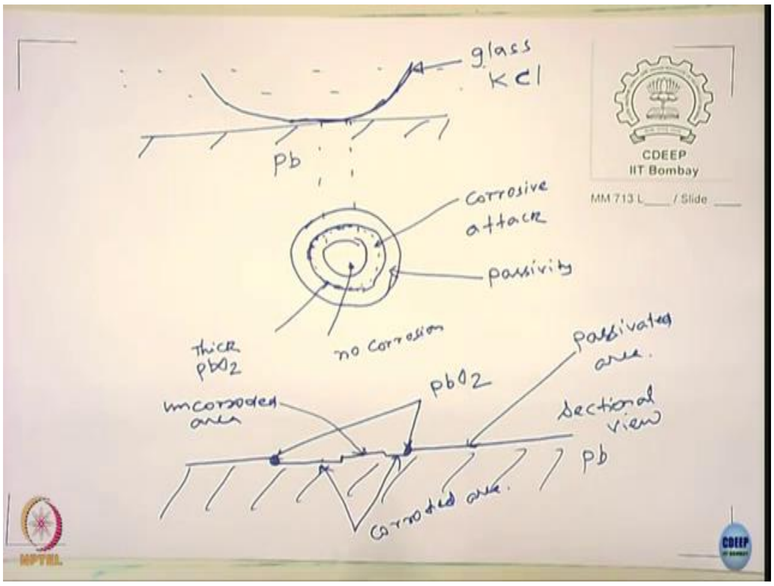

If you take a take a lead take a lead you immerse it in potassium chloride solution and you place a lenticular glass like this you keep a lenticular glass like this. Of course, in the glass you do not find liquid ok.

You allow the lead to corrode for some time and then you remove this the. If you remove this glass and observe the corrosion of the lead you notice somewhat similar to this ok. Here no corrosion taking place and surrounding this region corrosive attack and here onwards all you can case is you can see the passivity.

There is a corrosive attack and also you see you know over this place also see thick lead dioxide it is formed. This is the plain view; the plain view of the lead surface. You take a cross sectional view of this same thing you take a cross sectional view of this sectional view right. Now, of course, here you will see quite a bit of a lead dioxide. Here it is not corroded.

This is your uncorroded area. This is un corroded area and this area are all passivated area. It is very interesting observation right where the lenticular glass touches the lead quite you know I mean it touches I mean is the contact is so good it replaces the liquid completely. So, there is no corrosion between the liquid and the metal. So, it does not corrode.

But slightly away from it there is airline gap and in the airline gap I think corrosion takes place and this is the these are all the corroded areas area you see that. So, there is a very

very fine gap and there is a very fine gap that exist between the lenticular glass on the lead over there is a corrosion.

And the gap is quite large there is no corrosion and if the glass touches and replaces the potassium chloride solution completely of course, there is no corrosion, but in this is the place where the airline gap the corrosion takes place. So, airline gap is a critical issue in corrosion of the lead here. This one more illustration is very nice ok.

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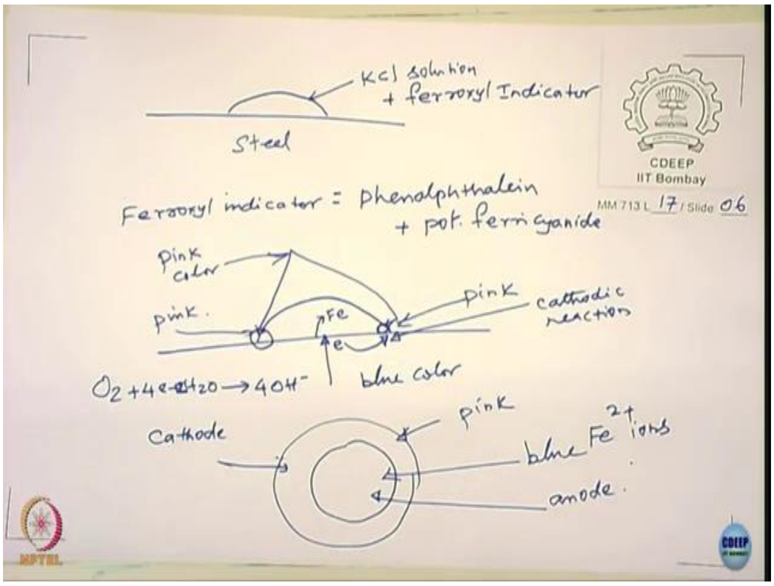

In another case you can take a steel take a steel and you have a drop of potassium chloride solution right you have a drop of potassium chloride solution with water. And to this you add what is called as ferroxyl indicator add to this and what is a ferroxyl indicator?

The ferroxyl indicator is prepared by mixing phenolphthalein with potassium ferricyanide. So, the solution consists of consists of what? It consists of a dilute solution of potassium chloride and the ferroxyl indicator and it consists of phenolphthalein and potassium ferrocyanide.

The very interesting thing happened in this case and if one watches closely you will see that over a time period here you will notice the blue coloration and here is location this location you will see pink coloration pink color ok. So, this is a pink color here pink and you have a pink color.

Anybody with the chemistry background you would understand this. When we have a phenolphthalein and you have a pink color what does really means the time. When do you get pink color in a solution containing phenolphthalein exist? Anyone?

Student: Acidic.

You said acidic. Is it alkaline? So, it is alkaline. So, when you have alkaline condition only you will get phenolphthalein giving rise to pink color. So, the edges in the periphery of the on the droplet completely if I take a; if I take a plain view of that if I see this as a plain view the droplet you will see the blue color and this is your pink color ok.

The pink happened because you have hydroxides and blue happens because you have Fe 2 plus ions. If Fe 2 plus ions they interact with the ferrocyanide potassium ferrocyanide you get a blue color and you have a hydroxide then what happens. You will get a pink color. How is that possible? How it happens it happens?

Because this area becomes a cathode. What happen to this area? This area becomes the anode. You take a steel you put in sodium chloride or potassium chloride solution the anode is where you have an oxidation. In this case the steel will get converted into Fe 2 plus and the electrons are released the electrons are consumed by a cathodic reaction.

If the water is a little you know neutral or little alkaline what is the cathodic reaction. The cathodic reaction is going to be what is the cathodic reaction here. It could be oxygen plus electron plus 2 H 2 O giving raise to 4 OH minus.

$$O_2 + 4e + 2H_2O \rightarrow 4OH^-$$

So, it becomes alkaline here you have the metal dissolved here. So, what does it mean here the iron is going out as Fe 2 plus.

$$Fe \rightarrow Fe^{2+} + 2e$$

The electrons are released here they go to this place and you have a cathodic reaction here ok.

Here you are going to have cathodic reaction at the center you have an anodic reaction. The reason is very simple what is involved in the cathodic reaction? What is the species involved in the cathodic reaction? Any of you? What is the species involved in the cathodic reaction?.

Student: Oxygen (Refer Time: 21:05).

It is oxygen present here. So, the oxygen; so, oxygen is the cathodic reaction in the peripheral or the periphery of the drop you know you have more access for oxygen there. The oxygen will enter from the air and go to the periphery and it start moving from periphery to the center the oxygen concentration decreases.

So, most of the cathodic reaction is confined to the periphery and the anodic reaction automatically is centered around the drop. So, you find that in a droplet you have separate anode and separate cathode spatially. So, it is not the uniform corrosion anymore. It is a localized corrosion it is essentially this is in fact, called as differential aeration corrosion.

The oxygen concentration at the centre and at the periphery is different. So, this leads to the another form of the corrosion called as water line corrosion. So, concentration cells. So, the key issue here is the concentration cell. What is the cell formed? The cell formed because of the change in the oxygen partial pressure in the electrolyte.

So, that is a key for the localized corrosion. This can be very well demonstrated actually. It can be very well demonstrated. Let us look at the a typical stainless steel which exhibits active, passive, transpassive behavior ok.

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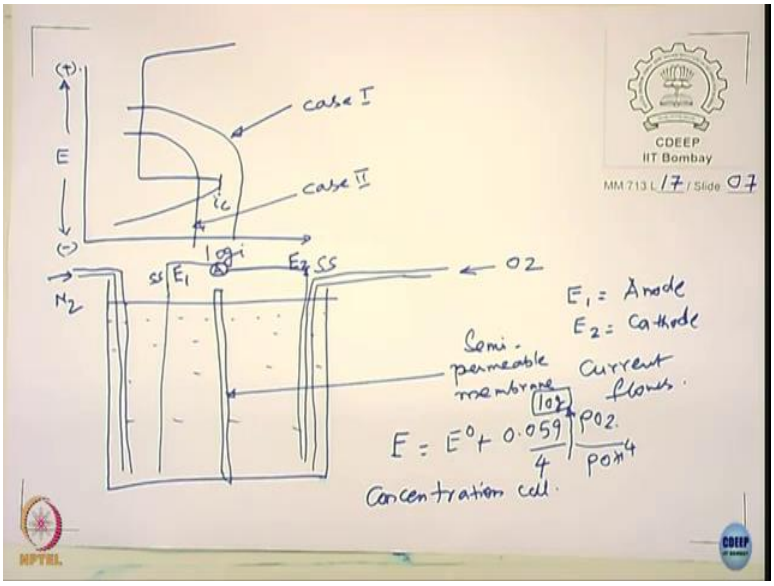

Let us just take a anodic polarization curve like this. This is your you know a schematic of anodic polarization curve showing active passive transpassive transition. The E_{corr} for this particular system would depend upon the cathodic reaction. Assume that the steel is exposed to water which is a neutral water.

The major cathodic reaction will be what. The oxygen reduction reaction. I consider water containing large amount of dissolved oxygen, the water containing other case less amount of oxygen there. So, I am going to draw the cathodic curves case I and case II. One case oxygen content is more other case oxygen content is less. Can you tell me which of the 2 has lower oxygen content?

Student: (Refer Time: 24:39).

Yes, case 2 how do you say that?

Right, but how do you say that? What are the basis for that? Why does it passivate readily? Why should it cross i critical?

Student: (Refer Time: 25:10).

If oxygen content is less so, what does really happen what is related to actually?

Yeah

Student: (Refer Time: 25:20).

Your oxygen is less then amount of oxidation amount of reduction may be less, but can you be a little bit more specifically you have seen some relation before.

Student: Oxygen is (Refer Time: 25:35) should be related.

So, the limiting current density is a factor that talks about right is not it. You all know that limiting current density is you know the concentration of the bulk of the species deduce that ok.

So, when the concentration of oxygen is less the limiting current density is less and so you will get E_{corr} of corresponding to this and you get E_{corr} with corresponding depending upon the oxygen content ok. Of course, we all know that when there is more oxygen content the more passivation takes place all these things ok.

So, on a metal surface coming back to the point on a single metal surface you know in one place you have more oxygen content another place less oxygen content. The place having less oxygen content would not be tending to passive.

The one place were having high oxygen content will tend to become passive actually. Because of what? Because the you need a certain you know current density to cross the i_c value which is i critical you need to do that. So, this is also was as demonstrated by another nice simple experiment actually you know.

What was done was, if you take a semi permeable membrane permeates for oxygen there and take this electrolyte. Suppose you take a it is a stainless steel take stainless steel and you close this, but what you do. You bubble one side with the oxygen there another side you bubble with nitrogen right. So, this is electrode 1, electrode 2 electrode 1 and electrode 2 take here and also you can connect this with an ammeter you connect with a ammeter there ok.

So, what will happen now? You have oxygen here and so what do you think will happen. Will that be a potential difference between E 1 and E 2 ok. So, what happens if there is a potential difference and you short that what will happen?

Student: (Refer Time: 29:12).

The current will flow. So, how does how does the current will flow here tell me? Current will flow from E 2 to E 1 or E 1 to E 2.

Student: E 1.

The current will flow from E 2 to E 1 right and so E 1 is going to act as

Student: Anode.

Anode this is going to act as a cathode and current flows agreed at these things.

So, what do you understand from here. If in a metal see the potential of the of the E equilibrium potential for the for the oxygen system ok, what is this one? E equal to E naught plus 0.059 upon 4 here right and the partial pressure of oxygen ok upon what the partial pressure OH minus to the power 4.

Yes thank you. I think I missed a log here log here ok.

$$E = E^o + \frac{0.059}{4} \log \frac{P_{O2}}{p_{OH}^4}$$

So, when the oxygen partial pressure increases the E increases tend to (Refer Time: 30:52) more noble and so it sets up what is called as concentration cell that leads to corrosion of metals.

Now, this is only one reason for crevice corrosion only one reason for gasket corrosion, but you will see that is not the only reason for that ok. You will see the environment plays a very important role. We will talk about soon, but the major initiative comes from the concentration cell.

Because the concentration cells make one place anode then other place as a cathode and making as you know localized anode and localized cathodes at macroscopic level. Please look at macroscopic. Why it called macroscopic? It is a gasket. They are few millimeters apart. It is not microscopic like the microstructures.

You see the if you see the situations. These are a as I told you important problem because you know there are you know you have a rivet joints for example, right you join in the metal with the rivets and you know flanges sometime heim joints and these joints would have some gap.

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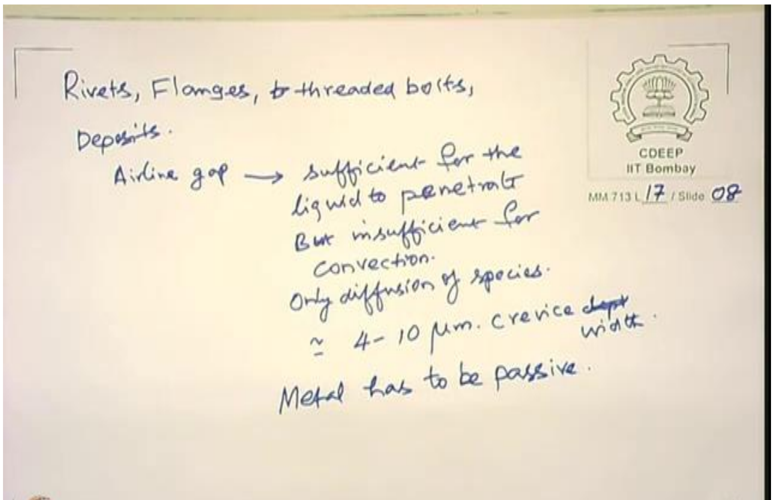

Rivets, Flanges, ~~to~~ threaded bolts,

Deposits.

Airline gap → sufficient for the liquid to penetrate

But insufficient for convection.

Only diffusion of species.

≃ 4-10 μm. crevice ~~depth~~ width.

Metal has to be passive.

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So, the like you have rivets, have flanges, you have in fact threaded bolts or the deposits you know. The idea is you must have an airline gap. This gap is sufficient for the liquid to penetrate, but insufficient for convection. Within this gap there is only a diffusion process ok. So, it is only diffusion of species.

So, what does it mean? If the gap becomes more suppose see these gaps are all in the range of few microns maybe about the say 4 to 10 micrometers is the crevice depth crevice width I would say width of the crevice.

If you are going to be a few millimeters what happens, then the oxygen the can migrate much easily through convection process. Though they do not form a cell at all due to concentration difference because it does not exist.

So, one of the requirement for crevice corrosion is there should be a gap and that gap has to be very small and there should be no diffusion taking place in the system ok. So, that is the basic requirement for crevice corrosion see whatever geometry whatever fabrication that you do?

See there are cases where people welded you know welding right you talk about TIG welding. In the TIG welding, if the fusion is not very good if there are airline cracks the airline cracks can become a crevice corrosion. It is not necessarily you have an external joints like that ok. So, that kind of things you know can lead to crevice kind of attack in very many industrial component.

Suppose I have a oxide scale I did not remove the oxide scale I make it loose can lead to form a crevice corrosion taking place on the metal. But, nevertheless you need to understand one important thing for crevice corrosion to occur the metal has to be passive. Please understand this, why? If the metal is not passive and you visualize the situation the crevice corrosion may not occur. Why may not occur?

No, I have same gap the gap is same, but it is not a passive metal like a carbon steel say suppose I take and little more an acidic environment I take it and say there is no crevice corrosion. Crevice corrosion more often occurs in stainless steels you know where the passivation is predominant. Why does not occur when metal is not passivating?

See when you does not passivate increase in oxygen content will only increase the corrosion rate. A decrease in oxygen content will only decrease the corrosion rate is not it. Is it correct or no? In a carbon steel you know where it does not passivating when you increase the oxygen content what will happen to corrosion rate.

It would not decrease it will would not increase because increase in oxygen content always rises the electrode potentials that is for sure right. No matter what the metal that is whether stainless steel or a steel the E_{corr} will always go up, but in the case of stainless steel when the E_{corr} go up goes up.

There is a chance that it passivates, but in the carbon steel when the E_{corr} is going up then what happens. The corrosion rate only will increase it is not going to decrease at all. So, the crevice corrosion is more applicable to the passive metal aluminum alloys yes true it has happen magnesium alloys crevice corrosion can occur ok. So, crevice corrosion also is has to be metal has to be passive in order to form a you know the crevice corrosion.

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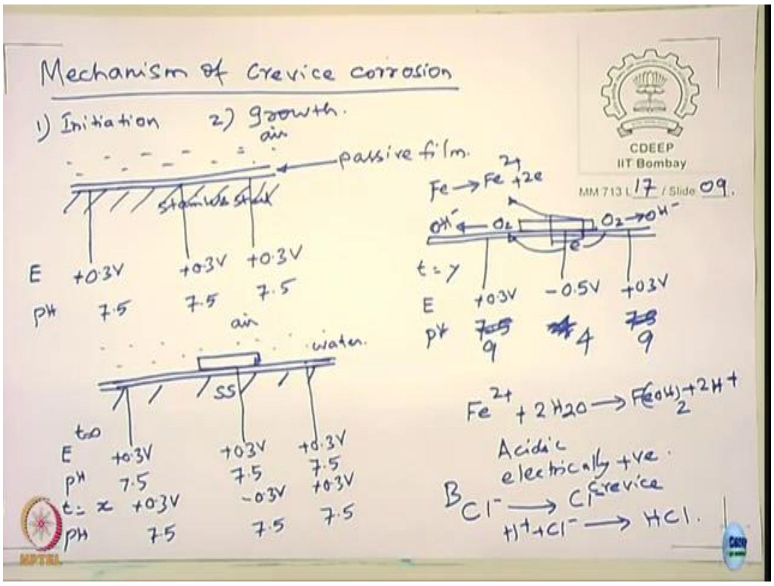

So, we have looked at the broad contours of crevice corrosion. Let us look at the mechanism of crevice corrosion ok. You can broadly say that the crevice corrosion involves 1 is the initiation the 2 is growth initiation of the crevice and growth of the crevice and the initiation of crevice is not so well understood as the growth of the crevice corrosion. Now, let me try to explain to you with some schematic what are all the things involved in the crevice corrosion of stainless steels initiation process.

Let us look at some thought experiments wherein I take a metal I take a metal which is a stainless steel. It forms a passive film. Please notice this passive film is thin you know. We have been talking about the passive film thickness in the order of angstroms about 40 angstroms to 100 angstroms like that.

They form a passive film and it is exposed to the environment and then you have exposed to the air. So, when a stainless steel is exposed to the air and environment what you expect. You will expect that to be passivated right. It is supposed to be passivating.

So, it is passivating now. If one measures the potential at say the 3 locations you measure the potential of this E measure the potential of this. It will be in passive range or active range what do you normally expect. The stainless steels nicely aerated condition on environment will be spontaneously passivating.

So, the potential will be generally in the passive range maybe something like 3 volt. Something I am just giving some approximate number. There is nothing you know unique about these numbers. If I measure the pH of this it will be neutral or slightly alkaline maybe let us say about 7.5 7.5 7.5 right.

So, that is a pH of the solution at location 1, location 2 and location 3 you get these things. Now, what we do, over this you keep a nice flat glass plate ok. Let us look at what happens now ok. Let us now take a this is stainless steel and I will just place a small place glass plate over this air it is a water. So, I measure the E value and the pH value at time t equal to 0 right.

At time t equal to 0, I measure these values just kept replacing. So, what would happen? It will almost show the same values right it will show right. Now, the corrosion reaction will occur. See when the metal is passivating it does not mean there is no corrosion. Only thing the rate of corrosion is less the anodic reaction rate is less. So, there is a corrosion. So, what will happen now?

When there is a corrosion metal get oxidized the reducing species gets reduced right. Like in this case you may have air oxygen present they get reduced. The oxygen consumption over here continues. But, what happens to the replenishing of this, it does not get replenished.

Because of crevice the oxygen content with the time decreases over here whereas, the oxygen content over location here and location here remains in the steady state it does not change at all whereas, the oxygen content here it decreases. So, what will happen to the potential here. The potential will drop with time.

So, at time t equal to some x some x value ok. Now, what happens now here this may become still 0.3 volts and this may become let us say 0.3 minus 0.3 volts and this is the pH may still remain the same it may remain the same. So, what happens now in this case? Now, the potential over here drops. It goes relatively to a more negative potential and this is remain the same. So, this now tend to become anode and this becomes now what the cathode now. Earlier they are almost the same.

So, what happens now with the next thing that can happen is t equal to y and E would this here will remain the same here may become a little bit a little bit more negative. Now, what happens now over here the iron gets suppose I blow this area. I magnify this; I magnify this what happens. Iron go as plus 2 electrons right and this electron from here put this over here am I right and here the oxygen will tend to become OH minus here the oxygen will tend to become minus. So, it establish a cathode here the cathode here and the anode here.

Now, what could happen? The one more thing can happen here what is that Fe 2 plus can combine with water it form ferrous hydroxide and 2 plus right. This is possible to happen. Yes, so this place tend to become more acidic and tend to become more positive. So, what happens now it becomes acidic and also electrically what electrically positive am I right?

Student: Yes sir.

You have more positive charges on this location as opposed to that if the outside is relatively more every charges right.

So, what will happen to pH now? The pH it might remain almost the same outside it remains almost the same or it can become maybe it can become maybe 9 something like that because the pH is increasing because of the cathodic reaction. Here the pH may go as about the pH can be about 4 can be pH can be about 4 that becomes relatively acidic.

Please notice what is happening that it is electrically positive. So, in order to neutralize this location what will happen? The negative ions from the surrounding areas like chloride it migrates to the chloride bulk chloride it goes to the crevice chloride ok. It goes to the crevice chloride. So, what happens now? The H plus Cl minus can form hydrochloric acid agreed understood.

$$H^+ + Cl^- \rightarrow HCl$$

So, the initiation part if I summarize the initiation.

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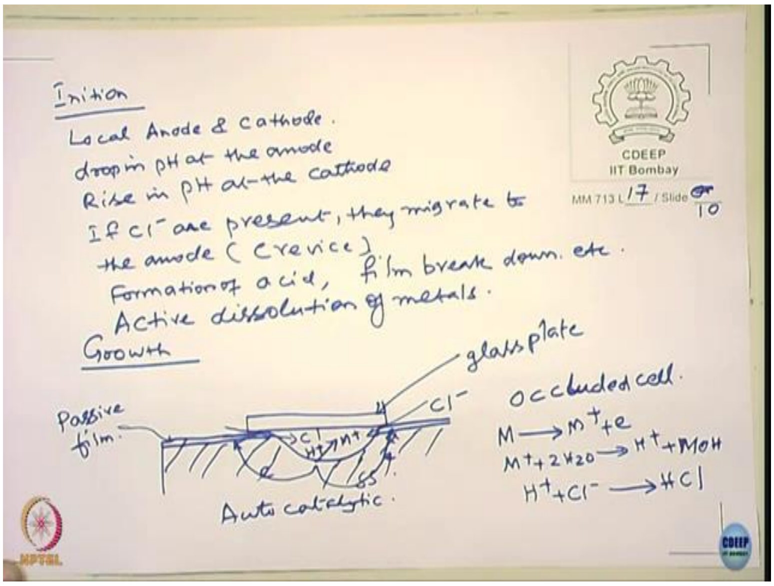

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Inition

Local Anode & cathode.
drop in pH at the anode
Rise in pH at the cathode
If Cl^- are present, they migrate to the anode (crevice)
Formation of acid, film break down. etc.
Active dissolution of metals.

Growth

occluded cell.

$M \longrightarrow M^+ + e$

$M^+ + 2H_2O \longrightarrow H^+ + MOH$

$H^+ + Cl^- \longrightarrow HCl$

So, if I summarize initiation, initiation leads to local anode and local cathode. It leads to drop in pH at the anode and say small rise in pH at the cathode ok. If chlorides are present if chlorides are present they migrate to the anode which is a crevice then what happens.

Then it is going to be formation of acid leads to film breakdown etcetera. So, that is in a active dissolution of metals. So, let us now take. So, we have seen that the initiation process is driven by the oxygen partial pressures and then is accelerated by the presence of aggressive ions such as the chlorides.

How does the growth occur ok? How does the growth occur ok? Let us look at the situation where stainless steel it is a glass plate and the passive film and here what happens. The metal ions M electrons held here and what happens.

The chlorides migrate this place chlorides migrate to place you have H plus over here right. Now, look at this situation that this place is now called as occluded cell. It is confined is fully diffusion controlled say no convection taking place now it becomes an autocatalytic process.

Please notice that the anode sorry the anode over here and the cathode they remain with time. We said in the uniform corrosion the anode and cathode will alternate. The time this will remain as a anode this will becomes the cathode and they establish a distinct potential anodic potential and the cathodic potentials.

You would expect this cathode to polarize this anode so that this become passivation right is not it. Can you see that we have saw the galvanic corrosion before right? If I have 2 different metals with different potentials what happens. The galvanic shorted, the anode will tend towards the cathode and the cathode will tend towards anode.

So, you it can drive it can move in a crevice that does not happen because the resistance between the cathode and the anode would remain. It does not allow the anode to ever become a cathode. So, in the crevice there is a resistance for ionic I am talk about ionic resistance.

See these electronic conductivity is very good in the metal no problem, but there is an ionic resistance taking place and so the anode the anode and the cathode would remain all the time ok. So, one of the conditions of the crevice corrosion is that it occurs more in the highly resistive corrosive environment.

When resistance is more in the electrolyte what happens the anode and cathode are well separated they do not become a single entity at all. So, that is a property of the environment that will promote the crevice corrosion as you see later. So, the growth of the crevice people have been modelling quite a bit on that actually. You know and the this is a very important problem for the naval applications. In fact, even the aircraft applications where the aluminium alloys undergo crevice corrosion at the joints all these stuffs.

So, lot of work has gone into understanding of crevice corrosion and modelling the crevice corrosion kinetics of metals ok. So, this now completes our discussion related to the mechanism of crevice corrosion any of you have any questions we can discuss ok. If it is not there I will complete another similar interesting thing about the water line corrosion ok.

Student: Starting inhibitors are (Refer Time: 61:23).

Yeah. Some inhibitors may cause, but overall the inhibitors lower the corrosion rate of the metals right.

Student: Does the increase in the conductivity of the electrolyte cause an increase in the uniform corrosion?

Uniform corrosion is always less when you increase the resistivity of the environment.

Student: Increases.

Yeah.

Student: Conductivity is increased.

When the conductivity is increased. So, the uniform corrosion will increase, but when the conductivity of the electrolyte is lowered it promotes more of uniform corrosion more of more of the localized corrosion than the uniform corrosion of.

Student: (Refer Time: 62:16).

The metals.

Student: Does inhibitor change the conductivity of the electrolyte?

Of course, there are you see the inhibitors does not reduce or alter the conductivity of the electrolytes generally you can say, but it can you know there are different mechanisms you saw before right. We saw that it can form a film on the surface. So, it covers if there is an anodic inhibitor you can very well go and absorb onto the anodic site and you can bring down the corrosion rate on the systems.

So, the inhibitors overall will bring down the even for forms of corrosion actually. In fact, you will see you know even you can bring down a pitting corrosion, crevice corrosion and erosion corrosion basically, but then it may not be. So, effective right it can bring down the uniform corrosion much much effectively as compared to crevice corrosion, but it could reduce the crevice corrosion to certain degree you can do that.

Student: In carbon steels is it possible that crevice corrosion starts occurring because of the presence of airline gaps.

No you are talking about the crevice corrosion with respect to carbon steel ok. See the carbon steel acid you know as I could say that if the oxygen content is quite large and you will always see that the corrosion rate is increasing only ok.

And in fact that is the reason why wherever the carbon steel is involved you always lower the oxygen content to that possible whether it is in a boil boiled water treatment or any cases ok. So, the crevice corrosion. In fact, the crevice corrosion of carbon steels never exist.

If it can exist probably it can happen in a case where you are tending to make these the carbon steel passive by increasing the pH. If you look at the Pourbaix diagram the stainless steel I mean the carbon steel also can passivate in the range of about 12.5 and all like that ok.

There it is possible, but in fact, the problem with the carbon steel is that if you add the oxygen content a little bit more it start pitting actually. You know it does not get into that you know because the breakdown of this oxide films on an iron is so easy ok. So, you slightly increase the potential beyond certain values you can break down and lead to pitting.

So, carbon steels they do not undergo any crevice corrosion that is why whenever you have chlorides we simply do not have any problems whereas, when you have some fasteners such kind of things used for marine environmental conditions stainless steel; stainless steels of most of the varieties they face a the what is called as the crevice corrosion problem primarily because they passivate and the chlorides can destroy the passive film you know quite effectively.

Now, as you noticed in the mechanism of initiation and growth. Now, the growth of the crevice would much depend upon the environment. Assume that there is no chloride present in the environment ok. So, the growth of the crevice is almost negligible ok.

So, you may have a concentration cell set up and make the one place anode where the oxygen content is low other place where the oxygen content is higher you may have a cathode ok. It does happen, but the growth of the crevice is much slow. So, that means, the time taken for the failure of the component would depend upon the chloride concentrations like if the chloride concentration of certain environments.

So, let us take let us say water. Some water may have 100 ppm of chloride and in some cases you can have a 1,000 ppm of chlorides ok. You will see later that 316 may not undergo crevice corrosion in water containing 1,000 ppm of chlorides whereas, a 304 stainless steel might undergo crevice corrosion in water containing 1,000 ppm of chlorides, but in 100 ppm none of them both of them they do not undergo crevice corrosion even though there may be oxygen cells that are formed at all right.

But, to sustain this you also had have to have a aggressive environment is this important for that ok. So, yes they are primarily driven by the oxygen partial pressures at difference between 2 locations, but is even more important to see the how I know the what kind of environment that you deal with that decides what the life is and that decides also the selection of materials for a given applications. You know you has to start increasing chloride more and more you are going to choose a better and better materials to resist the crevice corrosion.

So, oxygen is one part of it, but aggressiveness of the environment is equally important. So, then we will stop the discussion for today and we will talk about the so called you know water line corrosion ok. See what does this the water line corrosion really means actually ok. So, we discuss in the next class ok.

So, thank you and.