Aqueous Corrosion and its Control

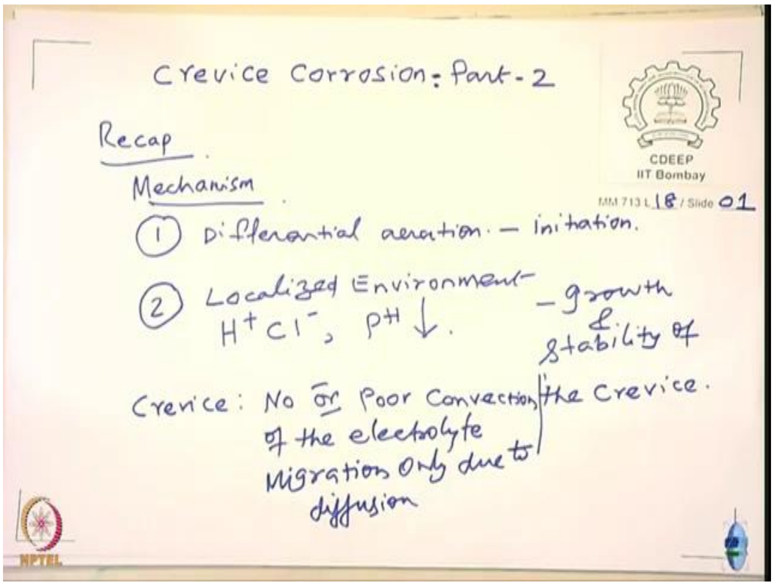
Prof. V. S. Raja
Department of Metallurgical Engineering and Materials Science
Indian Institute of Technology, Bombay

Lecture – 18

Forms of corrosion: Crevice corrosion (Part-II)

We, we shall look at the crevice corrosion of metals and in details today. Before we start discussing about the crevice corrosion further, it will be worthwhile to recollect what we have been discussing on crevice corrosion ok.

(Refer Slide Time: 00:52)



Crevice Corrosion: Part-2

Recap.

Mechanism.

① Differential aeration. — initiation.

② Localized Environment — growth & stability of the crevice.
H^+Cl^-, pH ↓.

Crevice: No or Poor Convection of the electrolyte
Migration only due to diffusion

So, recap. Now, we looked at the mechanism right. First of all the crevice corrosion, the origin of that is due to the formation of a crevice which can happen because of let say when you have a joints in the metal structures such as a flange joint or a rivet or an expansion joint or a threaded joints as you see in the fasteners, these are coming out of the design parameters ok.

You can also arise out of the other reason where like you have some deposition taking place because of the environment, is not it. We also called that as under deposit corrosion taking place. So, these are the factors that leads to the formation of the crevice. Now, why does the crevice corrosion occur? Can anybody recollect, what is the basic requirements?

Student: (Refer Time: 02:44).

Yeah.

Student: Large cathode is to (Refer Time: 02:46).

Is that the is the primary reason for that?

Student: Chlorine in (Refer Time: 02:50).

Yeah.

Student: High corrosion (Refer Time: 02:53).

Is that what it is? What is the primary reason, what why does is start primarily in crevice corrosion?

Student: For (Refer Time: 03:05).

So, the formation of the differential aeration cells right, the basic is that is a concentration of oxygen between the two locations starting point. So, the point is that the starting point comes because of differential aeration. Why would the differential aeration lead to this problem? First of all what kind of metals the crevice corrosion occurs?

Student: Passive.

The passive metals, so only in the passive metals you know so called passive metals, the crevice corrosion occur. So, in such a situation what is the role of differential aeration means what? For example, there are locations where the oxygen concentration is very high, there are locations where oxygen concentration is very less. So, what happens due to this?

Student: Iron.

Yeah.

Student: Iron might decrease or increase.

The limiting current density maybe, the limiting current density might increase when the oxygen concentration is more. So, what happens?

Student: (Refer Time: 04:34) can we transform our passive to active.

Which one? Suppose, you have more limiting current density, will it become active or passive? Passive. So, when you have higher oxygen concentration, the metals tend to become passive. The one where the oxygen concentration is less, the metal tend to move towards active potentials.

So, the crevice you know starts you know corroding over a time period, because again we say that it is diffusion controlled when you say crevice it is no convection right in the dimension is so small, there is no convection.

And so the diffusion process and so the oxygen within the crevice with time steeply decreases, so that becomes an anode it is the starting point of that. So, what happens again in the crevice, why would the corrosion, so in the crevice, what drives a crevice, what is a difference between a crevice and the outside the crevice?

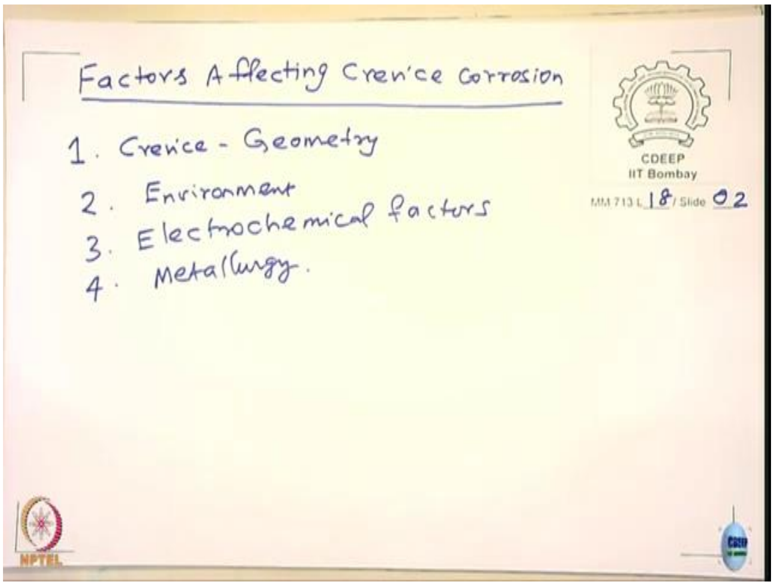
One is oxygen concentration. To start with happens ok, subsequently what happens, when the corrosion proceeds the crevice establishes its own environment different from what do you find externally right. So, it establishes the environment. So, it is a localized environment.

If you can browse your notes, you will see that right, in the crevice what happening over a time period, you will see that what happens, it forms it creates an acidic environment if the environment has chlorides the chlorides migrate towards the crevice. So, here what happen, the pH drops significantly. And you have chlorides, so the passive metals they start depassivating actually ok, it becomes totally active. So, corrosion occurs.

So, it establishes a localized environment which is different from the external surfaces. External surfaces are open there is a convection taking place and so that is the pH is not going to drop at all ok. So, the localized environment that is the reason for that. So, this leads to growth and stability of the crevice. So, we are seen these factors right.

Since, it is a crevice, what happens, that is no or poor convection of the electrolyte. So, migration only due to what? Migration only due to diffusion. So, this is a it is a kind of basic mechanism we saw in the last class. Now, we know that this is a industrial problem that we need to find a solution to the problem. In order to find a solution to the problem, you must know what are the factors or the parameters that affect the crevice corrosion right.

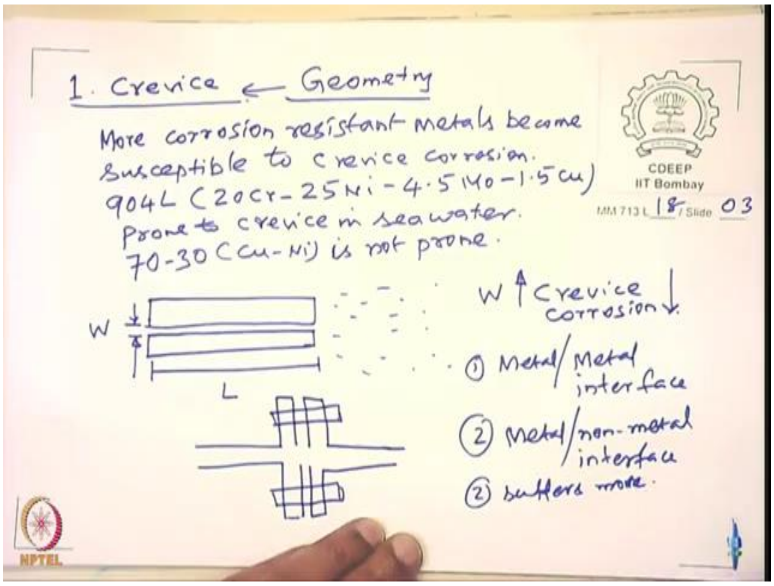
(Refer Slide Time: 09:24)


Factors Affecting Crevice Corrosion

1. Crevice - Geometry
2. Environment
3. Electrochemical factors
4. Metallurgy.

So, you need to you need to understand, it is very interesting that the fore most important factor is the crevice itself. It is a geometry of the crevice – one important factor. Second factor is the environment. Of course, when you have an environment, it also decides the electrochemical factors ok. The fourth metallurgy of this right. So, these are the factors broadly I would say that influence the crevice corrosion of metals right.

(Refer Slide Time: 10:54)


1. Crevice ← Geometry

More corrosion resistant metals become susceptible to crevice corrosion.
904L (20Cr - 25Ni - 4.5Mo - 1.5Cu)
Prone to crevice in seawater.
70-30 (Cu-Ni) is not prone.

W ↑ Crevice corrosion ↓

① Metal/Metal interface
② Metal/non-metal interface
② suffers more.

So, let us see this in details one after another. Let us take the crevice. When I said crevice, I was meaning that it is a geometry. Why this geometry must be important, why is the geometry important?

Student: (Refer Time: 11:28).

That is right, because the crevice corrosion more often is a transport controlled and the transport through the diffusion process. So, the geometry will play important role, because that is going to decide the how the diffusion will occur within the crevice ok. In fact, you would notice that you know the metal dissolution for ok, in fact, more resistant metals, more corrosion resistant metals become susceptible to crevice corrosion.

So, it is a no wonder that you know some cases the corrosion occurs some cases corrosion does not occur, the environment may be the same. But if the crevice geometry the crevice dimensions change, then the extent of crevice damage could change ok.

For example, I would say you know 904 L is a stainless steel ok, it has they say 20 percent chromium and 25 percent nickel, 4.5 percent molybdenum, and 1.5 percent copper is supposed to be far better than 316, 317 stainless steels ok. You see the high amount of nickel, high amount of chromium, but that is prone to crevice corrosion. But 70-30, what is this? This is the copper-nickel alloy is not prone gives corrosion, so very interesting thing ok.

Now, let us take; let us take a crevice and see what kind of dimensions will affect the crevice corrosion right. One dimension is the crevice width right, and this is the crevice length right. Suppose, I have an environment here – this side, where will the crevice corrosion occur, and will the depth of attack is going to be same throughout ok. So, you need look at this. Let just look at this, and you please tell me ok, let us take the W – width. If the width is increasing what will happen to crevice corrosion?

Student: Decrease.

The crevice corrosion will decrease. So, width increases the crevice corrosion. Why does it happen?

Student: More than stagger we see.

This stagnation is reduced; in other words, there can be no more convection right. So, because of that, the oxygen concentration within the crevice would increase if the width of the crevice is increasing. This is an irony of that right.

If you talk about a flange joint, suppose I take a flange and joint like this, suppose I take a flange joint right suppose I make a flange you guys might have known the flanges right, suppose, there is a flange joint, suppose I want to tighten this out. But in the mechanical engineering point of view what do you expect to happen? You expect that the gap should be decreasing then only it is going to be.

Student: Leak proof.

Leak proof, less vibration. So, typically these mechanical joints are expected to be as tight as possible. The crevice width has to be as small as possible, then only that becomes an affective joint otherwise it becomes a leak right.

Student: Yes.

So, that means, inherently the good joints will suffer more crevice corrosion than joints which are which are looser, but you cannot help it, you have to have tight ones right. So, this is a real problem in practice. So, width is this is important one.

If the you know you can also talk about other one a metal and a metal interface – 1. 2, a metal and a non-metal interface, like for example, a rubber for example, which of the two joints will suffer more corrosion. I have a metallic gasket, I put other layer on I have a metallic gasket, and other case I have you know other a rubber gasket incur more. You are right. Why do you think so?

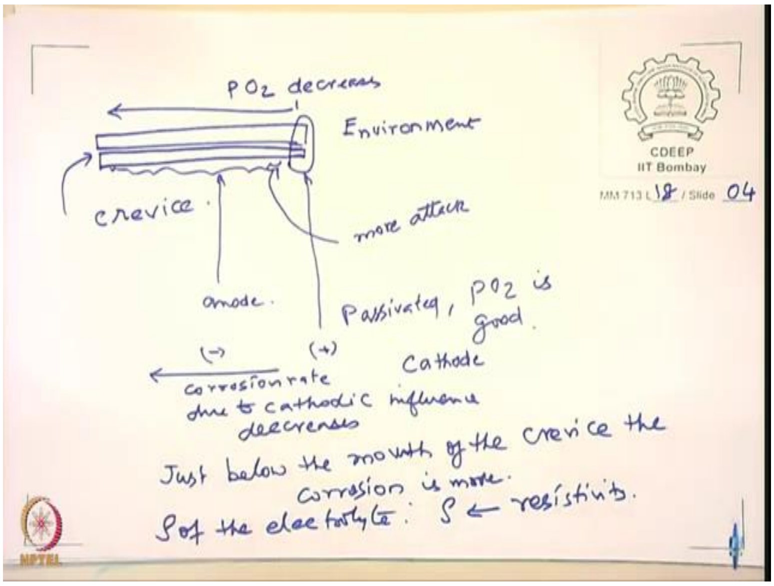
Student: The chances of pores being (Refer Time: 18:31) some water or air being trapped inside.

I mean the just come in, he is right I mean rubber, rubber claw problem, but that what is the reason for that? Suppose, if you want to tighten this right with a metal and metal, and metal and rubber, what will happen from the point of view of this crevice width? Where the more you know where the width of the crevice is more, metal and metal or metal and rubber?

Student: (Refer Time: 19:05).

So, you, so the crevice dimension also depends upon what kind of joints you are going to have. And metal and rubber the crevice gap is going to be small, and so you would have more crevice corrosion compared to metal and metal things ok. So, the two suffers more.

(Refer Slide Time: 19:33)



Just below the mouth of the crevice the corrosion is more.

ρ of the electrolyte : ρ ← resistivity.

Let us take the other effect of that. Now, here is the environment is the length through which, where do we think the crevice corrosion here will be the more this is the crevice right. This is the crevice. Where do you think the crevice corrosion will be more.

Student: (Refer Time: 20:28).

Yeah.

Student: (Refer Time: 20:30).

In the middle ok. So, at least you can say that the crevice corrosion at the mouth of the crevice is not going to be there at all. Why do why do you think so?

Student: (Refer Time: 20:42).

The oxygen there will be reasonable amount of oxygen present there crevice mouth would passivated right. So, here you find will be passivated right. Why, because the oxygen partial pressure is ok, is good. The oxygen partial pressure decreases from the mouth to interior, and after some time it becomes almost it not going to vary at all right. So, what will happen is at crevice mouth is going to be a cathode, and all these areas are going to be the anode.

Now, the cathode drives the corrosion of the anode right, is not it. The cathode drives the corrosion the anode. Now, what also have can happen is the if the distance between the anode and cathode is increasing, what would be the effect of cathode and the anode? Keeping other parameter same right, keep other parameter same ok. Assume that the chemistry of the electrolyte inside this crevice is same, and this is the anode, and the cathode. But if I move away from here inside what will be the effect of this cathode on the anode?

Student: (Refer Time: 22:30).

Will?

Student: (Refer Time: 22:32).

Would? The cathode drives anode right and because there is a potential difference between the anode and the cathode right, so that is going to be relatively positive, and this going to relatively negative. Now, when I start moving from here to this, what will happen to this driving force?

Student: (Refer Time: 22:57).

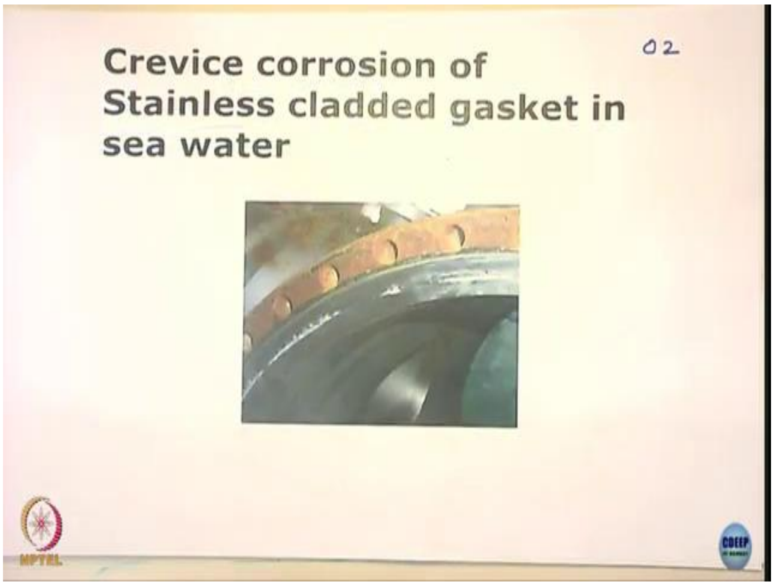
It will decrease right. So, the corrosion rate decreases because of this ok. The corrosion rate due to cathodic influence decreases. But the oxygen concentration, what happened to the oxygen concentration the oxygen concentration in this case concentration decreases right from here to this, but the potential like potential decreases.

So, that means, somewhere in between you are going to have high corrosion rate after that the corrosion rate will start decreasing. So, you will find that somewhere here ok, more attack, because as you move away from this, the effect of the cathode and the anode decreases. So, this is like galvanic cell right galvanic corrosion right. So, you have more just below the mouth of the corrosion. So, this leads to just below the mouth of the crevice corrosion. The corrosion is more.

Now, that depends upon what? That depends upon the of the electrolyte. What is rho? Rho is equal to resistivity of the electrolyte. So, very interesting one, you know the resistivity is 0, then also there will be no crevice corrosion; the resistivity is too high is confined to the mouth of this actually ok.

So, essentially it depends upon the resistivity of the electrolyte as well. So, put it in simple terms, the oxygen concentration decreases from the mouth interior, the galvanic interaction between the cathode and the anode decreases from here to this. So, there are two opposing factors somewhere in between maximum crevice corrosion occurs. So, this is an important one ok.

(Refer Slide Time: 25:57)



Crevice corrosion of Stainless cladded gasket in sea water

02

So, that is why you we will if you just look at the some data, so this is a typical gasket corrosion. And this is your stainless steel clad this is of course, the steel you know the shell here is cladded with a stainless steel. Now, it is here are you have the environment right. You see the attack here, the attack is happening somewhere here right, does not happen too far away, does not happen very close to the does not happened with the mouth, it happened somewhere in between.

So, the crevice corrosion normally occurs below the mouth of the crevice because that is optimization taking place, because you need a electrochemical driving force during the cathode and the anode on one hand, the other hand the oxygen solubility I mean the content of oxygen also decreases as you move from the mouth of the crevice to the central of the crevice.

So, that is how you see that the crevice corrosion always occurs below the mouth of the crevices. I hope you understand and this one is very important actually.

Student: Why (Refer Time: 27:14).

You are talking about this one or (Refer Time: 27:24).

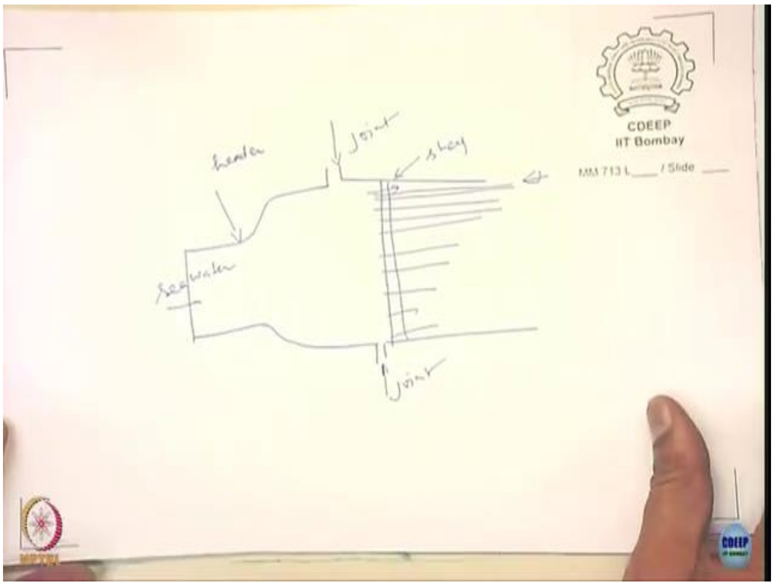
Student: (Refer Time: 27:26).

This is you know see, this is shell actually you know this shell, it is not a tube, this is shell.

Student: (Refer Time: 27:38).

This is gasket know I mean see.

(Refer Slide Time: 27:58)



This is the you know in a heat exchanger, you know in a heat exchanger, if you just look at the heat exchanger, not good ok. This is called what is called as a header or the shell. And you have not exactly, but here you have of course, tubes, all these tubes are going over like this ok. So, in this; so this is the, what we are seeing here is this joint.

So, this what you seeing here is this joint ok, is a flange you see these are place where you put the bolts and you fasten that actually right ok. So, it is a header that has suffered the corrosion and ok.

And through this what happens now through this you have a sea water right. Now, the sea water here is flowing through the shell side, the tube may be some other process liquid, you know it may be some hydrocarbon or whatever that flows into that actually ok.

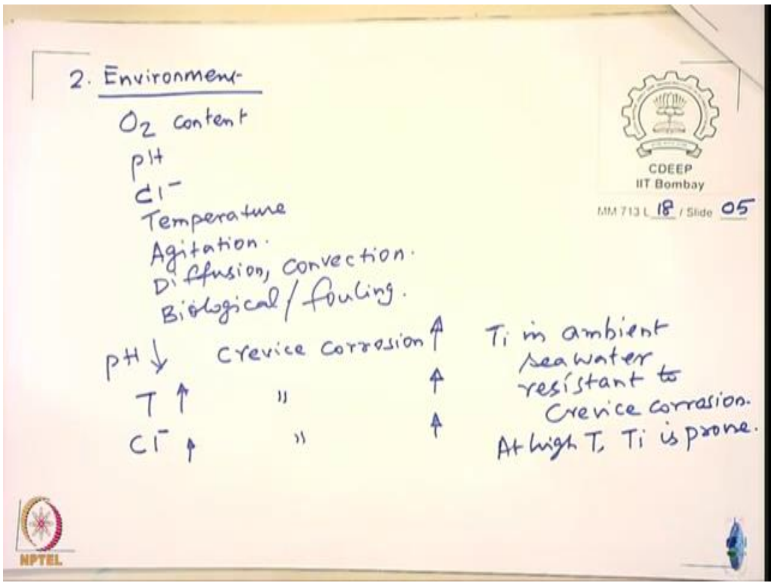
So, here the coolant is the sea water, that sea water is flowing through the headers, and then through the shell and the tube I think there are some process liquid in the off in a given refinery actually ok. So, what we were referring is this, this joint ok, which is a flange joint taking in this. Is that fine?

Student: (Refer Time: 30:08) the sea water.

The corrosion has occurred because of sea water. Because of sea water this was cladded with 2507 duplex clad stainless steels ok. You will see later that when you talk about pitting corrosion, this duplex stainless steel has got high resistance to pitting corrosion this is what as actually.

And you clad it because you cannot use of whole thickness of duplex stainless steel is expensive right. You just go for a 3 millimeter clad, because the basic carbon steel is cheaper for us to do that, so that is about the about the crevice.

(Refer Slide Time: 31:02)



2. Environment

O_2 content

pH

Cl^-

Temperature

Agitation.

Diffusion, convection.

Biological / fouling.

pH ↓ Crevice corrosion ↑

T ↑ " ↑

Cl^- ↑ " ↑

Ti in ambient seawater resistant to crevice corrosion.

At high T, Ti is prone.

The next important thing is the environment ok. When you say environment we normally refer the bulk, only we are not referring the environment in the crevice, because environment in the crevice is generated by the crevice by itself that depends upon the metal you are dealing with.

Of course, it has a bearing with the bulk electrolyte ok. But still you could have vastly different electrolyte in the crevice as compared to electrolyte composition in the bulk actually ok. So, when you look at the environment it is the oxygen content, pH, chlorides present in this actually, the temperature ok, if you want, you can add agitation or otherwise.

The other related parameters what is that like diffusion, convection, but all relate interrelate to each other ok. And biological factors, when I say biological or fouling you can put the word fouling actually generally we can say that when you decrease a pH, crevice corrosion increases. Similarly, the temperature, crevice corrosion increases, chloride crevice corrosion increases.

Student: (Refer Time: 33:36).

Which one? That may be some diffusion increasing ok. But that is not; that is not going to be commensurate with the passive film destruction, the passive film would destroy. In fact, if you look at titanium, let us take this case of titanium, titanium in ambient seawater resistant to crevice corrosion.

If you raise the temperature at high temperatures, titanium is prone the reason being the chloride attacks the film the passive film and exposes the bare metal. And so what happens the crevice corrosion occurs.

So, we will see this the role of metallurgy in crevice corrosion we see later, how does, how does the metallurgy of the alloy can influence the crevice corrosion we can see later how I mean you are seems this later. At this point it is sufficient to understand that the passive film stability depends upon the temperature in addition to the environment, chlorides attack the passive film.

If you raise the temperature, the pitting potential drop significantly. So, film gets damaged and so metal becomes active so that is going to be crevice corrosion occurring. Essentially in the crevice if you are able to make the metal passive very stable, then what happens, you may have differential aeration, but still you will not get a crevice corrosion at all right.

So, the crevice corrosion also depends upon, you know in addition to the aeration and all, but if the metal can be made inherently resistance to corrosion then the crevice corrosion resistance can be very high also we will do that ok. So, that is why the metallurgy is being developed actually ok.

So, titanium generally is very good, you see what obligation no problem does not pit and all, but the temperature is increased. What does it mean? Assume that I use an heat exchanger in a sea water, sea water is used to cool the heat exchangers right.

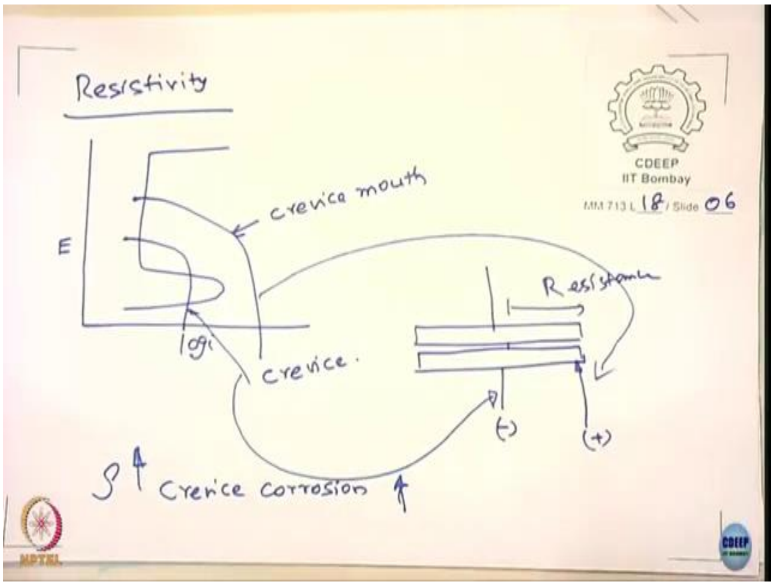
Student: Yeah.

Suppose, the temperature of the sea water is I was say 70, 80 degree Celsius or maybe 100 degree Celsius probably the titanium will also start undergoing crevice attack or the temperatures or in some situations where the it is not necessarily seawater, either it can be you know a gas turbine operating in the naval ship or a ship for example, you use titanium alloys. And then if salts go and deposit, the temperature of these components 120, 200, 250 Celsius, they undergo crevice corrosion.

So, the crevice corrosion would also depend upon the stability of the passive film, and that depends upon the environment, pH, in fact, same thing. If you increase if you load the pH, the passive film stability comes down, so crevice corrosion is now increasing at all.

So, they are of course, interrelated to each other that we can say ok. So, these are the parameters. The other important parameter in solution is the resistivity. So, very interesting thing resistivity is very interesting one, we just made a very passing remark earlier right.

(Refer Slide Time: 37:52)



Look at the resistivity. Let us take the case of the you guys are all familiar with the polarization curves of if the oxygen concentration is more, start passivating; if the oxygen concentration is little less right. So, this is the crevice mouth and this is your crevice.

Can you say that ok? So, what does it mean? So, this is the place where the this is the place where the potential is let us say there to be negative place potentially it is relatively positive ok. This corresponds to this. This corresponds to this correct or not. What moves the potential run here to this, it is the oxygen that makes the potential to move from here to this right. If I have an external cathode if I raise the potentials can this move up or not?

Assume that there is no oxygen is present if I have a external cathode I apply a voltage can this move up or not?

Student: This will move up.

That is what you do in anode anodic protection right you just move with. So, that means, if this is the cathode, can this cathode make this anode to move up to this, can it move? In principle, yes, right. If I have a same metal, one is positive, another is negative, this guy will start lifting this up and this guy will start lifting this down right, moving down both are possible right. If this guy has to have negative here, positive here, then there has to be a resistance between these two you know between these two places there has to be a resistance.

The resistance is 0 or less what happen now the anode and cathode will become almost like similar only. So, this guy also start passivating in principle possible, that means, the resistance of the electrolyte is very important. If there is no resistance, substantial resistance the crevice corrosion will not exist. One of the reason is why crevice corrosion occurs is that it happens in the low resistivity electrolyte ok.

So, if that means, if the resistivity increases the crevice corrosion increases, because they it keeps the anode and the cathode alive all the time they do not allowed them to make them one unit right not possible to happens. So, this is one of the important parameters in having because corrosion in that people model crevice corrosion they take this into account in terms of how the crevice corrosion occurs.

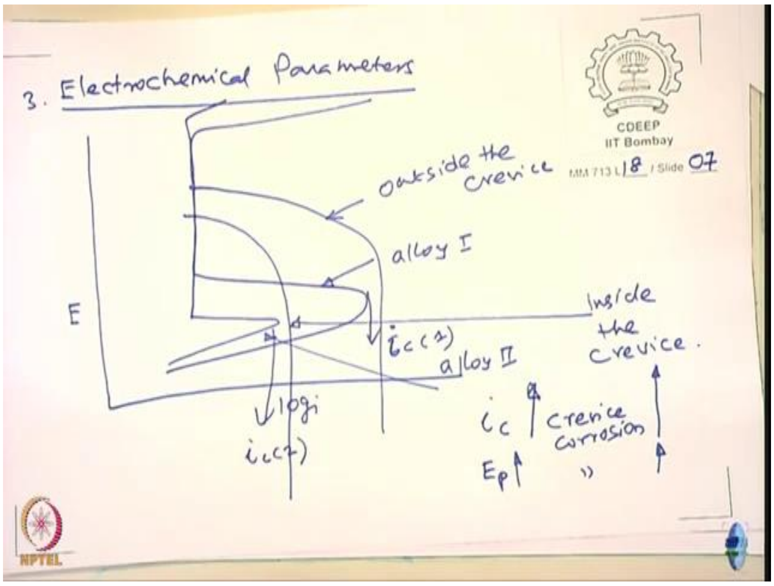
So, in principle if I give you resistivity you give all this I can even find out at which place the the crevice corrosion is going to be maximum right. So, these are the things that you know that happens in typical crevice corrosion of metals. I hope you understand this concepts here.

The resistivity of the electrolyte is another important parameter in deciding the extent of crevice corrosion the metal can have in addition to chemistry of the electrolyte we talked about like the pH, the chlorides, and you know in addition to that the resistivity is equally important ok. I hope you follow what I mean this saying. Have anybody has questions?

Student: Yes sir.

No problem ok. So, that is about the the environment and ok. Now, let us look at the electrochemical parameter we have been just discussing now so far right.

(Refer Slide Time: 42:38)



Let us look at the electrochemical parameters (Refer Time: 42:37) ok. Let us take this electrochemical parameters. It happens in the passive system right, so that means, you would have. Now, I am going to draw a few schematic diagrams to show how the electrochemical parameters become very important in deciding the crevice corrosion resistance of metals ok.

This is alloy 1, alloy 2. Now, this is the outside the crevice ok; this is inside the crevice. Tell me what happens? In the case of alloy 2 the passivation potential is lower not higher.

Student: (Refer Time: 44:35).

The passivation potential is you know is low it is or the range over which passivation occurs is much much more as compared to alloy 1 right. Alloy 1 passivates here and alloy 2 passivates here right it. In fact, it has it passivates even at more negative potential ok. I want answer from you people. Now, which is given this you know now you know the mechanism all the crevice corrosion gets initiated for example, now what happens the alloy 1, alloy 2, it is not complex, very simple.

Student: (Refer Time: 45:18).

You start telling more and more, and what more you find here in this. You take the case of alloy 1, alloy 2 what difference does it make? If you form a crevice with alloy one and you form alloy with crevice 2 ok, I mean you form a crevice with alloy 2 for example, both the both are formed as a crevices right. So, what happens?

Student: (Refer Time: 45:49).

You know alloy 2 what happens, in alloy see this is the; this is the cathodic curve within the crevice, the cathodic curve outside the crevice here right. So, alloy 1, alloy 2, now it should must must be easy for you to tell how the alloy 1 and alloy 2 will behave outside the crevice or inside the crevice. Outside the crevice what happens to alloy 1 and alloy 2? Both are passivating right? Within the crevice what happen?

Student: (Refer Time: 46:38).

Alloy one will remain in the, where it will go to?

Student: (Refer Time: 46:46).

It will go to active region right. What happened alloy alloy 2 then?

Student: (Refer Time: 46:54).

Alloy 2 is still remain in the passive state right, so that means, why does it happen. You look at this, now what is why does it happen? Do you know this polarization curves, what are these things?

Student: Because (Refer Time: 47:10).

Use a right terminologies.

Student: (Refer Time: 47:14).

So, the critical current density right it is a critical current density right i_c of the alloy 1.

Student: Yes.

And i_c of the alloy 2. So, simple right, it is not even a magic ha. So, it is a simple one so; that means, the the electrochemical parameter influences. Similarly, what (Refer Time: 47:47) has been talking about.

Suppose, if I move this the passive potential to higher and higher, you will see that the crevice corrosion tendency will keep increasing now actually or the ability to passivate at negative potential makes the alloy more stable. So, the two parameters that are important one is i_c. If i_c increases what will happen what will happen to crevice corrosion?

Student: (Refer Time: 48:19).

Corrosion.

Student: (Refer Time: 48:23).

Hm.

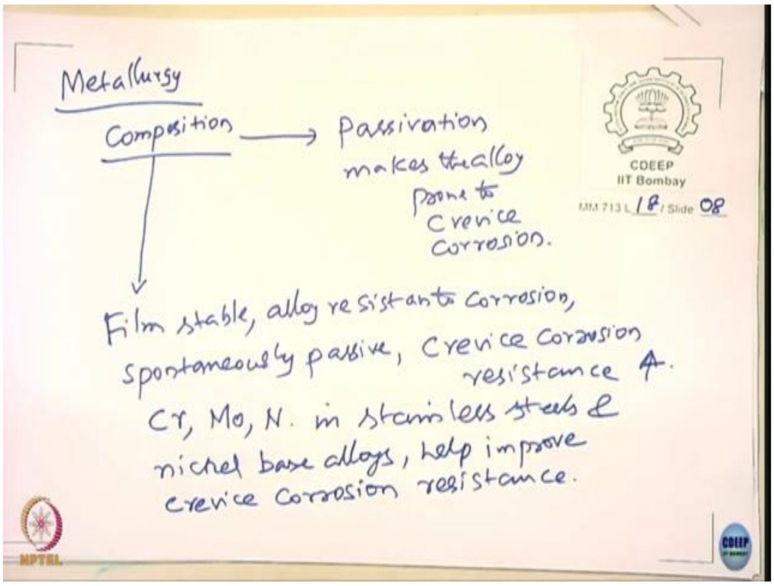
Student: (Refer Time: 48:30).

I want a clear answer.

Student: Increase.

Increase right. Crevice corrosion increases. Similarly, E passivation increases the crevice corrosion again increases. You want to make it more and more lower, so the electrochemical parameters are a very important in deciding whether the corrosion crevice corrosion will occur or not; if it occurs at what rate they really occur.

(Refer Slide Time: 49:10)



Metallurgy

Composition → Passivation makes the alloy prone to crevice corrosion.

Film stable, alloy resistant to corrosion, spontaneously passive, crevice corrosion resistance ↑.

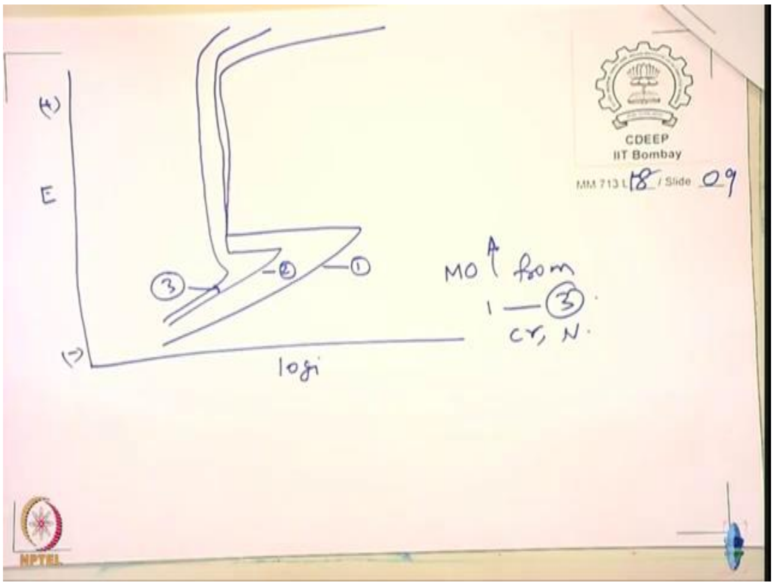
Cr, Mo, N. in stainless steels & nickel base alloys, help improve crevice corrosion resistance.

Having said that the metallurgy are related to each other right then, because the metallurgy of course the composition; what are the compositions, the all compositions that lead to passivation makes the alloy prone to crevice corrosion right.

But the compositions that makes the film stable, alloy resistant to corrosion, and makes it you know and makes it spontaneously passive; if you have all these characters, then what happens then the crevice corrosion resistance increases right. So, this is general thing we can talk about it right. So, those elements which are doing the job ok, you will able to see that these things really can happen.

So, there are certain some empirical rules which talks about this and you say that elements like chromium, molybdenum, nitrogen in stainless steels and the nickel base alloys ok; they all help improve crevice corrosion resistance.

(Refer Slide Time: 52:17)



I just give one example, three in all these cases moly content increases from 1 to 3; same is true of course with chromium and also with nitrogen ok, they all can change the passivation behaviour quite significantly and so.

So, if you look at the many alloys they are developed like you know if you compare 316, 304; 316 is better than 304 and 904 L is better than 317; and 254 SMO is better than 904 L, so 654 SMO is better than 254 SMO. So, all these are happening because of modifying the composition of the stainless steels in order to improve the passivation behaviour.

And more so the critical current density and as well as the overall resistance of the alloy to corrosion, corrosion, ok. So, we have seen now the electrochemical parameters of the corrosion of the metals and this electrochemical parameters are related to the metallurgical parameters.

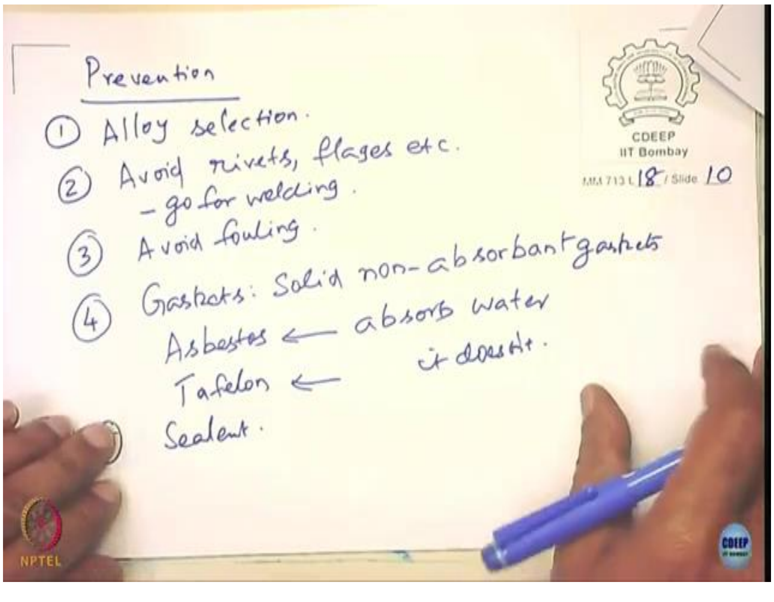
Of course they are all related to environment actually right and see for example, you take 304 and you carry out a polarization studies in say about this about 500 ppm of chloride solution of pH 7 and you determine the critical current density, passive current density pitting potentials all these stuffs.

And then you lower the pH from 7 to let us say about 3, you are going to have increase in critical current density increase in passive current density and also increase in the passivation potentials.

And so it also depends upon the environment as much ok. So, as much as the alloy chemistry they are all interrelated to each other. So, it cannot be seen that in isolation right, it has to be seen together when you talk about material selection for crevice corrosion resistance.

So, if you have an idea about the environment, then you can probably predict you know I mean what kind of materials can be used for crevice corrosion resistance for a given application.

(Refer Slide Time: 55:53)



CDEEP
IIT Bombay
MM 713 L 18 / Slide 10

Prevention

① Alloy selection.
② Avoid rivets, flages etc.
- go for welding.
③ Avoid fouling.
④ Gaskets: Solid non-absorbant gaskets
Asbestos ← absorb water
Tafelon ← it doesn't.
Sealent.

The next thing that we need to be looking at is what is called as the prevention. You can now start you know your own things right, because you know the principle and mechanisms, you know the factor controlling the crevice erosion; so writing I mean finding all preventing measures are not that difficult.

First and foremost is that we can look at the the right alloy combinations; if you cannot change the engineering you know design or if you can avoid joint such as rivets, flanges, etcetera, they form crevice around possible.

Then what do you; what do you do, you need to do go for welding if the design permits. This is the crevice former right, what else form the crevices we said about fouling right, so avoid fouling use filters. And if you are going to use a mechanical joints, then you want to use gaskets it must be solid non-absorbent gaskets.

See you know about you know that asbestos right, nowadays people do not use asbestos this is (Refer Time: 58:15) right, you take asbestos ok. And you take a Teflon, what is Teflon is its a commercial name of PTFE right, what is PTFE?

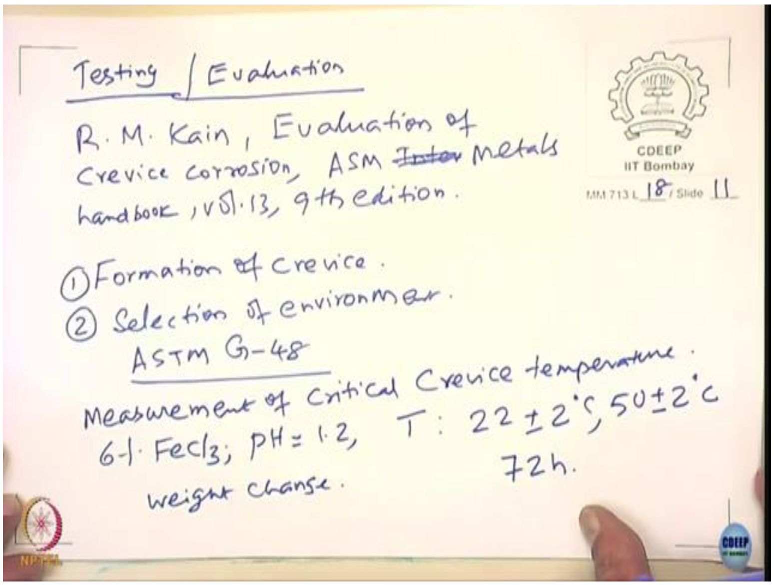
Student: (Refer Time: 58:33).

Fluoride ok, poly tetra.

Student: (Refer Time: 58:42).

Fluoroethylene right, ok. So, here asbestos they absorb water, moisture, whatever kind of thing, here it does not. You can use a sealant right if you have a problem, you can go for a sealant; if you use sealant, then all these gaps can be filled up, it is done in aircraft industries use a nice sealant. Well, we can keep adding many kind of variations that you can do I, I do not want to spend more time on this, because you should be able to devise methods by yourself.

(Refer Slide Time: 59:34)



Testing / Evaluation

R. M. Kain, Evaluation of Crevice corrosion, ASM ~~Inter~~ metals handbook, vol. 13, 9th edition.

① Formation of crevice.

② Selection of environment.

ASTM G-48

Measurement of Critical Crevice temperature.

6% $FeCl_3$; PH = 1.2, T: 22 ± 2°C, 50 ± 2°C

72h.

weight change.

CDEEP
IIT Bombay
MM 713 L 18 / Slide 11

I will go to the next method is the testing and evaluation or whatever. I would recommend you to go through this article by R. M. Kain, Evaluation of Crevice Corrosion, this is an ASM international; ASM metals hand book, volume 13, 9th edition, it is published by ASM international right you will also have it in your library, ok.

So, article by its a very nice article which talks about the complexities involved in designing the crevice corrosion. And now you need to understand the first of all the concept; what is that here you have to form a crevice, when I say a crevice that it has own geometry all these a crevice gap.

So, there are several variation that you get and you may choose a sample which is not flat versus the sample which is quite flat. So, do you think the results will be similar when the the sample with the flat and sample become rough sample will the crevice attack, it will be the similar or different; so where you think the crevice attack will be more.

Student: (Refer Time: 61:51).

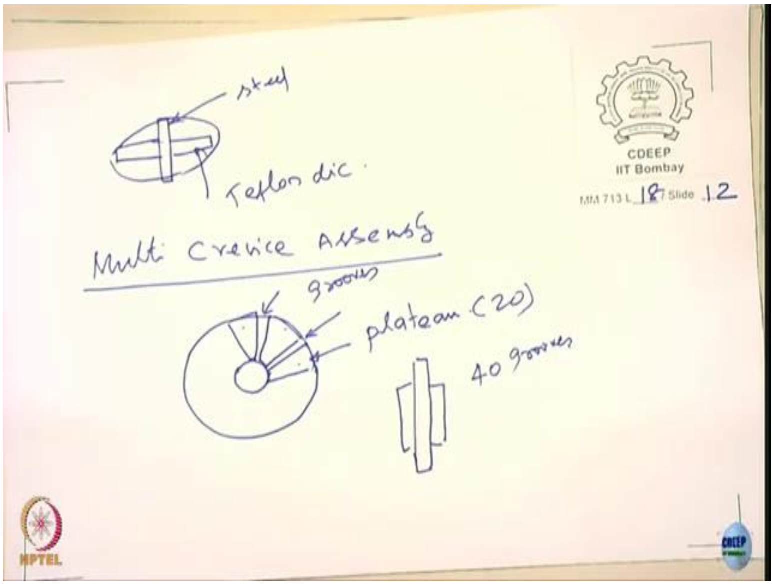
So, the crevice gap you know maybe more on a much more flat sample than on the rough sample ok. So, the tight crevice will increase it crevice corrosion rate, and the loose crevice will make the rate of crevice reduced. And I can form a crevice between two metals or I can form a crevice with a non-metal like a Teflon. So, a proper designing of crevice corrosion setup is very important ok, the formation of crevice and is one thing.

The second is selection of the environment and you can also look at the in the standard know, ASTM G-48 talks about the crevice this thing here ok. It is talking about measuring the critical critical crevice temperatures; here it talks about measurement of critical crevice temperatures ok.

And here the solution is 6 percent ferric chloride solution, the pH is about 1.2. Why do you take ferric chloride you take ferric chloride, because it is a good oxidizer ok; you can aggravate you can initiate the corrosion process much quicker, much faster than simply immersing in say sodium chloride solution.

So, ferric chloride is a good oxidizer; it is an aggravated test that people do and generally the temperature the chosen are 22 plus or minus 2 degree Celsius and 50 plus 2 degree Celsius, and they expose for about 72 hours ok, and then they look at the weight change. So, simple test actually what is done here you know you can in principle you can do a set up you know in your own labs right.

(Refer Slide Time: 64:48)



What you can do is see for example, you can you can take a stainless steel you know disc like that I can have a Teflon disc on this side, Teflon disc on the other side, I can do that I can have a rubber band holding like that the rubber band is tight enough to secure and it also forms a crevice right. So, you have a rubber band like this ok, this is the steel and this is your Teflon disc.

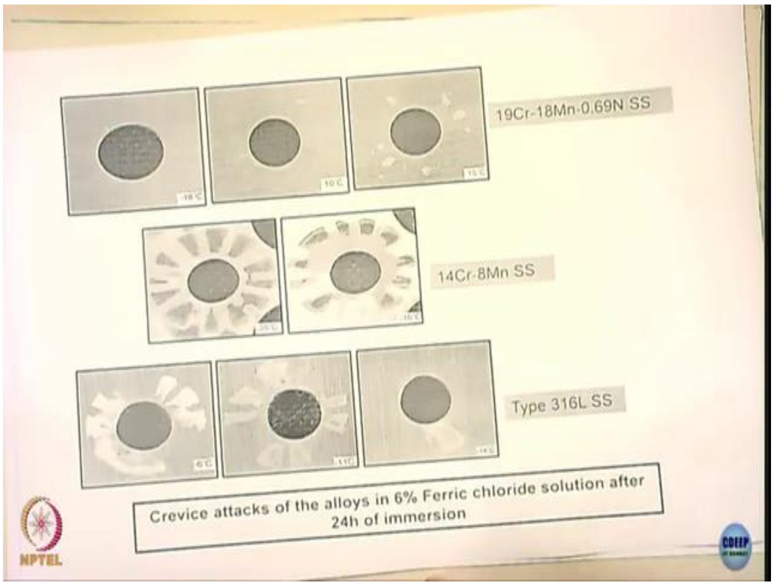
So, you immerse in ferric chloride solution and on the temperature of your own interest ok. And measure after 72 hours see what happens if there is a corrosion or not; there is no corrosion that means, at that temperature the material is you know resistance to crevice corrosion.

Now, they also made a little bit more sophisticated setup that is called as multi crevice assembly ok, where in a single experiment you can have many crevices formed. See here in this case you have only two crevices, right one on the right and another on the left you have, but I can also have a multi crevice assembly by taking a Teflon disc and I make various grooves right, I can just groove like this I can take this out, see this is the groove here right.

So, I can make several grooves like that ok. You can make as much as this called as this called as a plateau right. So, you can have about 20 plateaus, you can have 20 plateaus you can have actually ok; 20 plateaus means you about 20 grooves that you have. And what you can do? You can take a sample and you can put one assembly here, other assembly here; so you will are going to have about 40 grooves, that means you are going to have about 40 crevices are formed in one single test right.

The each other this is the crevice right, this is the crevice here; it is a potential crevice, because the liquid can go through this go through this. So, here is a crevice here it is a crevice here, so when it sticks on the surface and they form the crevice. So, there are about 20 crevice is formed one side one face of it, other face of these stainless steel sample we have 20 more if you have 40 grooves are formed. And you can now expose it in the ferric chloride solution ok, and you can get the attack you know see done.

(Refer Slide Time: 68:33)



19Cr-18Mn-0.69N SS

14Cr-8Mn SS

Type 316L SS

Crevice attacks of the alloys in 6% Ferric chloride solution after 24h of immersion

And this is something like an experiment done in our own lab here by one of the PhD students, you see here ok. Yes, this is the disc now you can see this here, these are all the attack these are the attacked portion see the attacked portion, these are the attacked portions because of the crevice see the attack, attack is more. And where there is a groove, there is no attack; see this is a groove, there is no attack; this is the plateau region, this attack you see here.

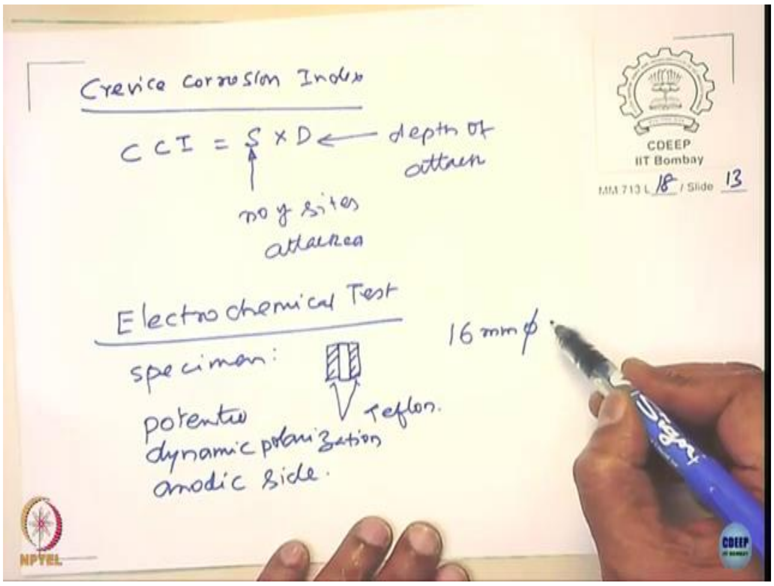
The the attack is on the on broader compared to the grooves, ok. So, you see kind of **sees** here the attack attack here there is no attack here, so the crevices taken place these cases. It was done in the lab and you can see this alloy is 19 chromium, 18 manganese, 0.69 nitrogen is you know the attack is much less you can see here; you do not see much attack here 1 or 2, but 14 chromium, 8 manganese is attack is quite severe and 316 the extent of attack is less now, so that means you can able to evaluate the crevice corrosion resistance of the alloy.

But here see here, here it is mean the expose only for 24 hours not for 72 hours actually. So, there is no hard and fast rule when you are going to allow develop an alloy, but then if you are going to follow the ASTM standard, you should strictly follow the ASTM standard, then only you can compare between the results obtained in the different laboratories now. So, these are the kind of thing that you can see and which are very useful in determining the crevice corrosion resistance of this alloys, but it be very interesting.

Now, 304 stainless steels can suffer crevice corrosion at sub zero temperatures can imagine, the crevice corrosion is much more severe even compared to pitting corrosion other forms of corrosion.

So, sub zero temperature means you can imagine that you know even, even the below the ice you have some chlorides the 304 stainless steel can suffer the crevice corrosion of course, the time taken for crevice corrosion is is going to be more actually. Now, so people use this as a criteria for the crevice corrosion, now this is called people also use term which is called as is called a crevice corrosion index.

(Refer Slide Time: 71:06)



Crevice corrosion Index

$CCI = S \times D$ ← depth of attack

S ↑ no of sites attacked

Electrochemical Test

specimen:

16 mm ϕ

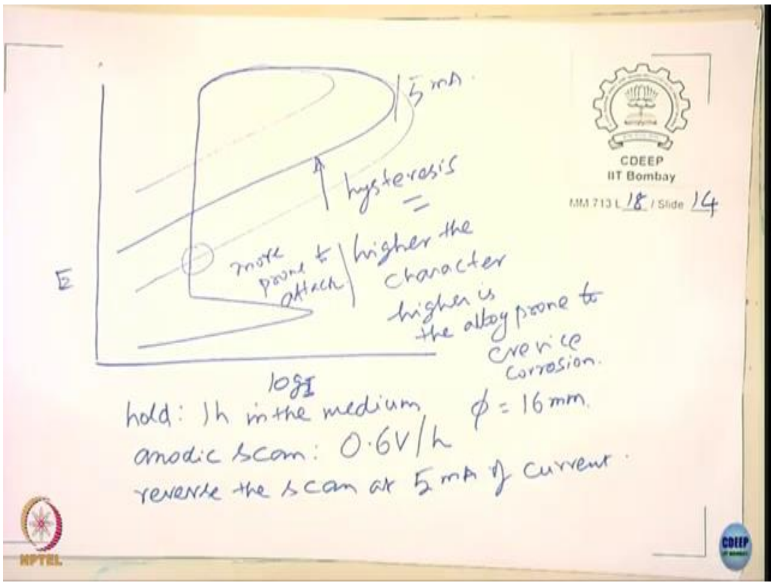
Teflon.

potentio dynamic polarization anodic side.

So, CCI is given as the multiplication of these two and S corresponds to the number of site attack number of sites attacked, and D is the depth of attack. So, this is a kind of index people use to quantify the crevice corrosion resistance of the metals actually, ok. This one more I before I close it is the test is electrochemical test, you have known a potential dynamic polarization curves are obtained right the laboratory to look at the passivation behaviour of the passive metals.

Now, in this case what you do is the specimen what people do in this case in this specimen, you have you have a crevice here right. Suppose you have a sample of here in this case, it is about 16 mm diameter and you have a Teflon cover this with a Teflon here, PTFE right. And this is your electrode in you carry out potentio dynamic polarization, in the anodic side only not in the cathodic side, anodic side; do that and if there is a crevice corrosion and then what is done here ok.

(Refer Slide Time: 73:46)



more prone to attack

higher the character higher is the alloy prone to crevice corrosion.

hold: 1h in the medium

$\phi = 16$ mm

anodic scan: 0.6V/h

reverse the scan at 5 mA of current.

To do a potentio dynamic polarization and you reverse this, you get like this and this is called as hysteresis and higher this, higher the character, higher is the alloy prone to crevice corrosion. So, what is done here is here before you do this can, you hold the sample for about 1 hour in the medium that will start establishing the crevice actually, crevice corrosion right.

And then scan anodic scan 0.6 volts per hour, this can they do that and reverse the scan at 5 milli amperes of current; so, that means this current is what this current is is equal to 5 milli amperes ok. So, it is a log I not small i, because the sample here you have taken; what is the dimension of sample here, the sample diameter in diameter is equal to.

Student: 16.

16 millimetre, right.

Student: Yes.

So, so the current density is going to be different hm. So, this hysteresis is an indication you compare the different alloys, like alloys it is alloy 276 or maybe 304 and so you compare with that alloy, and see how the newly developed alloy performs. In 304, of courses is is not an alloy meant for crevice corrosion resistance; C 276 is supposed to be the one of the best alloys from the crevice corrosion resistance point of view, ok.

So, this is how we can do that, but you can always have a several variations you can carry out a potentio static test you know, you know and basically you have a crevice and and how the crevice affects the electrochemical parameters of these things. So, with this you have any questions are there? Anybody has questions?

Is to see one example higher the hysteresis character right I mean you can have something like that right, you can have something like this ok. So, this alloy is not passivating at all, look at this, and look at this, look at this and this alloy is more prone to attack. You will see this little detail when you talk about the pitting corrosion ok, so this the the area of the crevice you see here as increases, the alloy becomes more prone to pitting corrosion I am sorry, pitting corrosion as well as crevice corrosion anyway.

They are not, I mean you will find the later that the if the alloy is you know resistance to crevice corrosion would also be resistance to pitting corrosion as well ok. So, with this we will close the discussion related to crevice corrosion. And, see you have any questions, think about it, in the next class when we meet we will discuss on this topic.