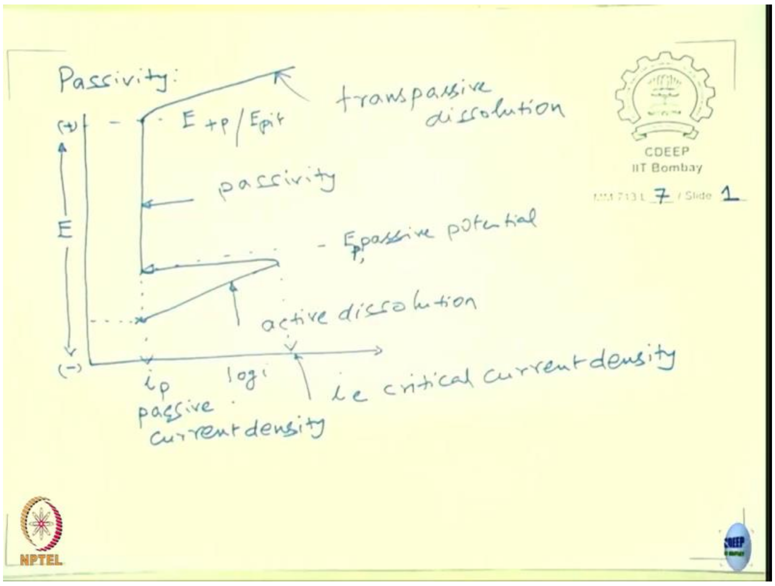
Aqueous Corrosion and its Control
Prof. V. S. Raja
Department of Metallurgical Engineering and Materials Science
Indian Institute of Technology, Bombay

Lecture - 07
Passivity continued

(Refer Slide Time: 00:33)



We started discussing the concept of a Passivity in the last class and you know, and passivity is a important property that is exploited to prevent corrosion of metals. We also saw that the passivity means it is the formation of an oxide film on the metal surface and this oxide film is not very thick usually. It could lie between 30 angstroms to about 100 angstroms thick. But they are quite impervious. They resist the flow of current and so, it offers excellent resistance to the corrosion of metals.

So, that is why the passivity becomes very important. We gave some examples also, where the passivity is very much exploited in engineering applications of metals. Stainless steel is an obvious example, where the passivity is very much utilized. The other metals are the titanium, zirconium, even for that matter aluminum, they are all tantalum; these are all the metals. They show a lot of passivity. And so, they offer extremely high resistance to corrosion.

Now, we looked at a qualitative description of what a passivity is. We also started defining the passivity from the point of view of electrochemical concepts. We started looking at the so-called Evans diagram, for a metal showing active passive trans passive transition right. That is if I can draw a schematic diagram, between the log current density and the potential.

And if you see a typically a metal in an environment, this is your equilibrium potential. We will show an active dissolution, it shows an active dissolution and then, it started reverting the current when you apply the voltage. Then, the current almost remains constant and again, the current increases with voltage applied voltage.

This is a transition, where metal initially undergoes active dissolution right and then, this is the passivity and this region, we defined as trans passive dissolution. We also defined the other parameters which are important for us, they are like what you call this i_c, it is critical current density and you call this as the i_p be the passive current density right.

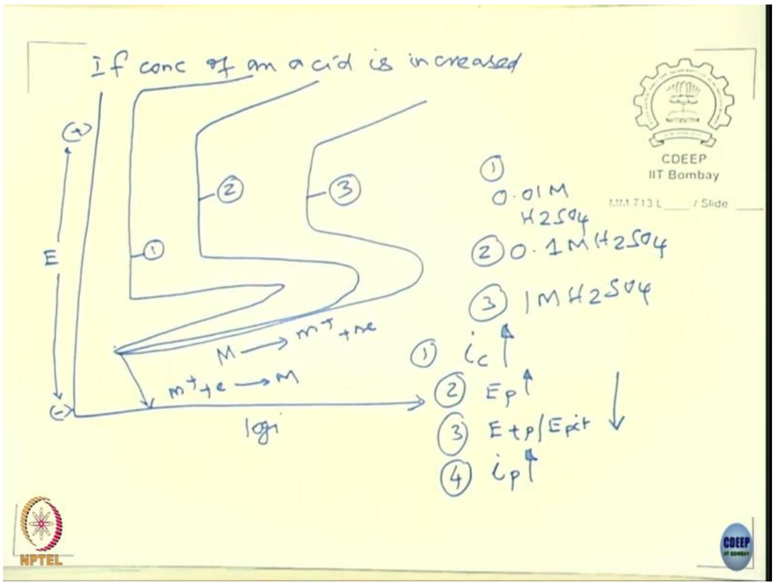
And you call this as a potential which is called as E_{tp}: trans passive potential. You can also call as E_{pit} which is called as a pitting potential and this is the potential above which the metal passivates this is called as a?

Student: Passive potential.

Passive potential; E_p. So, the metal will if I increase the voltage ah potential on the metal, the current increases and again, start decreasing here, current remains steady. Then again, current increases. This is how this metal start behaving. So, in order to understand how the metal in actual situation behaves, you need to first understand how this particular plot will change, if I change the environment.

If I change the environment, how does this change? So, we will see how does this change if I change the environment? Assume that I am going to change the concentration of the acid right.

(Refer Slide Time: 06:42)



If conc of an acid is increased

① 0.01 M H_2SO_4
② 0.1 M H_2SO_4
③ 1 M H_2SO_4

① $i_c \uparrow$
② $E_p \uparrow$
③ $E_{tp}/E_{pit} \downarrow$
④ $i_p \uparrow$

If concentration of an acid is changed and is increased let us say. So, what is going to happen to this right? So, again you need to draw the potential versus the log plot right, I will assume that you have a sulfuric acid of 0.01 molar sulfuric acid ok. Suppose I have 0.01 molar sulfuric acid.

So, this is 1; 1 is 0.01 molar sulfuric acid. If I make it say 2 molar sulfuric acid, I am sorry if I make it as let us say 0.1 molar sulfuric acid, you will see the active dissolution will increase. So, this corresponds to I am just giving a schematic, I am just giving a how the trend is looking like.

If I increase, let us say the concentration to 1 molar, then it is possible that this guy will go something like that. So, these parameters are all depend on the environment, it may also depend upon temperature. Suppose I increase the temperature, I may get a similar effect. Can you just tell me, what is happening to the anodic polarization? If I increase the concentration from 0.01 molar to 0.1 molar to 1 molar sulfuric acid, what are the changes happening? Can you point out, what are the changes?

Student: Actually

Electrochemical parameters?

Student: Current density.

What current density?

Student: (Refer Time: 09:36).

Can be very specific?

Student: (Refer Time: 09:38).

Yeah.

Student: Chemical, chemical parameter.

The critical content is changes right. So, i_c increases, 1 factor. What more is happening?

Student: E_p is also (Refer Time: 09:58).

E_p is also increasing, then?.

Student: (Refer Time: 10:05).

Ok.

Student: E_{tp} (Refer Time: 10:07).

The third E_{tp} or E_{pit}. You right now you do not worry about whether Etp or Epit; but it is also, it is what is happening. It is decreasing right.

What more is happening?

Student: (Refer Time: 10:23) passive.

Your i_p, the passivation current density is increasing. I am not really worried too much about the exchange current density at this point of time ok. Let us not worry about it. You see these are the changes, they are accompanied due to the change in the environment right. What will happen to the corrosion rate that we are not discussed. What will happen to corrosion rate, have we discussed? We are not discussed.

Now, please notice this is we are talking only about the metal dissolution right. Let us say this is a metal, $M \longrightarrow M^{n+} + ne^-$. If you wanted, you could also write another one as $M^{n+} + ne^- \longrightarrow M$. you want, you can do that ok. This is not going to give you corrosion rate right. How would I get a corrosion rate? I need to have?

Student: (Refer Time: 11:30).

What I should have?

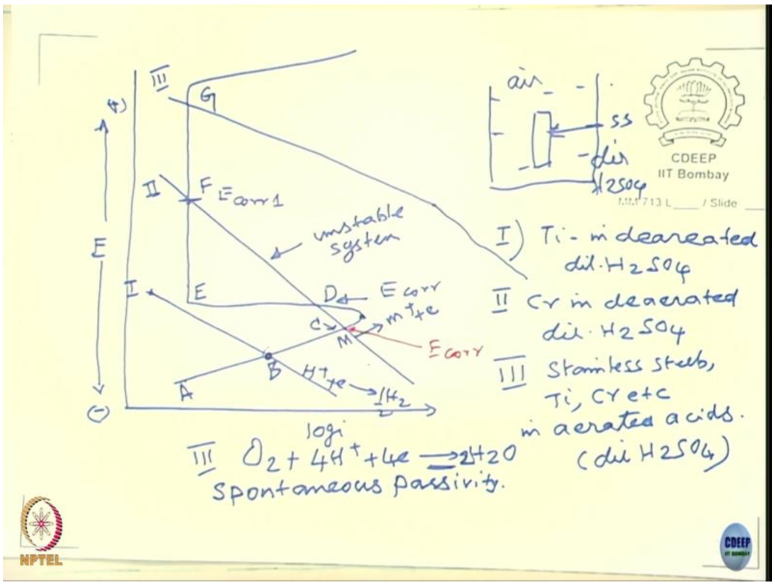
Student: i_{corr}.

I should have i_{corr}, how do I get i_{corr}? What I look for? I look for the second equilibrium. This if the metal is getting oxidized, there has to be a corresponding reduction reaction right, without that you will not happen right. So, I am looking for, what I am looking for another equilibrium that will drive the corrosion of the metal actually ok.

Student: Yeah.

So, I again go to the so called mixed potential theory. Apply this mixed potential theory and find out what is happening to corrosion rate right. So, let us look at this now and see how interesting these features are. I draw again schematically a polarization curve showing active passive transition ok.

(Refer Slide Time: 12:36)



You can also do yourself. Is that right? So, what I do? Increasing like this. Now, I am going to just look at the possibilities; three distinct possibilities, there can be several possibilities, three distinct possibilities I will consider ok. Now, I can draw a cathodic kinetics following this graph, it can follow like this ok. So, I have on this

$M \longrightarrow M^{n+} + ne^-$ here. Maybe I would say this is the $2H^+ + 2e^- \longrightarrow H_2$ like this here.

I can also have another you know characters characteristic lines like this. I can have one more. So, this is I can have one more line, this is line I, line II. You can also have one more, something like that. Let us say line III. They are distinctly different. You can now, we can draw so many in between right. They represent three different type of you know phenomena can happen on corrosion. You can look at the intersection points. You can label; this maybe you can start from A, B say C ,D, E, F, and G.

Of course, I think you know this is the C here right. This is the C that correspond to this. In the case of line, I, the mixed potential theory is applicable and happens only at one place right, they are seemly clear. Now, I know what the corresponding corrosion current density is I can know that. I can know the corresponding corrosion potentials. If I take the line II, the mixed potential theory is as well applicable for the location intersection point C, D, and F; am I right?.

All three places, the mixed potential theory is very much valid the line III which means they are different kinetics, you have only one point; where, the mixed potential theory is valid all other places it is not valid. So, if we know where the mixed potential theories are applicable, I can find out the E_{corr} value.

I can find out the corresponding i_{corr} value; am I right? So, the point you know C, D and M can also happen in practice. The point B can happen in practice, the point G can also happen in practice. If you want to give an example, what corresponds to (I)?

The (I) typical system corresponds to titanium in de aerated sulfuric acid dilute sulfuric acid. System (II) corresponds to chromium in de aerated dilute sulfuric acid. System (III) stainless steels titanium chromium etcetera. in aerated acid solutions, it could be mostly acid, it could let us say dilute sulfuric acid. Why, what happens in the aerated condition. Can anybody? Tell me?

Student: Oxygen.

Oxygen in the air right, you have one more reaction. What is the reaction here? The third corresponds to $O_2 + 4H^+ + 4e^- \longrightarrow H_2O$. This is the equilibrium that you have. So, the cathode reaction is quite having higher kinetics. You see now how you know the same material like titanium and chromium can behave differently depending upon the kind of environment that you deal with it ok.

Now, let us look at this little bit more carefully. Let us take the line (II), the kinetics (II), you can have the mixed potential theory, you can have a E_{corr} corresponding to this 1; you can also have an E_{corr} corresponding to this; you can also have an E_{corr} corresponding to this. Now, we need to understand, why does it happen? Let us take the case of G, the metal you know in this case, in this case of III, this is called as spontaneous passivity. The metal here undergoes spontaneous passivity.

Because why? Because I just immerse as let us say a stainless steel in dilute sulfuric acid, I do that, and I have air which is now this stainless steel is spontaneously passivating. There is no problem because the potential is going to the passive region.

When you remove air in the case of titanium, the current you know it does not exceed beyond this value. So, to passivate the metal, suppose I need this place, please notice the metal has to be polarized, you have to move up and move up and move up and reach this point.

Then what happens? Then, automatically, the current starts falling down. So, you need to cross this point, what you call this point called as? Critical current density. Unless you cross this, the metal will not passivate. The metal will start passivating only when you cross this.

To cross this point, look at this; the metal undergoes oxidation, there has to be equivalent amount of reduction, then only the metal will corrode; am I right? You take this particular potential here at this particular potential, if the metal resolution rate is higher than the reduction rate, what happen? If sorry, at this particular point, if the metal oxidation rate is higher than the reduction rate of the environment.

what will happen? The system will not sustain, it will come down or if the rate of reduction is higher than this, what happen? The metal starts tending towards up. So, in order to, in order to cross this particular point, the rate of oxidation here must be lower than the rate of reduction.

Then, only it is possible to cross; that means, the cathodic kinetics should be higher than the anodic kinetics. Then, only this can move. Let us take this line here, I extrapolate this line. You see at this particular point the rate of reduction is going to be higher than the rate of oxidation and so, the potential starts moving up. So, this is the requirement for that.

So, in this case, the metal can either stay here it will stay here. So, it has an option of one and two. The point D is a unstable. The point D is never happened? When will when you move over here? In case, the concentrations of this species is slightly increased, the guy will move over here; otherwise, they stay here only.

So, the system II, it is called as unstable system. Whereas, the system III, the system I, they are all the stable systems stably active corrosion, stably passive systems; whereas the system I can show either E_{corr} here or you can show an E_{corr} here. So, both things are possible in this case.

So, system II is not acceptable because it is uncertain. System III is ideal, we want that. The system I is predictable is better to have system I than to have system II ok. So, this is how you look at from the engineering perspective ok, which of these things can happen and these are all systems where chromium in de aerated sulfuric acid is uncertain. It may have high corrosion rate; it may have low corrosion rate ok; both are possible. We will see this in the subsequent discussion and how these things really happen.

So, we have now seen in detail the application of the mixed potential theory for the corrosion of metals, when they are actively corroding, when they are passivating. We also saw that how we can apply the mixed potential theory, if the system is under diffusion control and I suppose you are now in a conversion bit the understanding the kinetics and if you any of you have any questions, I think we can discuss and then, we can move forward.

Student: What does the possibility of C, D, F solely depend on potential?

Whether the metal will go to C, D, or F, we consider D is a little unstable. What does it mean by that actually? Actually, if you scan this potential little fast, you will see that this whole line starts moving up. If you scan it slowly, it will move down ok. So, this all of this horizontal line is an unstable line. In reality, you would not get the intersection point D. But what you will get is the intersection point F and the intersection point C, these are the point you can get it actually ok.

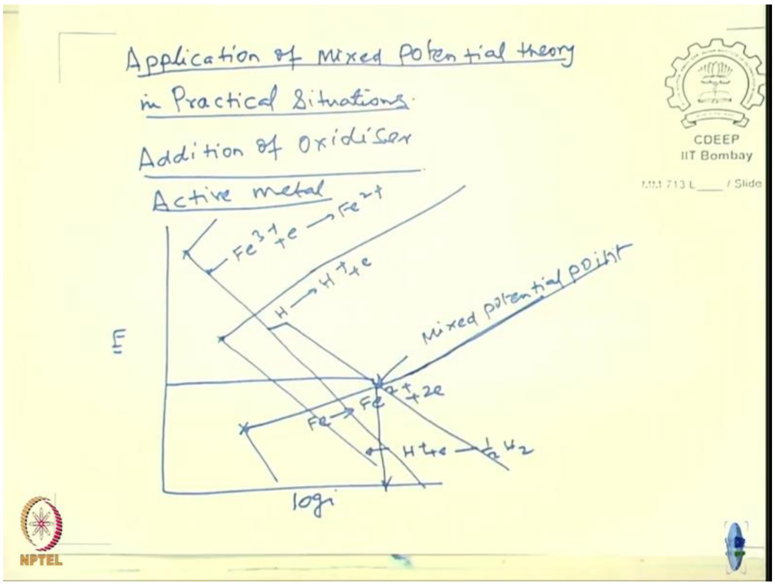
This also would depend upon the passive current density, you know if the you know for example, if the passive current density is going to be little higher for example, you will get this uncertainties much more much more can happen.

So, i_p value is equally important. You will, you will see subsequently and how this you know if for example, if you lower the i_p value, the reducing agents required to maintain the passivity is very low. So, you will find that once you reach this state that this state becomes quite stable ok.

So, if the kinetics of this reaction is going to be either here or here ok. Initially, it may start passivating you know but I think the passivity is going to be quite unstable because you need to reach the critical current density ok, above which only the metal will move up in the potentials ok. So, you will see that this you know system sometimes exhibit the two E_{corr} values; a E_{corr} value of this and E_{corr} value of this; whereas, this system III and system I would always show only one E_{corr} value.

And I would probably show you at later time when you talk about experimentation, how these systems are indeed showing two different E_{corr} values, when you carry out the experiment actually ok. Because the system is not becoming totally stable because of the poor the cathodic kinetics for this, this system. Any other questions ok?

(Refer Slide Time: 29:43)



Application of Mixed Potential theory in Practical Situations.

Addition of Oxidiser

Active metal

So, let us move on to the next topic of Application of Mixed Potential theory in practical situations. So, let us take a system, where you add an oxidizer. You have seen this earlier. Anybody recollect? We talked about an oxidizer and in the case of active metal and we said that the corrosion rate will?

Student: Increase.

Increase right. So, we saw this before you know for a active metal.

for active metal, we saw that when you add an oxidizer, the corrosion potential moves up. The corrosion rate indicated by i_{corr} goes up, we also made one more observation. What was it? The hydrogen evolution reaction in acid will come down actually. These observations are made right. Any of you recollect that actually?

Student: (Refer Time: 31:55).

Ok So, you know if you recollect that we see it is simple right. We are talking about some metal some may be you know maybe iron, maybe you can say Fe $\longrightarrow$ $Fe^{2+} + 2\ e^-$ and we were saying that say iron in an acid right and this was what; this corresponds to what? Corresponds to $H^+ + e^- \longrightarrow 1/2H_2$ right. And you have a corresponding reduction reaction right.

This is your $H_2 \longrightarrow 2H^+ + 2e^-$. We said that when you are going to add an oxidizing agent something like your this corresponds to what this corresponds to

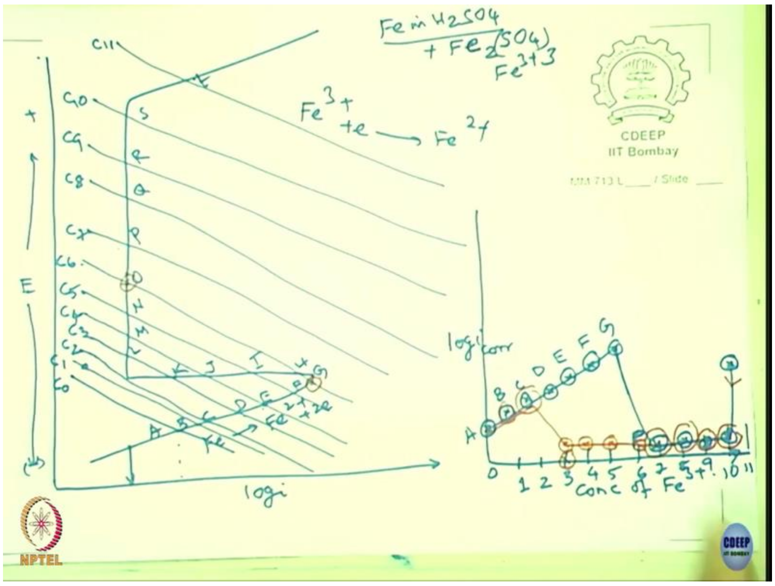
$Fe^{3+} + 2e^- \longrightarrow Fe^{2+}$ right. Is not it?.

Do you remember that? So, what did we do in that case? We added the; so, we added both the cathodic reactions ok, somewhere here and we say this is your mixed potential point right, where you have rate of oxidation is equal to rate of reduction. We also said right. So, we said that when you add an oxidizer the rate of corrosion is increasing right, we saw this earlier. Hope you will able to recollect this.

Student: Yes sir.

Right. Now, let us look at this in the case of in the case of a passive system and see how the mixed potential theory is revealing actually right. Let us look at this. So, I can add an oxidizer to this right.

(Refer Slide Time: 35:07)



Suppose without an oxidizer, this is let us say $Fe \longrightarrow Fe^{2+} + 2\ e^-$, it is iron is immersed in say it is iron in sulfuric acid. Fe in H_2SO_4 and to this I add let us say Fe_2SO_4. I am going to add a ferric sulfate sorry to this, I am going to add a ferric sulfate, ferric sulfate means I am going to have in this Fe^{3+} irons right.

Add to this. Now, without the addition of these irons, I would draw a cathodic line like that ok. What does this correspond to this corresponds to the corrosion rate of the metal in acid and this potential corresponds to E_{corr} and I am going to add to this certain amount of Fe^{3+}. What is going to happen now? You will have concentration right.

So, they have different concentration of the oxidizers and here C_0 is no without oxidizer; I add C_1, C_2, C_3, C_4, C_5, C_6, C_7, C_8….C_{11} like this. Any of you, who have not followed this diagram, please let me know. See what are these lines corresponds to the cathodic kinetics occurring on the solution containing what? Containing?

Student: (Refer Time: 39:02).

Fe^{3+} ions, am I right? This is only with the C_0 corresponds to the corrosion of iron in sulfuric acid without the addition of Fe^{3+}. So, this C_1, C_2, C_3, all this corresponds to gradual addition of different concentration of Fe^{3+}. I keep adding. You imagine an artificial you know, imaginary experiment right. In an imaginary experiment, you take a beaker and you take a sulfuric acid and you dip an iron piece and you can measure the E_{corr} value easily right.

But of course, you it is very difficult to measure i_{corr}. We will see later how to do that. But i_{corr} also is some way you can able to determine actually. I keep adding different extent of Fe^{3+} and each of these lines corresponds to the cathodic kinetics, for that addition of the Fe^{3+} in the solution. Agree? So, these are not simply lines, these are all corresponding to the different kinetic equations. They are different tafel lines that you have right, they are different tafel lines you have this.

Now, I can find out, what will be the corresponding corrosion potential and the corresponding corrosion current density? So, I can start plotting this. I can plot the $\log i_{corr}$, I plot versus the concentrations, can I? So, a 0 concentration, I know what the corrosion rate is. Somewhere its starts here at 0 concentration; there is 0 concentration. Then, what I have? I have 11. So, I have added different concentration.

So, I would find out what is the corresponding corrosion rate for each addition of the ferric ions. So, if I add C_1 concentration, the corrosion rate increases. So, I would approximately make this point here right. This corresponds to what? So, you can also label this if you want, there are so many lines is a problem. A, B, C, D, E, F, G, that is H, I. So, there are several points that you can label here in the polarization curves ok.

So, this corresponds to what this corresponds to A right. C_1 may correspond to B and what next, C_2 corresponds to what? C, C_3corresponds to the D, the C_4 corresponds to E right and C_5 corresponds to what? Corresponds to F, C_6 corresponds to G. Here please notice when I keep adding, I am not moving here because to move this particular point or to reach this particular point, the system has to cross this critical current density.

So, when I add these Fe^{3+}, it will not cross. For example, if you add C_4; C_4 corresponds to this, it cannot go beyond E. So, the corrosion rate only increases to from D to E, it do not reach J neither you will reach M also. So, it you can go only up to this. So, when I am adding the concentration higher quantities, you know the current increases. It does not go beyond these values, but when you add let us say C_7 what happens? When I add, C_7 what happens now? What happens to C_7?

Student: It decreases.

It decreases to this value ok. It C_7. So, now it becomes corrosion rate lower than this. It comes very close to this. What is this called P. C_8 remains the same; C_9 remains the same; C_{10} remains the same ok; then C_{11}, what happens? C_{11} it again, where does it go? It goes somewhere close to D actually right. It goes somewhere close to D here.

Student: (Refer Time: 46:04).

Yeah?

Student: It is not visible. Not visible.

Not visible, now is ok; fine. Now, so you can see that the corrosion, rate increases, it decreases here, it remains stable and again, it increases. So, what does this line tell you is that the gradual increase in corrosion current density on the addition of oxidizer, until it reaches completely the passive state. Then, there is a short decrease in the corrosion rate, current corrosion current density; it remains almost the same, then again it goes to transverse region, it goes here ok.

Now, let us look at the reverse situation. After reaching this particular point, I dilute the electrolyte by using water or I reduce the concentration of the Fe^{3+} gradually from C_{11} to C_1. I reduce the concentration of ferric ions gradually from C_{11} to C_1. So, what happens to the corrosion rate of that metals? So, at reaching this place, I start reducing the concentration of Fe^{3+}. Now, when I start moving from here to this place, what will happen now?

It will again follow the reverse path; it will follow the reverse path here right. It will again follow the reverse path here, it follows again same thing. It again follows, it again follows. So, from here to C_7, we are very clear, it is almost reversible. It has regained its passivity. Now, from C_7 you go to C_6.

Now, let us go to C_6. C_6 you have the options of having E_{corr} decided by this point or decided by this particular point at 2. And this H is an unstable point, we do not worry about it and you can have either E_{corr} here or here. How do you decide whether the E_{corr} will remain here, I will come over here? Do you think the E_{corr} will remain here or do you think it will shift to this place?

Student: (Refer Time: 49:02).

Yeah?

It will?

Student: It will remain.

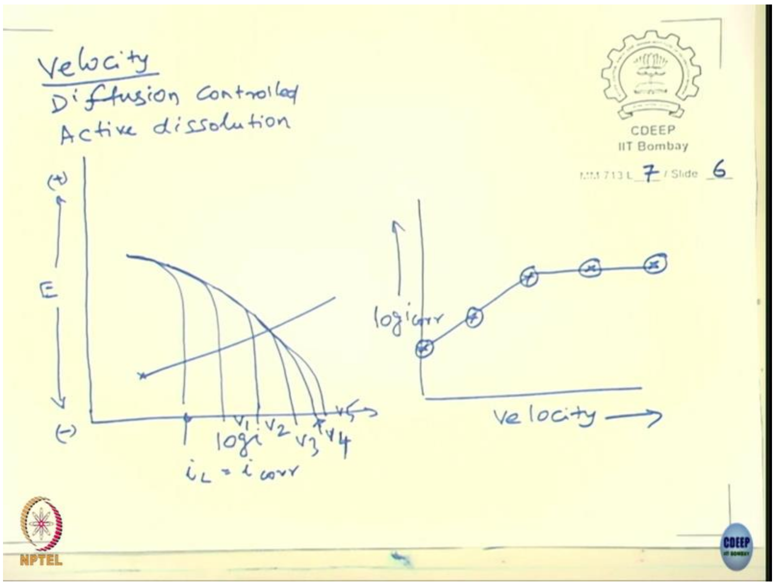
It will remain there because to maintain this anodic reaction, you do not need more amount of oxidizer. So, once you reach passivity, the amount of oxidizer required to maintain this passivity is much less. Because the rate of anodic reaction here is much less compared rate of anodic reaction here. So, once I have the passivity, the passivity remains stable because the rate of oxidation is equal to rate of reduction and you do not need too much of oxidizer for that. So, that will happen until you reach the point C_3.

So, until you reach the point C_3 ok, the passivity will remain the same. Then, what happens at C_2? At C_2, it will go back to C, it goes back to C and then, it will follow same line. Understood? For the you can label what these are all. All these lines correspond to what? Corresponds to $Fe^{3+} + e^- \longrightarrow Fe^{2+}$

Student: (Refer Time: 50:33).

ok. I will give another example, then we will move further into the other topics of electrochemical kinetics. Let us look at the velocity.

(Refer Slide Time: 50:50)



We have seen this earlier, how the velocity can affect corrosion. It need not affect corrosion. You tell me a case, where the velocity may have effect on corrosion. It may not have an effect on corrosion. If the corrosion is dash, then velocity has no effect; if the corrosion is dash, velocity has an effect.

So, if the corrosion is diffusion control, then the velocity has an effect. If the corrosion is activation controlled, velocity has no effect right. So, that has to be very clear about it. We will see later velocity has one more effect later, we call erosion corrosion, that is a different point. We will talk about later. Now, let us consider a case, where the corrosion is under diffusion control. So, diffusion control process and metal undergo active dissolution, then what happens?

You simply draw, it is very easy right. You just have to go be, do it very systematically ok; represent the kinetic diagrams, a metal undergoing only the active dissolution; but the cathodic reaction is what? Is diffusion controlled. This you have seen it and this corresponds to what? To i_L. i_L am I right and it will also be corresponding to the?

Student: i_{corr}

i_{corr}. So, if I increase the velocity, what is expected here? What will change? What will change?

Student: (Refer Time: 53:50).

Which one?

Student: (Refer Time: 53:52).

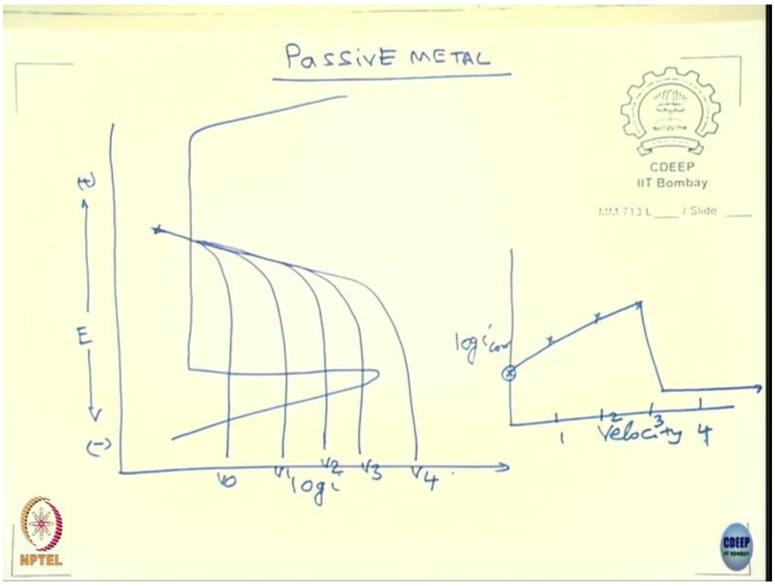
With the anodic curve will move.

Student: Cathode.

Yeah, the cathodic curve will move. Why should it move? Because i_L is inversely proportional to the diffusion layer thickness. The diffusion layer thickness decreases when you increase the velocity of the fluid. Am I right? So, we have to increase the velocity. So, v_1, then you have v_2, v_3, v_4, v_5. So, you can plot the i_{corr} versus the velocity. So, what happens?

At the zero velocity, you have this corrosion rate somewhere here. What happens when you increase the velocity, it is increases; then, what happens? Why it is not; why is that the velocity has no effect here? It has become activation control all right. So, both are happening in series, when the diffusion is not controlling it becomes totally an activation-controlled process ok. So, the active metal right. Let us go to the passive metal and see what happens. Can I move?

(Refer Slide Time: 56:35)



So, what you have to do? You have to draw an anodic polarization curve showing the active passive and trans passive dissolution and also, represent a cathodic curve exhibiting what? Exhibiting the passivity and you change the cathodic reaction kinetic with increase in velocity, find out the mixed potential in all these cases? And you can find out the corresponding i_{corr} right. So, there you go and see what happens. So, you can start plotting and see how things are different in this case.

So, what do you think will happen? Can you make a guess, before you go into this? What can happen with increase in the velocity? So, it is possible that the reduction rate can cross or go beyond the critical current density right. If you increase the velocity, the i_L can increase and go to an extent, where the i_L is going to be greater than?

Student: i_c.

i_c. Of course, there is one more caveat there, the caveat is the equilibrium potential of the cathodic reaction has to be much higher than the passivation potential. Just imagine what happens right. So, then what happens if you have i_L becoming greater than i_c, so what do you think will happen?

Student: (Refer Time: 58:57).

It will become spontaneously passivating right; the i_{corr} will drop, the i_{corr} will drop. So, let us draw this and see if it can happen at all. So, I am also drawing along with you right. This is a anodic polarization curve showing active passive trans passive dissolution right and I would go for a cathodic reaction, whose equilibrium potential is quite relatively positive; then, I represent the cathodic kinetics and if I increase the velocity ok.

So, zero velocity, V_1, V_2, V_3 and V_4 and you can know the corresponding limiting current densities, you can also plot log i_{corr} right. 1 2 3; is it ok? Now, I want to say that we are not going to stop using this mixed potential theory.

From now, we will be applying the mixed potential theory when you start discussing, let us say Galvanic corrosion, Crevice corrosion, Pitting corrosion. In all these cases, we will apply a later and see how they are useful in understanding the various forms of localized corrosion ok.

So, we will revisit it and to appreciate how they are useful to understand the concepts of various forms of localized corrosion and for the, for the time being, we stop here. We move on to next topic of what is called as how to use electrochemical principle or electrochemical technique to determine the corrosion rate.

See corrosion rate determination, you might have started discussing and doing experiments in the lab to measure the corrosion rates. One simple experiment is to use gravimetric study, where you may choose a sample of known dimension, known area right, known surface area.

You immerse it in a given electrolyte a corrosive medium, you may call whatever. For a given time, you measure the loss in weight using a balance and you know the time of exposure, you know the loss in weight, you would know the density and you will able to calculate the loss in thickness right. But when you do these experiments, it is a very time consuming. It is very time consuming when the corrosion rate becomes very low. Have you started this experiment? Any of you who are the guys, who have done the experiment?

What experiment did you do?

Student: Weight loss method.

For what material?

Student: Mild steel.

Mild steel. What environment?

Student: HCl.

Student: HCl.

HCl. So, what did you observe? Suppose you put you just dip steel in HCl, what concentration?

Student: Point O.

Point O. What have you observed; did you observed anything? Visually, did you see anything; what happened? It is very important that you know experimentation is observation. If you do not have observation, you cannot do research you know. a very important thing. You would have noticed a large amount of hydrogen evolving on the surface, there may be a solution turning into reddish brown color right; maybe ferric ions may be formed, whatever. Suppose I give you how long did you immerse?

Student: 24 hours.

About?

Student: 24 hours.

24 hours. In 24 hours, you are lucky; you are able to see an appreciable loss in weight that you can measure in a balance. I give you a titanium and I give you let us say NaCl solution of 3.58 %. I want you to determine the corrosion rate After 24 days. you just measure the change in weight. It will be so insignificant, you may not measure; you know appreciable, you know weight loss, it is very difficult to do this.

In fact, when you do an experiment the time of immersion, there is a Thumb rule you know. What is the thumb rule? 2000 upon MPY gives you the hours. MPY is in terms of corrosion rates. We will see later you know all the units in detail ok.

So, lower the corrosion rate, higher is the time required to expose in order to get a reasonable, you know weight change. Metal like titanium will take a lot of time. So, this technique is not going to be very good technique.

So, you have to find a technique that gives you corrosion rate, maybe in you know 1 hour, 2 hours, 3 hour, 4 hour depending upon the things; not only that, we measure the corrosion rates; we also try to understand the mechanisms, that is where the electrochemical techniques, they come in handy ok. So, electrochemical techniques are that way more powerful than the weight loss measurements; one it can be quite quicker, second is you can understand the mechanisms. You can look at the Tafel slopes all these kinds of stuffs.

Now, in order to interpret the so-called electrochemical data, we called as it is a DC polarization technique and you need to understand the plots. How do you really understand? What is a point of origin to interpret this data? The point of origin for that is a mixed potential theory. So, what we will be seeing now is how do you correlate a typical potential static or potential dynamic polarization experiment to the real electrochemical kinetics ok.

So, we are trying to now correlate between these two, that we will see in the next class. I do not know when you know in the next class we will start. I do not think we will have time to do that and so, that is a very important thing ok. So, we will see in the in the next class. So, right now, I think we close our discussion. You have any questions, so you please. Let us discuss ok.