Corrosion Part - II
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Lecture - 16
Theory of Sacrificial Anode for the Protection of Steel Objects

Welcome let’s start lecture 16.

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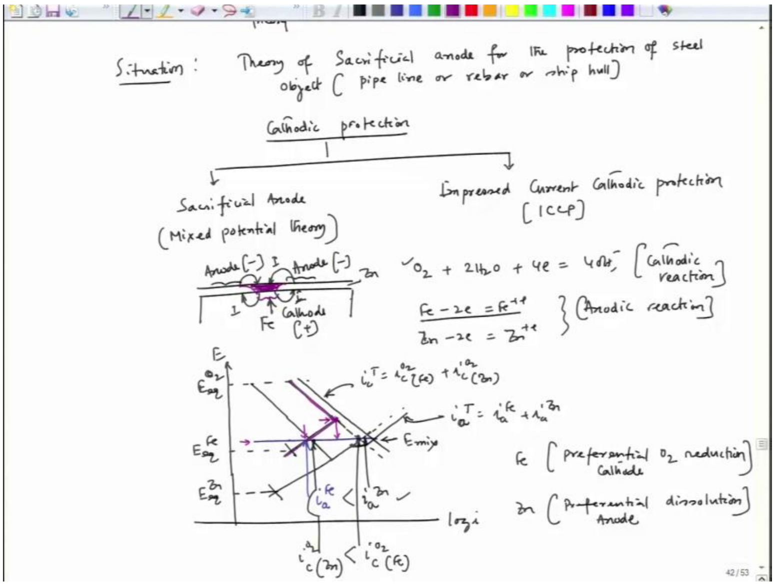

Situation : Theory of Sacrificial anode for the protection of steel object (pipe line or rebar or ship hull)

Cathodic protection

Sacrificial Anode (Mixed potential theory)

Impressed Current Cathodic protection [ICCP]

$O_2 + 2H_2O + 4e = 4OH^-$ [Cathodic reaction]

$Fe - 2e = Fe^{++}$
$Zn - 2e = Zn^{++}$ } (Anodic reaction)

Fe [preferential O₂ reduction Cathode]

Zn (Preferential dissolution Anode)

Today we try to the topic is again of course the explanation of corrosion events on the basis of. event on the basis of mixed potential theory and we have already discussed the situation where two active metals are galvanically coupled in a electrolyte when both the metals are active separately in that electrolyte and we have seen that zinc with in case of zinc and iron, zinc dissolution increases and iron dissolution decreases.

That means the iron gets protected at the expense of zinc and we have also seen that iron, the cathodic reaction which is hydrogen evolution reaction in the case what we have considered that preferentially takes place on iron surface and on the zinc surface the hydrogen evolution reaction decreases. So that suggests that iron is acting as a cathodic surface because since we have already understood that on the surface where cathodic reaction takes place.

That particular surface we call it cathode and anodic reaction preferentially takes place on a surface which is considered as anode. So in case of zinc and iron we have iron as cathode and zinc as anode and iron is protected. So that particular and actually the situation what we consider here the theory of sacrificial anode for the protection of steel object. So this steel object could be pipeline or rebar or ship hull so all those things are possible.

But sacrificial anode is nothing but as we have mentioned that cathodic protection we do it by using sacrificial anode. The cathodic protection if we consider we have two segments in that cathodic protection. One is of course sacrificial anode; another one is impressed current cathodic protection which is all it as ICCP. Now the sacrificial anode the mixed potential theory we have explained in lecture 15 with the reference of hydrogen evolution reaction as the cathodic reaction.

But it can also be possible in atmosphere and this comes into picture this particular sacrificial anode effect will come when will appear when the zinc coating over the iron surface is damaged at local positions. for example, if we have iron surface this is iron surface and then this is my zinc layer. So this is iron, this is zinc and when zinc is not damaged the corrosion behaviour is basically nothing but the corrosion of zinc. But there could be a situation where local position could be damaged.

This is the segment which is damaged let's say, so that time iron is exposed so this particular part is exposed. Now in case of environment the reduction reaction is this, this is the reduction reaction a normal atmosphere and of course this is zinc, this is iron and the anodic reactions this is reduction reaction or cathodic reaction I would say and this becomes and zinc. So these are the two anodic reactions. However, the theory of galvanic coupling between two active metals, we have explained it in lecture 15.

If we try to draw it again quickly and this time we will not put all those marking you can go back and see how the situation other things were drawn so this was a situation. So we are just this is E equilibrium cathodic reaction and this is E equilibrium anode 1, this is E equilibrium anode 2. This is a1 and a2 are basically anode, two anode materials, okay. And in this case let's say put it like this E equilibrium of iron and this is E equilibrium of zinc.

And why we have added it we have to add it because we have to maintain that mix potential theory so this line indicates ic, ia total is nothing but I gave iron + ia of zinc and this line ic = ic of cathodic reaction. Here it is oxygen I can mention it to be oxygen reduction or an iron surface and this is ic oxygen reduction on zinc surface and this point is nothing but E mix. Now when you have this particular situation.

So I can draw line corresponding to the E mix I could see that this point belongs to ia of iron and this is the point belonging to ia zinc and of course if we try to see the other current densities this particular is this. This is the connection between the horizontal line drawn this is log I axis this is E axis horizontal line drawn across the point of E mix with reference to log i axis. So this is ic oxygen evolution reaction or an iron.

And this becomes my, this is the connection which is ic oxygen over zinc surface. I could see that this is greater than this, however this is here also I could see that this is greater than this, so that means over iron I am having preferential this iron this preferential oxygen reduction so it becomes cathode and the zinc preferential dissolution, which becomes anode. So now interestingly in case of atmosphere when we have this kind of thing so this becomes cathode.

So that means the cathodic reaction which is nothing but this happens here so it takes the shape a positive electrode and then this region are anodes, where dissolution takes place so that means so this becomes negative electrode. So the current will flow in the electrolyte from negative to positive this is the current flow and in the conductor which is nothing but the metal the current flows from this to this.

And another interesting part what we could see that if we consider only the iron part this is the iron part this two lines let me draw it with this these two lines basically the iron part and this was the dissolution rate when iron is exposed to environment. Now after we have connected it to zinc the dissolution rate of iron has moved from this point to this point to this point. Now when I move it one thing we could see interesting observation is I could see that the if we consider this is to be my corrosion potential individually for the iron if I can take the potential downwards and bring it to this level, okay.

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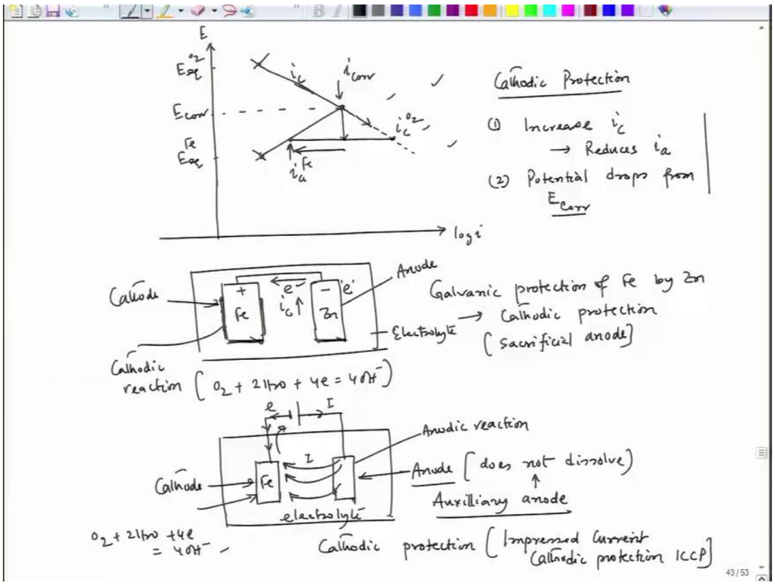

I could see that the iron dissolution rate can be decreased. Now when we do this that means individually if we consider only the iron part according to that particular drawing if we see the iron part so this is E equilibrium oxygen. This is E equilibrium of iron. And if we extend this particular line like this, now these are the two points. So it was the corrosion potential E corr and these are the corresponding i 0's and this is the i corr of iron.

And this is in log scale and this is in potential. Now as per this drawing, I could see that when iron is exposed individually the potential if the potential can be taken downwards with reference to the E corr for iron, I will experience lower corrosion rate or the dissolution rate of iron because the dissolution rate will move from this point to this point because of potential drop. So here also if I can have a potential drop like this.

Then this line this is the cathodic line, this ic line will keep continue along in a continue in its path and then will come to this particular region. I could see that ic of oxygen and ia of iron these two positions are changing. So the corrosion rate goes back from i corr to ia new this is much lower in the log scale. So the corrosion rate of iron reduces but the cathodic reaction rate on that iron surface increases. This is the typical concept of cathodic protection.

Where the intention is to increase one is increase ic so it reduces ia and when we do that potential drops from E corr. So these two concepts that increase of ic and reduction of ia and potential drop from the steady-state potential which is nothing but E corr, in this particular situation that is the basic principle of cathodic protection. Now here also we are getting actually cathodic protection because of this zinc coupling the potential has been taken downwards from the E corr of iron.

So this is my E corr of iron when iron is individually exposed and when you do that if I try to see the circuit, this is iron and this is zinc and they are in an electrolyte and they are connected. So what we have done the potential has been taken downwards so that zinc is acting negative this is positive and I could see that the ic, so that means electron will be generated more here so this electron will move this way this is electron movement and comes here on the iron surface.

So electron increase means ic increases and on this surface we have cathodic reaction because of the consumption of this electron so

$$O_2 + 2H_2O + 4e = 4OH^-$$

Since in the environment atmosphere we can consider it to be near neutral situation. So actually I am increasing the ic now here in this particular situation I am increasing ic but whether it be see whether here also ic is increasing or not.

Actually ic is increasing because I could see this situation is prevailing so the on the iron surface ic is increasing so this ic line is following this trap. So ic has increased so the same principle is holding true here. So the galvanic protection of iron by zinc is nothing but an example of cathodic protection. And here we are actually consuming zinc because in this particular situation zinc corrosion rate has increased after coupling. So this is the mode of sacrificial anode.

Now this principle can be true can be done separately or differently, for example if I have a situation this is an electrolyte, let’s say now where we have an iron object and this is this is iron object at which is to be protected. I can instead of having zinc which dissolves and because of the dissolution we have extra electron that electron comes to iron and actually we are increasing ic of that particular reduction process, okay. So I can also have an anode this is anode and this is cathode.

So whenever we try to protect any component by this cathodic protection that particular component is to be made a cathode. So we have an anode here in this case this becomes cathode and this becomes anode. So here also we are making the same situation but here if we do not want to dissolve anode so this does not dissolve. So how could we have this particular principle to be met. Now we can use an external power source which is a DC source so I can connect it to a positive terminal of a battery and a negative terminal to iron.

So that times I which is the current flows this way and then current will flow like this current will grow this is an electrolyte and here it is I have said that these are these two things are basically exposed to electrolyte. So the current is flowing and then it is going back this is the current the system current, the electrical current. Now since this is connected to the negative terminal the electron will flow this way so when electrons are flowing this way so this excess electrons need to be neutralized.

Because the charge conservation has to be made. So this electron will be neutralized by having this reaction. So now this is also a cathodic reaction so wherever cathodic reaction takes place we consider it to be cathode so here this is cathode this iron becomes cathode and the anode which does not dissolve there we have anodic reactions, okay. But if it does not and but since it is not dissolving so we cannot have generation of electron because of the dissolution what we had in case of zinc dissolution.

While we connected zinc with an with an iron object but these anodes are called auxiliary anodes. So this is auxiliary anode so this does not dissolve but it actually acts as an anode in that particular system. So that it can be connected to an external battery. This particular mode of cathodic here also we could see that the iron which is to be protected is made into cathode.

So this is also cathodic protection but here we are supplying that negative current to the iron that means this negative current to the iron piece or an iron object from an external power source, a DC power source by having that circuit completed with an auxiliary anode. So this is called impressed current cathodic protection or ICCP. So let’s stop here, we will continue our discussion on this cathodic protection and try to see the effect of different other metals which are acting as a sacrificial anode on the effect of on that potential drop and reduction in corrosion rate of that of iron piece. Let’s stop here, thank you very much.