Corrosion Failures and Analysis

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Lecture - 07
Galvanic corrosion (Part 2)

Welcome back to the course Corrosion Failures and Analysis and today is 7th lecture and we talk about Galvanic corrosion. So, we started discussing Galvanic effect in our previous lecture. So, this will continue right.

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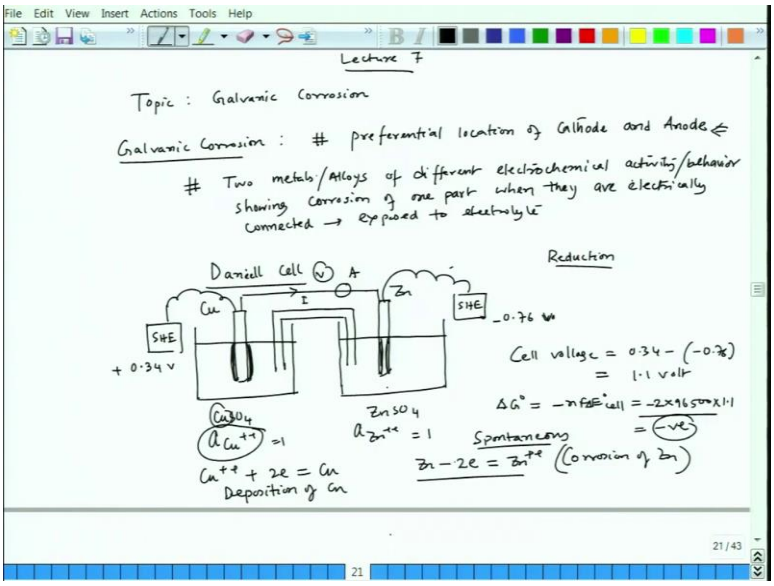

Lecture 7

Topic : Galvanic Corrosion

Galvanic Corrosion : # preferential location of Cathode and Anode ⇐

Two metals/Alloys of different electrochemical activity/behavior showing corrosion of one part when they are electrically connected → exposed to electrolyte

Reduction

$a_{Cu^{++}} = 1$

$a_{Zn^{++}} = 1$

$Cu^{++} + 2e = Cu$

Deposition of Cu

Cell voltage = $0.34 - (-0.76)$
$= 1.1$ volt

$\Delta G^\circ = -nFE^\circ_{cell} = -2 \times 96500 \times 1.1$
$= \boxed{-ve}$

Spontaneous

$Zn - 2e = Zn^{++}$ (Corrosion of Zn)

So, the course is Corrosion Failures and Analysis and this is lecture 7 and topic, Galvanic corrosion fine. Now while talking about definition of Galvanic corrosion, we said that once strong characteristics of Galvanic corrosion is there should be preferential location of cathode and anode.

An usual definition in the book as it is written that two metals or alloys of different electrochemical activity or behavior showing corrosion of one part when they are electrically connected and exposed to electrolyte and we have also seen that this definition is not all about Galvanic corrosion you have to consider this part, there would be a preferential location of cathode and anode fine.

Now let us get to the usual Galvanic whenever we talk about Galvanic corrosion, we talk about we start with voltaic cell ok or zinc copper cell. So, now, we see that Galvanic corrosion has one definition part another the major part is preferential location of cathodes and anodes.

Now whenever we talk about corrosion, we start with a cell which is Daniell cell which is nothing but two containers. In one we have a copper plate dipped in copper sulfate and another we have zinc dipped in zinc sulfate. Here copper ion activity is maintained as 1, here zinc ion activity is maintained as 1 or concentration let us say activity in terms of activity if we want to write we can write this ok.

This is the electrolyte level, we have one salt bridge which allows charge which allows charge flow, here it is a basically exchange mechanism these are electrically connected and now if we try to measure its potential with reference to standard hydrogen electrode and this is also connected to another standard hydrogen electrode ok and this path is high resistance path.

So, very little current flows between these two connections only it measures the potential of these two electrodes. This potential is developed you would find after stabilization you would find this potential becomes 0.34 volt and this becomes around 0.76 volt ok and this is minus this is positive.

You will see the minus positive all those and here we are only talking about reduction potential. In fact, the entire discussion of this course will be on the basis of reduction potential. Now, when we have this we have this potential. Now, if we connect this with a conducting wire we will see the current will flow and if we have a ammeter connected to this you will see that the current flow would happen from this end to this end.

This is the circuit current and we will see that the zinc will gradually deplete and our copper would gradually increase and here the copper ion here present the copper ion will take 2 electron and deposit on copper plate and in this case zinc will release 2 electron and then go to zinc plus plus ions.

$$Cu^{++} + 2e^{-} = Cu$$

$$Zn - 2e = Zn^{++}$$

So that way this is corrosion of zinc and this is deposition of copper and if we see the voltage here this cell voltage, the cell voltage would be 0.34 minus minus 0.76 it would become 1.1 volt ok. So, this is the cell voltage to start with and if we see the Galvanic condition delta G would become minus n FE cell which is delta E cell would be 2 minus 2 into 96500 into 1.1 volt. So, this becomes negative; that means, this process what we are seeing this is spontaneous process.

Now here zinc would corrode spontaneously and copper would deposit spontaneously and if you maintain this ion concentration, you would see that copper will keep on depositing ok and the zinc will keep on dissolving. So, this is one galvanic effect ok and copper zinc is corroding.

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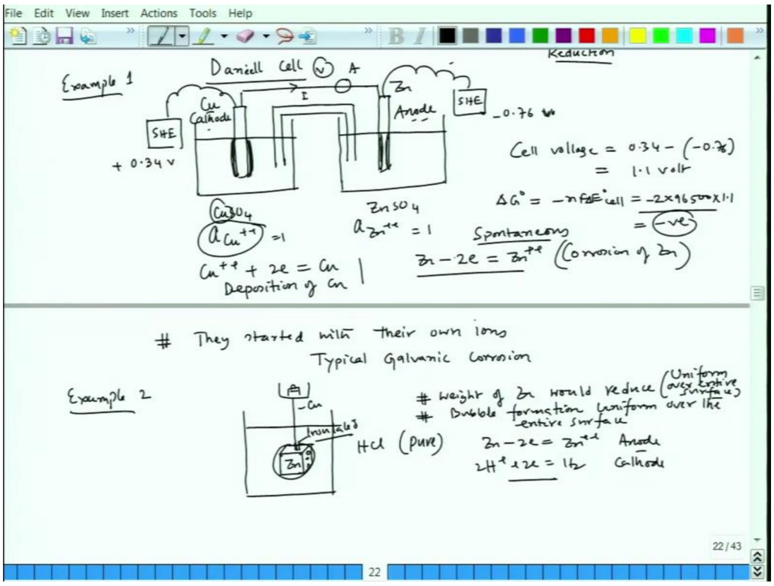

Cell voltage = 0.34 − (−0.76)
= 1.1 volt

$\Delta G^\circ = -nFE^\circ_{cell} = -2 \times 96500 \times 1.1$
= (−ve)

Spontaneous

$Cu^{++} + 2e = Cu$
Deposition of Cu

$Zn - 2e = Zn^{++}$ (Corrosion of Zn)

They started with their own ions
Typical Galvanic Corrosion

Weight of Zn would reduce (Uniform over entire surface)
Bubble formation uniform over the entire surface

$Zn - 2e = Zn^{++}$ Anode
$2H^+ + 2e = H_2$ Cathode

Now, interestingly if I see the observation, observation is they started with their own ions their own ions. So, in copper side we had copper ions to start with and zinc side we had zinc ion to start with, but still we could see that this preferentially the cathode if this becomes cathode, we have already seen that in the previous set of lectures.

So, this is cathode and this is anode and interestingly this will remain anode this will remain cathode. So, again it is a preferential cathode and anode positioning. So, this is a typical galvanic corrosion. Now let us take this is example 1, let us take another example. Now, if we have pure HCl we dip one zinc plate zinc block and if we let us say zinc block is hanging.

And you have actually hooked it and connected to the bottom weighing facility bottom weighing facility, you would see that the zinc weight would reduce fine and we would observe that there are the bubble formation, fine. Now and if we see and this is insulated. So, this connection is insulated remember so; that means, here we do not have any two metal connection because this since this is insulated that insulated part is not getting in contact with then an electrolyte and so, then let us say this is copper. So, or you can use a thread of polymer thread or a simple cotton thread ok.

So, then there is no question of galvanic effect because two metal effect and here we have two reactions one is zinc 2 e zinc plus plus and H plus plus 2 e equal to H 2 this is anode and this is cathode fine we will see that. This bubble formation is uniform over the entire surface and zinc dissolution is uniform over entire surface.

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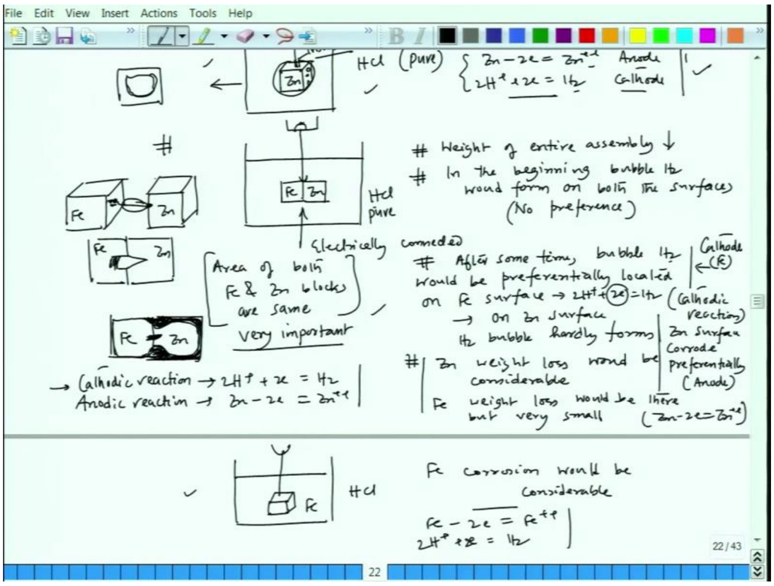

HCl (pure) $\begin{cases} Zn - 2e = Zn^{++} & \text{Anode} \\ 2H^{+} + 2e = H_2 & \text{Cathode} \end{cases}$

Electrically connected

Area of both Fe & Zn blocks are same
very important

→ Cathodic reaction → $2H^{+} + 2e = H_2$
Anodic reaction → $Zn - 2e = Zn^{++}$

Weight of entire assembly ↓

In the beginning bubble H_2 would form on both the surfaces (No preference)

After some time, bubble H_2 would be preferentially located on Fe surface → $2H^{+} + \boxed{2e} = H_2$ (Cathodic reaction) ← Cathode (Fe)
→ on Zn surface H_2 bubble hardly forms
Zn surface Corrode preferentially (Anode)

Zn weight loss would be considerable
Fe weight loss would be there but very small ($Zn - 2e = Zn^{++}$)

Fe corrosion would be considerable

$Fe - 2e = Fe^{++}$
$2H^{+} + 2e = H_2$

So, there is no preferential locations, but interestingly if we do the same experiment by putting two blocks one is iron, one is zinc and we same way we hang it with a cotton thread and we keep taking weight and here again initially to start with you will see that what are the observation you would see? You would see that the weight and these two are electrically connected.

How you can do that? For example, you take one block of iron; one block of iron you have taken another block of zinc you take and then make a keep a screw here and here also this screw will enter into this ok. So, you can make a thread screw connection and then that way you can tightly connect both of them and interestingly when you connect this screw material does not make any contact with electrolyte because that is covered up by the entire zinc and copper zinc and iron surface.

So this is electrically connected, but that the connection point if you are doing it with a kind of with a kind of screw tightening situation ok. So, if you can make a nail that nail is dipped into this. So, this is actually with the iron and now this on that on top of it you press fit the zinc this is iron. So, that way you can connect. So, this part will not come into contact with the electrolyte. So, this is electrically connected.

So, weight of the entire assembly would decrease gradually, similarly in the beginning bubble. So, this is also HCl let us say pure HCl bubble of hydrogen would form on both the surfaces no preferentiality, but after sometime you would see bubble of hydrogen would be preferentially located on iron surface and interestingly on zinc surface hydrogen bubble hardly forms fine.

Maybe one or two bubbles, but otherwise you can distinctly see that on the iron surface you will have lot of bubbles, but on irons of zinc surface we will have less bubble. And after you take it out and then open this screwing, you would see that zinc weight loss would be considerable, but iron weight loss would be there, but very small. So, these are the three observations we would see all those observation I have checked one by one.

Now, in this case it is very clear that the bubbles are forming which is hydrogen bubble which is coming due to cathodes and the zinc dissolution if you take it out this zinc plate and if you see the cross section, the zinc is actually corroding over the entire section uniformly through the depth direction.

But in this case you would see that this is the iron and this is zinc, the zinc is actually corroding more here and less around the other part, but here would be more and iron the corrosion would be again there will be corrosion, but a very small amount and that corrosion also would be located close to that zinc plate, but zinc would be corroding more where the iron plate is connected to zinc.

And one more condition just I missed it remember when you connect make sure that the area of both iron and zinc blocks are seen so; that means, the same area is exposed to the electrolyte. So, this is very important remember this is very very important. Now interestingly, initially this particular observation see weight loss the total assembly weight loss is taking place which is absolutely fine because zinc is corroding.

We could see that zinc is gradually decrease and then finally, if we take it out and analyze we will see the zinc is corroding heavily, sorry here I made a mistake. So, zinc corrosion would be more in these segments in these segments because the center part is not exposed if the corrosion will gradually happen from the surface to the center part, is not it?

So, that is what the zinc corrosion would be more where the joining is taking place. So, like this it will go like this it will progress like this it is progress it is progressing like this ok.

So, this is zinc part and this is the connector and we have to consider that when we do this experiment we have to also keep this both these blocks to be same size same area remember, same area. Now, first observation it is not surprising because weight is decreasing because both and after checking this we could see the both iron and zinc is dissolving.

But the situation starts different situation becomes different in the beginning bubbles of H 2 will form on both the surfaces, but after some time you will see that the iron surface bubble of hydrogen would be preferentially located and on the zinc surface hydrogen bubble hardly forms.

And if hydrogen bubble is forming that surely indicate that this cathodic reaction is taking place and we know this is cathodic reaction and we know wherever cathodic reaction takes place that is cathode. So, iron is acting like a preferential cathode and since zinc surface we do not see hydrogen bubble; that means, cathodic reaction or hydrogen evolution reaction is not taking place.

It surely indicates that in order to maintain charge balance this electrons need to be supplied. So, this supply would come from zinc surface and the zinc surface would corrode preferentially and whichever corrodes we call it anode and the anodic reaction would happen there.

Now, if we compare both this process where zinc only dipped in HCl and where iron and zinc are combined and dipped in HCl same acid concentration, we would see that in the case also we have two cathodic reactions sorry two reactions one is cathode another is anodic reactions. So, this is anode cathodic reaction, this is anodic reactions which is zinc dissolution here also I do not see any difference, here also I see the cathodic reaction is this is cathodic reaction and anodic reaction fine.

So, both the cases I have same reactions to make a complete electrochemical cell same reactions, but the positioning of cathodic and anodic reactions are actually leading to a localized or preferential collusion of corrosion of one object and the protection or the less corrosion of another object and another important aspect is wherever cathodic reaction is taking place.

That means, in case of here it is iron surface, the iron is not going to the solution, but zinc since there is no cathodic reaction, zinc is going to the solution ok. So, the zinc preferential corrosion is taking place. Now in addition to this one important aspect if we only dip iron here and measure the weight same HCl and this is iron, you would see iron corrosion would be considerable would be considerable.

And this corrosion phenomena would be exactly same as zinc corrosion when zinc was dipped in the same acid individually ok. So, that means, this phenomena and this phenomena will be same, here also iron will dissolve through this reaction and cathodic reaction happen.

So, this reaction would happen but the major difference is coming here because of these two metal connections we have one surface to be preferentially cathode, one surface is preferentially anode and another important aspect what we are seeing that initially to start with in all those experiments, we never had any zinc ion or iron ion to start with. So that means, this is different than the process what we have considered in case of galvanic corrosion of zinc in Daniell cell ok.

So; that means, we have to talk about the preferentiality of cathodes and anodes and at the same time whenever the preferentiality comes one part becomes cathode another part becomes anode and then the anode part would dissolve the cathode part would not dissolve much because here if we dip iron individually it corrodes heavily, but once we connect it to zinc and dip it in the same acid iron corrosion is suppressed and zinc corrosion goes up to a great extent ok.

So, we will discuss this exact this three experiments virtual experiments what we have done we will discuss this in our next lecture ok, where we will talk about the mixed potential theory along with it and that time you would understand that galvanic corrosion does not mean that the corrosion of one component which is cathode is stopped it is it happens, but it happens at a much much lower rate than the other anode component.

So, that is one of the important aspects of galvanic corrosion. So, let us stop here. We will discuss in subsequent lectures.

Thank you.