Aqueous Corrosion and its Control

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Lecture – 11
Forms of corrosion: Factors affecting uniform corrosion

We shall continue the discussion on uniform corrosion and the last class we saw that what are the parameters those affect the uniform corrosion. We saw that the nature of the electrolyte, the temperatures, the velocity and these are the factors that affect the corrosion of the uniform corrosion of metals.

We gave some illustration yesterday that the relation between the corrosion of the metal and the environment many times is not straightforward with respect to the concentration of the corrosive agent. It is possible that you may increase the concentration of the corrosive agent the corrosion rate may drop actually. We gave an example of sodium chloride how when you increase the concentration in water the corrosion rate goes through a maximum.

And, in this case the mechanism is simple that the oxidizer concentration decreases. The oxidizer here is what? Is oxygen, solubility decreases when you increase the sodium chloride concentration. We also recalled in the previous class that a similar example a lies with a corrosion of steel in nitric acid.

There if we increase the concentration of nitric acid; the corrosion rate increases and then subsequently decreases. The mechanism there was different. There it is related to the passivity of the metal when we increase the concentration of nitric acid the passivity increases.

So, the underlying mechanism of corrosion in each case is required to find a correlation between the concentration of the corrosive agent and the corrosion tendency of the metal. So, this is a kind of general relation we saw, but you know they are just illustrations. There are so many examples and there are so many actual cases in the industries and you know you should able to apply them conveniently and see how the corrosion rate of a given metal changes in any each of these cases.

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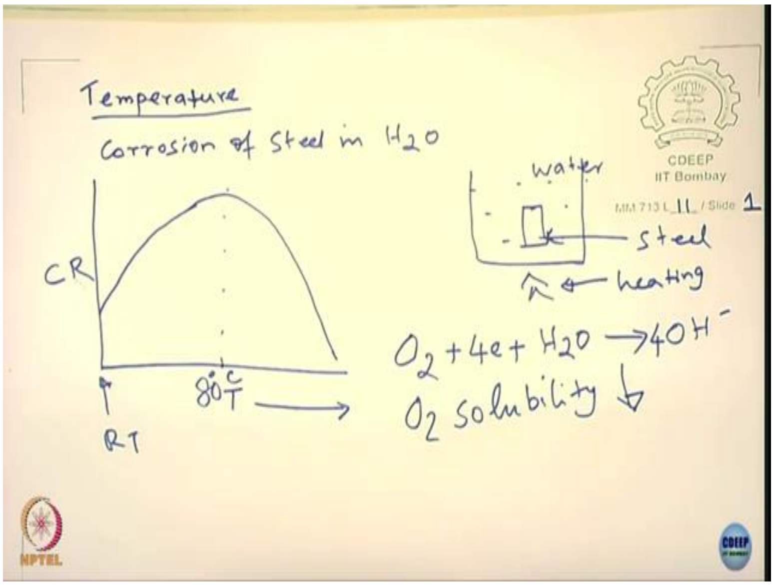

In the second the parameter that I would like to talk is on the temperatures ok. The temperature if you raise the temperature of the environment, what do you expect to you to happen? What will happen to the corrosion rate? The rate of reaction will increase that is what Arrhenius law says right. The Arrhenius law says that for every rise of 10 degree Celsius, the chemical reaction rate doubles actually, right.

But, there are situations is true also ok, but there are situations that you do not follow the same principle actually. I just give only illustration one illustration because there are several different cases that, this different tendencies are happening are all. For example, let us look at the corrosion of steel in water. Suppose, I take a beaker and I take pure water simply water here and immerse it steel sample and I just raise the temperatures ok. I raise the temperature by heating.

If I can measure the corrosion rate of the steel with respect to the temperature; if I make a plot temperature versus the corrosion rate. What do you might expect is the corrosion rate go you know goes like that, but interestingly the corrosion rate starts falling like this. This is the room temperature and temperature increases in this manner. Can you explain this? Say neutral water ok, can you explain this? Is it possible to have like this?

So, what is the cathodic reaction here in neutral water which of course, is open to atmosphere here?

Student: (Refer Time: 05:48).

Yeah? This is the oxygen reduction reaction right you the cathodic reaction here is oxygen will combine with 4 electrons and forms 4 minus.

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

So, now, you tell me what will happen? Yeah?

Student: (Refer Time: 06:16).

Yeah.

Student: Water vaporize.

Of course the water will be vaporize, but assume that water is not be vaporizing what happens, anybody has an idea?

Student: Dissolve oxygen.

Yeah, this is a reaction to dissolve oxygen right, even when water vaporizes what happens? The remaining water will have same corrosion tendency unless you have some salts or all. To take a pure water you evaporate the character of the water remains the same right it is the oxygen solubility with respect to temperature that counts. So, what happens when raise the temperature? The solubility decreases, right.

So, there are two opposing processes one the rate of reaction is expected to increase with respect to temperature, but this oxygen solubility decreases right. So, the oxygen solubility decreases. So, the corrosion rate is decreases. So, it is about approximately is about 80 degree Celsius. You see that the corrosion rate drops significantly. What happens if the same temperature effect of this what happens if the system is closed?

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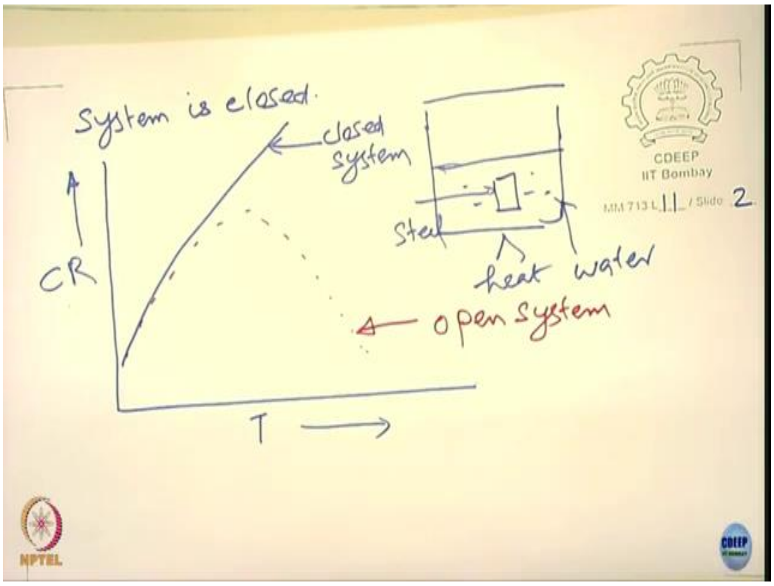

The system is closed not you know open to the atmosphere ok. Say, we have a beaker and I just close it here and I have water up to this levels, have a steel and this is water this is steel and it going to heat it now ok. So, what do you think will happen in this case? What will happen to corrosion rate with temperatures? Yeah.

Student: Increase.

The corrosion will rate will keep increasing right it will almost increasing right it increases. This is the corrosion rate versus the temperature. So, it is a closed system. So, in this case the oxygen does not escape, there is a pressure. So, remains in the system the corrosion rate increases with respect to temperatures.

So, this is different from what happens in the closed system. The closed system will decrease. So, this is your open system. So, the examples given here are a illustration. They are not exhaustive by any nature ok. Let us take the other parameter and then we will we will move on to the next aspect of the uniform corrosion.

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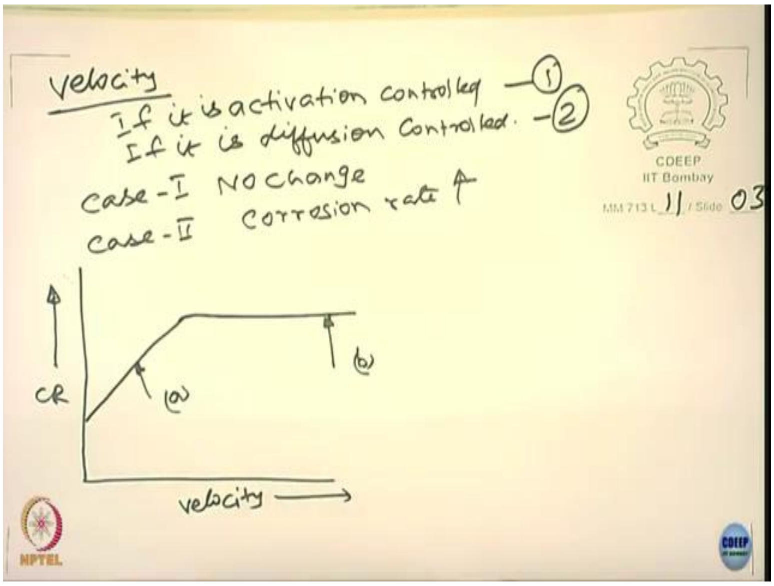

Next is the velocity. So, what are the effects of velocity on corrosion of a metal? Especially if it is diffusion controlled; if it is activation controlled, if it is diffusion controlled. So, what you think will happen in both these cases? So, in a diffusion controlled process the corrosion rate will increase. So, what will happen to the activation controlled case?

Student: (Refer Time: 11:01).

Yeah?

Student: No change.

No change will happen right. So, this is the case 1, the case 2; the case I – no change, the case II – corrosion rate increases. So, probably what would happen is something like this right. You will find that the corrosion rate might increase and then probably is going to remain constant can you can you. So, I am marking as the region a, the region b. What is the difference between region a and region b? Yeah.

Student: (Refer Time: 12:21).

a is diffusion controlled and b is activation controlled. So, it is a transition from activation controlled I am sorry, a transition from diffusion controlled to the activation controlled, where the corrosion rate does not change.

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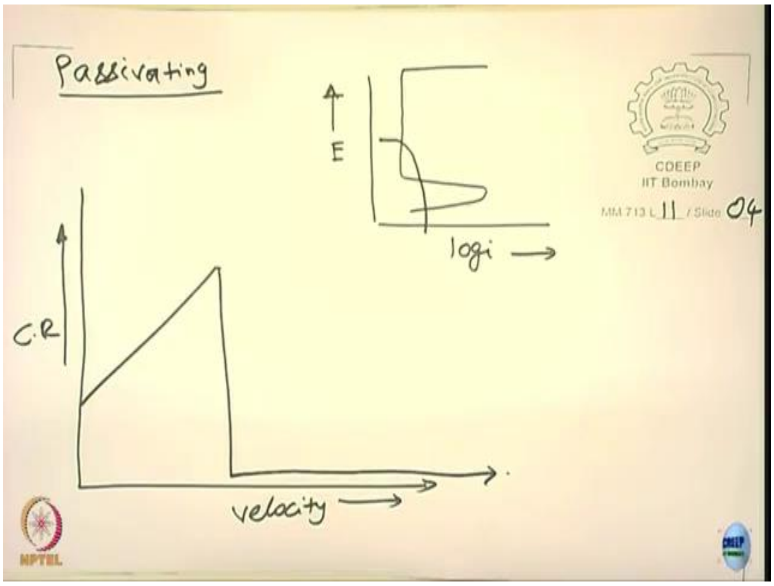

Now, let us move on to the next case where if the system is passivating let us say the system is passivating say if the metal shows. So, what do you think will happen in this case if it is diffusion controlled? Suppose, assume that you know something somewhere here it is diffusion controlled. So, what do you think will happen?

Student: (Refer Time: 13:33).

Yeah?

Student: (Refer Time: 13:35).

Ok, if I plot velocity against let us say the corrosion rate. How do you think will vary?

Student: (Refer Time: 14:00).

It first increases and then there will be first I think you will see there is increases and then there will be sharp decrease and could remain was the same. Again any doubts anybody has here? Can anybody tell me what will be this corrosion rate corresponds to in terms of current? Current density this corrosion rate it corresponds to I P right see passivation current density right.

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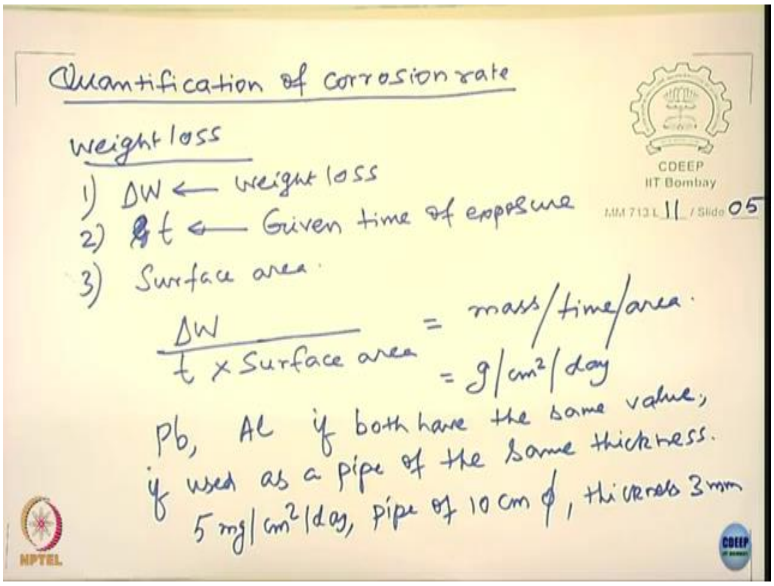

Now, let us get into the next aspect of quantification of a corrosion rate. Please again understand we are not talking about quantification of various forms of corrosion, we are talking about quantification of the corrosion rate in the in the case of uniform corrosion rate. You cannot you cannot say that there is only one way of quantifying corrosion rate in all the forms of corrosion we talked about the in the previous class ok. So, this corresponds to a uniform corrosion rate.

So, how do you quantify this? Any suggestions? Weight loss measurement right. So, the weight loss is straight forward one. What is meant by weight loss? So, what how do you what is the unit for this? Yeah, how we got means per year, how do you visualize this weight loss? What kind of how you do a test in the lab for example? How do you; how do you determine the corrosion rate? Yeah?

Student: Take the weight first.

Yeah. So, you take a known dimension of the specimen right. You immerse in a electrolyte of interest, corrosive environment and for a known period and then take it out and again measure the weight you see the change in the weight of a samples.

Now, what you are going to measure is the measurement what I want to do here is the weight loss what I want to measure, right and there is a given time of exposure as a t and given time of exposure. Of course, we need to always qualify you know what is the temperature; you know if you change the temperature then everything will change. So, we have measure the weight loss and what else you know? You should also be knowing?

Student: Dimensions.

Dimensions right, you know the surface area. The straight forward use of this data is going to be what? W t by surface area, is it not? What is the unit here in this case?

$$\frac{\Delta W}{t \times surface\ area} = \frac{\frac{mass}{time}}{area}$$

Unit is going to be mass; the time upon area right or not and there is a problem in this unit. What is the problem in this unit? When I say there is a problem in the in the unit I am talking in terms of its utility in material selection material design you know for a given application.

Suppose, I give this unit to someone let us say gram per centimeter square per day. Suppose, I give a unit for example, I say gram per centimeter square per day ok; suppose I give a unit like this unit may not be of any relevance in actual situations. You cannot compare this in terms of life of a given component. For example, I may use lead, I may have aluminum right and, if both have the same value and if used as a pipe of the same thickness.

Assume for argument sake that it is 5 milligram per decimeter square per day is the corrosion rate. I am giving 5 milligram? 5 milligram per centimeter square per day for lead and aluminum. In both cases the thickness of the pipe is 3 millimeter thickness aluminum and a lead, and the diameter of pipe maybe about say about 10 centimeter diameter pipe ok. If the unit of corrosion here in both the cases is 5 milligram per centimeter square per day which of these two pipes you will corrode will leak or with they leak at the same time?

If the question clear to you, if I have a corrosion rate of 5 milligram per centimeter square per day and the pipe of 10 centimeter dia thickness 3 millimeter thickness do you think the both pipeline will leak at the same time?

Student: (Refer Time: 21:36).

The density will matter right. So, which will leak first?. So, aluminum will leak first, is it not? For a given weight the aluminium will have larger volume larger thickness. So, aluminum will corrode first. So, this unit is not going to be useful in real applications should have a unit which is in terms of the thickness right. So, you should have a thickness. So, the weight loss measurement you know you should be used to calculate thickness. So, what happens now?

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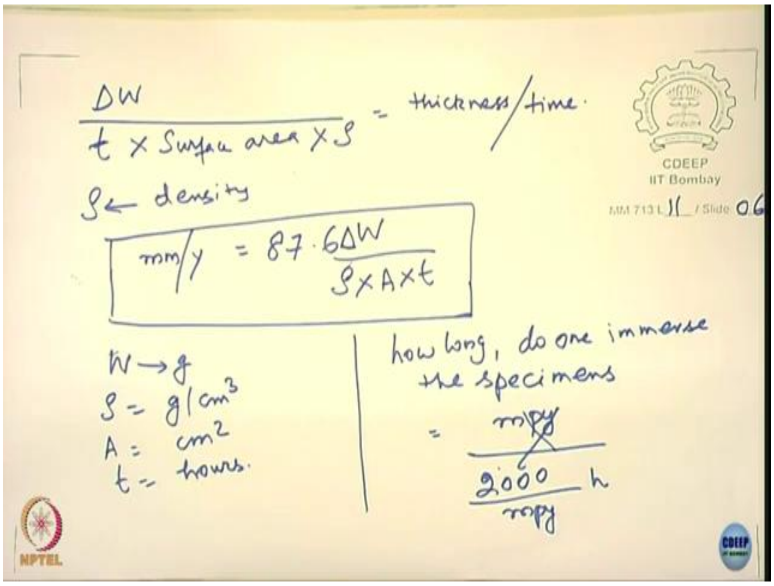

So, you have weight loss is known, you know the thickness, you know the I am sorry you know you know the time here and you know the surface area. So, what you should do? You should also thickness, what is a rho here? Is a density. So, this will be what is the unit of this? Please, look at this it is the dimension. What are the dimension is there? is the length are.

Student: (Refer Time: 22:54).

You can say length or thickness dimension per what? Per.

Student: Time.

Time. So, you can use it is no you can able to you know form rate any equation that you like you know it is not it is not that this equations are it will be taken from the book. So, if you want to calculate the corrosion rate in terms of millimeter per year you can able to substitute all this you know time in terms of year; surface area in terms of in maybe in the centimeter square and density maybe gram per centimeter cube and similarly the weight also can be given in terms of grams.

So, it is possible for you to calculate and arrived at an equation of this kind here ok. So, this is going to be the corrosion rate of the metal in terms of mm per year you can also have it for mm per year or whatever ok. And, do that I a small change here please make as delta W here.

So, W in terms of gram, rho in terms of gram per centimeter cube, area in terms of what? In terms of area in terms of centimeter square, time in terms of hours. You can have time in terms of you know if you want day, then automatically things will change ok. This is the way the corrosion rate can be readily determined, the weight loss measurements.

$$\frac{\Delta W}{t \times surface\ area\ \times \rho} = \frac{thickness}{time}$$

$$\frac{mm}{y} = 87.6 \times \frac{\Delta W}{\rho \times A \times t}$$

We also seen in the in one of the classes that why the weight loss measurement is not a very convenient one right. The question that comes is how long do one immerse specimen? Now, this is given as mpy is a different unit upon sorry it must be 2000 by mpy terms of hours that gives you the duration of exposure to the environment.

If the corrosion rate is very very less, then you would need to expose for longer time because what happens? There will be insignificant weight loss if the corrosion rate is very low ok, understood? It is just a thumb rule it is just a thumb rule ok.

You will see a reasonable you can find out you know you can do that. For example, if the you just substitute if the corrosion rate is 5 mpy or 20 mpy or 100 mpy, what happens to the corrosion rate in that many number of hours, right? You can do that? Right. So, you can see that there will be a significant weight loss will happen in relation to this equation 2000 upon mpy actually ok. Yeah, this is a thumb rule. There is no derivation is done to get this equation here.

Student: (Refer Time: 27:24).

Who?

Student: (Refer Time: 27:26).

For example if I keep it as 1900 hour by mpy, I do not think is somebody is going to question you what are all actually, right? The idea here is it gives a some see when I say thumb rule what does it mean? It means a kind of approximation that you will attempt to do in order to get a useful information right. So, thumb rule actually. So, it comes from experience. It is simple to understand right corrosion rate is on the denominator right. Automatically the time required for exposure is reduced when the mpy increases.

What is the second what is the other method of doing it we also discussed earlier ok. The other one was one electrochemical technique right.

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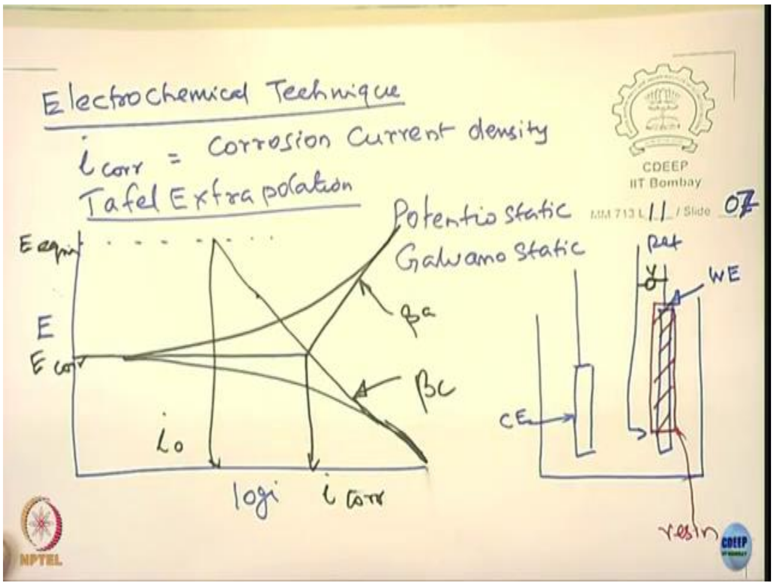

There are two methods we saw anybody can recollect? What do you determine here you determine? The i_{corr}, corrosion current density. So, you determine this corrosion current density. So, what are the methods? One is a Tafel extrapolation. So, we have seen this in detail when we discuss about the modern theories right. I have just only recollecting what we discussed earlier right. You can do two kinds of experimentation; one is potentiostatic, the other is galvanostatic. You might have done you have done this experiment any of you?

Student: Yes.

So far? What do you normally do is you normally use a potentiostatic or potentiodynamic test wherein you apply a given potential to measure the corresponding current.

So, in this case we use a cell a called a corrosion cell. The corrosion cell consist of what? A corrosion cell consist of three electrodes is a working electrode. You have again a counter electrode. You have a reference electrode. Please notice you normally choose you choose a small area of about 1 centimeter square you mask the remaining things with a resin right you mark the remaining things with a with a resin and you expose about 1 centimeter square area.

You marks this with the resin here. As we notice earlier and you pass the current between the counter electrode and the working electrode, then what happens? The potential on the working electrode is increasing.

You measure the potential of the working electrode in relation to the reference electrode. So, you have here a potentio stat and now it is they are connected to a potentio stat or the galvano stat. In fact, a single electronic system, you can operate in either mode a potentio static mode or galvano static mode.

So, you could able to obtain a right you have seen this earlier also right, please go back and refer your notes. So, you can draw a tangent to this Tafel line and you draw a tangent to this Tafel line here and this corresponds to right what is current called? i_{corr} and this corresponds to E_{corr} and this slope is what is the slope? Yeah what Tafel slope is called?

Student: Beta.

Beta. Beta c right and this is beta a, if one wants to measure the exchange current density for the cathodic reaction, how do you get that?

Student: We just probably put (Refer Time: 33:45).

Yeah, how do you get i^o? How do you get i^o from here, in this one?

Student: (Refer Time: 33:54) voltage in that equation.

What do you called in this graph, how do you get? The graph is given to you now we need to do ok. What do you need in order to get that? Now, what do you need what do you need to get i^o? E?

Student: Potential. Interpotential.

Yeah, you cannot use all the terminologies there is only one you can use right ok.

Student: (Refer Time: 34:23).

So, did not use equilibrium potential right. So, you cannot just please do not use all the words as it has no meaning at all ok. So, you can extrapolate these two in equilibrium potential. Suppose, this is your equilibrium potential and you could extrapolate this and you would get i^o here.

You can also get i^o for the corresponding anodic reaction and so, we can get this. From if I given i_{corr}, how do I determine the E corrosion rate?

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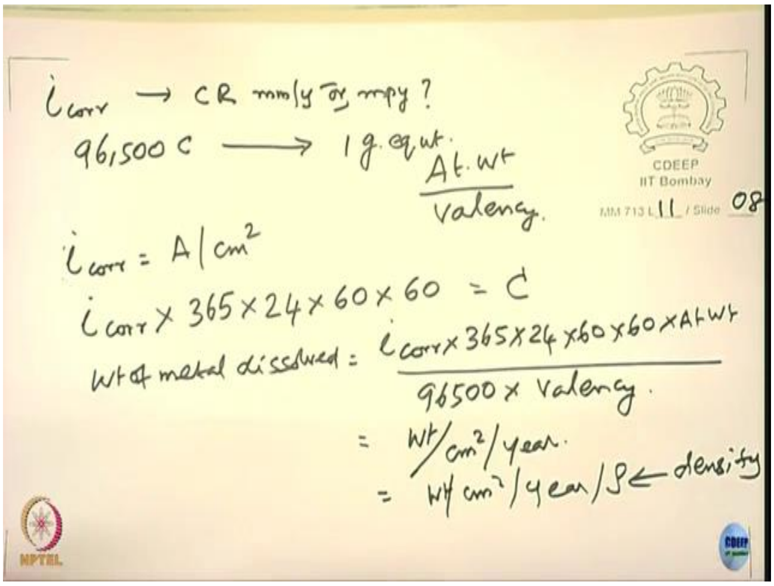

So, i_{corr} is given how do I get the corrosion rate? Let us say corrosion rate maybe in mm per year or mpy or what unit that you want how do I get this. What is the method? Is there any relationship that can be used to determine the corrosion rate? Anyone? What is that law that says that the current is equivalent to what? See this is a Faraday's law right.

So, you know that 96500 coulombs if the current is passed either you can dissolve metal or anything of 1 gram equivalent weight. What is 1 gram equivalent weight? It is it is equivalent to atomic weight by the valency. So, if you pass 96500 coulombs of current, you can either deposit this amount of metal or you can dissolve this amount of metal it depending upon whether the current is anodic or cathodic actually right.

Now, if i_{corr} is what you are you are getting this let us say i_{corr} is in terms of let us say ampere let us say per centimeter square is what the current is all about. How do I calculate now? How do I calculate per year for example? What is the first step? How do I convert this into coulombs? So, to convert this into coulombs, how do you do that? So, you have to so you have to find out what is the current that is flowing for 1 year right.

So, you have to have how many days, in a day how many hours, in an hour how many minutes in a minute how many seconds this gives you the coulombs how current that is flowing if the i_{corr} is given there ok. So, how do I get the corrosion rate from this? So, I can calculate what is the how many equivalents of weight the metal corroded for this many amount of coulombs right. So, how do you; how do you get this?

So, weight of metal dissolved equals to what? Equal to i_{corr}. So, this is the weight right. This is the weight of the metal that is lost in 1 year and 1 year in what is the so, what is this 1 year lost right? What is the unit here, can anybody tell me? This is ampere per centimeter square right; this is the weight also gram whatever ok. So, what is the; what is the it is a coulombs right. So, the whole thing is in coulombs; coulombs per centimeter square coulombs weight. So, whatever having here is what? Is?

Student: (Refer Time: 39:38).

Weight.

Student: (Refer Time: 39:40).

Per centimeter square per.

Student: (Refer Time: 39:42).

Per year right, no? So, you will get here weight with centimeter square per year. So, how do you get the thickness? So, I divide this by weight centimeter square per year per the density right. So, what should be the equation now?

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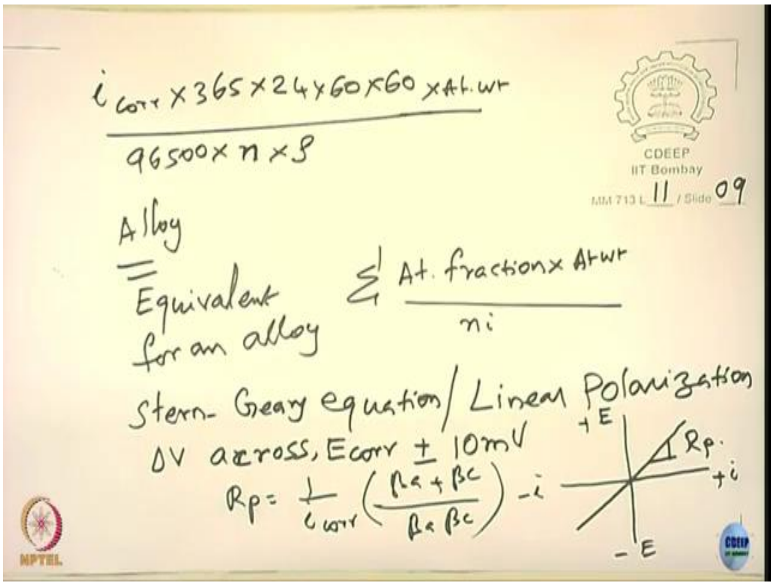

The corresponding equation is going to be i_{corr} 365 into 24 into 60 multiplied by atomic weight 96500 coulombs into the number of electrons, n number of electrons, rho density of this and if it is an alloy what happens?

$$\frac{i_{corr} \times 365 \times 24 \times 60 \times 60 \times at.wt.}{96500 \times n \times \rho}$$

If it is an alloy, the atomic weight is not very easy there. So, you need to calculate the equivalent of that ok. I have just giving this equation here, I wanted to analyze and understand that actually because we will not going to have time.

So, for an alloy so, equivalent weight of an alloy for an alloy it can be obtained by atomic fraction multiplied by atomic weight upon n i sigma of that. So, it is summation of all of them right. I have the number of species for example, I have a brass of copper 70 and 30 zinc, you should be able to do that right. You can you know the weight percent from there you convert into a atomic percent; from atomic percent you can get the fraction here and you can able to get this value without much of problem.

$$equivalent\ weight\ of\ an\ alloy = \sum \frac{atomic\ fraction\ \times at.wt.}{n_i}$$

I leave this for you to work out anyhow time. If you have any questions we can discuss you know later actually. So, I do not want to take too much of time in this class actually.

So, please do work out when you have time you have any questions you let me know about it. So, the electrochemical techniques you can use Tafel. What is the other technique electrochemical one is used to determine the i_{corr} anybody?

Student: (Refer Time: 43:15).

Yeah.

Student: Linear polarization.

Linear polarizing right. So, that is called Stern – Geary equation also called as linear polarization technique. Here, what you do? You apply a very small amplitude of voltage or current right. You apply delta V across what? Across E corr. So, it must be plus or minus about 10 millivolt, you apply and you measure the current this is your E positive, E negative, i positive and i negative ok.

What is a slope? Slope is equal to R p. Now, R p can be related to i_{corr} what is that? R p is equal to one upon i_{corr} beta a plus beta c upon beta c; please check this equation is correct or not ok. So, you can able to you can able to use this techniques in order to determine the corrosion rate of the metals now ok.

$$R_p = \frac{1}{i_{corr}} \left\{ \frac{\beta_a + \beta_c}{\beta_a \times \beta_c} \right\}$$

So, so far we have seen the basic reactions that are occurring on a uniform corrosion what are the possible cathodic reactions. We also saw what are the parameters that affect the uniform corrosion, then we also looked at how to determine the corrosion rate of metals from the uniform corrosion point of view.

Now, comes how to tackle this problem. How do you from engineering point of view how do we control the corrosion of metals or how do I design a system so that I have life which I need 20 years or 50 years or whatever time how I do this? So, that is the question now.

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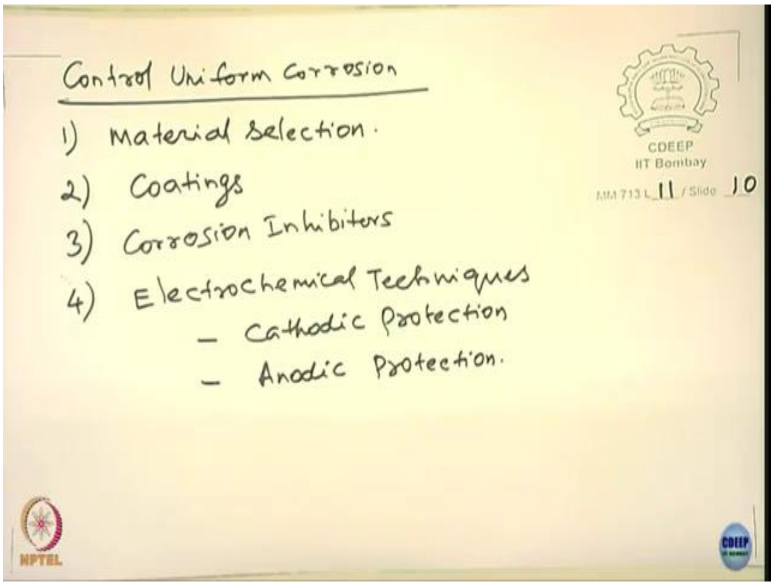

So, how do we control uniform corrosion? 1, I can choose a proper material selection you can do that you can also look at the coatings. We can also see the use of corrosion inhibitors and 4; we can also use electrochemical techniques. What I mean by this? Here you can use or employ cathodic protection we can also employ anodic protection.

So, let us try to address each of them and see how we can we can minimize the corrosion and how do we increase the life of the structures ok.

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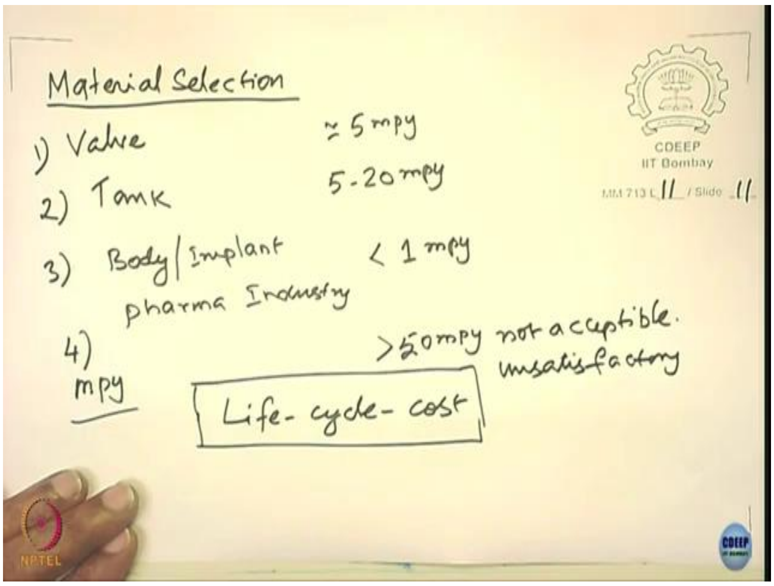

And, we will see now. Let us look at the material selection. What is the basis of material selection? Would you like to choose the best corrosion resistant material in all cases? Let us say oh, titanium does not corrode, let me suggest that everywhere do not tell them you know let us use titanium heat exchanger use titanium of course use titanium, is best way to do that. What is what is the criteria for that? Yeah, first is of course I mean?

Student: Availability.

Of course, availability is one more thing.

Student: Design set.

Design is other one.

Student: (Refer Time: 49:29).

Yeah?

Student: (Refer Time: 49:30).

Fabrication suppose you are going to a fabrication suppose you want weld, not weldable. So, the selection of material depends upon several criteria; cost is one important criteria no doubt about it. In addition to that availability, the ability to fabricate the shapes that you are really interested actually. The cost of the system, you forgotten very important one what is the expected life of the component. There is there are some more important issues which are not so obvious. The issues are like safety involved.

For example, you have very high risk like a nuclear power plant; there the cost is not going to be a primary issue ok. The safety is going to be involved actually here. So, you might choose a better material so that you do not have run the risk of any kind of failure and the consequences are very similar and.

So, when you when you talk about material selection there are several factors that have to be considered. The cost of course, obviously, a very important one and this general criteria if you choose materials depending upon the necessity of this. Suppose, I choose a material for let us say valve say one example or I choose a material for a tank or I choose a material for let us say a body implant or use it for a pharma industries.

Now, look at this let us look at the case 1 and a case 2 take an example here, what will be the criteria? You know the corrosion rate now see corrosion rates probably may be you can say you know you may have mpy. Now, still people start using though you know we still continue to use unit like mpy. You can also use mm per year.

Now, let us take the case of a valve and a tank. When you choose a material for valve and tank what will be the corrosion rate criteria? Would you like to have the same corrosion resistance for valve as that of the tank, what happens? I want you to talk, do you choose which is very critical here valve or tank? Valve, is it not? Because even there is a small corrosion occurring in the valve leak will occur, but in a tank even it corrodes it is not going to have immediate thread for any kind of leakages it will not happened at all.

So, selection of material for valve is more critical than that of the tank, same thing you can talk about a pipeline a pipeline a water pipeline is not. So, critical, but it is a gas pipeline is very critical and if there is a pipeline let us say oil and gas commission they have pipelines in the offshore, it is too remote.

You know even there is a leak is very difficult to repair that actually. So, maintenance is another important criteria which we did not talk about. If we were able to maintain very easily then you can have a bit of chance taking a low corrosion resistant material, but if it is not easily maintainable you do not have access to it. Then you have to go for a material which is more resistance to corrosion.

So, valve let us say about we talk about corrosion rate is about in the range of 5 mpy is a corrosion rate. It is this structures you have somewhere in the range of 5 and weighs this is a tanks and here the problem is not structural integrity, the problem here is more of tolerance right. The body will not tolerate a bit of nickel ions getting segregated and due to corrosion. You may have implant mechanically stronger no problem.

So, here the corrosion rate is because of the contamination issues. So, here the corrosion rate has to be lower than 1 mpy. If the corrosion is going to be greater than see 50 mpy or 20 mpy not acceptable, even in normal cases unsatisfactory. Why? You can contaminate the product, you can replace it, but replacing is not acceptable here you know. So, sometimes you can replace component not necessarily that you go for excellent corrosion resistance are all right it talks about the.

So, we use the term what is called as life cycle cost. This is the parameters industry use in deciding the selection of materials. The lifecycle cost of course, does not involve directly the safety issues. You can integrate safety issues in the cost if you want I mean then taking care off. So, generally when people talk about lifecycle costs they do not look at the consequences of corrosion in terms of safety and all this other issues. So, material selection is based on this right.

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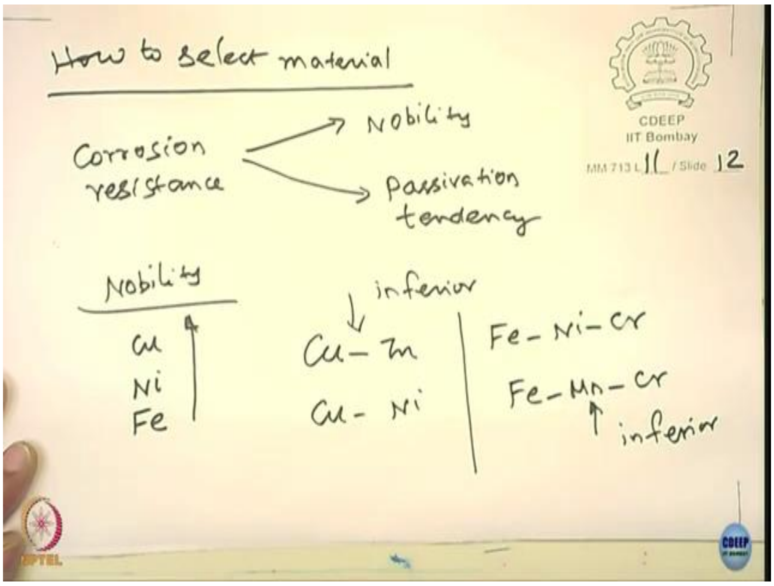

Now, you think that you would like to know is how do you select materials. I classify the corrosion resistance of the material. We can look at two; one is based on the nobility. A metal which is relatively noble would have better corrosion resistance right; also look at from the point of view of passivation tendency right. So, broadly you can see that the tendency of the metal to corrode depend upon two properties, the nobility and the passivation.

I give an example here right. Let us take a nobility. We are talking about engineering materials, we are not talking platinum, gold and all let us not worry about that right. Suppose, you take iron based material you have nickel based one and copper based one the nobility increases. So, iron base alloys are inferior compared to nickel base alloys and of course, copper base alloys are very good. For example, you take copper and zinc and copper and nickel. Can you guess which will be having better corrosion resistance?

Student: (Refer Time: 58:36).

Copper – nickel right. So, you should also able to get a feel for how the corrosion performance of the metal will behave based on the alloying elements. So, nobility there are other complexities we will not talking about the micro structure may complicate the issues, but generally the alloying elements if they are relatively noble you can say that yes, it is better material ok.

The other example is the stainless steel, you have what? Iron – nickel – chromium, iron – manganese – chromium, you know they are right. This is inferior; this is inferior. So, it is based on the nobility we can say that which metal which alloys is better or which alloy is going to be inferior you can talk about. But, you have a limited options here.

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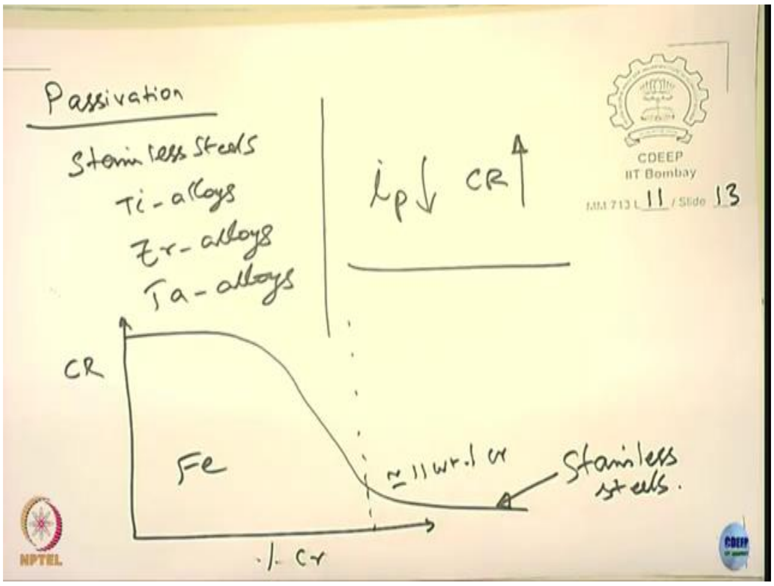

The alloys which are passivating are far better. See in this case stainless steels right say titanium alloys or zirconium alloys or we can say tantalum based alloys. Chromium cannot be used as a structural material because it is quite brittle right. So, stainless steels, titanium alloys, zirconium alloys, tantalum alloys they are all based on the passivity. What is the criteria here? If the i_p is low, then corrosion resistance increases, is the criteria for that.

I just give an example in stainless steel people have determined the corrosion rate of iron in atmospheric corrosion, corrosion rate of iron versus the chromium we talk about. So, somewhere here why things it closed about 11 weight percent chromium and you call this as stainless steels. This is for iron right, this is for iron ok.

So, the selection of materials of course, you can look at the there are lot of handbooks are available you know you can look at the you know the data available from there, they are used to for material selection purposes is done, but it is better to have a broad idea about how the metals behave with respect to the corrosion. Again, it depends upon the environment, the same thing cannot be said that the alloy will behave same manner if you change the environment conditions ok.

So, with this I think we will close it for the day. We will continue this discussion a next week and yeah, I would need probably one more class to complete the uniform corrosion of metals.