Corrosion Failures and Analysis
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Lecture - 03
Discussion of various factors affecting corrosion

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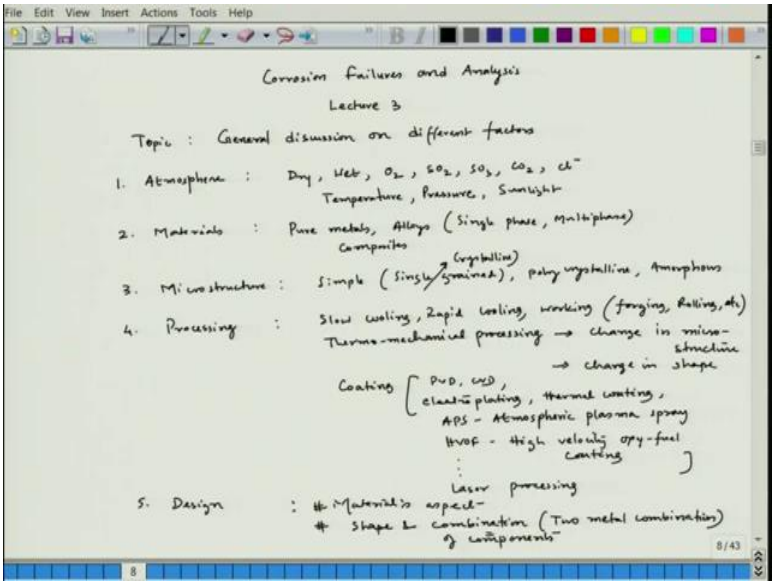

Welcome back to the course Corrosion Failures and Analysis and this is lecture 3 and if I see the topic. So, before we go to different forms of corrosion or patterns of corrosion. Let us look at a kind of generalized discussion on different factors, so, discussion on different factors.

Now, there if we recall our last lecture, some of the factors like atmosphere and when we talk about atmosphere, we talk about dry condition, wet condition, and there could be other pollutants. So, one factor is which is very common in environment is oxygen, then there are pollutants for example, SO_2, SO_3, CO_2. And, there could be possibility of presence of chloride ions, bromine ions.

Now, when we talk about atmosphere, we should also see the factors like, temperature, pressure, then of course, we can also talk about sunlight. So, these are the parts of atmosphere, what we have. Now, there could be influence of materials, we have briefly discussed that, there could be pure metals alloys, the alloys could be single phase or multiphase, fine. There could be possibility of composites ok.

Composite can have metal ceramic kind of stuff. Then, we could have effect of microstructure, this can be also a factor and microstructure could be simple. For example, single grain or multi grained poly crystalline and there could be a situation like both are crystalline this is also crystalline, and there could be another variance which is amorphous.

So, this change in microstructure can lead to change in corrosion behavior of a metal or an alloy. Now, there could be influence of processing ok. So, this processing means, for example, if we do as we have given example slow cooling, rapid cooling, there could be possibility of working means, forging, rolling, etc mean there could be extrusion and there could be thermo mechanical processing.

So, thermo mechanical processing means, we do working of the material when it is going through heat treatment ok. So, that is a kind of thermo mechanical processing. For example, when we see railway materials or let us say Rebar's. Those are mostly thermo mechanically treated steels.

Now, when we do processing it involves either change in microstructure or that could be involved of course, when we do forming operations, there is always will be a change in shape ok. Now, there will be effects of those processing on the microstructure, if we consider a fixed composition and as well as there could be possibility of change in compositions also.

For example, if we see the example of decarburization or carburization the surface layer. That is also a kind of heat treatment or processing, we do change the microstructure of the surface. Now, this processing can involve coating ok. There are different variations in coating, it could be PVD CVD or it could be thermal coating process like, atmospheric plasma coating, plasma spray rather ok.

So, if we just some example of coating is PVD, CVD, Chemical Vapor Deposition, Physical Vapor Deposition, electroplating ok then, thermal coating like, APS means, Atmospheric Plasma Spray, then HVOF; High Velocity Oxy Fuel coating. So, there are different variants of this plasma coating process.

So, if we do coating then of course, the surface property would change. Now, there could be laser coating or laser processing I would say. By simply changing the

surface microstructure by laser processing we can improve the corrosion properties of a particular metal or alloy system.

So, these are some of the examples I am just talking about those examples. These are basically processing, those are coming under processing. And, all those processing would have effect on microstructure or composition and then finally, it would also have a different interactions with atmospheres fine; and then corrosion property would also change.

Now, finally, I can talk about design or while talking about design, it can have two aspects; one is materials aspect, another one is shape as well as combination ok. So, these factors would definitely combination means two metal combination.

So, this part will talk in greater detail when you talk about galvanic corrosion, because the galvanic corrosion is one of the most important corrosion processes where, two different metals or alloys if they are coming into contact in an electrolyte, that would lead to change in the corrosion behavior.

One alloy could be active, another alloy could be noble and then you can have difference in corrosion of two objects, two components. So, I would say combination of components fine and shape.

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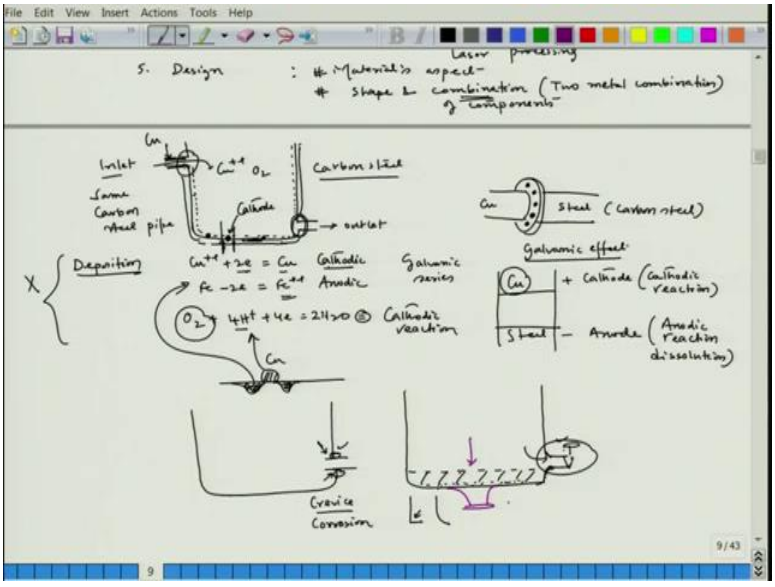

So, let me just discuss about the shape part little bit let me tell you just by changing shape, corrosion problem can be solved to a great extent, one such example let me just give you. Let us say you have a kind of tank design. So, this is my tank design let us say.

This is the tank let us say industrial tank and here we have an inlet, the pipeline is connected and this is another pipeline, which is the outlet ok. Now, if you see this particular tank design. Now, if it is an industrial tank it is a huge capacity 1000 gallons of fluids are kept.

Now, first criteria would come here, you know these are the sections. For example, generally tank material is mainly carbon steel ok. And, sometimes we do have a coating there inside we can use the coating. So, we will have a case studies we will discuss this case studies the effect of difference in coating in a tank.

So, that case study will come when we talk about galvanic corrosion. So, this coating can also be there, but let us say there is no coating only carbon steel a bare carbon steel tank.

Now, this outlet sometimes we use flange and in fact, we use a flange so, which is actually connected to the external piping system. Now, the flange material and the piping material could be different ok. So, I will also share one more example where the flange, when you have a flange. So, this is let us say a flange, this is the flange, this is a flange.

Now, that flange one side could be copper pipe, one side could be steel pipe. So, this example I will bring in needs an industrial experience or example. So, the copper end and the steel end you will see a difference in corrosion tendency and this all those bolts these are the bolts.

So, these bolts will have also difference in corrosion tendency. And, this difference should come mainly because of galvanic effect fine. We will see later, that in order to avoid galvanic effect, you have to coat one part of the component this combined component combinations. And, most of the cases we have to coat the cathodic part, not the anodic part, because the anodic part is now this is a kind of kind of confusion, is not it?

Now, anodic part actually dissolves and goes into corrosion, but here the thumb rule is we have to coat the cathodic part. And, we will see why, this is interesting observation the cathodic part needs to be quoted not the anodic part; if the possibility arises. So that means, here copper and steel and this is basically carbon steel, not stainless steel. If it is a stainless steel I will mention that.

Now, they were copper and steel, if you see a galvanic series, we will talk about galvanic series. In that galvanic series copper is sitting on top of steel. So, the copper would act as positive end or cathode and steel will act as a negative end which or anode fine.

So, when we have such situation the cathodic reaction would happen on cathode and anodic reaction which is dissolution would happen on anode. And, so, that time the steel would corrode, but copper would not corrode.

So, whenever we talk about would not corrode or steel will corrodes say would not corrode that does not mean that the corrosion is nill, I am saying that compared to steel corrosion the copper corrosion would be very very small. And, we will talk we will see that, why we are saying that there would be little amount of corrosion of copper, but that could be negligible.

Now, here if there is a flange let us say this is a flange, one end is copper, another end is steel of course, this galvanic effect would arise. And, then the steel part would corrode so; that means, the pipe which is connected to the tank part that would corrode, because the problem would be galvanic corrosion.

Now, here also if you see that this is copper made this piping is copper made. There could be possibility of copper ions coming inside, this copper ion can come with the solution, let us say it is a water. And, this copper ion there could be a possibility if it is a bare steel, there could be a possibility of copper deposits.

So, copper ion would collect two electron, it will go to copper and that would deposit on top of the steel tank and these two electrons will come from. So, this is anodic, this is cathodic fine. Now, this cathodic deposition, so, if this is a deposition.

Now, we have a copper small copper cathode, because we see that copper is cathode. So, this is a small cathode. Now, close to that particular section we have iron steel. So, there iron can dissolve. And, the cathodic reaction, this is one cathodic reaction, and there could be another cathodic reaction, if this water is acidic.

Then, this reaction can happen, see acidic means there will be H plus ion present in that particular water, and if this is exposed to environment there could be dissolve oxygen, and this cathodic reaction can happen. So, this is also a cathodic reaction.

$$O_2 + 4H^+ + 4e = 2H_2O$$

Now, we have a plate, we have a copper small copper bid on top of it this cathodic reaction would happen, and around this we have this reaction. So, around this the corrosion can happen like this. So, this part would get corroded. So, now, thickness of this particular tank, thickness of this particular tank would decrease in that two segments. And, finally, the tank might get leaked.

So, this is one example that because the only copper piping connection with the steel tank this problem arises, this does not happen one fine day it takes time, but if we use same carbon steel pipe, same pipe. So, the galvanic effect will be nullified. And, once galvanic effect is nullified this particular thing can be nullified. So, we can protect the tank for the longer duration.

So; that means, it is just by changing the combination of two metal, we can prevent corrosion. So, we are not doing anything rather, if we replace copper by steel, then we are actually reducing the cost. Now, there could be possibility of introducing plastics PVC pipes. So, that will further reduce the corrosion effect. So; that means, we are just changing the combination and we are reduce we are preventing or minimizing the corrosion effect.

Now, coming to the other design part, now if you see so, this tank if we only see the outer part. So, this outer part let us say this is my outlet, the design could be this another design could be this. And, you would experience that, this design is better rather than this design, why?

Because, here we are creating for example, a pipe is inserted into the tank, actually you are creating two crevice portion. So, these are crevice. And, in the crevice,

crevice corrosion can happen, which is very very localized mode of corrosion and then there could be possibility of leakage from here. But, this case there is no protrusion going inside and the crevice is avoided.

And, in fact, you have to make sure whenever you design a tank or something your corner should be rounded rather than sharp, this corner should not be like this, it should be like this. And, whenever rounded you are actually preventing crevice formation.

Now, another aspect is now the industrial tank time to time you have to actually clean it, because there will be dust particle coming here, depositing here you know. So, this dust particle need to clean you know you need to clean it off. Now, only way you can clean it off either by tilting or taking the water out if you tilt it ok. So, on see the big tank you cannot tilt even, because it is very difficult to tilt a huge tank.

So, the only thing is there would be a tap, there would be tap you open the tap your water goes out, but you could see that till this level, there will be some water level remaining all the time. So, that water you cannot take it out. So, the best design would be instead of putting this outlet here, you can put the outlet here, with a cap here, fine. So, whenever you want to drain it off you see entire water will go out. So, this is the better design rather than this.

Now, if we have this all the time electrolyte is there. So, you have the problem of corrosion persisting at the bottom of the tank, but here cleaning would be easy at the same time because there is a flow, this dust particle deposition of dust particle can be avoided to a great extent. So, I am just giving an example that only changing design, can improve your corrosion resistance or corrosion protection.

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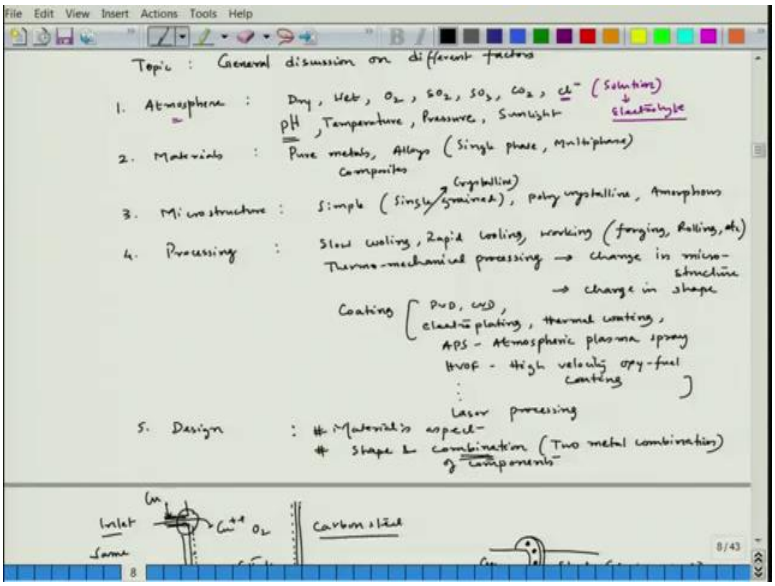

So, this is the design part. So, what I am trying to so, show you that what discussed here. That these are the factors, see there are other factors coming for example, atmosphere. When you talk about chlorine ion, the chlorine ion can only be present in a solution, solution that means electrolyte ok, fine.

So, that electrolyte can be different, there could be a presence of acid strong acid in the electrolyte, there could be presence of bases ok. Sometimes in base if you maintain for example, there is a kind of perception that if we improve the basicity of an electrolyte there is a possibility of passivation.

But, interestingly if you increase the basicity to a great extent; that means, OH minus concentration, if you increase it to a great extent, let us say if you go to 15, 14 to 15 pH in case of steel or iron actually it starts corroding rather than having passivation.

So, it is not only a single factor there are multiple factors associated with this corrosion phenomena when you talk about atmosphere. And, when you talk about atmosphere of course, one factor I have forgot to mention which is pH. So, this is very important factor pH.

So, we can discuss when we talk about different forms, the influence of different atmospheric contents or presence. And, materials of course, I have discussed a little

bit when we talk about pure metal alloys, for example, steel. You just take a single steel let us say 0.2 percent carbon steel, which is mild steel by changing the microstructure you can change the corrosion behavior.

And, even in the materials if you take a metal add something some other element, it can improve the corrosion behavior or it can decrease the corrosion improve the corrosion resistance, or it can actually deteriorate its corrosion resistance; there are examples we will talk about that.

And, microstructure definitely I have given an example in a in our previous lectures, when we talk about the change in microstructure of stainless steel by just doing little bit of change in the cooling rate; within the temperature range of 400 to 600 degree Celsius. And, of course, processing actually leads to change in microstructure, change in composition, and that would lead to a change in corrosion behavior.

So, I just wanted to give you a kind of general discussion on different factors influencing corrosion ok. So, now, in the next class onwards we will start talking about different forms, when we talk about different forms, we will talk about 5 aspects.

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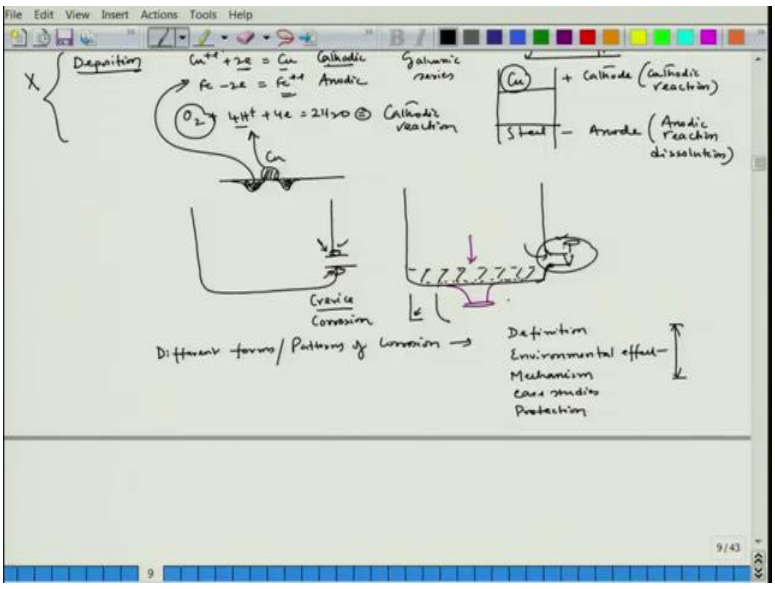

So, next class onwards we will talk about different forms of patterns corrosion and that will move in this fashion. So, we will talk about definition, then we will talk

about different environmental effect, then we will talk about mechanism, then some case studies, and finally, we will talk about protection.

Interestingly you will see that if we understand these three, one can with using by using common sense one can also decide the protection ok. So, let us stop here will start talking on different forms from next class onwards.

Thank you.