Corrosion - Part I

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Lecture – 01
Introduction to Corrosion – I

Hello everyone, today we will start our first lecture on this course Corrosion. This is a MOOC course a 20 hour course and 8 week this course will be this course lectures should be floated. And I will be giving the lecturers and in addition to that there will be three TA's teaching assistants available to respond to your queries as well as the problems what will be given to you, they will be the first interface with whom you will be interacting for those solutions as well as if you have any queries table respond and then of course, I will be also be available all the time. This three TA's are mister P. K. Rai, Mister N. K. Prasad and Mister B. Bhushan and interestingly this all three TA's are in their advance stage of PSD and they are all doing in corrosion related topics.

Now, as I have mentioned in my introduction that corrosion is a very very important subject. And it is to be understood carefully and we need to spend little time on this and also we mentioned that there are scientific aspects of corrosion, were electrochemistry is to be known, is to be understood. But there are many engineering aspects to this materials corrosion, where you would be seeing that many other factors like compositions of metals and alloys design of components, then environmental factors like oxygen concentrations and H 2 O presence; that means, moisture presence as well as sometimes you would see that the stress also plays major role.

We will go gradually one by one two different aspects of corrosion, but today we will have a kind of history that why we should study corrosion. And also you would find that there are some aspects which lead to kind of catastrophe and if we do not understand corrosion properly, we would not be able to protect our structures, which are made out of metals and alloys from corrosion and finally, from premature failure. Now, before we got into the subject, I would like to put up some of the corrosion books with are good books, and of course, other books are available thousands of books are available, there are materials available in internet you can Google anytime, and try to get as much as you want from the literature as well as from internet.

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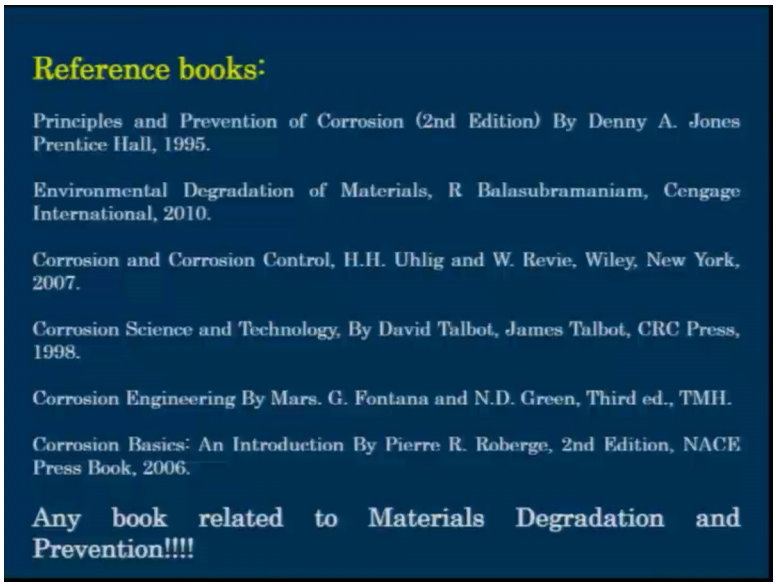

So, these books are just for reference, you can find any other books because, the aspects of corrosion is same whether you follow this book or that book. It depends on how it is a presented in that particular book, but still I have put some books. In addition to that you would find some of the lectures in YouTube as well as I mentioned that in this course we will also explain some of the intricate matters related to corrosion.

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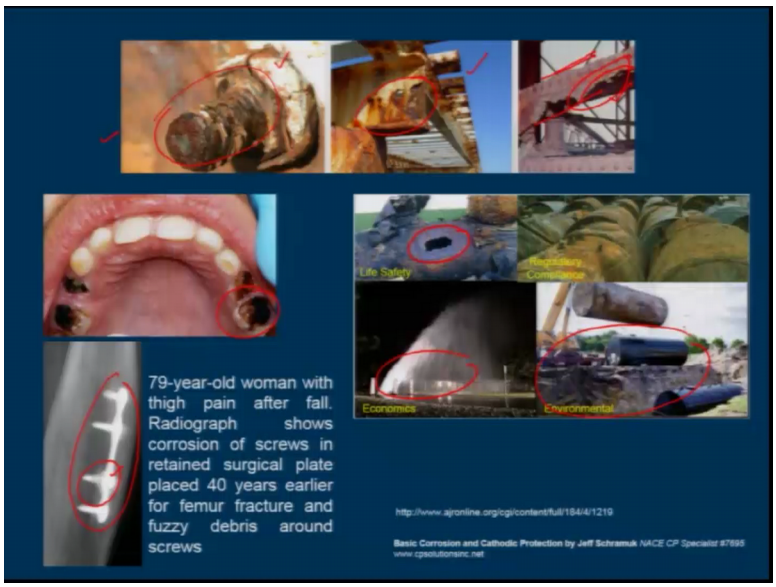

Now, coming to the subject directly; this slide is actually if you see this slide this slide is related to some of those is basically showing some the common features of corrosion.

Now in day to day life, every direction if you look at you would find examples of corrosion. I start with let us say our utensils, our a household goods, you will find that many a times household goods like scrubber or kind of a this spatulas those are corroded heavily. Even for example, the first picture if you see the first picture this picture if you see, this picture is related to the corrosion of bolt, you see this entire part is so, heavily corroded. This is the bolt part and this is the nut part nut is also corroded, this is commonly observed feature.

Now, another commonly observed feature is if you consider overhead structures beams, this is the overhead structures and beams they are also heavily corroded. And corrosion always it comes with the different colour most of the cases and many a cases you do not find any signature of corrosion, but still it happens and those cases are more deadly than any other cases, where you have a kind of signature in the form of colour change.

Here you have the basically red rust which is forming, which is a typical feature of iron corrosion. These are either a hydrated ferric oxide the ferrous of ferric ions are containing over there, and this is this happens because of the presence reaction with oxygen and moisture in the environment, this is basically a atmospheric corrosion. Again if you see this kind of structure, which is a basically a kind of beams as well as a kind of bridge also you will find this kind of corrosion.

If you can see that the entire material is out, and the kind of thickness what it had this being physical initially it was basically this much thickness and now it has reduced this particular section has reduced. That means, initially it is to it was designed to carry some load, now since the cross section has reduced of course, it will not be able to follow that particular load it will not be able to carry that load at some point of time it will definitely fail. And when this metallic structure fails it fails catastrophically without giving any signal that it is failing. Now, a typical corrosion features like this, if you see this is a kind of pipeline. I also relates to the safety of people walking around that.

Now, if it is a pipeline, now if it carries oil and if suddenly this kind of failure happens, it might catch fire or any other things and then it there could be explosions. Now kind of a failure here if you see, this is a kind of pipeline which carries water. And then with the pipeline corrodes and finally, it leaks before one could rectify and then finally, stop that leak you lose lot of water. And of course, if you see this kind of situation, where those

corroded products even if the, if it is carrying some kind of a liquid which contains heavy metals and other stuffs like what we have in chemical factories. If it leaks if that wall leaks it will leave that particular liquid into the environment in the, into the soil and that soil is contaminated.

For example if some sections some in if for example, in Kanpur specially, in it is basically a belt where lot of these tanneries are there. So, the tannery the this particular (Refer Time: 08:38) this particular kind of liquids, it lead to the environment those liquid contains lot of not so good metals. So, it is also leads to environmental hazards. So, this kind of corrosion we can see these are all visible naked eyes; now, if you consider this kind of corrosion, which is basically related to a corrosion of tooth fooling. Tooth filling this is also corroding, this is also not good if some metal is put up and then if it goes out again it leads to a health hazard.

Now, this is a typical corrosion failure for example, in this zone, this is a kind of broken bone which is locked which is connected by screwing and putting a rod. And now if a, this corrosion product is accumulating; and when this kind of attachment is fixed to the bone to the broken bone finally, it is function is to carry load. Now if there is a corrosion product, it becomes weak now it will no longer hold the load and it will fail. And when it fails, again if the person has to go and sleep on the operation table ok. So, in other invasive surgery and a kind of trauma and other things other pains those that person has to be here for another time.

So, corrosion see these are actually some of the pictures are taken from internet, but in the internet you just put this particular buzz word corrosion and damage or corrosion accidents, you will find thousands of example. Now, let me put up some small small examples like you might find in the though it looks a little awkward, in the urinal you will find that a, some kind of water connections, there you will find that the top this nuts are little shiny, but the base of that particular metal with the connector is corroded heavily. Now, the question is people always put nuts in the form of a kind of a better metal, which has little bit of extra corrosion resistance.

And that particular connector the small rod connector connects this particular nut to the main pipeline source. Is of a poorer great metal I would say compared to that nut material. Now, this I am telling poorer great means with reference to the corrosion

resistance of those metals. Now, that case a kind of corrosion happens which is called galvanic corrosion, and there the connector which actually takes water pipeline to the to the pipeline inside the bathroom that gets corroded and leakage happens. So, these kind of stuff many a times happen in our day to day life.

And for example, another example I can sight let us say water sink this kitchen sink. Kitchen sink sometimes we find that at the corners we do get little bit of a kind of small small dots like appearance, which are nothing, but pits and over the time this pit grows and then there is a leakage. Another example water storage tank; now water storage tank the typical failure point is in the corner positions, at the at the bottom corner you would find that leakage is taking place from there. So, that actually relates to another kind of corrosion which is called crevice corrosion. So, those everywhere you will find corrosion.

Now, some of the cases you would see if some construction is taking place. Sometimes people do construction and then they form the beam and that beam is half cooked beam, I would say that half is made the half is exposed; that means, all those reinforce birds are exposed to the environment. And you would find that that beam during the rainy season that beam will become a kind of reddish appearance, because that red rust what is forming on the expose reinforce spurs those are trickle down and then it will make the beam colour reddish ok. This particular nature is always visible if you look around

Now, coming to your house, sometimes if it is old house and if there is a problem of seepage; You would see after little if you if you see a for a longer duration of time, the corners or say where the seepage is more you would see that the cement is that particular concrete structure as if it is solemn and you will see the peel off of that particular a concrete pots. And after sometime you might find that the reinforce bar is also exposed.

And the, reinforce bar if you see carefully, it is a kind of a flect reinforce bar the reinforce bar if you see in the raw condition you will find that it is nicely ripped a reinforce bar with a little bit of red rust, but otherwise it is fine. But over the time inside the concrete that red rust is forming and that red rust has got a higher volume than the metal so; that means, that particular concrete reinfore rebar, which call reinforce bar the rebar is confined in the concrete structure.

So, when that corrosion is taking place in the rebar, it is getting solemn because of that rust formation and rust has got higher volume it gives huge pressure on the concrete. And since concrete has got a very very small elongation, so, at some point of time concrete starts cracking and then it falls off. And in fact, that makes the structure extremely vulnerable to failure; even it happens in bridges old bridges you will find that some places the rebar is exposed. Though it was initially confined in a concrete, but over the time this concrete is getting spoiled off and then finally, the rebar is exposed. So, those are kind of examples I am putting up.

So, these examples though you would not find that significant, but if we if we see some of the data you will see that yes it is a significant and we need to see that how to stop them. And in order to stop those we need to know how corrosion takes place. So, I when I know the reason then we can attack some problem. So, let us see a kind of accidents that can that have taken place due to corrosion.

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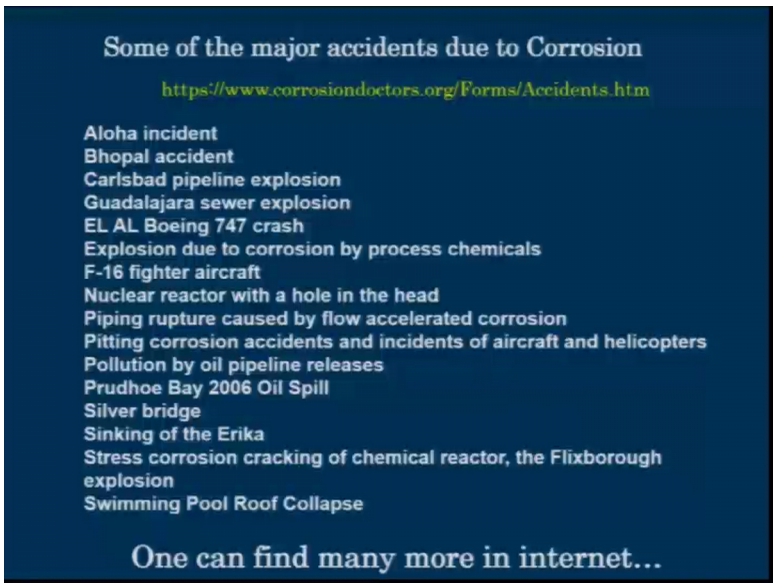

So, these data I am I have put Aloha incident Bhopal accident, Carlsbad pipeline explosion all sort of examples I am putting. So, this you can also find out in this particular website, it is basically called corrosion doctors dot org, there you can get the history of this particular failures there are other failures also, but here it is nicely recorded.

Now, in those cases the accidents many a times took life ok. Also if something breaks something fails for example, a silver bridge 1967, it broke down and there are lot of economy loss life loss finally, the connection is lost and then again you have somebody has to rebuild it so, those cost needs to be considered. And in fact, these particular failures all of though cases the corrosion is one of the major causes major cause.

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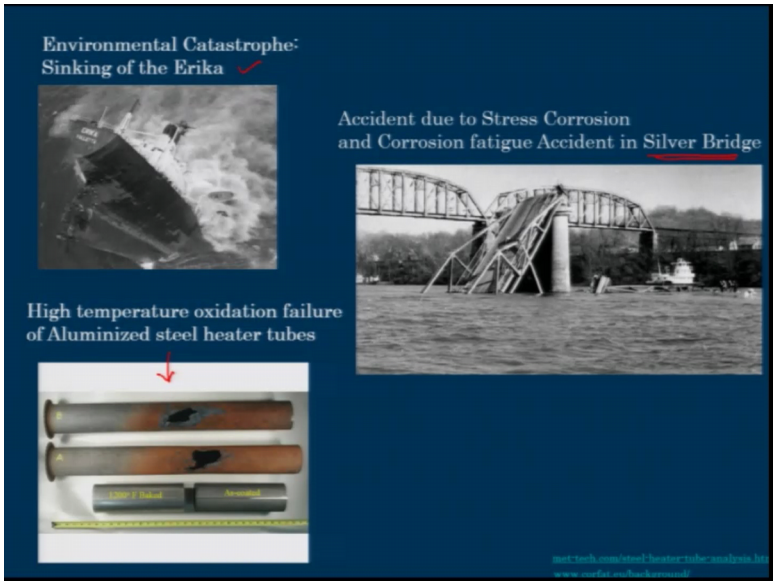

Now, if I see some of the pictures for example, this picture this is a kind of oil vessel Erika, this failed due to corrosion. This is a major reason that this failed this broke into half actually. Now this is the kind of failure I was talking about this is a silver bridge silver bridge failure, and I think it is it happen in 1967. And again if you come to see this part this particular situation, this is high temperature oxidation failure of aluminium steel heater tubes.

Now, here also since steel heater tubes now, here also since it is mentioned as oxidation later you will see that oxidation is also a kind of corrosion. So, this kind of failure I am just giving an example for sake of understanding that yes it can lead to a serious accident.

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Now, a coming to cost we do see lot of losses. For example, the USA it is basically I could find 1998 data, it says that the cost of corrosion means at the loss of money due to direct as well as indirect loss. I will come to that direct as well as indirect loss 260 billion dollar it is not a small money, it is 3.1 percent of GDP of that particular country.

Now, in India I have put two data, one is a this data which is 2012 data 2 lakh crore rupees and this is in the form in rupees. Then in 2016 data this is a kind of a data what we have the 6 lakh crore so; that means, 2012 to 2016, we have for the increase in loss of money due to corrosion is of the order of around 300 percent it is a quite a bit actually. Then it is also the 4 to 5 percent GDP of a our country, which is almost 2 trillion dollar economy. So, it is a quite up quite a bit of loss.

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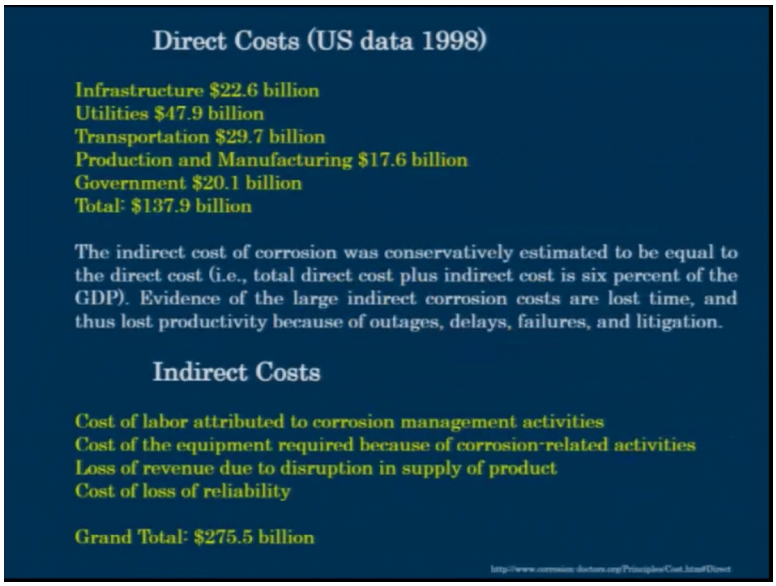

Now, direct cost is basically us data infrastructure. Infrastructure when I am talking about direct cost, this will be the failure of infrastructure bridge, buildings, utilities then transportation of course, transportation railways. If you have noticed railways and also you can find some of the pictures in the internet, that sometimes if you see the goods train ok. In beach vizag I will show later some of the pictures in vizag sometimes a one picture I have I will show it later.

One goods train was stranded for almost 2 months there was waterfall. And that entire bogie was full of with water and it was looking like a small swimming pool. So, now, you imagine, if it stays for longer duration how much corrosion it can take place? And then finally, what happens you have to throw that particular bogie and it is a loss of money.

Then a production and manufacturing around 17.6 billion, government expenditure point 20.1 billion, total around 137.9 billion. Indirect cost is a kind of cost of labour attributed corrosion management activities. For example, let us say painting time to time we have to paint the structures in the factory. So, for that you need to spend money on paint, you need to spend money on the manpower because somebody is to be there, to paint that particular structure.

Then cost of equipment required because the corrosion related activities ok. Of course, corrosion related for example, there is one corrosion protection system which is called

cathodic protection or anodic protection you need to monitor instruments that how good is that particular corrosion protection. So, that also needs money.

Loss of revenue due to disruption in supply of product for example, the bridge is broken. And once the bridge is broken then next at least 2-3 months the supply chain is broken. So, it is also loss of money of course, the loss of cost of loss of reliability and it is not mentioned here, there is nothing important other than life there will be life loss. So, this is a kind of data what I am showing. So, we have to study corrosion.

Now, coming to as we have mentioned about all those losses, kind of accidents kind of examples, what we have put for till now that there are corrosion incidents everywhere every direction. Now, coming to material degradation, material degradation something degrades and every structure everything what we have to do with the material.

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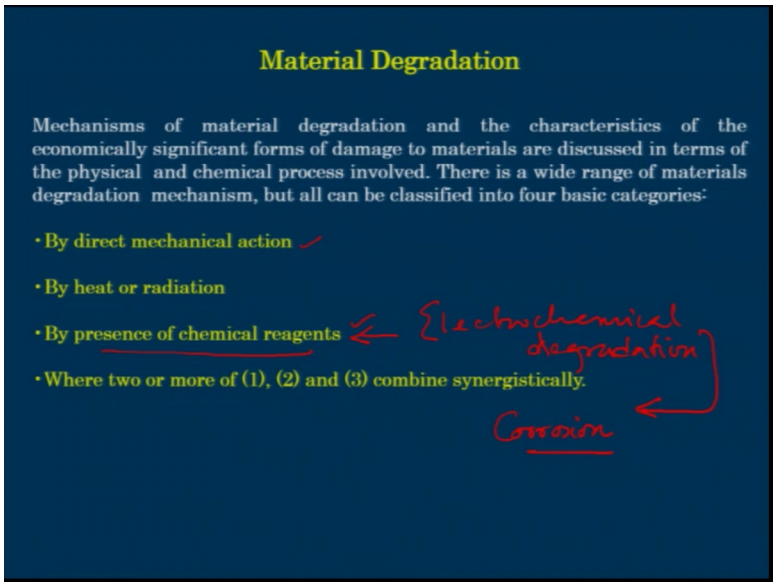

Mechanisms of material degradation and the characteristics of the economically significant forms of damage to the material are discussed in terms of the physically and chemical process involved. Yes there will be physical features there will be chemical process. For example, one particular example of physical features, let us say a kind of a structure we have built. Now, if their for example, in a stormy areas, where we have lot of storms. If there are sand particles and if that sand particles hits any structure it will always erode it is not corrosion, but it erodes that is also a kind of loss of material is a material degradation.

Now, coming to railways in the railways there is one form of loss of material is wear because wear happens when two bodies are in contact, and due to friction some part of the material is lost ok. So, there will be a thickness reduction and finally, you have to discard that particular product particular material and you have to replace that material with a new one.

So, by direct mechanical action of course, this wear; where you have kind of relative action a between two bodies and which are in contact. Heat or radiation of course, heat does play a major role. Radiation of course, for example, radiation damage one particular radiation damage is in nuclear applications. Radiation does lead to a kind of a loss of a material properties ok. We will come to that it can lead to a kind of void formation in materials. By presence of chemical reagents yes there are chemical reactions there are electro chemical reactions.

Now, we would concentrate on electrochemical reactions not chemical reactions of course, when we talk about electrochemical reactions, we would also consider couple of things. For example, if we try to see iron corrosion, and that iron corrosion you will see that iron is corroding in the form of electrochemical reactions, but there could be other aspects other reactions, which will be coming along with that electrochemical reactions. So, our interest would be mainly in these particular sections.

Now, if we see all three by direct mechanical action, by heat or radiation, by presence of chemical reagents, there could be combination of two or more or all three could be present. For example, erosion corrosion, this is a classic example of combination of all three; so, sometimes we for example, in heat exchanger. Heat exchanger the hot air is being cooled by water. So, this water when it is flowing it takes the heat.

Now, when it flows, it could also lead to erosion on the pipeline and at the same time this water also contains little bit of chemicals which can lead to chemical attack on the surface in the form of chemical reaction or electrochemical reaction so, there will be material loss. So, those kind of situation for example, mechanical action and chemical reactions. Classic example is fritting action; in the fritting also we have mechanical action as well as corrosion action.

So, this combination can also lead to material degradation fine. So, we would look at more in a in a greater detail on this part electrochemical reactions or rather electro

chemical degradation which is nothing, but corrosion. So, as we understand till now that, first of all we need to study corrosion and when you need to study corrosion we have to also see the features of corrosion, we also need to see k the reasons of corrosion, we also need to see how we can tackle corrosion. So, if we have all three combined then we can become the successful corrosion engineer.

Thank you.