**Aqueous Corrosion and its Control**
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**Lecture - 28**
**Forms of corrosion: Fretting corrosion**

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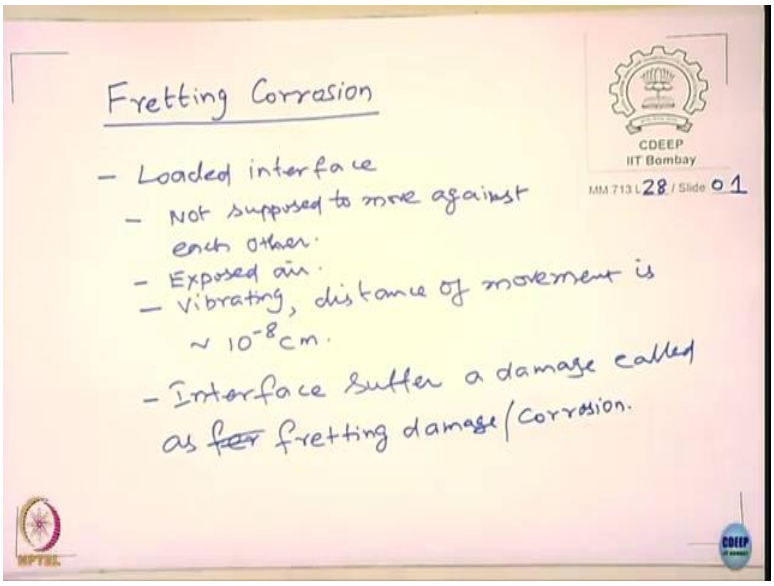


Welcome to the discussion on “Fretting Corrosion”. This is a special type of you can call a corrosion, occurring when the structures are loaded heavily. And the interface between the mating parts, the structures are not supposed to be moving against each other.

So, in the structural design what you do is; for example, you say riveting right. Riveting is a mechanical joint. Similarly, you can talk about bolting or you could see a tie plate that you see in the in the rails right been grubbing the rail with the with the wooden or a concrete slabs. Now, these are essentially the structures which are joined by a load ok.

But it is easier said than done right. When you apply when you have a bolt for example, a bolted structure there can be a vibration, when the vibration occurs the interface they start moving you know at certain distance. It could be as low as a angstrom, a nanometer distance. So, there is a relative movement of the interface which are heavily loaded which are not meant for moving is supposed to be held tight. In that case, there is a rubbing action that is you can call a wear, if you want to call ok.

Student: Yes sir.

But in this case we call this as a fretting damage, because in the wear process the movement between the mating surfaces are quite large right. Let us say in the ball bearing within the race, you have the balls you start moving ok, it starts moving maybe a few meters, it starts moving.

Student: Yes sir.

The gearbox gear starts, you know moving its a damage, but that we call as a wear process. But a bolted interface because of vibration it moves, it jiggles right, that movement is very small.

And when it moves and we also have exposure to the air or a corrosive environment that damage we call them as fretting damage. So, the fretting damage, the fretting corrosion refers to loaded interface first of all, which are not supposed to move against each other and they are exposed to air.

Air is an is a corrosive medium here, there is oxygen present and then they start vibrating. And the distance of vibration, the distance of movement, I would say is of the order of 10 power minus 8 centimeters is close to angstrom imagine. When these things happen, interface suffer a damage called as fretting damage, fretting corrosion you call it.

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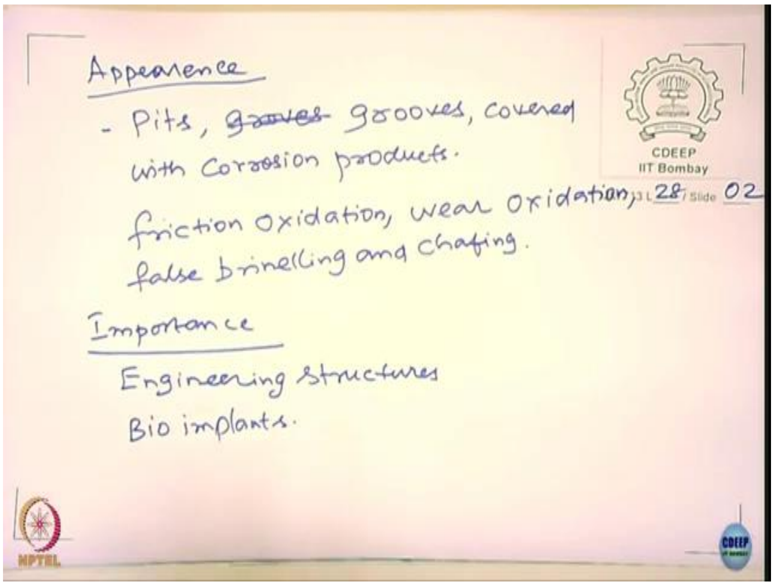

Now, how does it look like? Appearance, it appears as pits; appears as grooves and covered with corrosion products. Now, the fretting you know damage and fretting corrosion is also called as you know friction oxidation called also as wear oxidation. We call as false brinelling and or may be called as chafing.

Now, look at this that the term brinelling is arising out of the fact. You know the, you know brinell hardness, you know brinell indenter right. When you when you carry out a hardness test using brinell indenter you see kind of what hemispherical shape right. Brinells spherical balls right. So, the appearance of that indent is very similar to the fretting damaged locations the pits that you talk about.

So, that is why they called as a false brinelling. It is arising out of the appearance that you see, that the friction oxidation and wear oxidation, we will see later that. It is more related to the mechanistic aspect of fretting damage. How the fretting damage occurs in in reality actually. Now, the importance of that, it is very important for engineering structures ok.

It can be in aerospace industries, a transportation industries, it can happen in a you know, in a automobile. For example, it happens in rails, it could happen in a heat exchanger where you are securing bolts and then you know when the, when you when the liquid pumps you know, it pounce the thing then start vibration can takes place.

So, it happens in several engineering structures. It can happen, it can also happen in bio implants that you do for orthopedic applications right, you do that. I give some examples to get a feel for you know the fretting damage that can happen in engineering structures and as well as in the bio implants.

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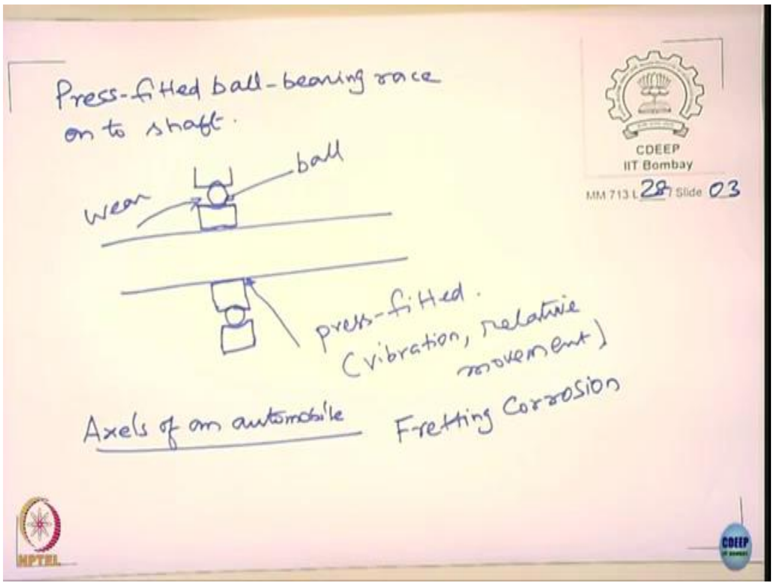


The one of the classic case of you know defining the fretting damage is press fitted -ball bearing race onto a shaft right. You know is not it. Suppose, you have a shaft for example, you may have a shaft here and right, this is the sectional view of the bearing right. This is the ball and this is the race right. This whole thing is called a race.

And this is press fitted right. So, when this shaft rotates, what happens? The race, the balls starts. You know I mean starts moving right. The whole race starts moving actually around the balls right. Of course, balls are located is not going to move from a place, but the race is going to move, but this press fitted place, this is supposed to be intact is not supposed to be loosened at all, but in practice it would happen ok. However, well that you fit it depending upon the loading conditions over a time period you see that there is going to be vibration and relative movement.

And the failure that occurs here within this interface, we call as fretting corrosion. The failure that happens here, what do you call this? We call a wear failure. If there are some corrosive liquid here. So, happen then becomes a corrosive wear. So, the difference between this and this place is that the movement, relative movement between these two are not very large, but here the relative movement is quite large.

The other example, clear example that one can also look at is the axels of an automobile. Assume, that I have a small car, it is manufactured at the one of the automobile company and they transport these cars from one place to other place before it is being sold to show rooms. For example, how do they transport? The transport through trucks right, they transport through the trucks. When they transport through the trucks the axel does not rotate completely rather what happens? Now, it jiggles it just starts vibrating back and forth.

On the other hand, when you drive the same car, the axel undergoes complete rotation. The failure that happens during the second one is called wear failure. The failure that happens during the first one is called as fretting damage.

So, the difference is that the relative movement of this happens. In fact, one of the real problems which is in fact, a burning problem that happens for the steel industries and I do not know how many of you have seen some of these trucks carrying coils, you know hot rolled coil, cold rolled coils, they have been rounded and kept on the truck right. They rounded ones, I have seen there are few tons, these coils sometimes are used for automobile, companies you know thin they are thin sheets right.

They are coiled and they are transported from the steel company to automobile company or any user companies. What happens when the when the truck moves the whole coil you can see that they start, you know vibrating, there is just something like bumping, you can see that.

The load is few tons, this is not simply low, very low load. There are few I mean very high loads. So, when there are high loads between this sheets the coil interfaces, you will see a clear damage and that damage is nothing but a fretting damage. You will see all pits, you know like a biting pits you see the things and the (Refer Time: 17:11) is one of the perennial problem for the steel manufacturers.

So, in essence to say that whenever we have a load interfaces very heavily load interfaces and they are under vibration causing a relative movement between the interfaces and you have exposed to the to the corrosive environment like air. They are going to cause a premature failure, they damage and such a damage is called as fretting damage.

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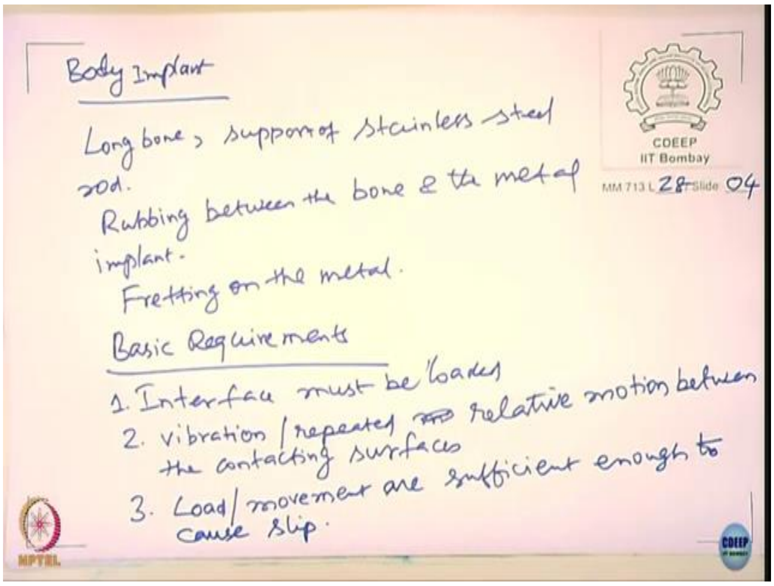


Now, I just give an example how this can happen in an implant. In a body implant you suppose, you have a broken you know leg or something. So, it is for let us say a long bone and you have a support of a let us say stainless steel rod, supports on the leg for example, and you start walking now ok.

What happens now is going to rub is going to be rubbing between the bone and the metal implant when it happens then the bone bears out, then what happens now you see that now, then there is going to be you know fretting damage on the metal.

Please, notice that the fretting damage is not just confined to only metallic structures. It can happen on a ceramics. Suppose, I have two ceramic interfaces right, it can happen. Very interestingly, people have noticed fretting damage even on the noble metals ok. So; that means, it looks that the corrosion is not the main requirement for fretting damage though corrosion assists, the fretting damage.

But, corrosion is not really a requirement basically, because you talk about noble metals having suffering the fretting damage, ceramics suffering the fretting damage. So, it is just not combined only to the metals it can also happen to the non metals as well actually.

So, there are three basic requirements ok. For the basic requirements are the interface must be loaded. Two; there has to be vibration or repeated relative motion between contacting surfaces. Third the load and the movement are sufficient enough to cause slip alright. So, it is a mechanical damage that taking place. The contact surfaces you know when, you see when the surfaces are rubbing for example, ok, what really happens you know?

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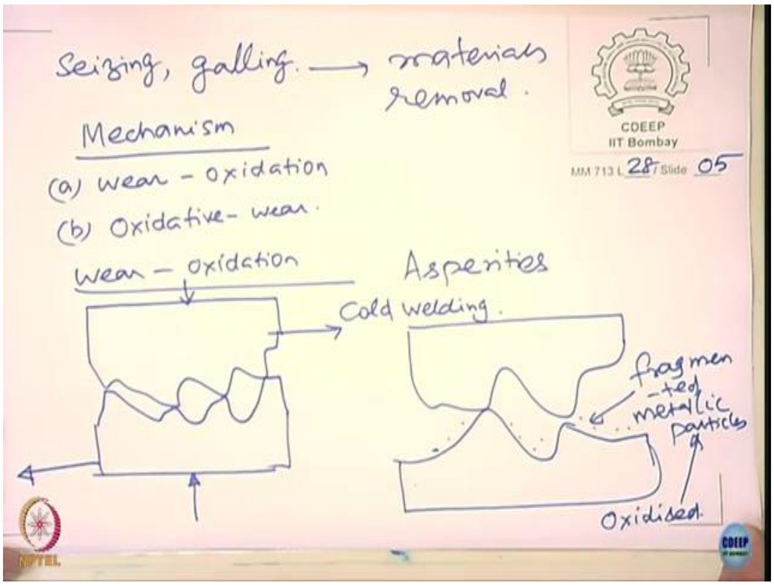


When they are rubbing, it leads to seizing, just seize, just sticks, you know when you start moving fast you can stick and then move right, it is called seizing. You can also have galling, you know what the galling means? When they are this this stick and when you remove it just comes off from the surface right. It just comes off from surfaces, it happens in the soft material; the soft material.

For example you have a zinc and you know zinc is zinc bolts for example, fasteners, you apply a coating, you have with the threads, you suppose you just screw them and what happens? Zinc will stick and just come out. So, the galling comes when we have softer material, when they stick and then when they move further apply the load just comes off.

So, the fretting damage leads seizing and as well as the galling and then finally, what happens. So, they are all related to materials removal, materials removal from the surface. So, we have now so far described what is mean by fretting damage and where it occurs? What are the requirements for fighting damage right?

If you need to control fretting damage so we need to discuss. In the mechanism, there are two types of mechanisms ok. One is called as wear oxidation; the other mechanism is oxidative wear. You will see, why we are proposing the mechanism. What do you mean by mechanism? So, how are the process are taking place? How are the physical processes are occurring right? What are the steps involved ok? What the route (Refer Time: 25:38) think the taking place. It talks about the path.

Now, how do you, many cases find out the path? You may have to analyze. Suppose, there is a process you might analyze, you know after the end of the process and then try to build, you know a theory assumption to describe the starting point, end point and then see how things have happened right. When you, when you do that then of course, you can also do a controlled experiments and prove that the path that you described is a right or not.

So, essentially you need to look at the experimental evidences to support this theoretically you can do another part of it actually experimentally you need to have a data to support the mechanism. In this case when you have a metallic surface the end product is always an oxide particle.

You can create an oxide particles by two means one; I start with the virgin metal I mean right nicely and, because of rubbing action you get a very fine particles, powders of the metal, because they are refine and exposed to the atmosphere they turn into oxides, one thing look at it.

The other theory is that what oh look most of the metals they are covered with.

Oxide layer right what really comes in contact with surface is not really metal, pure metal. So, when you have a contact surfaces when you apply a load these oxides fragment and become powders, because your end of the experiment you see what on the surface oxides. So, two possible routes are possible ok.

So, so that is how it means that wear oxidation mechanism an oxidative wear mechanism, both are successfully explaining the experimental observations right. So, that is what happens.

So, you want to do that schematically you can do this you can say that I have. So, the first is the wear oxidation mechanism. So, you have the contacting surfaces, you know the contacting surfaces are not atomically smooth right, they are not atomically smooth.

So, what how do you do? You always have hills and valleys right. So, you have always you always have asperties right, this you have hills and valleys something like that. So, I can just discuss this and I can draw schematically something like this.

. So, they are under load, am I right? These are under load. When they are in a load you have oxide free metallic surface. What happens? It leads to cold welding. They build each other some kind of you know local fusion takes place between these two surfaces and you apply a load, a shear load onto this. Now, what happens, because you know you do not need too much of load in order to fragment this asperites contact points right.

So, what happens now? You will you will see that of course, new things have come and it creates of course, a newer a surface and you have fragmented particles on this actually right. These are what are these? These are all fragmented metallic particles. When they, there we have very fine fragmented particles and surface is very reactive. So, they get a what? They get a, all these get?

Student : Oxidized.

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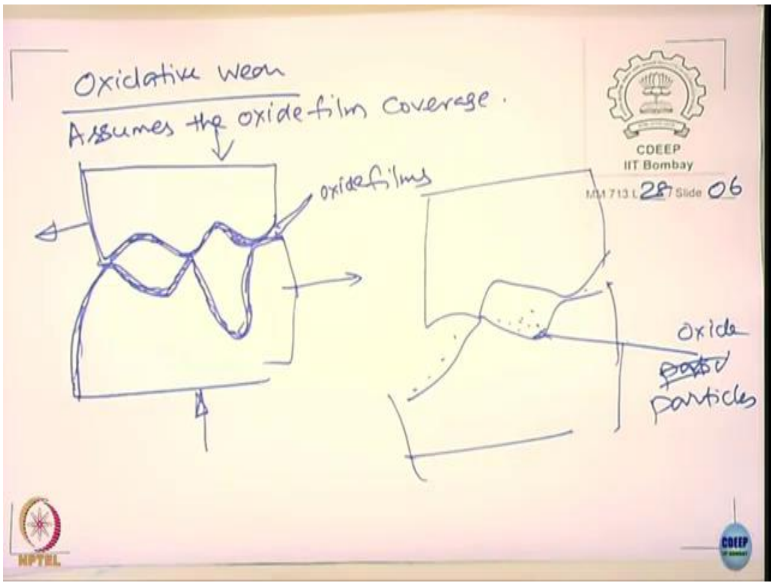


All they get oxidized. This is the one mechanism. The other mechanism is what is oxidative wear, it assumes oxide film coverage and it rightly. So, right you know most of the engineering materials, you know engineering alloys they are all prone to oxidation at room temperatures, ambient temperatures. And so, you can visualize a similar thing. So, these are all oxides right, these are all oxide films and they are the interface is under load of course, and there is you know vibration or shear that takes place. So, as a consequence what happens? Now, you have oxide particles ok.

And when you generate a oxide particles, fresh surface is created that surface gets oxidized and so on and so forth right. So, this process repeats right. The presence of these oxides or the interface, they damage the surface very severely why? Because these are all hard particles and they are the reason for having a pit like appearance is not it, they are quite hard particles and, because the relative movement is not too much what happens? These product accumulate within the interface.

See, if it is moving very I know very far away, it is possible that many of these corrosion products, oxide products are removed from the surface. Because they are the movement is very confined these oxide particles remain in the interface and start accumulating the damage with the time. So, that is something we should be understanding.

So, you should able to have some broad idea about what is wear; what is fretting and what is fatigue right. In fatigue also there is vibration; there is a load, but there is no contact interface. It all happens, because of the mechanical deformation, the load, this vibration takes place ok. In a wear process the relative movement is so large can happen ok. Of course, there is a surface damage taking place in fatigue damage vibration is there. The relative movement is very-very small, that is that is to be understood actually.

So, both these mechanisms the end product as you see here are similar and so, the both the mechanisms are considered to be operating. Or it is also possible it is not just one of the mechanisms, both of them can indeed can operate its possible in real situations. So, we have seen now the mechanism.

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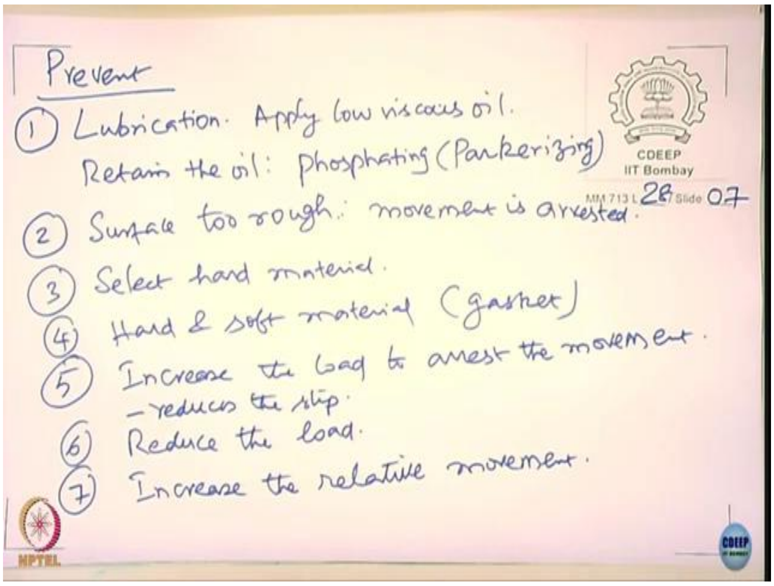


Then we must know how the fretting damage, it is very interesting thing. How do you control this? It can be considered as similar to wear process, can you? Right. So, if it is considered similar to wear process how we control wear?

Student: (Refer Time: 35:25) lubrication.

Lubrication, right. So, you can apply lubrication, you can do that. What people do? They apply oils, apply low viscous oil and in order to retain this oil, what people do is; they do phosphating. Phosphating makes the surface more rough and in the surface you put oil it retains for longer time. Otherwise, in a smooth metal surface you apply oil, this just goes away right. So, people do a phosphating treatment and they also called as parkerizing there is a term people use to, it is called parkerizing treatment.

We can do exactly a reverse of this. Make the surface too rough, then what happens? Movement is arrested. Well, you do not have control over movement and all and you want to choose a material.

So, what could be the property of the material. So, hard material ok, select hard material or what you can do? You can also choose hard and the soft material. What does it mean? I can use a gasket right, I can use a gasket. So gasket also arrests the movement of the interface ok.

So, sometimes people use lead you know. When you when you have a lead poured in between surfaces, what happens? The lead does not allow to, but then nowadays lead is being banned. You cannot use lead so much, because of the toxicity. You can also do one thing, I can apply a very high load ok; increase the load. When you increase the load what happens? The relative movement decreases right. Increase the load to arrest movement.

So, it reduces the slip, if you cannot do that, what do you do? Reduce the load. You do not find any other any other corrosion mechanism, where solutions are given, exactly opposite right. You can see the solutions are exactly opposite, but you do understand what happens right. So, you can also reduce the load. So, that you have vibration fine, but then when the load is reduced then the damage becomes less, you can do that right. If at all not possible to arrest the movement, increase relative movement right. So, you can also reduce the fretting damage.

So, in the lighter way, if somebody asks a question, any answer give you a mark. See, it is you know they are all bought out of the understanding of the phenomena happening at the contact surfaces which are loaded. So, it is a very nice, you know kind of these things and. So that I think we have seen a very I mean briefly, we have it is not a mechanical engineers of course, deal with this very extensively, if they are in turn tried a problem for many of the industries.

Student: So, the environment is also having an impact right. So, can we?

You can use any, you know if you use a vacuum conditions, you can do that, but in practice.

Student: Here it is (Refer Time: 42:09).

We cannot do that right. We can do hermetically  sealed situations, it can happen, but that can hardly possible, but then when you do hermetically sealed conditions. Fretting damage would still occur right.

Student: Yes sir.

The rate of you know the damage would be reduced, because the air is not there that can be a purely mechanical damage can happen actually ok. But nonetheless yes, if you reduce the environmental severity you could lower the corrosion rate. In fact, the applying this lubrication oil it has two purpose; one it lowers the friction, the second it excludes the surface from.

Student: (Refer Time: 42:51) air.

The air and other corrosive environment right. It does both the purposes actually ok. So, this is one way of isolating the material from the environment any other questions hm?

Student: Sir, can we do this grounding, that is active shaft grounding, can we do this?

No, it is not grounding, you are talking about a (Refer Time: 43:16) ship right.

Student: Yes (Refer Time: 43:20).

Yeah, yeah that is called active shaft grounding.

Student: Active shaft (Refer Time: 43:20).

That probably is reduce, you know signatures, you know that happens there. And also it reduce the what you call as stray current corrosion that happens in the in the shafts right, because the current. Is all cathodically protected right.

Student: Yes sir.

So, the current will start leaving in one place and entering in another place right.

So, the active shaft grounding is to maintain the, you know a path through which current will flow. It does not go into electrolyte, it goes through the grounding path. It also reduces the signatures developed, because of the continuous rotation taking place. That of course, is slightly different subject altogether happening in the especially, they are required for naval ships. You do not worry too much about what happens in the commercial.

If there are no further questions, I think we shall close the discussion today. And we shall continue our discussion on stress corrosion cracking in the next class.