Corrosion Failures and Analysis
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Lecture - 33
Erosion Corrosion: Introduction

Let us start lecture 33 and we will talk about Erosion Corrosion. And as you know that this is the course on Corrosion Failures and Analysis.

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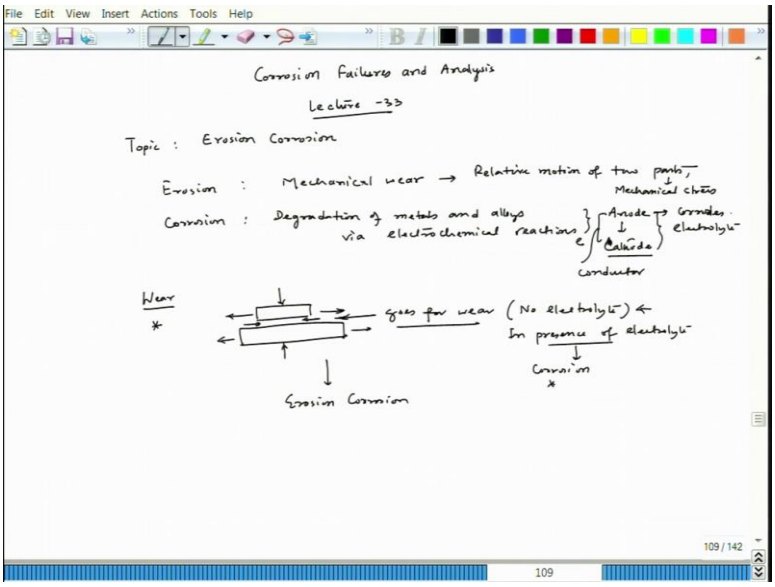

So, the course is and the lecture is 33 topic Erosion Corrosion. As we see this name erosion which involves mechanical wear and corrosion which is degradation of metals and alloys via electrochemical reaction.

Now of course, in this case we need anode which corrodes and that in order to maintain electron balance or charge balance we need another cathode ok. So, this is the basic part of corrosion of course, you have electrolyte both are in electrolyte and we have electron flow via conductor this is a conductor right. So, that is the component of corrosion.

Now in the erosion part mechanical wear we need relative motion of 2 parts which are under basically this is this 2 part is under mechanical stress ok. So now for example, if we talk about wear let us say this is a metal piece this is another metal piece. So, this metal piece can move like this or this one can move like this.

So, one can be stationary one can move or both can move in a relative way that relative motion could be simple reciprocating type or it can be rotating type. But there will be also mechanical stress or pressure acting between these 2 parts and the interface between this. So, actually this part goes under goes forward ok there will be material loss.

Now, this can happen even when there is no electrolyte situation, but it can also happen in presence of electrolyte ok. So, when it happens in presence of electrolyte, of course that time this corrosion factor gets associated. So, then this one and this one if we combine them that would lead to erosion plus corrosion, but if we only consider the mechanical wear part if there is no electrochemical reaction then it is basically only simple wear or erosion.

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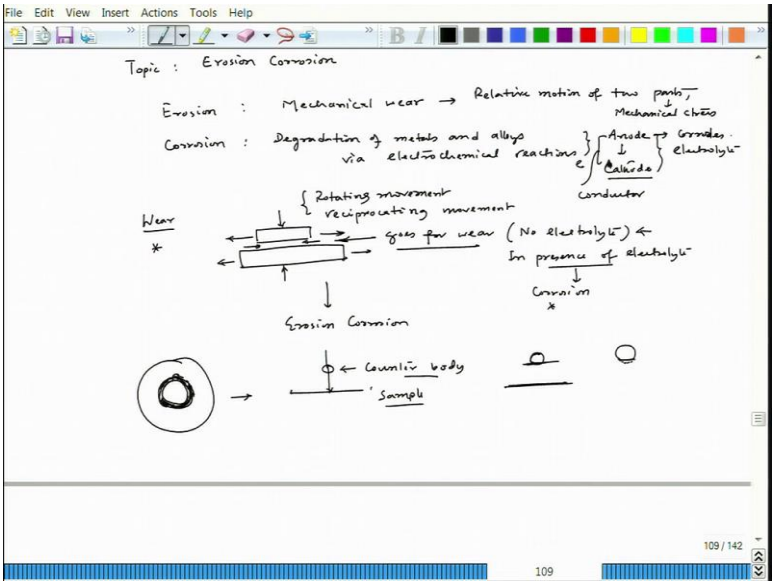

Now, there are methods of doing wear like as I said that there could be rotating movement or there could be reciprocating type movement reciprocating kind movement fine. So, that actually leads to a kind of friction factor which leads to material loss and of course this is under mechanical stress. And to test wear you can do different kinds of test, but there are two very popular kinds of test methods; one is pin on disc another one is simple reciprocating kind.

So, the pin on disc what you have so you have a circular disc on top of it a pin will be there, that pin could be in the form of ball ok. So, that ball will rotate like this fine and it can form a wear zone like this.

So, if we try to look at this so this is the pin which this is the plate row and this pin is actually exerting pressure on top of that plate and either and that plate can be rotated ok and then you have wear. And this zone forms a basically circular section where the material can be removed due to either abrasion or adhesion ok.

Abrasion means you have a swiveling action, because the pin will try to force that material to get removed it is just like machining operation to some extent. But if it is adhesion because of that pressure and because of the friction there will be heat generation and that heat can have a kind of little bit of cold working effect and or little bit of local welding and that can pull apart little bit of material. So, that time some material loss would take place.

So, this in this case this process can happen very short duration and you can also take place it can also if you have a controlled environment. So, where no moisture and no you can also have it under control organ flow. So that means, there is no electrolyte as such so that time it will be pure wear.

But it can also happen let us say you have some acid bath, in that acid bath you put a material and then have a pin on disc operation and then you can have wear. So, this pin is basically called counter body ok and this is the sample, but sometimes you can also make this counter body to be a sample and this disc to be your test surface where you can have the erosion or the wear of that particular body counter body.

Now for example, let us say this counter body this ball is your count instead of counter body this is a sample and this plate that actually acts as a counter body, then this particular pin can have erosion. So, some part of it will be chipped away. So, this particular wear can take place. So, instead of roundish appearance so this particular part is removed. So, this is a typical pin on disc operation.

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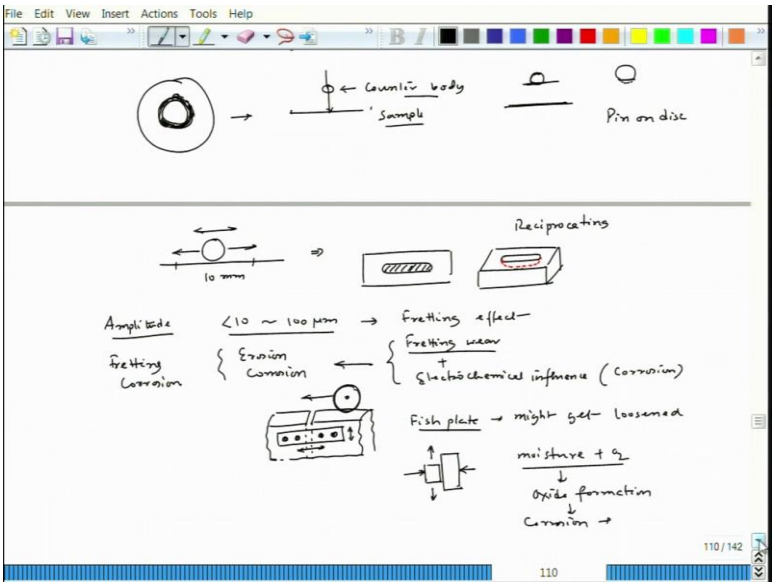

But there is one more method where you have a counter body this is a counter body and this is on top of a flat plate and this counter body is given a of a specific amplitude reciprocating movement. So, this particular thing would move back and forth in a linear way on a line and this particular amplitude could be around of the order of 10 millimeter.

And of course, you see material loss this particular counter body would always act as a counter body your substrate would become the sample. So, that time you have a wear part would be like this if it is a flat surface. So, this particular area would be the worn out portion ok and if you see under cross section part it might look like this ok.

So, this red part is basically within this material, so that is what the appearance becomes. So, this is basically reciprocating this is pin on disc this is reciprocating, but in case of reciprocating you can also have a situation that this during this reciprocation can happen at a very very small amplitude ok. So, instead of 10 millimeter this particular length could be of the order of few microns let us say around close to less than 10 to around 100 micrometer it can vary. So, that time this is the amplitude of that particular counter body movement.

So, that time that will come under the heading of fretting effect and that time the wear we call it fretting wear ok.

Now, when this fretting wear happens under electrochemical influence we call it if we add up electrochemical influence. So, that time that means, whenever we talk about electrochemical influence we are talking about corrosion. So, that time combination of this can developed a particular erosion damage, because it is a wear plus corrosion. So, then again it is becoming a erosion corrosion this is also an example of erosion corrosion we call it Fretting corrosion.

So, this is having a special name fretting corrosion ok. So now, we will talk about this fretting corrosion later I am just giving a kind of overview that what kind of situation you might experience when you have erosion plus corrosion. So now, this fretting item kind of corrosion you might experience in case of a rail joining part with the help of bolted fish plate ok.

So, for example, if you have a rail part let us say this is my rail part, let us say this two rails are being joined. So, this is the two rail part they are to be joined, so then we put a plate this plate is bolted. So, this particular plate actually fastens two parts of that two rails. Now this is called fish plate, now the fish plate is a place where you might experience this fretting. If it is a long amplitude thing reciprocating thin, then it should not be considered as a fretting corrosion. Fretting corrosion happens when there is a very very minute amplitude relative motion of two bodies under contact or under stress.

Now, when train moves this is this is a wheel that moves, that wheel when it moves that will gives you a pressure on top of that two rails. So, that pressure one set of wheel goes the next set of wheel comes in between we have a vibration and that vibration can create a kind of fretting a small amplitude up and down motion. At the same time if it gets heated up ok, so that time there could be a possibility that it can also have this kind of motion also. So, it is a basically you can have multiple degrees of this kind of small amplitude motion ok.

For example this can bend down little bit before that rail that particular wheel moves to the next rail and then the next wheel bends down like that there could be a kind of a very complicated fretting motion. I have just given two simplified mode that one is up and down one is side by, but there could be a complicated fretting mode.

Now, that time this fish plate might get loosened and in fact, it gets loosened. Why because within this fish plate the between the that plate and the rail that gap we have a strong pressure because if this is my fish plate and this is my rail body.

Now, we are under this is under stress and there is a small amplitude fretting and there will be because it is also exposed to the atmosphere. So, that atmosphere we can have moisture plus oxygen.

So, that might lead to that would definitely lead to oxide formation and this oxide formation is basically taking place due to corrosion. Why even if we consider iron Fe minus 2 equal to Fe plus 2 and then Fe plus 2 will react with H_2O in presence of oxygen that would form FeOH whole 2, I am not balancing it you can do balance part. So, we can definitely do balance part.

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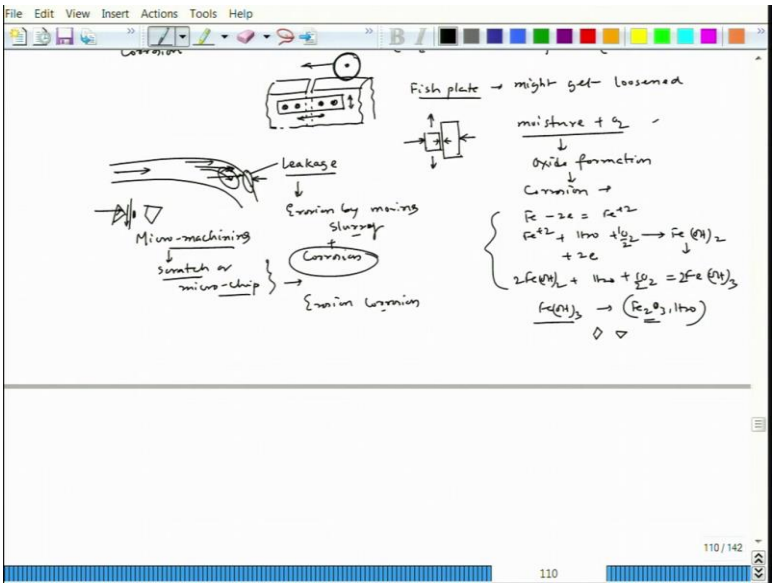

For example here if we put half air and of course because 2 electrons; that means, you add 2 electrons here. So, this is an electrochemical process and you get FeOH whole 2. So, this FeOH whole 2 can convert to FeOH whole 2 plus H_2O plus O_2 it can again convert to FeOH whole 3. So, let us. So, if it is two. So now half if we do half here so then this is balanced.

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

$$Fe^{2+} + H_2O + 1/2O_2 + 2e = Fe(OH)_2$$

$$2Fe(OH)_2 + H_2O + 1/2O_2 = 2Fe(OH)_3$$

Now in fact FeOH so this kind of reaction can take place. So in fact, FeOH can be as basically nothing but hydrated ferric oxide. So, this hydrated ferric oxide so now you see the oxide is forming, so that means moisture and oxygen that would lead to a metal oxide or hydroxide formation. So, those are actually on top of that both the metal because both are iron in case of fish plate and because of that relative fretting action under stress that oxide layer might get would get knocked off.

So, the trace surface is exposed and the trace surface because after one train passes the next train comes little delayed fashion. So, by that time the oxide layer can reform and the when next fretting action happens that time again that oxide layer would get knocked off.

So, like that way you get to see lot of debris within this fretting zone ok fretting zone means this particular interface you get lot of debris those debris are nothing but oxide debris and that oxide debris would further would enhance this wear action because this oxide could be sharp cornered oxides particles.

So, let us say this particle is a sharp edge corner particle. So, those particle again those are fastened between those are thick those are actually held between these 2 meeting surfaces. When the next fretting action happens those oxide will also give a kind of kind of a erosion action ok or machining action. So, that would further remove the oxide layer of the metal particles.

And those particles because of the heat generation there will be also heat generation because it is a lot of friction had taken place, that friction can also lead to oxide formation or even later on because of the corrosion process electrochemical mode this mode oxide can form.

So, like that way oxide forms oxide gets knocked off and the next layer of oxide forms like that where the metal loss is taking place. But that metal loss is not due to only corrosion because there is also this fretting action and that actually leads to a loosening of this particular bolted jointed bolted fish plates and sometime time to time one has to tighten it otherwise this line will get loosen and so there could be a possibility of accident.

Now, this is one other mode of wear erosion corrosion ok. So, this will talk later in little greater detail, because there are 2 theories how fretting action happens. So, this is about fretting you could see that fretting corrosion because corrosion and fretting both are there.

Now, there is one more mode for example let us say a pipe, a bent pipe let us say this is the pipe ok. So, this bent pipe let us slurry is moving fluid let us say water and some dust particles are mixed with it is a forming a slurry. So, that slurry moves at a high speed and when it moves initially it is actually having a linear motion or without much of turbulence. But as the direction of the fluid flow is changing there will be turbulence one is this fluid is hitting this particular wall ok.

This footing this particular wall at the same time there will be lot of turbulence around this place the turbulence would happen and those turbulence effect at the same time that fluid at or itself has it is own corrosive action and because of that this portion so this portion would get lot of erosion corrosion ok.

So, there is a possibility that this segment might get leaked. So, this segment leakage can happen leakage. So, this is the effect due to you can say erosion by moving slurry plus corrosion.

Now, when we talk about slurry movement and leading to erosion action. In fact, if you see the slurry that small particles tiny particles if we zoom it that particle might be like this ok, a shark cornered particles. Now let us say this edge hits a metal surface and if there is a because this particle hits there and since there is a direction change of that fluid that might lead to a kind of shearing action here ok.

Now, this is giving a normal force at the same time there is a shearing action, the local point around this point there could be a micro machining and at times it can also make a scratch or micro chips you can say micro chip can form ok. So, that actually has a direct wear effect.

Now if it is a scratched zone, now we know that if a scratch part is there; that means, it is liable or susceptible to greater corrosion. So, now, you have this kind of micro machining due to that small particles in that slurry which is hitting at a high rate and there will be shearing action due to the change in motion or movement of those of that

fluid and that would lead to a micro chip formation or scratch and that scratch would lead to corrosion ok.

So now this is also a kind of a erosion corrosion. So, this is erosion corrosion. Now, coming to why we are saying that it is a micro machining kind of situation.

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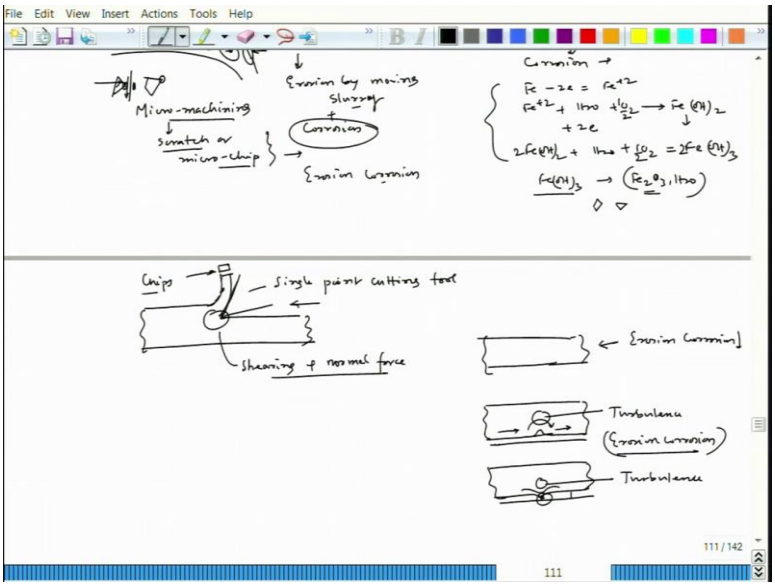

Because if we look at a single point cutting tool cutting operation. So, this is a single point cutting tool let us say and this is actually flowing moving this way it is moving at a given load. So, chip will be forming so like that way so this is the this is the single point cutting tool fine and this is the method this is the material which is machined and this is the chip these are the chips fine.

So, these chips are forming because of the machining effect. Now here you could see those are the tiny particles and it is not like that a continuously a single point cutting till is the cutting tool is moved against that object here tool can move or object can move fine. But here what happens the object is stationary, but the tool which are basically those tiny particles those are actually giving stress.

So, here you have shearing action in this zone you have shearing plus normal force, that would lead to a chip formation of machining surface. Now here also this particular edge this particular edge would give you a small zone of machining. So, that is what I am we are saying that this is a kind of micro machining situation. So, that also lead to a leakage

where the fluid hits the surface and there is a change in movement or turbulence is experienced.

For example if it is a pipe let us say this is a pipe a smooth pipe no problem. But if the pipe inner pipe part is having a kind of small protruded part or if it is this is the pipe this is the pipe and another pipe could be like this. So, this is different zone so in this case erosion would be very less very low, this case and this case because here fluid is flowing and then fluid is changing it is direction.

So, in this zone we have turbulence, here also fluid is changing direction and this portion also would have turbulence fine. So, this the because of this we have greater erosion corrosion fine erosion corrosion might take place. In fact, when we have this kind of pipe inner pipe situations that might lead to a greater more problem, because you know your wall could be like this ok.

Now, in this case leakage would be less leakage problem would be less, because this part would get chipped off. But in this case if this part is gradually moving down and cross sectional thickness it less here compared to this. So, this part might get leaked, so that kind of situation might arise. In fact, this particular debris formation that debris can also hit another portion of that pipe where the direction is changing and that might lead to a if it is a clean water let us say there is no dust or something.

Because of the local erosion those particular particle might form another a small chip kind of thing and that particular small dirt particle can also hit an angle of or direction change can lead to lot of erosion fine.

So, this is a situation what can experience one can experience such kind of defects or erosion corrosion situation. Now before we end the a kind of introduction to erosion corrosion there is one more serious effect which happens in case of impeller blades.

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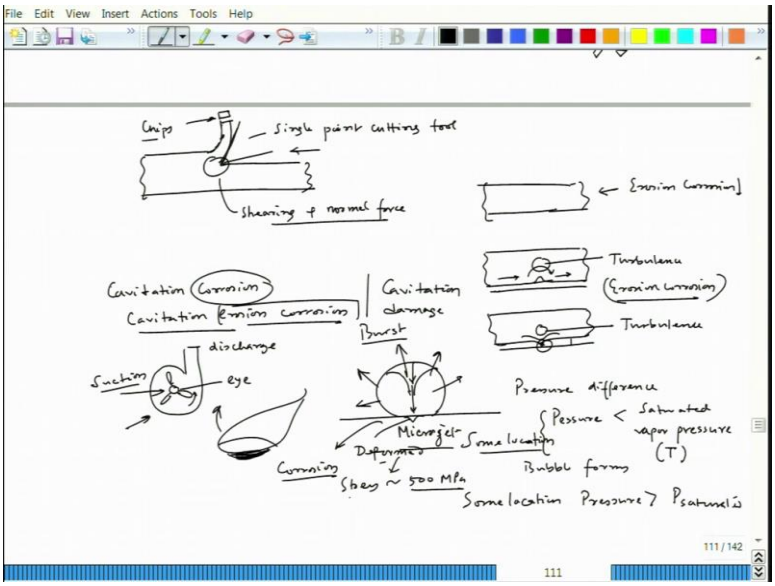

So, we call it cavitation damage cavitation corrosion, in fact this is more popular in the form of cavitation erosion. But there are there will be definite effect of corrosion ok. So, that is what it is better to put is at a cavitation erosion corrosion.

So, this happens in case of moving objects where the pressure difference is experienced when that particular object is moving in a fluid ok. Now consider a pump let us say a pump is constructed. So, this is the pump let us say when so this is the small eye part of that pump, so this is the eye this is the discharge part and this zone here water is sucked, so this is the suction zone.

Now, here the blades are moving. So, these are the blades of that particular pump and this blades are moving in this direction that is where the water is pumped inside and it is discharged, interestingly those blades if the blade design is like this and if it is moving like this the back of the blade so around this zone we experience a small spots of defects.

In fact, at times this back of the portion could be so develop. So, much of defect or kind of a dent or a pit like situation and this particular might get fractured ok. Because it gets weaken and weaken because it is also moving there is a stress effect at the same time those kind of small pits are forming ok.

So, this happens due to bubble formation and it bursting process. Now if let us say a bubble is there ok and that bubble forms when let us say when there is a pressure

difference if the pressure goes low pressure is less than water pressure. Of course or the pressure exerted in that particular water system is less than the saturated vapor pressure, saturated vapor pressure at the temperature of that fluid then water can evaporate ok and that evaporation lead to a small bubble on top of a metal surface ok.

So, this is the bubble let us say and that bubble and in that particular fluid process at some location the pressure drops below the saturated vapor pressure and that time bubble forms and some location pressure increases beyond let us put it as pre saturated fine.

So, then these bubble will collapse so this bubble will collapse or we would say burst. So, the bursting of bubbles lead to a shock wave so this bubble bursting happens like this ok and that creates a micro jets micro jet on top of a metal surface and because of this bursting of bubble the micro jet hits the surface and deform this particular portion. So, this part is deformed because that di micro jet forms and that deforms deformation happens and the pressure the stress it exerts on the by the micro jet could go up to around even 500 mega Pascal.

So, this is the amount of pressure that is exerted by that micro jet, because of the collapsing or the bursting of bubbles and that lead to a deformed portion. And now till the next bubble forms we know that the deformed part is highly active zone and that might that would go for a corrosion to go for corrosion and so that corrosion happens in this zone deform zone corrosion happens.

So, now again the next bubble forms next bubble burst micro jet hits that particular bottom surface of that metal and again that deformation happens. Next step is again corrosion because the deform zone is highly active for corrosion.

Now, like that way that deformation corrosion deformation corrosion continues and deformation happens because of that bubble formation that is what it is name cavitation ok. Now that bubble forms and collapses due to this change in pressure within this rotating system or in the fluid. So, that actually creates a huge amount of dents deformation pits on the low pressure side of one of a moving object or the object which is there what is there in the fluid.

So, that would create a lot of damage and that damage is basically nothing but cavitation corrosion. Again you see it is a basically a kind of deformation wear is also a kind of

deformation also of course the material immobile. But here the wear or the deformation is taking place due to the micro jet formation during bubble collapsing. So, that also comes under a special category of erosion corrosion. So, this is also erosion corrosion fine.

So, this is also corrosion sometime it is only say that cavitation damage fine. So, like that way we have lot of such situations arising in a fluid system ok and that time in a fluid system or a corrosive system. For example, cavitation happens in the fluid system, but erosion corrosion can also happen in a gaseous system, where let us say high temperature oxygenated high temperature gas is flowing into the metal system that particular gas can also oxidize that metal part and then erosion can also take place oxidation is nothing but corrosion.

So, now combination of this also leads to erosion corrosions, the erosion corrosion can happen in the presence of an electrolyte fluid electrolyte or liquid electrolyte or it can also happen in a dry condition. But there will be a definitely a mechanical wear effect comes in plus the corrosion factor comes in then combination of these 2 gives you a erosion corrosion effect. So, now let me stop here we will continue our erosion corrosion discussion in our subsequent lectures. But till then let us stop here.

Thank you.