Fundamentals of Surface Engineering: Mechanisms, Processes and Characterizations

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Lecture-12
Surface Damage: Types and Categories

Hello, I welcome you all in this presentation related with the subject fundamentals of surface engineering. In the initial phase we have talked about the introduction aspect related with the surface engineering like what is the importance what are the applications advantages and what are the common techniques of surface modification and how those techniques can be classified what are the important surface properties from the wear and friction point of view.

Now we will be moving ahead and we will be talking about the different ways by which degradation of the surfaces can take place which in turn will be affecting the performance of the component as I have said earlier that the performance of any component to a great extent is influenced by the surface properties. And most of the mechanical components the failure is triggered by failure is triggered from the surface.

So, it is important that surface properties are tailored in such a way that the life of the component is enhanced we know that the surface degradation will be leading to the failure of the component.

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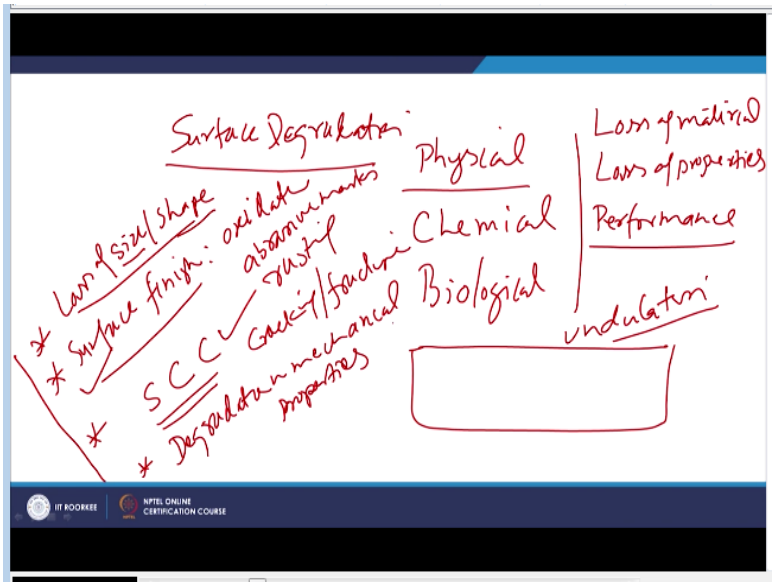

Because many failures are triggered from the surface so, that is why it is important surface properties are controlled tailored in proper ways. So, that required tribological life can be achieved now the surface degradation of the component can take place in different ways. So, there are three broad categories 1 is that where physical phenomena are involved and the second 1 is where the chemical interactions are involved.

And third category is the 1 where biological interactions are involved and whenever these interactions with the component in use occur. These interactions lead to the degradation are damage to the surface of the component. And this damage or degradation may occur in various form which may be like in these degradations basically the loss of material from the functional surfaces takes place.

And sometimes detoriation in properties or loss of selected properties also take place. So, these losses will be reducing their functionalities and these may also reduce their capability to deliver or to do the required job. So, basically the performance of the component due to the degradation of the surface properties takes place. So, what are the ways by which this kind of the degradation can occur surface degradation and damage can occur.

It may be in form of like loss of size and shape because whenever there is a loss of material due to these interactions these losses will not be uniform actually if this is the component then losses will in the material will not be uniform from the functional surfaces. And if it is not uniform then it will be leading to the undulations or regularities on the surface, so not just the size but also the shape is lost.

And this may lead to the improper functioning of the component which is a being used so, loss of the size and shape is a 1 aspect. The surface of finish is also degraded or reduced and this reduction in surface finish may be attributed to the factors like the oxidation the formation of the abrasive marks on the surface or rusting where chemical reactions take place.

So, these are the things which will be damaging the surface finish or increasing the roughness of surface and which may lead to the improper performance of the component. In some of the cases

where combination of the stresses and as well as the chemical interactions lead to the cracking and fractures. So, it may appear cracking and eventually fracture using the phenomena like stress corrosion cracking.

So, heat will start from the surface in form of a like crevices and deep pits and then coupled with the tensile stresses it may lead to the complete suppression due to the faster growth of the cracks. So, it may also appear in form of the fracture sometimes depending upon the service conditions for which component is being exposed. It may lead to the degradation in mechanical properties of the component.

So, degradation or detraction in mechanical properties of the component reduced load carrying capacity and which may eventually lead us to stop the functioning stop it this situation may force us to stop the use of the component and replace it or the repair or repair it. So, surface degradation may lead to the various kind of effects in form of like loss of size and shape loss of surface finish the fracture or cracking and then even degradation in the mechanical properties.

So, we know that proper functioning of any component what we need is that it has the certain combination of the mechanical properties, dimensional properties, physical properties and the chemical properties. So, that it is able to retain it is performance and the surface which are expected from the component and therefore if we plot one very variation in the performance of the component as a function of time during the service.

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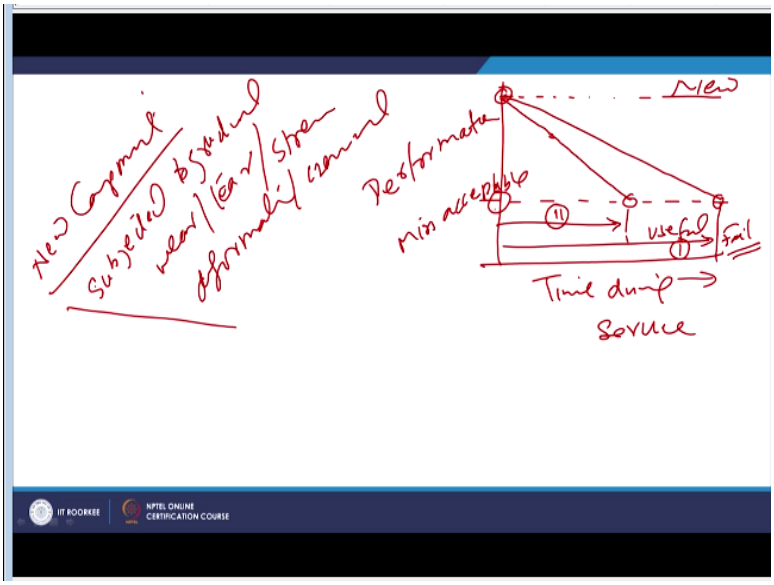

So, here time during the service in the X-axis if we have the service period and in the Y-axis if we have the performance this is very qualitative diagram. So, whenever a new component is put on use it gives as the best performance. So if the performance level is the high when the component is new. But as soon as it is put in use it is subjected to the gradual subjected to the gradual wear and tear stresses deformation chemical interactions.

So, because of these experiences by the component there is continuous decrease in performance of the components. So, that performance if we see as a function of time with the increase in service period there is a continuous reduction in the performance of the component. And if so, this is the rate at which the performance of the component will be decreasing.

And if there is a minimum expected level of the performance which is expected from the component minimum acceptable level of performance is this 1 acceptable level of the performance is this. Then what will say that after this much period of the service of the component this will considered to have failed, and if the performance of the component under the more severe conditions is degrading more fast or rapidly none.

The reduction in performance may be like this and in that case we will say that the component has failed much earlier under the more severe conditions. So, what we can see here when the component is new it is performance is at the peak it delivers each and everything whatever is

expected. But as soon as it is brought in use as the component experience is various service conditions related to the stress temperature, gases, environment etc.

There is a continuous reduction in the performance of the component, so as per the service conditions the different components made of the different materials, different designs. They may experience the reduction in performances as a function of time at different rates and accordingly it will be offering as the different life. So, this is the useful life for 1 component and this is the useful life for the another component which is whose performance is degrading at a much faster rate.

So, this is the general qualitative characteristic or qualitative way of explaining the performance of the component and as a function of time and what happens when the when it experiences the effect of the service. Then we will see what are those broad categories of the surface degradation or surface damage mechanisms.

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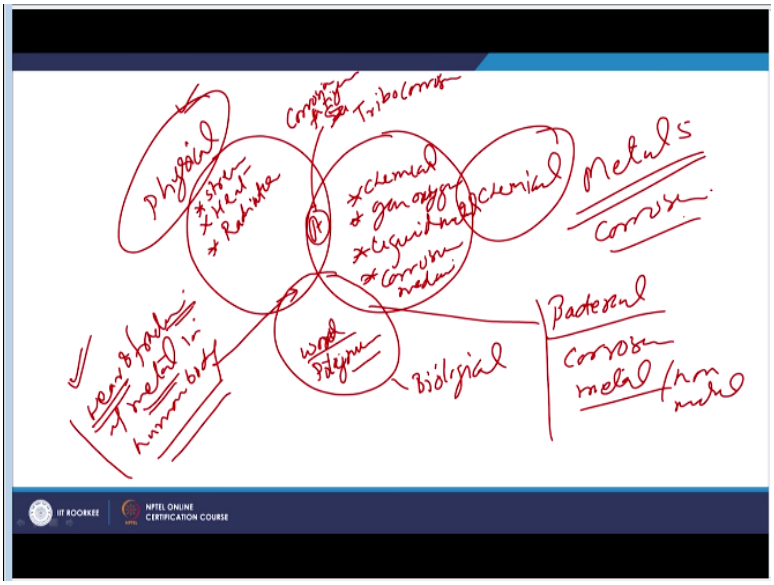

So, what will do this is one will say where the physical phenomena are involved and the second is one where we have where the chemical phenomena is involved and third is one where biological phenomena are involved biological phenomena takes place and they are responsible for the surface damage. So, under the physical mechanisms are the physical phenomena category the factors like the load or the stress the heat radiations.

These are the factors that will be affecting the way by which loss of material from the functional surfaces will be taking place while on the category of the chemical interactions and then the surface damage accordingly it will be due to the action of the chemicals various gases like oxygen, nitrogen or like interaction of the component being use with the liquid metal wherever chemical interactions is involved like steels in case of the molten zinc.

And corrosive media which is affecting the performance of the component and leading the loss of material from the functional surfaces, then under the biological category like under the biological category we have the damage on the surface of the wood due to termite and then there will be damage on the surface of the materials like these are the biological aspects related with the surface damage.

So, if you want to see the common zone between the two shows like the zone which the type of the mechanisms where both physical as well as chemical interactions lead to the surface damage and eventually the failure of the material that will be indicating by this kind of zone A which shows that, in this zone there will be certain activities which will be combining the effect of the physical and the chemical interactions.

And examples of such kind of the damage is like corrosion fatigue this is one aspect and another one is the tribocorrosion where both physical as well as the chemical phenomena are involved where both chemical as well as the biological interactions are involved. So, this will be related with the due to those corrosion related aspects where which are assisted by the bacteria assisted corrosion.

And corrosion of the metals where corrosion metals are the non-metals, so where bacteria play big role in accelerating or affecting the surface damage and third one is where the physical and the biological interactions are involved that any consist of the wear and fracture of the metals which are used in the human body for dealing with the like various kind of the fractures of the bone are replacement of the vital body part.

So, that the physical devices can work, so they will obviously be made of the metals these metals when interact with the blood and other chemical species in the body. Then they there will be the degradation of those surfaces in form of the wear and sometimes even in form of the fractures. So, they are three broad categories and their common zones where the 2 or more phenomena are involved.

Now if we see in our this subject will be focusing on the metals which primarily and significantly affect the surface degradation due to the physical phenomena as well as also we will talk be will also be talking about the chemical interactions surface degradation due to the chemical interactions in form of corrosion or oxidation. So, now after this what we will see that based on these physical, chemical and biological surface damage categories.

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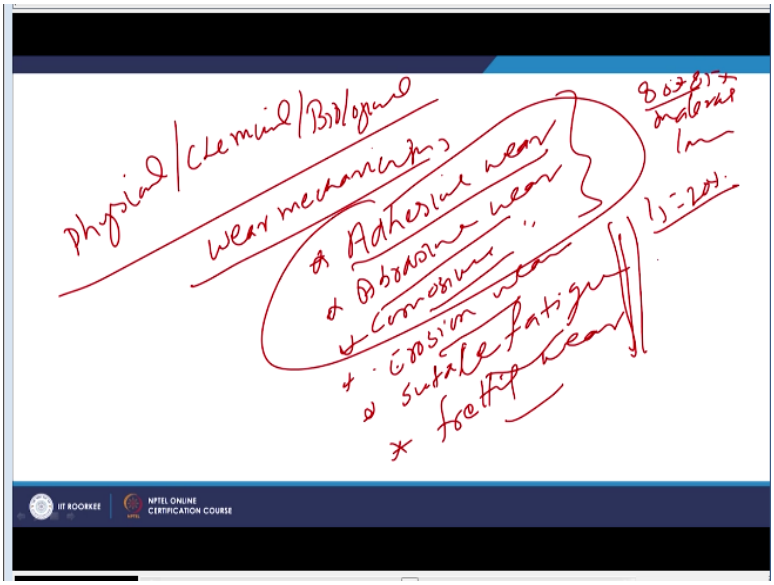

If we put all various types of the surface damage or the wear mechanisms then these can be written as like adhesive wear, abrasive wear, corrosive wear, erosive wear, surface fatigue and then fretting wear if we see then these 3 types of the wears like adhesive wear, abrasive wear and corrosive wear combination of these three types of the wear in general leads to the 80% of the material loss by these 3 mechanisms 82 to 85 % of the material loss is caused by the adhesive wear, abrasive wear.

And the corrosive wear remaining 15 to 20 % material loss is contributed by the other important wear mechanisms like a erosive wear, surface fatigue and the fretting wear. So, since the material loss mechanisms are different in each of these categories. And therefore it is required that surfaces are designed according to the type of wear experienced by them. So, that they have required properties to tackle the issues related with the material loss.

Now will be talking about the first type of the wear which is very important and commonly encountered is adhesive wear adhesive wear normally takes place whenever the mating components are having the direct metal to metal contact.

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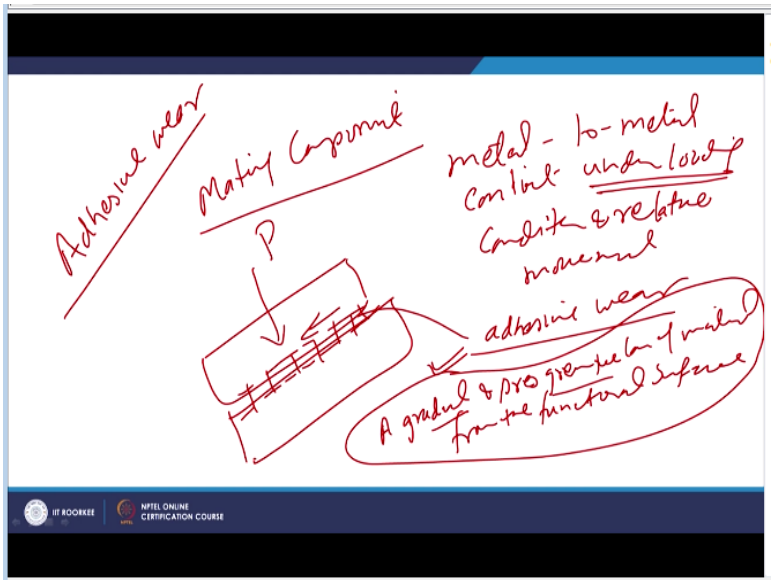

So, under the loading conditions this is 1 the rest will load and relative movement between them. So, like one component is mating with another component and this is under some kind of the load and relative movement exist between the 2. So, the contact between the 2 is direct in form of the metal to metal means direct metal to metal contact is present under the relative movement conditions under external loading conditions.

The loss of material from the functional surfaces is termed as the adhesive wear if we have to simply define the wear, wear means it is gradual and progressive loss of material from the functional surfaces. This definition is applicable for all types of the wears it is basically this is

how we can understand where it is a gradual and progressive loss of the material from the functional surfaces.

And if it happens then it will be leading to the loss of the ambitions, loss of surface fitness and sometimes even change in the mechanical properties. So, those undesirable effect will adversely be affecting the performance of the component.

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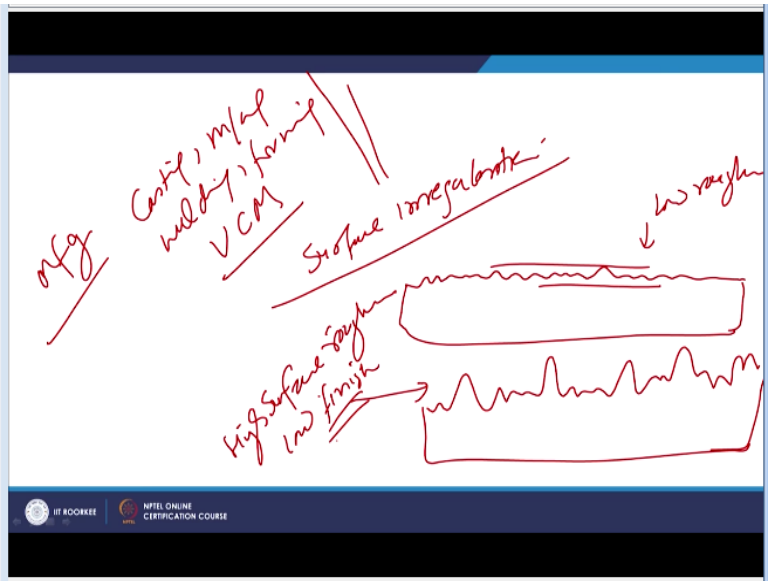

Now if we have to understand the adhesive wear then what we need to see that all components which are manufactured using one or other kind of the mechanism maybe like casting, machining, welding, forming or unconventional machining methods. They will always have some kind of the surface irregularities. Now these surface irregularities may be present will always be present on the functional surfaces.

But the extent of irregularities may vary like few manufacturing processes may result in the surface irregularities of very small in magnitude. So, if these surface irregularities undulations in form of the peaks and valleys are very limited then it will leading to the very low roughness and high surface finish. On the other hand few manufacturing process which result in very high degree of the surface undulations.

Then it will be leading to the high surface roughness and low surface finish. So, since the these peaks and valleys are always present on the functional surfaces. So, whenever the such kind of the surfaces are brought in direct contact with each other.

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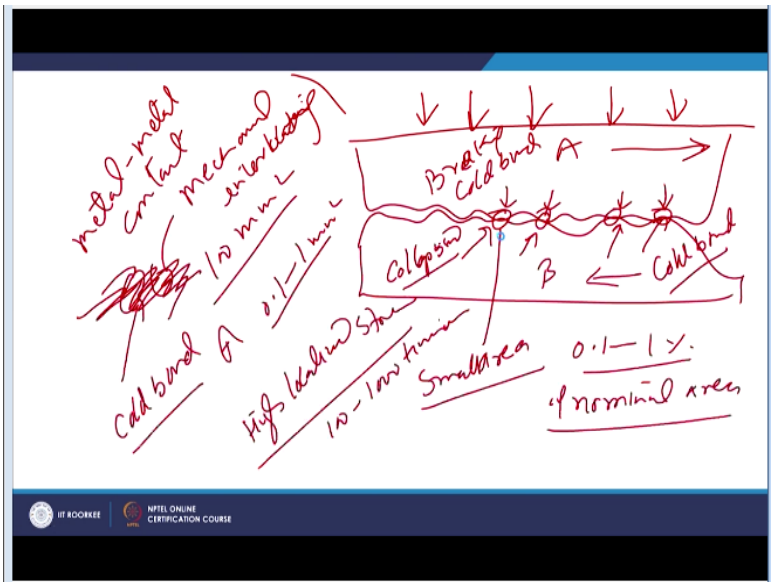

The contact always happens through these peaks and values say this is one surface and this is another surface which is in contact. So, if we see this one surface and this is another this one component A, this is another B and the 2 are in contact with each other at very localized points like this one this is another, this is another and this is another. So, there just 4 points for just for example there just 4 points which are of very small in terms of the area.

Area cumulative area of these 4 point 4 locations where the components are direct in metal to metal in contact is very this area is very small. So, under the external load conditions, since this area is very small so, what happens is that this area a small area is considered to be about 1 to above 0.1 to 1% of the nominal area. So, if like say if the area is like say 100 units 100 mm square.

Then actual contact area will be like just 0.1 to 1 mm square which is very very small. So, under the given load conditions the true a stress at these points at these locations will be extremely high because the nominal area is too high while the actual contact area is very small. So, this will be

leading to the very high localized stresses at these contact points. And very high stresses these may be like say 100 to 1000 times of the nominal stresses.

Since these stresses are too high then under such stresses conditions the all surface irregularities which are present. They will be collapsed and once these collapsed means they will be deformed plastically. So, surface irregularities will be deforming like this and this will be leading to the some kind the mechanical interlocking due to the collapse of or plastic deformation of such kind of the irregularities under the very high contact stresses.

And this will be leading to the very large area of direct metal to metal contact. So, mechanical interlocking and large area of the metal to metal in contact will be leading to the cold bonding. So, the components so, which are brought together in direct metal to metal contact will have some kind of the bonds between them. Since there is no external heat is still the joint is being formed under the external stress conditions.

So, such kind of the bond is termed as cold bond now since it is required that for adhesive wear to occur. It is required that there is there should be a relative movement between the 2. So, but the relative movement can be maintained only by such cold bonds breaking such cold bonds, cold bond should be broken and to maintain the relative movement between the 2 components.

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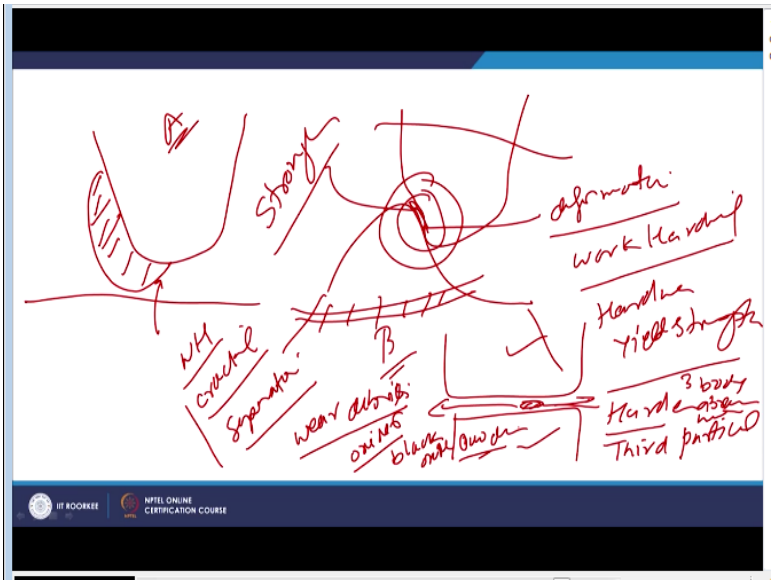

And so, whenever there is a breaking of the cold bond very interesting thing which happen like this is 1 area where the bond has been created. So, since this bond is created through the deformation, so this deformation of the surface or near surface layers will be leading to the work hardening. And this work hardening will be increasing the hardness will be increasing the yield strength of the near surface layers.

And increase in yield strength means the metal will be strength and ultimate strength and yield strength both will be increased. So, out of these 2 components near the surfs I means below the subsurface layers whichever is weak. Since this area has been strengthened due to the deformation and the bond exist. So, this area is normally this is stronger than the underlying material. Then underlying material from which side the fracture should take place to maintain the relative movement.

If the bond is break weak then of course the failure will occur from the in interface of the cold bond. But if the bond is strong enough then failure or fracture will occur from either component A side or from component B side. So, whichever is weak if the B is weak then failure will occur from this side and once this failure occurs then the material from the small piece of the metal from the component B side will be transferred to the component A side.

So, this is the piece which will remain attached on the component A side this is this what happens initially but in meantime what happens this small lump of the metal will remain will attached with the A side. And likewise there may be number of such kind of the small pieces are lumps of the metals remain attached with the component A side or the component B side as per their strength.

So, the continued relative movement formation of the cold bonds will be leading to the continuous work hardening. And eventually there will be cracking suppression of such kind of the lump of the metals and whenever such kind of the separation due to accumulation of the cracks or suppression of such kind of the particles take place it will be present in form of the wear debris between the 2 mating component.

And now this wear debris which has been separated from both the sides since it is harder due to the continuous deformation and work hardening. Then the either of the metals then it may act as a third particle which is harder. So, it may cause the 3 body abrasive wear. So, sometimes formation of such kind of the particles between the two mating components leads to the increased wear.

And eventually it will be removed from the interface due to the continuous relative movement between the mating components and this whenever it is removed it will be coming out in form of the wear debris which is normally in form of the oxides or black oxide powder. So, this black oxide powder if characterized using XRD technique most of the time it becomes the oxides of the various constituents which are present in a given metal.

So, this is how the suppression of the material during the adhesive wear takes place now there will be various factors which will be affecting the such kind of the bond formation like loading the direct and loading the yield strength of the material and the kind of the speed or the time. They have form such kind of the bonds so, about those factors will be talking in a next presentation.

Now I will conclude this presentation in this presentation basically I have talked about the broad 3 categories of the surface damage mechanisms like the physical phenomena, chemical phenomena and biological phenomena. And I have also introduce the concept of the adhesive wear and the way by which material loss from the functional surfaces and adhesive wear conditions take place. So, now we will be talking in detail about the various other aspects of adhesive wear in coming lectures, thank you for your attention.