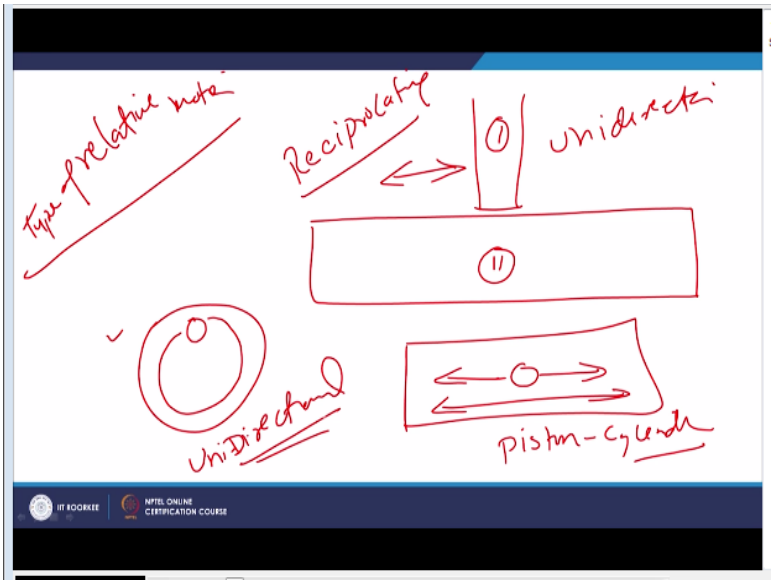
Fundamentals of Surface Engineering: Mechanisms, Processes and Characterizations

Prof. Dr. D. K. Dwivedi
Department for Mechanical and Industrial Engineering
Indian Institute of Technology-Roorkee

Lecture-15
Surface Damage: Classical Law of Adhesive Wear and Abrasive Wear

Hello I welcome you all in this presentation related with the subject fundamentals of surface engineering and we are talking about the adhesive wear it is mechanism and different factors that affect the adhesive wear. So, for we have talked about the mechanism of the adhesive wear as well as various service and material related parameters that affect the adhesive wear behavior of a material. We have left with one topic or one parameter related with the adhesive wear which affect the wear rate or the wear behavior.

(Refer Slide Time: 01:11)



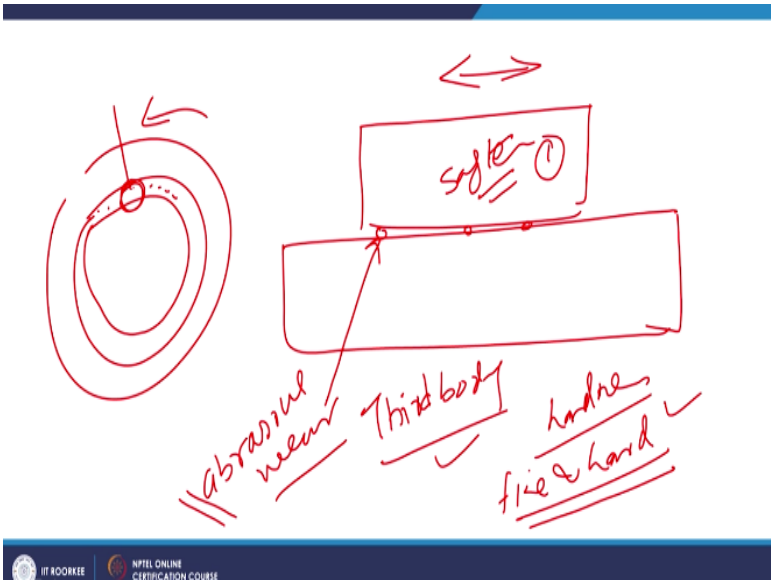
So, that parameter is basically that parameter is the type of the relative motion so which means what is the nature of the component which is under the consideration movement with respect to the counter surface. So, if this is the component one which is being considered and counter surface is this. Then this movement is reciprocating type or unidirectional type. These are the 2 possible situations whether it is reciprocating or unidirectional movement type.

In case of the reciprocating movement like say in the top view if we see this set up then movement of the component or counter surface will be in both the directions like this. So, the

wear track path will be repeated in the case when the reciprocating movement is involved and this kind of the movement is typically observed in case of the piston and cylinder assemblies. But there is another kind of the movement where in will see that the movement is unidirectional.

So, in that case this is the counter surface and this is the pin so, the pin keeps on moving in one direction only it does not reverses it is direction of the movement. So, in case of the unidirectional relative movement the direction of the movement remains 1 and single. So, what is the implication of the relative movement of the component with respect with the counter surface.

(Refer Slide Time: 03:16)



So, that is what will be saying now so, here if we see if this is the component and this is the counter surface and if the reciprocating movement is taking place. So, under the adhesive wear conditions and when the reciprocating movement is taking place obviously the wear particles will be formed due to the adhesive wear in course of the sliding or in course of the movement and these wear particles will remain for a while between the mating components and these will act as a third body.

So, since most of this wear debris and wear particles are they are harder. Then the respective base metals and this hardening happens means their hardens is increased because of the work hardening effect. So, fine and hard particles present between the 2 components which are under the relative movement. These acts as a third body and because of their hardness greater than

because of their higher hardness then the respective base metal sometimes these also act as a these facilitate the abrasive wear.

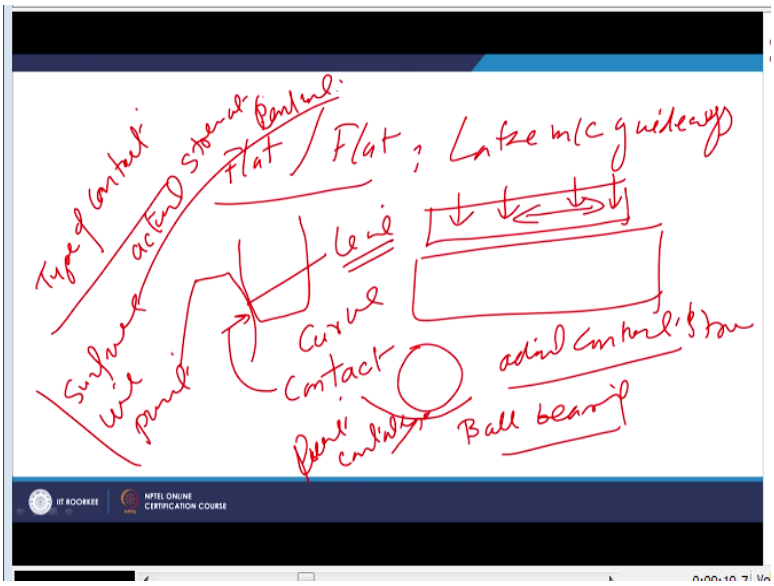
So, under the reciprocating movement when the wear debris particles are present between the mating components at the interface presence of such kind of the hard particles sometimes they act as a third body and cause the abrasive wear of the components obviously the abrasion will happen more in the component which is softer. So, if the component 1 is softer then it will be subjected to the more abrasion is compared to the another components.

So, this is one phenomena that in case of the reciprocating movement we may find more wear rate higher wear rate as compared to the unidirectional movement. In case of the unidirectional movement like say in this particular situation where this is the wear track and this is the pin. So, the this case is moving and the pin is a located at particular position. So, the movement of the disc counter surface with respect to the pin will be continues movement will be generating the wear debris at the pin and the counter surface interface.

And this wear debris particles under the effect of the centrifugal force will be thrown out of the wear path. So, chances for the presence of such wear debris particles at the in the wear path or wear track the those will be minimum and therefore the chances for the wear debris particles to act as a third body will be less in case of the unidirectional relative motion between the components.

So, this is how we can compare the type of the relative motion and it is effect on the wear. So, in case of the reciprocating movement possibility for presence of third body between the mating components is more compared to the case of the unidirectional relative movement, now another point regarding this is the type of the contact.

(Refer Slide Time: 06:55)



So, there can be various types of the contacts like it may be the flat surface is sliding over the another flat surface like this is typically observed on the lathe machine guide ways. So, in this case 1 flat surface is having the movement over the another surface. So, back and forth movement takes place a in this particular case. So, this is one where the entire load is transferred through the interface over larger area.

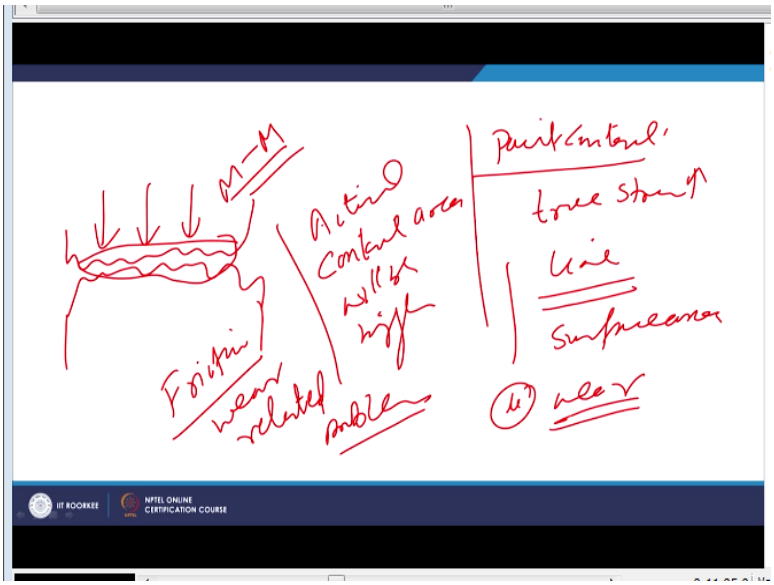
So, actual contact stresses in this case are very less as compared to the case when the other types of the contacts exist like the curve kind of the contact which normally takes place. In case of the gear tooth contacts like these are the gear tooth present on the 2 gears messing with each other at this particular point since both surface is will have the curves.

So, it these will be having the curve contact so, contact will be along a particular lines. So, it will have the line contact. So, in case of the line contact the stresses will be more localized compared to the case when the entire surface was in contact with the counter surface. And there can be another possibility where 1 ball is in contact with the another curved surface this happens in case of the ball bearings.

So, where ball is in contact with the curved surface like bearing race, in this case it will be point contact. In case of the roller bearing it will be the line contact. So, there will be a surface there will be a line or say there will be point contact. So, the area of contact will be different in all

these three case so, accordingly the actual or the true stresses at the contact location that will be (()) (09:17).

(Refer Slide Time: 09:21)



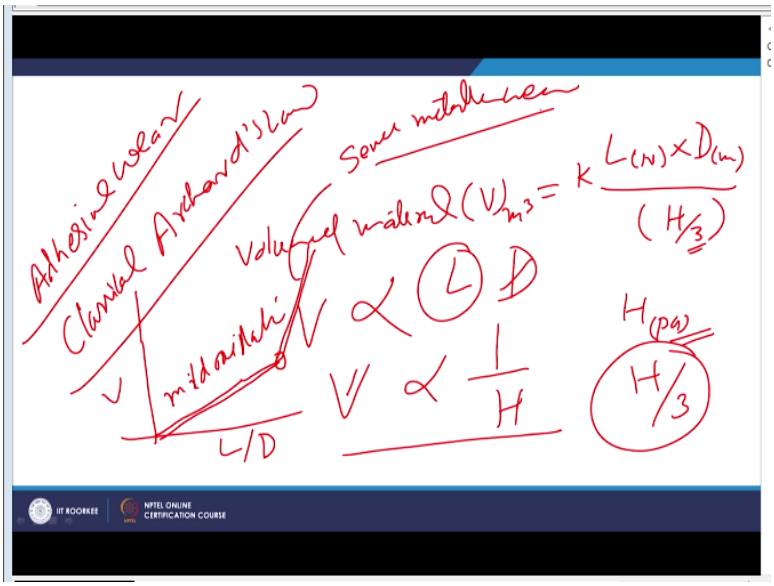
So, especially in those cases where the point contact exist in case of the point contact the true stresses are actual stresses will be much higher as compared to the case when there is a line or the surface area contact. And because of this when the stresses are true high a stress true stresses are higher than we can say the actual contact area will be higher, while in other cases when the true stresses are lower than due to the limited stresses the extent of the deformation of peaks and values presented the surface layers that will be limited.

So, the actual contact area will be less so, if we see since the all surfaces will have some kind of the peaks and values at the surfaces and when the contact stresses are high than these will be collapsing and forming the greater actual contact area direct metal to metal contact area will be more and this will be causing the more friction and wear related problems, if the proper lubrication is not carried out.

So, effective lubrication will help to avoid the direct metal to metal contact and thereby it will facilitating the reduction in the friction and the wear behavior of the material. In case of the ball bearing in roller bearing we know that since the contact area is very less and the lubrication is

very effective. So, this helps in having the relative movement at very low wear rate and very low with the very low frictional effects.

(Refer Slide Time: 11:20)



So, adhesive wear is represented through one of the very classical Archard's Law on the adhesive wear and according to this what it says that volume of the material lost by the adhesive wear V in a meter cube. This is given as a V is in meter cube can be given by the k is the proportionality coefficient and L is the load in a Newton and the D is the sliding distance in meter.

And the flow stresses which will be determining the extent of the plastic deformation at the surface which is given as a one third of the hardness. So, H is in the pa pascal and the load is in Newton and this so, distance in meter, k is the wear coefficient. So, the volume of the material loss v is given as actually proportional to the normal load which is applied and the sliding distance.

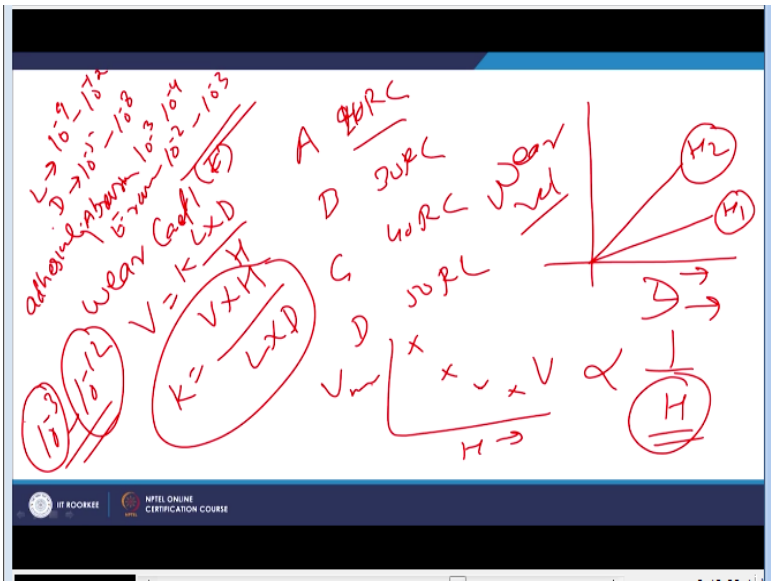
While it the wear volume is inversely proportional to the hardness of the material. So, this coefficient 3 is since the flow stresses are approximated with the help of one third of the hardness when the hardness is expressed as in pa unit. So, this wear volume is inversely proportional to the hardness of the material which means the increase in hardness will reduce the adhesive wear.

Similarly the increase in the normal load and the sliding distance will increase the adhesive wear proportionally or the linearly. So, normally what is observed according to this one for the different materials although trend may be very significantly. So, the load in general increase in load increases the wear volume same is true for the increase of distance, increases the wear volume.

But this happens especially under the mild oxidative wear condition for if there is any change in the wear mechanism from mild to severe then there will be another wear rate through which will be governing the wear volume. So, when the wear rate is increasing linearly up to a limit and thereafter there will be sudden increase in the wear rate beyond a certain point which will be suggesting that there is a change in the mode of wear.

And now severe metallic wear mode has started, similarly if we see the hardness of material which if we can increase through the different thermal processing and mechanical methods.

(Refer Slide Time: 14:29)



Then for 1 material as a function of the sliding distance if we see for 1 material having the one level of the hardness and for another material wear may change through the another level. So, in y axis if we have wear volume and in x axis we have sliding distance then for material same material of one hardness will you will be subjected to the wear at 1 rate as compared to the wear of the material wear of the same material.

But having the another hardness so, H1, H2 is representing the different hardness values of the same material which is achieved through the different processing roots may be thermal method or the mechanical methods which may be inform of like burnishing or heat treatment or nitriding etc. So, any kind of the method which can be used for regulating or for achieving the required hardness.

Now so, this was the Archard's law but most of the time we do not see that the variation is that linear for the hardness means the wear volume is not exactly always inversely proportional to the hardness sometimes we may have the different kind of the various trends of the variation in wear volume as a function of the hardness. So, this law not necessarily will be following under the all situations.

But this is classical and original law which was derived to understand how the different materials will behave if they are harnesses are if they are having different harnesses. If we see if we take like say the 4 different materials of the different hardness values of like say the 20 RC, 30 RC, 40 RC and 50 RC. And then we try to see where we may find that there is some kind of the consistency with the increase of the hardness.

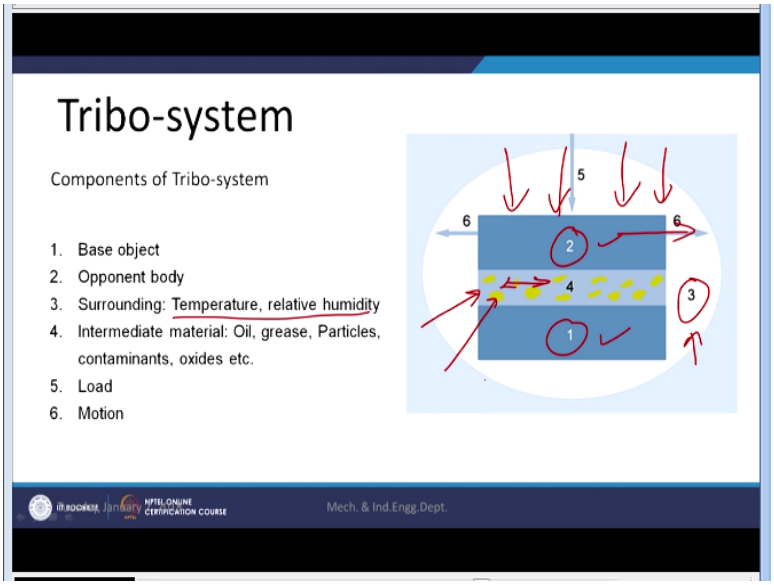
There is a reduction in the wear volume so, for under the simplified condition normally this law behaves a like this where the wear volume is found inversely proportional to the hardness values, another interesting aspect is this wear coefficient which is basically V=k L*D/H. So, k is basically the wear coefficient k which is often through V into H divide by L into D.

So, this gives as very interesting parameter which indicates the different bands for the different kinds of the wear. And normally the adhesive wear under the well lubricated conditions shows the wear coefficient like say 10 to the power -9 to 10 to the power -12 while for under the dry conditions it is lower may be like 10 to the power-5 to 10 the power -8, for abrasive wear it is like say 10 the power -3 to 10 to the -4.

For erosive wear 10 to the power -2 to 10 to the power -3 so, very high erosive wear rate and abrasive wear rate can take places. So, the 2 body abrasive wear offers very high wear rate has wear coefficient as compared to that of the lubricated and the adhesive wear under the dry sliding conditions. So, normally the wear coefficient is founded 10 to the power -3 to 10 to the power -12 depending upon the wear rate.

Most of the engineering components under the adhesive wear conditions are designed to have the wear coefficient in the range of like say 10 to the power -12, while erosive wear like solid particle erosion are the slurry erosion under those conditions we experience the much higher value of the wear coefficient. Now will be going through the another type of the wear, that is basically about the abrasive wear, this which, we can understand from this tribological system, as I have talked yesterday about the Tribo-system here.

(Refer Slide Time: 19:19)



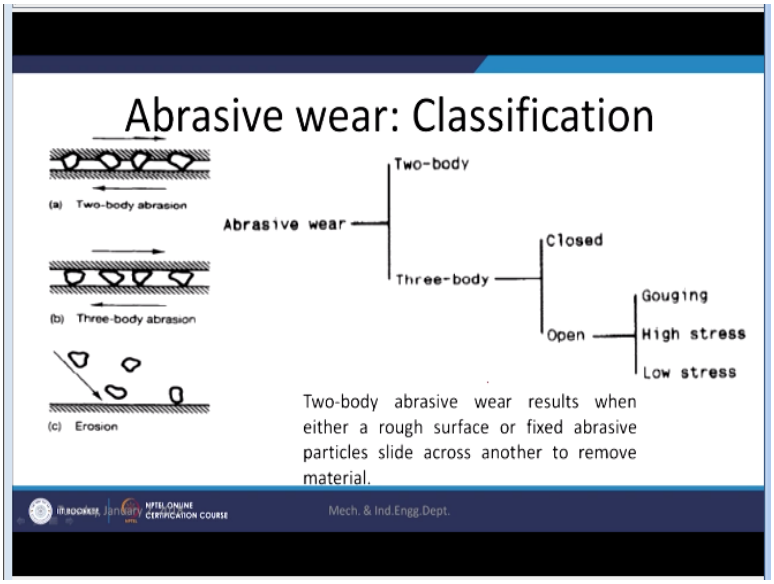
This is say component which is be which is under consideration and it is in contact with the another mating component 2 and between the 2 components some kind of the separating field may be in form of oxides or the lubrication or the steam or something else is present. So, this is what we can say the substance or the material which is present at the interface.

And then this system will be working in particular environments. So, that we can say surrounding and it is temperature, humidity all that will be important from the wear point of

view. And then will see the particular kind of the load is being service load which is being transferred during this service from 1 component to another and the kind of motion which exist between the 2 components.

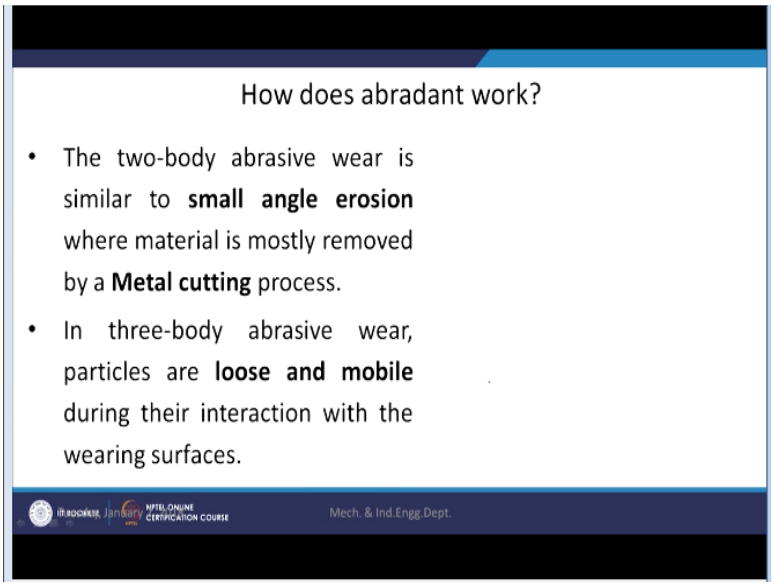
So, these have the 6 different components component one and two are the parts which are interacting with each other there is 1 the something which is present in between the 2. So, that they can be isolated from each other to avoid the direct material to material contact or some other kind of particles are present like in a abrasive wear. These can be there in form of the particles.

(Refer Slide Time: 20:36)



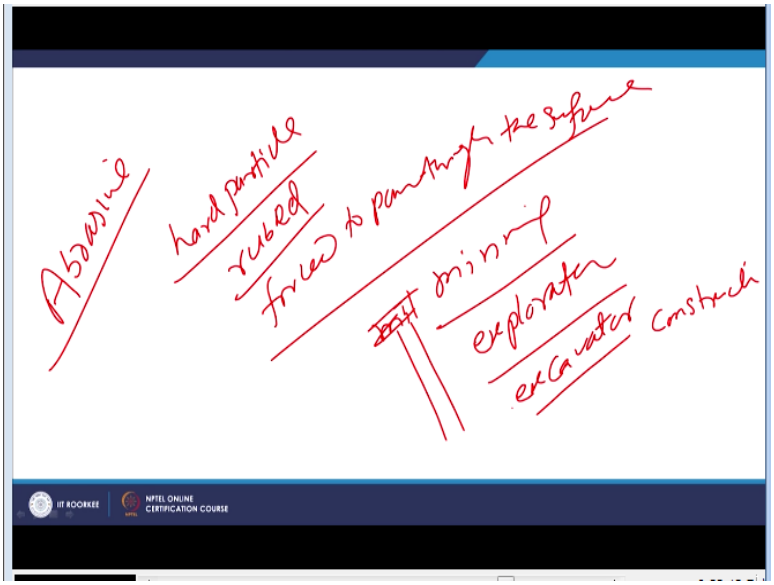
So, these the typical Tribo-system now if we have to understand abrasive wear then for understanding the abrasive wear.

(Refer Slide Time: 20:45)



Abrasive wear is basically here.

(Refer Slide Time: 20:51)

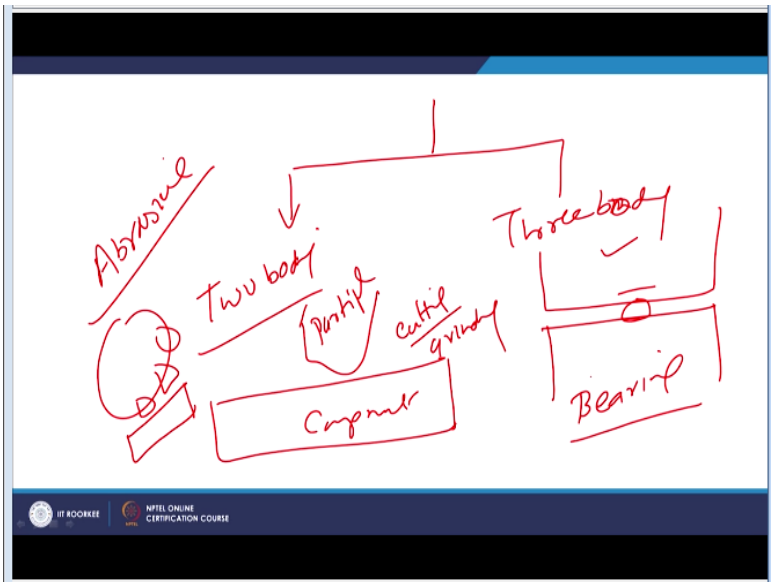


We can see abrasive wear which is very commonly observed in those industries where hard particles, they are rubbed or forced to pass through the surface of the component. So, it can happen like the all those components which are used in the mining industries. Those which are used like jolt tools used in a petro chemical industry for exploration drilling the hole.

And it can be there in the field of the like earth moving components like excavators which are used for digging the swipe end for creating various types of the constructional features. This is basically used in a construction industry. So, wherever the hard particles are forced to or rubbed

forcefully against the other components will be seeing that some kind of the abrasion is taking place.

(Refer Slide Time: 22:15)

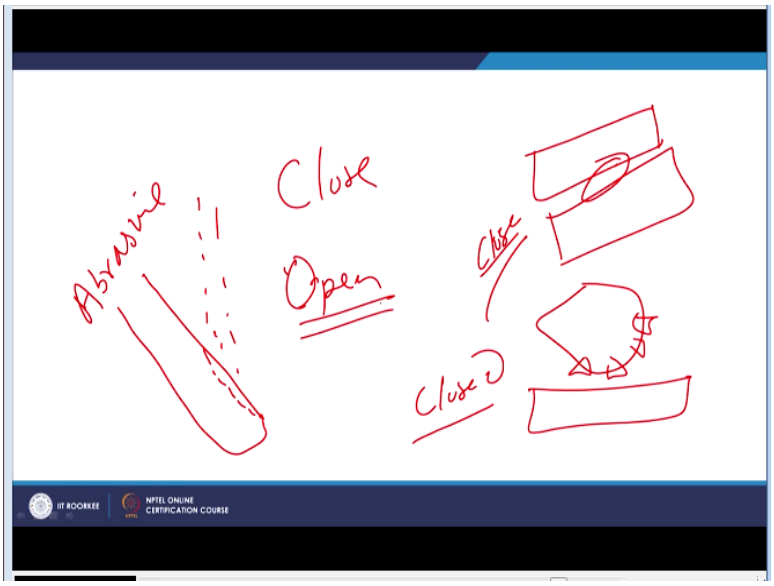


So, rubbing of the hard particles with the metallic pieces basically causes the abrasion. So, there can be the 2 types of the abrasive wear behavior or means the 2 types of abrasion 1 is the two body abrasion and second is the three body abrasion. In case of the two body abrasion alike these particle is being rubbed over another surface, surface of the another components. So, this is basically one component which is being rubbed or which is abraded by the another hard particles.

So, this is the particle which is being rubbed. So, this is the situation of the two body abrasive wear and in case of the three body abrasive wear between the two components third particle third hot particle comes in between. So, it causes the abrasion in both or 1 of the 2 whichever is softer so, this is the situation of the three body abrasion and this is a typical this is the case similar to that of the like metal cutting or grinding where like in grinding wheel various abrasives are fitted.

And these are rubbed against the work piece, similarly in the three body abrasive wear this is like the hot particle enters in the bearing system. So, between the 1 roller and it is resist here what will you see the 1 hot particle has enters so, this will be causing three body abrasive wear.

(Refer Slide Time: 24:20)



Now there can be other ways of the classifying the abrasive wear like the closed or the open type. In close type like between the 2 components 1 is forced to pass through in the hot particle is constructed or restricted between the 2 components or like in this in case of the grinding wheel where abrasive particles are fitted and the they are rubbed against the work piece. So, the relative position of the abrasive and work piece is very fixed when this kind of system exist it is called closed or between the 2 components which are closely spaced third particle comes in between.

This is also an example of the closed abrasive wear and in open one like over this component the send is freely falling over the component. So, this will be whatever wear will be happening of the component due to the flow of the send particles that will be coming in category of the open abrasion. So, this is what we can see from these examples the two body abrasion where the position of the abrasive and the component which is subjected to wear it is fixed and the 2 are having the relative motion and so, this is the two body abrasion and three body abrasion.

When between the 2 interacting surfaces third particle comes in between that is three body abrasion and when the particles are freely falling onto the surface of the component. Then this is called open abrasion and in this case what will see how these will be working. So, in case of the two body abrasion in most this two body abrasion is similar to that of small angle erosion where in the material is removed mostly by the metal cutting process. And in three body abrasive wear

particles are loose and they will be moving and during the interaction new with the wearing surfaces. So, we have already seen the examples of the two body and three body abrasive wear.

And it is further classification of the abrasive wears and the wear mechanisms will be seeing in the next presentation. So, now I will summarize this presentation in this presentation basically we have talked about the effect of the type of relative motion on the adhesive wear as well as 1 Archard's classical Law on the adhesive wear which indicates the effect of the normal load and sliding distance and hardness of the material, and the adhesive wear, and have also introduced the idea of the abrasive wear, thank you for your attention.