Fundamentals of Surface Engineering: Mechanisms, Processes and Characterizations

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Lecture-13
Surface Damage: Adhesive Wear l

Hello, I welcome you all in this presentation related with the subject fundamentals of the surface engineering and we are talking about the various surface damages which adversely affect the performance of the component. And as we have talked that there are few wear mechanisms through which most of the material loss takes place and causes the damage to the surface and which internally leads to the reduction in performance of the component.

And these mechanisms are like adhesive wear, abrasive wear and corrosive wear. So, these 3 mechanisms account for about 80 to 85% of the loss of the material from the functional surfaces. While the remaining loss is caused by other mechanisms of the wear, now we have also talked about the few basics related with the adhesive wear. And today will be talking about the various mechanisms which are involved in adhesive wear.

So, for understanding the adhesive wear and related aspects it is important to understand that any wear system forms a tribological system which is called tribo system what tribo system includes like 1 mating component this component 1.

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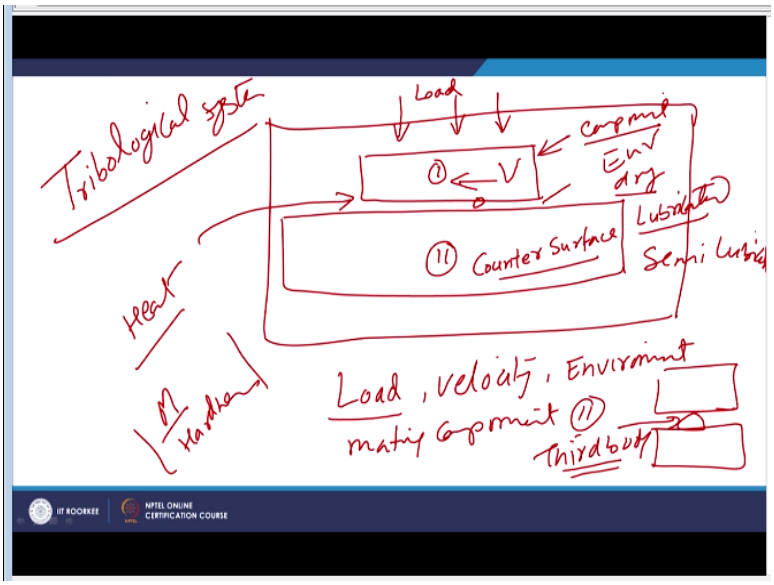

And there is a another component which is basically component number 2 this may be considered as a counter surface also. Then these 2 components will be mating and interacting in certain environment. And these components will be working under mating and working under some kind of the loading either because of the own weight or externally applied load.

So, there is some kind of the loading and the whenever there is a movement of 1 component none 1 component with respect to another. There is a relative movement that is called relative velocity or sliding velocity depending upon the kind of configuration and whenever there is a relative movement some work is done and that work frictional work gets converted into the heat.

So, some kind of the heat is also generated, so if we see these are the different constituents of any system where we have the load which is being transferred externally applied load or it may be due to the on weight of the component components own weight. Then the relative velocity or the sliding speed of the component then the environment in which this interaction is taking place.

This is also another big factor, so this is third component then these the mating components which are involved. Obviously these will be the 2 in numbers and there can be more like in abrasive wear conditions between these 2 between any 2 components third particle also appears, so that forms the third body but that happens in case of the abrasive wear.

Although in adhesive wear also whenever wear particle is removed from one of the surfaces then it is presence also can act as a third body. So, these are the important aspects related with. Then one of these component is termed as counter surface and the 1 component is maybe termed as the component which is sliding over the another, so 1 will be harder or softer than the other.

Normally both are not made of the same type of the material, so that they have same crystal structure properties and the hardness. But it is always preferred that the 2 are different with regard to the materials with regard to their hardness. And this is this place an important role in controlling the wear and having very reduced rate of the wear, so this as a whole is termed as the tribological system.

Now environment in which this sliding is taking place this can vary significantly like we this sliding may happen under the dry condition or it may happen in the well lubricated conditions for control wear or it can be under the semi-lubricated conditions. So, likewise and accordingly our wear rate or the loss of the material from the functional surfaces will be affected.

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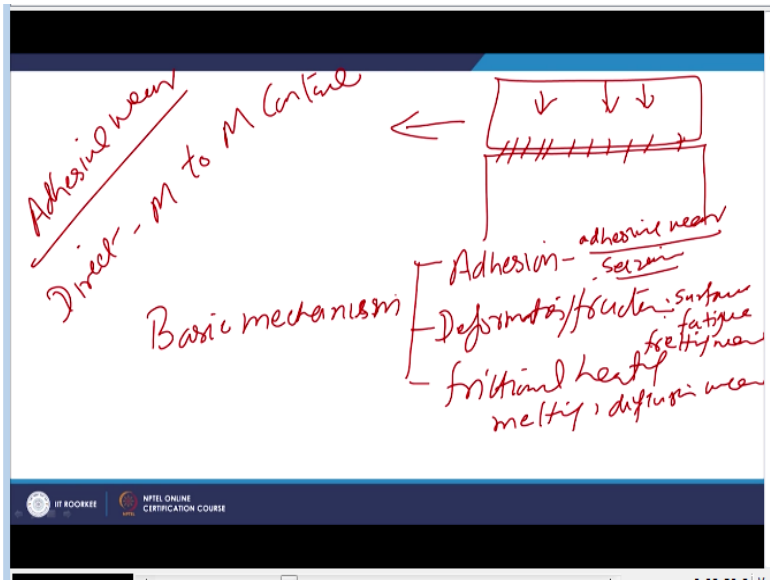

Now if we see they are for the adhesive wear there has to be direct metal to metal contact between the interacting surfaces. And under such conditions whenever there is a loss of material from the interacting surfaces then as per the load and the sliding speed conditions and the

frictional heat conditions which is generated there can be the loss of material from the interacting surfaces through these 3 basic mechanisms.

These basic mechanisms are like adhesion then deformation and fracture and third is frictional heating all these 3 maybe involved actually in any kind of the sliding conditions but the relative contribution on the material losses may vary significantly normally simple adhesion is the way by which the material is removed from the functional surfaces under simple adhesive wear conditions or under the seizer like conditions.

The deformation and the fracture are involved under the conditions of the surface fatigue wear and fretting wear**.** And the frictional heating plays a big role in melting wear and the diffusion wear. So, these are the 3 broad categories of the fundamental mechanisms involved in the adhesive wear and as we have seen in all these cases the kind of the direct metal to metal contact to which exist that governs the friction force frictional force generated during the relative movement or the frictional resistance which has to be overcome during to maintain the sliding.

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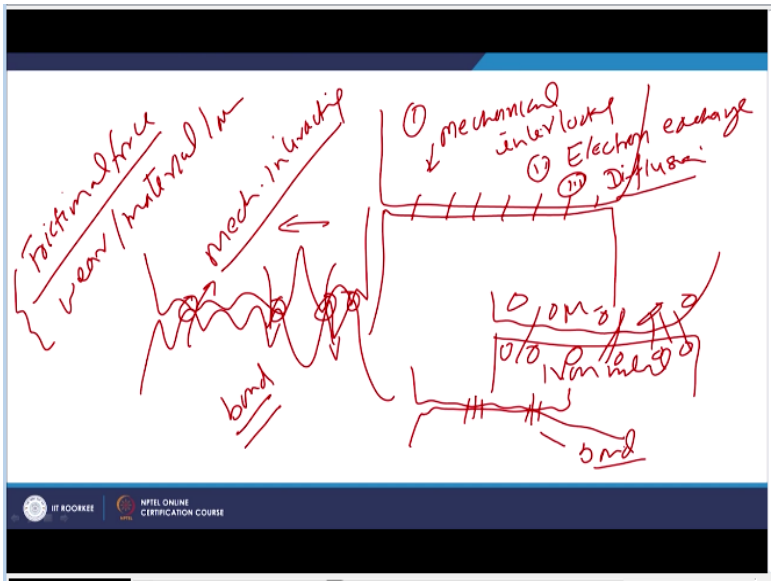

And the wear or the material loss from the functional surfaces that these 2 aspects are governed by the kind of the direct metal to metal contact which exist between the mating component and this direct metal to metal contact whenever it exist it happens through these 3 mechanisms. 1 is

like mechanical interlocking and the second is electron exchange or free electron exchange and the third is the diffusion across the interface.

Because most of the time metals are different their compositions are different and the energy levels of the 2 sides are difference. So, the diffusion is also facilitated what is important since all surfaces have surface regularities. So, the contact exist at very localized points where 2 stresses are very high. So, the surface layer deformation takes place which leads to the mechanical interlockin,g greater is the mechanical interlocking greater will be the force with which 2 components will be holding together.

And accordingly it will require greater force to maintain the relative movements. So, the frictional forces will be high when it has greater mechanical interlocking. Similarly the electron exchange is the another mechanisms whenever 2 comes in contact with each other the free electrons move from ones side to another and forms the bond between the 2 components.

So, if ones side has metallic matrix and another side it is non-metallic constituents then this kind of transfer is not that much facilitated. So, it is always good to have this situation wherein 2 metals out of the 2 metals they are reinforced with the non-metallic constituents. So, wherever the non-metallic constituents are present such kind of the free electron exchange will not be possible across the interface.

So, the bond formation tendency is reduced, the third mechanism is the diffusion which also facilitates the bonding between the mating components. So, wherever the direct contact exist the diffusion starts due to the compositional gradient across the interface. And that in turn firm leads to the or facilitates the formation of the bond between the 2 mating components.

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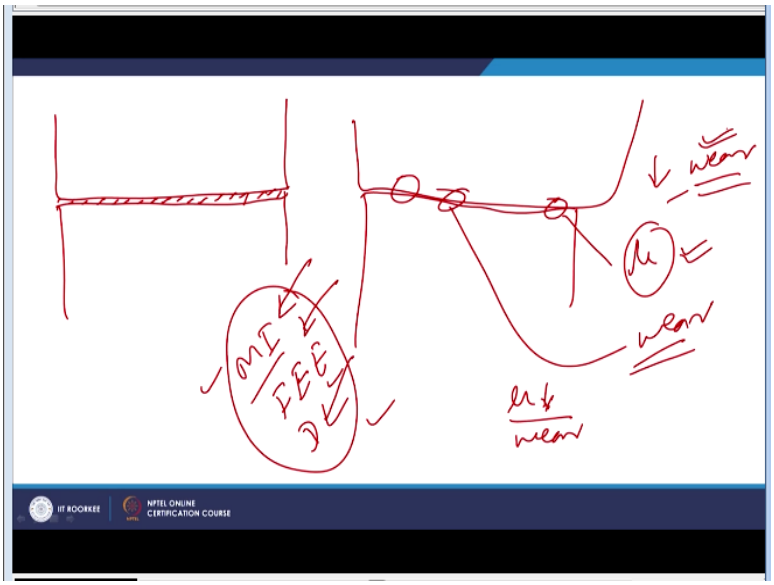

So, if there is a general principle that if greater area or between the 2 mating components comes under the cold bond or the metrological bond are the bonding is created between the 2 over a larger area. It will increase the frictional force at the same time it will also increase the wear volume. So, all those factors which will be discouraging the mechanical interlocking free electron exchange and the diffusion.

Then it will be helping to reduce the friction coefficient as well as the wear loss from the functional surfaces. So, what is the most common approach to have this 1 is that if the 2 mating components are isolated from each other. In such a way the neither mechanical interlocking nor the free electron exchange and diffusion is facilitated and for this purpose under the actual working conditions 1 common thing which is facilitated is the use of lubricant between the 2 components.

So, the 2 components will not be indirect metal to metal contact. But contact will be existing through the some kind of the lubrication and this will resist significantly the mechanical interlocking free electron exchange and the diffusion and which in turn will help in reducing the friction as well as wear.

But, so this will be the situation where the good lubrication exist between the mating components. But if there is a loss of lubrication or if the sliding is taking place under the dry

conditions then certainly all this phenomena will be present. So, now we need to see what are the factors which affect this bonding which in turn determine the frictional force and determine the way by which material loss from the functional surfaces which will be taking place.

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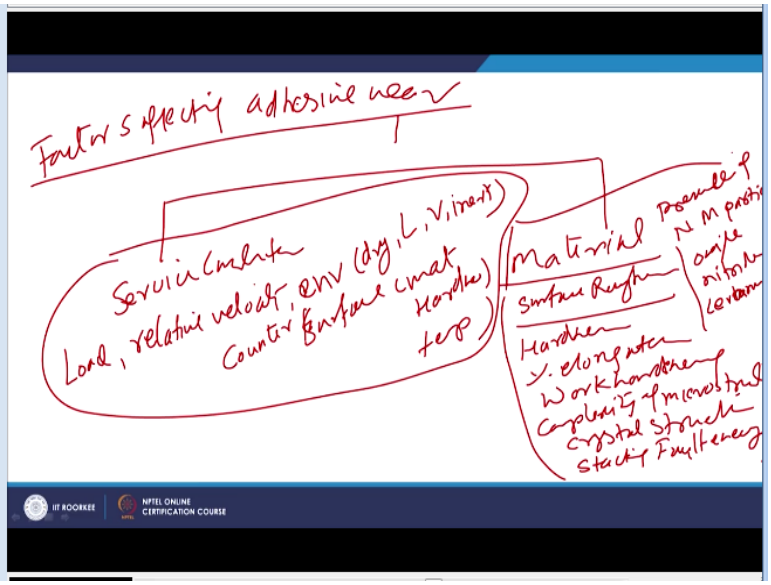

So, there are 2 broad categories all they are large number of the factors which affect factors affecting the adhesive wear broadly there are 2 categories, 1 is the service condition related factors and another is the material related factors material means the material which is being considered from the wear point of view. And the service conditions related factors, so under the service conditions related factors we have the normal load.

The loading conditions under which sliding has to take place and the relative velocity of the mating component which is another important aspect then environment in which sliding is taking place whether it is dry or it is lubricated it is vacuum or it is inert atmosphere. So, accordingly the kind of the interfacial interactions and the metallic intimacy between the mating components will be affected and these factors.

So apart from these factors we have the another mating component against which rubbing is taking place which is termed as counter surface, counter surface material it is hardness and it is temperature. These are the 3 important aspects that affect the kind of the metallic intimacy the way by which material loss. And the frictional effect which will be offered by the component

which is being considered. On the other hand in the material side we have the material which is being considered from the wear and friction point of view is it is surface roughness.

So, this is 1 parameter then it is hardness, then percentage elongation or the ductility of the material it is work hardening tendency. Then complexity of the micro structure then it is crystal structure then stacking fault energy**.** So, this is these are some of the material related aspects in addition to these we have the presence of non-metallic constituents or particles present in the metallic metrics like presence of oxides, nitrides or ceramics.

So, these will be reducing the free electron exchange across the interface and which in turn will help in reducing their bonding. So, now we will see their role at length one by one but before going into that we need to see what happens these factors of course will be considered with regard to the way by which wear of the material takes place. So, if we have to go through one by one about these factors.

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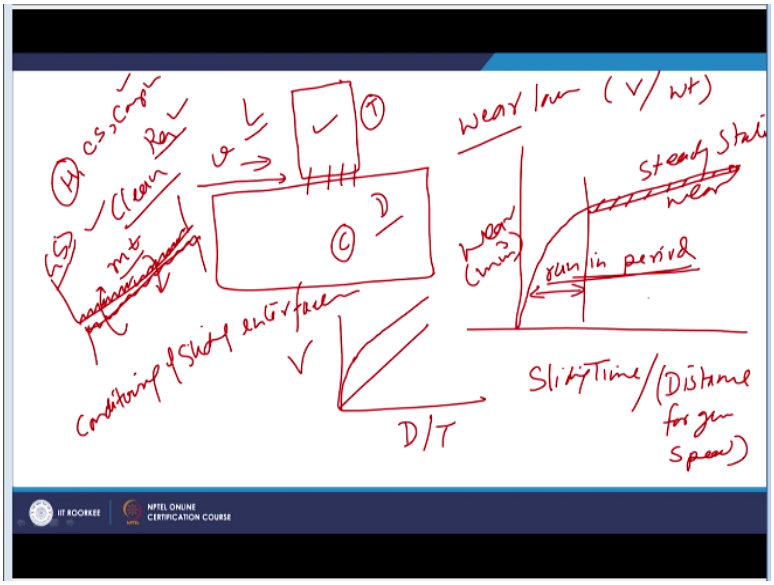

But before that what will see that if we take 1 component and it is under control conditions it is subjected to the wear test or sliding wear test then we will be able to measure the way by which wear or the material loss from the functional surfaces from this test piece is taking place. And this is the counter surface, so under given load conditions and given sliding is speed conditions

and for sliding over given distance, what is the wear or the loss of material from the functional surface which may be measured in terms of the volume loss or in terms of the weight loss.

So weight loss is generally U common method which is used for calculating the wear as a weight loss divided by the density that gives us the wear volume**.** Wear volume is commonly used method for expressing the wear or the material loss from the functional surfaces. So, as a function of time means if the sliding continues for longer period over a longer distances and then we try to see the way by which the wear or the material loss from the functional surface is taking place say in mm cube.

And as a function of the sliding time or for a given sliding is speed there will be sliding distance. So, of course it will for given a speed of sliding, so if we see the way by which the wear volume changes as a function of time what we normally notice initially there is a sharp increase in the wear volume and then it becomes constant like this. So, what it shows initially the wear continuously changes wear volume or the material loss from the functional surfaces continuously changes as a function of sliding time or the sliding distance.

So, the period in which there is a continuous change in the slope of the curve that period the distance over which distance up to which from the start of sliding to the period up to which there is a continuous change in the rate at which wear is taking place which we can see from the slope of the curve because this curve is basically the wear volume and the sliding distance or sliding time.

So, if this curve is straight which will show that the wear volume is linearly related with the sliding distance but it does not happen actually the wear volume initially it is high. The rate at which the material loss takes place is high. And then it keeps on decreasing and then it becomes constant. So, the distance or the time up to which there is continues decreasing wear volume as a function of time that is termed as run in period.

And there after the relationship between the wear and the sliding distance or sliding time becomes constant for a given sliding speed. So, this is termed as steady state wear, so steady

state wear is normally used for the comparison purpose and if we see why there is a change in the wear in the initial stage of the sliding. So, for understanding this, what we say that in the initially stages conditioning of sliding interfaces takes place like say the both the surfaces are farce.

So, they are clean and they have their own roughness, they have their own hardness crystal structure, they have their own composition. But whenever the 2 starts interacting with the each other the surface roughness will change due to the interaction frictional heat is generated. So, oxides are formed at the interacting surfaces. So, here oxide layers will you formed on the both the sides of the contain components.

And there will be continuous exchange of the constituents from one side to another. So, we can say metal transfer takes place across the interface. So, there is continues change in the composition, roughness and the cleanliness because oxides are formed even because of the change in composition crystal structure. Because structure is damaged the grain size everything is modified during the sliding.

And because of which hardness also changes and these things will be happening very fast in the initial stage of the sliding that is termed as run in period and once this kind of conditioning of the sliding interfaces completes there after it attains the steady state of the wear. So, normally this steady state of the wear is used for the comparison purpose or the way by which the material loss from to understand the kind of resistance it offers to the loss of the material.

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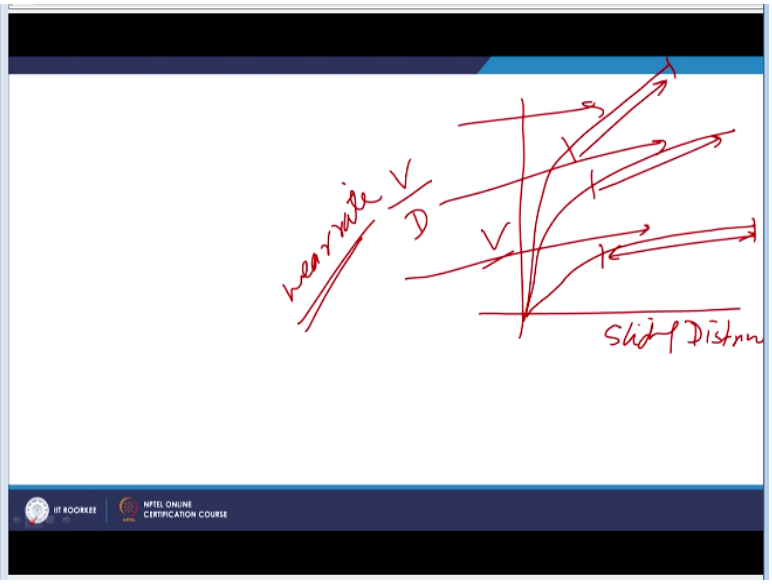

Because during the run in period itself if we see 1 material may show this trend in this way and another material may show completely different trend. Wherein for one material slope is like this for another material slope is lower, fro third material slope maybe further lower. So, basically this slope shows the wear volume verses the distance relationship which is termed as wear rate.

So, slope of the curve in wear verses the sliding distance or the sliding time curve for given sliding velocity it shows the wear rate. So, the slope of the curve basically shows the wear rate. So, if the slope is high wear rate will be high, the materials are selected in such a way that whatever is the wear rate under the control conditions of the sliding that wear rate is able to complete the expected life of the component.

If the wear rate is too high then it will loose the dimension shape much earlier and it will be leading to the failure much earlier. So, it is important that most of the tribological systems or designed most of the tribo systems or designed to perform under the mild wear conditions what these mild wear conditions means.

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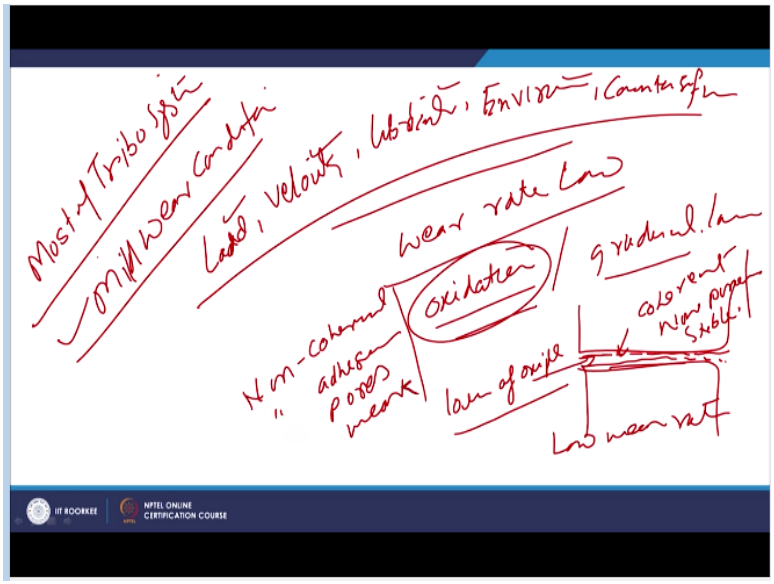

The load, the velocity of the mating component during the sliding the lubrication, the environment means counter surface or the mating components all these are such that the simple wear rate is very low. And the loss of the material is primarily taking place through the oxidation and it is very gradual loss of material from the functional surfaces.

So, under the mild wear conditions the load velocity, lubrication, environment all these are favorable in such a way that the loss of the material from the functional surfaces primarily takes place by the mechanism of the oxidation of the surfaces, oxidation of the interacting surfaces. And then the removal of these oxides leads to the loss of material from the functional surfaces in form of the oxides.

So, if these oxides are very coherent non-porous and stable, then these will be resulting in very low wear rate. On the other hand if it is non-coherent, non-adherent means it is very loose and porous and weak in terms of the stability. Then it will be dislodged such kind of oxides which are being formed between the interacting surfaces they will be dislodged very rapidly from the functional surfaces.

So, they will be offering the higher wear rate or the higher rate at which material loss will be taking place from the functional surfaces even under the mild oxidative wear conditions. So, the depending upon the kind of oxides which are being formed at the surfaces, that will also be

affecting the rate at which material loss from the functional surfaces under the mild wear conditions which will be taking place.

Now will summarize this presentation in this presentation basically I have talked about the basic mechanisms of the adhesive wear and what are the different factors that affect the adhesive wear of the material, thank you for your attention.