Fundamentals of Surface Engineering: Mechanisms, Processes and Characterizations

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Lecture-60
Characterization of Modified Surfaces: Wear Behaviour

Hello, I welcome you all in this presentation related to the subject fundamentals of surface engineering and you know that we are talking about the characterization of the modified surfaces and under this we have talked about the metallurgical characterization and chemical composition analysis in connection with the metallurgical characterization

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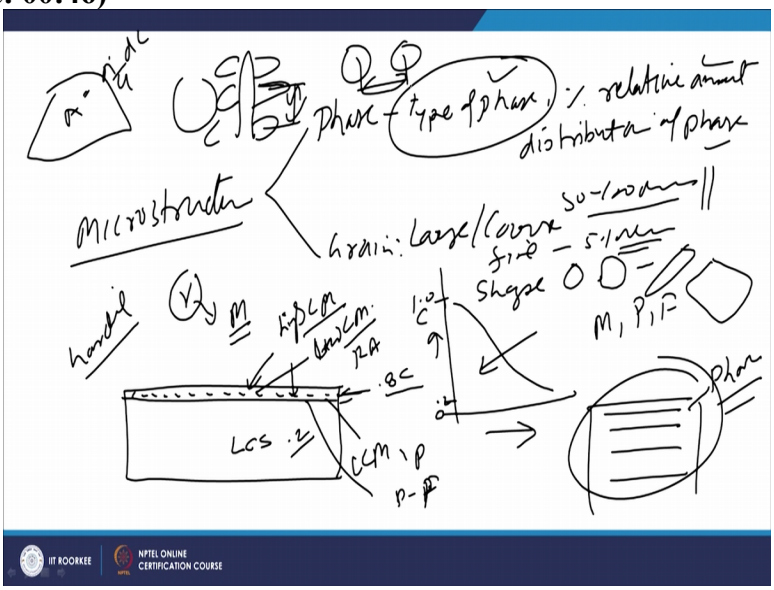

As you have seen you basically will try to see the micro structural aspects of the modified surfaces where in we see the phase structure and the grain structure. In the phase structure we try to see the type of the phases which are present but all types of the micro constituents which are present and their %'s or the relative amount their amount and where which phase is present that is about the distribution of phases so these are the three aspects.

For example we start with carburizing of the low carbon steel perform the carbon enrichment the surface layer up to the 0.8% carbon followed by the hardening. So, when we perform the hardening, hardening is performed by heating the component to the austenitic state followed while having the martensite transformation. Since the carbon concentration may vary from top to substrate top surface to the substrate layer may vary like this.

Since the carbon concentration may be very high at the surface layers and it will be decreasing like say 0.2 which was already there in low carbon steel low carbon steel and like say this is about 1% carbon. So, this is the carbon content is decreasing with the increasing depth. So, accordingly the phases usually formed at the different zones increasing depth below the surface they will also be changing. At the surface definitely we are going to have the high carbon martensite.

But below that will be having the somewhat low carbon martensite plus some retained austenite. Then there after we may have the martensite low carbon monoxide plus purlite and low and then parite ferrite. So, the in the different zones if we take the different layers of the carburized component we may have the different phases present in the different zones. So, that is what is determined where which phase is present and what is the approximate percentage or relative amount of that phase.

What is the proportion of the martensite, purlite ferrite in the carburized and carburized component and which has been hardened after the subsequent hardening process? This is one aspect where in we try to look for the types of the phases and their amounts and the distribution. Apart from this even for the given phase we may have very large or coarse grains of like say 50 to 100 micrometre or we may have very fine grain like say 5 to 10 micro meter.

We know that the coarse micro coarse grains offer the poor mechanical properties, poor wear behaviour as compared to the fine grain structure. So, we need to see that what is the kind of the grain size which is present at the difference in the different zones of the modified layers. Apart from that what is the shape of a grain spherical and equatic shape grains offer the better resistance to the wear as compared to the needler shaped or sharp-edged polyhedral shape large size particles.

So, the shape is characterized for characterizing the size we have to see the average diameter like this is area A then we can we can determine the average diameter from pi by 4 D square. So, this area we can determine from the image analysis and similarly we can we can determine the like for the dendratic structures like there we have relates like this inter dendratic armed spacing is used. In case of the cellular structures intercellular spaces is used, so the different parameters are used for quantifying the grain size.

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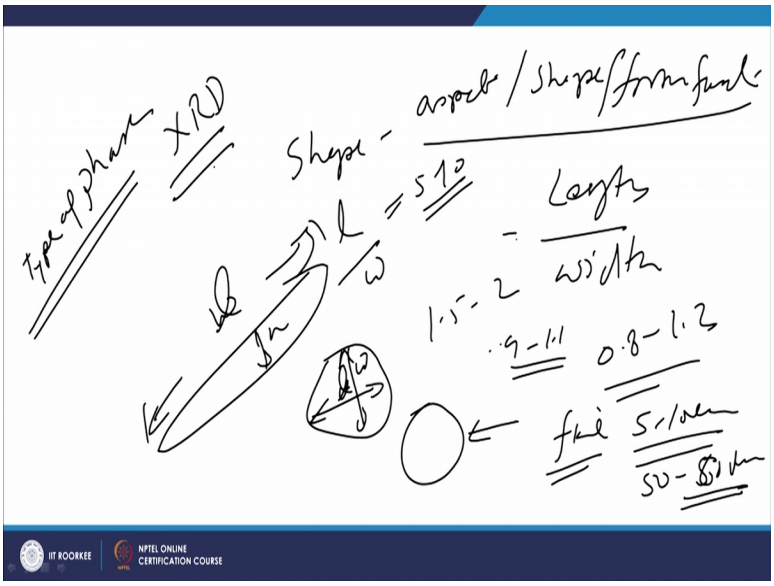

Similarly for quantifying the shape of the grain various parameters like aspect ratio or the shape factor all form factor all these are obtained through the length to the width ratio of a given micro constituents. Like needler shaped micro constituents will be offering much greater length and very smaller width as compared to the much greater length the smaller width. So, here it will be like 5 to 10 for needle shaped structures. While for polyhedral shape it may be like 1.5 to 2 or more like this is the length and this is width.

But for the spherical shape products it may be like 0.9 to 1.1 where length and width are almost same. For wear resistance applications it is always preferred that micro constitutes of this spherical family or close to the spherical family where aspect ratio is like 0.8 to 1.2 so that the length and width are almost same. And at the same time they are fine in size like 5 to 10 micro metre very fine size micro constituents will be offering much better resistance as compared to the like 50 to 60 micrometre grain size micro constituents.

So, the size and shape the type of this is these are the things that we try to quantify. For determining the type of phases simple microscope does not help but we need to perform the XRD analysis. So, XRD analysis actually helps us to identify the various phases which are present.

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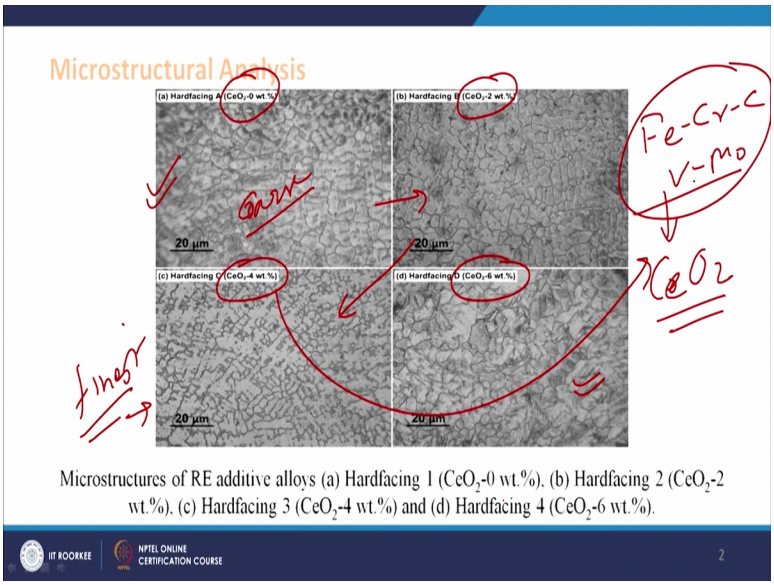

Microstructures of RE additive alloys (a) Hardfacing 1 (CeO_2-0 wt.%), (b) Hardfacing 2 (CeO_2-2 wt.%), (c) Hardfacing 3 (CeO_2-4 wt.%) and (d) Hardfacing 4 (CeO_2-6 wt.%).

If you see this typical micro graph this is for the iron, carbon, chromium, vanadium, molybdenum hard facing which has been modified by the various the proportions of the Ceria edition. Like this hard facing was developed using the 0% of the Ceria than this was developed using 2% of the Ceria than was developed using the 4% and for this 6%. So, if we the micro graph we can see this offers very coarse grain structure and this is somewhat finer and further finer for this case.

So, if we perform the image analysis of this micrograph we find the finest grain size for this kind of a composition where this base hard facing system is modified with them 4% of this Ceria. There after further addition of the Ceria is leading to the increase in the grain size. I mean to say there can be different compositions, different processes, different processing conditions which will be leading to the different kind of the grain size is different kind of the phases and those need to be identified and established.

Similarly if we see these are the two different micro graphs of the same coating. So, what it shows? That when in as a spread conditions like say this is the Nickel chromium Boron Silicon flame spread coating developed by the flame and optical microscopy of this coating primarily shows.

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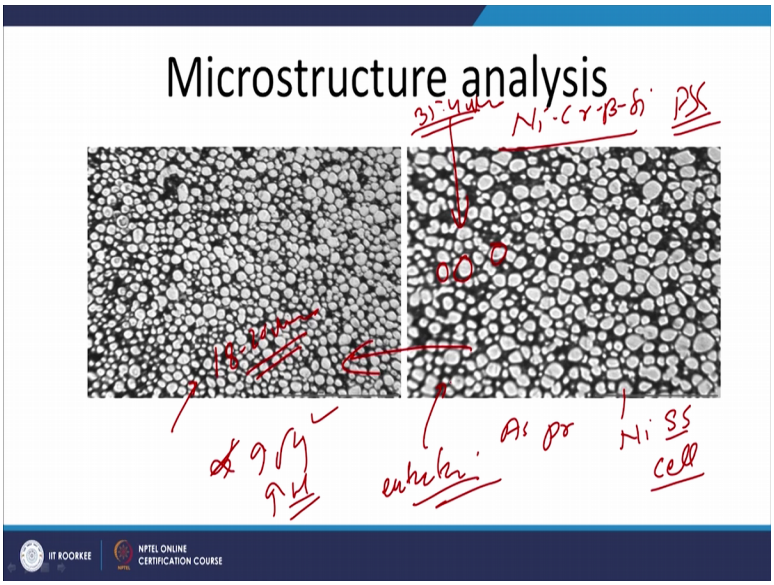

So, that Nickel solid solutions cells and in between the black one is showing the eutectic matrix. So, if we see the average size of the Nickel solid solution sources cell is coarser in this case it was around like say 35 to 40 micrometre while after the grain refinement this size was reduced. And in this case for the reduction of left to them like 80 to 20 micrometer average grain size of the Nickel solid solution cell. So such kind of the refinement is expected to increase the yield strength and increase the hardness and which in turn will be able to enhance the wear resistance.

So, it is important to the image analysis to find out the average grain size the fractions of the various constituents. Here we can determine the fraction of the Nickel solid solution cell and the eutectic percentage separately.

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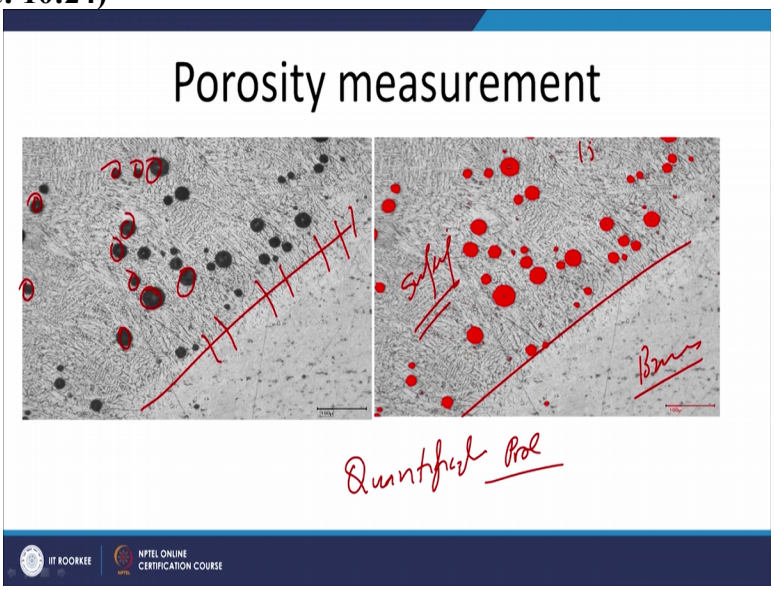

And at the same time image analysis can also be used to for used in quantification of the pores which are present like say in this surfacing we can see this is the base metal and this is the surfacing and here we can primarily see that the epitaxial growth is there at the weld interface in the weld surfacing. But at the same time it is having lot of pores to quantify the proportion of the percentage of pores the image analysis is carried out. And we found that these sports are about 15 to 16%. Porosity measurements are also possible through the image analysis apart from using other techniques.

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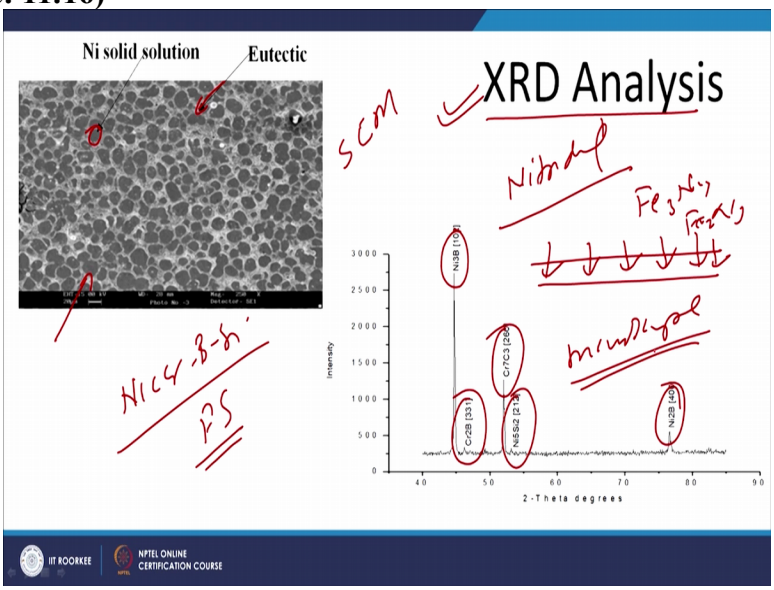

As I have said if the Nickel Chromium Boron Silicon coating developed using flame spraying process as I have said Nikhil solid solution cells and in between we have eutectic matrix. So, there is a difference this is the same image and earlier what I have shown was the this was the optical image there is a difference here Nickel solid solution cells are white and the eutectic matrix is dark and this is optical micrograph.

On the other hand just reverse receive and the same is taken of the same component eutectic will be looking white this is the eutectic mixture is white and Nickel solid solutions cells are looking dark. So, this adjust the reverse kind of them the shades and the colours are achieved when the optical and the same is used for the analysis. From this we can simplicity see the micro consider the number of micro constitutes which are present their sizes and shapes but we do not know what it is exactly so for that purpose XRD analysis is carried out.

XRD analysis helps us to know that there is a Nickel Boride, Chromium Boride, Nickel Silicide , Chromium Carbide is Nickel boride these various constituents can be analysed through the XRD

analysis. Similarly we can do this kind of analysis on the component subjected to the nitriding and the component which has been subjected to the nitriding will be leading to the formation of the various types of the nitrites like a Fe3 and 4, Fe2 and 3.

And which type of the fiches are being formed and where these are being form that is what can be easily identified through the XRD analysis and the microscope. Similarly we can find the brides the types of the borides and their relative amounts through the XRD analysis and the metlography of the component.

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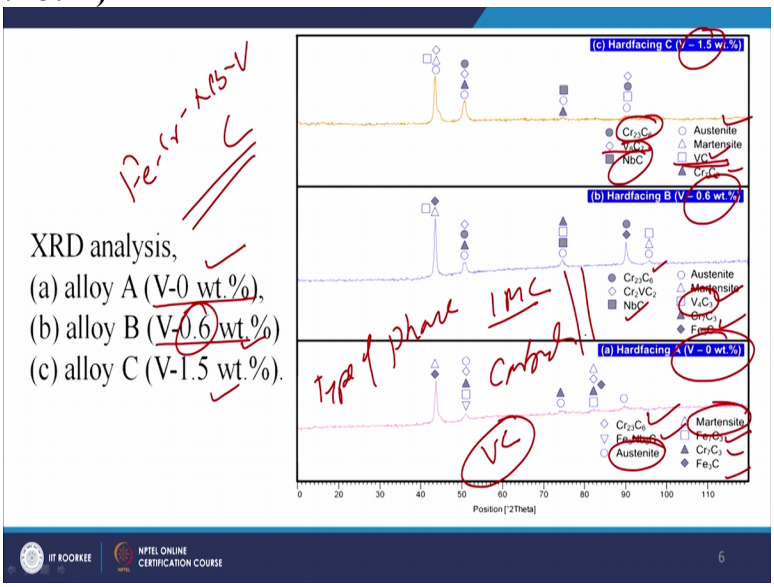

In this case like say iron, chromium, niobium, vanadium, carbon system whose weld surfacing was developed and weld surfacing was developed by varying the vanadium concentration. In case A vanadium concentration was 0, in case B the vanadium was. 6% and then vanadium was added to .1%. So, what happens when the when vanadium content is increased in terms of the various phases which are present if we see when there is no vanadium, 0 percentage of the vanadium.

There is no vanadium carbide formation rest of the alloying elements are forming carbides and that is what we can see the presence of the various carbides apart from that these is a presence of the of martensite and the austenite in the weld surfacing produced of these alloy system. But when we add the vanadium .6% that is in this case we find that there is a kind of vanadium carbide present apart from the other carbides under the phases which are present.

Like in this case cementac chromium carbide is also present and when the vanadium chloride is added in 1.5 % then vanadium is added 1.5% vanadium carbide vanadium carbide is there. There are the two types of vanadium carbides are there one is this and other is this is, this in addition to that we have chromium carbide Niobium carbide martensite and assonates. What are the various phases because each phase has different hardness values and which offers the different kind of effect on the wear resistance.

That is why it is important to consider that types of the phases and inter metallic compounds and the carbides which are present in the given modified surface. So, we can and accordingly we can anticipate its hardness its wear resistance under the surface conditions as per the requirement.

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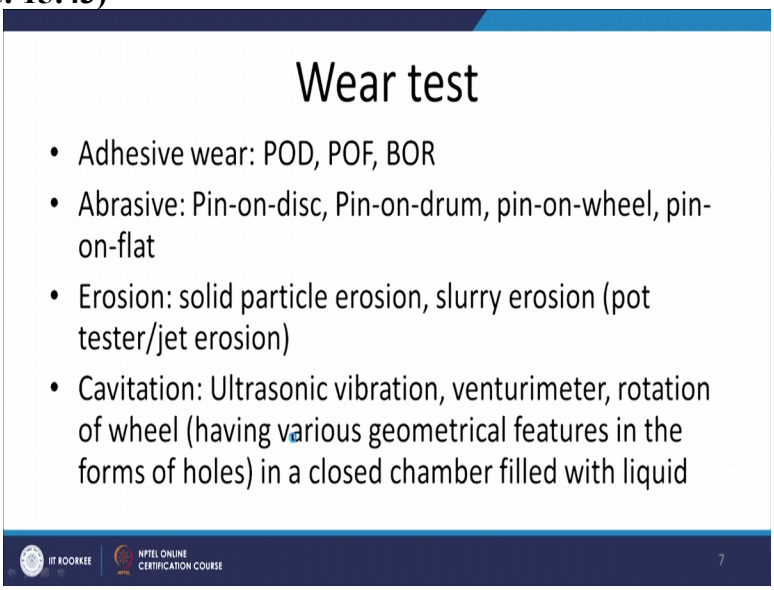

For performing the wear test like say will be

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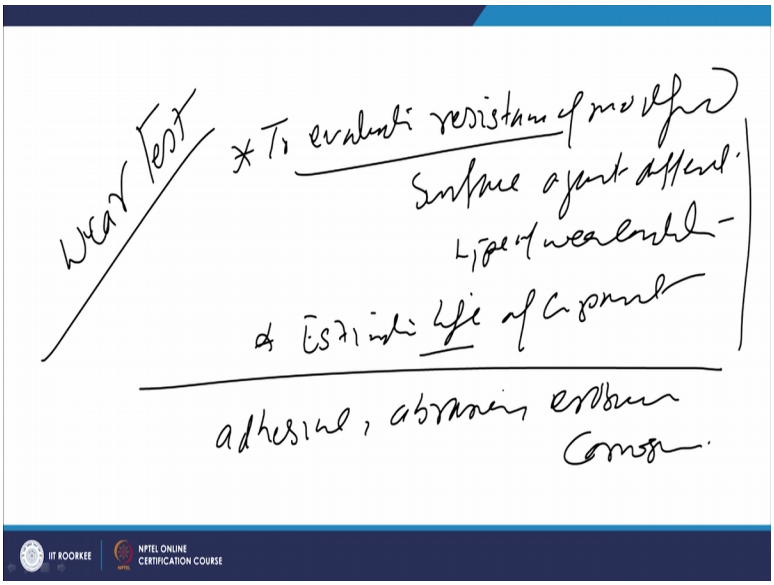

Talking about four types of the wear tests are conducted to check the; area to evaluate the resistance of modified surfaces against different types of wear conditions. And this will help us to know that at what rate the modified surfaces will be wearing out under the service conditions against particular type of the wear. So, that will also help us to estimate the tribological life of the component under the tribological conditions.

And based on this we can take suitable decision whether the modified surfaces have will be able to perform the internet function under the actual service conditions are not. The most common types of the wears which are commonly encountered included adhesive wear, abrasive wear, erosive wear, corrosive wear will be talking about this that these three types of the wears and the way by which these are performed.

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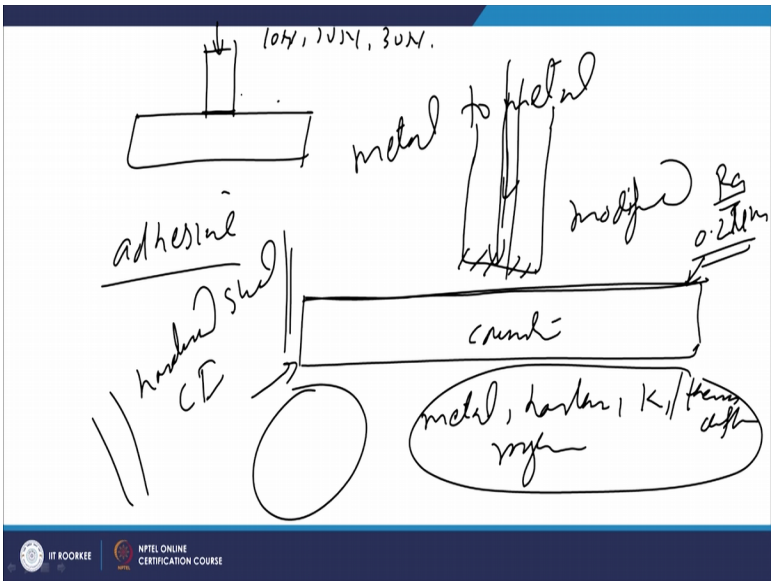

So, will be talking about this that these three types of the wars and the way by which these are performed as you know the adhesive wear is performed through the contact between the metal to metal contact. So, in this case we take one modified surface like this is the modified surface whose wear resistance is to be checked under the adhesive wear conditions. So, the sample of the modified surface is prepared and it is it is kept against another counter surface.

Counter surface will be taken of the suitable material against which the wear resistance we want to check. So it is a; the metal system is hardness its physical properties like thermal conductivity and thermal diffusivity and its roughness. All these affect the adhesive wear behaviour significantly. So, the counter surface must be selected in light of the application against which wear behaviour of the modified surfaces is to be checked.

It may be like say it may be hardened steel or it may be cast iron as per the application the suitable counter surface is is selected it and so that it has the required hardness. Then will be smoothening it to the required level. Now counter surface is smoothen to very high and degree of finish like .2 roughness value .2 Ra is the roughness value and against this counter surface it is usually in form of the disk which is the hardened ground smooth and finished and against this we place the some sample of the modified surface whose wear resistance is to be checked.

And then we apply the normal load so basically against this disk the count the specimen is kept and we apply normal load. This normal load may be like 10 Newton, 20 Newton, 30 Newton and this one is selected according to the application. We have to see what will the kind of the contact

pressure during the service and accordingly we select the suitable load and then the relative movement is given between the two.

After applying the load holding the specimen over the counter surface relative movement is given to the counter surface in such a way that the direction of the movement can be uni-directional like in case of the disc or it can be reciprocating type.

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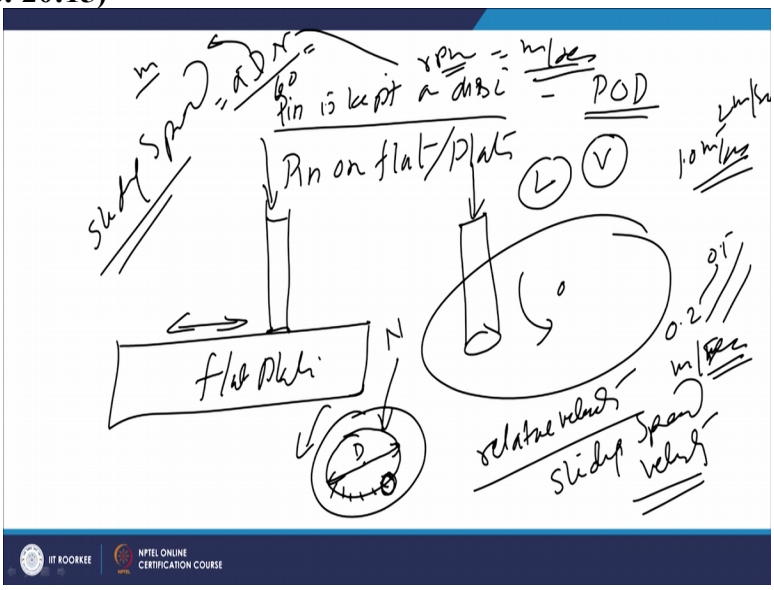

So, accordingly will be having the two types of the configurations one is where the pen is kept on the disk which is rotated this is commonly known as POD. The disk, like this and pen is kept over the disk in this manner and then we apply load and the disk is rotated. So, this kind of configuration is called Pin On Disc. Then there is a Pin On Flat or Pin On Plate. In case of the Pin On Plate the material of the counter surface in form of the flat plate the pen is kept under a pen is held over the counter surface and the required normal load is applied and then it is reciprocated.

So, there can be uni-directional movement through the rotation of the counter surface or there can be reciprocating or relative movement between the pin and the plate progressive location of the plate. Now what will be the velocity or the relative velocity between the two? Relative velocity basically determines the sliding speed or sliding velocity. As per the application the range of normal operation in the range of .2 to .5 this is the normal operational speed this in mm per second.

For high; if the modified surfaces are to be used for higher relative movement conditions then of course will be going for like 1.5 .5 to 1 m to 2m per second sliding speed. So, that the pin will be kept at a fixed location while the counter surface will be rotated at the different speeds for achieving the required sliding speed, now there is one more additional aspect like this is the disc this the centre.

So, this is the location or you cancel the wear track where like this is where pin has been kept and the disk is made to rotate. So, this the wear track diameter D the rotational speed N determines the sliding speed. Sliding speed is obtained from the Pi DN/ 60 where N is the RPM D is the diameter in mm and how it can be in metre for if you want that the sliding speed is obtained in the metre per second.

So, if the D is in meter and N is in RPM Revolution per minute and divided by 60 will be giving us metre per second sliding speed. So, they are two important parameters one is the load and another is the sliding speed under against which the wear test is being performed.

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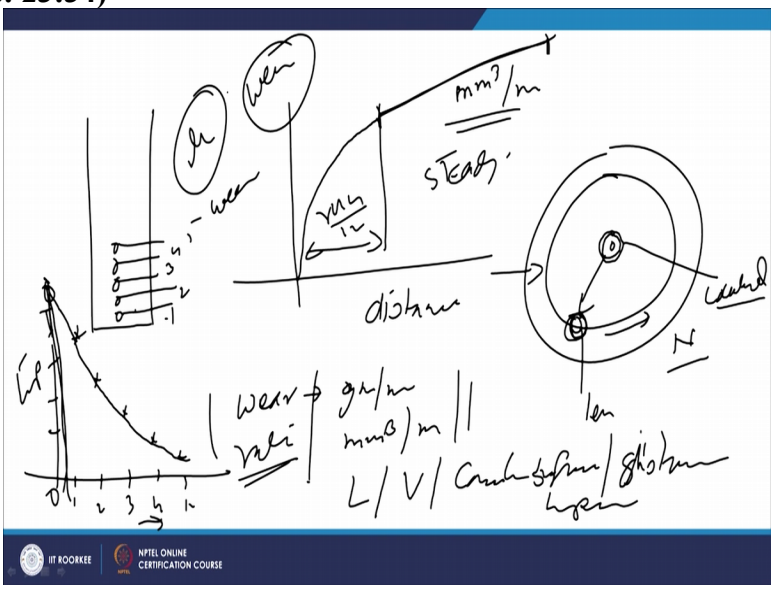

Apart from this the rotational speed and wear track diameter like say if the wear track diameter is very small then the then the time for dissipation of the heat from the wear track will be very small as compared to the case when the other wear track diameter is large. In this case it will take longer time for given RPM it will take longer time to get the particular location of the counter surface come across the frictional effect.

So, here there will be more localisation of the heat and here less localisation of the heat. So, rise in temperature of the counter surface affects the wear behaviour. So, even that wear track diameter can be important in effecting wear behaviour of the material. Then so there another parameter is the sliding distance like for a given at a given location for how long is the test is conducted so that the continuous wear of the material is taking.

So, if we plot 1 typical sliding distance versus wear plot then we may notice that initially wear is changing as a function of distance and then it becomes constant. So, this corresponds to the initial stage corresponds to the run in period and this is the study state period. For adhesive wear the test must be conducted for long enough period so that we achieve the study state and this will be indicating what is the kind of the material loss for unit sliding distance.

This that that is that is what the slope will be indicating. So, that the conditions against which the test is being conducted like the wear which is a quantified maybe in terms of like a gram per metre or mm cube per metre that is how the wear rate is achieved. And then and this wear rate is to reported along with the value of the load velocity kind of the counter surface material the sliding distance, temperature realised.

We know that during the sliding there will be continuous rise in temperature. So, sometimes measuring the temperature of the wear pin at different locations also helps in explaining the wear behaviour. So, normally be inside the thermocouples at different locations increasing distance from the sliding surface sliding interface like say interval of 1 mm and then we try to plot like say 1, 2, 3, 4, 5 mm 5 different thermocouples inserted at 5 different locations.

Increasing distance from the surface so. 1, 2, 3, 4, 5 increasing distance from the sliding interface and then here we plot the temperature value, we mention the temperature value. Obviously at the interface we do not have and thermocouples for measuring the temperature at the interface temperature at location one at 1 mm distance sliding interface is located on the plot and then for 2 mm and 3 mm then 4 mm and 5 mm is how it is plotted.

And so this will be giving us the trend of variation in temperature and extrapolation of this will help us to get the value of the temperature at the interface and this and temperature of the interface value can be useful in explaining the friction and wear behaviour of the modified surfaces which have been used.

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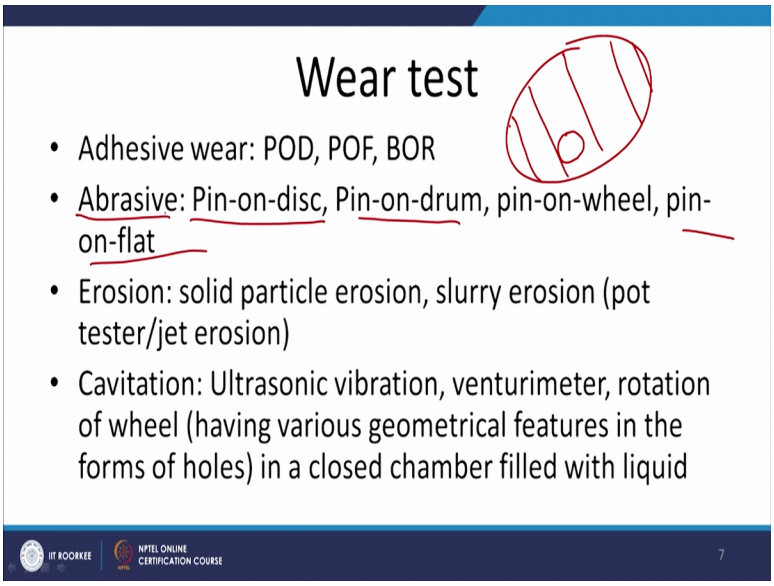

So, now likewise instead of the metallic plate like here on the counter surface we can fix the abrasive paper over the disc. And then we mount the heavier specimen for the wear pin so in that case the wear pin or the pin on drum are the pain on the flat in all this case is metallic plate is replaced with the abrasive medium or abrasive paper and thereafter the same method is repeated. So, instead of the rubbing of the modified surfaces against the metal in this case rubbing will be happening against emery paper assessing the wear behaviour.

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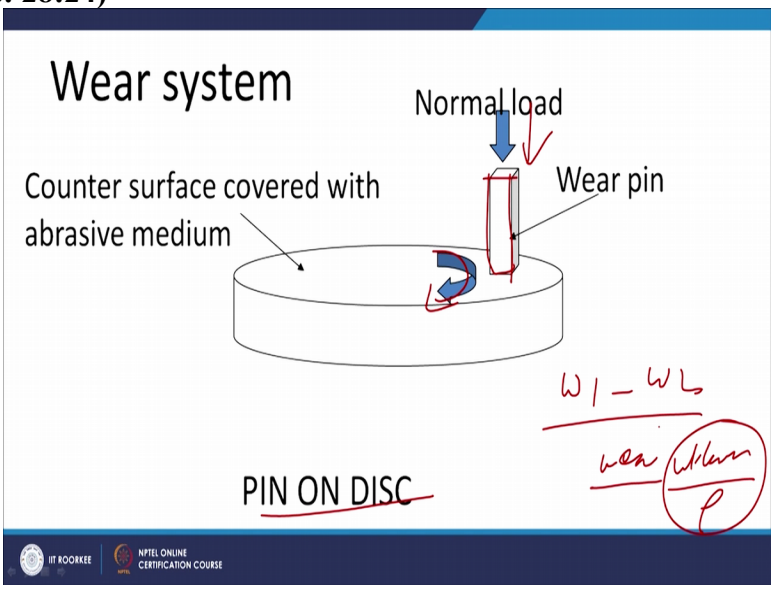

So, that is what we can see here this is a pin on disc arrangement this is the disc rotating disc and this is the wear pin whose wear is to checked in which we apply the normal load and counter surface is rotated we take the initial weight and the final weight difference of two giving us the

wear or the weight loss. Weight loss may be divided with the density to check the wear in terms of the volume wear volume.

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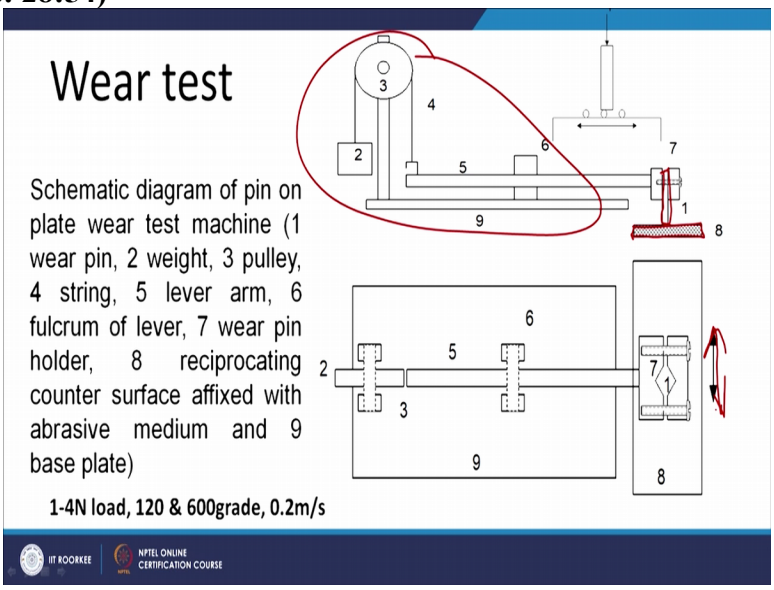

This is the wear test setup for a reciprocating kind of the arrangement. So, in this case this is just a arrangement for holding the work for applying the normal load. The main thing is here where in the this sample is held against the counter surface this is a counter surface and counter surface is made to reciprocate and this counter surface for reciprocating wear conditions reciprocating conditions this will be the metallic surface.

And otherwise I will this a metallic plate will be covered with the abrasive medium so that the modified surfaces or the wear pin sample will be rubbing to the abrasive medium.

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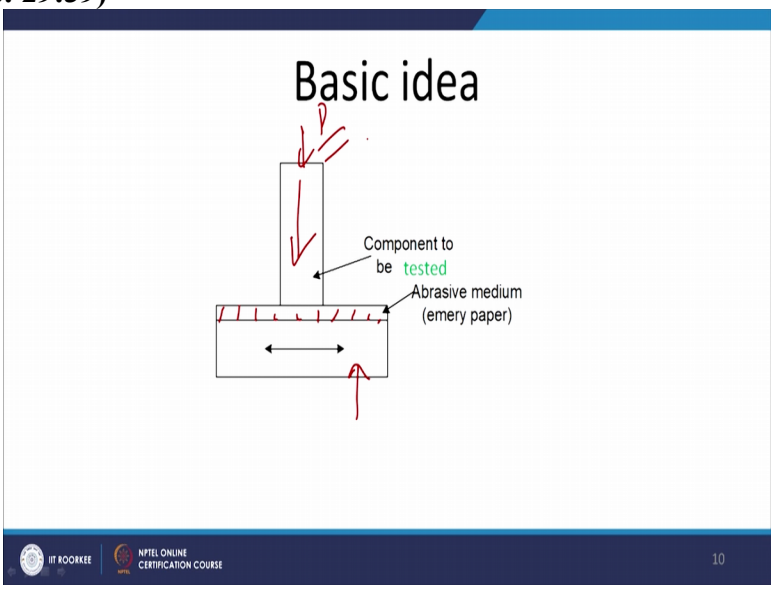

Abrasive medium this is the simple concept of the reciprocating configuration of the wear test. So, the counter surface is placed with the impressive medium and against which the component whose wear resistance is to be checked is kept under the normal load and then reciprocating movement is given.

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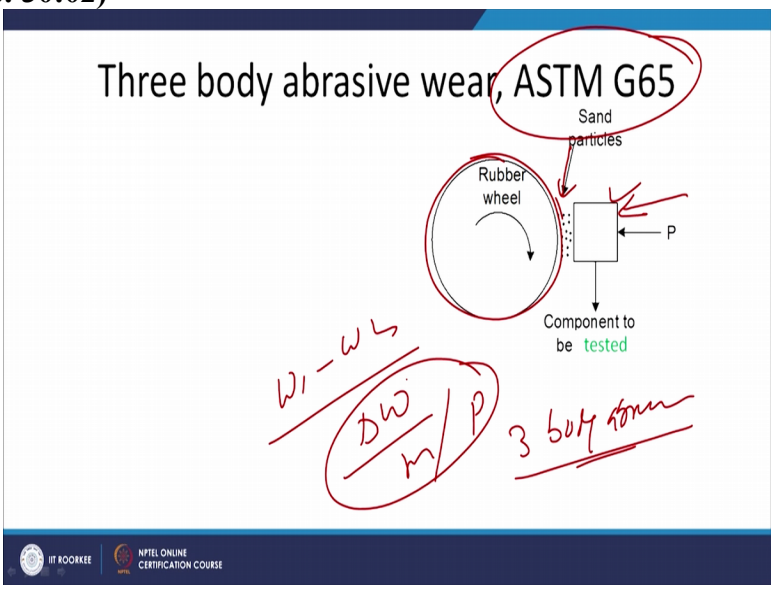

Whenever this kind of thing is done will be having the possibility that the weird average particle is left at the interface and which will be increasing the tendency for the increased wear due to the three body where condition. In case of the three bodies wear conditions like say this is the sample to be tested and this is the standard rubber wheel. And this sample is pressed against the rotating rubber wheels and in between that we feed the sand particles.

So, rubbing of the sample against the rubbing wheel in while the sand particles are coming in between will be causing the three body abrasive wear conditions and distress corresponds to the ASTM G65. In this case also will be measuring the initial weight of the sample and The Final weight of the sample and difference will be giving us the weight loss. And here we can check the wear rate in terms of the wear loss as per metre or the kind of the load which is being applied for the unit weight loss.

Like the weight loss against the 100 gram for weight loss against that 200 grams is very less load is used under the abrasive wear conditions as compared to the adhesive where conditions because wear happens at very high rate under the abrasive wear conditions. Now I will summarise this presentation, in this presentation basically I have talked about the importance of the

microstructure all aspects with regard to the wear behaviour and also have taken up the two types of the technique assessing the wear behaviour.

One was the ways by which we can assess the adhesive wear behaviour of the material and another was about the methods which are used for assessing the abrasive wear behaviour. Thank you for your attention.