Fundamentals of Surface Engineering: Mechanisms, Processes and Characterizations

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Lecture-55
Surface Modification Techniques: Surface Roughness and Thickness I

Hello, I welcome you all in this presentation related with the subject fundamentals of surface engineering. And you know that is so far we have talked about the various aspects related to the surface engineering like the fundamental mechanisms causing the wear of the material from the functional surfaces. And then we have talked about the various methods which are used for modifying the surface properties so that the improvement tribological life can be made. And under this we have talked about the methods where in just the surface metallurgy was modified for improving the wear behaviour.

And there after we have also talked about the methods which were associated with the changing the chemical composition of the surfaces to improve the properties. And there after third category of the methods were talked about where in we have discussed about the method where in a layer the required material is deposited on to the surface so that time the improvement in wear resistance can be made for enhancing the tribological life of the component.

So, once over the surface modification is over for improving the tribological life of the components it is important to assess really how much improvement has been made and we do not really access just the tribological property improvement but will also see that whatever properties and the characteristics that can affect the wear behaviour must be investigated systematically. And these must be standardized or stabilized so that the process can be applied in very controlled way for using the surface modification at the production level.

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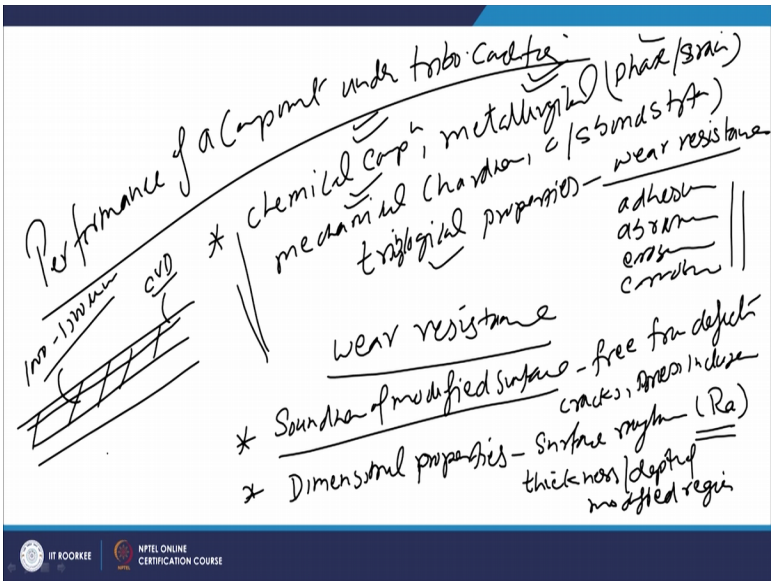

You know that time does the performance of a component under the tribological conditions is influenced by the various group of the properties which includes like those which are associated with the material are the modified surfaces itself. For example chemical properties primarily chemical composition of the material and then for a given chemical composition what kind of the metallurgical properties it has.

So, I like the phase and the grain structure of the material. Then we have to see for what kind of the mechanical properties it has primarily these include like hardness or in case of the codings it maybe coating substrate bond strength. Apart from and combination of the mechanical properties will be leading to the given set of the tribological properties which will be determining or dictating the life of the component under the tribological conditions.

So, that tribological properties of the material which we measure in terms of likes a wear resistance of the wear rate under the adhesive wear conditions, abrasive wear conditions or corrosive conditions for corrosion as per the need of the given application. So, that the performance of a component under the tribological conditions whether it is a modified or not before modification that will be influenced by these characteristics.

So, it is important that whatever the properties are there of the substrate or after the modification whatever we have realised they are understood well. So, that we can achieve the expected resistance to wear for a given set of the conditions, so obviously it will be important to investigate the chemical composition metallurgical properties, mechanical properties and the tribological properties for a given set of the wear conditions.

Apart from the properties for a given modified surface certain under another aspect is one there is another aspect that affects the performance of tribological component which is like say soundness of the modified surface means how sound the modified surface is means it should be free from defect and discontinuities. We know that whether it is a the laser hardening or induction hardening, carburizing, nitriding or the flame spray weld surfacing with different categories of the surface modification techniques.

These will you plan to have the defects maybe in form of cracks, pores, inclusions as per the nature of the process which is being used for surface modification of the component. Then there are like say another kind of the properties that also affect the tribological performance of the component and that is about the dimensional properties. Among the dimensional properties like say the surface roughness indicating the extent of the ups and downs peaks and valleys present at the surface primary quantified using the Ra surface roughness parameter.

And another one which also determines the performance of a modified surface is significantly is the thickness or depth of the modified region or modified zone of the substrate like in some of the cases the modified zone is of very few micrometres like 5, 10 micro metre or even 1 micrometre in some of the cases the modified zone may be further thickness like PVD, CVD will be offering like 1 or 2 or 5 micrometre modified zones.

But there can be the weld surfacing processes which may be offering the modified zone of thickness like 1000 to 15000 to 1500 micrometres depending upon the process the thickness of the depth of the modified zone can vary significantly. Since the have this modified zones significantly determines the capability to sustain under the external load conditions. So, if the load or the stress conditions are very light then maybe very thing coatings will be ok.

But if the the load magnitude to load taken to be taken by the component is very heavy then obviously the modified zone thickness must be high enough. So, it is important that is the surface roughness and the thickness of the modified zones is characterized because it will also be a dictating or determining the resistance of the modified zone against the wear we always want that way of the material is as less as possible and that in turn will be determined by all the set of the properties.

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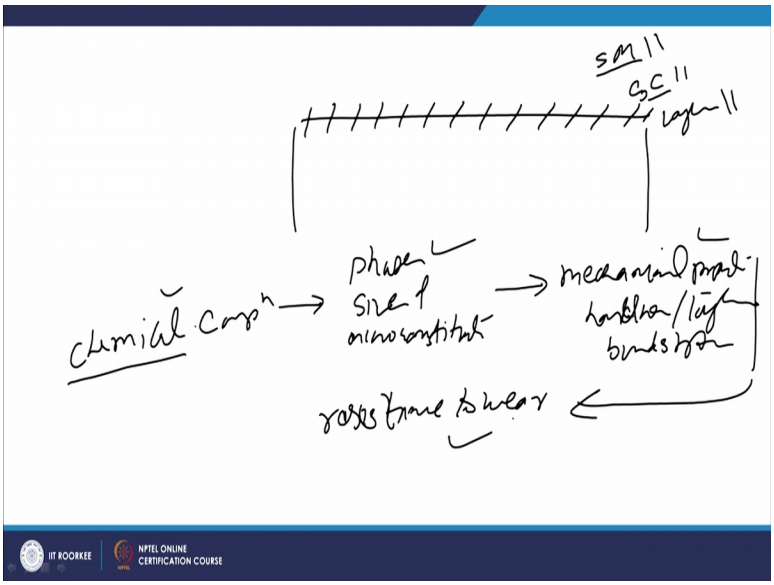

So, whatever is the modified substrate component whose surface like substrate component whose surface is been modified either using one of the processes where is just the surface metallurgy has been changed or surface composition has been modified or a layer of the material has been deposited using any suitable process. There are three approaches whatever the modification has been applied for enhancing the tribological life of the component we need to characterize the surfaces for the set of the properties.

As I have said we need to see chemical composition chemistry of the surface is to be determined. Since the chemical composition directly affects the various phases and the various size of the micro constituents which will be present constituents which will be present at the surface and these in turn will be governing the mechanical properties like hardness, toughness, bond strength etcetera and these intern will be governing the resistance to wear.

So, obviously there is sequential relationship between these set of the properties we need to therefore we need to assess the chemical metallurgical mechanical and then tribological properties of the modified surfaces

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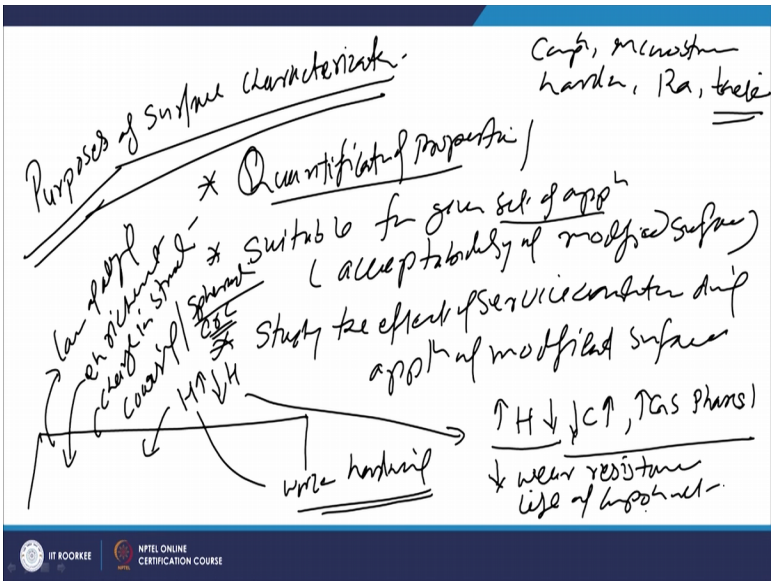

What we have to see so why do we need at all a characterization of the modified surface. So, purpose of the surface characterization or characterization of the modified surface. So, that we can say that 3 important dimensions are aspects related with this characterization of the modified surface one is the quantification of the properties given properties which maybe in terms of decomposition it may be terms of the kind of microstructure and the grain size is it has.

The kind of hardness it has kind of roughness it has what is the modified thickness, thickness of the modified layer. So, all these properties are characterized and based on this we can really take a suitable decision whether the modified surface is suitable or suitability suitable for given set of application. So, basically we try to access the acceptability of the modified or engineered surfaces for a given application.

Weather after the modification it will help us to realise the required goal of improving the tribological life or not suitability of the modified surfaces for a given set of application is assessed after the quantification of these properties. We know what are the values of the various properties and whether it will be suitable for given set of the offer given application or not. There is no more dimensions to this.

It also helps us to study once the modified surface has been exposed to the surface at to the service then under the service how it has been performing that is also to be assessed, so, to study the effect of the service conditions during application of the modified surfaces. And what we basically can observe like if the component has been exposed modified surface has been exposed to the high temperature for longer period.

There can be loss of alloying elements which will be leading to the modification of the chemical composition of the wear surface layer there can be enrichment of the alloying elements also. So, this can be leading to the embrittlement of modified surfaces due to the enrichment like say the carburizing is one typical example of this. Then there can be changed in microstructure due to the prolonged exposure at high temperature change in structure can take place which may appear in form of likes a coarsening or destabilization of the certain phases.

Prolonged exposure at high temperature may lead to the decomposition and destabilization of the surface is leading to the formation of the soft surfaces and like say sporadization. Sporadization in steels one typical example and this graphitisation is another and then formation of the chromium carbide in chromium molybdenum steel and austenitic stainless steel is the another example where in modified surfaces at high temperature are adversely affected due to the change in advance undesirable change in the microstructure of the material.

Then since the structure has been modified for obviously after the service it will be leading to the change in the surface mechanical properties of the surface which may appear in form of increase in hardness or decrease in hardness. Increase in hardness can take place especially if like this surface has been subjected to the carburizing or the work hardening or similar kind of the effects where structural modification is leading to the change in surface properties.

There can be in the reduction in hardness as well if there is being destabilization of the microstructure micro constituents which contributing to the required hardness or there can be the loss of the alloying elements from the surface is leading to the reduction in hardness. So, the chemical composition modification or the micro structural modification this can lead to both the hardening and softening.

In addition to that hardening can also occur in case of the work hardening is the surface layers are being deformed due to the external stresses during the service then it will be leading to the work hardening of the service and that will be changing the surface properties. Any change which is the leading to the variation in properties in terms of increase in hardness or decrease in hardness. In terms of the chemical composition like loss of alloying elements or increase in concentration of alloying elements or coarsening of the grain size like grain size is being coarsened

And or the phases being destabilizer so the metallurgical properties are getting modified due to the exposure during the service conditions all these are undesirable changes can be leading to the reduced wear resistance and once the wear resistance is reduced for a given type of the service conditions that it will be reducing the tribological life of the component for those service conditions. So these are the various purposes and the various aspects that will be leading to the need for effective characterization modified surfaces.

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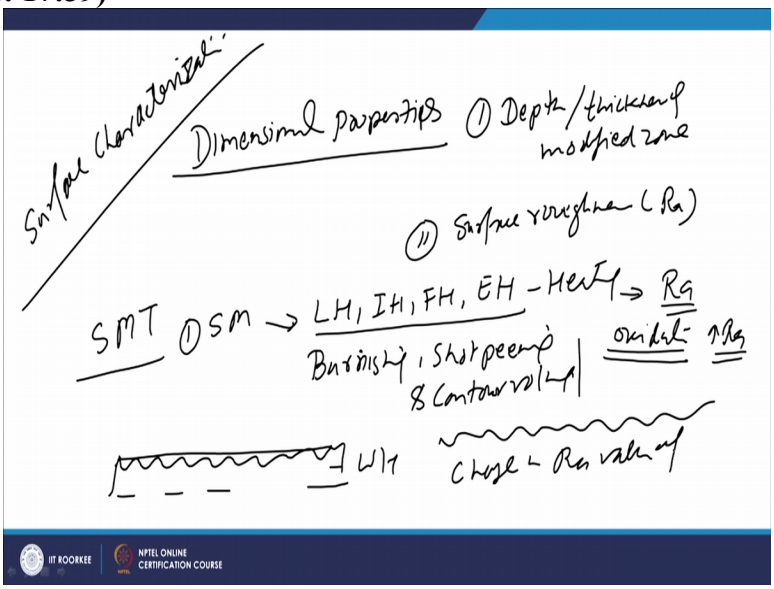

So, will be starting the surface characterization or characterization of the modified surfaces for assessing their suitability with regard to this we will be taking of first of all the dimensional properties. Among the dimensional properties basically there are two aspects about which will be talking one is the depth/thickness of modified zone. And the second one is about the surface roughness that is Ra.

Since we use; since the surface modification techniques vary or changed significantly are there approach is different the basic principles applied for modifying the surfaces are different. And that is why the kind of the thickness of the modified zone and surface roughness vary significantly or they changed significantly with the change of the modification process. For example if we take the category 1 process where just surface metallurgy was used for modifying the surface properties.

Under that we had like laser hardening, induction hardening, and flame hardening, electron beam hardening. So, in these methods; there was; so this is what are the cases where the heat was used

for hardening purpose. In this case we have to just heat it to the austenitic state and followed by the rapid cooling. So, there are no dimensional changes as such this the surface the phases present at the surface layers are modified for improving the properties.

So, there is no reason for variation in the surface roughness in this approach of hardening except that due to the heating if some oxidation is taking place so that will be increasing the Ra value. Otherwise mechanically the surface properties with regard to the presence of surface regularity surface properties are not modified except whatever change in the surface roughness will be taken place that will be happening primarily due to the surface oxidation.

Then there is another group of the processes under this that is where we use the mechanical stresses. For example in burnishing, shot peening and contour rolling. So, in all these cases what we see basically the surface layers are intentionally deformed for to achieve the required work hardening effect. So, that the enhancement in surface properties can be achieved, so, definitely when these methods are applied the kind of the ups and downs present at the surface those characteristics are modified. So, there is always change in Ra value of the surfaces modified using burnishing, shot peening or the contour rolling.

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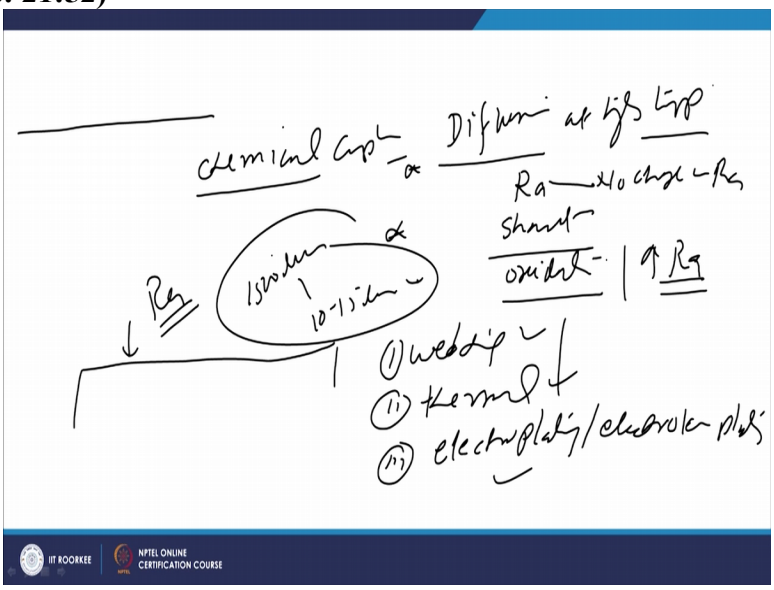

Then we have second category of the methods where chemistry of the surface is modified chemical composition of the surface is a modified. So, where ever diffusion is used by putting the component at high temperature due to the oxidation there is a possibility for change in the surface roughness. While there is there is another kind of the approach diffusion can happen like at high temperature like in processes carburizing, nitriding etcetera.

So, the chances for the change in Ra is very less so no change in Ra. But if surface layers like some kind of the shoot formation is taking place due to the deposition of the carbon or some kind of the oxidation take is taking place and that will be leading to the minor increase in the surface roughness value. There is a third method where a layer of the model required material is deposited on to the surface by various processes.

For example welding, weld surfacing or thermal spraying and then electroless plating and electroplating or electroless plating. So, in all these methods in wherever the complete certificate complete melting are the partial melting is taken place there will be the possibility for the greater roughness and whatever is the roughness of the substrate in the beginning based on the approach of the surface modification whether it is the weld's surfacing or thermal praying or electroplating and electroless plating.

All these methods will be offering the different roughness values and which can vary significantly from like say the 1500 micrometre to the very less value like a 10 to 15 Micro meter. Based on the process being used for surface modification there can be large variation in the surface roughness value. So, it is important considering the application of the modified surfaces it is important that surface roughness is characterized.

And modified accordingly as using a suitable secondary processes like machining, grinding or other surface finishing processes so, that the required improvement in surface roughness. Required reduction in the surface roughness can be achieved so that the components of the surface modification can be used for given application.

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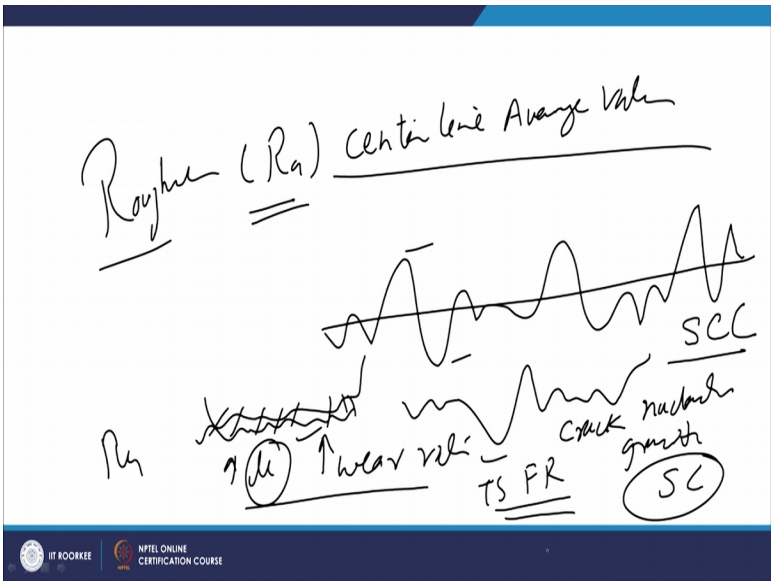

Surface roughness is primarily measured roughness is measured using parameter Ra which is also known as the centre line average value. It is about like they are certain peaks and valleys present at the surface. So, whether reference to imaginary center line average height and depth of these peaks and valley is taken into the consideration for measuring the surface roughness.

So, this is one of the most commonly used parameters for measuring the surface roughness in India. Roughness is important because roughness measurement is important because of the certain reasons like the kind of the unevenness which is present at the surface that will be dictating the kind of bonding which will be there when the when it mattes or in comes in contact with the another matting component.

So, if the roughness is high then the interaction are the kind of bonding between the peaks and valleys and the mating interface is too much and that will be leading to the increased friction. So, higher roughness will be leading to the higher friction and similarly the wear rate is also increased. So, increase in the Ra value will be increasing the roughness as well as the wear rate. So, in order to reduce the wear, in order to reduce the friction coefficient it is required that modified surfaces are of the lower values as lower as the possible.

Or if these are not of the required values then suitable surface modification techniques applied so that the required roughness can be achieved. Apart from affecting the friction and wear behaviour the surface roughness especially the values present at the surface acts as a point of the stress concentration and which facilitates easy crack nucleation and growth primarily due to the highest concentration.

And therefore under the tensile stresses in the surface roughness is more than it promotes the stress corrosion cracking. At the same time stress concentration due to the deeper valley especially these promote; these lower the tensile strength as well as the fatigue resistance of components. So, in order to enhance the fatigue resistance, in order to enhance the tensile strength and reduce the stress corrosion cracking tendency reduce the wear and reduce the friction coefficient. It is important that surface roughness is as low as possible.

So, there are two categories of the methods which are used for measuring surface roughness about that I will be talking in the next presentation. So, now here I will summarise this presentation, in this presentation basically I talked about the need of the characterization of the modified surfaces and how it is; how the characterisation can help in taking the informed decision about the suitability or use of the modified surfaces for given set of the application. Thank you for your attention.