Fundamentals of Surface Engineering: Mechanisms, Processes and Characterizations

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Lecture-56
Surface Modification Techniques: Surface Roughness and Thickness II

Hello, I welcome you all in this presentation related with the subject fundamentals of surface engineering and you know we have started the surface characterization of the modified surfaces to see how effectively the surface modification has been carried out so, that we can take decision about the suitability of this modified surfaces for a given application. So, we have already talked about the importance of the characterization of the modified surfaces. And you have seen that it is good to characterize the modified surfaces in terms of the chemical composition.

In terms of the mechanical properties at metallurgical properties, tribological properties and then we have to see the integrity and soundness of the modified surfaces apart from the dimensional properties like surface roughness and thickness. So, I will be will be starting our; the different techniques which are used for this characterizations of the modified surfaces.

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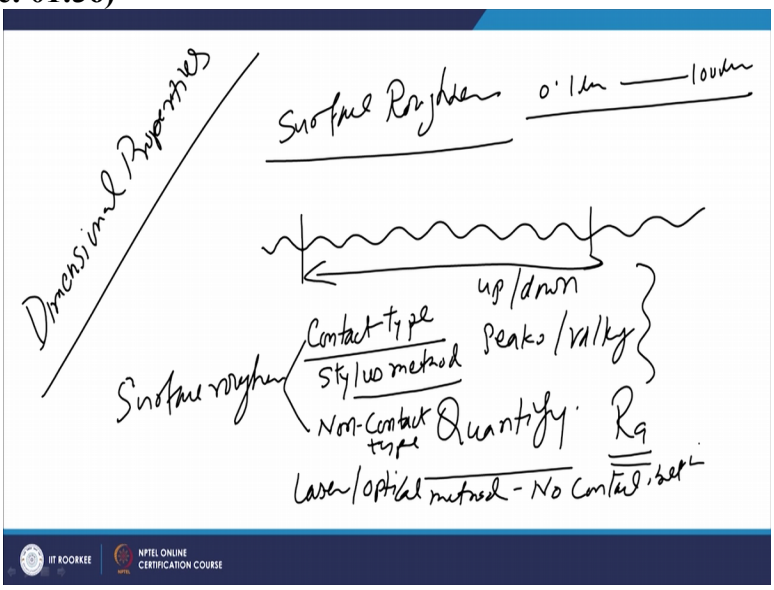

So, will be starting with that dimensional properties of the modified surfaces and under this like the surface roughness will be taking a first. We know why it is important to check the surface roughness so that we can take decision about whether the as modified surfaces can directly be used in a given application or they need secondary processing for improving the for reducing surface roughness and improving the surface finish.

We know the surface roughness indicates the kind of ups and downs peaks and valleys present at the surface. So, such kind of the ups and downs or the peaks and valleys present at the surface they indicate the kind of irregularity is present at the surface and to quantify this, one of the most commonly used parameter is called Ra which is centre line average value of these peaks and valleys.

So, it indicates the height of height average of the height and depth of these peaks and valleys present over certain length that length is called sampling length. So, these length is normally is smaller than this one, we measure what is the height and what is the depth of these values which are present. So, basically the extent of ups and downs present at the surface modified surfaces quantified and disc and very significant leave from say like a 1 micrometre or even less than 1 micrometre to the like 100 micrometre depending upon the surface modification process being used.

There are two board categories of the methods which are used for characterization of the surface roughness. And there are two categories those one is those methods where the contact between the measuring instrument and the surface of the work piece takes place that is called contact type surface roughness measurement. And in this is a category basically we use one stylus based method where stylish is moved over the surface of the component which is to be quantified with regard to the surface roughness.

And then there is another category non contact type method, so in this case basically the light and the laser based methods these are called laser or optical methods are based on the non contact type of the surface roughness measurement. In this case of just like this category reflects there is no contact between the measuring instrument and the surface of the component whose roughness is to be measured. So, we will see what are these methods and how do easy method work.

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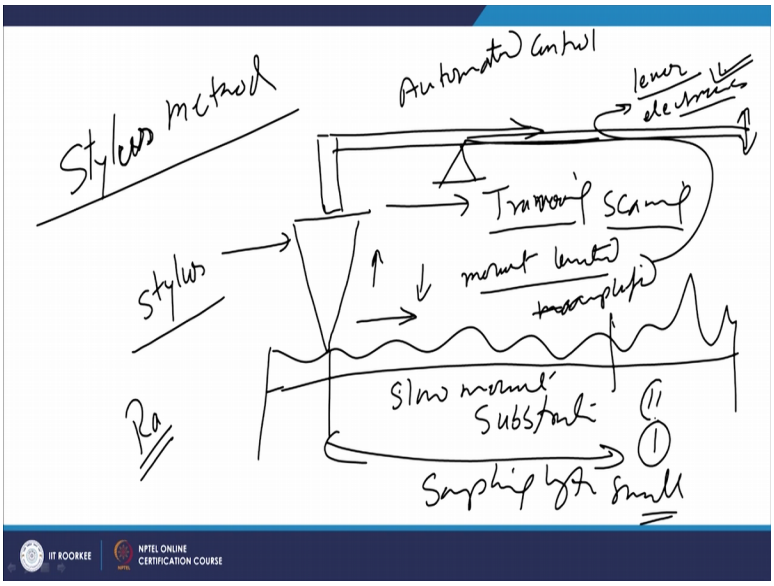

So, stylus based method in this case one pointed stylus small diameter is used and this is stylus is moved over the surface of the component whose roughness is to be measured. So, this is a stylus in very controlled way it is moved over the surface of the component. So, using automated control stylus is moved over the surface whose roughness is to be modified. So, this is the substrate and like say this is the modified zones.

So, at the surface of the modified zone is to be a surface roughness of the modified zones to be measured. So, stylus will be moved over the surface so as soon as it was stylus scans the surface of the component it according to its height of the peaks and valleys stylus will also be moving up and down when it is it will be traversing or scanning the surface of the component. So, this up and down movement while it is scanning the surface is used to quantify the roughness values.

Since the extent of the movement is very limited movement is very less in order to make it measurable this up and down movement is magnified or amplified using two approaches. Both the approaches are used in combination one it uses the lever principle for amplification and then it also uses the electronic methods. So, the extent of up and down is increased using the suitable Lever principle.

So, that whatever little bit up and down movement of a stylus is taking place that is magnified at another and as per the leverage and which is farther magnified using the suitable capacitors or electronic methods so, that we can get the extent of up and down movement of the stylus to the measurable or the quantifiable level so, that the extent of the Ra value over a particular length can be measured.

Since in this case the stylish is moved very slowly over the surface so that it can properly scan the ups and downs present at the surface and therefore answer this one aspect the slow movement of the stylus and the length over which stylus is moved is also very limited. So, this one is called sampling length. Sampling length is a small, so if the surface roughness of the large area is to be scanned then stylus will be used to scan the surface roughness over the number of places.

So, that two things are there one is the smaller sampling length and second slow movement of the stylus. This makes the surface roughness measurement of the large surfaces difficult and that is why;

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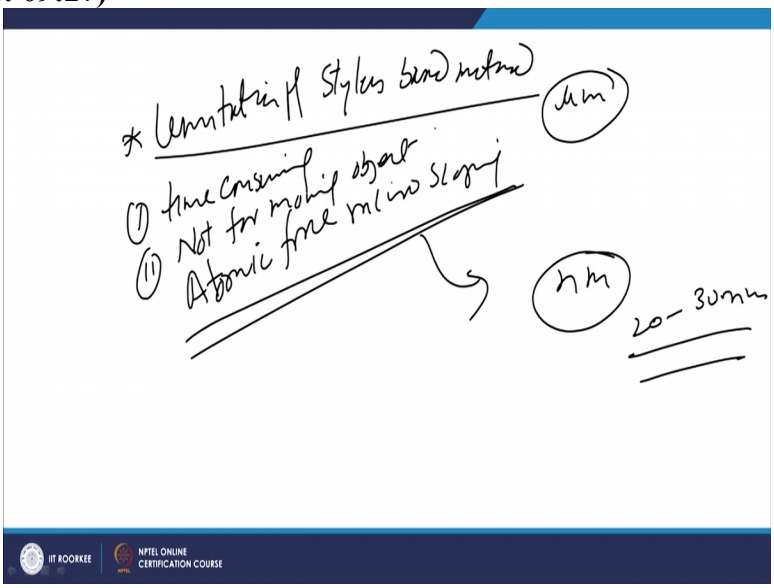

So, this we can considered as one limitation of the stylus based method because it takes time for quantifying surface roughness of the large surface area of the component which is to be characterized. So, I have said this is used for measuring the micro level surface roughness measurement. And if the nano level surface roughness is to be measured then there is another equipment which is atomic force microscopy.

This helps us to measure the measure the surface roughness of lower very low values like it 20, 30 nano meters. But for the micro level surface roughness simple stylus base the surface roughness measuring instruments are sufficient. Atomic force microscope is used for measuring surface roughness of very small area of very high level of the surface finish. So, if we consider the limitations of the stylus method the first one is it is time consuming.

And it needs to be repeated at number of places for the large for scanning the large area because this model sampling length is used in one go. And then it cannot be applied on the moving objects so not for moving objects. Since it requires the contact between the stylus and the surface whose surface roughness is to be scanned or measured then and for that object has to be in a stationary position.

So, that is why this method cannot be applied for measuring the surface of the moving objects. So, these are the two limitations as far as stylus based methods are concerned.

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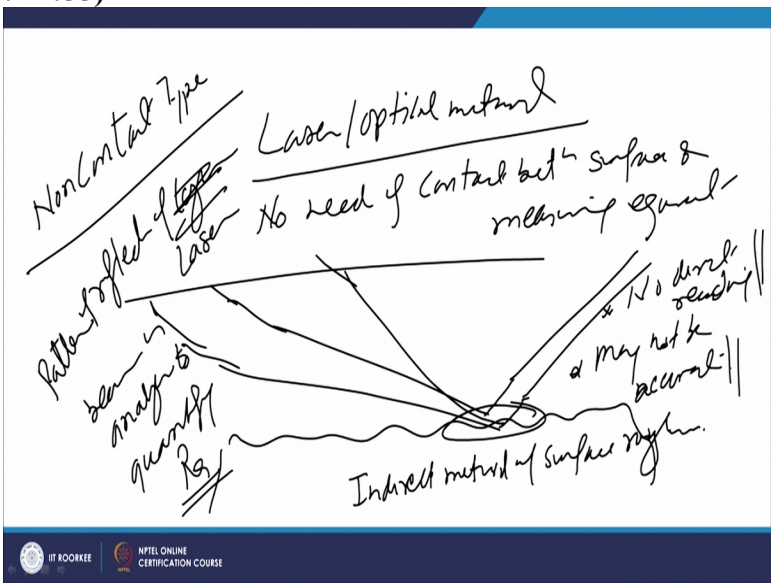

There is another category which is of the non contact type of the surface roughness measurement it uses the laser optical methods. In this case there is no need of contact between the surface and measuring equipment. So, this is one very good side and how does it work like the surface which is to be scanned or whose roughness is to be measured as directed with the beam of the laser. So, based on the kind of ups and downs present at the surface laser will be reflected in the different directions.

And this reflected beam is the pattern of reflection of the laser beam is analyzed to quantify the surface roughness value. So, in this case basically we are not moving any object which is coming in contact with the surface to measure the extent of ups and downs. But then the laser or any suitable light is directed on to the surface of the components. Based on the reflection, pattern of the reflection we try to quantify the surface roughness of the component.

So, this basically is an indirect method of surface roughness measurements. So it may not be accurate. And another issue is that no direct reading it is indirect method of because based on the reflection we try to relate with the extent of surface roughness was presented the surface and then we try to come up with some value of the surface roughness. So, this is indirect method it may not be very accurate and it does not give the direct reading of the surface roughness.

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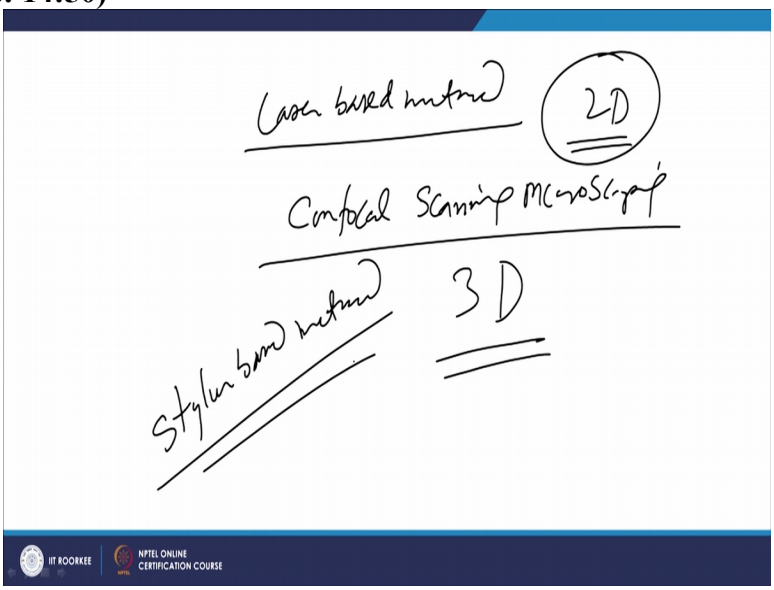

Then basically this laser based method gives us the 2D plot of the kind of the ups and downs which are present at the surface. There is there is one equipment which is called Confocal Scanning Microscope this also a laser based method but this is a confocal scanning microscope is also a instead of the two dimensional variation of the ups and downs present at the surface. This equipment gives a 3 dimensional variation or 3 dimensional patterns of the ups and downs present at the surface.

But most commonly used method of measuring surface roughness is the stylus based method. However it comes with the limitation that it cannot be used for measuring surface roughness of the moving object. While implementation of the stylus best method for measuring the surface roughness little bit difficult as compared to that of non contact based methods.

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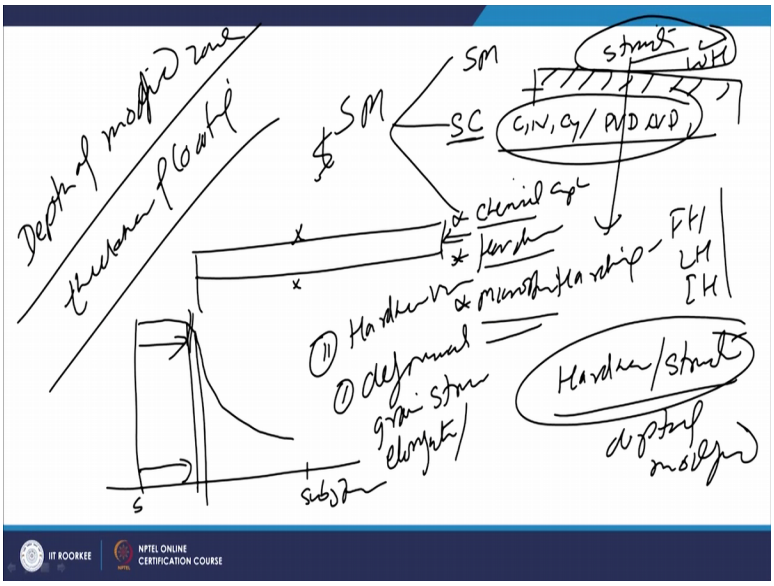

Now will see how to measure the depth of the modified zone or there is the thickness of coatings. So, there are basically the different principles which are involved like we have seen that the surface metallurgy surface modification we can carry out using three methods. One surface metallurgy is modified so just the near surface layer either structural modification will be carried or it is work hardened in the both the cases either structure is modified or work hardened in work hardened based methods burnishing and shot peening.

So, to quantify the depth of the modified zone in case in this case where the hardening transformation, hardening is used like a flame hardening, laser hardening, induction hardening. In these methods basically the combination of the hardness and the micro structural variation is used to quantify the depth of the modified zones, so, it combines the two methods to really arrive at the depth which has been modified using the hard transmission hardening based methods like the flame hardening, induction hardening and the laser hardening.

On the other hand if the work hardening is been used then we have to see the extent up to which the plastic deformation has been realised. So, the grain structure which this we can realise from the grain structure of to what extent does the elongation or the grain structure has deformed and the second parameter which is used to quantify the depth of to which modification has taken place in the work hardening these methods like burnishing or contour rolling or shot peening.

So, in that case we also need to measure the variation and if we see in both these cases if we measure the hardness from the surface it to the substrate then hardness will be variation will be

like this. So, this is showing the extent of to which the surface either microstructure has been modified in the laser hardening or the distance up to which the work hardening has taken place. There after its magnitude will be decreasing.

So, this is how we can quantify the depth up to which the surface modifications has taken place in case of those methods where does the surface metallurgy is modified. Then we have the another category of methods like the surface composition is modified using like carburizing, nitriding, cyaniding or likewise there are other methods where PVD or the CVD methods used or ion implantation is used.

In all these cases these methods based on the chemical composition modification. So, the depth of the modified surface in this category of the methods of the surface has been modified using 2nd category of the methods then there will be changed in chemical composition of the surface layers. Like this is a depth which has been this is the depth of to which the modification has been implemented using any of these methods like carburizing, nitriding, cyaniding, PVD, CVD or any other methods.

Then for this purpose primarily we have to measure the chemical composition modification. So, we can perform the line scan from surface to the subsurface zone and see that the distance of two surface modification of the required level has been realised. Apart from this is also can be confirmed through the hardness measurement if the some chemical composition has been modified up to the required the depth and has delivered the expected change in terms of the improvement in surface properties like the hardness.

It can also directly be measured with the help of the micro structural variations. So, these are the 3 parameters that we can measure to see or combination of all these three will give us the better representative picture of the modified depth of the product of the modified zones using the chemical composition based methods and in case of the third category of the methods where a layer is deposited at the surface we need to measure the thickness of the modified like this.

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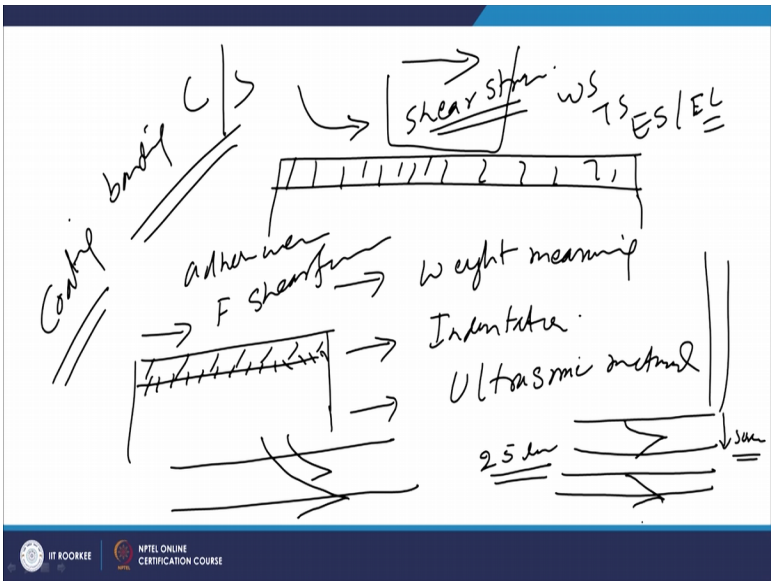

To measure the thickness of the modified layer like this is a substrate and this layer has been deposited either by the weld surfacing or thermal spraying or like electrolysis or electroless process electrolysis process. In all these cases thickness of the layer or the coating is to be measured. So, for measuring that there are 3 methods which are commonly used these are like these methods for measuring the thickness includes light weight measurement, then second is the indentation and third is the ultrasonic method.

So, why it is important to measure the thickness? It is very important to measure the thickness of the modified zone thickness of the coating because in case of the coatings wherever layer is deposited we need to see that the bonding between coating and substrate is good. Why because whenever a component is put in use where and the surface is modified surfaces are interacting with the other components interact with other components or other medium where the shear stresses are acting at the surface.

Like during the abrasion during the adhesion and like one component modified surfaces mating with another component and there is a relative movement between them. Then the modified zones the layer which has been deposited will be under the especially like say adhesive wear conditions. The surface due to the friction force experience is the shear force and because of the presence of the shear force the shear stresses will be acting in the modified zones.

And because of this, if the shear stresses magnitude is maximum at the interface level then it interface means coating substrate interface then the chances for the removal or delimination of the coating from the substrate will be very high. And that is why like say for the given loading

conditions if the maximum shear stresses are acting within coating then its fine from the coating can sustain the shear stresses.

But if the maximum shear stress level is acting is occurring at the interface then chances for the removal of the coating from the substrate becomes high. And therefore in light of the location where the maximum shear stresses are acting in the modified zone we need to take decision about the thickness of the modified Zones. For example if the maximum shear stress is occurring at 25 micrometre below the surface.

Then it will be appropriate to have the coating of 50 micrometre so that the maximum will be accruing within the coating itself. If we deposit the coating of the 25 micrometre thickness only then the maximum stresses will be acting only at the coating substrate interface and that in turn increase the chances for the denomination of the coating especially during the surface especially during the service.

So, we should that take proper decision about that does the depth up to which thickness which is to be achieved after the surface modification, so, that the maximum shear stresses do not occur at the coating substrate interface. Now quickly I will go through the different methods which are used for measuring the surface; thickness of the modified surface.

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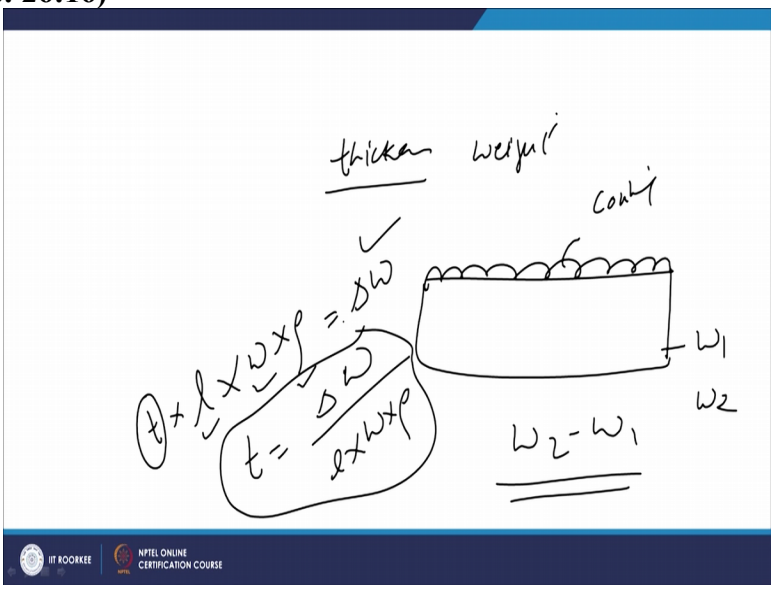

So, one is for thickness measurement we use the weight method. So, in this case the component which is to be whose surface is to be modified its initial weight is taken first and then after the modification again we take the weight of the component and difference of these two will be

indicating the weight of the kind of the amount of the material which has been deposited in form of coating.

So, if we have the length of the coating and if you have the width of the coaching for a given material having the density and then change in weight, so which dimension is left now is the average thickness. So, if we have the data about the weight gain due to the development a of coating. If we have the information about the density, if we have measured the length and width of the coating then average thickness of the coating deposited can easily be measured using this weight gain method.

So, this is how we can we can calculate this again the indirect method of measuring the thickness for weight gain method is the applied for being the sample for the substrate before and after the coating is applied for measuring the thickness of the coating. So, now here I will summarise this presentation, in this presentation basically I have talked about the two aspects one was the surface roughness and their two methods for measuring the surface roughness one is the contact type and another is the non contact type.

Contact type is one of the most commonly used as it gives direct reading of the surface roughness value. While non contact type methods are good for measuring surface roughness of the moving objects. However this method may not be very accurate and then we have also talked about the different methods of measuring the thickness of the modified zones and there are two more methods of measuring the thickness of the coatings about that will be talking in the next presentation. Thank you for your attention.