Fundamentals of Surface Engineering: Mechanisms, Processes and Characterizations

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Lecture-07
Scope of Surface Engineering

Hello, I welcome you all in this presentation related with the subject fundamentals of surface engineering and we are talking about the introduction of the subject as a whole. In the previous presentation we have talked about the different factors based on which surface modification techniques can be compared as well as what are the things which fall in under the a scope of the surface engineering.

So, there were 4 aspects as we have seen 1 was the design of the required properties for given purpose and the second was the modification of the surfaces using suitable material and processes, third one was the characterisation and investigation of the modified surfaces and fourth one was the application of the modified surfaces among this we have talked little bit about the design aspect of the surface engineering like what are the things we have to keep in mind while designing the properties required in the modified surfaces.

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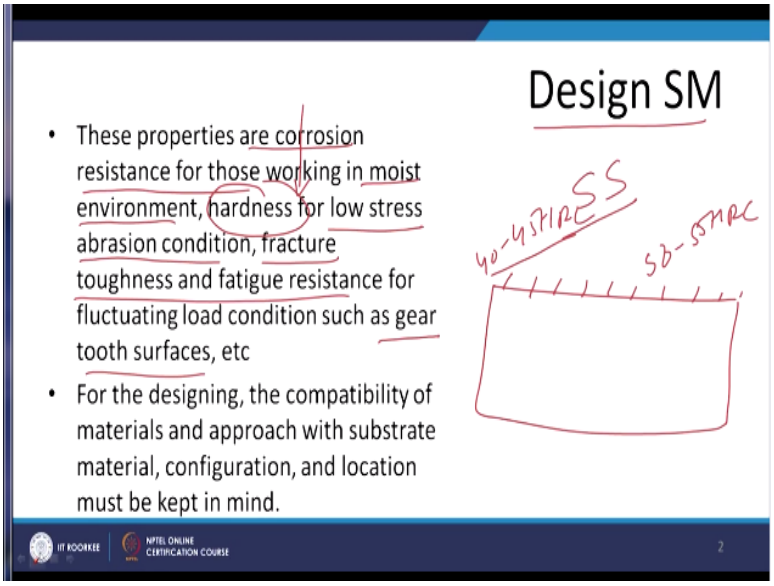

So, in addition to the things which we have talked about the design aspect related to the surface engineering we need to see the like for each kind of situation different set of the properties are

required after the surface modifications. So, that a component can perform the intended function, so like we have said something about what kind of properties are required for the cavitation and adhesive wear conditions.

Similarly, if we need a good corrosion resistance for the longer life of the component working in say moist environment or in chloride environment. Then according to the environment and material we need to select the suitable material, so that it offers the good corrosion resistance. For example for under the normal ambient conditions stainless steel is good, but so stainless steel coatings can be applied onto the simple structurally steel.

Similarly if the component is expected to experience the lowest stress abrasive wear condition, then focus is primarily made on the hardness. So, the modified surface is will be developed in such a way that it has a required range of the hardness which is expected. For example hardness maybe expected the range of like say 50 to 55HRC 1 particular application while for another application it maybe like 40 to 45 HRC.

So, as per the case loading conditions the different kind of the hardness values can be preferred. So, hardness will be the focus will be the identify if the component is expected to work under the lowest stress abrasive conditions. Similarly the fatigue fracture and the fatigue resistance will be important parameters, if the component which is to be modified is subjected to the fluctuating load conditions like gear tooth surfaces.

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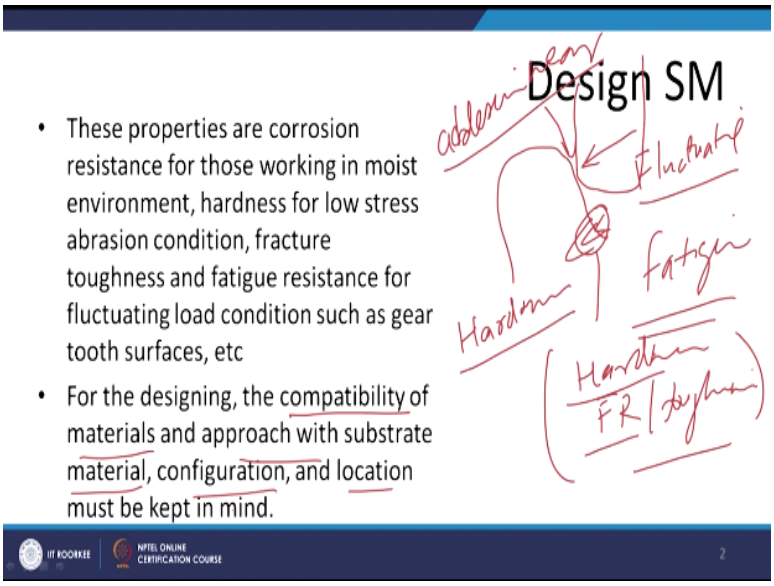

We know that the gear tooth surfaces which will be subjected to the fluctuating loads. So, under the fluctuating load conditions it will be how the fracture will be taking place basically it will be the fatigue fracture. So, for the fatigue fracture it is necessary that it resist the nucleation of the crack and their it is growth is also resistant, so for both these purposes what is important it has required hardness as well as it has required the fatigue resistance and combination of the good toughness also.

So, that it can offer the required resistance for the fatigue fracture at the same time since the gear tooth surface will be messing with the counterpart and there will always be relative motion between the gear tooth surfaces during the operation. So, this kind of the component is always under the adhesive wear conditions, so for adhesive wear it will be required that not just the good fracture toughness and the no fatigue resistance it has, it also has the good hardness.

So, that it can resist the adhesive wear also properly, so for designing the properties target properties the compatibility of the material approach with the substrate material configuration and location, locations are kept in mind.

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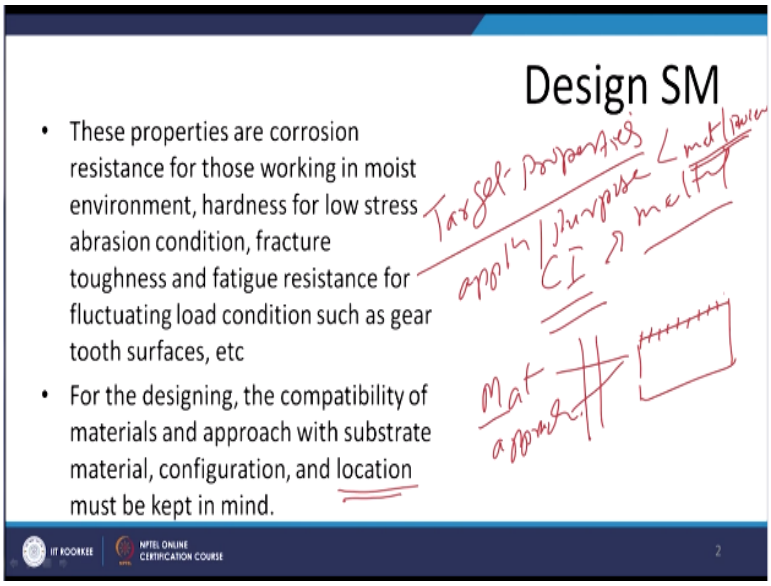

For example if the cost iron is to be modified then melting based approaches are not preferred because they will be leading to the embrittlement and cracking tendency. So, better some other thermally spread coatings or other processes can be applied like laser hardening can be applied on the cost iron surface for improving the wear resistance rather than melting based approaches.

So, when we are targeting the required set of the properties at the same time we also have to keep in mind what kind of the materials which will be used to achieve the required set of the properties what kind of the approach will be used for modification purpose. So and when we are choosing these 2 aspects we need to consider what will be the configuration of the component on which this kind of modifications is to be carried out.

And under what and at which location this kind of surface modification can be achieved whether surface modification needs to be done only in the soft load conditions or in the at the site also surface modification is possible. So, these are the points which we need to keep in mind but at the design stage primarily will focus on the identification of the target properties.

And this target properties are identified in light of the applications or the purpose for which the surface modification is carried out whether it is for improvement in surface properties or for bringing in something a new set of the properties. If it is about bringing something new kind of

properties then which kind of material can offer and which process is to be used for those kind of the new surface properties.

And same is true for your enhancement of the surface properties like if the low quality material is there then which good quality material will be able to offer the required set of the properties that is selected.

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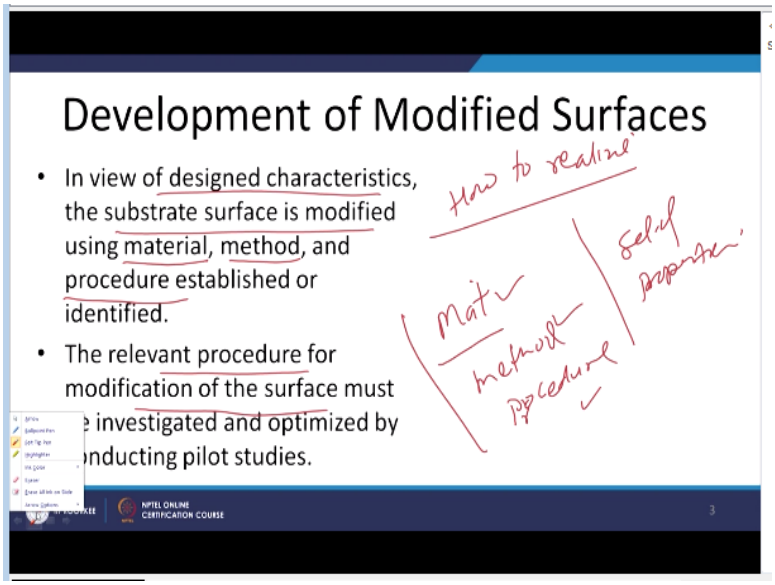

So, after identifying the required set of the properties in light of the application in light of the service conditions the kind of improvement in surface properties required will be looking for how that can be achieved. So, how after identification or joining the properties required how to realise those properties that is what is done in the second stage.

So, what we do in view of the design characteristics the surfaces of the substrates the substrate surfaces modified using the kind of material, method and procedure. So, what we have to do, which material is to be used for the surface modification which method is to be used for surface modification. And using that method what procedure will be followed, so that we are able to realise the required set of the surface properties for required improvement.

So, this is what is done at the design stage we identify whatever at the design stage has been identified with regard to the properties required will determining the material, methods and the

procedure. So, that we can carry out the required surface modification, so relevance procedure for modification of the surface must be investigated and optimised at this is stage say we have got through.

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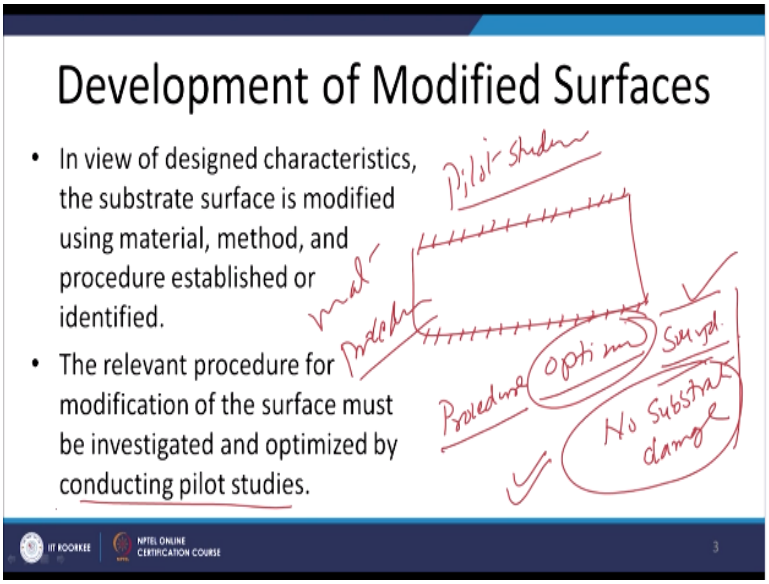

In this stage we have identified okay on the mild steel surface will be applying this austenitic stainless steel material. So, that it is a either hardness or the corrosion resistance can be enhanced, so but which method will be using whether it will be mechanical method like accumulated roll bonding or it will be well surfacing or it will be thermally spraying because the same material also can be deposited can be applied using the different methods.

So, which method will be using for a given purpose with that is to be investigated, so first the procedure is optimised, procedure optimisation is important to see that surface is sound means it is free from the defect and no substrate damage or the minimum substrate damage. So, required soundness and required and minimum possible damage to the substrate is achieved, so procedure of the selected process is established through the optimisation of the various parameters.

So, for this purpose various pilot studies will be conducted since the processes are different, so steps to be followed by the different processes will also be different and that is why some pilot studies are conducted to see that our modified surfaces or sound and there is no measure damage

to the substrate of the component and the that is why the material and the procedure establishing is one of the important aspect at this stage.

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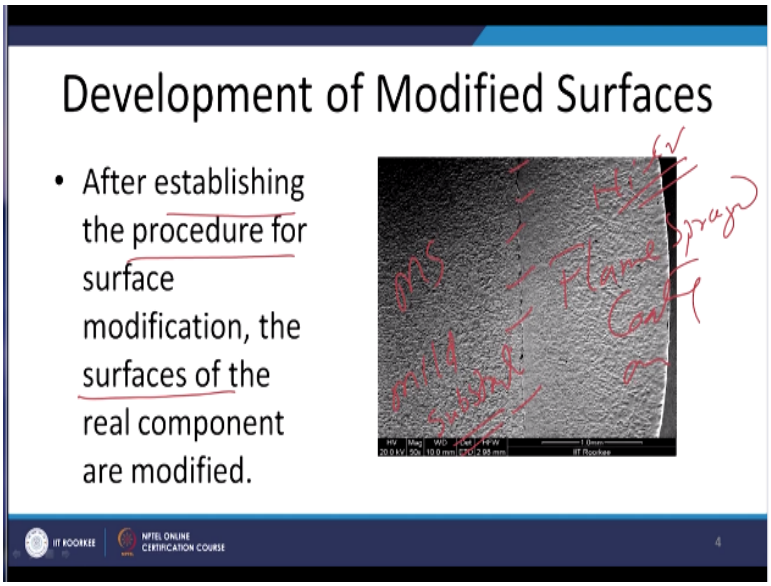

Say in this case after establishing the procedure for surface modification, surfaces on the real component are applied say this is an example where the flame spread coating is applied on the mild steel substrate for improving the wear resistance. In this particular case say Nickel Chromium based coating was applied through this is the interface of the coating this is the mild steel.

And this is the Nickel Chromium based coating to see that up to what extent improvement in the life of the component takes place when it is subjected to the adhesion or for the high temperature conditions like oxidation.

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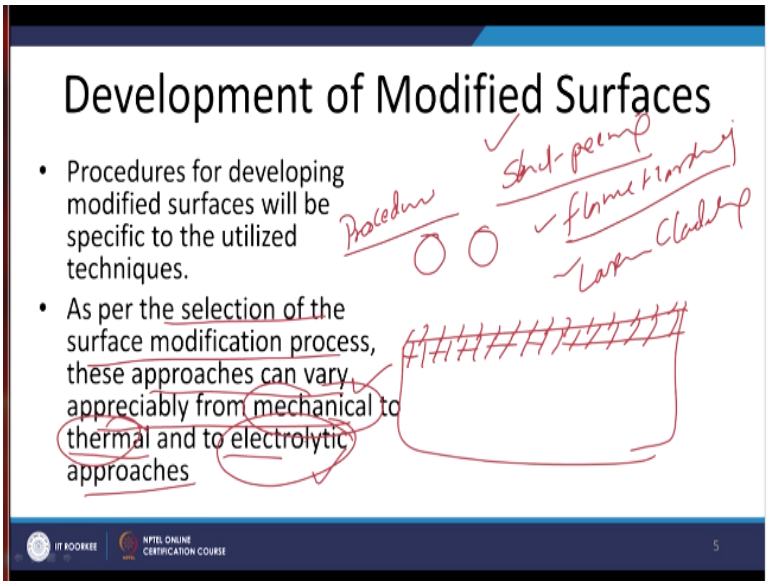

So, whenever the procedure is established which will be unique to the particular process. For example if it is the short peening for so short peening for surface modification to develop to increase the surface hardness to induce the residual stresses, short peening it will identified what size of the balls are to be used at what velocity they will be directed on to the surface. So, that the required depth of the surface is modified and improvement in properties can take place, so this is 1 aspect.

Secondly say if it is the flame hardening then will be identifying which kind of the flame is to be used at what speed it will be moved. So, that the material below the surface is heated to the temperature followed by the water quenching, so that it is harden to the required depth. Now similarly say in case of the laser cladding will be identifying like will be putting the material to be applied onto the substrate followed by moving the laser in very control is so, the melting of the substrate as well as the coating material takes place and after fusion of the 2 1 coherent and sound layer is formed.

So, if we see as per the process to be used the steps will be very different and unique to the each process. And those steps need to be identified exactly in the way it will be applied on the real component, so, that the surface which modified surface which is free from the defect and having the required set of the properties can be achieved as per the selection of the surface modification process these approaches can very appreciably from the mechanical, thermal to the electrolytic.

So, we know that electro if it is the electroplating the procedure or steps are different than the accumulated roll bonding which is used for again in cladding purpose and if it is as the laser hardening then which kind of material can be subjected to the laser hardening we need to see that it has required hardenability high carbon steel or medium carbon steel. So, that simply laser hardening or flame hardening methods can be applied.

So, as per the method whether it belongs to the mechanical category or thermal category or the electrolytic category. We need to identify those unique specific procedure a list steps those procedural steps will be identified through the pilot studies on the coupons or in this the small size components and once we are able to establish the different procedural steps for the process identified the surface modification will be applied onto the real component.

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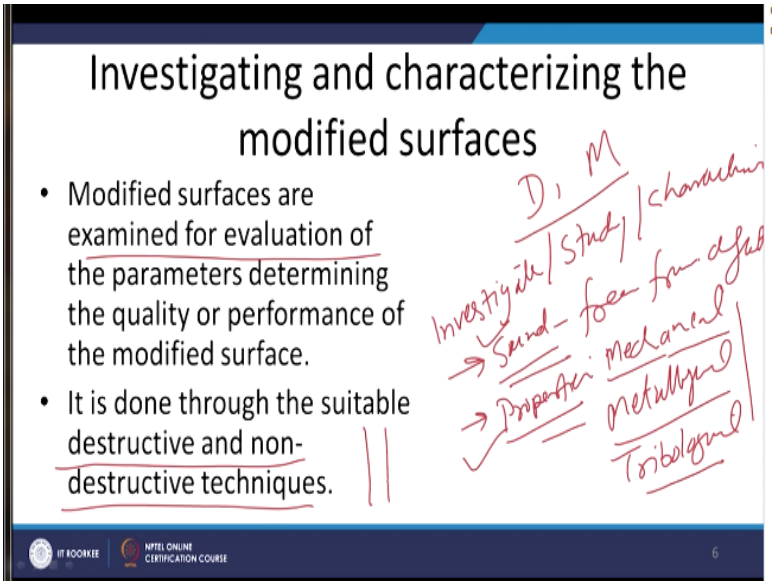

The third step of the surface engineering is the after the designing and modification of the surfaces say modified surfaces have been developed. We need to investigate, we need to study and characterise, characterisation is done for certain things like whether the modified surfaces are sound or not which means they are free from defects. There can be porosity, there can be cracks inclusions there can be too much distortion of the base metal.

So, we need to see really if there is any kind of issue or not, so soundness assessment then property assessment as per the requirement or the target properties whether the target properties have been realised, if it is a set of the mechanical properties then what is the hardness, what is the kind of the bond strength. So, those are established then we also be looking for the meteorological properties.

If there is any issue with the meteorological aspects will be looking for the tribological properties because these will be governing the life of the component under the wear conditions. So, will be conducting the suitable adhesive wear test, erosive wear test or the abrasive wear test, corrosion test as per the requirement or interest will be conducting the different tests to see if the modified surfaces will be able to offer the required set of the properties on the application of the surface modification on the real component.

So, modified surfaces are examine for evaluation of parameters those parameters are evaluated which will be determining the quality or performance of the modified surfaces. So, quality means soundness and the kind of properties it will be offering because these aspects will be determining how good the modified surfaces will be in terms of the performance under the real surface conditions.

And for this purpose we apply various destructive and non-destructive techniques, so that we are aware of whether the modified surfaces are good sound or it posses the required set of the properties mechanical, meteorological, tribological, corrosion or any other set of the properties which is expected from the functional surface. So, once we have those properties will be confident that yes it can be applied into the real component surface.

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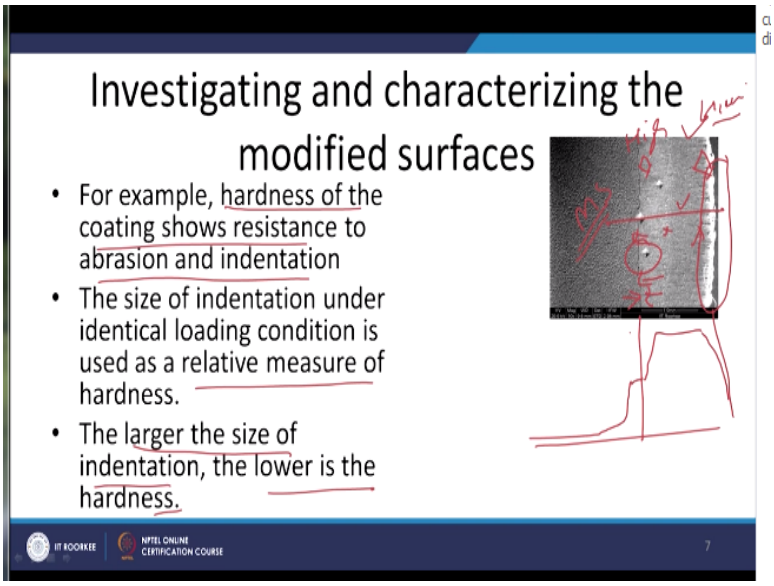

Now I will give just few examples with regard to the investigation and characterising the modified surfaces. For example 1 modified surface as I have said that the 1 coating applied onto the surface of the mild steel, so we need to see if the coating is having required bonding with the substrate or not otherwise it will be peeled off during the application or it is having the required hardness or not.

So, what we do hardness is checked at different locations to see if it is having the required uniformity or if there is any kind of re ability in terms of the hardness if it is to be used under the wear condition. So, hardness of the coatings shows the resistance to the abrasion and indentation that is what we know from the hardness definition and the size of the indentation shows the indicates the hardness value greater is the size of the indentation lower will be the hardness.

So, size of the indentation under identical loading conditions is the relative measure of the hardness, larger is the size of indentation, lower will be the hardness. So, if the indentation size is more at the surface and less at the interface will suggest that hardness here at the interface is high then at the surface and that is why hardness across the interface is measured at different points to see if there is any kind of the variation in hardness.

Normally what we see this is the base metal hardness near the interface we may see some increase in hardness like this and then there may be certain increase in the hardness at the

interface and then hardness will be dropping near the surface. So, because some of the alloying elements are oxidised or lost from the near surface layers, so hardness we know generally find lower at the surface.

Similarly hardness is somewhat lower at the interface because of some kind of with the dilution possibilities or diffusion of alloying elements from the modified surfaces, modified layers to the substrate. So, the maximum hardness we find somewhat in between in the middle of the surface coatings like in this particular example, so will be having somewhat lower hardness at the surface. And once this external layer is removed will be having very good performance of this modified surfaces.

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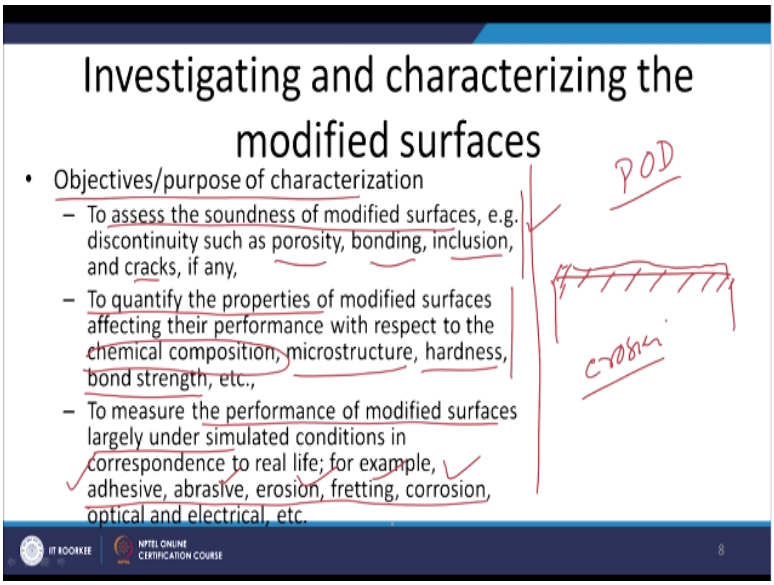

So, what we try to find out and try to study under the investigation and characterisation is stage of the modified surfaces what are the purpose is of. So, purpose order to the objectives of the characterisation we really want to achieve something although this is ridden and because it will not be leading to development of anything but it will simply ensure that whether the developed modified surfaces were as per expectation or not.

And if it not if these were not so then we have to repeat it again, so what is the objective or the purpose of the characterisation it will help us to assess the soundness of the modified surfaces with regard to the presence or absence of it is continuities in form of porosity, bonding,

inclusions or cracks if they are present at the surface, presence of these defects will simply grade the modified performance of the modified surfaces.

And so our objective of enhancing the performance and functionality of the component will be defeated that is why it is important that modified surfaces are free from the discontinuities. We also want that whatever modified surfaces are there, they have required set of the properties as designed as identified in the designed stage and that is why modified surfaces are characterised to quantify the properties.

In respect of whether it has desired composition or not what kind of micro structure it has with regard to the size, shape and type of the phases which are present, what is the kind of hardness what is the kind of bond strength of the modified surfaces are there. So, once we are having the quantified value will be ensured that yes if these are the characteristics of the modified surfaces.

Then whether it will be able to offer the required performance during the actual surface or not, so quantification of the modified quantification of the properties of the modified surfaces ensures as that modified surface will offer the required or expected performance or not and the third objective of investigating and characterising the modified surface is to measure the performance of the modified surfaces largely under the simulated conditions.

So, once the modified surfaces are developed will be running the test under the stimulated condition like a component is subjected to the adhesive wear then will be performing the sliding wear test 1 of the most commonly used test is the pin on disc(POD) test. Then pin on block also is their block on ring is also there the various kind of the test which are conducted then there is erosion test which is called solid particle erosion there can be cavitation test.

So, as per the requirement will be conducting the test on the actual modified surfaces to see how it will perform if it is placed in the real application. So, performance of the modified surfaces can be measured according to the application. So, suitable test will be conducted for that purpose whether it is adhesive test, abrasive test, erosive test or fretting wear test, corrosion or determination of that optical and electrical properties of the modified surfaces.

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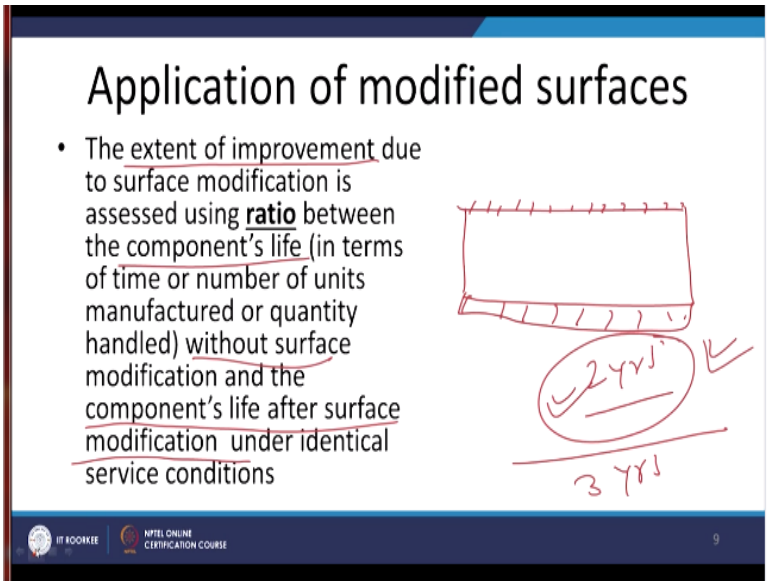

The fourth aspect of the scope of the surface engineering is about the application say there is a 1 component which under the actual surface conditions lost just for the 2 years and after the 2 years it loses it is dimension to such an extent that it needs replacement. So, we would like to do the surface modification and of surface modification whether it is like say the laser hardening or the development of some kind of the coatings over the surface.

Both these are the 2 different types of the surface modification approaches and of the surface modification of the component which was losing it is life after whose life was just 2 years and after that it was to be replaced. So, after the surface modification we need to see what is the extent of improvement in the life after the surface modification. So, again after surface engineering of this component will putting under the identical conditions and will see that what is the life of the component.

Now life of the component we can measure in number of ways like how many hours say it is lost, how many components it is produces during the use and what is the actual working what are the actual working hours for which it is last, so likewise there can be number of ways to identify the life of component. So, what is the life of the component when there is no surface modification.

And what is life of the component after the surface modifications that is what is compare, so after the surface modification if we find that it lasts for 3 years. Then which means so this ratio is use to quantify the extent of improvement which is taking place due to the surface modification. So, extent of improvement due to the surface modification is obtained 1 using 1 ratio, the ratio between the life of the component without surface modification.

And the components life after the surface modification under the identical conditions. So, these are ratio of these 2 is used to determine how much improvement in the life of the component has taken place.

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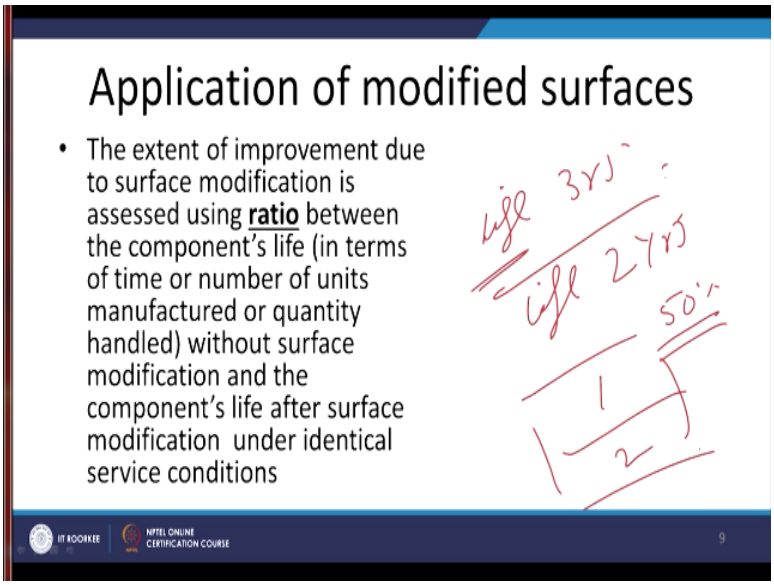

There can be another way also the life of the component 3 years after the surface modification and life before the modification it was 2 years. So, there will be 50% improvement in the life of the component because life has increased by 1 additional year. So, it will like 50% improvement in the life of the component. But it is conventional to say that life of the component without surface modification to that of the with surface modification.

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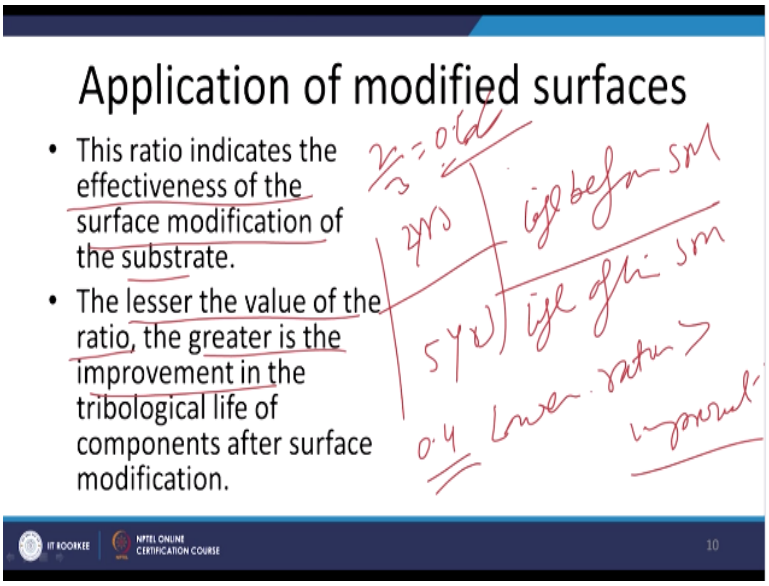

So, this ratio indicates the effectiveness of the surface modification, so according to this definition where life before surface modification and life of the component after surface modification. If this is used so lower is the ratio, greater is the improvement this is the simple thing, so lesser the value of the ratio greater will be the improvement. If the life of the component before the surface modification is just 2 years and after the surface modification it is 5 years.

Then this value will be further lower it will be like 0.4 and earlier case it was like 2/3 when the improvement was of 3 so, it was 0.66. So, lower is the value greater will be the extent of the improvement which will can the assessed through the change in the life of the component.

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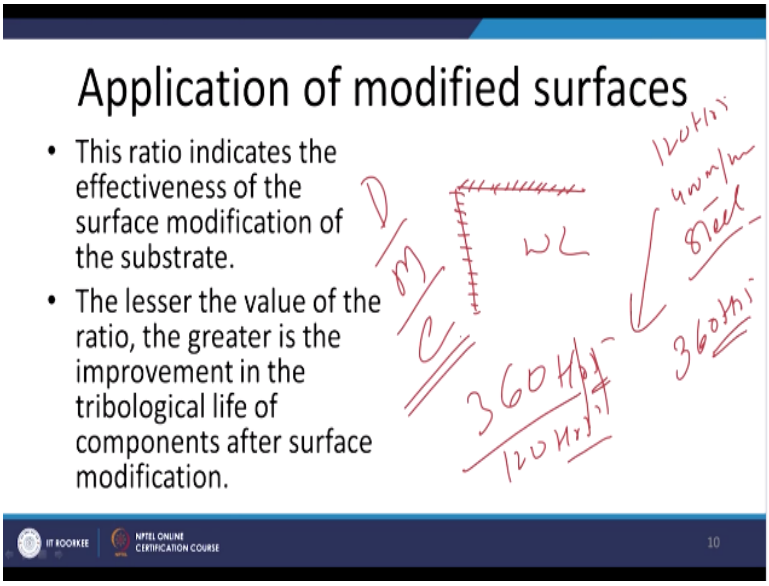

Life of the like say simple tungsten carbide tool sustains the life of 120 hours during the machining at 400 meter per minute cutting speed of the steel. And once the tungsten carbide is modified using suitable titanium, carbide and nitride and Alumina using suitable PVD and CVD coating approaches. And if the life is improved so, like say 360 hours then this life improvement is also 300 times.

Because 360/120 hours, so here the life of the cutting tool expressed in hours and the life of the tool after the surface modification like PVD, CVD coatings. If it is 360 hours, so there has been 3 fold change in the improvement. So, once we have designed once we have modified and characterise the surfaces and the same is replicated into the real component, so that we can get the required improvement in the surface life of the component or improvement in the functionality of the component.

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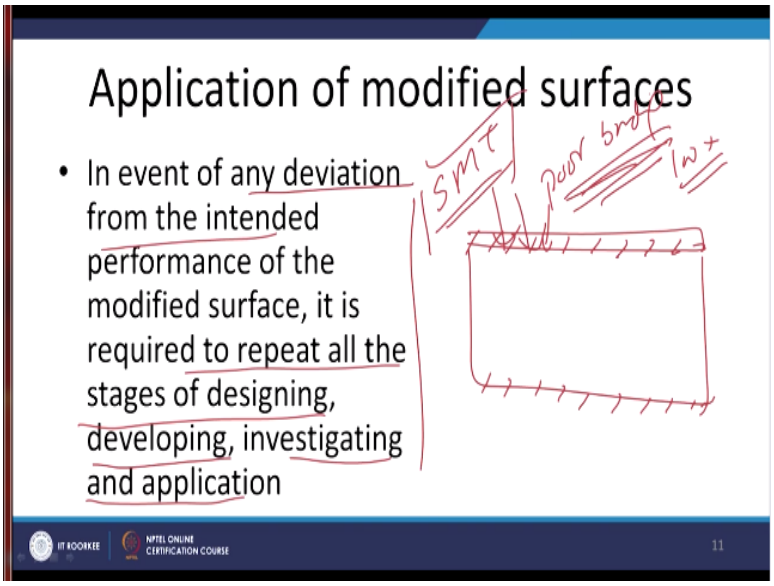

In the event of any deviation from the intended surface intended performance of the modified surface it is required to repeat all the stages of designing, developing and investigating and application of the component. Suppose we had expected that application of flame spread coating onto the mild steel substrate will be leading to the improvement in the life of the component by 100%.

But in meantime what has been observed that the coating was delaminated and or removed or peeled off from the surface because of the poor bonding. So, means despite of coating a good material if it was not bonded properly then it will peeled of a our purpose of the surface modification will be defeated which means the modification was not proper. So, we need to go back to our the initial stage, we need to see if the properties are perfect.

But the modification approach or the development modification or the development of the surface modification was not perfect. So, we may have to apply some other method of the surface modification and for that we may up to work more onto if it is a poor bonding is the case then we have to work on the second stage most significantly more properly and effectively.

So, that the surface modification techniques is optimised in much better way, so instead of flame spring we may use some other better technique. So, that our bond strength is better or some other improvement in the flame spring process itself or brought in, so that it does not delaminate

during the actual application. Now here I will summarise this presentation in this presentation basically I have talked about what are the things are usually falling under the scope of surface engineering especially the 3 factors.

One was like the development of the surface modification, second was second one was the investigating the investigation and characterisation of the modified surfaces and third one was the application of the modified surfaces. And under these headings what we have seen that once we have identified what set of the properties or component should have these properties are then realised using the suitable surface modification approach.

And once the surface is modified then will be characterising and investigating to see whether those properties have been realised or not and once if the same is very effect through the characterisation and investigation will be applying the surface modification into the real component. So, that the life of the component can be enhanced, thank you for your attention.