Fundamentals of Surface Engineering: Mechanisms, Processes and Characterizations

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Lecture-06
Comparison of Surface Modification Techniques and Scope of Surface Engineering

Hello, I welcome you all in this presentation related with the subject fundamentals of surface engineering and in the last presentation we have talked about the classification of the various surface modification techniques. Wherein we have seen that there are 3 broad categories of the surface modification processes like 1 category belongs to the processes where no change in chemical composition is used.

But only the structural changes near the surface and surface layers is brought in by the various processes like induction hardening, flame hardening, laser hardening or the plasma hardening. Then there was another category of the processes where the change in chemical composition of the surfaces near surface layer is used to achieve the required properties and the functionalities of the surfaces and the processes which fall in this category includes like carburizing or nitridizing, cyaniding, vanadizing, chromizing.

And then laser cladding sorry laser alloying was an another process and then there was a third category of the processes where a layer is build up onto the surface of the component in order to achieve the required set of the properties. And the processes like the coatings like development of coating and films to the use of thermally spray processes, welding overlays.

Then mechanical methods like accumulative roll bonding and explosion bonding etc., so there were so many other processes. So, if we see each of these processes we using the different kind of principle and accordingly the complex treason control over the processes will be different.

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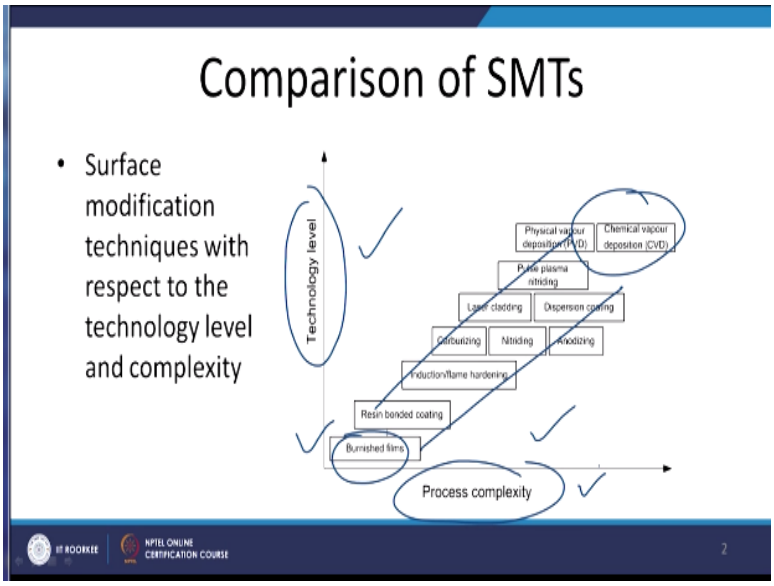

So, that is what we have seen like the kind of technology level which is associated with the these processes which are used for surface modification technique and the kind of complexities involved with those processes they are different and they will keep on changing from one process to another, simplest process is like the mechanical method where burnishing, short peening kind of methods are used for surface modification.

And very complex processes were surface films are made using processes like physical vapour deposition and the chemical vapour deposition and there is a range of the processes in between which are used to modify the surfaces to get that is required set of the properties and these processes will have the intermediate level of the technology as well as the process complexity associated with them.

Now since the each process uses the different kind of the technology and different kind of control systems and therefore the capability of the each process is found to be different. So, if you have to compare the different processes then we need to have certain factors based on which we can compare the capability of the surface modification techniques.

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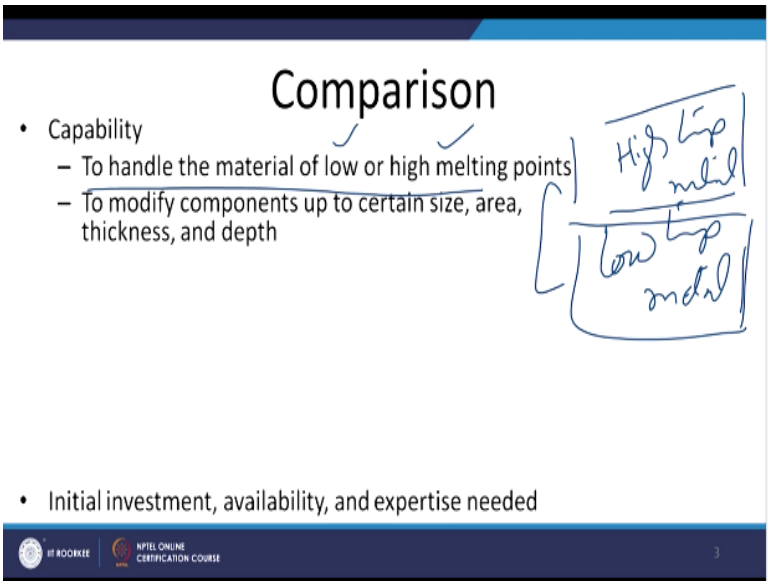

Like the one the point which can be there can be use to compare the different processes based on that capability to handle the kind of material that they can process for surface modification. For example few materials can work only with the high temperature metals few with will be eligible for surface modification of the low temperature metals which means ability of the metal to with it is strength at thigh temperature or low temperature during the surface modification.

Because during the surface modification especially they are some methods which will be generating too high temperature in course of the surface modification like melting will also be facilitated well there are other processes where very low temperature is raised for the surface modification. Because temperature is one of the important points because whenever there is a temperature is high then it leads to the changes in meteorological properties of the material and which in turn can affect the base metal properties also.

So, what is expected from the surface modification techniques is that the rise in temperature of the base metal is as minimum as possible, so that the related thermal dimensions to the substrate or minimum. So, the different processes will have the capability to handle the different kind of the metal systems. So, whether they can handle the low melting point metals or the high melting point metals. And accordingly the extent of damage on the metal properties will be determined.

The second aspect is their ability of the different process with regard to their capacity to modify the surfaces. So, what is the extent of what is the size of the components that they can handle what is the area which can be modified a particular process.

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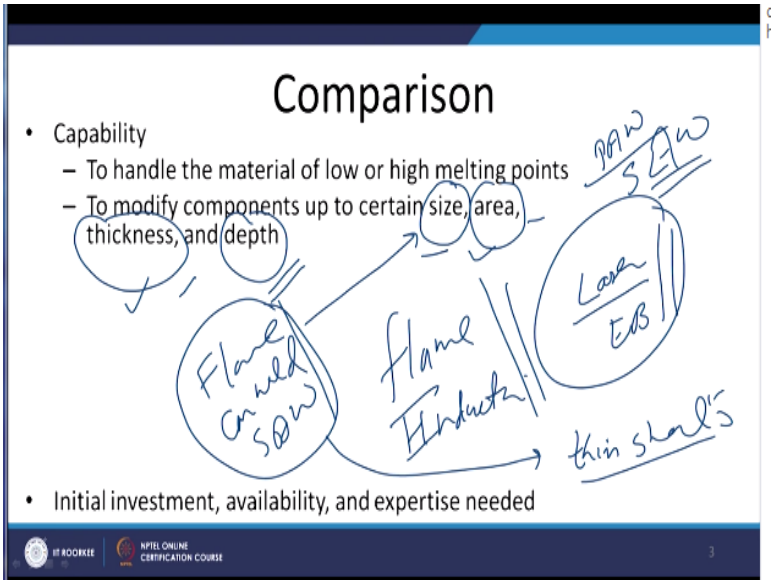

Like what kind of thickness process can work in and what is the extent of modification with regard to the depth from the surface is possible. We have seen that different processes allow the different degree of the alteration in properties as for as the surface depth which is modified by the different process is concern. So, they are certain processes which will be able to modify very small area like the processes which are basically high energy density based like laser or electron beam.

They can be used for modifying the surface properties of somewhat smaller areas as compare to those which are used for like the flame and induction hardening. Flame and induction hardening really can cover the larger areas as compare to the laser and electron beam. Similarly surface modification using PAW will be somewhat a smaller area as compare to that of the submerged arc welding processes for using the well surfacing approach.

So, as per the process they will be able to handle or they will be able to modify the surface properties of the component of the different sizes, different areas, different thicknesses and different depths. For example we will take another example like to use a mechanical methods

component has to be rigid and robust enough otherwise there will be chances for distortion and damage to the component itself in course of the surface modification through the mechanical methods.

Similarly low energy density processes for example flame hardening or like gas welding or SAW welding processes. These processes cannot be used for a surface modification of very thin sheets because these will be these will increase the tendency of the melt through kind of condition. So, and there will be causing the greater tendency for the distortion of the components also. So, with regard to the size, area and thickness the different process will have the different capabilities same as true for the depth also**.**

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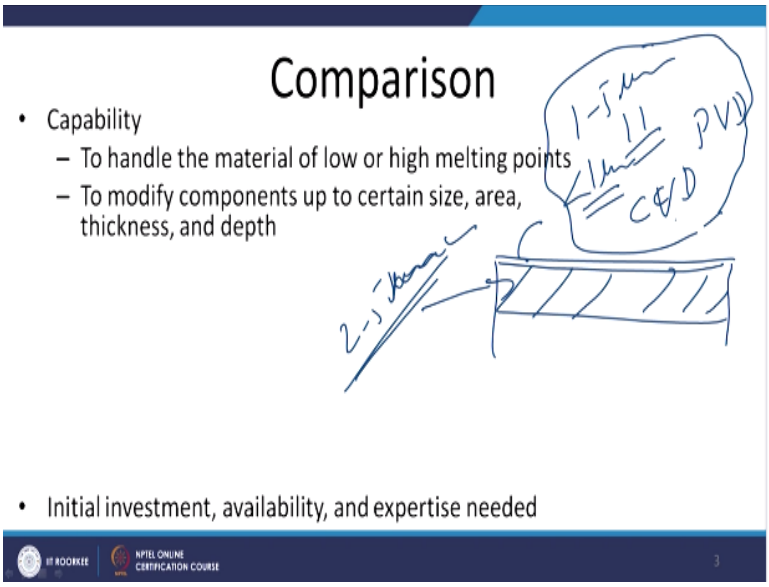

The depth of to which surface is modified that varies with the kind of process, for example like chemical vapour deposition, physical vapour deposition these are the process which can modify very thin layer of less than like say in the range of 1 to 5 micrometer. Then there is a iron implantation method which can modify the depth even less than 1 micrometer while on the other hand the well surfacing methods can be used to modify the surfaces or and can have the modified surfaces up to the depth of like 2 to 5mm also.

So, greater thicknesses can be achieved using 1 category of the methods while other kind of methods can modify and develop the surfaces up to the very smaller and a very less depth.

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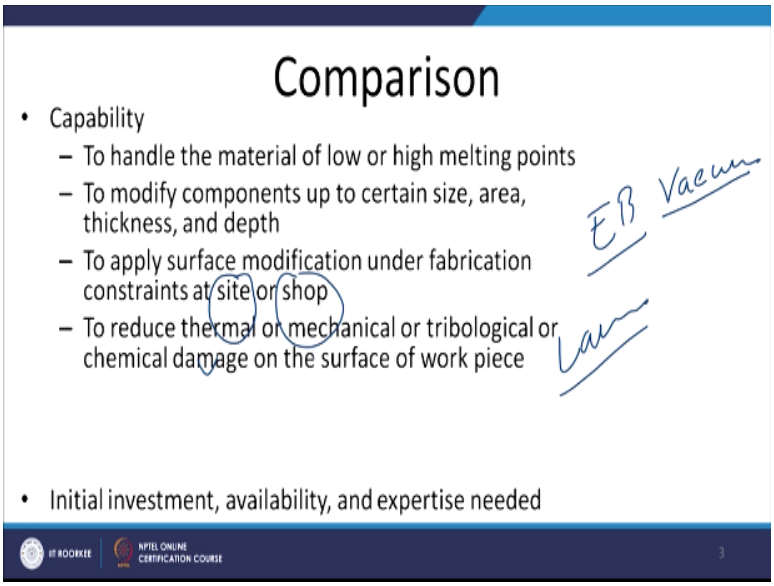

Then there is another point based on which different processes can be carried out like some of the processes which can be executed only under the controlled conditions. For example electron beam, it needs it usually needs the vacuum similarly the laser kind of processes they also can be carried out only at the shop flow, if the modification is to be carried out in the site at the site then it will be difficult to use such kind of methods.

So, depending upon the complexity of the process, process controls and the environment in which it can be use to modify the surfaces, decision is taken like which kind of process we should go for and that will be based on whether the modification by a particular approach can be carried out at the site or it needs to be done only at the shop. So, as per the process the suitable kind of a approach is selected.

So, the different processes will have the different kind of capabilities few can be used at the site and others can be used at the under the controlled conditions of the shop itself. Then as I have said that the different approaches are based on the different principle.

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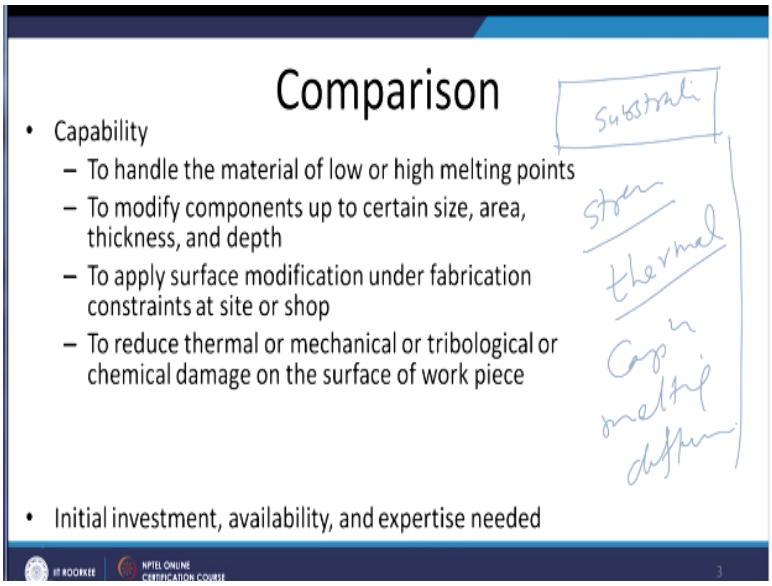

So, few use the mechanical stresses for controlled deformation others will use a like controlled heating followed by rapid cooling under the thermal methods, few use the compositional modification at high temperature and few use melting that is used diffusion as well for modifying the surface compositions. So, since the principles underlying principles associated with the different processes or different therefore the kind of the damage which will be taking place to the substrate like the component which is being modified is termed as substrate.

So because of these stresses and the heating and the melting what is the extent up to which changes in the properties of the substrate itself is taking place that must be considered.

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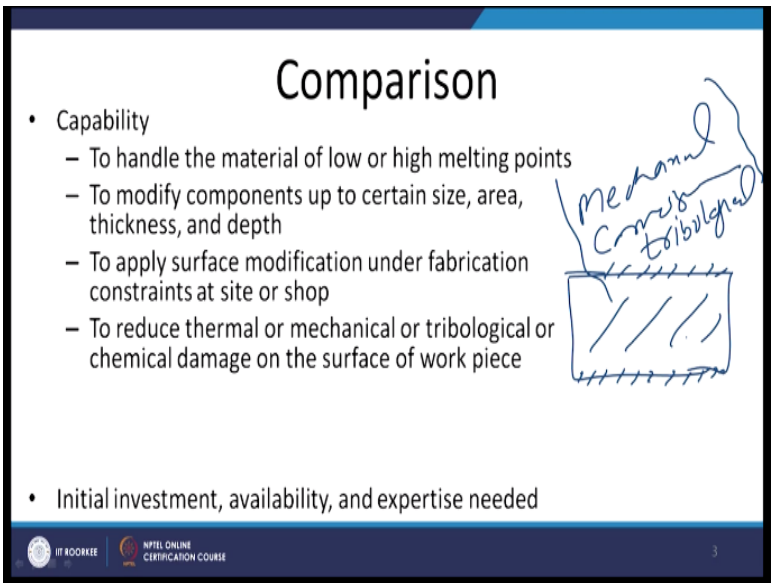

And what is the objective of the component whose surfaces are bring modified using suitable process, the underlying base metal or substrate should not be much affected because of the changes which are being experienced by the component during the surface modification. So, there should not be any major change in the mechanical corrosion and other tribological properties of the component.

Because any alteration or undesirable effect on these properties it will be leading to the reduction in performance of the base metal or substrate of the component itself, so that should be avoided. Otherwise this can lead to the premature failure of the component despite of the surface modification because surface modifications will simply be improving properties of the surface and through the improvement in properties of the surfaces life is improved.

And the functionalities are also improved but if the base metal properties are compromised then it can adversely affect the life of the component also.

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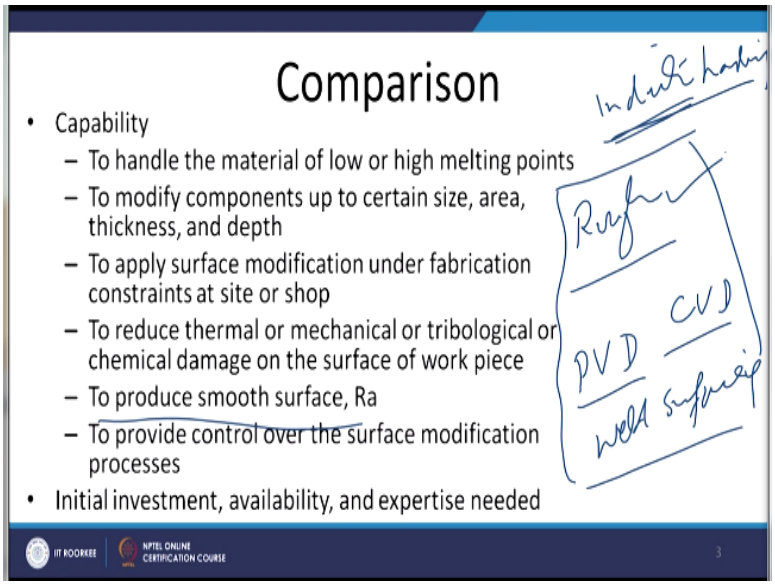

Another important point based on which different processes can be compared is the kind of finish which is offered by these processes like short peening, burnishing these produce very rough surface while there can be physical vapour deposition, chemical vapour deposition and like weld surfacing each process offers the different kind of the surface roughness or surface smoothness.

So, those processes which offer the good surface finish obviously they will preferred because they may not be requiring much post processing for improving the surface finish of the component. But most of the in most of the cases modified surfaces result in the somewhat poor surface finish link processes like induction heating maybe offering the good surface induction hardening maybe resulting in the very good surface finishes compare to the mechanical methods like burnishing and the rolling or as the short peening.

So, different processes can be compared with regard to the surface roughness which is offered by the processes after the surface modification.

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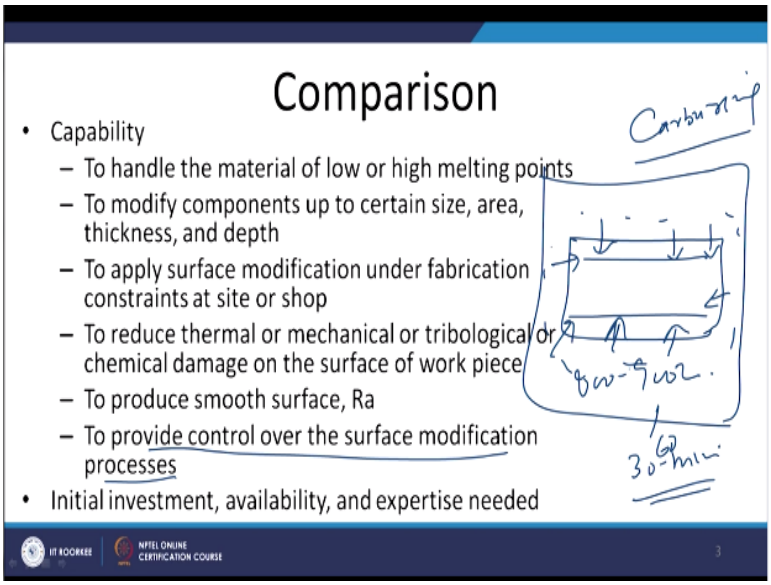

Now another important point based on which different processes can be compared is the kind of control which is there for altering the properties of the surfaces, few processes like carburising offers very poor control over the conditions. Because the sample to be carburized is kept at a high temperature of 800 to 900 degree centigrade for say 30 minute to 1 hour.

And then the carbon rich environment will be diffusing the carbon inside the sample but since the temperature conditions in the different zones can vary and accordingly to will be diffusing to the different depths because temperature directly affects the rate of diffusion. So, what will be the extent of the modification in this kind of process that is not very well controlled in case of

carburizing methods like solid carburizing or a the gas carburizing as compare to the liquid carburizing.

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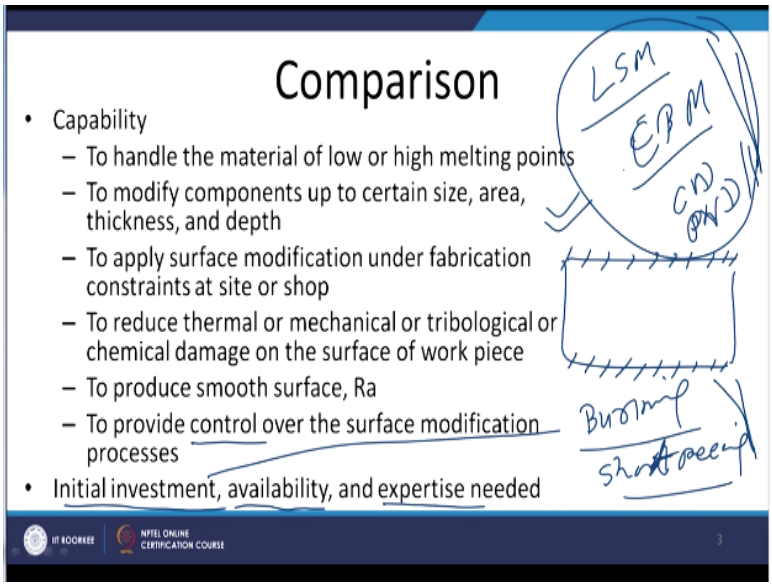

So, they are some other methods where we have very good control over the conditions under which the processing or surface modification is taking place for improving the properties. So, if the control is good will have control over the kind of alteration which is taking place at the surface and that will be leading to the requirement required surface properties for a request improvement or required performance of the surfaces for long life of the component.

The last point which is not which is all the important but it is not technical in nature is the kind initial investment which is needed to have the system for surface modification kind of system which is available also and expertise which is needed certainly is the important. So, like thus the very cheapest methods which require very minimum possible investment is like burnishing mechanical methods short peening thereafter we have short peening.

Then very costly methods are like then we have the laser surface modification approaches where laser is used or electron beam surface modification approaches and the costly methods are also like chemical vapour deposition and physical vapour deposition. So, these are very costlier fares as compare to the other methods which require somewhat less investment.

And these processes also these process although have very good control over the properties, good control over the processes as compare to the other processes. So, these are some of the points based on which different surface modifications processes can be compare with regard to their capability and the kind of investment which is required in terms of the funds which are required for having the set of and the kind of expertise which they will be using.

So, after looking into the various surface modification techniques their classification and their capabilities, now will try to see as a whole the entire scope of the surface engineering what does it include and what are the different things under the surface engineering are carried out.

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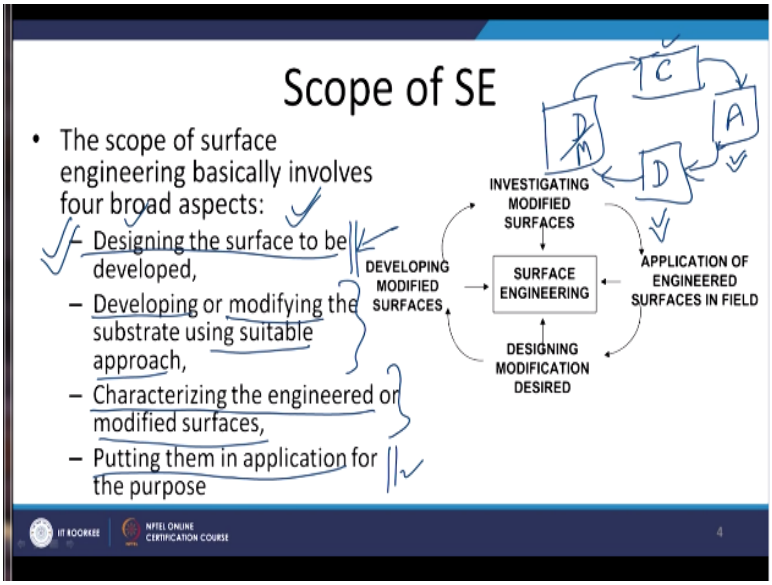

So, if we see this is basically loop kind of situation where which is starts with the designing the surface modification which is a required. Then it is about the development of the modified surfaces and those modified surfaces are thereafter checked or characterised. So, characterisation of the modified surfaces to see if the required design properties have been realised or not.

And if the results are expectation after the characterisation we simply put the designed surface properties which are realised through the required development through the surface modification techniques it is subjected in application or it is applied in the real component. So, we follow these paths first of all designing the surface modification then development of the surface modified surfaces and once these are developed.

Then these are characterised and investigated to have the required set of the properties followed their application into the real component and if these are as per expectation means after the application if you are getting the expected result the entire is standardised and if we do not get then again we go back to the designer stage, this is a kind of cycle. So, enlight of this the scope of the surface engineering includes the 4 aspects designing the surface which is to be developed for a given application.

So, that the required performance in terms of the life in terms of the functionalities can we achieved. The second aspect is development or the modification using the suitable kind of the material and the process which can be used for achieving the required or the designed surface properties. So, what which method and which material will be used for modifying the substrate using the suitable approach that is what is identified in the second stage.

And third stage about investigation or characterizing the engineered or modified surface to see up to what extent the designed properties have been achieved. If they have been achieved then the things will be put into use through the application of the required design properties or required surface modification. So, putting the surface modification into the real application for so that the required purpose can be realise and if you find the required target results.

Then this process is standardised and if you do not get then will be going back at the design stage, so these are the 4 important components and now will be looking after one by one each of the components and in this subject also will be focusing these aspects one by one where will be looking for what kind of surface properties we should have to deal with the various kinds of the applications.

So, that the required functionalities and performance can be achieved, second one will be looking for the various materials and the processes which can be used for developing the required target properties. And will also we looking after the various investigations and characterisation methods which can be used to study the modified surfaces to see their suitability for given application.

And once all that is then this processes all these means the surface modification is applied in the real application. So, the next point will be starting with the designing the surfaces to we developed.

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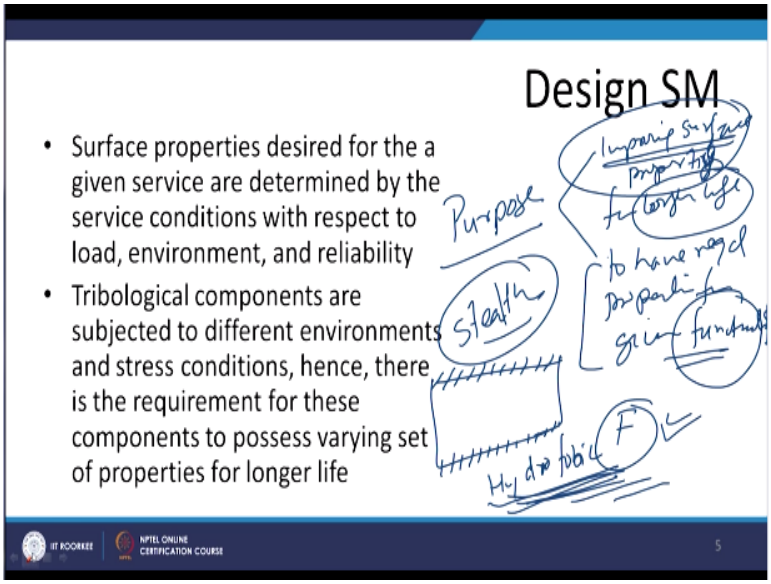

We know that the surface modification or surface engineering is carried out for a purpose that purpose is to be identified first, what for we are modifying the surfaces. Whether it is just for improving surface properties, so that the surface properties, so that the required longer life can be achieved for longer life another purpose of the surface modification can be to have required properties for given functionality you see.

The component may not be having at all any kind of such kind of properties, so by surface modification we may like to have those properties at the surface. So, that the required function can be achieved, so target here is to have the required function and here the target is to increase the life of the component. So, here just simply improvement in the surface properties will help to enhance the life of the component.

And here in the second approach will try to have those unique characteristics which are absent in the substrate surface of the substrate. So, those unique characteristics are brought in, so that this component can perform the required function. So, in this case the functionality is improved or

functionality is ensured, so the example of this type of coating is like of development of the optical coatings or development of the stealth coatings.

So, that it can really the component can become invisible through the electronic radars through the use of stealth coating or it can be application of the hydrophobic coatings. In case of the hydrophobic coatings it does not the water or the liquid will not wet to the surface, it will not sustain to the surface. So, in such kind of the coatings are stealth coatings or the hydrophobic coatings.

These will simply we improving the functionality of the component, otherwise whenever a component comes in contact with the liquid or with water it will be wetting to the surface. So, but when such kind of the coatings are applied the wetting tendency will be reduced or will be eliminated similarly use of the stealth coating will make the aircrafts invisible to the radars of the enemy.

So, now enlight of the purpose of the surface modification whether it is just for improving the surface properties or to have those properties which are absent in the substrate but will be brought in through the application of the suitable surface modification. So, that it is functionality is improved based on this purpose**.**

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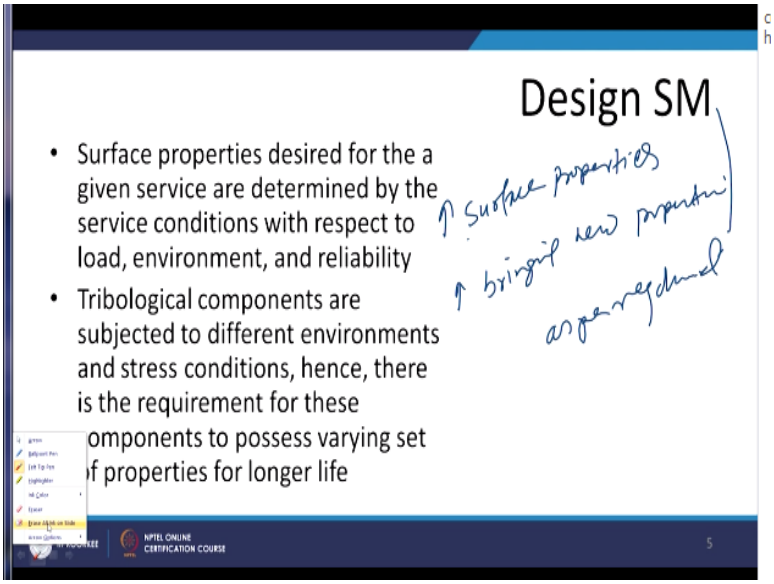

We need to identify what we are looking for improving the surface properties or bringing altogether new kind of the properties at the surface as per of course as per the requirement, these can be electrical properties, these can be optical properties or thermal properties. So, as per the purpose we need to have the suitable combination of the properties for given purpose. So, now if will see how it is designed, surface properties desired for given surface or determined.

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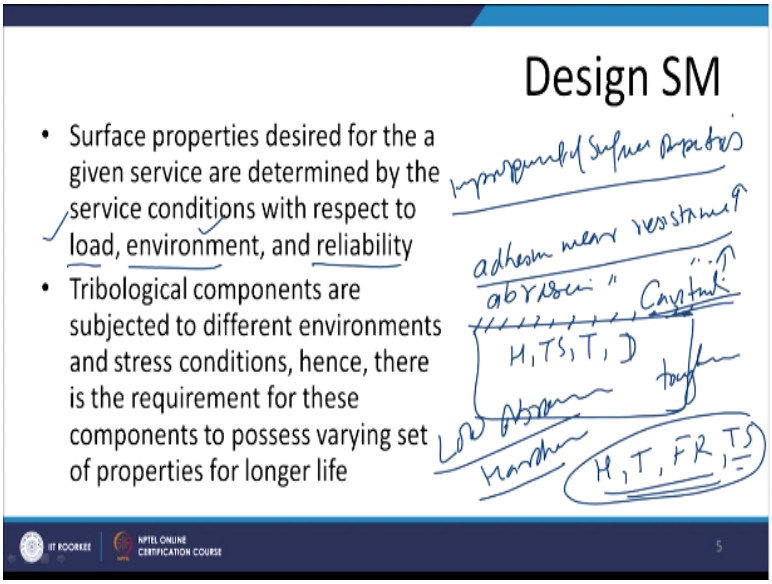

So, if it is about the improvement of surface properties improvement surface properties like substrate will already be having some kind of the properties with regard to the like say hardness, tensile strength, toughness, ductility etc. But the substrate is not able to really perform the required function under the given set of the loading, environment, conditions and with given required reliability.

Then in order to improve then in order to have the surface properties in such a way that it can sustain the load, environment to offer the required reliability, the surface properties are need to be improved. So, if so this is very crucial part as for as the combination of the properties which are required for a given application those are identified as per the service conditions.

So, service conditions will be dictated by the kind of load environment and the kind of reliability which is required for. Now there can be different situations like we want that the adhesive wear

resistance is improved. So, for that purpose we need to have the combination of the good hardness, toughness and the fatigue resistance and resistance to the thermal softening.

So, if these properties are there in a material it will offer the good combination, so how to have those set of the properties at the surface, so that it can really perform for long under the adhesive wear conditions. So, if it is abrasive wear resistance is to be improved then will be looking for as per the kind of abrasive wear conditions like low abrasive wear conditions, low where load is limited under these abrasive wear conditions maybe hardness is the only property which is required.

But if the abrasive wear conditions exist in combination with that impact then we need some kind of the toughness also. If the required properties are needed safe or the cavitation conditions, if you are looking for the properties, surface properties for the cavitation conditions.

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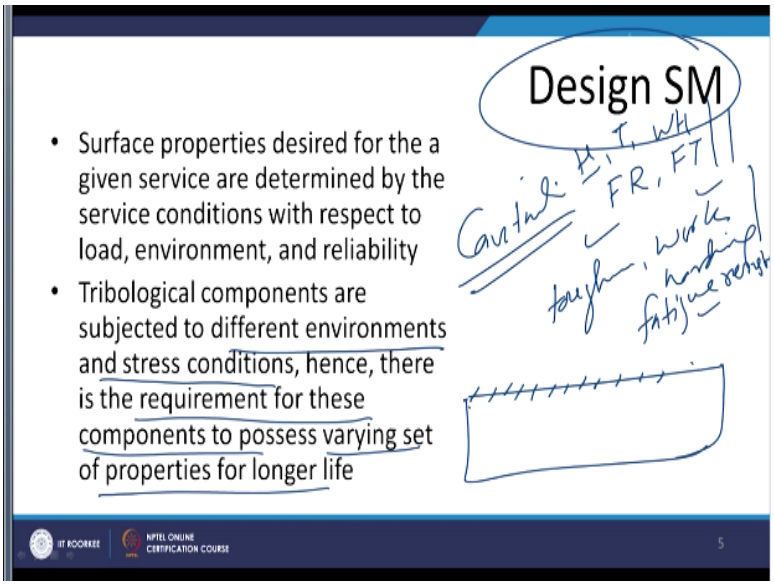

Then for cavitation certainly there is a kind of the bubble busting of the bubbles which will be continuously acting onto the surface. So, we need good toughness not just hardness but the good toughness maybe sometimes good work hardening capability of the surface. So, we need to have the those surfaces which can offer the required toughness work hardening capability and it remains stable and coherent under the impact conditions.

So, even sometimes efforts are made to related with the fatigue resistance also. So, if the material those materials which are offering required toughness, work hardening capability, good fatigue resistance, then it will be showing the good resistance to the cavitation. So, what we can see the properties like hardness, toughness, work hardening capability, fatigue resistance, fracture toughness all these properties are needed for the different kind of the wear conditions.

So, which kind of so for each type of wear each kind of the properties will be each set of the property one unique kind of the set of the properties will be needed and efforts are made to modify the properties of the surfaces accordingly. Now another aspect is that tribological components are subjected to the different environments and stress conditions, hence the requirement for these components to posses varying set of the properties is also changing, the requirements are changing for the require longer life of the component.

So, the design stage is very crucial because we have to anticipate the service conditions, based on the service conditions we have to identify the properties which will be required for longer function and once those required properties are identified in the at the designed stage efforts are made to realise those properties subsequently in the second stage of the development or the modification of the surfaces.

Now I will summarise this presentation here, in this presentation basically I have talked about different points based on which different surface modification techniques can be compared and what are the different things which fall under the scope of the surface engineering also I have talked about the one important aspect in the scope of the surface engineering is designing the surface modification or what we should look for at the design stage of the surface engineering, thank you for your attention.