Fundamentals of Surface Engineering: Mechanisms, Processes and Characterizations

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Lecture-01
Introduction and Need of Surface Engineering

Hello, I welcome you all in this presentation related with subject fundamentals of surface engineering. Basically in this subject we will be talking about the mechanisms related with wear of material processes which are used for modifying the surface properties and how to characterise the modified surfaces. So that we can really check the extent of improvement which has taken place after the surface engineering of a particular component. You know this the surface engineering is a comparatively new field which is still being developed.

We know that the most of the mechanical components which are subjected to the external loading fail during the surface and the failure occurs or failure weakens primarily from the surface. So the surfaces become the primary source for the failure especially when there are certain weaknesses in terms of the poor mechanical properties, in terms of the presence of a stress rangers or some kind of the irregularities or the defects if they are present at the surface.

And therefore to enhance the life of the mechanical component it becomes important that the properties of the surface of mechanical component are enhanced in such a way that the life of the component especially which are subjected to wear can be enhanced. We know that as I have just said that surfaces many times trigger the failure of the component through the nucleation and the growth of crack.

Therefore improving the surface properties becomes of the prime importance and therefore various techniques and technologies have been developed for improving the surface properties. This is the first presentations I will be basically talking about the general things related with the surface engineering and what are the purposes which are solved or addressed by the surface engineering, what kind of the needs can be fulfilled by the surface engineering.

There after I will be talking about the different features related with a surface and sub surface regions. So we know that the surface engineering is a field are related with the science and technology of modifying the surface characteristics as per need. So that the life of the product can be enhanced especially during the surface and the need you know as I have said the surface characteristics are to be improved as per need.

So the need that need for the properties is primarily governed by the conditions under which a particular component has to work and another purpose is that after modification of the surfaces properties are enhanced in such a way that the functionality of the component is improved. For example if we see 3 components, the first one is this gear part of the gear where the 2 or 3 tools we can see.

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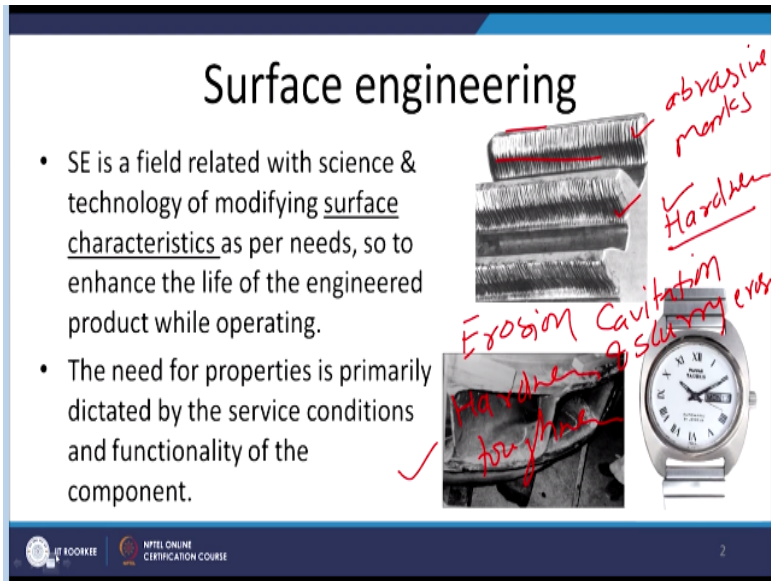

And the number of marks on the gear tooth are present these marks are basically abrasive marks. So abrasive wear is one of the mechanisms by which material loss from the metallic components take place and to improve the resistance of the material for abrasive wear it is important that it has required hardness. So that the indentation on to the surface of the component can be registered by the abrading material.

Similarly this is the another part of the hydraulic turbine and which commonly experience the erosion, erosion of the 2 types, 1 is like a cavitation and another is arrows solid particle erosion

or slurry erosion. So the properties that we need to enhance the erosion either due to the cavitation or by the slurry erosion, it is required that it has the hardness required hardness it also has a good combination of the toughness.

So, that the particles which are impinging on to the surface or the bubbles which are busting onto the surface of a the impeller or the turbine blades they those can be registered very effectively in order to reduce the loss of material apart from resisting the wear the surface engineering can also be useful especially regarding the improving the aesthetic value of the product.

And increasing the sign and the surface finish for a longer period and the coatings present on the watches especially the metallic watches play these kind of role, they resist all the abrasive marks during the use of the watches as well as the aesthetic value is also improved by even proper finish, proper shine.

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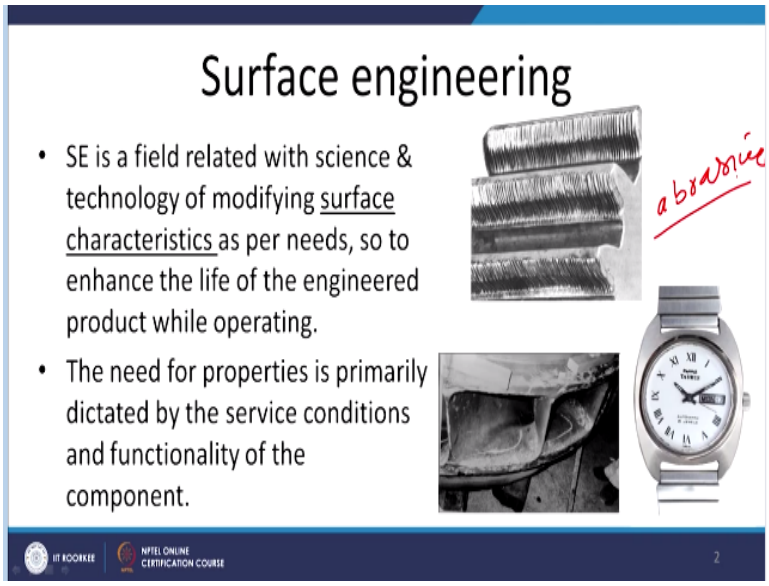

And this is done through the coating of the suitable material on the metallic cases of the watches. So basically the surface engineering involves modifying the surface properties. So that the performance of the product can be enhanced in number of ways. So I have given here all the just do examples like a increasing the resistance to wear or improving the aesthetic value of the product or increasing likewise there can be other examples where improving the mechanical properties of the product or improving the electrical or optical properties of the surfaces by

applying various types of the coatings onto the surface. So that their functionalities as per the requirements can be enhanced.

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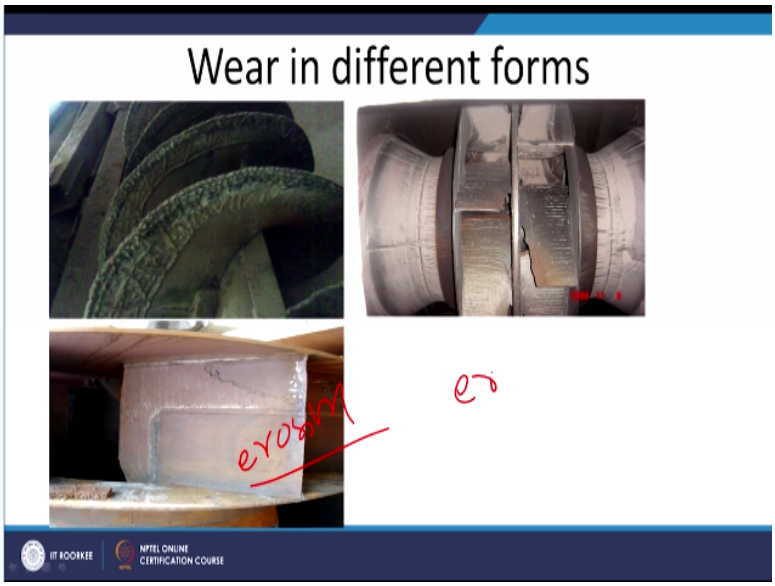

So, here what we can see there are number of examples like this is one typical component which is commonly used in the cement industry for transport of the raw material in course of the manufacturing and during these service it is in variably subjected to the erosion and this is another fan blade which is also subjected to the erosion used in the cement industry and this is another component used in cement industry.

And all these are basically subjected to the erosion due to the presence of the hard particles present in the cement or in course of the manufacturing of the cement which primarily causes the alumina as a hard particle alumina, silicon as I go to silicon oxide. So, it is required that various components which are subjected to the wear by different ways it is required that the surfaces of those components are prepared in such a way.

They are made in such a way that such kind of the material lost by such kind of the wear mechanisms can be registered or reduced as much as possible. So that the component can work for longer time. Now we have seen that the loss of the material from the surface can occur in different ways and different forms of the wear. Now we will see the surface engineering in a different way to see how does it work like surface engineering is an approach which involves

number of the aspects of developing the surfaces having features different from the bulk material for enhancing the life and functionality of the engineering component.

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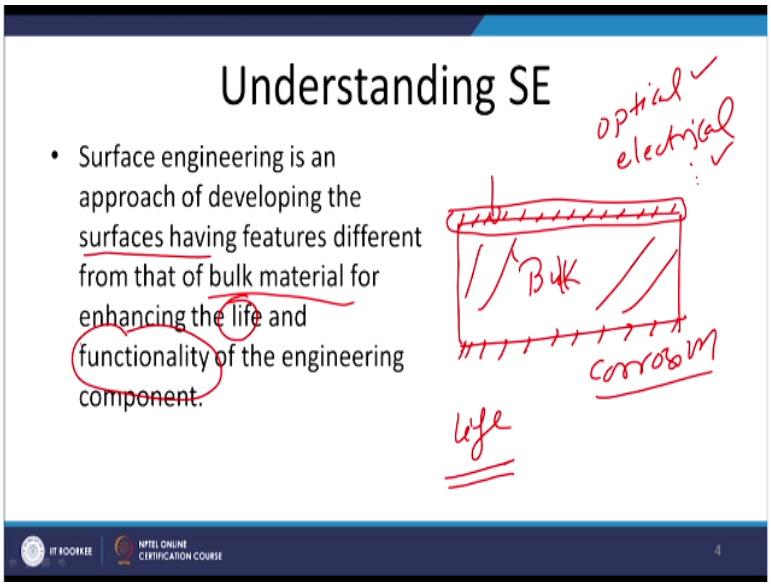

So what we do basically like this is the component in which is being considered for enhancing the performance either in terms of the life. So, that the loss of material are from the surface takes place gradually at reduced rate or the functionality of the product is improved means the properties of the surface are enhanced in such a way that it is able to perform the required functions.

So, like optical properties, electrical properties like steeled coatings are examples of such kind of the surface engineering where material at the surface are applied in such a way that they perform in much better way with regard to a particular property which is desired like a entrance of the optical properties or electrical property, electrical conductivity or electrical resistivity both it is done in both ways.

Similarly we apply the material at the surface in such a way that it offers the better corrosion resistance, but the corrosion resistance will improve the life of the product while electrical, optical, mechanical properties are application of the steeled coatings like thermal barrier coatings etc., they will be improving the functionality of the product and in all these cases whatever engineering is done at the surface.

We try to develop the properties which are different from the bulk material property. So this is the bulk material and whatever properties we are trying to develop at the surfaces they are different. So, it applies the large group of the processes to develop the required set of the properties at the surface which are of course different from the bulk material.

So that the required improvement in the life of the component can be achieved or the functionality of the product can be improved. So, this is the purpose of you can see this work in the surface engineering is done.

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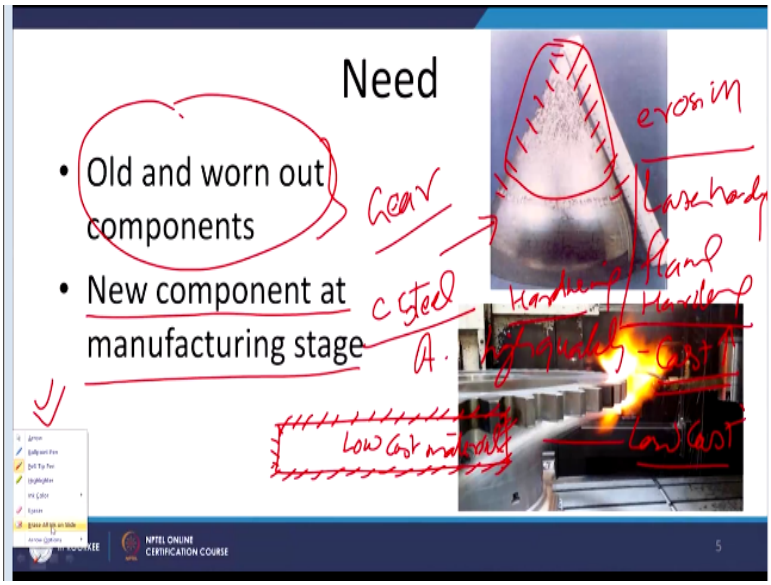

Now at what stage it is applied that is what we had to see, so like this is the 1 particular part which is used in a hydro turbine component to regulate the flow of the water and it subjected to the erosion. So, because of the erosion what will see the loss of the material from this region has taken place, so it will be required to bring it back in the service through the surface modification.

In such a way that the loss of material from the surface takes place gradually at the lower rate, this is a case where surface engineering is applied or surface engineering of the component is done on to the worn out component or the whole component. So, that it can be brought back again into the application while offering the service for longer period. So, this is one typical case

where the surface engineering can be done once the component has been subjected to the failure or has been worn out beyond the acceptable limits.

Another case is one wear, so in this particular case will be applying the coatings or the layers by wears of facing or the thermally spray methods. So, all around the affected areas, so that the surface is rebuild using the material which can offer much better erosion or the cavitation resistance. Similarly it can the surface engineering is also applied at the manufacturing state for number of, for realising the number of objectives.

For example what you want that any product is made at lower cost but performs for longer period, the required function is given by the product for longer period and for such kind of the output what is needed because these are the 2 contradicting requirements. We can always make a product A using a very high quality material, so that it will perform for long but at the same time cost will also go high.

So, the higher cost will make it difficult to be consumed by the general public, so what efforts are made that the same good performance product is made at the low cost. So, for making the low cost what we do basically we choose the low quality material like simple mild steel which comes out like 40, 50 rupees per kg and this low cost material once the desired size and shape is given it is surfaces are modified or engineered.

So, that it has the properties of those good quality materials that will be able to perform the required function for longer life, so using the low quality material product is made and the surfaces are engineered using the high quality material. So, that the required functions are performed for longer time even at the lower cost. So this is the 1 case where even in the in case of the new component surface engineering is applied.

And in number of cases when we understand that a given product is going to be subjected to the wear by particular mechanism, then we will try to develop or try to engineer the surface in such a way that it is having the required set of the properties to deal with those adverse conditions

which will be experienced by the product during the surface. So, well and an example of this is what like gears, gears are made of the like carbon steels or alloy steels.

So, if the gear is made of the carbon steel or alloy steel it will wear out at much higher rate life will be less, so we need replacement or repair much earlier. So to do deal with this problem what we do gear will be made of the same simple carbon steel and once required size and shape is given the surfaces are hardened. So for the hardening purpose like we can use flame hardening, we can use induction hardening, we can use laser hardening.

So, these are some of the approaches which are used for engineering the surfaces of the gear tooth. So, that it can offer it can have the desired surface properties desired hardness resist the adhesive or abrasive wear during the surface. So, surface engineering can be applied onto the wear worn out or old components or it can be applied on to the newer components as well. So, that it performs for long or the worn out component is brought back into the surface and again it performs for longer period.

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So, this is what is an example of surface engineering of the gear tooth surface by flame hardening. So here this is a flame which is applied onto the gear tooth and once it reaches to the required temperature of 850 to 950 centigrade it is subjected to the water jet cooling. So, that quenching phenomena takes place and surface is hardened. So this is what is applied for the

surface hardening of the gear tooth, this is what just as I have given example of this. But whenever surface engineering is applied surface engineering techniques can be applied in number of ways.

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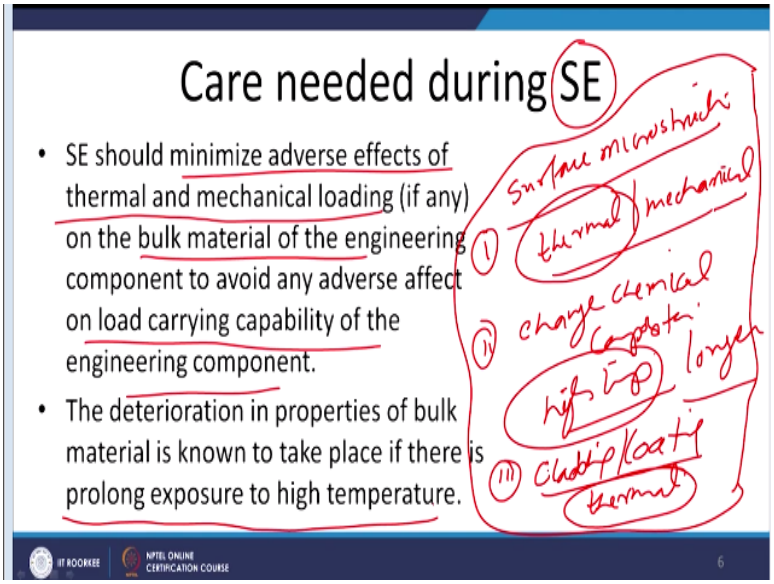

They actually broad categories just in brief I will let you know what are those where only the surface microstructure is modified through the thermal or mechanical loading or means we apply the heat in very localised manner. So, the microstructure at the surface is modified or the stresses are applied in very control way at the surface, so that they start work hardening takes place and it is structure gets a deformed.

This is 1 group of the processes, in second group of the processes we try to change the chemical composition of the surface. So for changing the chemical composition again high temperature exposure is important. So this high temperature exposure when given for longer period it tends to damage the bulk material properties also. So, third one is where the claddings or coatings onto the surface are applied and no chemical change.

But one complete layer of the required material is applied onto the surface and again in this method also thermal treatment or the application of heat is done. So that the required coating or the cladding can be applied onto the surface. Whenever these techniques are applied especially in those were heat is used whether it is for category 1, category 2 or category 3 processes

application of the heat tends to modify the characteristics or properties of the bulk material especially when the exposure is given for the longer period.

So, that is what we have to take care of the during the surface modification, surface engineering , the adverse effect onto the bulk material properties are reduced. So surface engineering should be applied in such a way that it minimises the adverse effect of the thermal and mechanical loading obviously as per the case onto the bulk material properties. So the bulk material properties because the components are designed in such a way that the bulk material will be carrying the required load during this surface and performing the function.

And functionality for longer period will be facilitated by the improved surface properties of the component. So, the bulk material property should not be degraded due to the mechanical or thermal loading of the component during the surface engineering. Otherwise, it is a load carrying capacity will be adversely affected and this kind of the deterioration in properties is known to takes place especially when the exposure at a high temperature is given for longer period.

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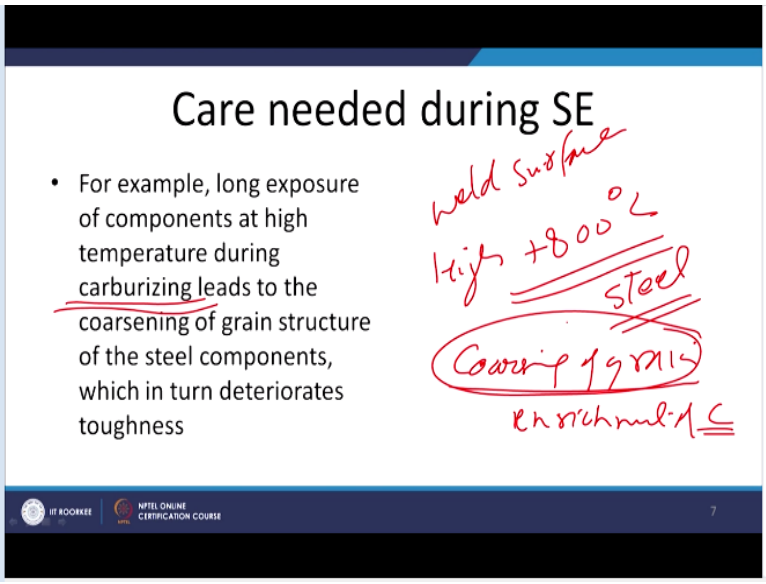

And 1 typical example of this is what like carburizing is one typical surface engineering method, likewise well surfacing also lot of heat is delivered and carburizing nitrating or those methods are there. The high temperature like 800+ degree centigrade is maintained for longer period and

especially if the steels are subjected to the higher temperature for longer period then they will be subjected to the coursing of grains.

Apart from the required modification in the structure, in terms of the like the enrichment of the carbon in the during the carburizing enrichment of carbon during the carburizing, if the coarsening is taking place that may deteriorate the toughness another mechanical properties of the steel. So, it will not be good to have any adverse effect on the bulk material properties of the component as it is result of the surface engineering of the component.

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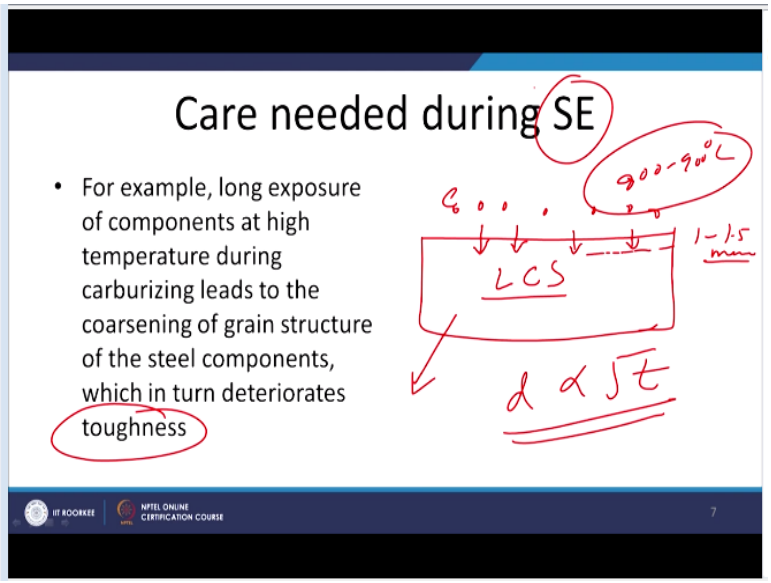

So, I explain in brief how the surface how the carburizing is carried out like carbon rich environment is created all around the component especially at the high temperature of around 800 to 900 degrees centigrade. And the carbon this carbon rich environment results in the diffusion of carbon on to this surface of the steel component. And normally low carbon steel component are subjected to the carburizing.

And so the carbon defuses up to the required depth and once that the diffusion of carbon up to the required depth is achieved which is normally say on like 1 to 1.5 mm depth from the surfaces as per the application different depths are case hardening or the carburising up to the depths is carried out and so, that the hardening up to the carburizing up to the required depth can be achieved.

Since carburizing takes longer time to get the required diffusion like depth of the diffusion is found proportional to the square root of the time. So, if the gritted depth is required greater time it will take so, higher temperature exposure of the steel for longer period can lead to the grain coarsening. And grain coarsening kindly to the loss of the toughness of the steel component that is why proper care is required when the surface engineering techniques are applied to avoid any adverse affect on the bulk material properties.

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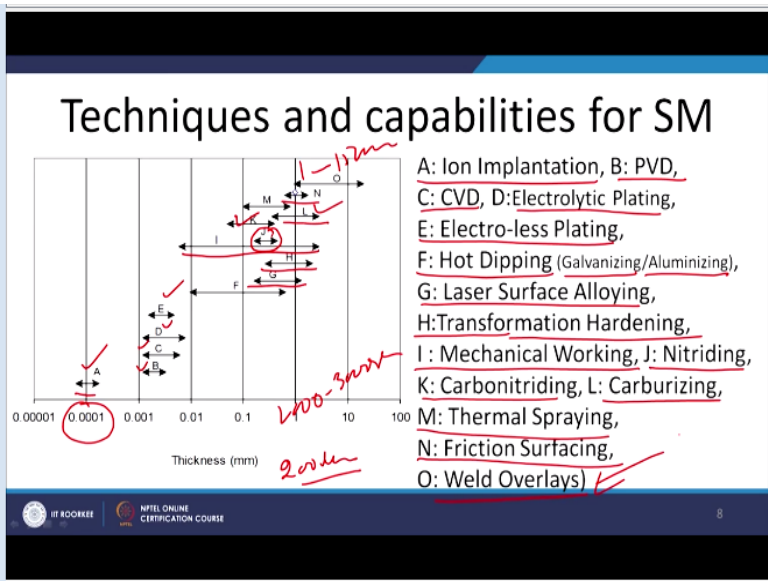

There are different very wide range of the surface modification techniques which are used to achieve the modification in surface properties are improve this surface properties and the depth which is modified during these surface engineering by the different techniques very significantly are that changes significantly with the type of process. So, here what we can see these A, B, C, D indicating the range indicating the process.

And this range of the arrow means this arrow double sided arrow shows the range of the thickness which is normally achieved during the surface modification. So, if we see implantation results in the surface modification or engineering of the surface to a minimum possible depth it is less than 1 micrometer. And then somewhat greater depth like say 0.001 to 0.01 like it is a 1 micrometer to the 100 micrometer.

This is the kind of the depth which is modified in case of the process like B, C, D and E which are physical vapour deposition, chemical vapour deposition, electrolytic plating and electro-less plating. So these are the processes where similarly so, these are the processes which will be offering the thickness over a narrow range of less than 100 micrometer less somewhat greater depth which is modified in other process like the is the process.

Hot dipping showing the 100 to the 1000 micrometer depth which is modified by the galvanizing which is zinc coating or aluminizing coating of the aluminium primarily for the coarsening resistance application. G is the surface laser surface alloying which results in the 100 to 1000 micrometer modified depth even it can be greater Transformation hardening results in the further greater depth which may be like say this one somewhat like 400, 500 micrometer to like 1200 to 1500 micrometer.

Then the mechanical working like varnishing or the short pinning are those methods related with the mechanical working which results in a much greater range of the modified depth from say 100 micrometer to 1000 micrometer or 1200 micrometer. Then J is the another process nitriding normally it has very narrow range like say it is in the range 100 to 1000 micrometer than carbon nitriding and carburizing are the other process K and L carburizing let us L process where somewhat 500 to 1500 micrometer or 1.5 millimetre depth.

And then we have M Thermal spraying it the range is very wide for thermally spray like hard material coatings are applied in the range 200 micrometer while for the soft material it can range of 200 to 3000 micrometer like 2 to 3 mm, then friction surfacing further greater thicknesses. And the weld surfacing weld overlays are the weld surfacing results in the much greater depth like the 10 to 50 micrometer.

So, 1-15 mm sorry 1 to 15 mm depth of the weld overlays especially of the soft materials is deposited for weld overlays are applied for like improving the wear resistance by abrasion erosion or corrosion resistance. So, these are the different techniques we can say some of the techniques which are showing that the each techniques having the capability to modify the surface up to the different depths.

So, as per the application and as per the purpose the surfaces are engineered up to the different depth and accordingly the suitable process is to be selected. Now coming to the purpose is which are fulfilled in by the surface engineering.

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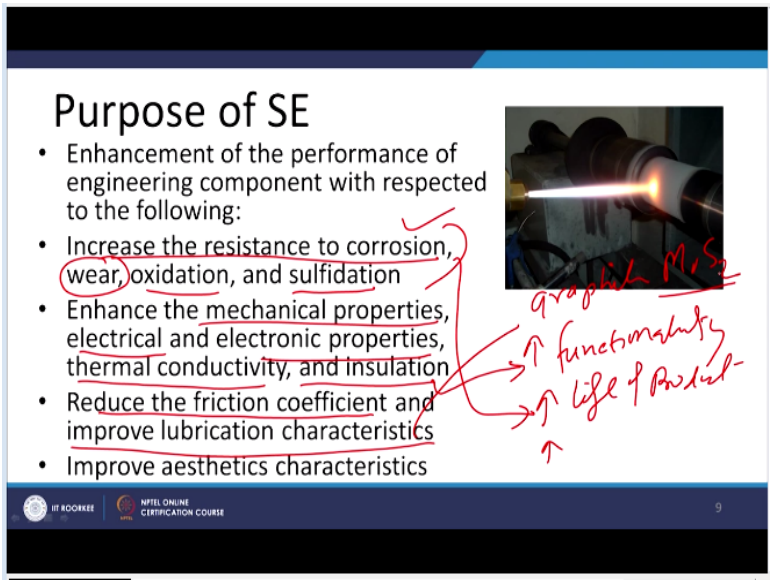

So, you know primarily it is carried out for improving the performance or enhancing the functionality of the product. So, that it is capability can be enhanced and enhancing the life of the product. So that it sustains the required conditions it sustains the weir conditions more effectively apart from that it also has to improve the appearance looks. So, we can say aesthetics characteristics and the esteem value of the product is enhanced.

So the primary purpose of the surface engineering to increase the resistance to wear basically through the different modes like corrosion, oxidation, sulfidation and different forms of the wear improving the surface properties. So, the functionality can be improves. So the first one is for improving the life enhancing the mechanical properties electrical and electronic properties, thermal properties, optical properties.

And insulation thermal and electrical insulation these are used for improving the functionality of the product. And additionally there is 1 more additional purpose which is achieved reducing the friction coefficient between the melting surfaces. So, that the lubrication characteristics can be

improved, material loss can be reduced and wear assistance can be enhanced. And for this purpose basically the graphite and molybdenum sulphide kind of the constituents are added.

These are the solid lubricants which are added with the metallic metrics so, that required lubrication characteristics can be impacted to the components.

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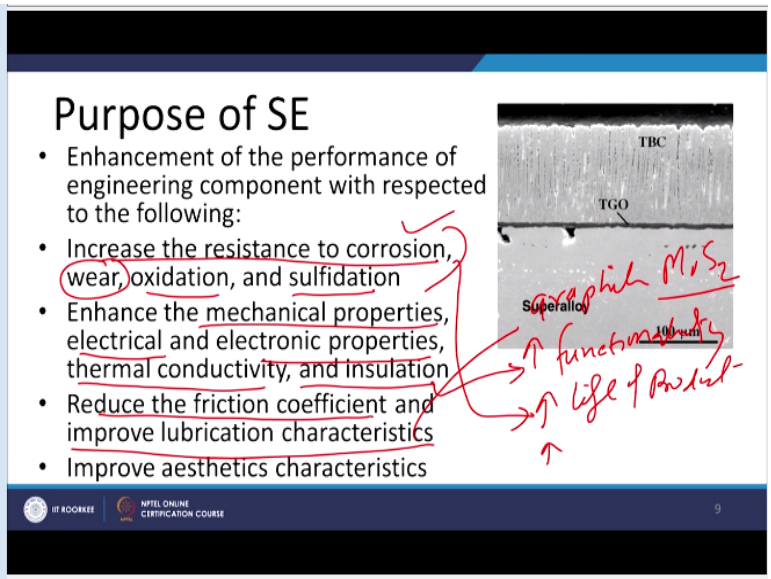

So, now we will see as for the functionalities consent the initially here like coating the component using the suitable wear assistance material through the thermal spray process. So, that it have sustains the wear conditions effectively and this is like the components which are subjected to the high temperature if they are given a thermal barrier coatings.

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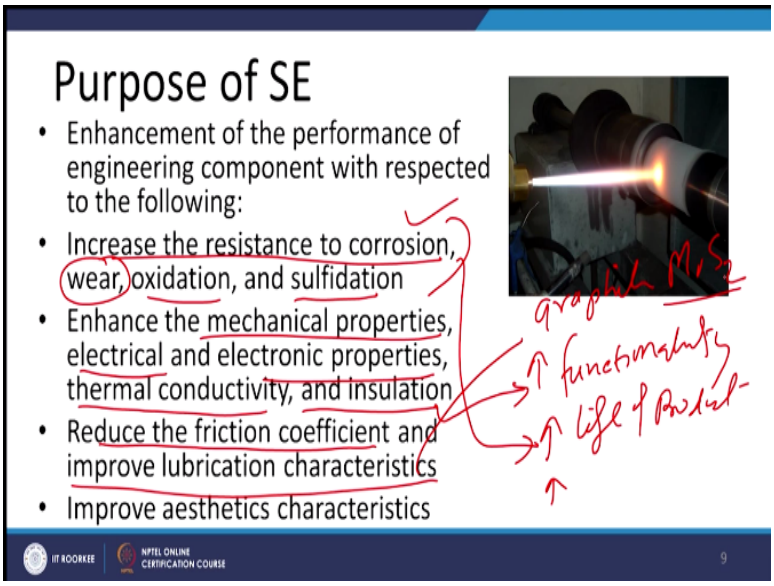

So that the temperature outside is high, but it assist the transfer of heat towards the main bulk material and thereby it maintains the underlying the bulk material at lower temperature. So basically the purpose of the thermal barrier coating is to maintain the temperature of the bulk material to the lower level and this temperature may be temperature bulk material may be like 50 to the 100 degree centigrade lower than the outside temperature for reducing the friction.

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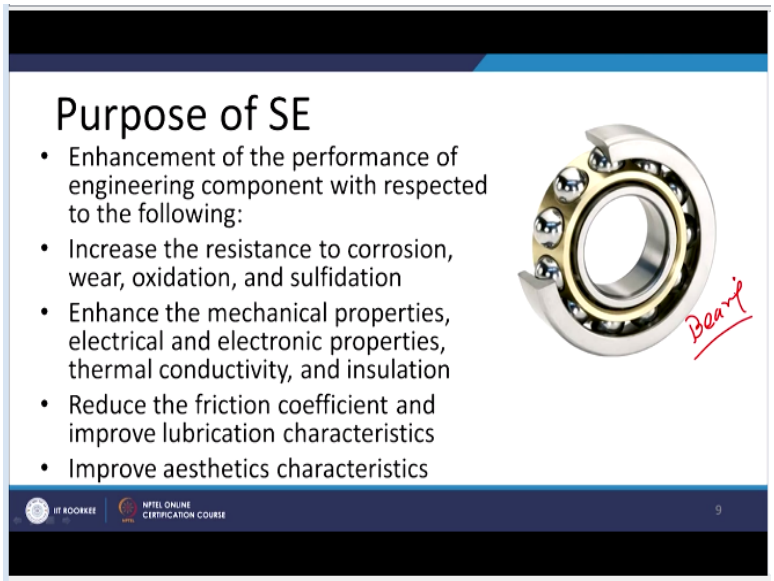

And improving the lubrication like in the materials which are used for making the bearing components molybdenum sulphide and graphite kind of the materials are used. So, that we can provide the required lubrication.

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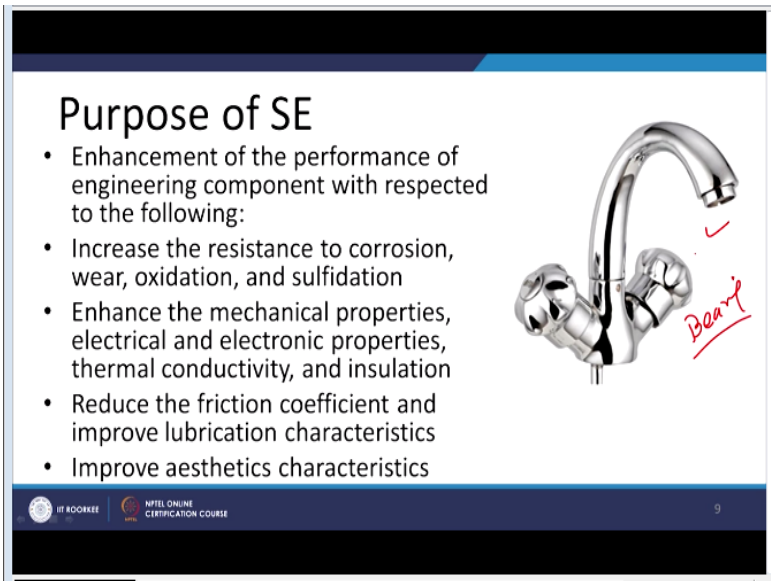

And aesthetic characteristics is improved like coating chrome coating and platings are applied in the bathroom fittings and the watches and structure for improved their assistance to the corrosion as a lesson improved appearance. So, that they can really improve the esteem value of the product term now here I will summarise this presentation in this presentation.

In this presentation basically I have talked about the introduction of the surfacing engineering, different techniques which are used and they are capability to modify the thicknesses up to the great different depths and what for surface engineering is generally used, thank you for your attention.