Fundamentals of Surface Engineering: Mechanisms, Processes and Characterizations

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Lecture-11
Issues and Application of surface Modification

Hello I welcome you all in this presentation related with the subject fundamentals of surface engineering and we have talked about various aspects related with the surface engineering starting from the classification of the techniques for the surface modification. And the properties important for wear and friction performance like surface energy, surface compositions, surface microstructure, surface hardness and surface roughness.

Now will we looking after the advantages limitations and application of the surface engineering technique or the surface modification approaches what we what advantage we get from these approaches. So, what we can see here like whether it is old or new component the surface engineering or SMT surface modification techniques can be applied onto both.

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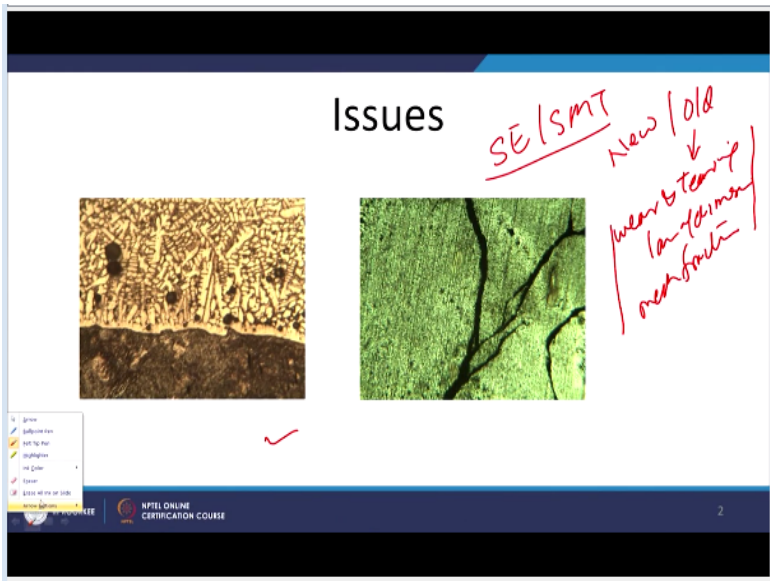

It can be a new component or old component or used component will they start from the old component like whenever a tribological component is put on use it is subjected to the wear and tear gradually which in turn leads to the loss of dimensions loss of shape. And eventually event it

may lead to the mechanical fracture if the dimensions or last to the great extent and component is not able to take up the load.

So, in order to bring back to the working conditions surfaces of such old warn out components are modified. So, for the modification what we basically do whether we can do the refurnishing using the weld surfacing or hard facing thermal spraying are as per the requirement of the characteristics of the surface is we can perform suitable kind of the surface modification of a the old component another aspect is here for which the surface modification is applied is on the new component like what we want.

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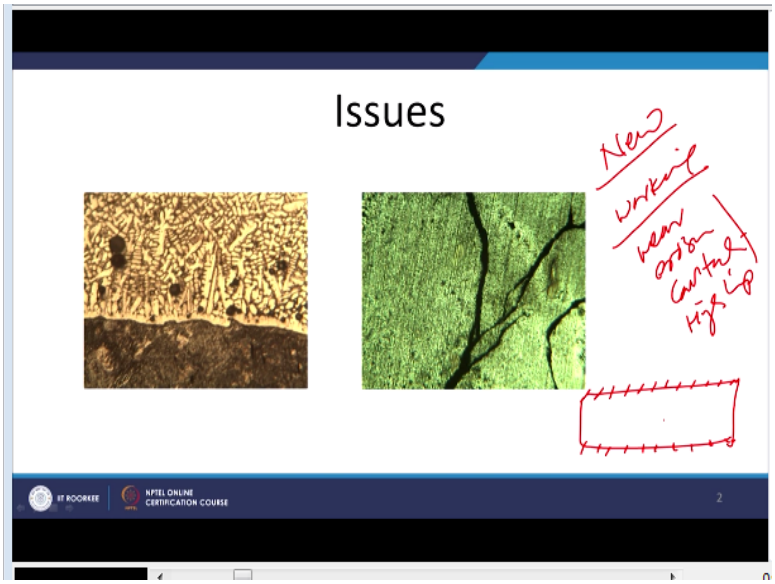

We know that the component will be subjected to the severe working conditions the severe working conditions of wear erosion, cavitation like high temperature exposure. So, to make the component capable enough to deal with the harsh working conditions sometimes the even new component surfaces of the new component are modified. So, that they can withstand effectively under the different tribological conditions or the working conditions, so even the new components are subjected to the surface modification.

Now there can be different purposes for the surface modification as for as the purpose of the surface modification or surface engineering is concerned

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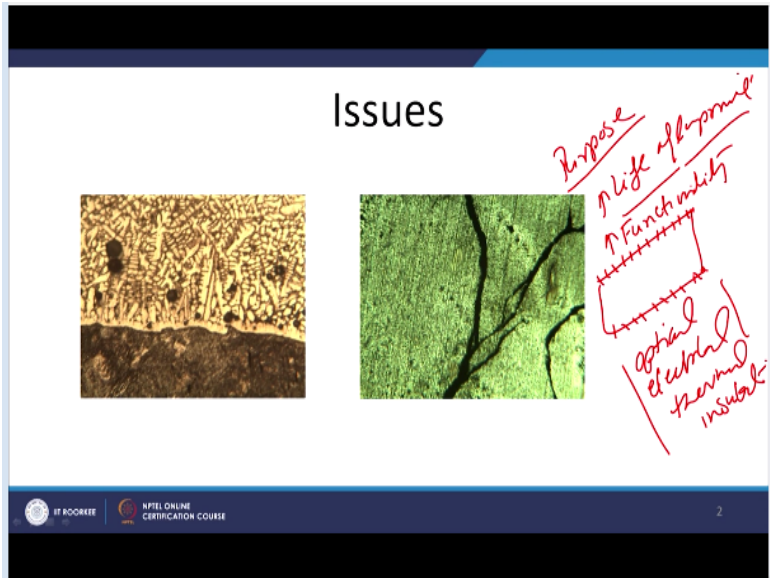

It can be to the increase the life of the component under the tribological conditions like we know that the component will be subjected to the different kind of the wear and tear conditions. So, the surfaces must be strengthened in such way that it can sustain those conditions effectively. And it is subjected to the lower metal removal rate. So, that the tribological life of the component is enhanced and for this purpose as per the requirement of the surface.

We may have the surface of the very high hardness or combination of the hardness and toughness or the work hardening material is deposited. And if the objective is to improve the functionality means the in normal case surface is not capable is not able to deliver the required physical properties or mechanical properties. In that case like we want certain kind of the optical properties, electrical properties or like say we want some kind of thermal insulation.

So, in all these cases the surfaces are subjected to the surface modification using those techniques which will help to have such kind of the functionalities, so that the component really can perform the required function. So, these are the two important aspects or the purpose is of the surface modification. And there can be another important aspect with the surface modification that is making the good quality product which can offer the longer life but at low cost.

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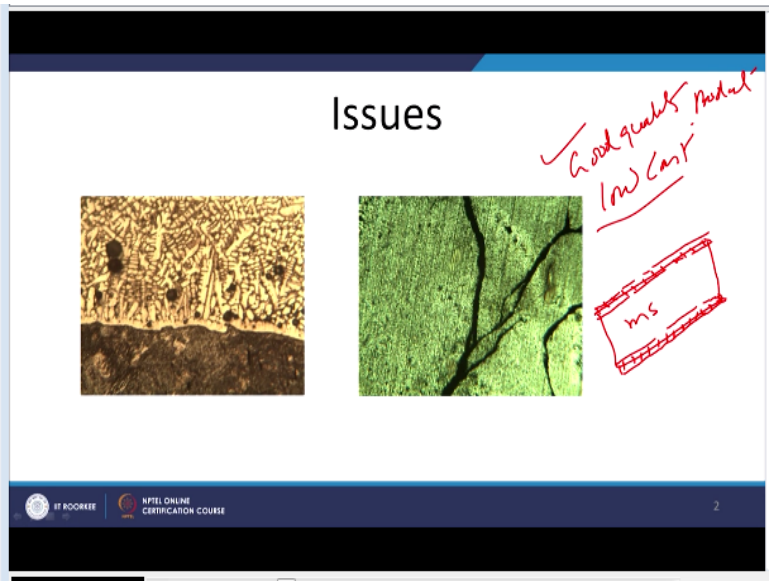

So, for this purpose we will making the major component of the low quality material like mild steel. And then surfaces will be modified using those techniques those material which can help us to have all those functionalities required for good performance of the product. So, in that case instead of making the entire component of the good quality material only the functional surfaces are modified.

In such a way that it can perform the intended function because making the entire component of the good quality material can be costly affair. So, to have the required performance even at the low cost surface modification techniques and surface engineering helps a lot. Now so, as for as the advantage is of the surface engineering is concerned we can in list certain enlight of these purposes.

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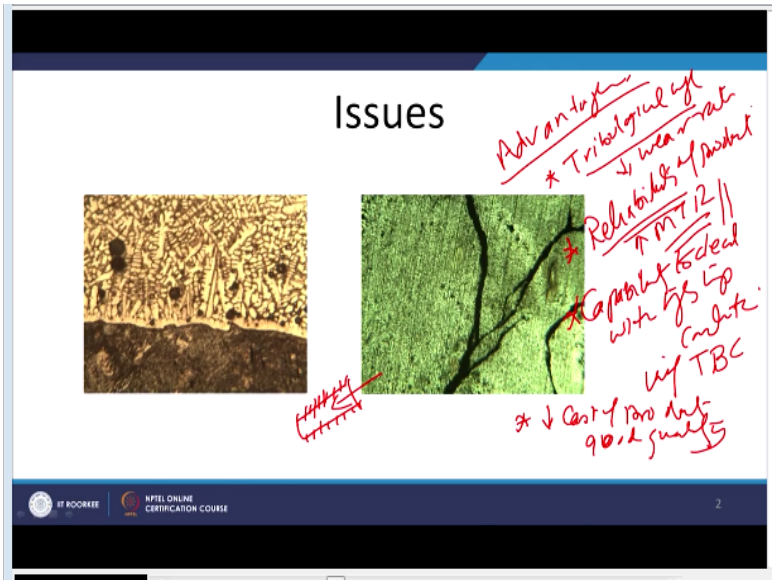

We can write certain the advantages of the surface modification and surface engineering first it increases the tribological life of the component. How by reducing the wear rate the rate at which material losses from the functional surfaces and during the service which will be taking place that it is reduced and that intern increases the life of the component. Second is it increases the reliability of the product subjected to the surface modification and engineering how by increasing the mean time to repair.

If the functional surfaces are really good with required surface properties to deal effectively with the service conditions then it will help in increasing the time which is required between the repairs and that in turn you will be increasing the reliability of the product third is it improves the capability it increases the capability to deal with the high temperature conditions. And how this is facilitated like a component to be used at high temperature.

So, if the functional surfaces are coated with the thermal barrier coatings then it will maintain the temperature of the main product at lower level as compared to the functional surfaces. And the heat dissipation to the core material will be means heat transfer to the core material will be reduced from the external hot environment. And that it is how it will be able to increase the capability of the product to deal with the high temperature conditions through the use of the thermal barrier coatings.

Another advantage of the surface modification as I have just described it helps in reducing the cost of product or it helps in making the low cost products of the good quality, good quality product at low cost. So, the base material or the substrate material will be of the low quality which will be able to take the service loads. But improved functional functionality and surface properties will help in improving the performance of the product.

So, instead of making the entire product of the good quality material the main product can be made of the low quality material. But the functional surfaces are made of the good quality properties. So, that the cost of the product is reduced for the good quality product even when we are using the low quality or the cheap material. It also helps in improving the mechanical performance of the product why because if we select the surface modification techniques in such a way that they are even to develop the residual compressive stresses on to the component.

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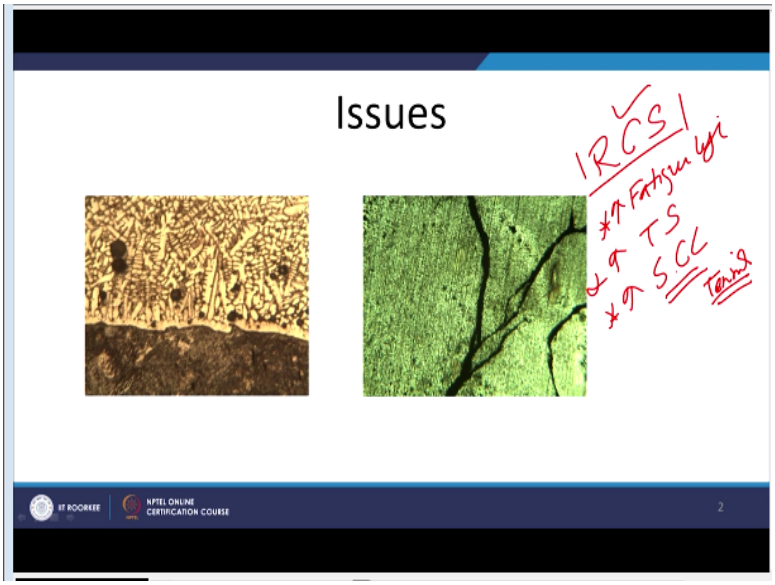

Then this will help in increasing the fatigue life of the product it will help in increasing the tensile strength of the product. And it will also increase the stress corrosion cracking why because stress corrosion cracking for a stress corrosion cracking presence of a tensile stresses necessary. But the presence of the residual compressive stresses will help in neutralising or reducing the magnitude of the tensile stresses even if they are present.

So, stress corrosion cracking tendency is reduced tensile strength capabilities improved and the fatigue life is also improved. So, these are some of the advantage is of the surface modification techniques.

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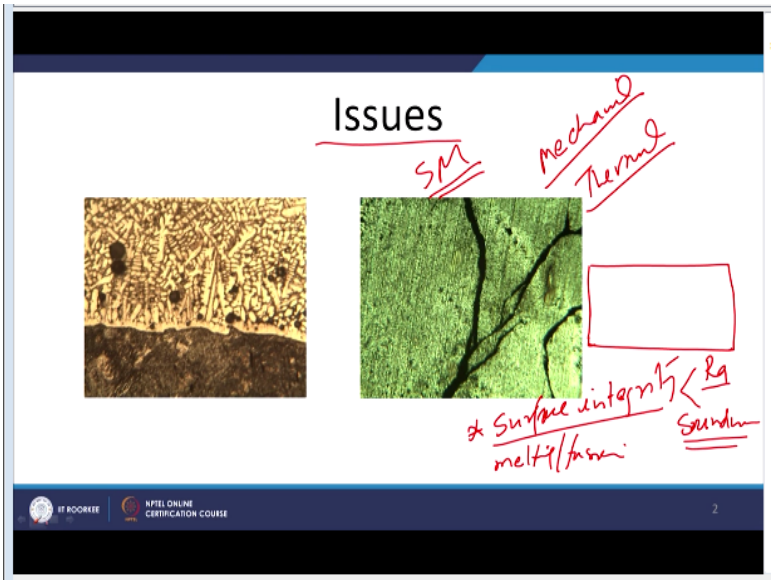

Now, but since there are various surface modification techniques like mechanical methods where we talked about short peening, burnishing, contour rolling. And then there were thermal methods involving like look like surface heating. In case of laser hardening, induction hardening, flame hardening or localised diffusion also was there like in case of the laser cladding or laser melting and weld surfacing.

Then electro chemical electrolysis based method like electro-less plating or electrolysis plating. So, they are different methods and each method of offers it is own set of the positives and negatives. So, whatever the method which is used for surface modification it should not affect the bulk material or the main component material appreciably. Otherwise the mechanical capability of the main component itself will be adversely effected.

And it may not perform as intended so, what is important that whatever the process is being used we should apply carefully. So, that certain undesirable problems related with the surface modification can be reduced the some of the common issues which are absorbed during the surface modification using variety of the processes include like the surface integrity of the

modified surfaces, surface integrity, surface integrity of the modified surfaces includes the two aspects like surface roughness and the soundness.

So, of course if the surface is not rough then it is good and maybe it can be put into the use directly if the surface is rough. Then we need to perform the secondary processing like finishing and the machining or grinding. But if it is not sound then it will be leading to the increase tendency for the failure of the modified surfaces. So, surface integrity can be a problem especially in those surface modification techniques where melting and fusion takes place like the laser melting weld surfacing etc.

So, in those cases is the common problems which are observed with the regard to the surface integrity is a like there can be presence of the cracks.

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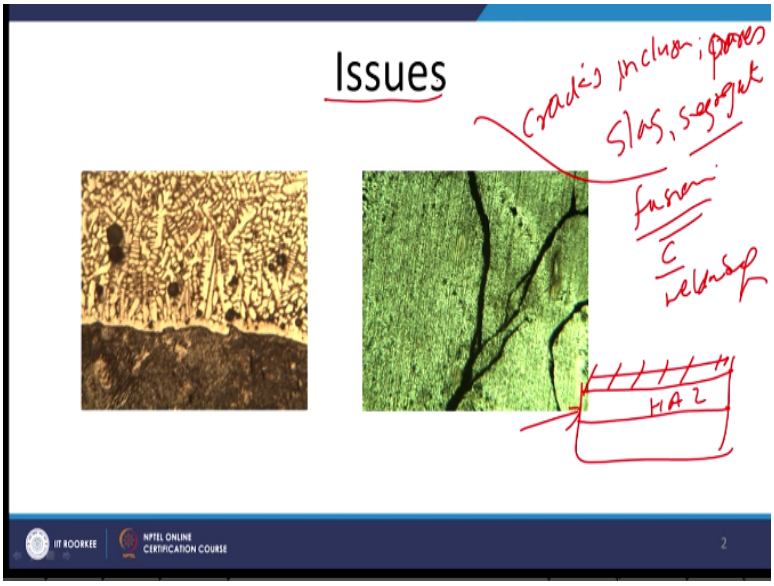

There can be inclusions, there can be pores or porosity, there can be slag inclusions or so, these are some of the issues. There can be segregation of some of the elements these are the issue which are associated with those surface modification techniques where fusion is involved. And sometimes if the lot of heat is applied during the surface modification like in processing like carburizing or weld surfacing.

So, in those case even the bulk material properties are adversely effected like in case of the weld surfacing apart from development of the weld surfaces one heat effected zone is also formed where will have the properties which are not expected which we may different significantly from the base metal. So, formation of such kind of the zones may further degrade the performance of the modified surfaces.

So, one aspect is related with the issues of associated with the surface modification is the surface integrity which includes the surface roughness. And the second is soundness of the modified surfaces. The second aspect is an isotropy which is also observed commonly in the modified surfaces an isotropy properties.

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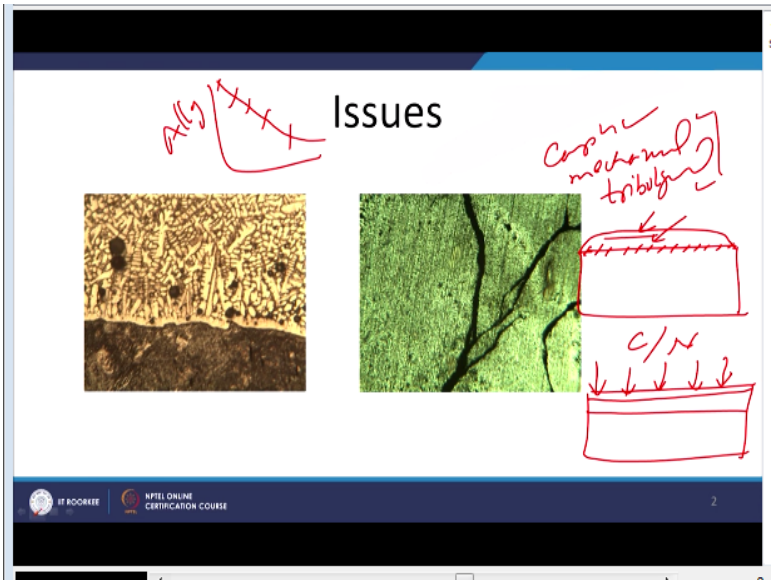

So, an isotropic properties, it may be with regard to the composition with regard to the mechanical properties even the tribological properties. So, there is always property variation there are number of examples like whenever we develop any flame spread coatings. So, flame spread coatings like this at the surface due to the loss of alloying elements we have different kind of composition and the properties as compare to the middle of the coating well at the interface there may be some kind of dilution due to the melting of the substrate.

So, there can be continuous variation in the properties with regard to the composition mechanical and tribological properties. Similarly in case of the process like a nitriding where nitrogen is

diffused on to the surface of the ferritic steel. So, nitrogen content is more near the surface layers as compared to the surface region, same as true for the carbon and nitrogen. So, in all these cases there is always concentration gradient like alloying concentration is great at the surface and then it will be reducing.

And accordingly there will be variation the micro structure there variation of the properties and accordingly it is resistance to the tribological behaviour or tribological performance will be affected sometimes this kind of situation also leads to the increased corrosion behaviour of the material. There is another aspect related with an isotropic behaviour wherein like process where like thermal spread coatings are used.

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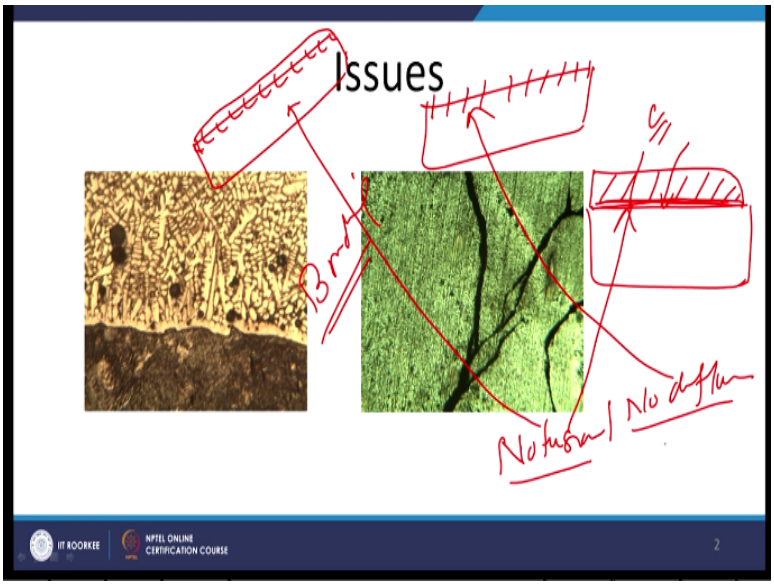

So, we have it is intended that not much of the melting of the substrate will be taking place. But the coating will have the coating may have the completely different composition than the substrate material. In that case sometime one a segregation of the alloying elements near the interface takes place. And this can be a problem under the certain conditions this may be too hard or this may be too soft zone formation.

And variation in composition at the interface, with respect to the base metal and the coating can be a problem with regard to the corrosion. And the cracking tendency because like say if there is a too high carbon then it will show the greater hardness as compare to the other zones. So,

sometimes even the segregation of the alloying elements at the interface can be a problem in those process where no fusion and no diffusion.

In these two categories those surface modification process where fusion and diffusion is involved modified surfaces like carburizing, nitriding chromizing, boronizing. In all those cases the elements will be diffusing and forming the integral part of the substrate. So, there is no question like the bonding of the modified surfaces with the substrate. Similarly in those cases where the base metal is fused and the layer is developed.

So, whenever there is a fusion on solidification it will be resulting in the metrological continuity between the surface layer and the substrate. So, in these two cases there is no question of in case of the diffusion based processes and in the case of the fusion based process there is no question of the bonding. Because in both the cases the substrate and the surface layer of form the integral part but in those processes where no major diffusion and fusion is absent. In those cases the bonding of the modified surfaces are coating is an issue.

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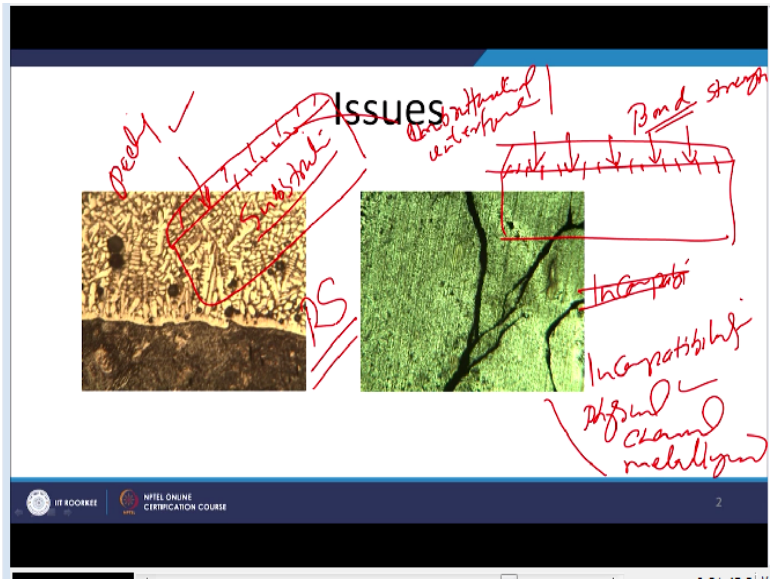

So, in those processes where there is no melting and there is no major diffusion just the layer is deposited like electroplating thermal spread coatings like high velocity of fuel spray process, detonation spray. In all those process flame is flame spray process. In those sprays processes

where there is no fusion only the coating is deposited the bond is normally formed by the mechanical interlocking and some little bit extent on the diffusion.

So, the bond strength becomes crucial parameter if the boding of the coating with substrate is not good. Then it can lead to the peeling off or suppression or delimitation of the coating. And once the coating is delaminated or separated from the substrate then the purpose of surface modification is lost. So, what is important that there has to be reasonably good bond is strength of the coatings with the substrate.

So, that it can remain with the substrate for long during the service another issue related with this is the incompatibility of the material being developed at the surface and the substrate material. So, if the substrate material is having entirely different physical properties, chemical properties, metrological properties. Then there can be issue of the metrological incompatibility metrological, physical and chemical incompatibility between the modified surface and the substrate.

And if the incompatibility is too much then it can lead the peeling of like very high difference in the thermal expansion coefficient or if there is a metrological incompatibility. Then it can lead to the formation of the embrittlement of the interface. So, or if the alpha expansion coefficient thermal expansion coefficient is too high then it can also lead to the development of the residual stresses.

So, we need to carefully see before deciding the kind of material and the method which can be used for surface modification is that the physical chemical and metrological incompatibility are limited. So, that there is no major issue regarding the delimitation or the peeling off of the modified surface is formation of the imbrittle interface or development of the residual compressive residual stresses in the modified surfaces.

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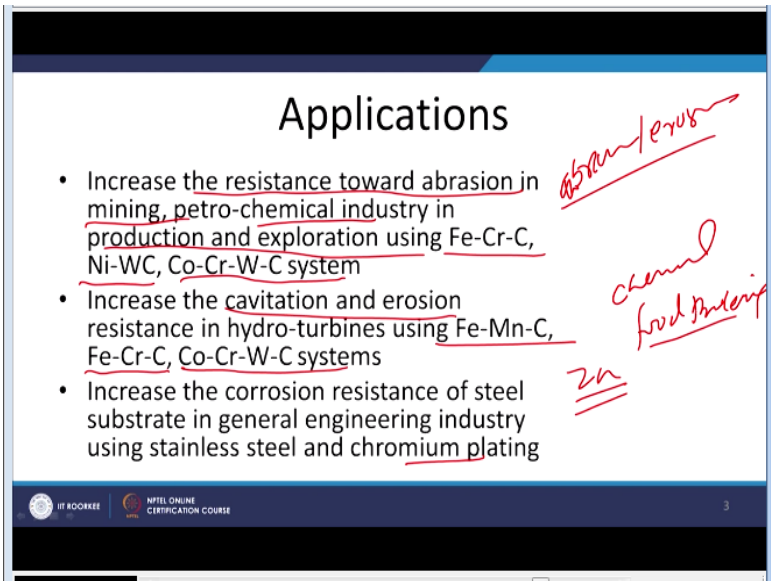

Now as for as the application of the surface modification techniques is concerned it is used in very large scale for variety of the purposes. Here we have certain examples where the surface modification techniques are used for improvement of the tribological life of the component like increasing the resistance towards the abrasion in mining, petro-chemical industry in petro-chemical industries especially in production and exploration.

And wherever the abrasion and erosion is involved basically the functional surfaces are modified using the iron chromium carbons system, nickel tungsten carbide system and covalent chromium tungsten carbon systems for increasing those fluid flow systems where cavitations and erosion is involved like hydro turbines pumps the functional surface is are modified using the iron manganese carbon system, iron chromium carbon system and cobalt chromium tungsten and carbon system to increase the corrosion resistance of the steel for general engineering industry.

We normally perform like galvanizing using zinc coating chromium plating is also carried out and stainless steel coating mainly in like say the chemical industry and food processing industry, processing industry for enhancing the corrosion resistance the austenitic stainless steel, claddings and the coatings can be applied chromium plating can be applied and galvanizing is normally done for normal ambient conditions for better corrosion resistance.

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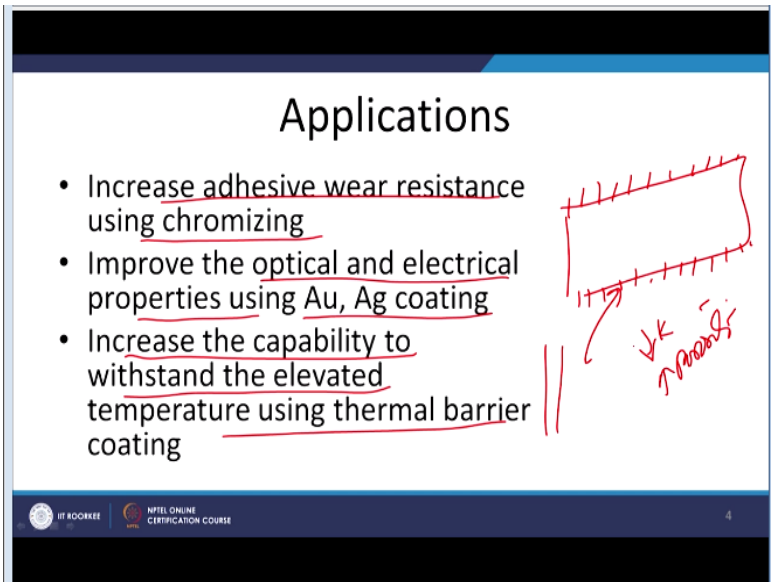

To increase the adhesive wear resistance like in normally in automatic components the chromizing is used and to improve the optical and electrical properties normally the coatings of the silver and gold is used. And for improving the optical properties suitable kind of the materials are also used for development of the cladding to increase the capability to withstand at elevated temperature thermal barrier coatings are used.

Normally Zirconium and titanium based coatings are commonly used for the thermal barrier coating purposes. So in that case like say this component is to be used at high temperature, so the surfaces will be applied with the coating. So, that the heat transferred to the core component is reduced after the development of a thermal barrier coatings. It works in the 2 principle like the thermal conductivities low and there is a high percentage of porosities. So, the heat from the surrounding to the core material is reduced.

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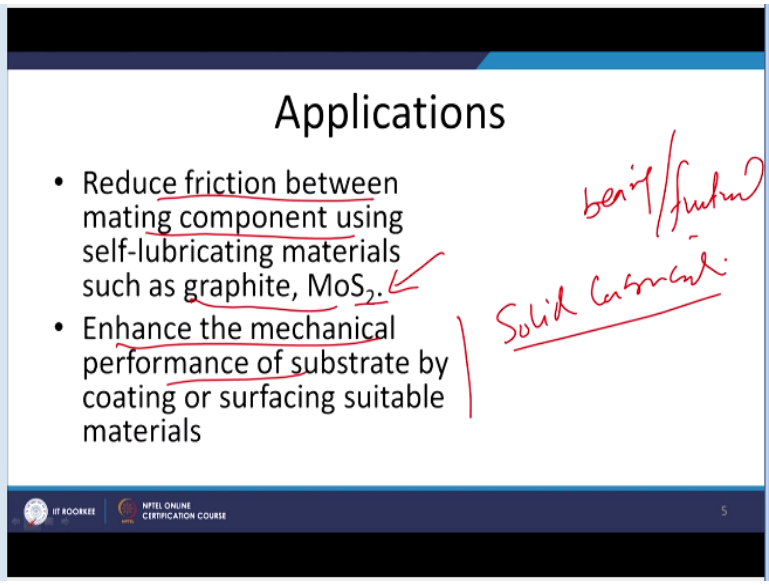

The surface modification is also used to reduce the friction between the mating components and for this purpose whatever the bearing or the functional materials are there. They are reinforced with the graphite and the molybdenum sulphide. So, the bearing materials and all the components which are used for making such kind of the mating components, these are reinforced with the graphite and the molybdenum sulphide.

These constituent sectors solid lubricant so, these provide under the service conditions these provide the required lubrication effect of primarily the separating the mating components to avoid the direct metal to metal contact. And ensure the and reduce the adhesive wear these are also used to enhance the mechanical performance of the substrate by developing coating and weld surfacing of using the suitable kind of the material.

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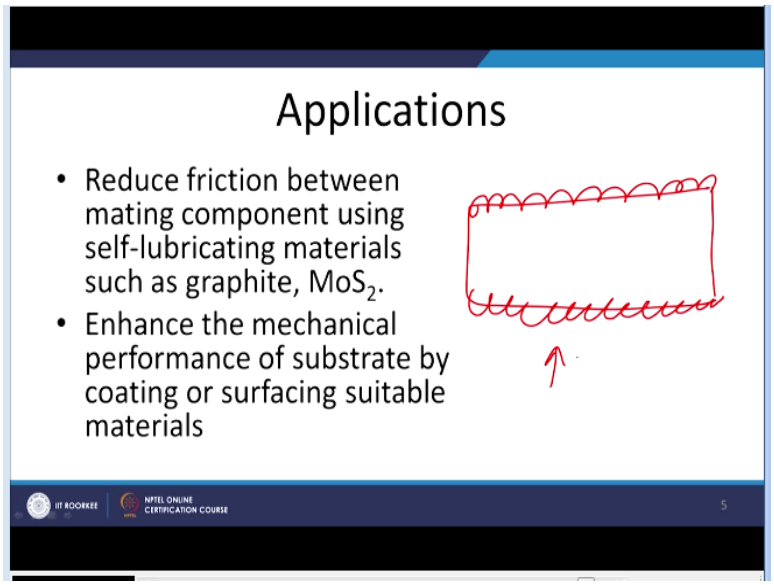

Under this category basically, I will take over a simple example like the mild steel having the say somewhat lower strength. So, if the high strength material is coated at the surface. So, this will increase the load carrying capacity it will delay the nucleation and growth of the crack at the surface. So, such kind of the methods are used for enhancing the mechanical properties and the performance of the component.

Now I will summarise this presentation in this presentation basically I have talked about the advantages and applications of the surface modification techniques. And also I have seen that, what are the things to be taken care of to avoid the adverse effect of the surface modification technique onto the substrate, thank you for your attention.