Fundamentals of Surface Engineering: Mechanisms, Processes and Characterizations

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Lecture-04
Classification of Surface Modification Techniques I

Hello, I welcome you all in this presentation related with the subject fundamentals of surface engineering and we are talking about the introduction aspects related to the surface engineering, in this presentation we will be talking about the classification of the various surface engineering techniques or surface modification techniques which are used to improve the properties of the surfaces.

So, that the life of the component under the tribological conditions can be improved as well as functionality of the surfaces also can be enhanced for the specific applications. So the need of classification actually arises or you can say the processes are classified primarily for 2, 3 regions like grouping of the processes based on the fundamental principles help us to have the easy understanding of particular process.

So, if we classify the different processes based on the certain principles then it will be easy to group or it will be easy to understand which that particular process belongs to which category. Second aspect is that whenever new process is developed we will be able to put that process in a particular category as per the kind of approach or principle being used. The classification can be based on the number of prospects like the basic approach the kind of energy which is being used.

So, if we have 2 group the surface modification processes for which are used for improving the surface properties, they are 2 broad category of the approaches which are normally used. These are like whatever surface we have we know that if the surface having the surface regularities and the 5 different zones.

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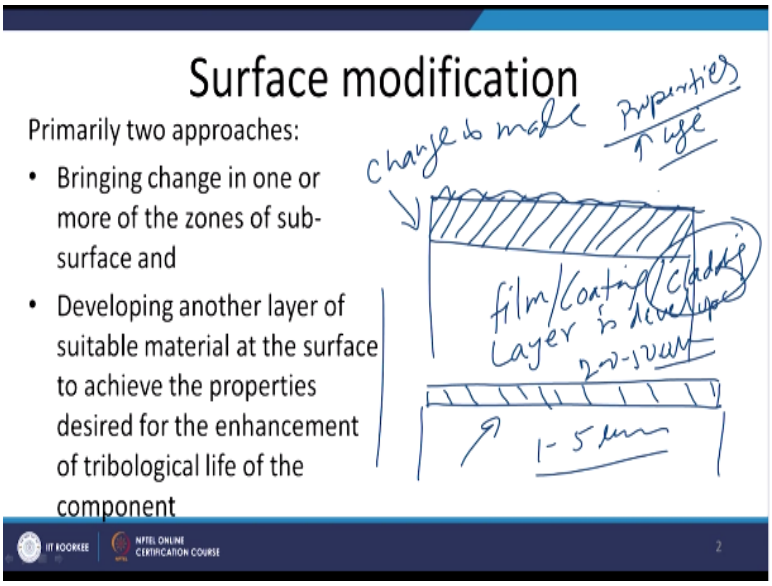

So basically changes in at the surface or in some of these zones are made for improving the surface properties or improving the functionality or ability of the surface to perform a particular kind of function. So, basically the one aspect is that some change is made at the surface or near surface layer. At the second aspect related to the second approach in the surface modification belongs to another category where the surface which is not able to perform the required function.

On that surface we try to build up or develop a layer of suitable material which can actually perform or result in the properties which are expected. So, in this case 1 layer is developed onto the surface of the substrate, so here layer it can be layer in form like very thin films less than 1 micrometer or it can be coating which can which is nor we say like a 10 to 500, 600 micrometers or it can be cladding all as well which are quite like thicker 1mm, 2mm thick claddings are also developed.

However the functions maybe significantly different, harder is the material which is being coated lesser will be the thickness like PVD, CVD coatings are made in very small thickness is like 1 to 5 micrometer while softer materials like Nickel, chromium or tungsten or cobalt based systems like they are developed in form of the coatings of like say 200 to 500 micrometer.

And then for the softer materials like austenitic stainless steel, martensitic stainless steels which are developed for much greater thicknesses and form of the claddings to enhance the surface

properties. So, basically these are the 2 broad approaches which are used in surface modification like 1 changes are made at the surface and sub surface region using the various principles.

And the second one where 1 layer is a developed at the surface, so that the required set of the properties can be realised at the surface which will help to improve the travelogical life of the component as well as these coatings and fins are also sometimes use to in increase the functionality or capability of the surface to perform to particular kind of function.

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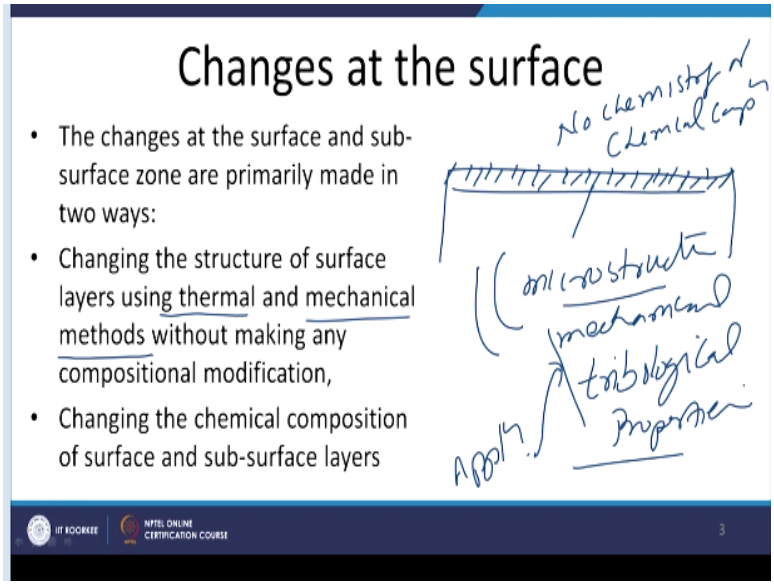

Now as for as the first category means first type of approach is concerned where the changes are brought in at the surface and near surface layers, again they are 2 broad categories in this approach where the surface or near surface layers will be altered. So, for this approach again there are 2 broad categories. These broad categories include like it includes changing just changing the structure of the near surface layers.

Structure means microstructure of near surface layers is altered, so that we have a required set of the mechanical properties and which will be able to deliver the required combination of the tribological characteristic required for the performance tribological properties required for given or expected performance of a given product under the certain set of the condition. So, what kind of the properties required to for performance and are given set of conditions that will be dictated by the application.

So, application will decide the kind of properties that we should have chemical, mechanical or a tribological property and which will be realized to the micro structural modification of the surface. So, and for this microstructural modification we can use thermal means the heat is used in very localised manner for heating the surface layers there after control cooling helps the desired structure.

And the second approach was just a sulphur mechanical forces applied at the surface in very localised manner. So, surface layer deformation is achieve to enhance the properties of the component and in this case there is no chemistry, no change in chemistry or chemical composition of the chemical composition of the component just the microstructural changes are brought in at the surface a near surface layers.

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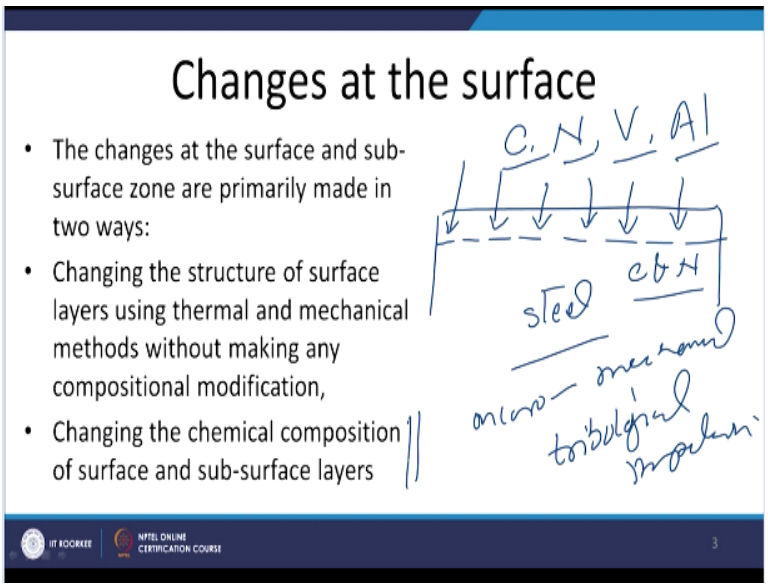

And the second approach involves the changing the chemical composition of the surface layer. So, in this approach like this is a surface, so whatever the sub surface zones are there like 1 to 4, 5 whatever we have talked earlier the modifications are made in these zones through the suitable chemical or compositional alteration and for this purpose as per the property requirement for a given application.

We identify what kind of a chemical modification or chemical changes to brought in at the surface and for that purpose we may add carbon like in case of the steels, we may add carbon, we may add nitrogen, we may add vanadium or we may be add aluminium. So, accordingly the purpose will be termed as like carburizing, nitriding, vanadizing or Aluminizing or some like combination of the carbon and nitrogen both are also added alike in case of the cyaniding process.

So, this is the another approach where the compositional modification of the surface and near surface layers is carried out to achieve the desired micro structure. So, that is add mechanical properties are realise which we in turn will be able to deliver the required set of the tribological properties. So this is a kind of sequence which is used for a realising the properties through this approach were compositional modification of the surface and near surface layers is carried out**.**

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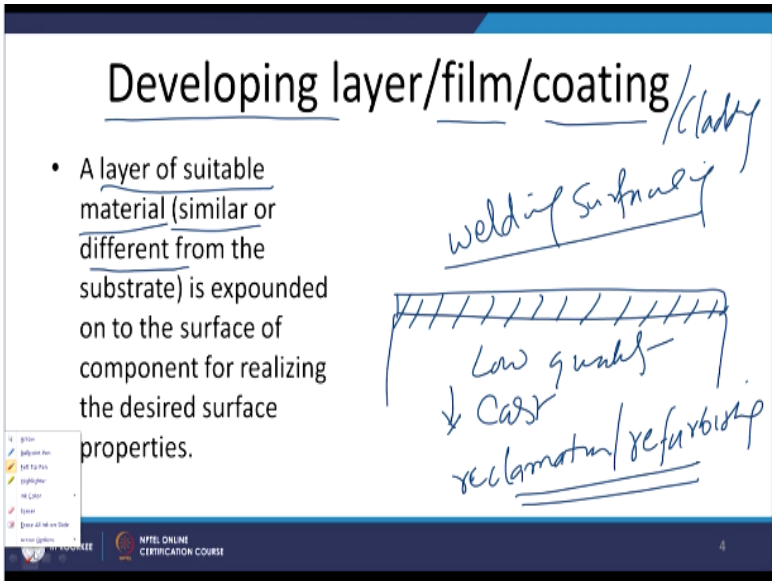

So, another category of the approach of the surface modification is where developing a layer or film or the coating or it can be cladding also if it is very thick. So a layer of the suitable material which can be similar or it is similar from the substrate, normally the substrate is of the low quality material which is not able to offer the required set of the properties and this also helps in bringing the cost of the component down.

But only but only the functionality improvement or property improvement at the surface is required. So, that expected a performance of the component under the tribological conditions can be realised and for this purpose the approach is simple material or either the same composition or that similar, same composition layer is applied especially under the wear conditions when the loss of dimension of the component is leading to the failure of the component.

So, under such conditions material is deposited again of the type and after machining we regain the dimensions which were lost due to the wear. This is 1 approach were just reclamation or refurbishing of the component is tried. So, this will help bring the dimensions of the component back to the original one, so that it can be brought in use again for the given purpose.

So, under such conditions a layer will be build up of the same material and this one is called the reclamation or refurbishing, normally in this case the weld surfacing or the welding based methods are used for building up of the layer of the material of the same material.

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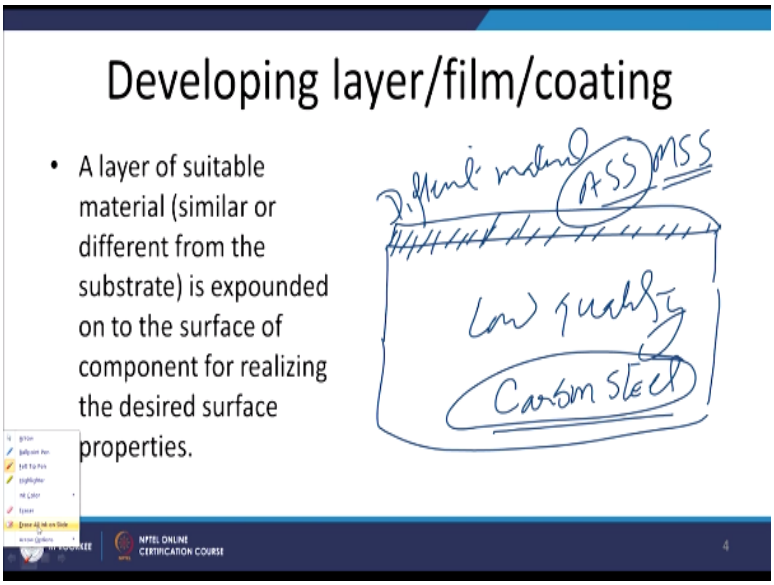

In another case when the different set of the material is used like the low quality material, for example most of the components made of their simple carbon steels or mild steel, if they are able to carry the load that is fine of the surface. But the component is designed in light of the mechanical properties, so that it can take the surface load but if the surfaces are not that good

enough to carry out the surface under the given set of the conditions because of the accelerated wear conditions for the given material of the substrate.

Then in this case material of some other material which is having the required set of the properties is applied in form of the layer of the coatings. So, the different material a layer of the different material is applied in this approach. For example simple carbon steel or mild steel component is applied with the layer of the austenitic stainless steel or the stainless steel as per the requirement martensitic stainless steel.

So, that it can offer the required corrosion resistance and martensitic stainless steel is used when not just the corrosion resistance is required. But also good combination of the harnesses needed, similarly if the component is to be exposed to the high temperature conditions and we want that it is prevented for from any kind of the oxidation.

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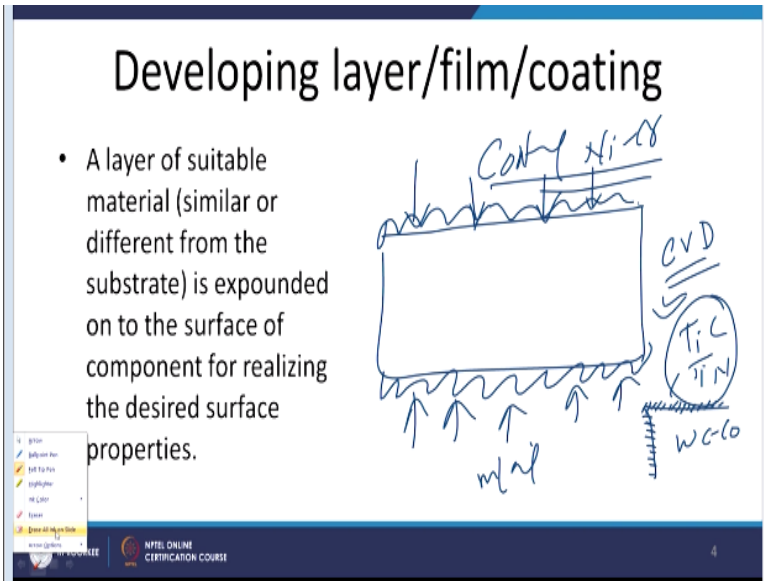

Then it is common that the layer or the coating of the Nickel, chromium base systems is applied at the surface. So, coatings of the Nickel, chromium systems help to prevent the oxidation of the iron at a high temperature and thereby protecting the component which is being used at a high temperature. So degradation of the low quality material under the adverse service conditions can be reduced by developing the layer of the suitable material.

So, that it can really perform the indented function for long, so that is how the tribological life of the component can be improved by developing layer of a film or the coating. The similar to this one is an example of like tungsten carbide these tools are coated with the CBN or chemical vapour deposition coatings like Titanium nitride, Titanium carbide coatings are applied.

So, because of the very good resistance to the adhesive wear and abrasive wear of these coatings like TiC or TiN coatings developed onto the surface of tungsten carbide cobalt based tools. So, these coatings will actually be reducing the material loss from the tool during the machining conditions and such kind of coatings are developed through the approaches like chemical vapour deposition process.

So, these coatings are actually very thin, so this is another example where in the performance or a performance of a given component is enhanced in terms of the life of the component by developing a layer or the coating or film of the suitable material. So, that it can sustain the conditions it was a working conditions for long and the life of the component can be enhanced.

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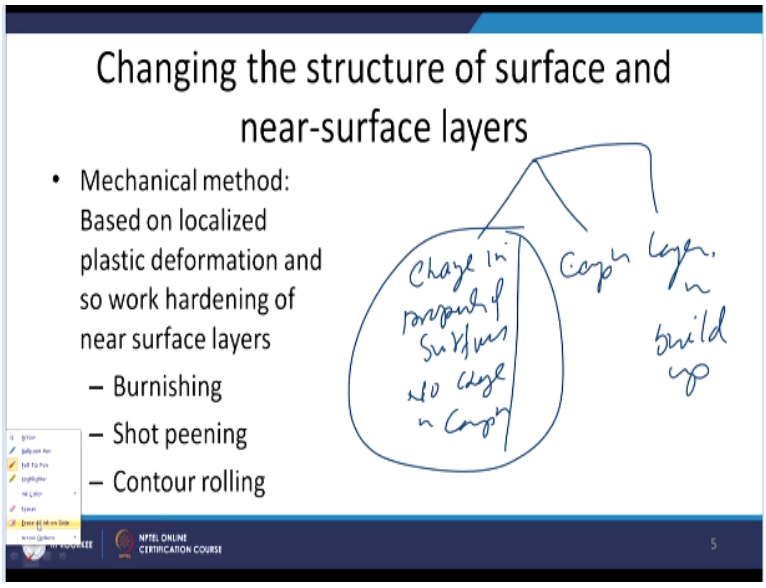

Now, apart from these 2 broad categories where the changes are brought in at the surface changes in properties of surface where no change in composition, this is one category. And the second category here is the change in properties by the compositional modification and third one

is here where layer is built-up. So, as for as the first one where the no change in the composition is made just a changing in properties are achieved through my structural modification.

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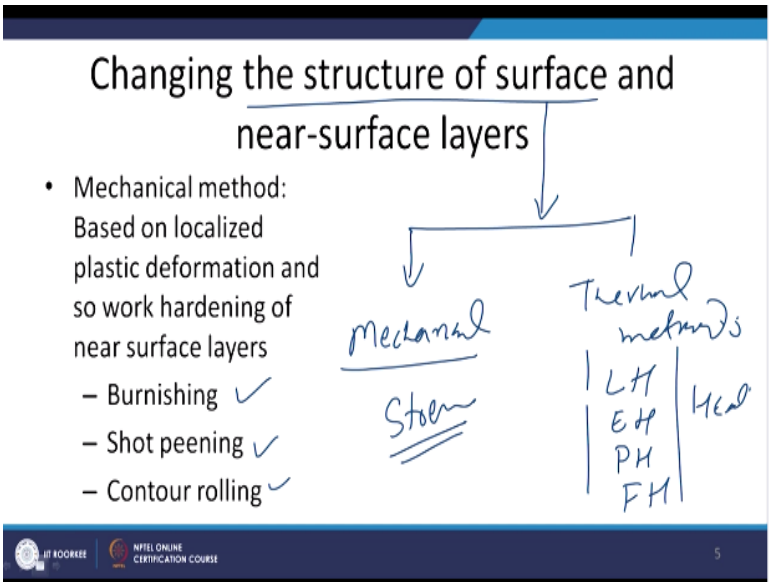

Again this kind of the processes which fall in this category where in just change in the structure is achieved for required improvement in properties. They are 2 broad categories 1 is so means this category of the processes can be grouped under the 2 headings, 1 is where mechanical methods are applied and second where thermal methods are applied. In the mechanical method the methods are like the burnishing, shot peening and contour rolling.

And in the thermal methods there is like the laser hardening electron beam hardening plasma hardening. So, the flame hardening, so these are the hardening methods where the heat is used and in the mechanical methods localised plastic deformation through the application of suitable stresses is realised.

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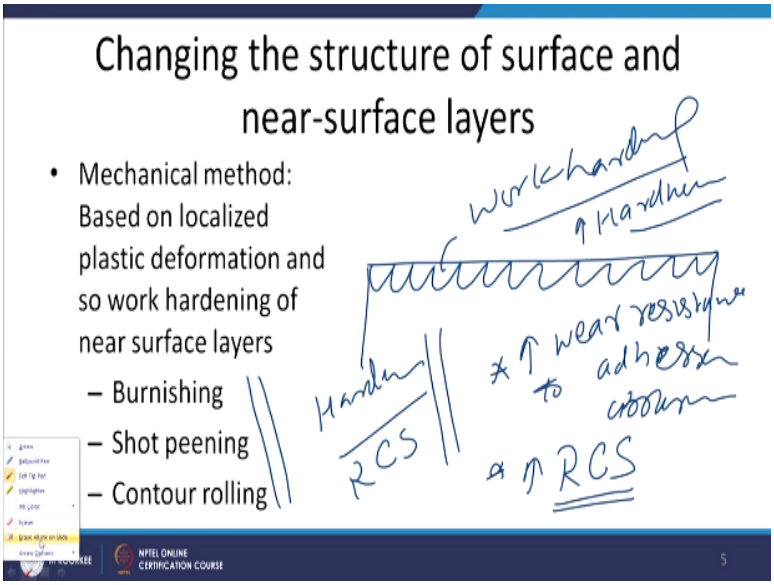

So, how does it work that in brief explain here like the surface with whose properties are to be improved then what will be doing through the suitable means like burnishing or shot peening or contour rolling near surface layers are plastically deform. So that the work hardening takes place and whenever there is work hardening improvement or increase in the hardness of the material takes place.

And which in turn develops which in turn increases the resistance to the wear resistance under adhesive and abrasive conditions. So resistance to adhesion and abrasion conditions. The second one this kind of the techniques also helps in increasing the residual stresses of compressive types. So development of the residual compressive stresses, so a combination of the increase in hardness and the development of the residual compressive stresses.

This combination actually improves the mechanical performance as well as the wear resistance of the material. In this case as such there is no chemical change in the material, however the different materials behave differently because of the different work hardening behaviour.

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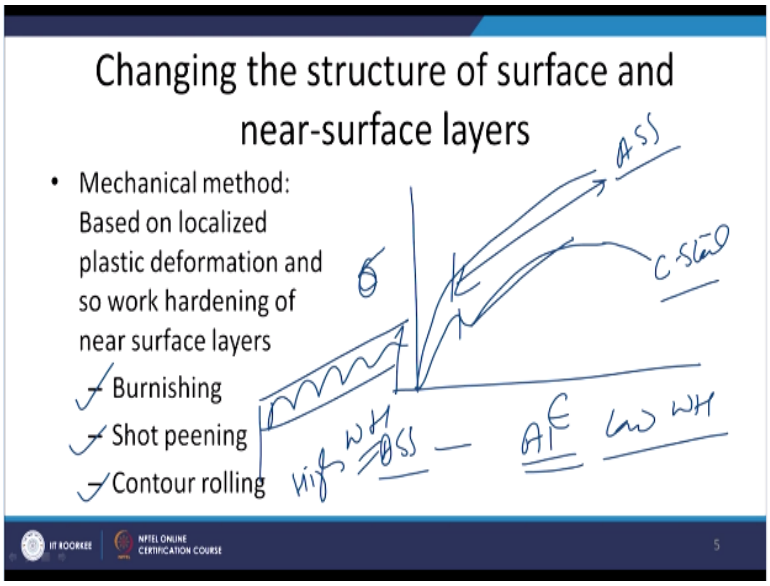

For example simple carbon steel may show this kind of the change in the stresses chain the sigma and this is the stress and this is the strain, another material may show they work hardening behaviour like this were say this is the kind of the plastic zone and in the plastic zone it shows the work hardening. So, here work hardening is taking place at very low rate than in another case.

So, the different materials will be experiencing the different work hardening rates, for example ASS work hardness very rapidly as compare to the simple mild steel. So, whenever the mechanical methods are applied few metals show very good response to the improvement properties as compare to the others. So, if you compare ASS or aluminium under the identical conditions of the surface deformation will find more improvement in the properties in case of the ASS as compare to that of the aluminium.

And that is activated to the low work hardening tendency of the aluminium as compare to the austenitic stainless steel, martensitic stainless steel shows the very good work hardening tendency and that so it results in very good improvement in the properties after these approaches.

So, as burnishing, short peening and the contour rolling these are the 3 mechanical methods which are used for improving the properties of the component depending upon the type of metal in it is work hardening maybe a there can be different extent of the improvement in properties of

the components subjected to the improvement properties through the mechanical methods another category is the thermal methods.

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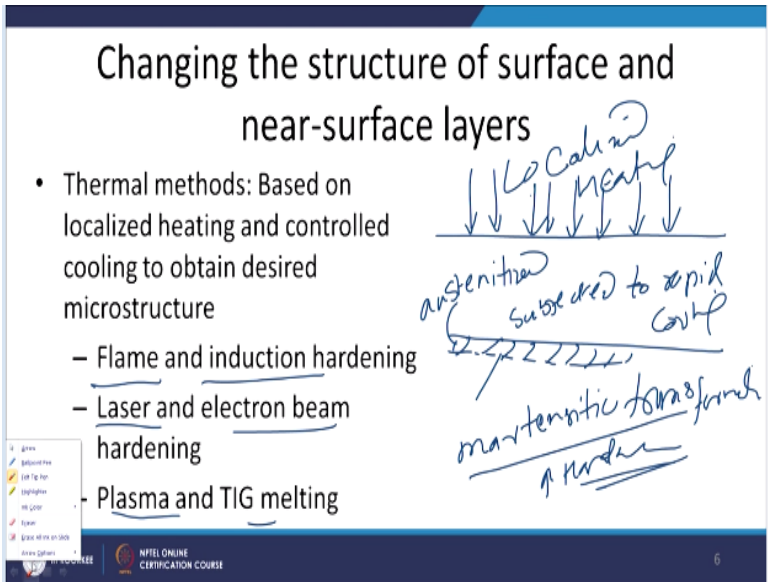

And in thermal methods what is done basically the very localised heating is carried out of the surface. So, suit using suitable heat source like heat source maybe laser or heat source maybe electron beam or heat source maybe the flame or the plasma arc. These are the basically heat sources or it can be through the induction effect. So, electron beam laser or the plasma or TIG arc, in all these cases very localised heat sources applied.

So, near surface layers get austenitic and this austenitic layer near the surface is subjected to the rapid cooling and this rapid cooling results in the wherever austenitization is taking place that will be subjected to the martensitic transformation and this kind of transformation will be leading to the improvement in the hardness of the material. So, depending upon the area being covered depending upon the energy density associated with the particular heat source, we will be finding the different depths which will be which will be different depths were improvement will be experienced.

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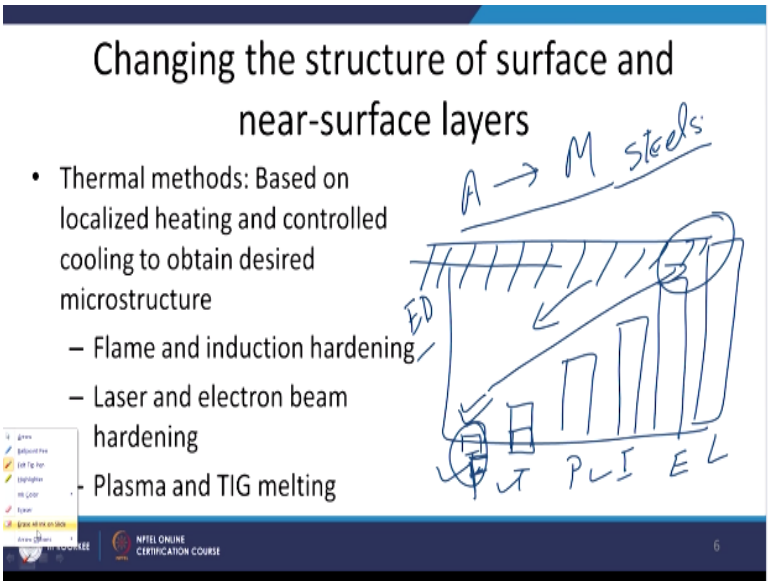

For example the low heat in put processes like the lowest heat it put here will be like say all the there is no flame there is flame. So, flame offers the minimum heat lowest energy density then we have a TIG here initially we have flame TIG has somewhat higher energy density then we have plasma and then we have induction and then we have electron beam and laser.

So, increasing energy density makes how rapidly we are able to heat the material to the required depth otherwise melting will start. So, what we do if the flame is applied it will be able to heat the metal to the greater depth and will be causing the hardening up to the greater depth. But since the energy density lows it is a slow process it will be heating the large area will be causing the transformations up to the greater depth.

So, if you see this will be the sequence and which is that laser, plasma sorry the flame, TIG, plasma then we have induction, then electron beam and then laser. This is a this is in order of increasing energy density and the depth of which will be hardened through these techniques that will be in opposite order maximum depth will be heated maximum depth will we modify by flame hardening approach and the minimum will be here at this higher end.

So, we can say the energy density and the depth of to which hardening will be hardening taking place due to this thermal methods that will be inversely related. So, this is about the approach and as I have said since the method is based on the austenitic transformation due to the heating

followed by the martensitic formation, so this kind of transformation in variably takes place in case of the steels. So, steels of low carbon steels are not subjected to the significant change in properties to the martensitic transformation.

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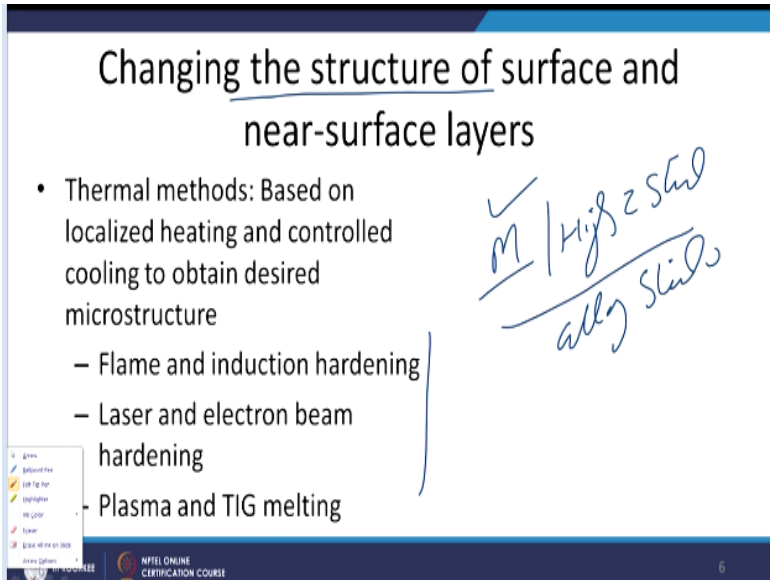

So, these are good for medium or high carbon steels the change in the other non porous metal systems that may not changes may not be that much as compare to what will be observed in case of the medium and high carbon steels. So, these methods thermal methods for improving the properties are basically applicable to the medium and high carbon steels and alloy steels.

So, this is what is there under the category, so if you compare the approach where changes are brought in the structure for improving the properties no change in composition they are 2 broad categories 1 was the mechanical methods where the localised plastic deformation is achieved and the second one is the thermal method where localised heating is carried out followed by the rapid cooling.

So, that required change in the microstructure of the component can be brought in for improving the properties of the component. Now the another group of the processes is where the change in improvement in properties is brought in through the compositional modification. So, as I have said like if the component go surface properties are to be improved.

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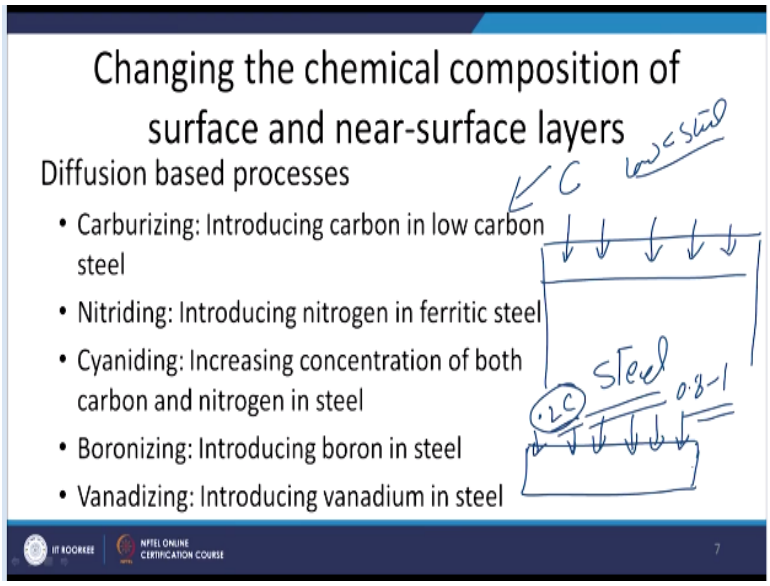

So, in this case these most of these methods are for steels where property improvement is brought in by modifying the chemical composition or modifying the chemistry of the component of the surface and near surface layers. It depending upon the process it can be like 1mm, 2mm depth also it can be thinner as well. So, depending upon the kind of element which is being introduced in this, they are different methods like carburizing is used for when the carbon is introduced at the surface.

And near surface layers for improving the properties again this method is applicable for the low carbon steel, steels which are deficient or having the low carbon content. So, the property improvement requires the additional carbon content at the surface and near surface layers. So, that after the subsequent heat treatment required combination of the properties can be achieved, as I have said that low carbon steel components those like say especially having the 2% carbon even after the rapid heating and cooling.

They cannot result major change in properties even through the martensitic transformation because of low carbon content. So, such kind of the steels are introduced with the carbon content and carbon content is increased up to like say 0.2 to 1%. So, obviously there will be gradient in the concentration of the carbon from surface to the sub surface region. But depending upon the depth of few improvement is required the carbon is diffused and the sub surface region maybe like say 1 or 1.5mm depth from the surface.

And for this purpose once the carbon is enriched then will be doing the austenitization followed by rapid cooling hardening of the surface to the carburizing approach.

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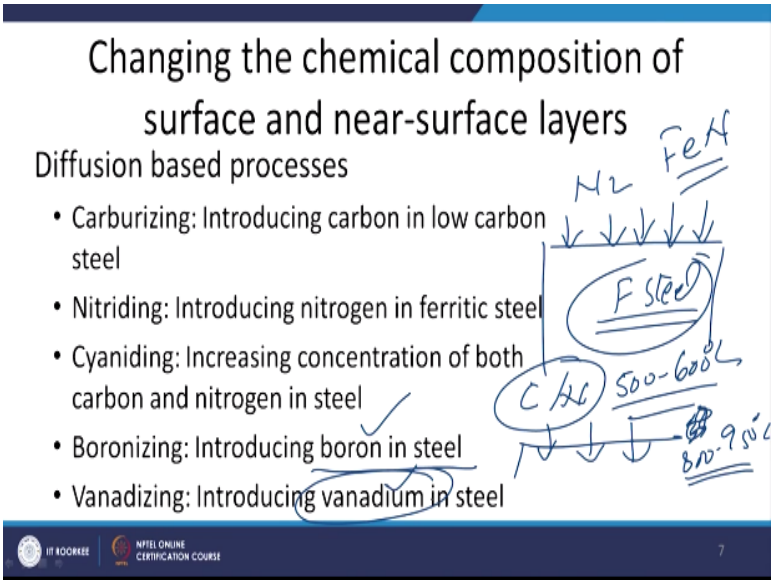

In case of the nitriding approach is little bit different here, this is primarily used for the steels where the ferrite is dominating, so ferrite steels this method is used where the nitrogen content at the surface is enhanced. So, this nitrogen content will increase in nitrogen content will be forming the iron nitrides and they are by improving the properties of the surface, another advantage is that it is just carried out in the ferritic zones the temperature high enough.

But high enough to ensure the diffusion but low enough to avoid any kind of austenitization of the steel, so 500 to 600 degree centigrade is the temperature which is normally used for this purpose. In case of the cyaniding both nitrogen as well as carbon are introduced at the surface for improvement in the properties using temperature of like say 800 to 950 degree centigrade, this is the range of temperature which is used.

But cyanidizing process is faster than what is used in carburizing but in this process both carbon and nitrogen are introduced at the surface. Similarly in case of boronizing boron is introduced in the steel for improving the hardness and wear resistance of the component and vanadizing in

case of the vanadizing vanadium is introduced the surface of the steels and these steels are like they are grouped carbon and nitride formers.

So, whenever these are introduced they will be like boron carbide or boron nitrides and the vanadium carbide, so their carbides and nitrides are hardened stable. That is why whenever these are introduced in this steels they will be reacting with the carbon and nitrogen to form their carbides and nitrides for improving the properties of the steel, now we will summarise these presentation.

In this presentation basically we have talked about the broad approaches which are used for the surface modification and what are the different categories of the processes where improvement in properties is brought in without any change in chemical composition but just changing the microstructure helps to improve the properties of the component, thank you for your attention.