Fundamentals of Surface Engineering: Mechanisms, Processes and Characterizations

Prof. Dr. D. K. Dwivedi
Department for Mechanical and Industrial Engineering
Indian Institute of Technology-Roorkee

Lecture-05
Classifications of Surface Modification Techniques II

Hello, I welcome you all in this presentation related with the subject fundamentals of surface engineering and we are talking about the classification of the surface modification techniques. In the previous presentation we have talked about the 1 category of the process wherein the improvement in properties is achieved through the structural modification of the surface without any changing chemical composition.

And also we have talked about 1 type of the processes where improvement in properties is achieved through the compositional modification. And that compositional modification can be achieved through number of approaches such as diffusion, diffusion based approaches are like the carburizing, nitriding, boronizing, vanadizing and there is another category of the processes where the chemical composition is achieved through the use of the ions and use of the laser beam.

So, we will be talking about the further 2 approaches of modifying the chemical composition of the surface layers. So, that the required improvement in properties can be achieved, so under the chemical compositional modification for improving the required set of the properties of surface and near-surface layers.

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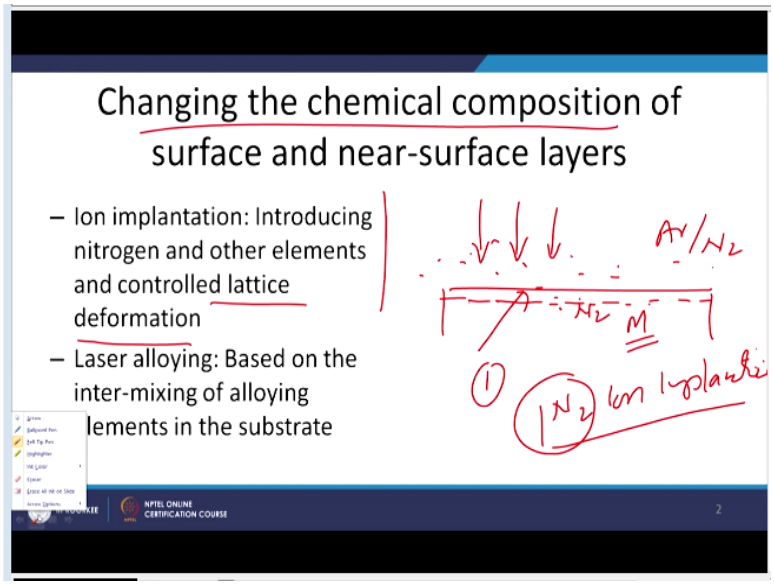

The one approach is the ion implantation, so what is done in this approach the element which is to be introduced at this surface of the component environment enriched with that element is achieved like Argon or nitrogen. And, then these environment through this environment the beam of the ions is directed onto the surface. So, intermixing of the nitrogen and nitrogen with the substrate material is facilitated through the impingement or impact of these ions.

And so, ions work in 2 ways, 1 it damages the crystalline structure makes it first for improving the properties. And the element which is to be introduced in the surface of the component whose properties need to be improved proper mixing is facilitated through this impact of the ions onto the surface. So, proper mixing of the nitrogen with the metrics will be facilitated through these impacts of the ions and that in that case it is called nitrogen ion implantation.

So, this is one example where nitrogen ions nitrogen is introduced through the impact of the ions onto the surface for improving the properties. So, apart from introducing the particular element which is to be introduced the lattice is also deformed.

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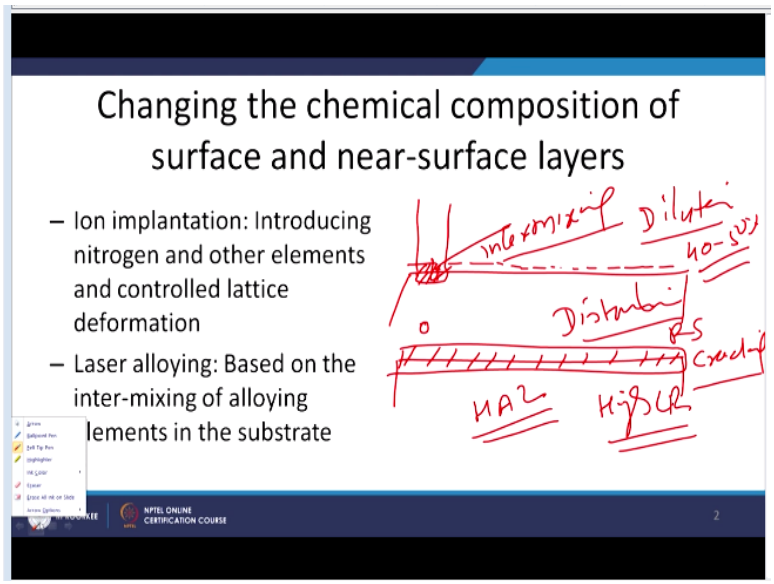

And combination of both these help to improve the hardness and so wear resistance of the material. Although this kind of the improvement is over a very thin zone which maybe less than 1 micro meter another approach is of the laser alloying. In case of the laser alloying for modifying the chemical composition, so that required improvement and properties can be achieved what it involves laser alloying uses a very high dilution approach where the material to be introduced is a pasted or applied onto the surface of the substrate.

Or the component whose composition is to be modified for improving the properties and then laser beam is directed onto the surface. So, melting of the material pasted onto the surface as well as little bit melting of the substrate also takes place. So, melting of both material which is applied at the surface as well as melting of the substrate material.

Both leads to the intermixing and this intermixing is called dilution, dilution % or the extent of the mixing of the base metal with the material which is applied at the surface is very high in case of the laser alloying like 40 to 5o%. So, in this approach certainly the melting of the base metal as well as the melting of the material which is to be applied is realised for altering the composition of the surface and near-surface layers.

So, that the required set of the improvement in properties can be achieved since the laser is the high energy density processes and it focuses is very small area. So, we need a high power lasers

in order to cover the larger area, if the compositional modification of the surface layers is to be achieved. At the same time it also will be leading to the development of the heat affected zone and faster cooling subsequent high cooling rates after the laser heating.

Sometimes also leads to the distortion and the residual stress and cracking related issues of the component which has subjected to the laser alloying. So, but this is also one of the approach so, there are 3 broad categories of the compositional modification for improving the surface properties.

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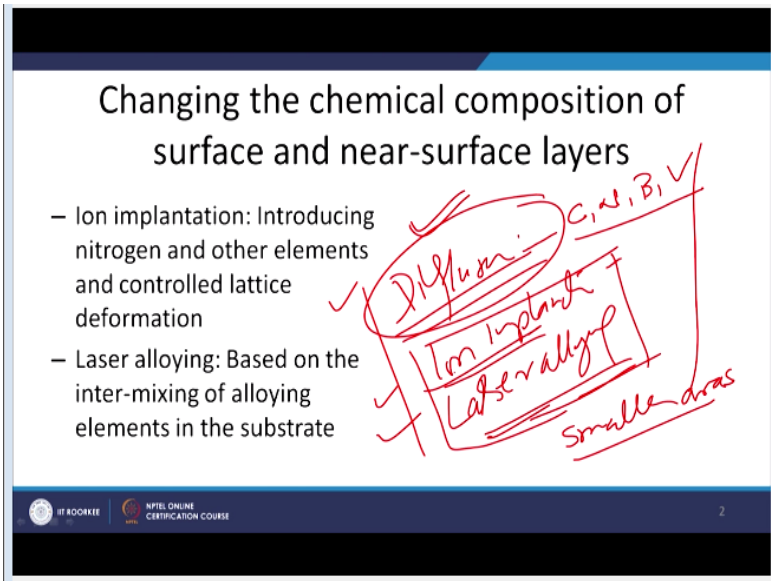

One is diffusion about which we have talked involves like carburizing nitriding boronizing vanadizing another is ion implantation where the nitrogen or other suitable at element is introduced at the surfaces as well as the lattice structure of the near-surface layer is also deformed or damaged. And third one is the laser alloying so, the component remains in the solid state in these 2 cases.

But here the surface layer of the substrate or the base material is brought to the molten state in case of the laser alloying the very commercially used process involves like carburizing, boronizing, nitriding etc., where diffusion is used for modification of the chemical composition. While these are the 2 very advanced processes these are completely slow. So, these are to be used

for very specific applications where it is not possibility use the diffusion based processes where entire component needs to be exposed to the high temperature conditions.

So, that required chemical composition modification can be achieved, so smaller areas which are to be improved or the conditions do not fair for using the diffusion based approach for surface modification of a particular component. So, for those cases ion implantation and the laser alloying can be used for the modifying the surface properties.

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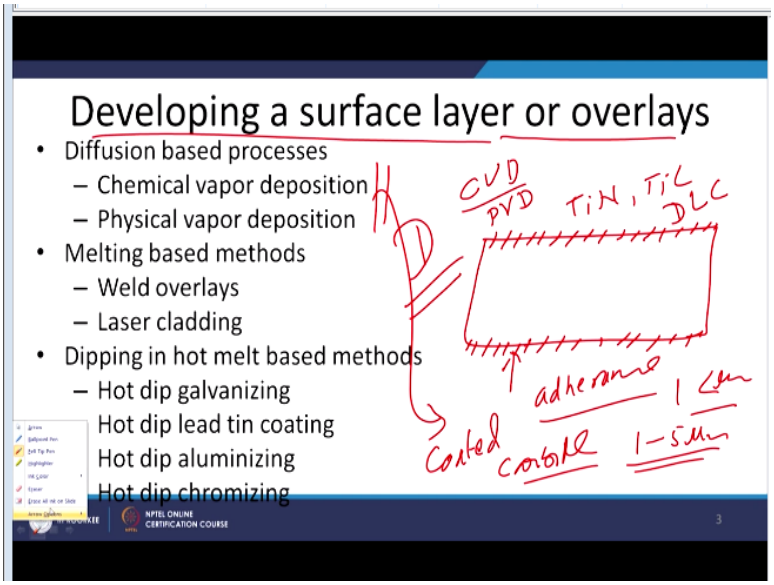

Third approach is like developing the surface layers and overlays or films onto the surface. So, various methods are used where there were categories under this method 1 is the diffusion in the in case of the diffusion like the component whose surfaces are to be modified for improving the surface properties basically the chemical composition is modified at the sorry the surface layers are developed through the diffusion.

So, here in this case they are 2 methods one is the CVD which is called chemical vapour deposition and another is PVD physical vapour deposition, so required elements which are to be introduced at the surface. So, that it can form like titanium nitrides, titanium carbide or the DLC diamond like coatings. So all these suitable rich environment is created onto the surface.

So, that they are compounds can be form at the surface of the component it is required that whatever film or coating is formed that is having the good adherence with the substrates. So, that it remains attached with the substrate material for imparting the required set of the properties. But in these process the elements like titanium, nitrogen, tungsten, boron etc., are introduced at the surface layers for forming the desired compounds at the surface in form of thin films.

And films are really very thin less than 1 micro meter to a watt or sometimes you meant 1 to 5 micro meters in the thickness for imparting the desired set of the properties. This method is commonly used for developing the coated carbide tools. So, in this approach basically a thin-films of these kind of the materials are developed on the surface of the tools. So, that they can really perform, so tungsten carbide tools are HSS tools are coated basically using the CVD, PVD process for improving the life of tool.

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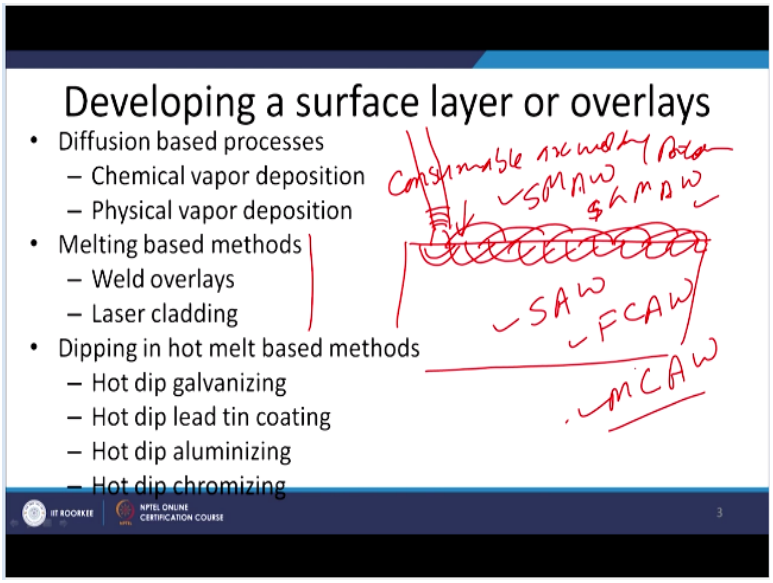

Then we have the another category of the process, where surface layer are the films and coatings are develop this includes a the weld overlays. So in case of the weld overlays basically we use the consumable or welding processes, so like this is the substrate and we use the electrode of the suitable composition whose coating or weld overlays is to be develop. So, here arc at the end of the tip of the electrode.

This will be causing the fusion of the substrate as well as the heat of the arc will be fusing the electrode as well. So, the metal will be transformed from the electrode to the molten base metal and 1 layer is developed in this way onto the surface of the substrate. And this layer can be machined out subsequently to be at the required size, safe, finish etc., so, the process like shielded metal arc welding, gas metal arc welding GMAW gas metal arc welding.

And then even submerged arc welding, flux code arc welding and the metal core arc welding process. These are the some of the welding processes where electrode is consumed in course of the welding processes for depositing the metal to be metal onto the substrate. But since in these process the significant fusion of the base metal takes place.

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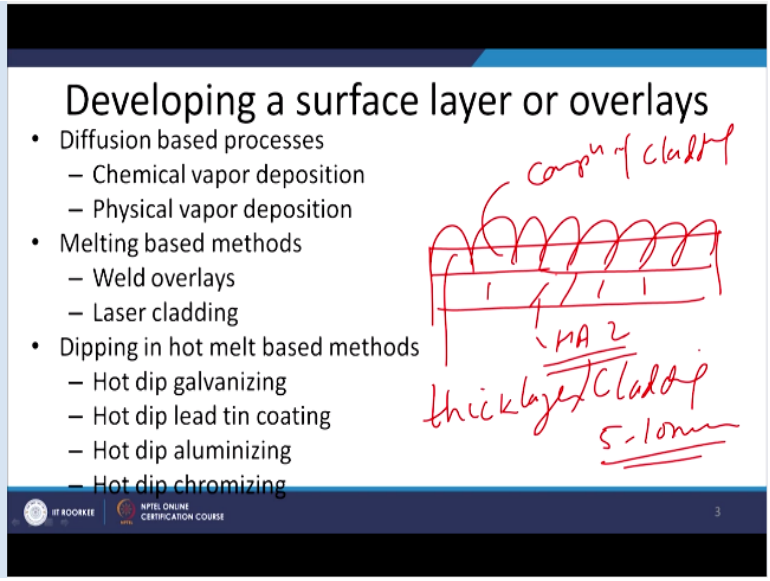

And because of this 1 like melting of the whenever base metal melts and mixes with the filler metal for developing the weld overlays or the thicker claddings the composition of cladding is altered due to the dilution. And because of this the properties of the overlays are compromised or we get the properties which are not as per the properties of the material which was deposited in form of the electrode.

So, that is what is to be kept in mind while developing the weld overlays one more thing significant size of the Hz is also formed heat affected zone in the base metal is also form. So, that maybe problematic especially in the case of the hardenable steels, so this is 1 approach and the

different kind of the process which are used for developing the weld overlays and very thick layer or cladding is deposited using welding based methods which maybe like 5mm to 10mm thickness.

So, especially for corrosion resistant applications are wherever primarily refurbishing is required then material is deposited using the welding process or consumable arc welding process. So, that the required properties at the surface and required dimensions can be achieved the laser cladding is one where we use the 2 approaches.

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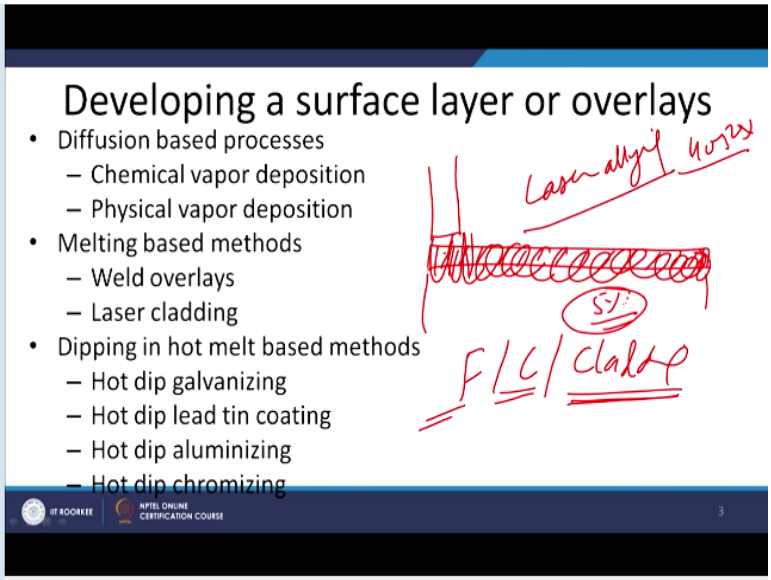

One is the simple where the pre placement method required material which is to be deposited onto the surface means the material whose coating or the cladding is to be achieved through the use of laser that is applied first. And then with the help of laser the melting of the material applied at the surface is melted and part of the base metal is also melted. So, that after the solidification 1 sound coherent coating or the film is realised or cladding is realised claddings are thicker coatings are thinner.

And films are further thinner, so depending upon the thickness there is no although very hardened and fast dimmer occasion line for these 3 categories films, coatings and claddings. Now the thickest the films thickest layer is developed in the case of the cladding then somewhat thinner in the case of the coating and then films are very thin. So, application of the laser will be

melting the material at the applied at the surface which will be causing the melting of the base metal as well.

And intermixing will lead to the development of the claddings onto the surface. So, this kind of the melting will be leading to the development of a film or cladding sorry cladding onto the substrate if but the this one if we see this is similar to the laser alloying. But with the difference is that laser alloying has the dilution level very high while in case of the laser cladding dilution is controlled significantly.

And dilution maybe like say 5% means the melting of the base metal is very less. So, the alteration in composition properties of the coating material is less as compared to that of the case when other welding processes are applied. So, the limited dilution will be changing the composition of the cladding which is being applied will be very less. And therefore we may expect much better improvement in properties of the component which has been subjected to the laser cladding.

Normally this method is used where we where heat input to the base metal very less heated input to the base metal is required. Because too high heat input sometimes causes the problem of distortion residual stresses and even cracking. So, to avoid those undesirable effects laser cladding helps to have a limited heat input to the base metal and which is good from the surface modification point of view.

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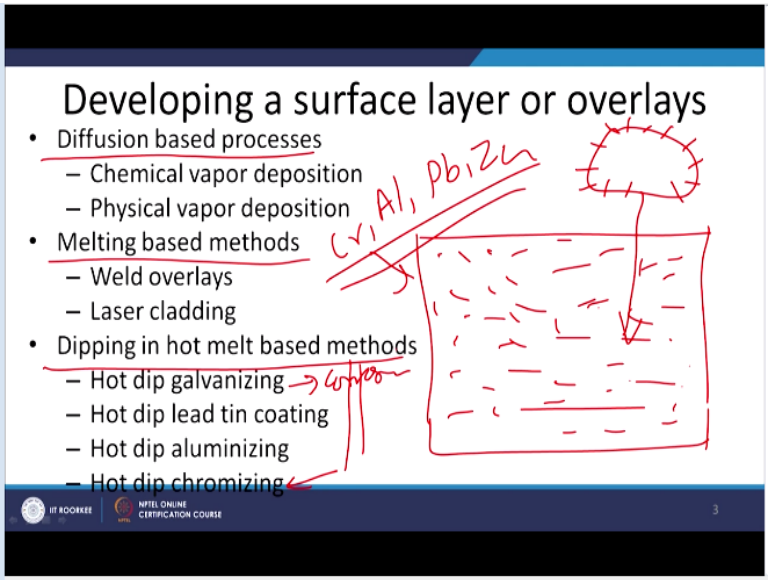

So, coming to the dipping of the component in hot melts, so that the film or the coating can be develop onto the surface of the components. So, what is done basically a bath of the molten metal is prepared by heating. And component on which film is to be developed like for galvanizing purpose or for developing latin etc., aluminium and chromium the bath is a developer of the suitable element which maybe like chromium for chromizing and aluminium or the lead or zinc.

So, the suitable bath is developed and then component article which is to be coated is dipped into the bath and then it is taken out. So, after the solidification of film or will be there onto this surface of the component and sometimes interaction between the film and the substrate material leads to the good bonding. So, the bonding maybe the metrological as well as it maybe the mechanical interlocking that is how the bond is made.

But this kind of approaches are used for various purpose is like improving the corrosion resistance or improving the set equally through the chromizing or aluminizing, aluminizing is also used for improving the corrosion resistance. So, depending upon the purpose suitable material is selected, so that required purpose of surface modification can be realised through the development of suitable films.

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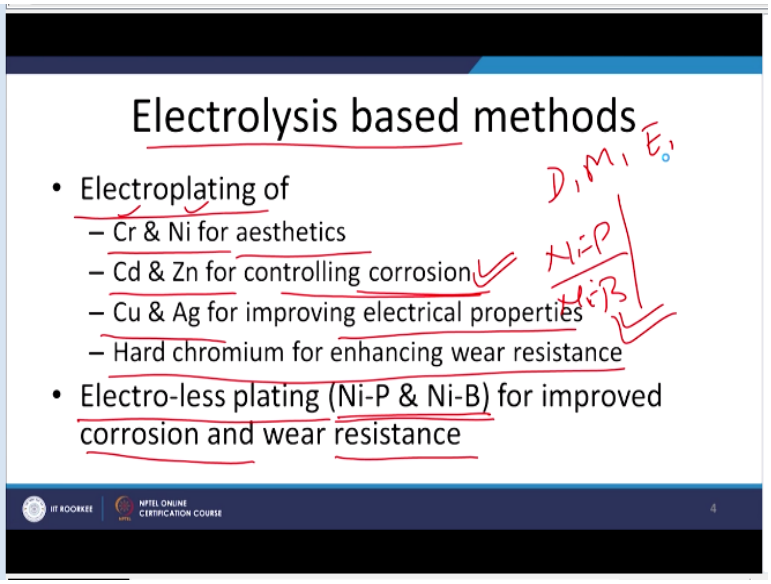

There are other methods also of developing the films which are based on the electrolysis. So, if we see the developing this is one approach, where surface layer is develop. And this layer can be developed through various approaches like diffusion based or the melting of the substrate and the material and the dipping the component in the hot metal bath. These are the 3 different approaches one more approach is where electrolysis is applied.

So, in case of electrolysis approach the electroplating is used for developing the coatings of the different kind of the metal systems. So, that the surface properties can be improved and it includes like the chromium and nickel coatings are used for improving the aesthetic value or for improving the appearance of the product. So, most of the bathroom fittings and the components which are need to be used of very good in appearance.

They are coated with the chromium and nickel, similarly cadmium and zinc are used for developing the coatings through the electrolysis approach are electroplating method for controlling the corrosion resistance copper and silver are used for improving the electrical properties of the surface electrical properties of the component. And hard chromium is used for improving the wear resistance of the surface.

So, this is very extensively used for variety of engineering components for improving the wear resistance. And apart from the electroplating there is another group which is called electro-less

plating where electro where solutions are used for developing the coatings of the nickel phosphorous and nickel boron. And this type of the coatings are used primarily for improving the corrosion and wear resistance.

So, apart from the diffusion, melting, electrolysis and there was one more method which was hot dipping of the molten metal hot dipping of the component in the molten metal. So, these are the 4 different categories of categories are 4 different approaches of developing the films.

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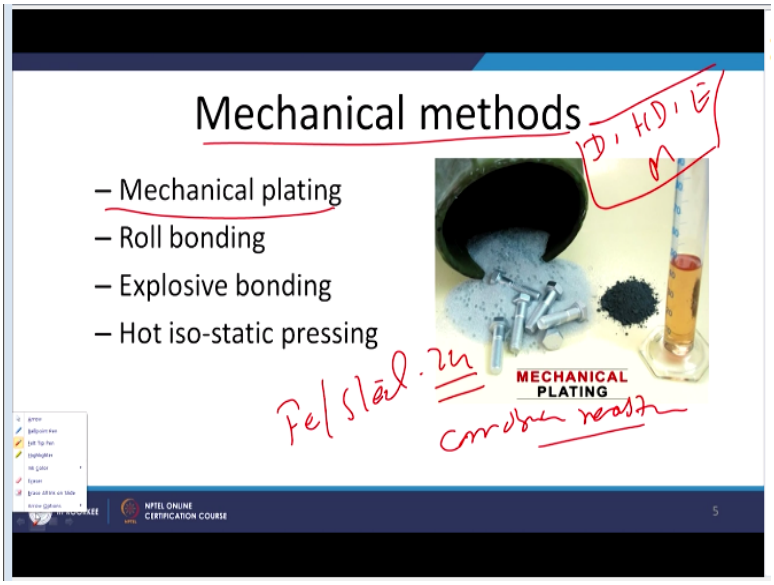

One more approach is the mechanical methods where no diffusion or hot dipping or electrolysis or the melting is used. But basically the mechanical force is used for having the film of particular component onto the substrate mechanical plating is say the zinc and the component on which coating is to be done is intermixed for long periods. So, that the coating of the zinc onto the component of the iron is made.

So, coating over the iron or the steel component of the zinc using the mechanical plating is commonly used for improving the corrosion resistance.

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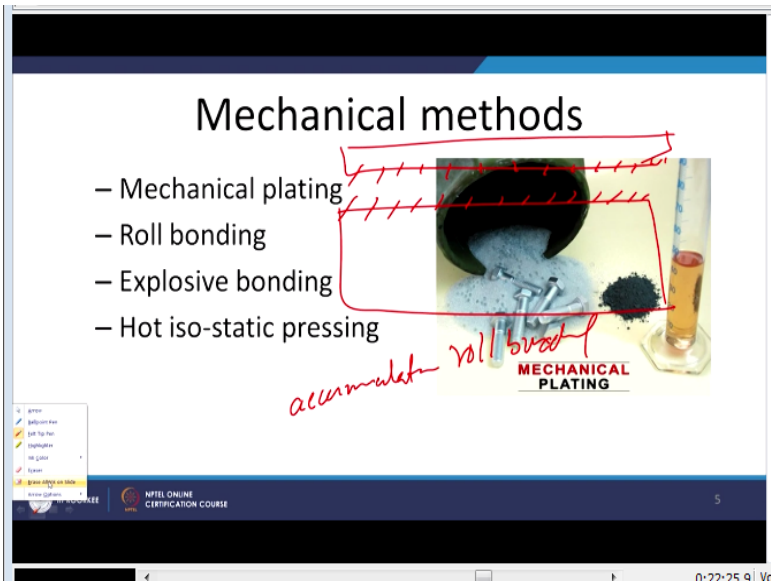

Roll bonding is another method where this is called accumulative, roll bonding. In this case like this is one component on which layer is to be developed so, what we doing this surface will be cleaned very using mechanical and chemical methods. So, that it is free from oxides another impurities and another materials whose cladding is to be developed will also be subjected to the proper cleaning using mechanical and chemical methods then 2 are brought together.

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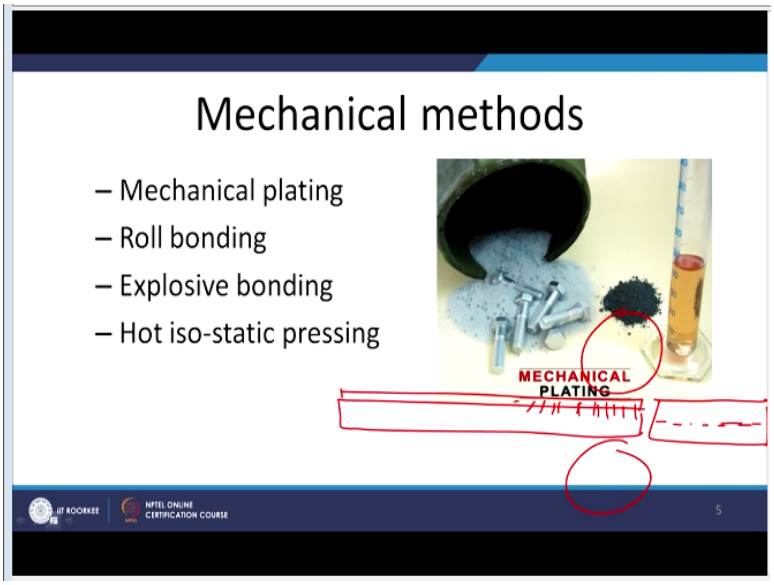

And once it is once that 2 are placed one over other like this then they will be pass through the suitable combination of the rollers. So, roller when it will pass through the rollers the some kind of the bond mechanical interlocking between the 2 will be taking place. And after passing

through the rollers the very thin bond line will be existing and the 2 will be bonded very firmly with each other.

This is also used for developing the sandwiched component where layer of 1 material is developed over another layer through mechanical interlocking. This is called accumulative roll bonding and in case of explosive bonding of course as name appears.

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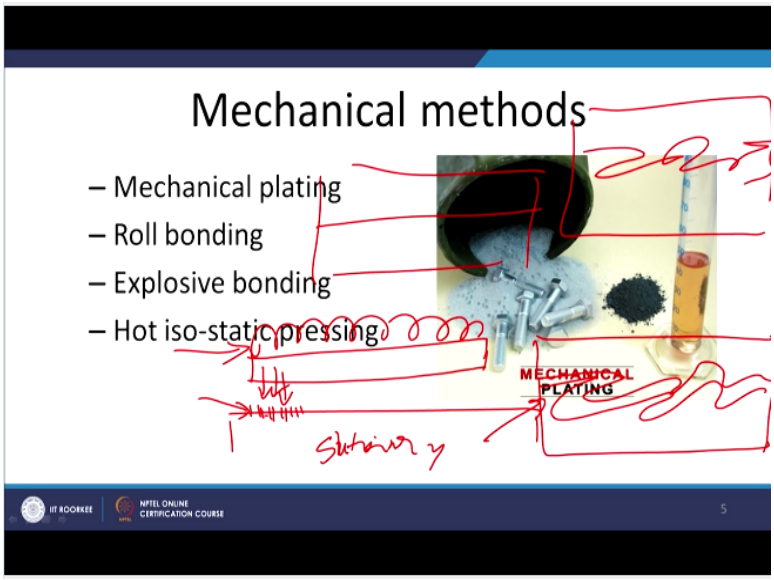

The there is one fixed or stationary component and cladding of which material is to be and the material of which cladding is to be applied is used as a prime component or the moving component. And over this we put the explosive material like this. And this is done at a certain angles. So, when the explosive is fired the prime component will be moving towards the stationary component on which coating is to be applied.

And with the impact it hits the surface and forms the bond, so the kind of bond which is formed that is determine by the kind of the interface which is which will be there. So, the interface is heavily damaged machine plastically deformed and this is the kind of interface is formed. So, greater is the interfacial deformation between the 2 component at the interface greater will be the bond strength.

And if the interface is flat of the 2 sides then it will be leading to the poor bonding. So, in case of explosive, explosives fired this prime component hits the another component on which it is to be applied and forms the by the impact surface layer deformation at the interface takes place and that results in the wavy structure of the interface which provides the required bond strength.

And that is how the cladding of the 1 material over the another material is applied through the use of explosive. This kind of method is especially used for those which were other methods are not feasible.

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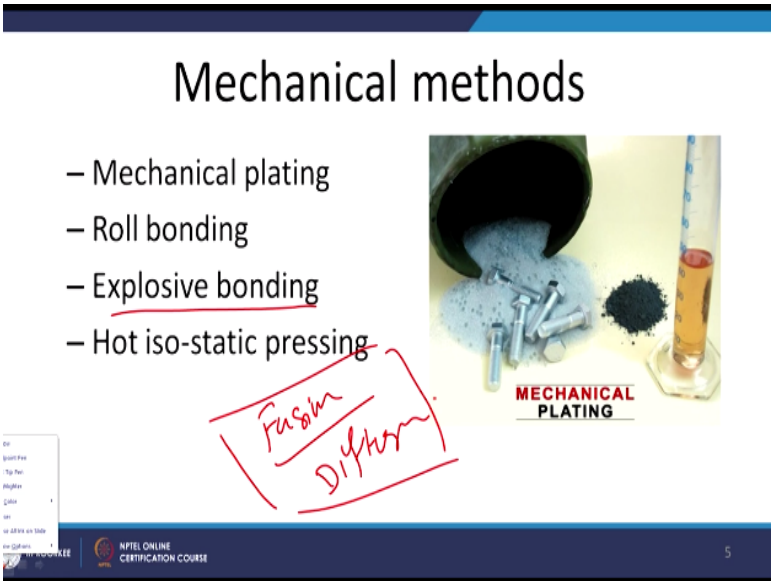

Like the due to the metrological incapability fusion methods cannot be applied or the diffusion is not that feasible because of the larger area and greater sizes if the diffusion is not feasible then such kind of the methods explosive bonding is applied.

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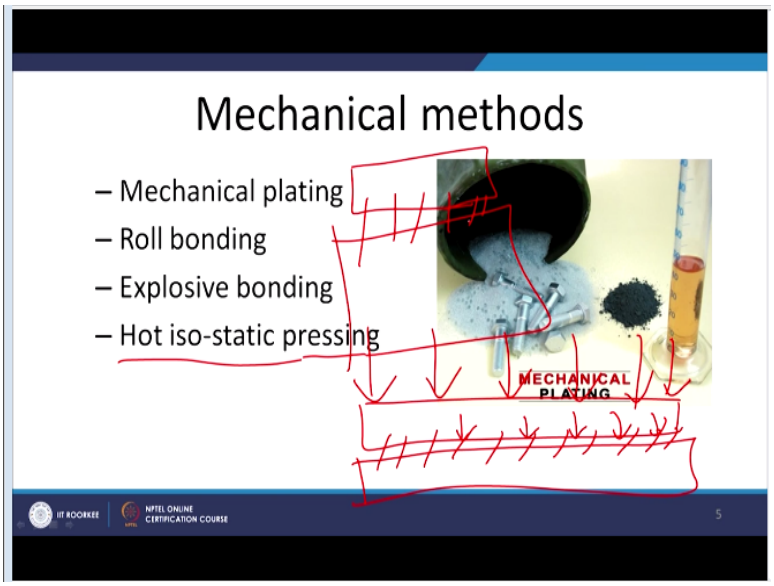

And in case of the hot iso-static pressing it is a kind of the diffusion which is facilitated at high temperature like this is 1 component and this is another whose which is to be applied onto the substrate. So, the 2 will be kept at high temperature under pressure, so that at the interface so, the surfaces cleaned polished condition are kept under pressure at high temperature. So, across the interface diffusion takes place and the bond is formed.

So, at constant pressure at high temperature the 2 components a 2 parts means the material whose coating is to be applied onto a particular substrate the 2 are kept under pressure at high temperature. So, interfacial diffusion facilitates the bonding between the 2 for developing the coatings of particular material onto the substrate.

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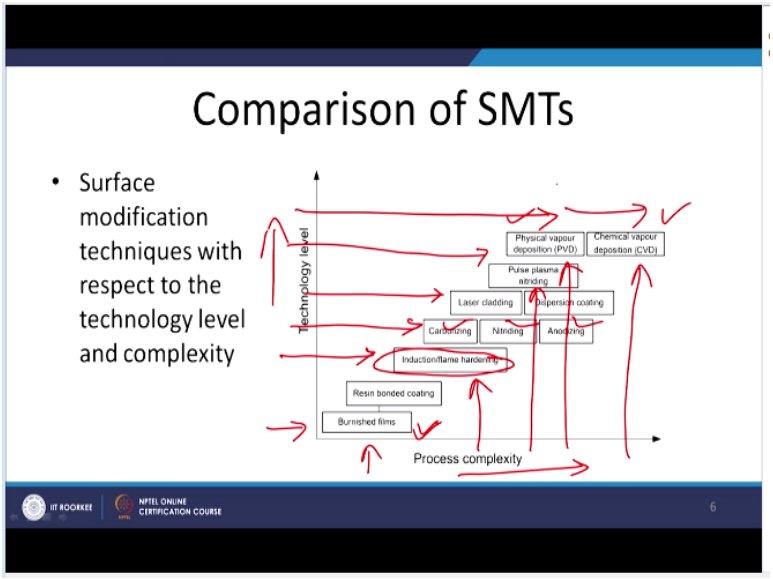

Now we have seen that there are different approaches for modifying for improving the surface properties by changing the chemical composition or there is no change in chemical composition just structural modification is achieved or thin films are developed or coatings are developed onto the substrates. So, that the required set of the properties can be achieved but all these methods are not of the same type because they will be resulting in the modification up to the different depths.

Because they each will one will be having the kind of the different approach, so the different methods have been compared based on the technological level which is involved with the particular method. And the kind of process complexity which exist in. So, the lowest technology level and the lowest process complexity exist in the process like where burnishing is carried out.

And then raise in bonded coatings are used will be having somewhat greater technological level and the process come complexity then further on higher side we have the induction and the flame hardening very good control over the temperature the frequency and the current in the case of induction hardening and the control of the flame. You can say the flame movement so, that required astantisation is taking place followed by the rapid cooling, in order to have the desired modicity transformation,

So, somewhat greater technological level and greater process complexity exist in the induction and the flame hardening. And somewhat greater further greater is there for carburizing, nitrizing and anodizing and similarly for further more technological level is involved in laser cladding and dispersion coatings, pulse plasma nitriding are that is one other advanced form of the nitriding process where further higher technological level.

And process complexity exist in and the most advanced processes technologically or like physical vapour deposition and chemical vapour position process. And they are also complex in terms of the control which is needed to have the desired set of the properties in the modified surfaces. So, very close control over the process and very high technologically good coatings are developed using the physical and chemical vapour deposition process.

So, now here I will summarise this presentation in this presentation I have talked about the grouping of the surface modification techniques based on the various approaches which are used for modifying the chemical composition development of the surface films. I have also have tried to compare the various surface modification techniques based on the technological level and the process complexity involved related with those process, thank you for your attention.