Fundamentals of Surface Engineering: Mechanisms, Processes and Characterizations

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Lecture-35
Surface Modification Techniques: Plasma Carburizing and Plasma Nitriding

Hello I welcome you all in this presentation related with the subject fundamentals of surface engineering and so for we have talked about the various mechanisms which lead to the loss of material from the function surfaces, we have also talked about the important surface properties and the materials which are available for a surface modification. So that the surface properties can be modified according to the requirements.

So under the surface modification techniques we have seen that there were 3 categories classification of surface modification 1 where in the just the changes in surface metallurgy is used to modify the surface characteristics and in this process only the metallurgical changes are brought in, then we have also seen another category of the processes where the change in the surface properties is brought in through the chemical composition modification and near-surface layers.

So what we have seen that whatever the elements we want to introduce at the surface and near surface layers other suitable environment enriched with that particular element is created and so through the chemical interactions to the diffusion and so diffusion these alloying elements of these elements get mixed with the subsurface of the substrate and in this category what we have seen that we have talked about the 2 processes.

These were like carburizing and the nitriding, apart from these 2 processes where in carbon and nitrogen is introduced at surface as we have also seen like a carbonitriding in which carbon and nitrogen both are introduced followed by the surface modification heat treatment and in case of cyaniding primary nitrogen is introduced along with the carbon to improve the surface properties.

In both in all these 4 processes we have seen that the carbon and nitrogen concentration at the near surface layer is introduced in which in turn helps in improving the properties after the heat treatment. Heat treatment primary here is used to have the metallurgical transformations

like transformation so that the hardness can be enhanced while in case of nitriding surface modifying treatment is needed.

And this process directly forms the kind of nitrates which are required for improving the hardness via resistance and introducing the surface and compressive residual stresses which in turn help them at Ansal properties as well as fatigue resistance, what we have seen basically in the processes like a carburizing under the nitriding.

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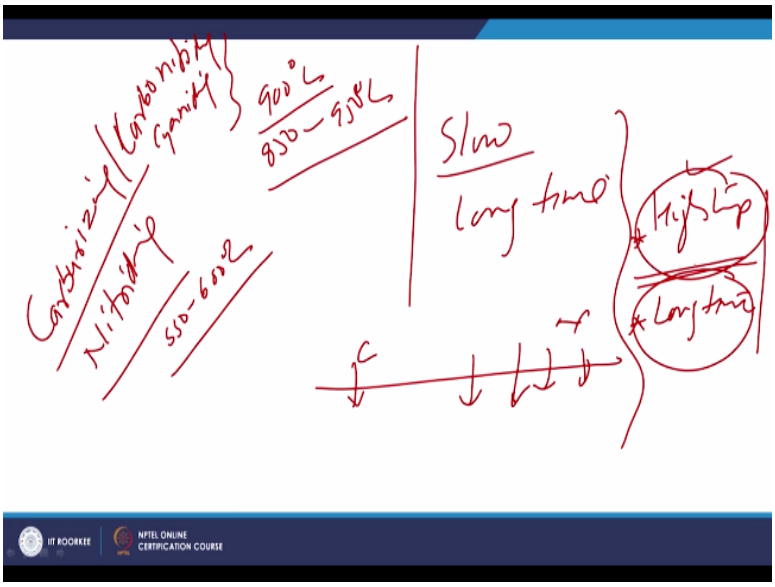

Both these kind of the processes carburizing and carbonitriding and cyaniding. These processor are carried out at quite high temperature like a 900 about 900 degree centigrade is temperature may vary from 850 to 950 degree centigrade while nitriding is carried out at low temperature like say 550 to 600 degree centigrade . These processes are slow and they take long time.

These processes are slow and they take long time to modify the surface composition by introducing the carbon or nitrogen at the near surface layers and this is the another negative sides. So there are 2 negative thoughts related with this process is the high temperature which tends to modify the surface structure of the bulk material also and that have undesirable for the mechanical properties of the main component itself.

And another undesirable aspect apart from the high temperature exposure is the long time requirement. So the process is slow, so these are reduce the high temperature adversely affects the mechanical performance while the long time adversely affects productivity which

in turn reduces, increases the cost of the product and reduces the productivity and considering both these aspects like high temperature as well as longer time the further improvement in this processes have taken place in form of like plasma nitriding.

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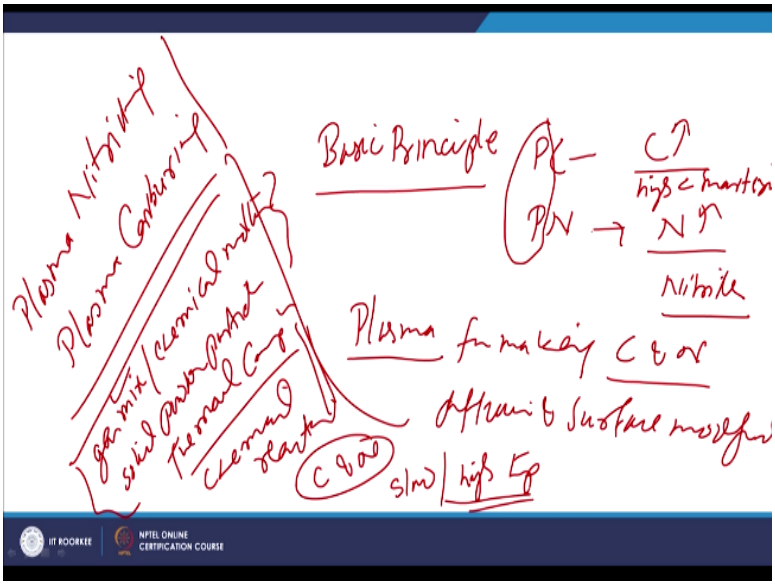

And plasma carburizing, so if you see a both these processes the basic principle in both this process is saying where in like in carburizing and carbon content at the surface layer is increased or in case of the plasma nitriding nitrogen content at the surface layer is increased. This is used for formation of the nitrites as in case of the simple nitriding and this is used for forming the high carbon martensite after suitable heat treatment.

But the only difference is here is that that we use the plasma, the plasma for making the carbon and nitrogen available for diffusion and subsequently surface modification. So this is the only difference in this process. In conventional processes what we have seen conventionally what we do have we use the suitable gas mixture or chemical in form of the molten bath or we use the solid powder particles.

And lot of the thermal decomposition are involved for making these required constituents into the carbon and nitrogen available for diffusion. So lot of the thermal decomposition and chemical reactions at high temperature take place for making the carbon nitrogen available for the carburizing and nitriding respectively and these in turn make the process slow and needs to perform at high temperature.

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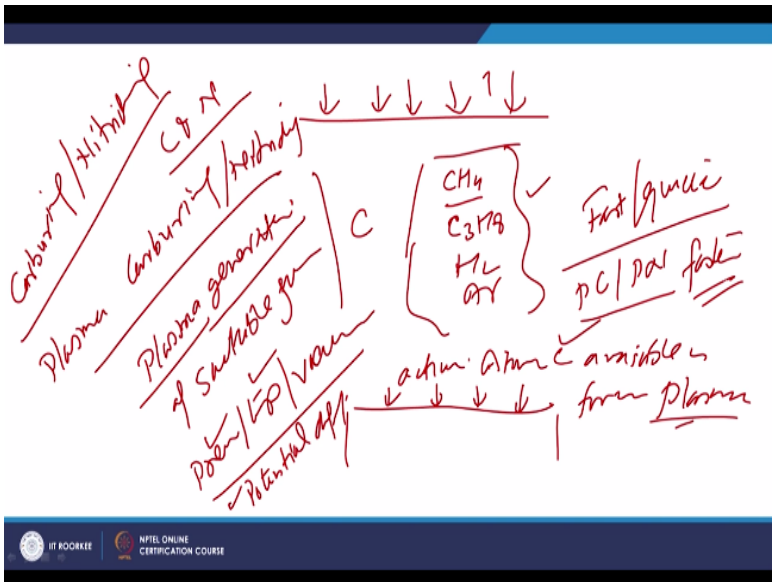

The high temperature is needed so that we can get the sufficiently high diffusion rate in order to achieve the required depth of the modified surfaces for surface property enhancement. So as compared to our conventional carburizing and nitriding process where lot of thermal decomposition and chemical reactions take place for making the carbon and nitrogen available at the surface.

So that these can be introduced at the surface, in case of the plasma carburizing and nitriding basically using the suitable conditions for plasma generation of suitable gas is used. So like if you want to do the plasma carburizing then suitable the gas mixture containing the hydrocarbons like methane or CH3H8 or the hydrogen are mixtures are used. So that the plasma of these gases is created around the component and making the active atomic carbon available in form of plasma.

So this carbon is formed immediately and making the carbon available under the suitable conditions of pressure, temperature and vacuum. So and the potential difference between the anode and cathode. So these are the conditions pressure, temperature and potential difference once we are able to optimise the suitable conditions in presence of the required the gas mixture.

Then the plasma of that particular gas is produced and that plasma will be making and the required elements like carbon of nitrogen available in atomic form and which will be available for diffusion in to the surface of the component. So he has this plasma of that

particular gas is directly making the elements available for diffusion and this makes the process fast, quick.

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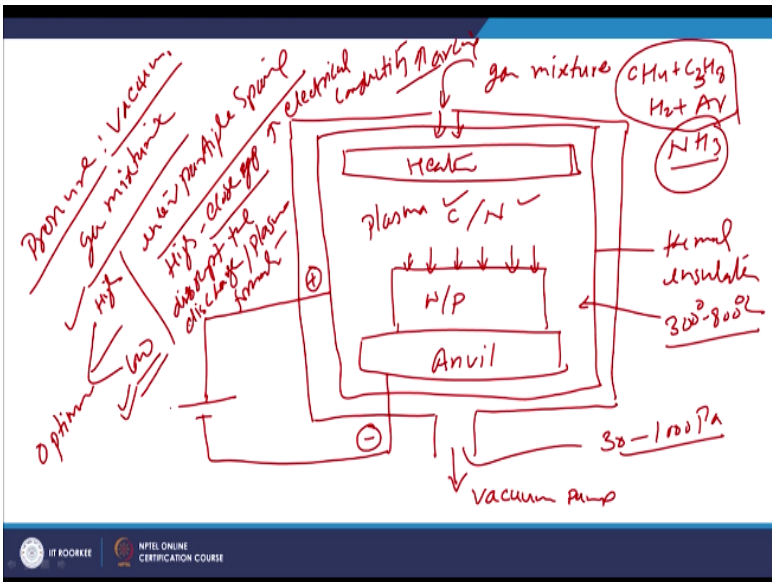

And therefore carburizing and plasma nitriding processes are completely faster than the conventional carburizing and conventional nitriding process. So what we do basically in this process basically we use 1 big chamber like this and this chamber will be connected to the vacuum pump. So this will be creating the required low pressure, then we have the another opening through which we can feed the suitable gas mixture like for plasma carburizing it can be Methane+C3H8 propane+hydrogen+organ.

Such kind of the gas mixture is used or for plasma nitriding we may introduce the ammonia, then we have 1 heating arrangement this we can say as heater which will raise the temperature sufficient to form the plasma and around this we have 1 anvil for the support over which the job to be modified will be placed like say this is the workpiece which is to be modified.

Now all these things will be enclosed in insulating chamber and that will also be connected to the that will also be made anode. So basically there is another you can say thermal insulator and this is made anode, so we need to connect we need to make one component as anode and one component have cathode to form the plasma. So that surface and potential difference between the anode and cathode can be created.

Workpiece is made cathode by connecting it to the negative terminal and the thermal insulating chamber is connected to the positive terminal. So it is made cathode and the sufficient when we have the sufficient potential difference, when we have sufficient potential difference between the anode and cathode in presence of the suitable gas mixture whether it is ammonia or the other hydrocarbon and gases are these form the plasma.

Making available carbon or the nitrogen available for diffusion to take place at the surface, once the active carbon or nitrogen available in atomic state this will be in the workpiece because of the concentration difference these will started using under the favourable conditions of the temperature we need a very good combination of the temperature within the plasma chamber and the temperature may vary in the range of 300 to 800 degree centigrade.

So as compared to the typical carburizing and cyaniding temperatures this temperature is quite low, because that is considered that is normally performed in the range of the temperature like say 850 and the higher values and then the pressure which is created through vacuum is also varies in the chamber which can vary from 32000 pa and then these are the gases which are ferritin.

Under the optimum conditions of the pressure which is maintained through the pressure is to the vacuum pump. So we need to see that the pressure for a given a gas mixture which will be used for forming the plasma the pressure is optimised properly because if the optimum pressure will we resulting in the plasma with the required conductivity and availability of the plasma forming gas to which will be leading to the plasma of that particular gas mixture to make the carbon and nitrogen available.

But if the pressure is high or pressure is low in both the cases we get the required kind of the plasma formation process and that can spoil the process as a whole. For example the pressure actually affects the inter gaseous particle spacing so interparticle spacing in the chamber is affected by the pressure. So when the pressure is high it will be leading to the close gap between these gases particles and which in turn will be leading to the increase of electrical conductivity.

So when the pressure is high electrical conductivity will be high due to the closer gap between enclosure interparticle spacing and high electrical conductivity will have the

tendency for increase tendency for arcing between workpiece and between anode and cathode is what we can in simply say and when the pressure is low interparticle spacing is wide which will be leading to the higher lower electrical conductivity.

And low electrical conductivity will disrupted the discharge or plasma formation process and so it is neither it is good to have the higher pressure within the chamber or not it is good to have the low pressure within the chamber because in either case it will be leading to the problem in terms of the arcing for high pressure and the destruction of the plasma formation under the low pressure conditions.

Now if we see the typical plasma nitriding when it is carried out on the typical steel Ai Si 410 steel when it is subjected to the plasma nitriding for surface modification or to the depth of the 30 micrometer by forming the iron nitrides and nitrides of the nitrides of other elements present in the steel. This will be leading to the increase of hardness or 2000 Hb. So this significantly increase in the hardness is achieved like the multiply martensite of first law hardness of the 800 to 900 hz.

So after the plasma nitriding we get the sufficient depth and the hardness value which is much higher then what is typically achieved to the carburizing by then martensite transformation. So 100 Hz hardness is achieved and this will be achieved after the carbon rise nitriding plasma nitriding for 20 hours. So we get the significant depth and significant improvement hardness in the hardness through in the hardness to the plasma nitriding.

And we know that when since these the transformations take place through the increase of specific volume and therefore these will be leading to the development of the residual compressive stresses and these residual compressive stresses will be in increasing the tensile extent of the material, this will be increasing the fatigue resistance of fatigue strength of the material. At the same time that increased hardness in a developmental compressive stresses will be leading to the improved wear resistance.

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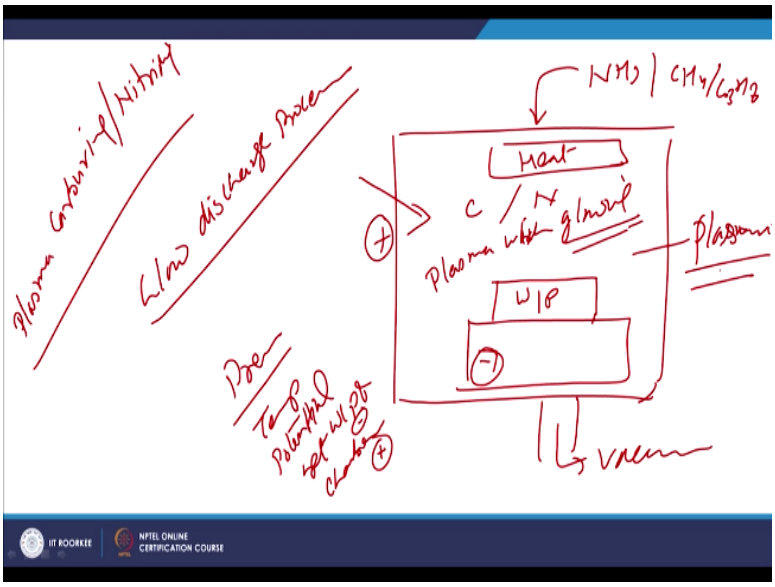

So it is always good to have the plasma nitriding and for those applications where it is required to have very good combination of the improvement in tensile properties fatigue resistance and wear resistance of the material. Now here there is additional aspect related with this process this is called like the plasma carburizing or plasma nitriding. In these processes whenever we see that between the chamber and the workpiece which is negative acting as a cathode and the chamber is acting as anode and we are placing the workpiece here.

So the heater we are generating the required heat for increasing the temperature of the workpiece. So and the vacuum is created using suitable vacuum system. And the suitable plasma forming gas like NH3 or CH4 or C3H and these will be making the carbon and nitrogen available for diffusion to take place, whenever under the suitable conditions of pressure, temperature and the potential difference between workpiece and the chamber which is means anode and cathode workpiece is cathode and chamber in closed chamber is anode.

So whenever this plasma is formed plasma that particular plasma forming gas is formed through the discharge process we get the plasma which is glowing. So this plasma glowing leads to the very typical feature of this kind of the process and that is why it is called glow discharge process and this glow discharge is typical indicative of the formation of the plasma during the plasma carburizing or the plasma nitriding.

So for we have talked about environment of the suitable element is created around the surface of the component which is to use properties are to be improved and this may be in form of the

solid particle like in pack carburizing or this may be in form of the molten salt bath like in case of the liquid carburizing, cyaniding and it may form the gases like nitriding and gas carburizing. But in those processes we have seen that the lot of thermal decomposition and the chemical reaction to produce the carbon and nitrogen which can be used to define to the surface.

And subsurface region of the component for realising the surface modification, in case of plasma carburizing and nitriding what we have seen that basically the plasma is produced using the suitable combination of the pressure and temperature. So that the required elements like carbon and nitrogen can be made available in atomic state for the diffusion on the surface of the component.

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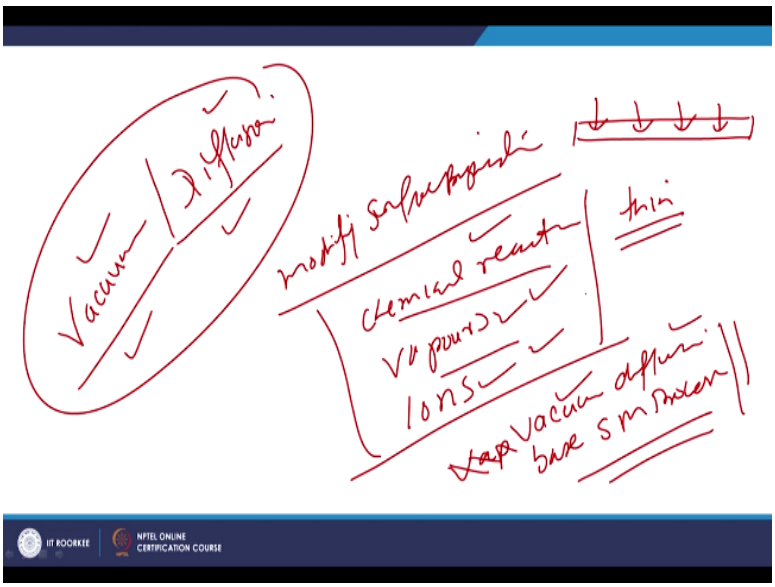

So that required improvement in surface properties can be achieved. Now we will be talking about the another category of the surface modification process by changing the chemical composition and which basically involves the use of vacuum, also those are we can say this also involves the diffusion. So there are few categories of the process where we need vacuum and diffusion is used to modify surface property.

And for this purpose we may use the chemical reaction, we may use vapours or we may use iron these are the 3 category of the processes which are used, these are 3 we can say the mediums which are used to modify the surface composition in presence of the vacuum using the diffusion mechanism. So that the surface layers a surface layer properties can be modified

up to the required. However this category of the process how will be leading to the development of very thin modified layer.

However this is significant improvement in properties. So those properties where we use vacuum and diffusion to modify the chemical composition by using the different mediums in form of chemical reactions vapours and the ions such kind of the processes are called the vacuum diffusion based surface modification processes. So in a coming lectures will be talking about the few processes where vacuum and the diffusion is used to modify the surface compositions using the chemical reactions vapours.

And other ions are so that the required property is required improvement in surface properties can be realised. Now here I will sunrise this presentation, in this presentation basically about the plasma carburizing and the plasma nitriding to make the carbon and nitrogen available for surface modification, thank you for your attention.