Fundamentals of Surface Engineering: Mechanisms, Processes and Characterizations

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Lecture-32
Surface Modification Techniques: Carburizing II

Hello I welcome you all in this presentation related with the subject fundamentals of surface engineering and in the previous presentation we have talked about the basic principle of the carburizing and how does the addition of the carbon in the low carbon steel surface leads to the variation in properties. Now will see that what are the different methods of the carburizing to introduce the carbon at the surface and subsurface layers of the steel.

So that the required improvement in the properties can be achieved but as I told you that the carburizing basically helping to increase the carbon content only at the surface layers. So the carburizing is helping to increase the carbon content where in there will be gradient like say 0.8, 0.6, 0.4 like that and 0.2 in the subsurface zone. So for ensuring that this carbon is utilised effectively, it is necessary that the post carburizing heat treatment is carried out.

So that whatever austenite with the high carbon content is present is transformed into the high carbon martensite in order to increase the hardness as well as to develop the residual compressive stresses at the surface. So as to have the enhancement in properties and therefore we utilise a particular heat treatment cycle for the carburizing purpose and the heat treatment cycle which will be showing the variation in temperature as a function of time.

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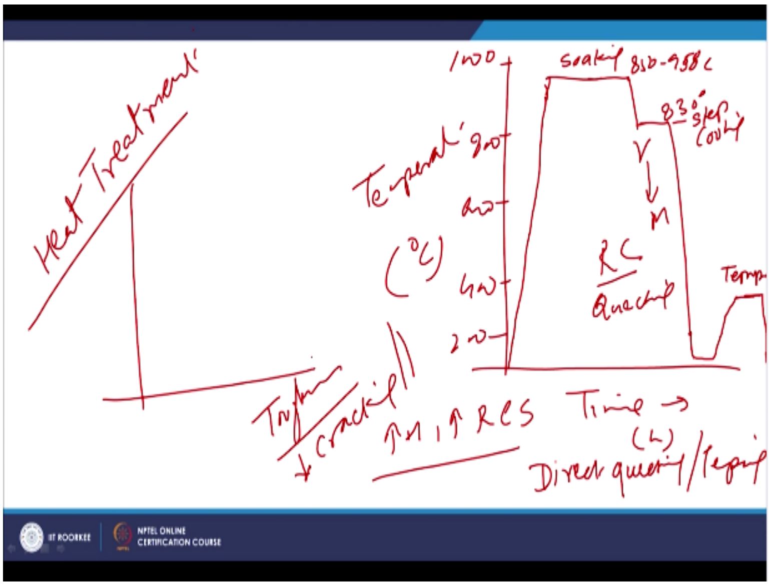

So in x-axis we have time say in hours or in minutes, in y axis will have the temperature the temperature say 800, 600, 400, 200 degrees centigrade. So what we do first of all for carburizing purpose we heat the component to the high temperature, temperature high enough like say it this is 1000. So normal heating used in the band of 850 to 950 degree centigrade and after heating it is held at that temperature for some time.

So that carburizing take places this is soaking time. So after the shocking at this at the required a temperature like say 850 to 950 degree centigrade it is given a first stage cooling like say at 830 degree centigrade once the things are 3 component is carburized and once this somewhat lower temperature is achieved it is subjected to the quenching. So this is rapid cooling or quenching process.

In this process if direct quenching is possible then in this rapid cooling or quenching process austenite to the martensitic transformation will be facilitated. Since the austenite to martensite transformation will occurring with lot of increase of specific volume of due to the development of increased hardness as well as increased in casual compressive stresses at the surface.

Therefore in order to induce some of the toughness and avoid the possibility of the cracking tendency due to the hardening. The carburizing component is subjected to the tempering. So tempering will be done like 300 to 400 degree centigrade. So again heating is done for the tempering purpose and after doing it will be cool. So this is the tampering heat treatment.

This is the like say step cooling followed by rapid quenching and this is soaking for carburizing purpose. So this is called direct quenching case followed by tempering treatment, but if the geometry of the component is complex the size is big, then we need to follow the 2 stage or 3 stage quenching for the second stage and for the dual quenching or dual cooling it is done this way first of all heating.

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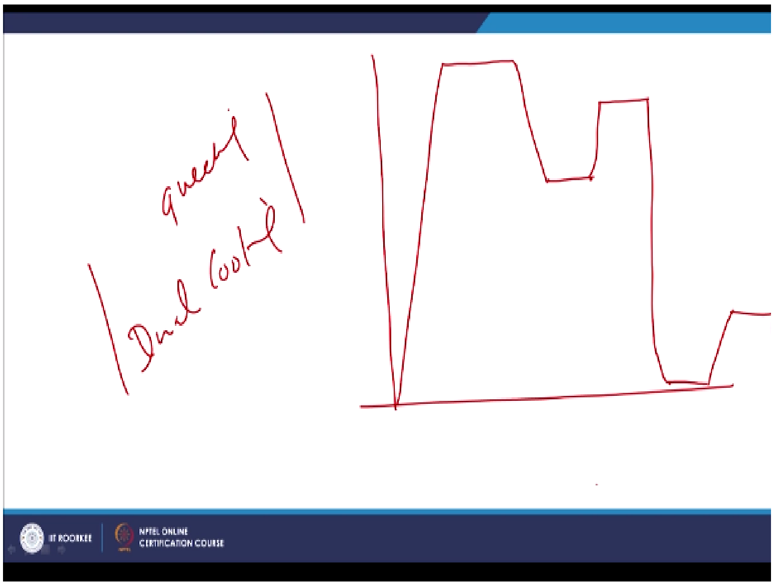

Then once stage quenching then again heating to the AC3 temperature followed by quenching to the room temperature. Then tempering will be done.

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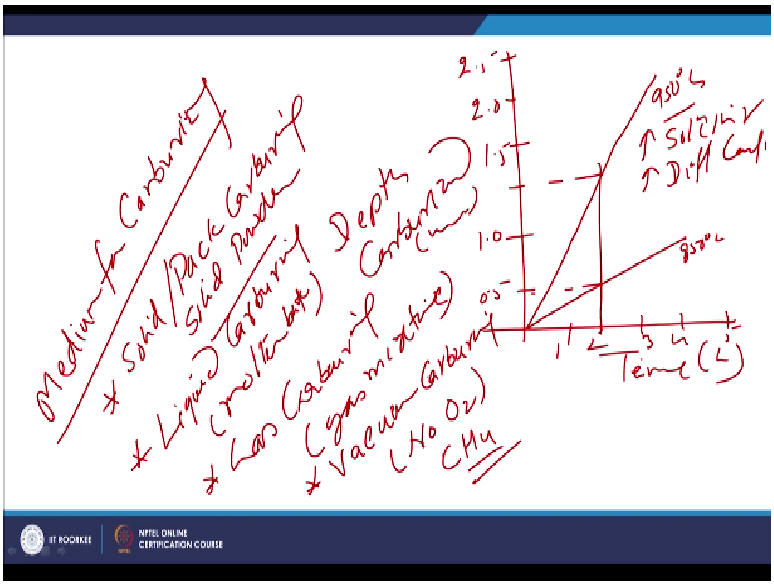

Now as far as the relationship between time for carburizing and the carburized depth is concerned that depth carburized like say 0.5 mm, 1 mm carburized at in mm 1.5 mm, 2 mm and 2.5 mm and here we have in hours 1, 2, 3, 4, 5. So carburized depth at a low temperature even increasing gradually like this at 850 degree centigrade while at 950 degree centigrade it will be increasing rapidly 950 centigrade.

And reason for this at a high temperature much higher solubility of the carbon in austenite of carbon in austenite and increased diffusion coefficient of carbon. So the faster diffusion at a high temperature facilitates the carburizing up to the greater depth in short time if like say in the 2 hours if we see in this particular case carburising is happening you say 1.5 and here the carburizing is happening up to the 0.5 only.

So there is a lot of a difference as per as the case depth which is achieved and high temperature carburizing. Now as per the medium being used for medium for carburizing there are different methods of carburizing like there is 1 solid or pack carburizing in solid or pack carburizing basically the solid power mixture is used.

In case of the liquid carburizing the molten bath is used for the carburizing purpose, in case of the gas carburizing or gas mixture is used for in reaching the carbon content in the steel surface and vacuum carburizing, vacuum carburizing is performed under the vacuum condition. So that there is no presence of oxygen and there is no oxidation of the component mainly the Methane is used for this purpose.

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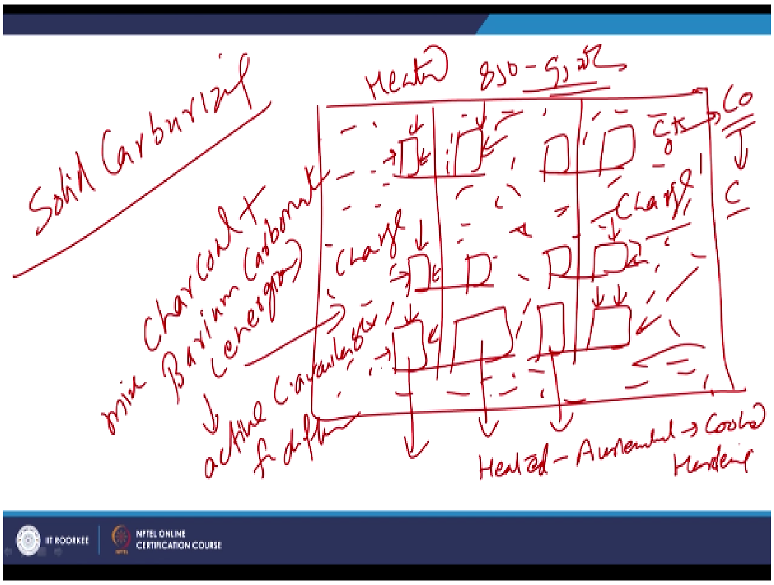

So as per the medium being used for the carburizing purpose there are different methods of carburizing. In case of the solid carburizing basically the 1 steel container is used fitted with the different compartments like this and here the components to be carburized are placed like this and the entire space is filled with the charge which is a mixed. So here to fill the charge.

Charge is a basically mixture of the charcoal and barium carbonate. Barium carbonate act as an energizer for decomposition and making the active carbon available for diffusion. So this mixture is filled charcoal and calcium or barium carbonate mixture is filled in this space where the component to be carburized have been kept and this entire space is closed and then it is subject to the heating to the high temperature 850 to 950 degree centigrade.

So this charcoal having primary that carbon in presence of limited oxygen forms the Co and this CO on thermal decomposition provides carbon and nascent carbon which diffuses onto the surface of the steel component which is being carburized. So deficient oxygen in this space provides the carbon, the carbon monoxide and which on subsequent reactions like thermal decomposition leads to the formation of the nascent carbon or carbon in atomic state which gets diffuse into the surface of the steel components to be carburized.

And once we are able to achieve the carburizing up to the required depth these components are taken out. So there are these components are taken out and after that the these carburized components are heated again to the austenitic state and after that these are cooled or quenched for hardening purpose. So now there are certain problems with this approach, those problems include since there in 1 in close chamber.

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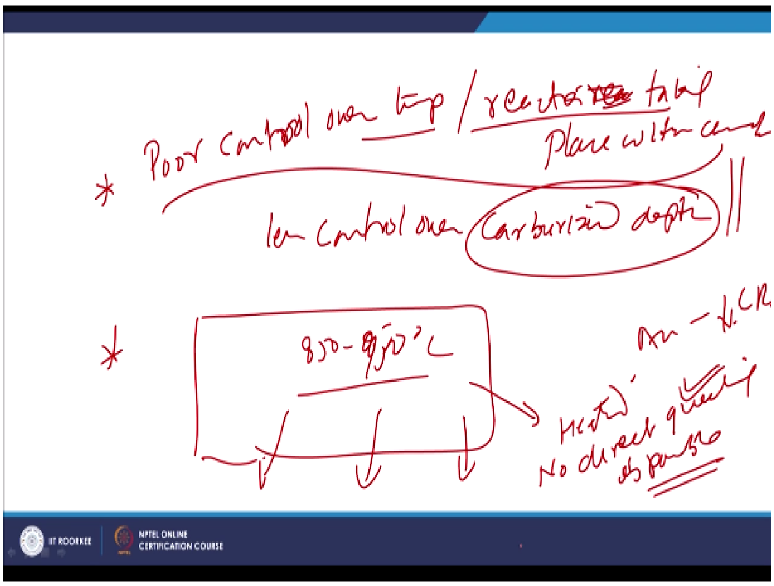

All the components to become carburized or kept in the charge along with a charge mixture and then entire system is heated to the high temperature. But we have very poor control over temperature 1 and the kind of chemical reactions taking place within the chamber and because of the poor control over the temperature as well as reactions we have less control over carburized depth.

So we have a limited control over the depth of carburizing in the case of the solid or crack carburizing and therefore it is somewhat less preferred method. On the other and there is one more issue that since the component is heated to the high temperature of 850 to 950 degree centigrade, thereafter we have to cool it down for taking out after the carburizing and after that again it is to be heated to the austenitic state then cooled rapidly for quenching purpose.

So in this method no direct quenching is possible. So in case of pack carburizing we cannot do the direct quenching from the austenitic is state for forming the high carbon martensite. So that the required improvement properties can be achieved and we have poor control over the temperature during carburizing and control over the chemical reactions which are taking place and therefore carburized depth is also very poorly controlled.

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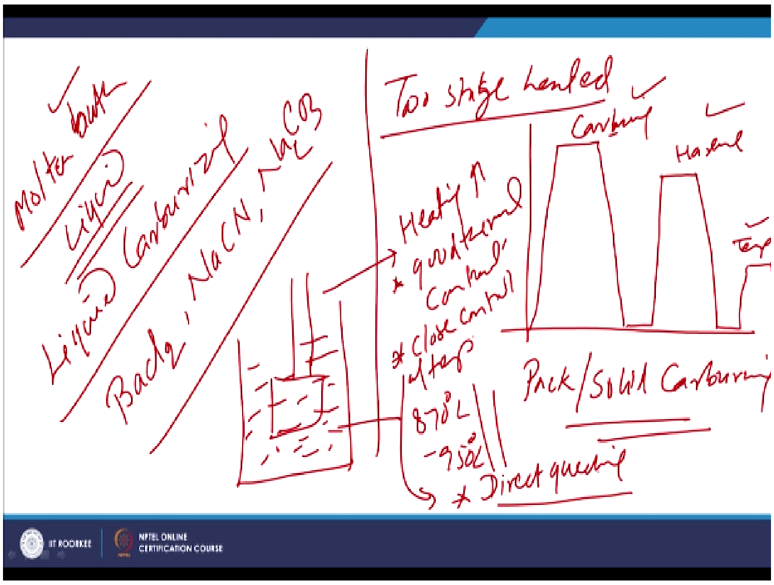

So these are the two major issues related with the carburizing, pack carburizing and therefore it is somewhat less preferred method and this kind of situation forces us to go for the 2 state heating because first of all we have to take out the sample after the carburizing and then again it is lead to the austenitic state followed by the rapid cooling. So in this case we follow the heat treatment cycle of this kind just take out the sample.

This after the carburizing and then it will be heated again to the austenitic state followed by rapid cooling. So this is the hardening treatment, this is the carburizing treatment and then again we have to perform one more tampering treatment to induce the set of properties that are required. So we need to perform the heating 3 times in this case first for carburizing then for hardening and then for tempering purpose.

And this is what is applicable in case of pack or solid carburizing. Now will be a talking about the another carburizing method where the Malton bath is used so the liquid molten bath is used in case of the liquid carburizing. So liquid carburizing basically uses some of the chemical mixtures like barium chloride, sodium cyanide and sodium carbonate. So these 3 Na2Co3, these are the 3 mixtures or chemical.

The chemicals in the liquid form are used in the molten bath for the carburizing purpose. So basically bath of these 3 chemical is heated to the required temperature of 870 to 950 degree centigrade and once we get the required temperature component to be carburized is dipped in bath. So when the component to be carburized is dipped in bath which is in the liquid state with these chemicals offers the quick heating. So heating is fast due to the good thermal contact of the liquid with the component being heated.

This is one thing so the rapid heating is achieved and we have close control over the temperature close control of temperature. So this is another good side of the molten bath which is used in the liquid carburizing and another important point is that we can take out the component carburized from the molten bath easily for required quenching. So it is possible to perform the direct quenching after liquid carburizing.

So all the 2 issues which were there with the pack carburizing can be effectively resolved using the liquid carburizing. The 2 major problems with the pack carburizing were there that direct quenching was not possible because of the nature of the process where we were supposed to take out the sample after the carburizing first and then operate was required to heat it again to the austenitic state before quenching .

But in this case the component can be taken out directly from the molten bath after carburizing and then it can be quenched to achieve the direct quenching. The second positive point of this process is that it offers the processes first because of the good thermal contact of the molten bath with the component. So the fast heating takes place and we have very close control over the temperature and close control over the reactions.

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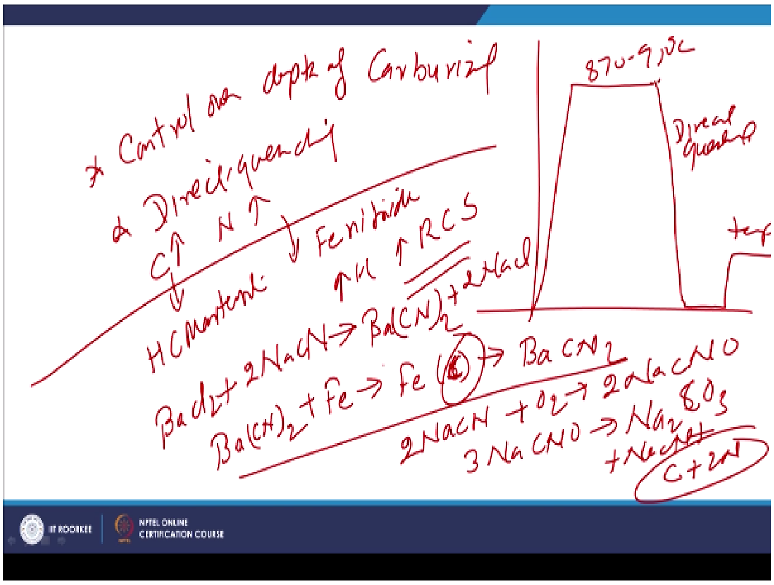

So we can closely control the depth of being carburized the depth of the component which will be carburized. So the 2+ points which will be plus points of the liquid carburizing which share will be overcome in the issues of the pack carburizing or closed control over the depth of carburizing and another one is direct quenching is possible in case of the liquid carburizing.

So the heat treatment cycle which will be used in liquid carburizing is this, first heat into the temperature of 870 to 950 degree centigrade followed by direct quenching for hardening purpose. Because nature of the process that we can take out the sample and quench into the bath directly for the hardening purpose and there after we can go for tempering. So it requires the heating just twice one for carburizing and second for tampering purpose to induce a required toughness and required properties.

The chemical reactions which are observed during the liquid carburizing is that in this case basically the carbon is introduced at the surface and some of the amount of nitrogen is also introduced at the surface and but the carbon basically helps in forming the high carbon molten side. On the other hand presence of nitrogen leads to the formation of iron nitride and both these will be helping to increase the hardness and increase the residual stresses being developed at the surface.

So the common reactions which are observed in case of the liquid carburizing includes like barium chloride reacting with the sodium cyanide and this will be leading to the formation of the barium cyanide+twice of NaCl sodium chloride and this barium cyanide will be further reacting with the iron to form nascent carbon which will be getting diffused with the iron and barium cyanide.

So this is 1 set of the reactions which will be taking place and there is another reaction set of reactions which can occur during the liquid carburizing is NACN sodium cyanide reacting with oxygen to form NACNO and this NACNO will further be leading to the formation of the sodium carbonate Na2CO3+sodium cyanide+carbon+2Nitrogen. So both carbon and nitrogen and this carbon will be made available to get diffused into the surface of the steel.

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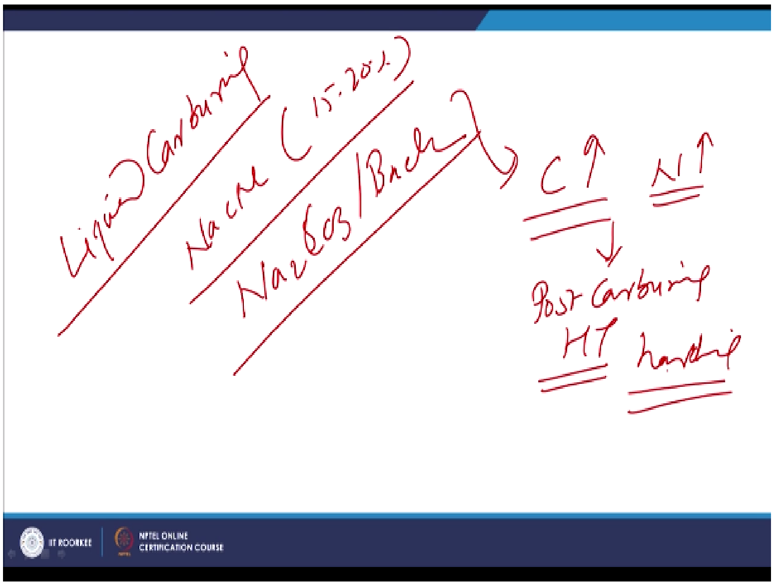

So basically in case of the liquid carburizing sodium cyanide and NACN is about 15 to 20% and the remaining is in form of likes a NA2CO3 and barium chloride in the mixture. So primarily the property investment in case of the liquid carburizing comes due to the engagement of the carbon and little bit due to the increase in the nitrogen content. So but in both the cases post carburizing heat treatment is needed for hardening purpose.

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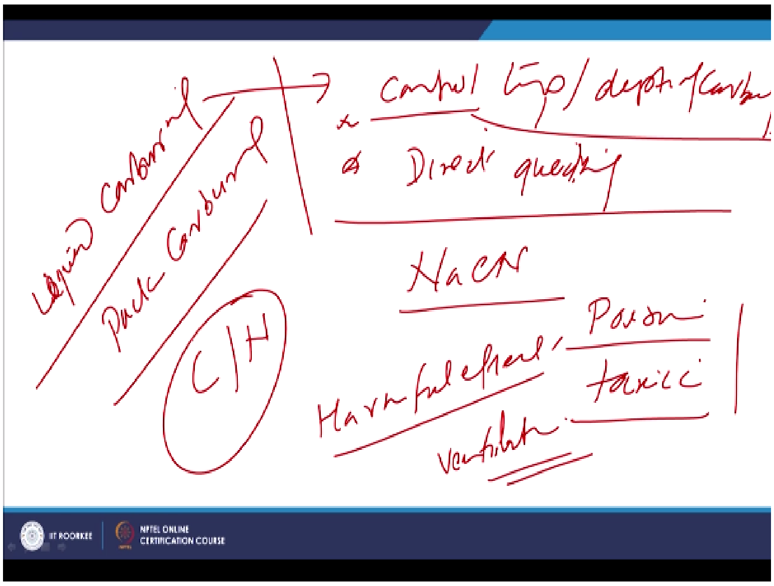

However in case of liquid carburizing we can perform quenching directly followed by the tempering. So that the required as a set of the properties is achieved. So the liquid carburizing in like of this problem is liquid carburizing is beneficial over the back carburizing. However this one is better on 2 counts, 1 close control over the process with regard to the temperature, with regard to the depth of carburizing.

And the second benefit is direct quenching is possible with the liquid carburizing. So direct quenching is possible, but there are certain issues with the liquid carburizing because sodium cyanide is used, so this is poisonous and toxic gases are this process, so we need to be careful with the harmful effect of the sodium cyanide and the toxic gases which are released during the process or so we need to have the good ventilation during this process.

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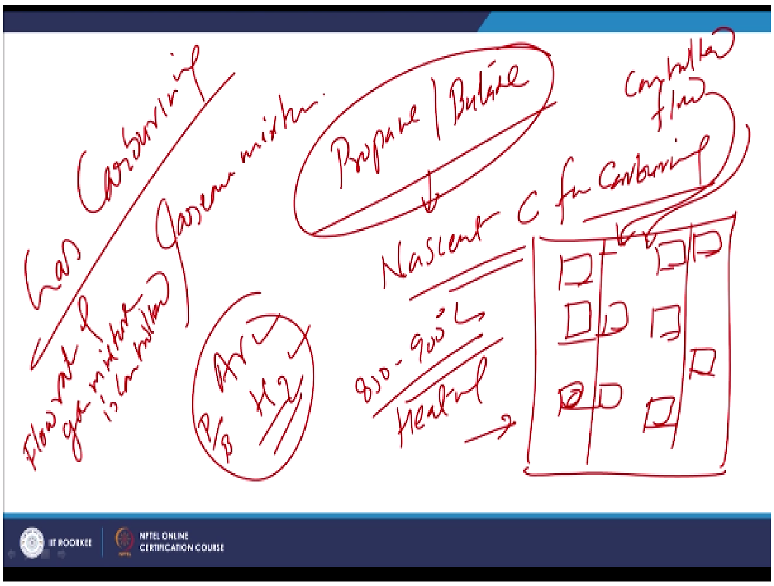

As compared to the carburizing or in case of pack carburizing it was just the carbon content which was leading to the improvement in properties. In this case the presence of the carbon and nitrogen both helps in improving the properties. Now next is the gas carburizing, a gas carburizing is a process where the gaseous mixture is used. So basically the propane and butane kind of gases are used for this purpose.

And the basic principle is same these gases will be providing the nascent carbon for carburizing the steel components. So in this process basically there is a glow in closed chamber and here that the components to be carburized will be tracked properly like this components to be carburized will be placed inside the chamber in enclosed this space and then it will be heated to the high temperature heating to the temperature required in a range of like say 850 to 900 degree centigrade.

And after heating means after putting the component the system is heated and the flow of the gases inside the chamber is arranged, so control flow of gas mixture which includes basically propane butane and apart from these 2 gases we also use a mixture of the organs and hydrogen. So these 2 gases propane, butane propane, butane organ and the hydrogen. This entire gas mixture is bad in close the chamber which is to be where the components to be carburized have been kept under chamber is heated.

And inside the chamber the chemical reactions which will be taken place will be providing the nascent carbon for diffusion into the steel components. So that the required carburizing of the components can be achieved. Here some of the things which are very crucial that the flow rate of the gas mixture is controlled properly because access gas flow will be reducing the availability of reducing the diffusivity of the carbon or the rate at which carbon will be getting diffuse into the surface of the steel components.

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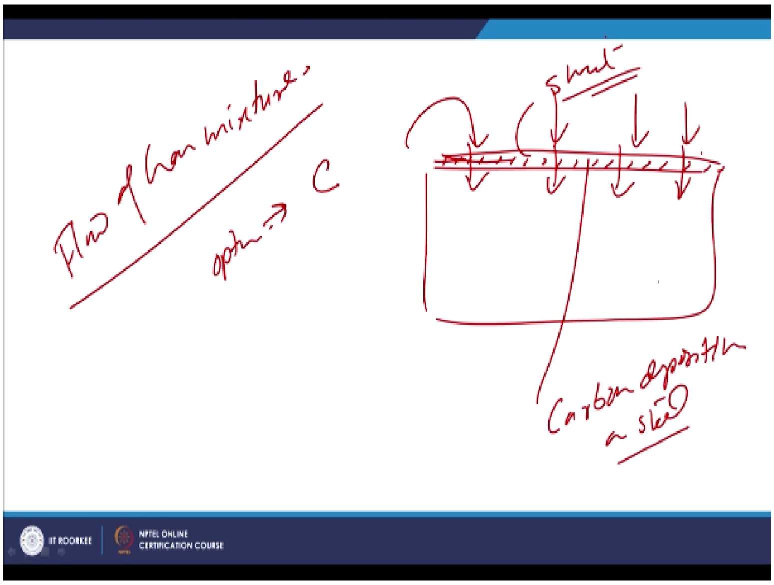

So the flow of gas mixture is crucial because if the flow is optimum it will you providing the sufficient amount of the carbon atoms which will be getting diffused into the component. So only the limited amount of the carbon only such amount of the nascent carbon atoms has to be made available which can get into which can diffuse into the surface of the steel means.

Whatever the rate at which the nascent carbon atoms are being made available this rate should be equal to the rate at which carbon is getting diffused into the steel component. If nascent carbon is being made available in excess quantity and the carbon is not actually is able to get diffuse into the steel components then it will start to get deposited on to the surface of the steel components.

And this will be leading to the formation of the shuts on to the surface. So this kind of the carbon deposition on steel surface will be reducing the rate at which the steel will be carburized and therefore 2 high flow rate is not good the floor it has to be controlled properly in such a way that whatever is the rate at which the carbon can penetrate into the steel component at the same rate it should be provided at the surface of the steel.

And surface of the steel and that can be made available through the proper control over the flow of the gas mixture. Now what are the different reactions which will be taking place inside the gas chamber about that I will be talking in the next presentation, thank you for your attention.