Fundamentals of Surface Engineering: Mechanisms, Processes and Characterizations

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Lecture-48
Surface Modification Techniques: Laser Cladding

Hello I welcome you all in this presentation related with the subject fundamentals of surface engineering and we are talking about the technique where in a layer of the required material is deposited on the surface of the substrate so that the improvement in tribological life of the component can be realised. And under the heading we have talked about the various welding processes which are used for depositing the bead on plate so that surface modification using weld surfacing can be achieved.

Now will be talking about another process which is a called laser cladding, this is also we can see the improved version of the weld surfacing where in the laser is used.

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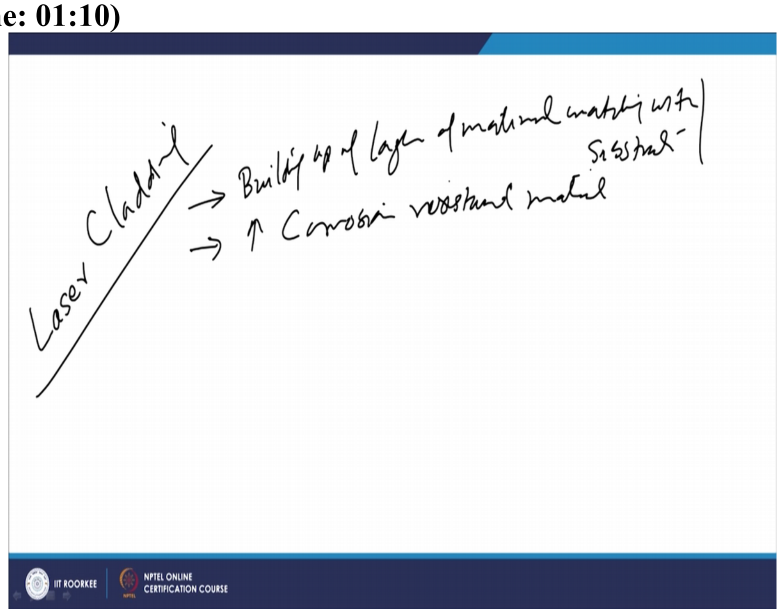

So the process is used so the process is laser cladding you know the cladding is used for depositing a thick layer of the material to be deposited on to the surface of the substrate for surface modification. And this can be used for building up of a layer building up of layer of the material matching with the substrate this one possibility. So, this can be machined out and we can regain the required size and shape.

It can also be used with just for developing very thick layer of the material of the corrosion resistant corrosion resistant materials so that the tribological life of the component and the corrosion conditions can be enhanced.

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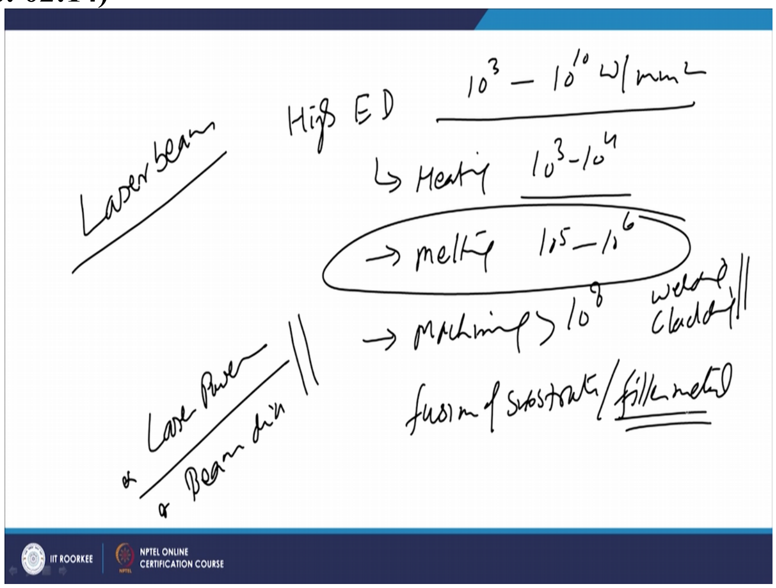

So, the fundamental approach of this process is that it uses the laser beam. Laser beam we know that offers very high energy density which may range say 10 to the power 3 to 10 to the power 10 watt per mm square. So, as per the need of the energy density we can regulate its suitably like for those applications where just heating is needed we use the lower energy density is like 10 to the power 3, 10 to the power 4 for the higher energy densities are used where fusion is needed like welding over the laser cladding 10 to the power 5, 10 to the power 6 kind of the energy density is used and for those conditions where abrasion and the evaporation is needed.

For machining purpose is much higher energy density like 10 to the power 8 or more energy density is used. So, for weld; for laser cladding where fusion is involved for processing like the welding and the cladding purpose is the energy density of 10 to the power 4 to 10 to the power 6 is what % square energy density can be used. There various ways to adjust the energy density associated with this process.

One is laser power and another is the beam diameter over which laser is applied and these two parameters significantly help in regulating the energy density as per requirement. So, that the fusion of the substrate and the filler metal or the material which is to be applied on to the surface of the substrate can be realised

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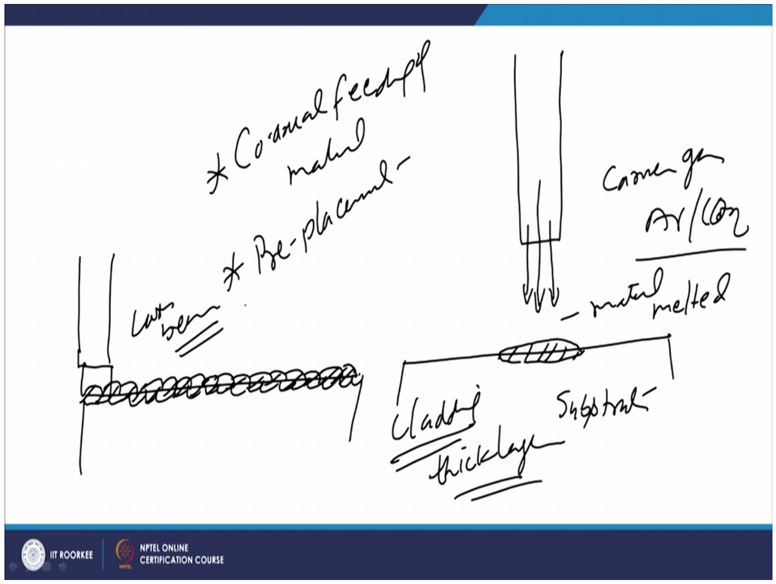

So there are there two variants associated with this process here the laser beam is directed on to the surface of the substrate. So, this will be facilitating diffusion of very thin layer of the substrate. Here the descent and to apply the material for surface modification there are two variants where in the coaxial feeding of material means material in powder form is fed along with the laser itself on to the surface of the substrate.

So, that time and this can be fed with the use of the suitable career gas like Argon or Carbon dioxide as per the material. So, when it passes through the beam and then by the time it reaches to the surface of the substrate the material which is to be applied is brought to the molten state. So, it is melted and gets mixed with the other substrate and that is how it forms the cladding. Cladding is nothing like developing a thick layer of the material thick layer of the material on to the surface of the on the surface of the substrate.

So, this is one approach where coaxially material is fed coaxially or in line with the laser beam itself and when it passes through the laser and by the time it reaches surface of the substrate it is brought to the molten state and then it mixes with this substrate molten substrate material and to develop the required modified surface. Another approach is the pre-placement. Pre-placement so, the material to be applied on to the surface of the substrate is placed with the; in form of either paste or it can be applied by the thermal spray process.

And then this material is brought to the molten state with the help of laser. So, laser beam is directed on to the surface of the substrate this will be fusing the material already placed and the substrate and thin layer of the substrate will also be melted. So, that is how the mixing proper mixing of the substrate material and the metal which has been placed at the surface of the substrate facilitated with the use of the laser beam.

So, these are the two approaches of applying the required material on to the surface of the substrate with the help of laser coaxial feeding of the material or pre placement technique.

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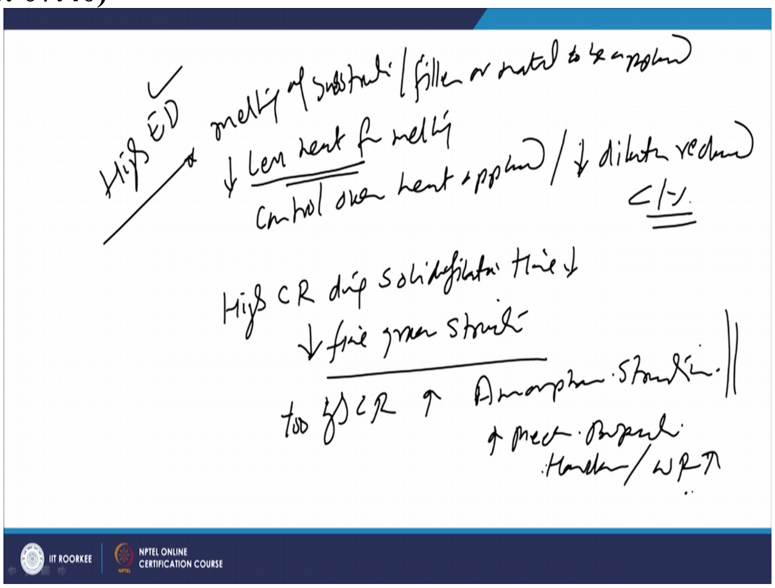

Now is this process uses the higher energy density for melting of substrate and the filler or you can say the material to be applied. So, because of this it requires very less heat for melting purpose and we have very good control over the heat applied for this purpose and because of the good control we find that the dilution is reduced. Reduced dilution reduces the possibility of the degradation in quality of the material being applied.

And here the dilution is found even less than 1% in effect the process is applied with very good control. So, since the energy density as compared with associated with the process is high and therefore it uses less heat in at heat input for the melting and developing of the development of the layer of the suitable material for surface modification and because of this we find the high cooling rate during solidification.

So high cooling rate means solidification time is reduced. Reduced solidification time leads to the refined grain structure. Refined grain structure refinement means high cooling rate if it is moderate then we get the fine grain structure but if the too high cooling rate conditions can also lead to the formation of the amorphous structure also. So we get both these factors will be helping to improve the mechanical properties especially the hardness and which in turn helps in improving the wear resistance of the material.

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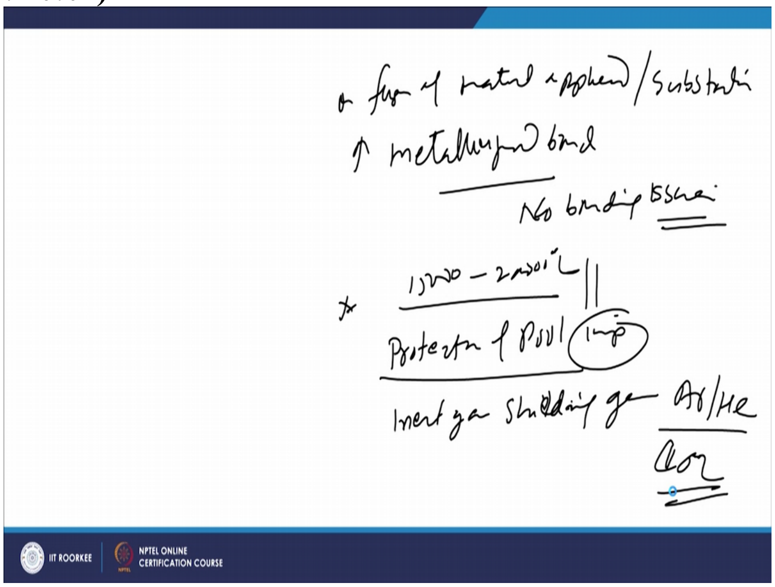

Since we get the fusion of the proper material being applied by coaxial feeding approach or through the pre-placement technique and the substrates both are fused together. And this in turn leads to the formation of the good metallurgical bond. And therefore there is no bonding issue which is commonly found in case of the thermal spread coatings. And apart from this since the temperature increases significantly higher than the temperature required for fusion temperature rise maybe like say 15000 to 20000 degree centigrade.

So, such a high temperature will be making the materials being heated to reactive to interact with the atmospheric gases all around the molten zones. And there for the protection of the pool for the molten zone which is being formed becomes important. And therefore this protection to ensure that the pool is properly protected like inert gas shielding is used Argon or Helium or for the ferrous metals even carbon dioxide can also be used for protecting the pool from the contamination by the atmospheric gases.

So, now if we see the advantages of this process we can we can apply any kind of the material because the heat generated and the temperature rise is sufficient to use any kind of the material.

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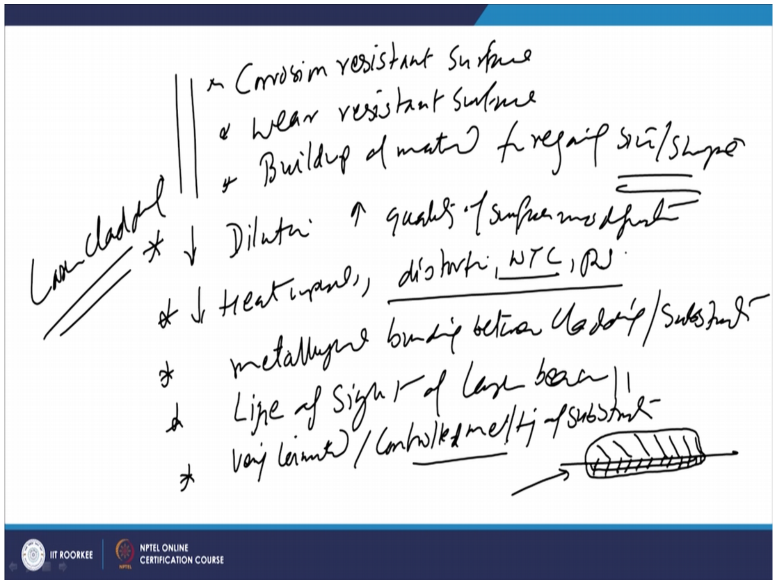

And that is why this can be effectively used for developing the corrosion resistant surfaces, wear resistant surfaces as well as for the surface modification of any surface; whose surface modification of those components where in we need just build up of the material for regaining the size and shape after the machining. And because of these excellent applications of the laser cladding it offer certain advantages.

Laser cladding offers many advantages these are primarily in form of the higher energy density controlled heat melting of the substrate leading to the reduced dilution even less than 1%. So, the good control over the dimension dilutions helps in improving the quality of the surface modification because there is no degradation in the quality of the material which is being applied during the surface modification by laser cladding.

Reduce the heat input due to the higher energy density process reduces adverse effects related with the distortion or weld thermal cycle adverse effects associated with the weld thermal cycle or the residual stresses to there; the problems associated with the weld thermal cycle or a differential heating and cooling are reduced and because of the excellent the fusion of the material being applied and the substrate we get the very good metallurgical bonding between the cladding and substrate.

So, there is no issue for the de-bonding or delimination of the layer which is being applied. And since the laser can be used for controlled melting of the material being applied and substrate very effectively that is why all those difficult to access surfaces where other methods can be applied laser can be effectively used for surface modification of those surfaces is which are direct in line of sight.

Line of sight of the laser beam is those difficult to access surface is which are having the line of sight of the laser beam can be easily modified with the help of the laser cladding approach. So, this another good advantage because if the success of the surfaces is not easy than surface model; it will make the job of the surface modification more difficult. Further very limited or you can say very controlled melting of the substrate.

Like we may control the melting just half might half mm or 1000 micrometre. So, this controlled melting and then development of the thick layer of the material to be applied. So, the extent of the melting of the substrate can be reduced, it can be controlled very well. And this internally facilitating is the deposition of the material by the laser cladding even the metallurgical incompatible material systems on to the surface of the substrate.

So, very controlled melting of the substrate helps us to develop the weld surfacing or the laser claddings of the metallurgical incompatible materials also. So, this is another advantage associated with the laser cladding.

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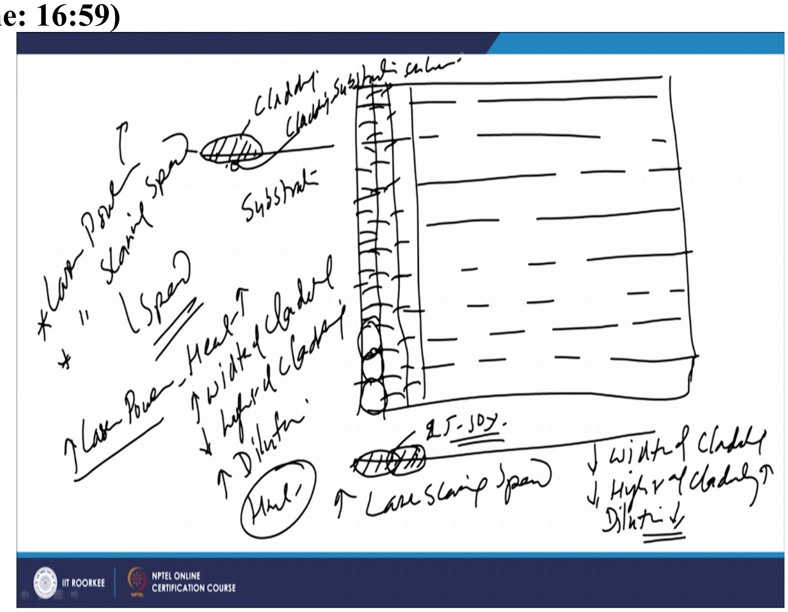

And whenever it is applied how it is applied because the laser beam diameter is very small and if the large areas to be scanned then say we are using the pre-placement technique than the material to be applied will be spread all over the surface area either in form of the paste or by the thermal spraying. And then after applying the material on the surface of the substrate the laser beam will be scanning the surface one by one like this.

So, the laser beam will be passed through the particular path so that the fusion of the material applied on the surface in the substrate can be facilitated for the surface modification and thereafter tracking another path like this. And normally between these two pass some overlap is used and that we can see in this front view where we see if this is one path which is being created by one pass this is the one section which has been developed by 1 parts of the laser beam.

Then another pass is developed by overlapping the earlier developed path. This overlap may vary from like say that 25 to 50% and this will help in having the proper continuity and the bonding between the various cracks and various passes which are being developed. And therefore some extent of the overlap is always used between the different passes which are being applied as for as the parameters of the laser cladding is concerned.

Their parameters like laser power and the laser scanning speed. So, this is the laser scanning speed about the speed at which the beam is moved over the surface of the substrate and the power is about the energy associated with the laser beam. So, how does it affect the quality of the cladding are the coatings which are being applied. So, like say the increase in the laser power will be increasing the amount of the heat being applied and increase an amount of the heat being applied will be will of course by increasing the width of the cladding.

It will be reducing the height of cladding because of the; increased heat input will be made facilitative flow of the molten metal to the greater width and the height will be a reducing. At the same time this will be increasing the dilution level. On the other hand if we see if we increase the laser scanning speed increase in laser scanning speed will be reducing the width of the cladding or the listening which is being applied it will also be a reducing them.

If the metal being applied per unit length is reduced then height will also be reduced but if the material is same and is the speed of the metal is deposited the same amount then an increase of the speed due to the reduced fluid it will be increasing the height of the cladding. But for the same the flow rate of the material for same amount of the pre-placed material the width of them cladding; height of the cladding will be increased.

At the same time the dilution will be reduced with the increase of the scanning speed. So, because when the; for the given power if the speed of laser scanning on the surface of the substrate is increased then actually it will be reducing the net heat input which is being supplied. And because of the reduction in the net heat input this will be reducing the dilution although it will be increasing the cooling rate.

So, if the cooling rate as I have set is too high then it will bleed into the amorphous structure. Otherwise moderate cooling rate will be leading to the development of the fine grain structure. If you typically see the laser cladding cross section then at the interface like say cladding which is been developed; so cladding this is substrate and this is the cladding substrate interface.

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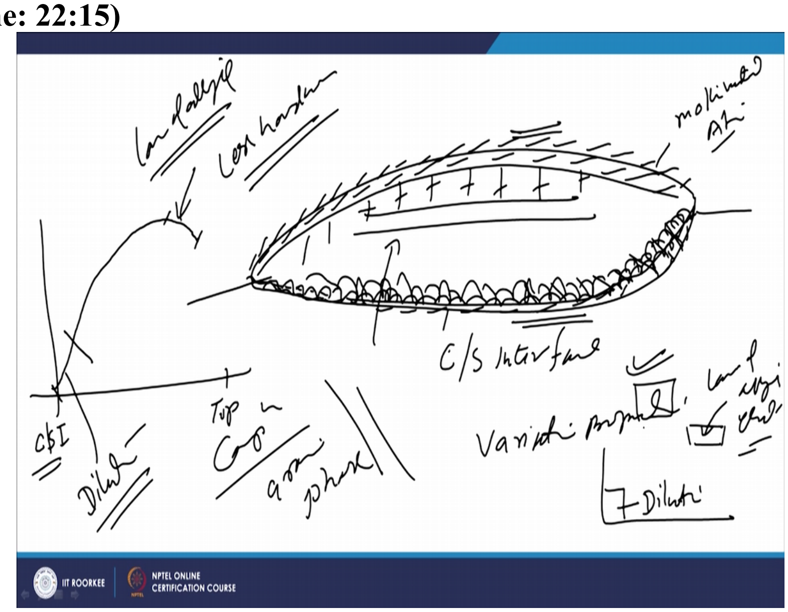

So, on approaching for from like say this is the cladding substrate interface. Initially normally we get the planar structure next to that it is very thin. This is a planar structure sometimes it is absent also. There after we get very fine cellular structure width very fine. There after we get another layer of the columner dendratic structure. These structures are very, very fine, columner dendratic structure.

And then we find the very fine equals grain structure as we move away from the substrate interface. There is a continuous difference in terms of the composition and in terms of the grain size maybe in terms of the phases as well. And that is why we mostly fine in that the there is a variation in the continuous variation in the properties from the substrate coating interface to the top of the interface.

So, and if the protection of the pool is not proper there may be some of the losses of the alloying elements from the surface region or near surface regions of the claddings due to the interaction of the molten metal with the atmospheric gases. And because of this there maybe absence of the alloying elements and their; and this will be leading to the reduced hardness at the top layer. And that is why if we measure the hardness variation from the coating substrate interface to the top surface layer.

Than at the at this interface hardness is lower and then it will keep on increasing and then at the top surface layer again it is starts decreasing because of the loss of the sum of the alloying elements with the protection is not proper. So, maximum hardness we find somewhere at them middle or middle to the; and or the between middle and the top layer of the cladding.

So, and this reduction is attributed to the loss of some of the alloying elements if it has not been there and somewhat lower hardness at the coating substrate near the coating, near the cladding and substrate interface this is attributed to the dilution. So, the width of such kind of the hardness variations and the loss of hardness reduction in hardness at the top layer all these factors will be governed by the that the extent of influence of the atmospheric gases or the extent of the dilution which is taking place at the interface.

So, we; in both the cases near the interface we get the lower hardness and near the surface again we get some hot lower hardness while at the middle we get the higher hardness. So, the lower hardness at the coating substrate interface or the cladding substrate interface this is attributed to the dilution and the little loss at the top surface layer is attributed to the loss of alloying elements due to the interactions with the atmospheric gases or other impurities if they are there at the surface maximum.

We get the just below the top surface layers because here we have the limited effect of the dilution or limited effect of the loss of the alloying elements.

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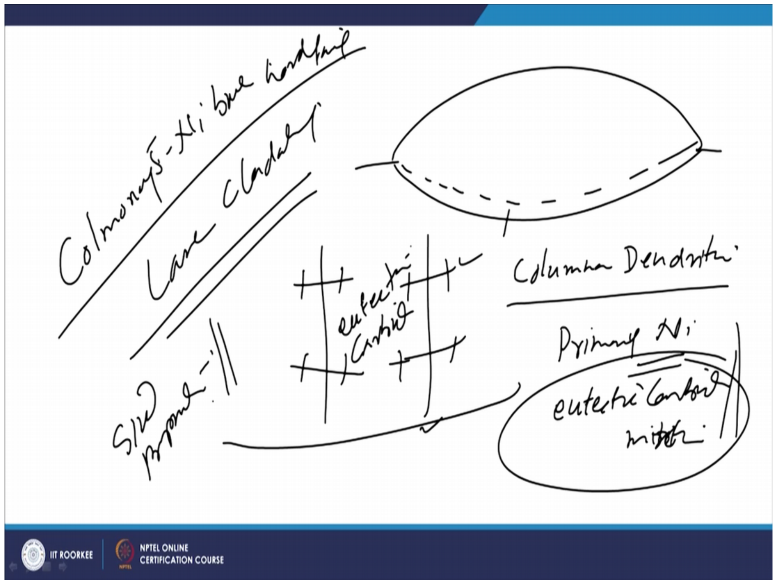

And typical materials like on columnoy there is one nickel base hard facing material are the cladding of this is deposited using the laser. Laser cladding of the columnoy and whenever it is it is just for an example whenever columnoy 5 coating cladding applied using the laser. It results in coating substrate interface results in columinor dendratic structure which is primarily made of the primarily it is nickel and between the dendratic forms we have the eutectic carbide mixture.

And these are the prime components and the heat input pile primarily governing the dendratic size of the; the dendrites and the amount of the eutectic thermite mixture which is present in between the primary dendratic armour spacing. So, like say this is the primary dendrite these are secondary dendrite and there may thrice dendrite. So, between the dendratic arms this is the columnor, so this is the interface.

So this is a columnor dendrite and between this we may have the eutectic carbide mixture which will be and these are factors like a the size proportion of the various phases means the average size grain size of this micro constituents. And the proportions are the fraction of the constituents will we determine the mechanical properties and wear resistance if they are developed by the particular process.

And since the laser cladding offers the advantage of the higher energy density low dilution high cooling rates and the effective protection by the typical environmental protecting approach like use of the Argon or the Helium gases. Then it results in a very good quality laser cladding for surface modifications. Now I will summaries this presentation, in this presentation I talked about the fundamental approach of the laser cladding and why does it good quality surface modification as compared to the conventional the weld surfacing processes. Thank you for your attention.