Fundamentals of Surface Engineering: Mechanisms, Processes and Characterizations

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Lecture-42
Surface Modification Techniques: Fundamentals of Surface Modification By Weld Surfacing and Thermal Spraying

Hello, I welcome you all in this presentation related with the subject fundamentals of surface engineering and we are talking about the surface modification techniques. And now we have started the third category of the surface modification techniques where in a layer of the suitable material at the surface is developed for improving the surface properties. So, that the required tribological life of the component and can be achieved. So, in this category basically we have the two broad groups of the surface modification techniques.

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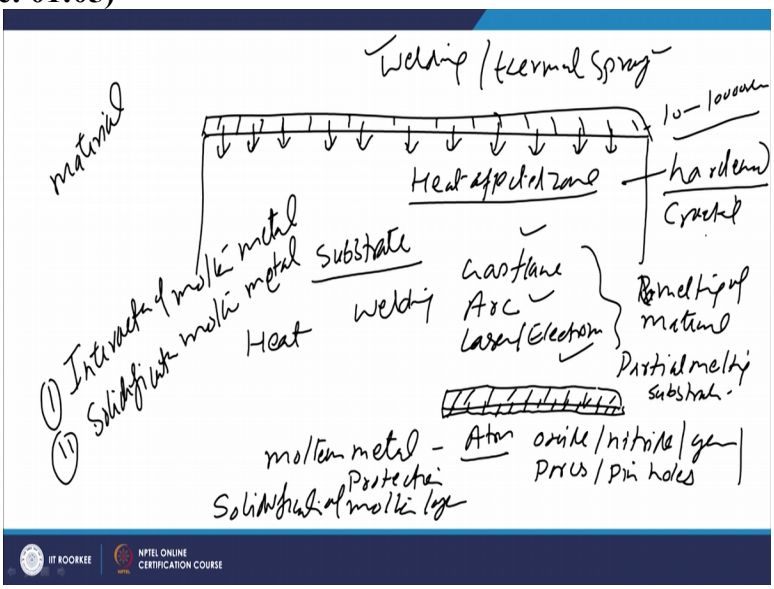

Where surface layer is developed or either using the welding or thermal spray based processes. So, using both this process completely thick layer ranging from 10 to 10's of 1000's of micrometer is developed. Like the welding is used for the claddings and the layers of the thickness greater than 1 mm or 1000 micrometre while recruiting is normally used for lower thickness is like a 10 to 1000 micrometre.

So, whatever layer of the suitable material is being developed, so the first thing is that we have one substrate material which is not having the required set of the properties and layer of the material and the material which is having the required property is applied at the surface. So, up

now there are various issues when they are applied by the using the welding or by the thermal spray process.

They will be going through the application of heat. So, heat in case of the welding basically heat can be informed can be applied using the gas flame or using the arc or using the laser or electron beam in all these cases purpose of these heat sources is to realise the melting of the material which is to be applied on to the substrate and at the same time partial melting of the substrate.

So, this is, in this case for better understanding if a material for surfacing is to be applied by the welding then the material will be melted at the same time little bit melting of the base metal is also required. So, that the good metallurgical bond between the materials applied and the substrate can be realised. But when this is achieved what means when the melting is achieved what we see that we have molten metal of the material which is to be applied at the substrate.

As well as the molten metal is also there of the substrate material and then intermixing will be leading to the development of layer of the required properties. So, this molten metal at high temperature will be very sensitive and very reactive for reactive with the atmospheric gases. So, it will tend to form their oxides, nitrites or even the gases will get dissolved in the molten metal leading to the pores or pin holes in the layer which is being build up.

So, the one; this is one aspect a related with the application of heat in the welding based method where heat applied melts and when the metal is in molten state it reacts with the atmospheric gases. And subsequently to avoid these interactions with of the molten metal with the atmospheric gases we need proper protection. So that formation of oxides nitrides as well as pores and inclusion can be reduced.

There is another aspect this metal that has been brought to the molten state intermixed layer molten state is available that will be solidifying. So, solidification of the molten layer is another aspect that will be governing the that kind of property of the modified surface layer which will be achieving which in turn will be affecting the mechanical as well as tribological properties. So, basically there are two things, one is like interaction of the molten metal with gases all around during the surface modification.

And the second is the solidification of the molten metal during the surface modification by welding based approach. At the same time are some of the heat which is being applied during the

welding for surface modification either using gas flame or arc or laser are some of the heat is also transferred to the underlying base metal and that is why especially in case of the hardenable metals it forms a heat affected zone.

So, is the material is really hardenable then it can tend to get hardened and this hardened layer may show the cracking tendency. So, these are other undesirable effects as well as surface modification using the welding is concerned. Now I will see the, another approach of the surface modification using the thermal spraying.

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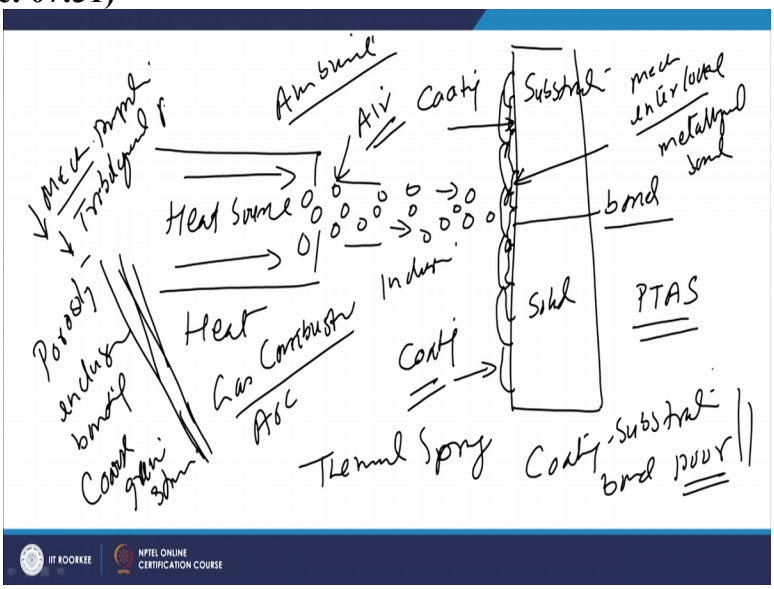

So, whatever is the type of the heat source we are using whether it is the flame or arc? So, this we can see the heat resource. So, here we are having the heat either from the flame or from the arc or any other source is being used. So, here the material to be applied on to the surface is brought to the molten or partially molten state and then it is accelerated towards the substrate using the suitable means it may be high velocity jet. And then how these molten or semi molten particles when impinge they get flattend after the impeachment with the substrate surface and then there will be getting solidified.

So, this is how a layer of the material required to be applied on the substrate is developed in case of the thermal spray process. In thermal spray if you are using the gas combustion then the rate of the amount of heat which will be transferred to the substrate will be less as compared to the case when some kind of arc is used. Because the cooling rate of the coatings and the cooling rate of the cooling rate which is experienced by the metal which is solidifying is very crucial from the performance of them modified surface layer is concerned.

So, in thermal spraying after the solidification will be getting the layer of the required material but here we see this is the substrate is in the solid state. And molten or semi molten particles are impinging with the substrate and then after getting flattening they will be solidified. So, some kind of the bond is created between the substrate and the solidified splax which are being formed and getting deposited on the surface of the substrate.

So, eventually when we get the sufficient thickness of this layer which is being developed we get a coating of the required material on the substrate. And that is why bonding between the coating and the substrate becomes crucial because there is no fusion of the substrate and the molten or partially melted material is impinging and after impingement it is getting flattened and getting solidified.

So, the bond between them is actually relatively poor because mostly in the initial stage it is the mechanical interlocking and then little bit metallurgical bond is created due to the diffusion. But the bond between the coating and the substrate in this particular case this bond is somewhat poor. So, the bonding becomes one important parameter with regard to the performance of such kind of the coatings.

If the bond is poor then there will be the tendency of the separation or removal of coatings from the substrates. In those processes where the melting of the substrate takes place like the plasma transferred arc spraying. So, there heat being applied is too much leads to the melting of the thin layer of the substrate and in those cases the bonding between the coating and the substrate becomes extremely good because of the presence of the very good metrological bond this is one aspects the melting.

Since melting normally if the melting of the material being applied in form of the coating for the substrate using thermal spray process is being achieved under the normal ambient condition and then there will definitely be possibility for interaction of the molten metal of these quantities with the atmospheric gases. And so there will you possibility for formation of the inclusions as well as possibility for the presence of the pores between the different particles which are getting deposited different layers which are being deposited over the surface of the substrate.

So, that thermal spray coating basically suffers from the porosity inclusions and the bond strength. So, these are the common things which are there and if the cooling rate being

experienced by the by the material being deposited is very low then we make it very coarse grain structure as well. And these characteristics will be lowering the mechanical properties and will be reducing their tribological performance of such kind of the coatings official.

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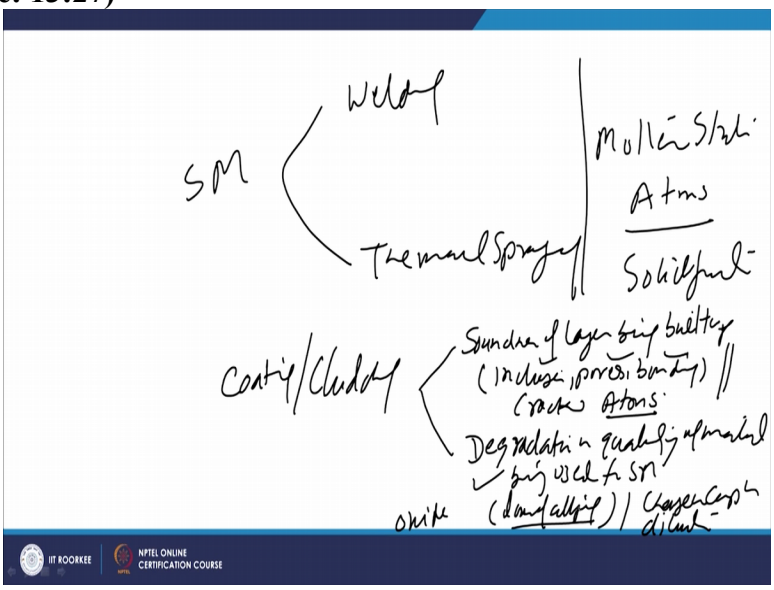

So, If you see both these approaches of the surface modification where either we are using welding or we are using thermal spraying. In both the cases the material to be applied is brought to the molten state and the molten metal interacts with the atmospheric gases. And subsequently it solidification leads to the development of the required modified surface layer. And that is why the performance of such kind of the coatings or claddings in this kind of surface modification approach is primarily influenced by the two aspects.

One is the soundness of the layer being built up which we may see in the presence of inclusions, pores, bonding or cracks at the surface in the coating which is being developed and this is happening due to the primary interaction probably due to the inner and nature of the process itself what are the factors that govern these aspects about that will be talking later. And another aspect is during the surface modification using either welding from thermal spraying.

What kind of the degradation in the quality of the material being used for surface modification. So, sometimes if the process is not good then it can lead to the degradation in quality of the material and this may happened in form of the loss of alloying elements from the material which is being applied itself or there can be change in composition of the material itself. And this can happen due to the dilution or loss of alloying elements can be due to the oxidation of the elements due to interaction with the atmospheric gases like oxygen and nitrogen.

Now will see the things in a little bit finer details like the formation of inclusion, pores, bonding the different factors which affect the soundness and their different factors which affect the greatness which determines and dictate the degradation in the quality of the material due to during the surface modification either in the form of loss of alloying elements or the dilution or it can be also in terms of the way by which solidification takes place.

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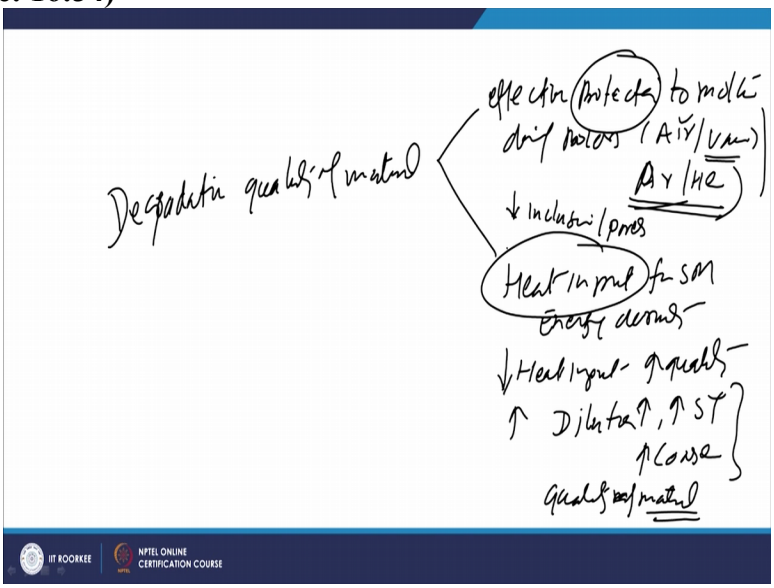

So, the degradation is a very big point as far as the quality of the surface layer is concerned degradation in the quality of the material being applied for the surface modification and this will be influenced by the two aspects. One is how effective protection is being given to the molten metal protection, how effective protection to the molten metal either in form of weld pool or during which is spraying is being given protection to the molten metal during the process is being given.

Like if it is being carried out in the air or in vacuum or in the control atmosphere like Argon or Helium. So, as for the kind of the environmental conditions in which spray is being carried out that will be affecting the kind of interactions between the molten metal and the surrounding environment, so if air is present then certainly the quality will be poor as compare to the case when the vacuum is there and when the inert atmosphere is used during the spraying.

So, if very good control over the environment is being maintained there is no and other molten metal is being well protected from the adverse of interactions are undesirable interactions between the molten metal and the atmospheric gases. It is due to the presence of the inert gases

or vacuum then it will be leading to the reduction reaction of the inclusions or pores. So this in turn will be increasing the soundness and the quality of the surface modified layers.

And then another aspect is how much heat is being used heat input for surface modification is being used and this in turn depends upon the energy density associated with the process which is being used for the surface modification. So, if heat input is less for given search for given surface modification then quality will be better. There will be less degradation in the quality of the material as compared to the case when the high input is used.

And is primarily happens due to the; because the heat input will be leading to the increased dilution and increased solidification time which will be leading to the increased coarse grain structure and these factors intern will be degrading the quality of the material layer which is being applied on, for the surface modification. So, the protection of the molten metal as well as the heat input being used for surface modification.

These are the two big points as far as which as far as the quality degradation and quality of the material being applied during the surface modification is concerned. So, we need to consider both these aspects when we are looking behind the surface modification using the welding or the thermal spray based processes. Now we will see some other aspects like a protection.

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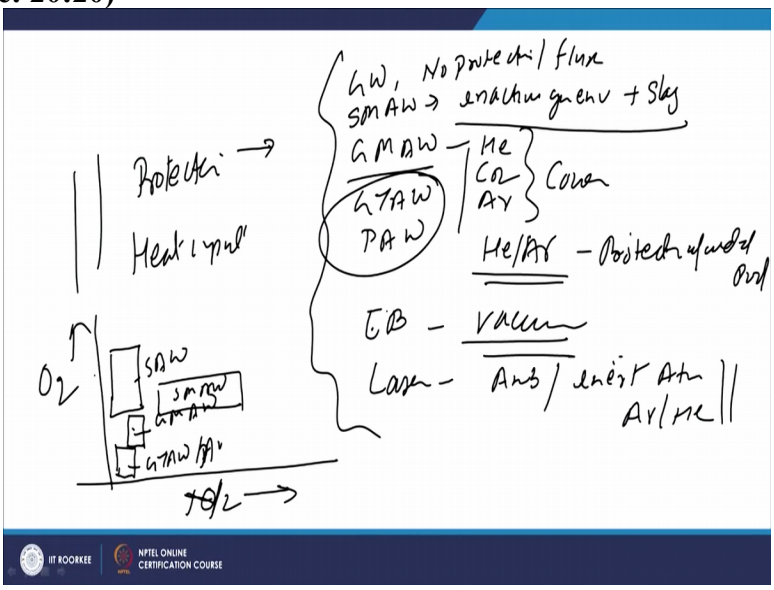

So, as we have seen the protection and the heat input are the two big points which will be affecting the quality of the layer which is being developed. So, as far as protection is concerned in the different processes like a gas welding there is no protection or we can use of flux for

removing the impurities if they are being formed as far as the gas welding is concerned. In shielded metal arc welding for protecting the molten metal.

We use the in inactive gas environment or envelop of which is created due to the combustion of the coating plus the slag cover which is formed. So, this will be protecting protection is poor but I still this is the approach for protecting the molten metal from interaction with the atmospheric gases. And then we have like that gas metal arc welding where we can use Helium, we can use or of Carbon dioxide, we can use Argon. So, these will be protecting the cover of these gases during the welding will be protecting the molten metal from the interactions with the atmospheric gases.

And the same is true for the gas tungsten arc welding and plasma arc welding. So, the inert or inactive gases are used basically in case of these two processes gas tungsten arc welding and the plasma arc welding primarily use Helium or Argon not the Co2 for protection of the weld pool to avoid the contamination and adverse effects related with the interaction of the molten pool with the atmospheric gases.

And then in case of the electron beam vacuum is used for that is very good it will not allow the interaction of the molten metal with the any gas because of the vacuum and then the laser which is now which can be carried out either in ambient condition or in the inert atmosphere using the Argon or Helium as a shielding gas. So, these are the different approach different things which are used for protecting the molten metal during the development of the modified surface layers through the weld surfacing.

For the purpose of protecting the molten metal from the atmospheric gases so that undergo interactions between the molten metal and those gases can be reduced. Now will see there is another aspect so obviously if you have just a general look about the different time in the clean the kind of cleanliness which is offered by the different processes here in x axis we have Nitrogen and Oxygen in y axis.

And if we see the gas tungsten arc welding process offers the minimum concentration of the Oxygen and Nitrogen then we have the gas metal arc welding. So, GTA welding process GMA welding process and then we have shielded submerged arc welding process SAW and shielded metal arc welding process is here, SMAW is a process if we compare the GTAW and PAW will be offering the minimum concentration, minimum Oxygen and Nitrogen in the weld metal.

So, the cleanest weld claddings will be proper will be offered by the GTAW process and PAW processes while the gas metal arc welding process will be offering greater oxygen similarly with the submerged arc welding process. Greater is the oxygen, greater will be the possibility for interactions with the molten metal and which will be increasing the possibility for the inclusions as well as a porosity in the in the modified surface layer in form of the weld surfacing. Now you will see the another aspect related with the heat input in case of the heat input you know.

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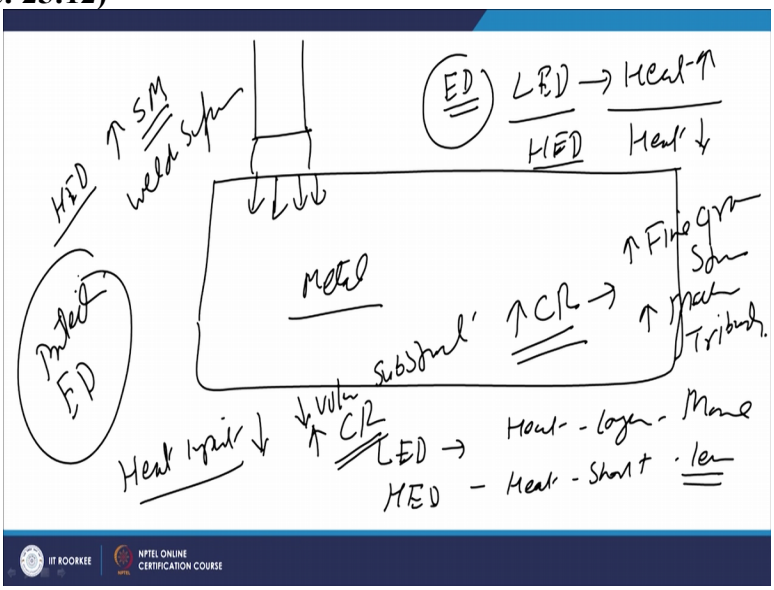

Whenever any source of the heat is applied on to the substrate for facilitating the melting, so the in every material that the substrate material will have one latent heat, so that heat must be applied for facilitating diffusion. Since the most of the metals are good conductors of the heat as well, so whenever heat is applied to heat is transferred to the underlying metal as well, so, if the energy density associated with the heat source or while welding process is low then the heat to be supplied for facilitating diffusion that will be more.

Because in low energy density process will require longer time to deliver the required amount of heat so that the fusion can be facilitated. And therefore and therefore we need to provide more heat. So, when the low energy density process is used only require more heat for fusion as compared to the case of the high energy density process is used. In high energy density process a lot of heat is applied in very less time so that the fusion is facilitated.

And so in using the less heat itself and less heat is sufficient for ensuring the fusion of the substrate so that the world surfacing can be realised. So, low energy density processes given amount of heat takes longer and that is why more heat. And high energy density processes for a

given amount of heat it takes short time. So, actually it takes it requires less heat because the heat dissipation to the substrate is reduced.

And we know that when the heat input for heat amount supplied is reduced this then reduces the volume of the substrate melted this increases the cooling rate experienced by the substrate during solidification and increase in cooling rate. So, all those processes which are higher energy density they will be leading to the higher cooling rate during the solidification of the molten metal and air cooling rate will be leading to the fine grain structur. And fine grain structure improves the mechanical properties improved tribological properties.

Of those processes which are high energy density process under the same material they offer the better quality of the modified surfaces even through the weld surfacing. So, like if you have the laser and electron beam plasma arc gas welding, all are of the different energy density is and that is why they offer the different kind of the qualities. So, each process differs in terms of the protection in terms of the energy density and that is why they offer the different qualities of the modified surface layers through the weld surfacing.

About others aspects related with the thermal spraying are you talking in the subsequent presentations I will summarise this presentation basically I have talked about the fundamental aspects related to the surface modification using the weld surfacing and thermal spraying and we have seen that the quality of the material being applied is significantly affected by the protection during the surface modification.

And the heat input which is being given for the surface modification. So, if the production is good and heat input is less than will be getting the good quality modified surface layers through the thermal spraying and through the weld surfacing, thank you for your attention.