Surface Engineering for Corrosion and Wear Resistance Application

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Lecture - 42
Thermal Spray Deposition – II

Welcome to part II of Thermal Spray Deposition technique. So, in this particular talk we will discuss about different thermal spray deposition techniques in brief.

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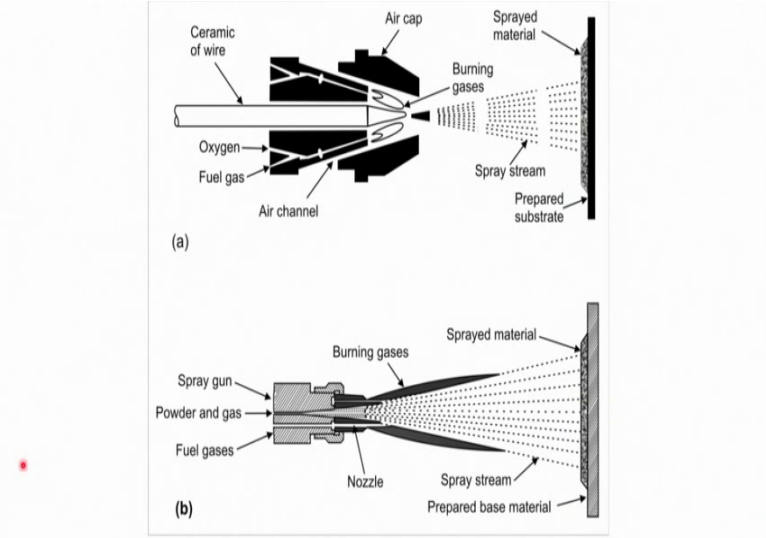

Summary of Flame Spraying Process

So, as I mentioned you there are a wide varieties of thermal spray deposition techniques are available and theses classifications are based on the kind of heat source you are using for spraying operation and other parameters like velocity parameters, then may be the speed of the coating.

So, these few parameters are very important to dictate the different different or maybe they act as the driving force or genesis for the classification. So, among these all processes you can say that, flame spraying is the a index and also you can say that most primitive in nature and also it is quite cheap.

So, in flame spray deposition process what you do is that, people do use the oxy acetylene fuel as a source of heat for as a fuel for generating the flame and subsequently

is the source of heat. So, ignition of oxy acetylene flowing is done in flame spraying process.

So, this technique can use the material or precursor powder in the form of rod or it can also used in the form of powder or it can used in the form of wire. So, depending on teep of the precursor powder, you have different kinds of nozzle, you have to design the nozzle accordingly.

So, if it is if your precursor powder precursor quoting if your precursor is in the form of lot, then naturally you have one kind of that nozzle where there is chance of there is a possibility of inserting the tube continuously and subsequently it gets impeased in that it gets inserted in the teep of the flame and gets melted and subsequently through other part of the nozzle there is a flow of the luscious pieces, usually the you flow air or you can also flow argon or nitrogen as carrier gas and that carrier gas is use to just grad mint the moulted material into smaller smaller droplets and subsequently it is propelled in to the surface of the substrate to get the desired coating.

It can also be in the form of powder, when it is in the form of powder then there as to be the powder feeding nozzle, powder feeding through the powder feeder you basically feed the powder with carrier gas; carrier gas may be argon and then what you do is that, you feed it. And then that feed powder is actually flown into the teep of the this particular flame and then in that flame is actually melts the powder and subsequently the molten powder is again a just a broken into small small droplets with the help of the air gaseous high velocity air and air or may be argon or may be nitrogen any gaseous pieces you use, and then it propelled at a very high velocity onto the surface of the substrate.

So, in this case there has to be provision of powder feeder or so, that you get the powders get feed properly into the this that into the flame teep here again you have the you should have provision for the ceramic wire or may be that typical rod to get into and subsequently get melted and molten material is get subsequently sprayed over the surface of the substrate.

So, in this flame spraying operation your main parameters will be the oxygen to acetylene ratio or may be oxygen to propend ratio what if the powder or what if the fill you are using for heat generation, your another parameter is powder particle size as well

as safe and also in which form you are using the coating material whether it is in the form of the rod or it is in the form wire.

So, third parameter is the velocity at which it is sprayed over the surface of the substrate. So, these are three important coating parameters which play very important role in determining the quality of the coating and final parameter is the substrate pre treatment, what kind of the technique treatment has been done on the surface and distance between the nozzle to that of substrate.

So, these are 4 5 important parameters which control the that quality of the coating which you are looking for.

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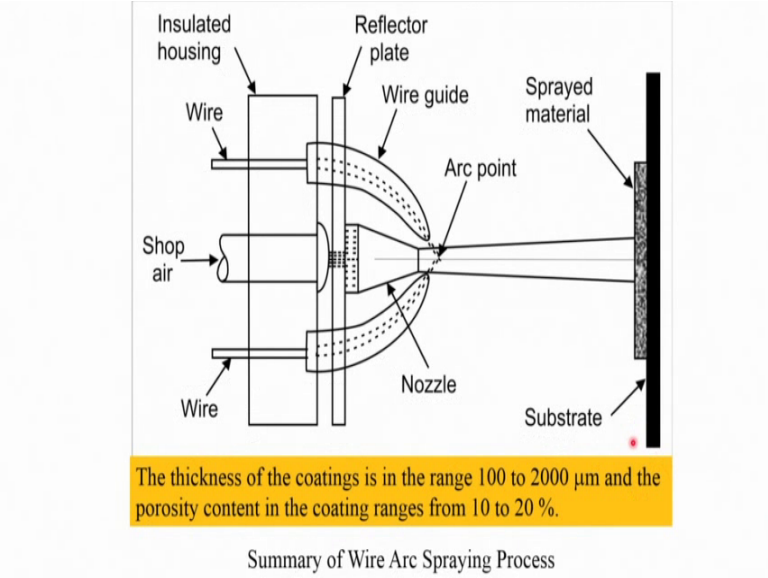

Summary of Wire Arc Spraying Process

Now, in this particular flame stream process you will I have mentioned you this process is vey much cheap in nature and versatile nature, but can be applied for the coating of the low melting material particularly that your aluminium zinc tin and the steel flue steel, but it cannot be applied for deposition of high melting point material like molybdenum, titanium or may be the carbide, nitrides, aluminates or oxides.

So, those coatings cannot be achieved by flame spraying process that can be applied for the deposition of the particularly metallic material and particularly low melting materials and another disadvantage of this particular process is that after this flame spraying operation, you end up with a porosity as high as 8 to 9 percent.

So, large numbers of porosities are large numbers of inclusions are also present in the structure. So, it does not give the typical flawless coating and immediately out of flame spraying you need to do sealing operation so, that the coating is sealed and there is no chance of corrosion if you are interested to develop the coating by for corrosion resistance application by flame spraying.

There is second type of coating is arc spraying. So, in arc spraying as I mentioned you that it is you are using your arc or source of heat. So, here usually people do is oxy. So, people do usually is that arc which is consumable out of the consumable wire. So, you have the DC power supply unit and two wire you feet and then at the contact point you have the arc generation and that arc generation is capable of melting the these particular tubes or may be wires and subsequently you basically use the complex air to just break the molten material in the form of droplets and subsequently spray over the surface of the substrate.

So, this is how the arc spray unit operates. So, if you just quickly go through the typical variables in the arc spray deposition technique, these are like typical variables are like the arc the rate at which here feeding the arc the usually the rate which you are feeding the arc you feeding the wire for arc generation has to be optimized because if the wire feeding rate is higher than the rate at which it is consumed. Then you will find that there will no arc which is generated there will be short circuiting effect on the other hand the rate at which you are feeding the wire if it is lower than that of the rate at which it is consumed then you will find that the arc will not get generated.

So, for generation of perfect arc and subsequently its used for melting of the material your arc speed as to be the wire feeding speed has to be maintained or has to be you can say that standardised so, that there is no chance of any problem related to arc generation.

And second parameter is that velocity of the air or inert gas which is used for propelling purpose. So, third parameter is the distance between the arc generation and that of substrate so and which material you are using to coat. So, these are few important parameters which playing important role for determining the quality coating and usually the thickness of coating is in the range of to 100 to 200 2000 macron and in this coating also powder you can say that coating pauses its lot of defects particularly porosity. So,

porosity content varies from 10 percent to 20 percent as its there in the case of flame spraying.

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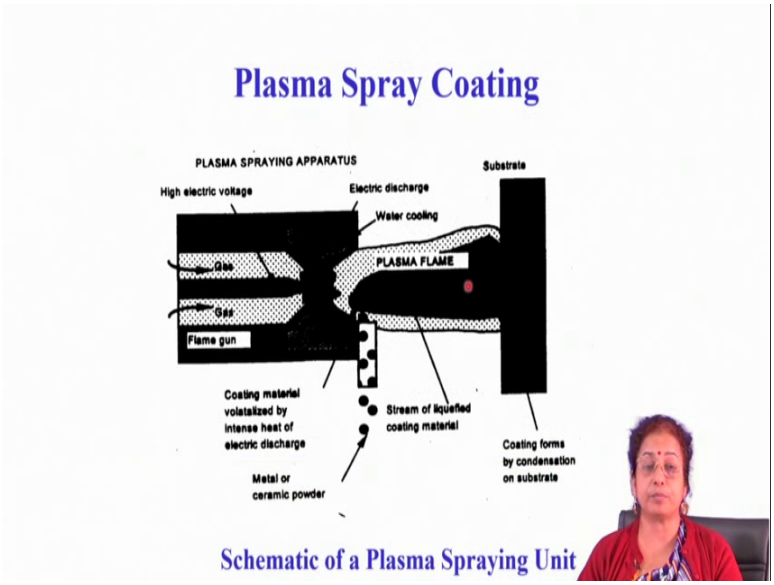

So, a little bit of advancement of these particular technique is the plasma spray coating. So, plasma spray coating is the little bit advancement in the in this stage that in plasma spraying you really get a very high heat into the teep of the torch. So, heat content in flame spraying or arc spraying can be 1500 to 700 degree Celsius, on the other hand in plasma spraying it can be as high as 25000 to 30000 degree Celsius.

So, in this particular plasma spray coating what you do is that, you basically generate the plasma; plasma is nothing, but cluster of ions and electrons and nuclear atoms. So, that particular plasma whenever is generated then naturally that plasma is very it is having very high energy and depending on the density of the plasma.

Basically in this particular plasma you generate lot of plasma densities lot of ion densities and because of the generation of very high density ions your temperature also reaches to a very large level. And basically the plasma is generated in between these copper and tungsten electrode and as very high is generated in this particular torch, you should have the constant cooling arrangement of this particular copper tube.

So, proper cooling has to be done so, that there is no damage of the electrons and that plasma heat is used for the heating or melting of the powders which you are going to

coat. So, in that particular plasma zone you basically feed the material in the form of powder and then subsequently it is sprayed on to the surface of the substrate. So, this is how the plasma spray operation plasma spray coating is carried out.

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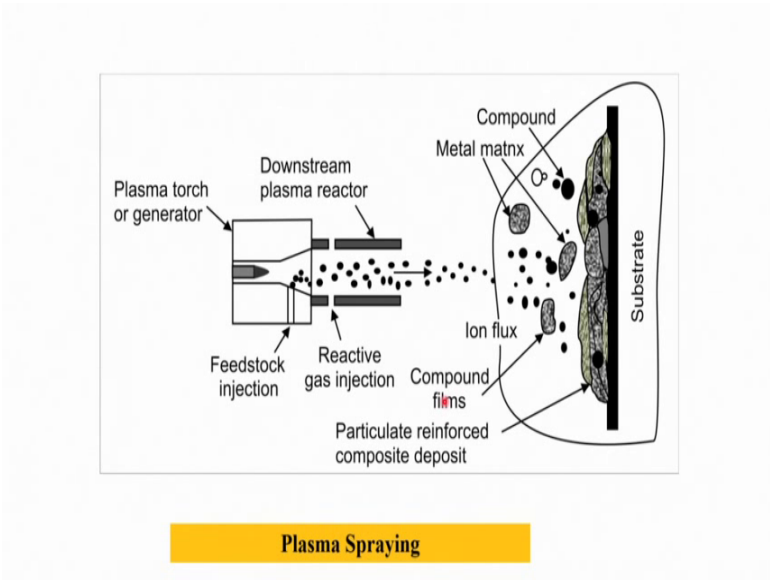

So, in plasma spraying by plasma spraying you can coat any material of your choice because it is having very high melting temperature, but plasma spraying is not applied for the melting of the low melting material particularly zinc and aluminium and also you can. So, think of the particularly metallic material having no melting temperature, polymeric material those materials cannot be deposited by plasma spraying.

But high melting material ceramic material sulphates they are coated by plasma spraying. So, little bit advancement of plasma spraying is reactive plasma spraying. So, when you are interested to have metal matrix composite coating or any ceramic coating, you can have metal precursor powder and you can also flow nitrogen oxygen as the reactive gas ah.

So, you will find that inside the chamber there will be reaction and then formation of the ceramic particles metal matrix composing and that get deposited on to the surface of the substrate.

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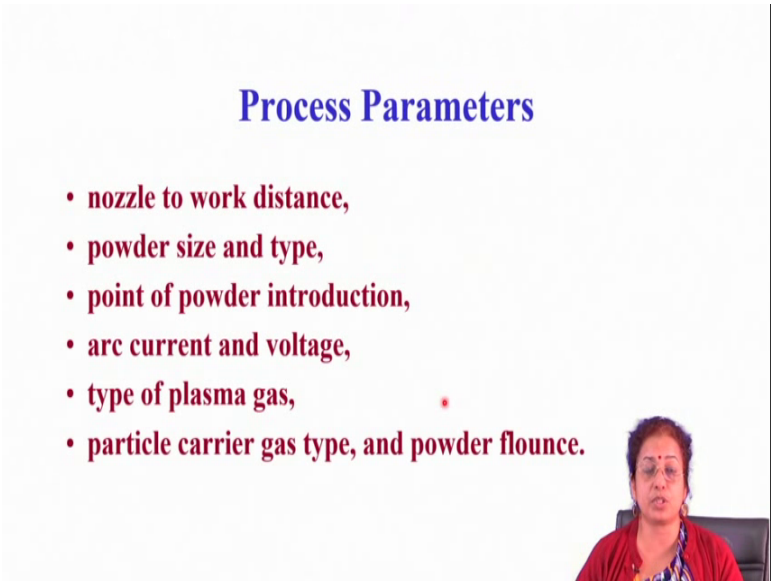

So, this is a very new form of the deposition actually. So, now, if you think of the process parameters this is nothing, but the nozzle to work distance then powder size and type, then point of powder introduction, arc current and voltage, types of plasma gas type of plasma gas which you are using, then particle carrier gas type and particle powder flounce. These are the different parameters which basically play a important role jointly to determine the coating quality.

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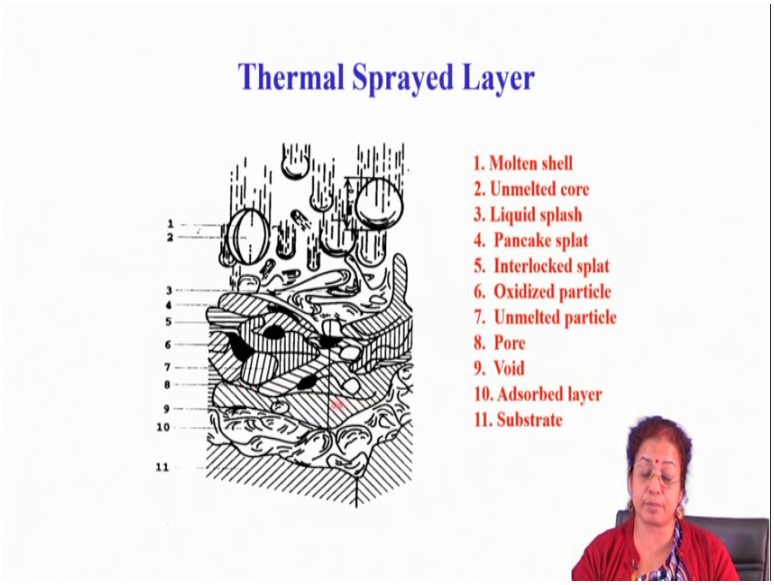

Now, if you quickly go through the thermal sprayed deposited layer cross section, you will find that as I mentioned you in the last few slides that there are lot of defects in the coated layer like oxide particle inclusive small small unmelted particles and then the parts are basically a they are in the form of the this molten material are in the forms of spalt.

So, splat formations are always there. So, because of splat formation there is also you can say that it is typical pancake type of structure and it is not really regular in shape it is irregular in shape. Because molten material there basically strike the surface of the substrate at a little higher velocity so, it does not remain in uniform shape it is always having the default shape. So, pancake kind of typical structure. So, and in between two say pancake there is lot of porosity formation there may not be porosity formation there may be inclusion of the oxide particles. So, those problems are always there.

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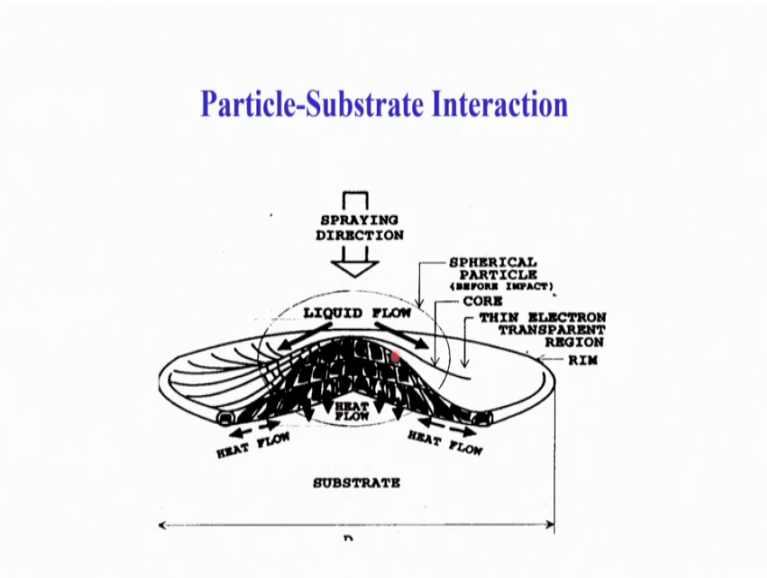

So, if you see that particles have straight interaction phenomena, you will find that at the interface there is always chance of very thin diffuse layer ado sine at the interface this is very important and in sapient fusion is also there.

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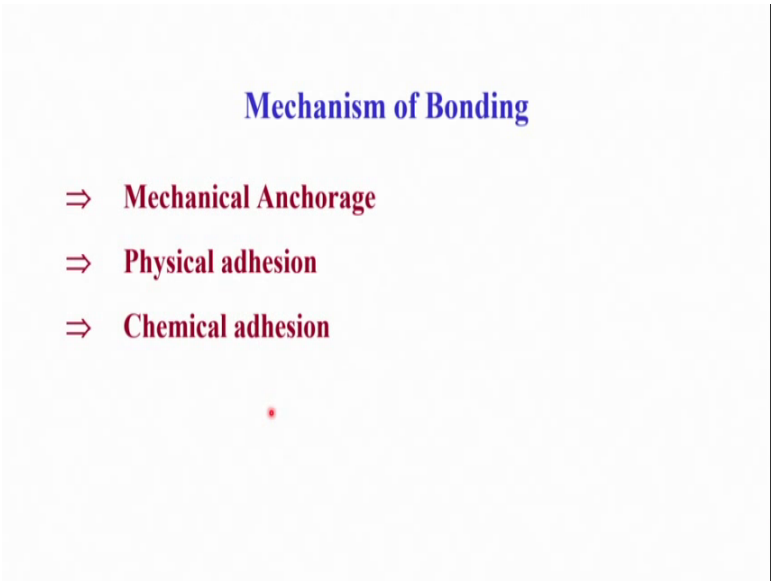

Now we quickly go through the mechanism of bonding in thermal spray deposition, these are mechanical anchorage physical adhesion as well as chemical adhesion. So, mechanical anchorage is always they will show accordingly for all the processes so, you have to prepare the substrate so, that there are lot of roofs on the surface we usually do it by sandblasting operation.

So, that actually gives the anchoring on or promotes the anchoring as a result of which we will get very high strength in the coating. There is also physical adhesion as well as chemical adhesion phenomena after this spraying operation.

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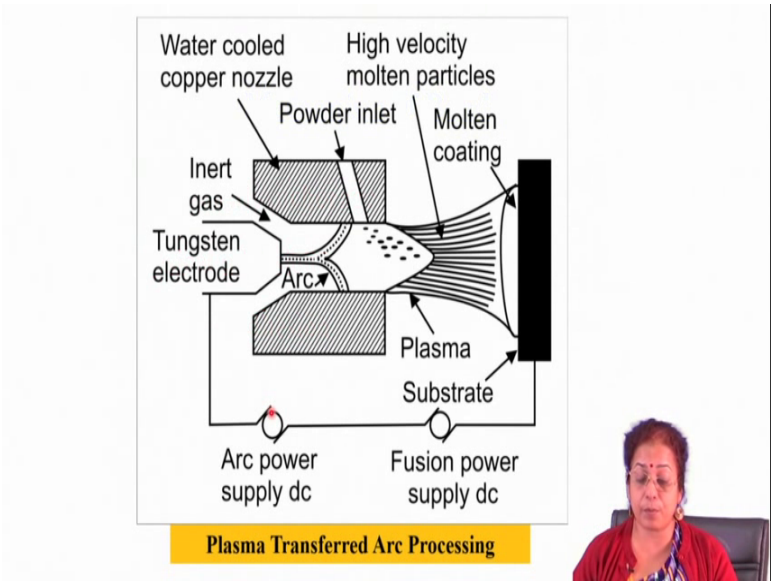

So, another type of you can say that little bit closer to quelling process is plasma transferred arc processing. So, where basically the arc process though the electrical arc current passes though the plasma and then it strikes the substrate surface. So, plasma is very close to the substrate because of its closelyness in nature, you will find that molten material get deposited over the surface of the substrate like way lowerly.

So, this is called plasma transferred arc quelling. So, you will find that by this particular process you do not really get coating which is like in spraying because no porosities will be there, here you get continuous molted layer melted layer likewise you are getting cladding in operation. Plasma transferred arc quelling process is very much applied for deposition of the clad layer on the surface of the substrate.

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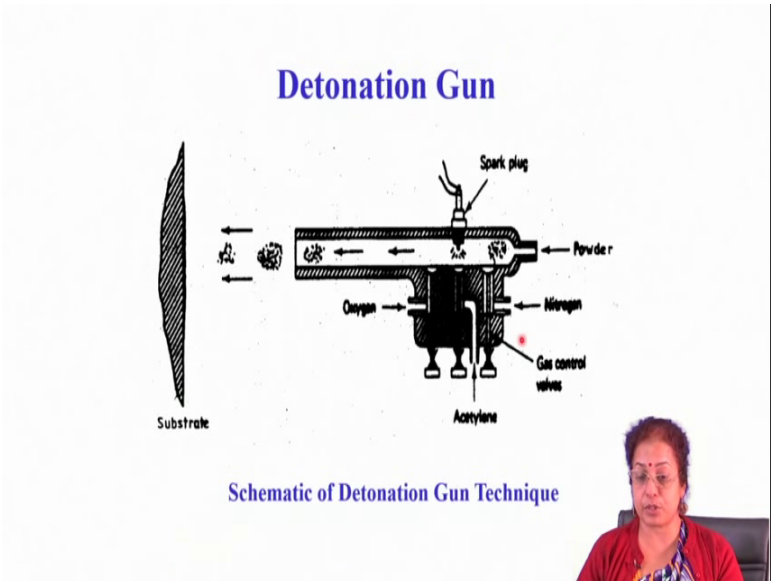

So, another kind of coating is detonation gun coating. So, in detonation gun coating you basically use the spark plasma and you use spark plug for fuel for a ignition of the fuel. So, what you do is that, here actually instead of having the torch for fuel ignition you can have the local localised zone for ignition of the fuel and hence heat generation.

So, because you are using the spark plug for heat generation you will find that this chamber is actually sound proof, in very large chamber and most of the parameters are patented. The material which you are going to deposited this is also patented. And you use the powder in a small quantity and that small quantity for because zone is low where you generate heat that region is very low region actually where small I mean the area of that particular region is quite low and as a result of which the capacity that is capacity of melting is also quite low.

So, by this particular detonation gun spraying process, part pass you cannot deposit more than half a macron thickness. So, where you are interested to deposit very large thickness there are or they are this particular detonation gun can be used, but you have to do it for a long time multiples so, coating has to be applied, but otherwise it is very slow process actually.

So, these technique can be applied for deposition of the metallic as well as metal matrix metallic material and metal matrix composite can be deposited, but ceramic material

cannot be deposited because here again you are using oxy acetylene fuel as a torch of heat as a source of heat.

So, you your temperature is quite low it is not as I as in plasma spraying, but here the basic difference between flame spraying and detonation gun string is that here as spraying is done in a very low slow rate and you have apply several layers of spaying for getting the deposited thick very thick deposited layer.

This particular technique is basically its it generates very less craze in the coated layer and by this particular detonation gun spraying coating you get very densed coating. So, coating density is quite high because the velocity of coating is very high. So, first of all so, first important advantage of detonation gun coating over that of flame spraying is that, this particular coating in this coating rate is quite slow and you get very thin coating control is very easy.

Then there is less porosity in the coated layer. So, because of the very less porosities in the coated layer you get very sound coating and that particular coating can be applied for corrosion resistance application as well as wire resistance application.

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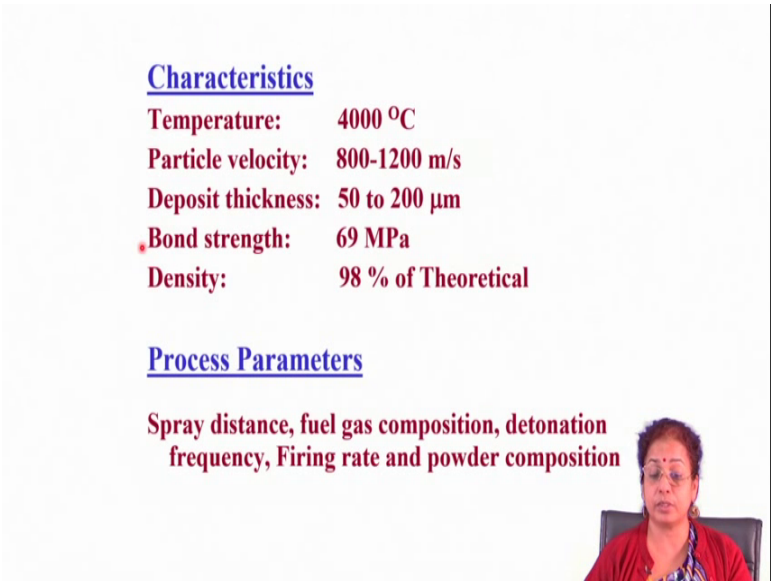

So, as I mentioned you temperature is a quite reasonably good for metallic and metal matrix composite coating. Particle velocity is very high above sound velocity; deposited

thickness varies from 50 to 200 micron bond strength is approximately 69 MPa density is 98 percent of theoretical density.

And parameters as spray parameters fuel gas composition detonation frequency firing rate and powder composition these are the process parameters. These are more or less seen everywhere. So, here also the similar parameters are used, but firing rate is very important here because ignition happens in a very small area inside the typical chamber actually.

It is not at the outer part of the chamber where you are igniting the gaseous spaces where that igniting zone is quite high quite large actually here it needs ignition zone is small and as a result of which the firing rate is also quite low and you have to use very small powder for the coating purpose.

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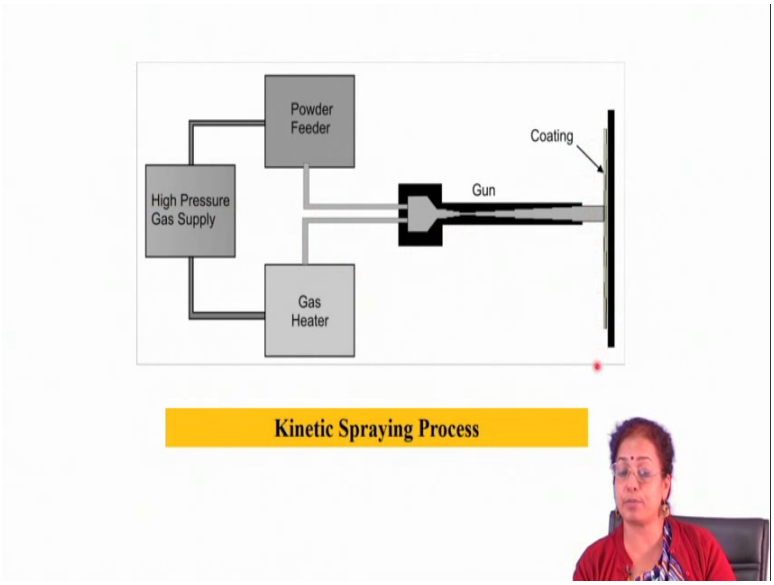

So, the last technique is that kinetic spraying technique where you do not use the heat for spraying operation, but you use basically large kinetic energy for spraying the powder is usually heated because if you do not heat the powder on the powder surface, there is always chance of lot of moisture accumulation moisture absorption.

So, you have to take out the moisture out and usually the material is in the form of semi molten state. So, you do apply this particular this a you do heat it of using the oxy

acetylene flame again to quite low temperature and then these powders are basically flowed at a very high velocity very high pressure gas pressure gas supply and get coated.

And so, this particular kinetic spraying technique is very easy technique, but it needs special gun because as the velocity of this particular sprayed material is higher than that of oxy that higher than that of sound velocity so, there is always chance of the erosion of the nozzle.

So, nozzle has to be made of very special material so, that it does not erode away because of the spraying operation. So, you should have very tungsten carbide coated or diamond coated tool is used for this particular spraying purpose and your deposition you can do any kind of material deposition there it is better that you use no material melting deposition like you deposit the aluminium, deposit zinc, deposit nano structure material, deposit copper.

You do not go for deposition of high melting material because here you are not melting the coating your basically spraying it at a very velocity to get the desired bond strength.

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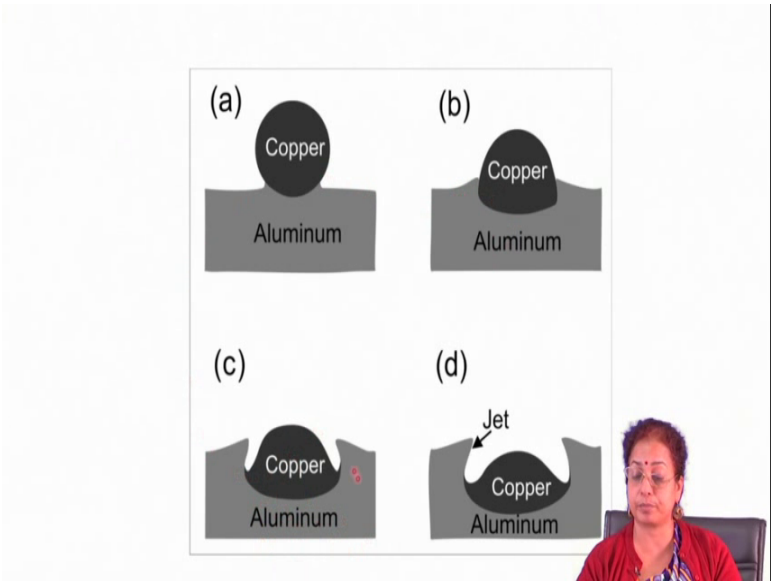

So, this is typical because this is not bonding for example, copper particle here impeased over surface of the coating that is aluminium. So, this kind of a sake it retains because you will find that this is at the very high velocity.

So, as a result of which mechanical impingement is always there and it is quite high to a very large degree because of the very high velocity and copper is also in semi molten state it is not really in solid state. So, it is again get it get fused deep deeply into the molten aluminium.

So, you will find that sometimes if the speed is very high at the interface there is also chance of some aluminide or inter metallic formation or the diffusion phenomena.

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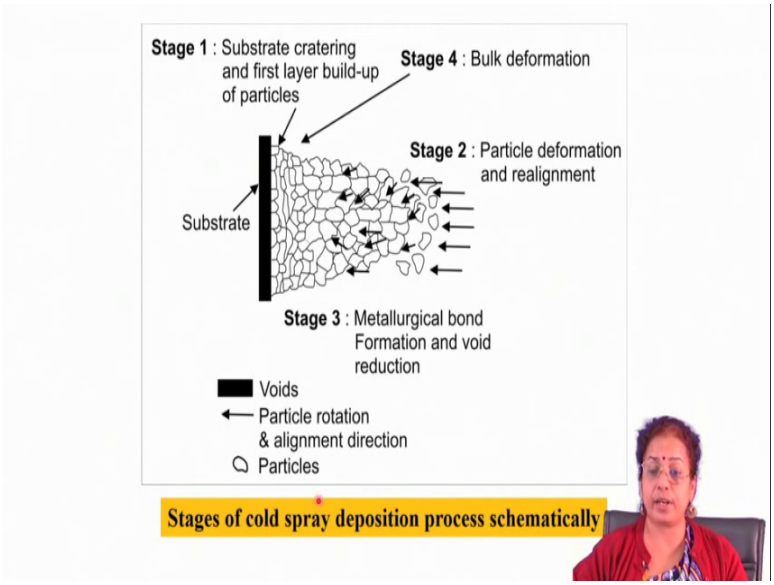

So, if you quickly go through the stages of cold spray deposition process, you will find that it consist of 3 stages where, a first stage is that the initial time gap required for the coating to be to strike over the surface of the substrate and to get impeased it.

So, you should create critical velocity, which is around 800 to 900 meter per second. So, below the critical velocity we will find that particles will not get impeased in it will go out. If it is equal to that of critical velocity then it will be remaining on the surface of the substrate, it may erode away the substrate if it is higher than that of critical velocity, then it will get impeased on impeased in the surface of the substrate.

So, initial layer we will form like that, then there will be second par stage 2 where the particle deformation and realignment will be there. So, once the first layer founds the next layers will go on forming one by one, then in stage 3 there is a metallurgical bond formation and void reduction. But there is always bond formation because as soon as the

first layer forms, then you are not really depositing another onto the surface of another substrate your coating are made of the same material.

So, you will find that there proper bonding because similar materials similar materials come in contact with similar materials and then finally, there will be deformation. So, in these 4 stages the particular deformation proceeds is coating proceeds.

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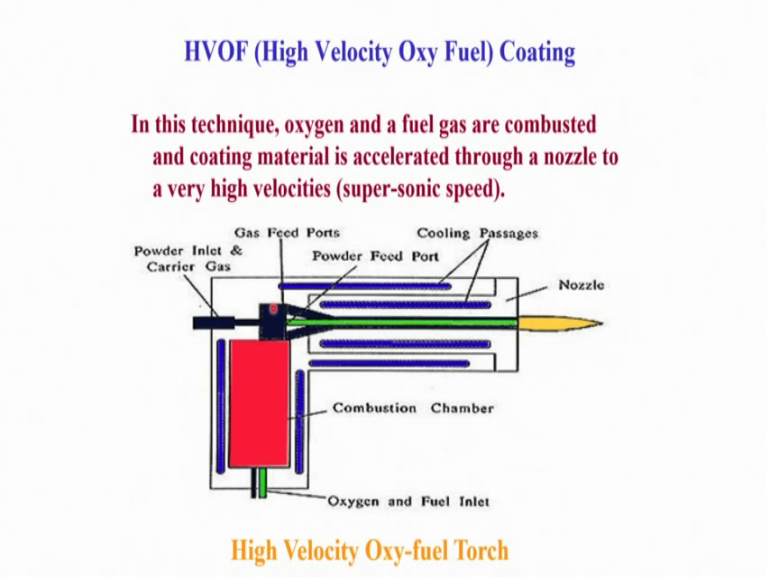

So, you can apply the thermal spraying for any kind of finally, another type of coating is high velocity oxy fuel coating. So, this particular coating is very much applied for coating of again low melting material and ceramic material can also be used for coating purpose, but there you have to use very special gun and in this particular coating as the name impels high velocity oxy fuel coating. Your oxy acetylene is used as source of heat that bonding of oxy acetylene and then I mean the uniqueness of the process lies on the fact that, you basically melt the material which is not done in kinetic spraying.

In kinetic spraying you do not melt the material is in solid state in the form of powder but here in HVOF spraying your material is in the form of liquid. So, you have to melt it and subsequently spray it at a much higher velocity higher than that of that velocity of sound that on to the surface of the substrate.

So, this HVOF spraying is very much applied for the deposition of the low melting coating as well as nano structure coating, you get very fine ranged in microstructure after

this HVOF spraying coating and can be applied for deals coating here density activity is much higher than that of density activities of flame steam those flame stream is used and same temperature is attained.

So, here density is around 90 to 99.5 percent in contrast to 92 to 93 percent in case of flame spraying operation and there is melting of the coating which is not there in kinetic spraying. So, you have to always think of these all advantages and disadvantages of individual technique to know which technique should be applied for which purpose.

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Now, if you quickly go through the different applications of these thermal spray deposition technique, you will find that this thermal spray deposition technique can be applied for deposition of a wide varieties of metallic materials like ion and steel, nickel, conium, cobalt it can also be applied for coating of the carbides, oxides then the ceramets and the metal matrix composing cermets can be applied for the deposition of self using and self fluxing self fluxing alloy like nickel carbon silicon or boron.

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Kinetic spraying can be applied for polymeric coating, can be applied for corrosion resistance application like anodic coating, zinc aluminium, cathodic coating stain less steel, tantalum coating and natural coating like alumina chromium oxide coating.

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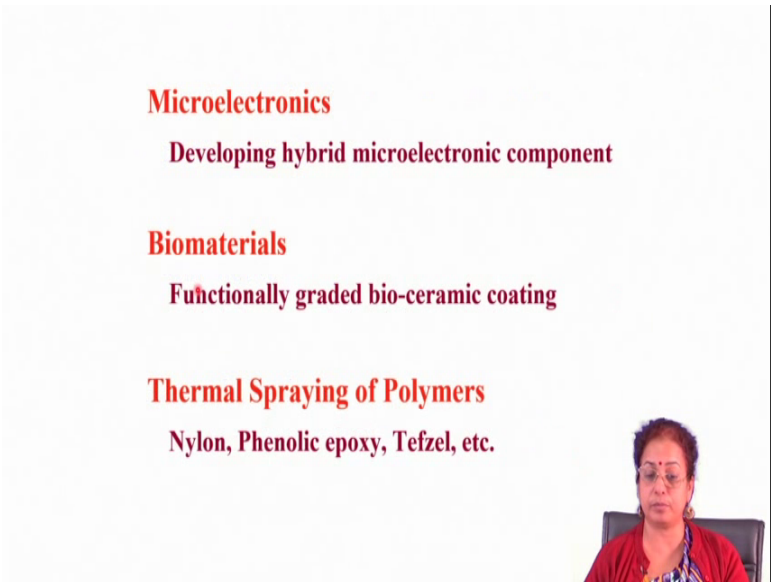

May be for any application like microelectronics biomaterials or polymeric application for improving the nodes checking properties.

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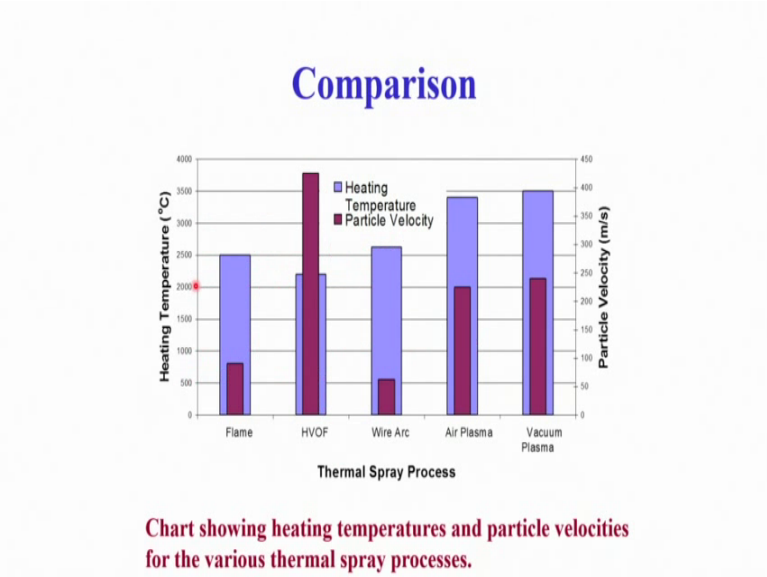

If you just now we went through all the techniques, now if you quickly go through the comparison of different techniques, you will find that main features which distinguish we say each technique for each technique from another is that the heat content of the field which your using and also the speed of the coating.

So, if you see the these two parameters for all cases you will find that in plasma spraying the temperature is quite high and on the other hand in the flame spraying or HVOF spraying, wire arc spraying temperature is of the similar level. Now if you see that particle velocity again you will find that particle velocity is highest in HVOF stream, but it is very low in flame stream, oxy stream, oxy where arc spraying or vacuum plasma or may be air plasma spraying.

Though particular velocity is little higher in air plasma and vacuum plasma spraying, but it is higher than that of flame stream, but maximum velocity is attained in HVOF stream. So, depending on the these two parameters you will find that density is one variable density depends on the velocity of the coating and also the temperature which is generated in the particular coating chamber.

It also depends on the for example, if you talk about the kind of coating you develop, it very much dependent on the temperature of the nozzle. So, the temperature are the particular heat source which you are using. So, higher is the temperature you can say that there is more probability of the coating or the ceramic coating of ceramic as well as

salmours. So, these things are very important and to consider for the coating of different types of material in practice.

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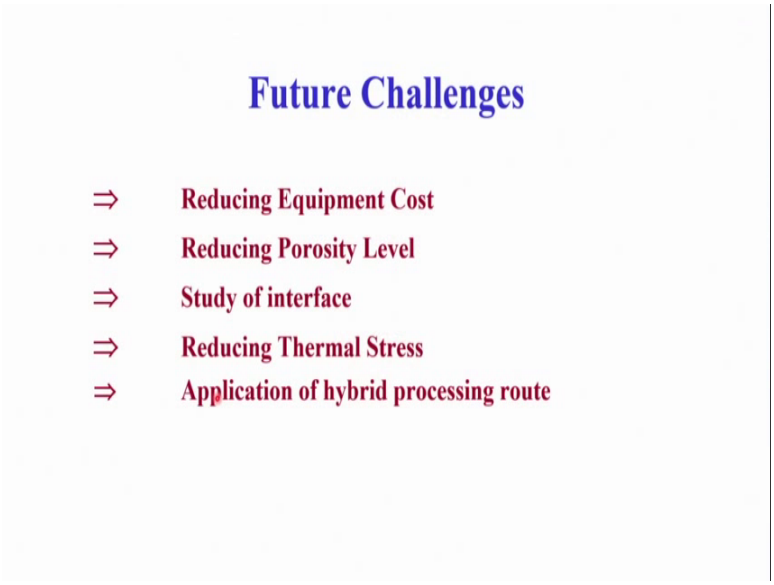

Now, future challenge lies on the reducing the equipment cost reducing the porosity level, interface study is very important, then application of hybrid processing route is quite important.

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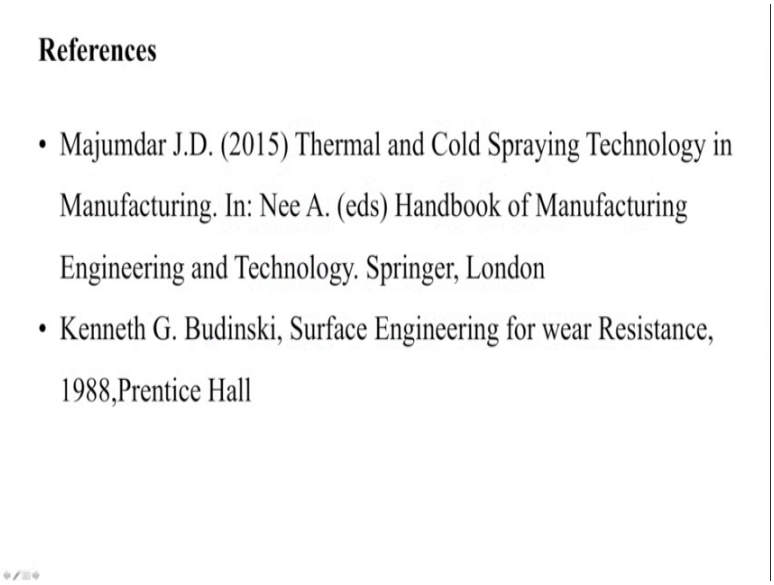

So, in the next few slides I will say about the different types of thermal spray deposition technique and its applications.

Thank you very much.