Fundamentals of Surface Engineering: Mechanisms, Processes and Characterizations

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Lecture-53
Surface Modification Techniques: Cold Spraying, Arc Spraying

Hello, I welcome you all this presentation related with the subject fundamentals of surface engineering and we are talking about the different methods which are used for developing a layer of the suitable material in form of coatings weld overlays so that the surface properties can be enhanced for improving the tribological life of the components. So, under the different thermal spray processes we have talked about the high velocity oxy fuel detonation flame spray processes.

In this presentation will be taking up the three thermal spray process these are this like cold spray, arc spray and the plasma spray processes, now if we see in case of the cold spray why this process is called cold spray.

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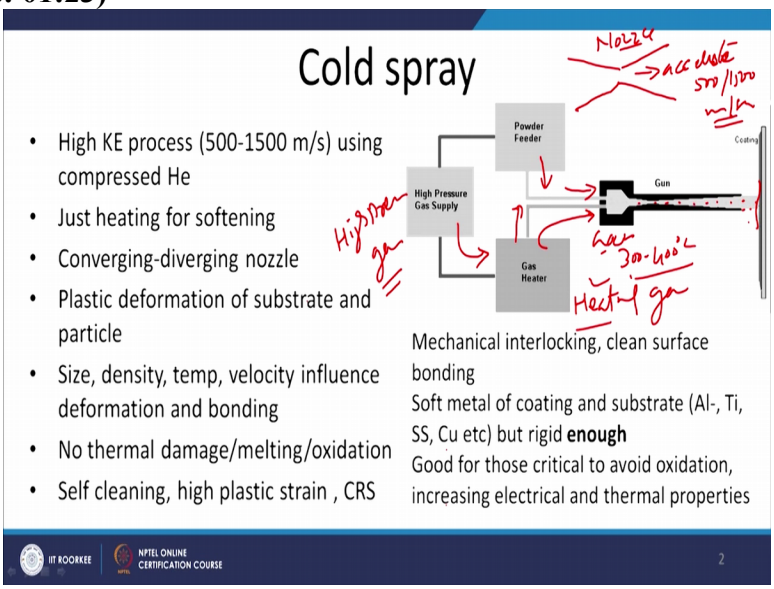

Because it is primarily used is the hot gases for heating purpose. It uses the hot gases for heating purposes. It is uses the hot gases for heating the material like so there is a heater which is used for heating the gases and this heating is performed these hot gases of the temperature like 300 to 400 degree centigrade hot gases are used and in addition to this high pressure gas is also used. And so the high pressure gas which is at high temperature of 300 to 400 degree centigrade is fed to the gun.

Now this gun is made of typical geometry like this which is basically converging and diverging and this converging diverging nozzle helps to accelerate the gases. So, that I attend very high velocity in the range of 500 to 1500 meter per second so such a high velocity helps the particle to move the particles at high velocity. So if you see high velocity of the gases help to move the particle high velocity during the spring.

If you see this schematic then these gases are also used to feed the material to be coated through the suitable powder feeder. So, high pressure hot gases and the material to be coated is fed from the feeder to nozzle gun where the converging and diverging design of the nozzle helps to accelerate the hot gases and along with that powder particle also accelerated to high velocity and they are in fact help substrate to develop the coating.

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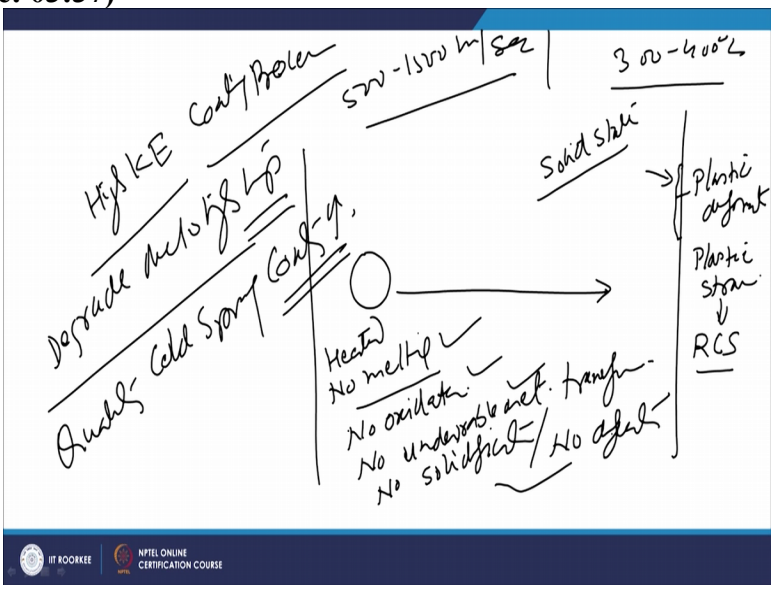

So, if you see this process is characterized as a very high kinetic energy coating process because the particles attain very high velocity of 500 to 1500 meter per second and the rise in temperature of the particle is also not the high as the gas temperature. The hot gas temperature is limited to 300 to 400 degree centigrade. So, if we see the particles which have not been heated too much higher temperature when they are accelerated to very high velocity after the impact they get flattened.

So, the flattening actually happens in the solid state itself and this leads to the plastic deformation of the powder particles while flattening and this causes the plastic strain in the material which is being deposited in form of the powder particles. So, this plastic strain

eventually results in the development of the residual compressive stresses. If we see the material powder particles are just being heated.

There is no melting and since the rise in temperature of the powder particle is very limited. So, absence of the melting and also there is no oxidation of the material which to be coated and there is no undesirable metallurgical transformation. So, these are the some of the benefits at the same time there is no; since there is no melting so there is no solidification as well and accordingly the no solidification related defects.

So, because of these very positive features associated with this process this process is found extremely suitable for the materials which have the tendency to get degrade due to the high temperature in case of the other thermal spray processes. And because of this we find that the kind of the quality of the cold spray coatings is much better as compared to the other processes as there is no melting, no oxidation, no undesirable metallurgical transformation and no defects associated with the solidification.

In addition to this we have one more advantage in this process that is like whatever powder particles are being accelerated at high velocity and after impact will be getting flattened. So, if they are having any of the impurities or oxide layers on its surface this brittle oxide layer due to the plastic is training deformation after the impact this is broken down. The breaking of the oxide layer basically the fracturing or breaking of the oxide layer takes place and which leads to the deposition of the clean material.

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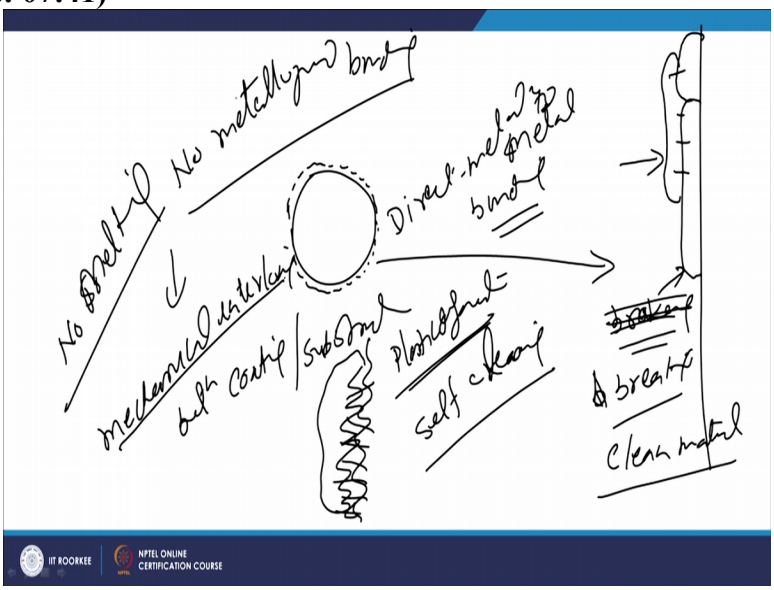

So, this we can say the self cleaning self cleaning of the powder particles is inherent in this process. And similarly the other powder particles which will be impacting with the substrate are already deposited the material there will be due to the removal of such impurity is an oxide particles there is a direct contact between the various particles and direct metal to metal contact. So, what we say direct metal to metal contact is established and which results in very good bonding between them even in the solid state.

Since in this case there is no melting so there is no metallurgical bonding in the initial stages. Bonding is primarily caused by the mechanical interlocking between the coating material between the coating material and the substrate. So, what is the meaning of interlocking that if the securities are present at the surface then the particle also get flattened with them and they will get deformed all these peaks and valleys will get deform and get mechanical interlock like this.

So, the presence of regularities at the same time the plastic deformation of these regularities is important for mechanical interlocking of the material which is been deposited.

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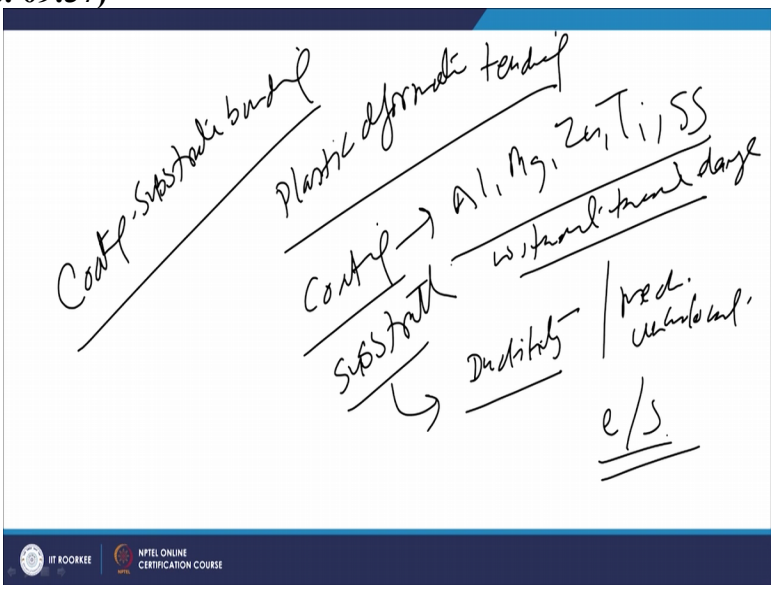

The prerequisite for development of the coating substrate bonding is the ability of the material to get plastically deform plastic deformation tendency. And this one is needed in both the material to be deposited in coating for inform of coating and also the substrate. And therefore the coating materials which are comparatively soft like aluminium, magnesium, zinc, titanium, stainless steel etcetera coating of these materials can be effectively easily deposited without any without thermal damage. While is little bit ductility or the ability to get the form is also needed in case of the substrates.

So, substrates which are which have the reasonable ductility can be coated with this process some amount of the ductility with the coating material as well as substrate material is required so that the surface layer deformation can be facilitated to ensure good mechanical interlocking between the coating and the substrate so that the good bond strength can be realised.

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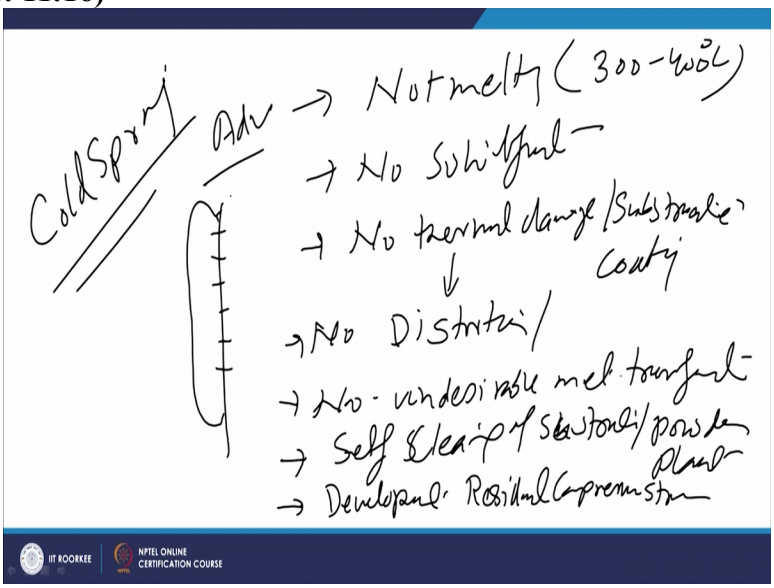

So, as far as the cold spray process is concerned there very few advantages associated with this one is that there is no melting due to the low temperature. Temperature is limited to 300 to 400 degree centigrade, no solidification in this process. There is no thermal damage to both substrate as well as coating material. So, absence of thermal damage will be leading to the no distortion tendency and no undesirable metallurgical transformation undesirable metallurgical transformation.

So, these are few extremely favourable points associated with this at the same time it also offers the advantage of the self cleaning of the substrate as well as powder particles due to the kind of the plastic strain which is associated with the impact of the high kinetic energy powder particles the surface of the substrate. At the same time the requirement of the surface preparation like shot blasting shot peening etcetera is also reduced because impact of the particles at high velocity results in the good mechanical interlocking.

So, in addition to the associated with In addition to this one a very favourable point associated with thermal spray process is the development of the residual compressive stresses. Because whenever material gets flattend plastically like this, so part of the material will under the plastic

strain and then elastic strain for the elastic strain portion tends to get back in its original position and that is restricted by the for mechanical interlocking with the substrate and that is why we get the residual compressive stresses in the substrate itself.

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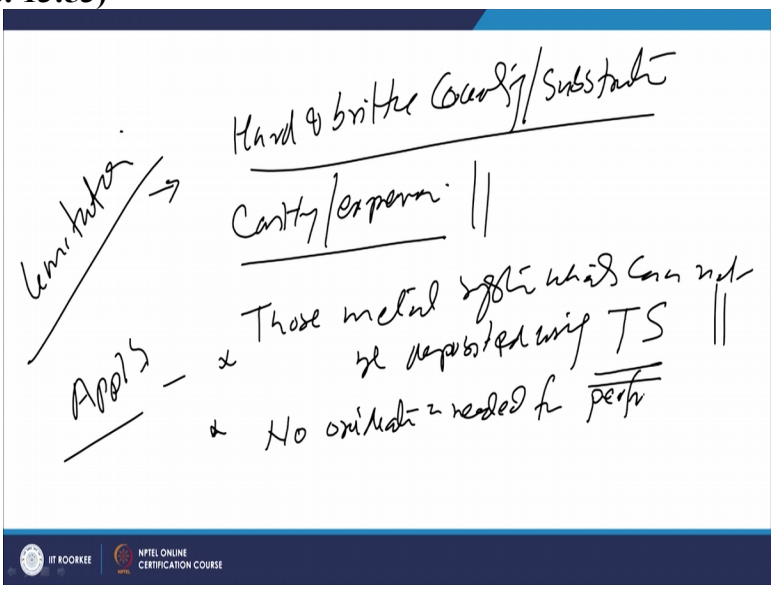

So, these are few very favourable points as far as cold spray concerned. Apart from this there are few limitations associated with this process also like the very hard and brittle coating materials as well as substrate material are difficult to develop the coatings by this process. So, the material coating materials are the substrate materials which are extremely hard and brittle and show the very limited ductility and it is found difficult to develop the coatings using this process.

So, indirectly we can say the process is limited to the soft and ductile material at the same time the process is bit costly and expensive because the gas high pressure gas consumption associated with this process is very high and that is why the application of this process is limited to those metal systems which cannot be deposited using conventional thermal spray processes like detonation gun or HVOF are the plasma arc spray process.

So, this is one and it may be in form of like; if there will be significant improvement in performance of the material. If there is no oxidation is required or needed for excellent performance then the materials are coated using the cold spray process.

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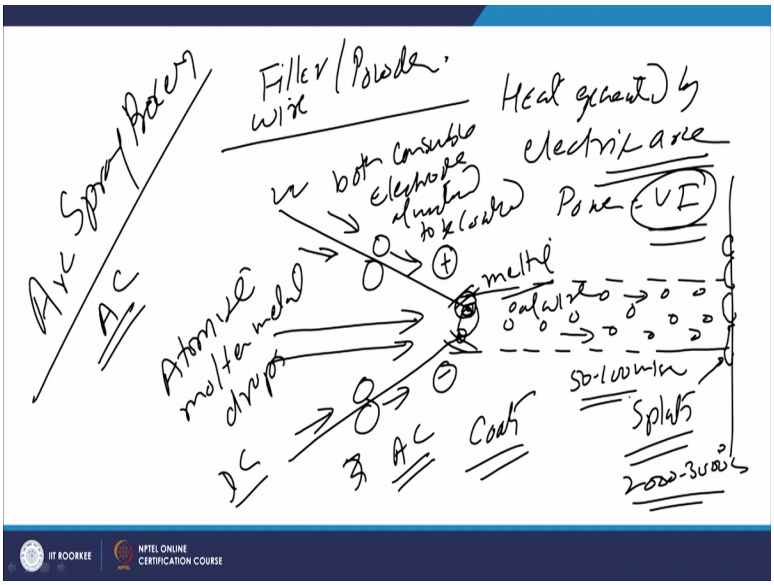

Now will talk about the, another is process that is the spray process that is the arc spray process. So, this arc spray process where the material may be in form of the filler or filler wire or powder basically this process uses the heat generated by electric arc. So, electric arc is heat of the electric arc which we can say the power of arc is given by VI decide the amount of the heat being generated mostly this process used is the two wires like this. So, one is and these wires both are like both are consumable electrode of the material to be coated.

So, like if the zinc is to be coated then both the wires will you made of the zinc and they are connected to the suitable power supply. So, were there will be arc is established between these two wires. So, when the arc is established between these two wires the melt heat generated facilitates melting of wires. And once the melting of the wires at the tip starts where ever arc is there so heat of the arc been established between the two wires a facility it's melting.

So, this molten metal molten metal whatever is created needs to be transferred on to the substrate and for this purpose high pressure air is used to atomise the molten metal drops. So, high pressure jet is used to atomise and accelerate this towards the surface of substrate. So, fine droplets of the molten metal are accelerated towards the surface of the substrate where after impingement they get flattened inform of sports and after the solidification they get developed in form of coating.

So, basically the filler wire; coating material is used in form of filler wire and arc is established between them. Then the molten metal is atomised with the help of the compressed air and this after automation fine molten metal drops are achieved and then these drops are accelerated

towards the surface of the substrate where the molten metal drops after the impingement will get flattened and will and eventually after the solidification.

These will be leading to the formation of splats and so continuous the deposition of the splats on the surface of the substrate leads to the development of the coating. So, for this purpose since both wires are consumed in this process this wire needs to be fed automatically during this process. Since during arching it should be generated equally in both the sides of the filler wire so, that the consumption rates of both the electrodes are both the wire is same.

Otherwise if we go for this purpose only we use the AC for establishing arc between the filler wire. So, for arc spray basically we use AC. In case of AC if you use DC say this one is connected to the positive terminal and this another wire is connected to the negative terminals and we know that if the DC is used then the negative terminal the electrode with the positive terminal with generating more heat.

So, it will you melting at a faster rate we need to feed it at a faster rate to maintain the arc gap or to maintain the gap between the filler wire so that the process can continue. To avoid this difficulty AC is used because in case of AC is polarity keeps on changing after every half cycle and therefore the equal amount of the heat is generated both the sides of the arc that in turn facilitates the melting of the electrode or the wires at the same rate.

And the and therefore we are in position to feed them, feed the wires at the same rate and this kind of the process generates the temperature of the molten metal in the range of 2,000 to 3,000 degree centigrade. But the velocity which is attained moderate it is not very high it may be like say 50 to 100 meter per second. So, moderate velocity and the high temperature these are the two aspects associated with this process.

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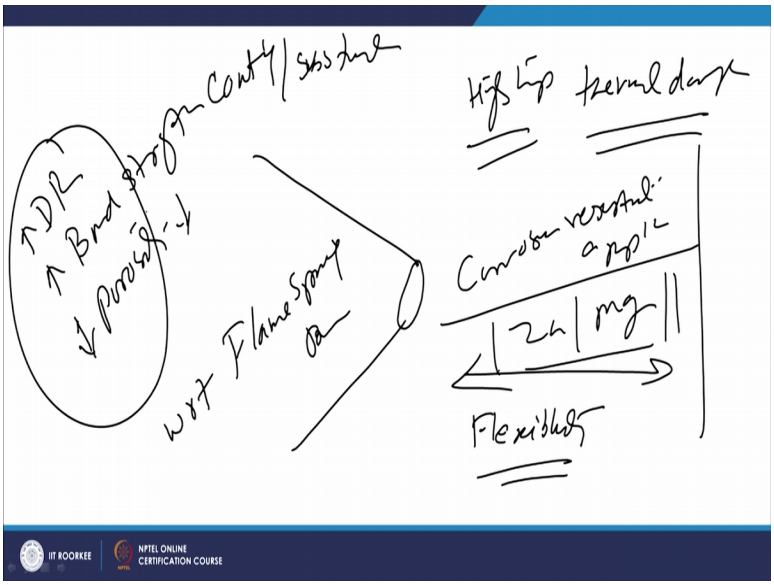

So, because of high temperature there is will be there will be the tendency for thermal damage to the material which is been deposited. But since in this case the work piece is the substrate is independent of the electric circuit and arching is taken place between the two wires only. So, there is a good flexibility as far as standoff distance between the arc spray nozzle and substrate is concerned.

So, that distance are there is a flexibility with regard to the distance and arc will not be affected with the minor variation in the distance from the spray to the work piece surface because the arc is established between the filler words and work piece is not the part of the electric circuit. So, this process is a considered to be the fairly good for depositing the material at very high deposition rate. It also reserves in the good bond strength between coating and substrate.

At the same time since the, it officer moderately higher velocity show the porosity is also limited because the impact of the molten metal at moderately higher velocity leads to the good form contact between the splats or between the molten metal and the substrate particles. So, the porosity is reduced and all these effects are favourable as compared to the flame spray process.

And this process is commonly used for depositing the metals for corrosion resistance applications for example if you want to deposit zinc, magnesium in the coatings of these materials can be effectively developed with the help of the electric arc spray process.

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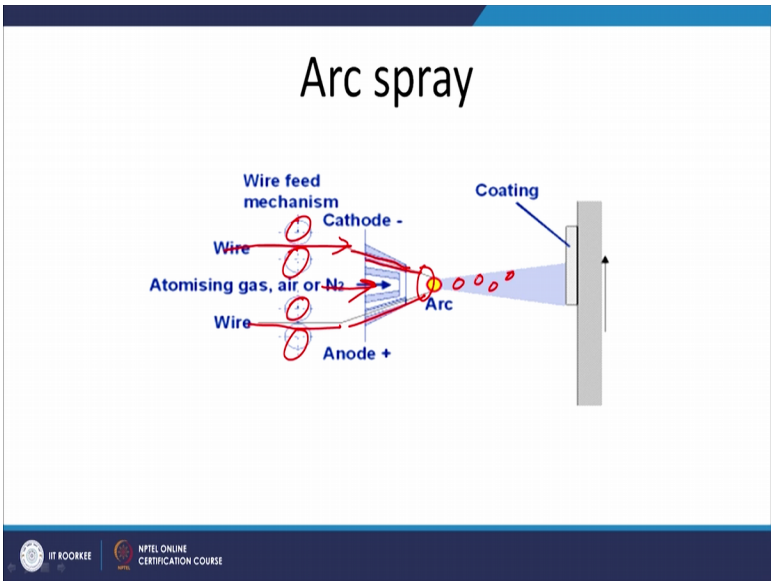

Electric arc spray process so this is where the schematic of the arc spray process where there are two wires which are being fed through the every the help of them via wire feed systems and there are rollers and rollers of rotation will be deciding the rate at which these are being fed and through the nozzle in control with you are fed up through the guide ways. And then as soon as the arc established between the two the melting is facilitated and the molten metal is subsequently atomized with the help of the high pressure air or any suitable gas can be used.

So, once the atomisation of the molten metal drops is it takes place this accelerated towards the surface of the substrate where coating is to be deposited. So, there are other thermal spray process is also like plasma spray process. Plasma spray uses the non consumable electrode for developing arc between the electrode and the nozzle. And the heat of the arc is used to develop the plasma.

Plasma is passed through the nozzle and where in we feed the material to be coated on to the substrate. But the kind of temperature which is achieved in the plasma spray process and the velocities which are realised so plasma spray process much higher and therefore the plasma spray can be used for developing the coating of the high temperature materials.

Now I will summarise this presentation, in this presentation basically I have talked about the two spray processors one was the cold spray and another was the arc spray. In case of the cold spray process only the high pressure hot gas which is heated to the 300 to 400 degree centigrade is used for achieving the reasonably high velocity which helps in moving the particles at very high velocity.

And the particles during the spray remain in the solid state there is no melting and the process because of the high velocity impact with the substrate remains the self cleaning in nature for the for the substrate as well as the coating powder particles. And apart from this high velocity powder particles a spraying in the solid state facilitates the development of the residual compressive stresses.

On the other hand wires arc spray process which colour use is the heat of arc for melting of the material to be coated. And this molten metal is optimised with the help of compressed gas and subsequently after impingement with the substrate solidification facilities in the development of the coating. So, the arc spray offers much better coating characteristics as compared to the flame spray processes. Thank you for your attention.