Surface Engineering for Corrosion and Wear Resistance Application

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Lecture – 43
Thermal Spray Deposition- III

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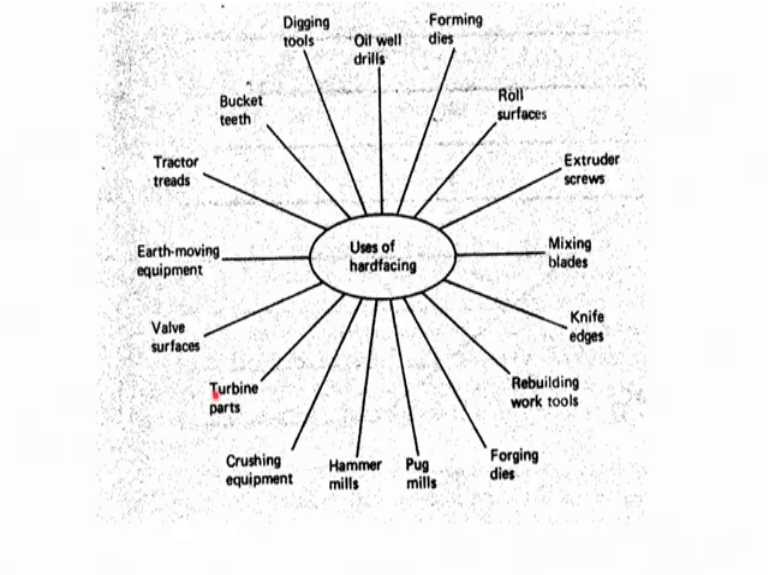


So, welcome to part III of Thermal Spray Deposition technique, where we will specifically say about the different applications of this particular technique. So, as we mentioned that there are a wide varieties of techniques available under thermal spray deposition and depending on the materials which you are going to choose, you can do different kinds of coating by application of different kind of technique actually.

So, that coating materials may be polymeric, may be metallic, may be ceramic, may be cermets, may be metal matrix composites. So, any materials can be used for coating purpose and may be for corrosion resistance application may be for high temperature oxidation resistance application may be for wear resistance applications.

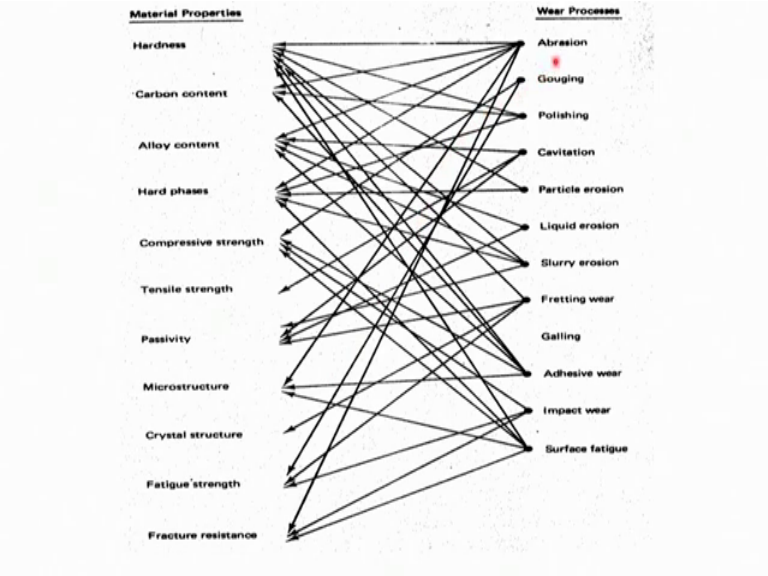
So, these particular technique can also be applied for hard facing purpose, where basic purpose is to improve the abrasive wear resistance to a large extent for different components and you call it as hardfacing. For example, hardfacing may be applied for deposition on for the development of coating on turbine parts crushing equipments, hammer mills, pug mills, forging dies, rebuilding work, tools, knife edges the mixing

blades extruder screws roll surfaces forming dies. So, where everywhere if you see the application areas you will find that in all the application areas you need different types of wear resistance coating.

For example if you see turbine parts here, you will find that the main coating is main application is the coating for erosion resistance application. Crushing equipment you will find that gouging wear is the main problem, hammer mills you will find that impact wear is your major trouble. Pug mills again you will find that impact wear is of major trouble, forging dies again you will find that that is typical impact wear, the rebuilding work tools again it is a kind of typical gouging wear and knife edges again you will find that high stress abrasive wear is there.

Mixing blades again you will find that main wear is basically typical polishing wear, extruder screws there is again typical gouging wear roll surfaces again gouging wear then forming dies impact wear. So, oil well drills there is erosive wear, digging tools again you will find that when wear is the adhesive wear and also adhesive wear.

So, bucket teeth also different types of wears are existing particularly sometimes fatigue wear is also there, tractor treads again you will find that they are high stress wear is there abrasive wear is there, earth moving equipment again low stress abrasive wear. Valve surfaces again you will find that adhesive wear is there. So, like that different types of wears are there in practice where this hard faced materials are used. And these all materials can be deposited by typicals with thermal spray deposition technique.



So, now if you quickly go through the different material properties which are required for different wear application you will find that, for abrasive wear application it is very important that the material should have the harder as well as should have a good fracture toughness, fatigue strength should also be quite high. So, where micro structure and composition plays very important role and even different types of wear if you see in different types of wear different properties play role.

For example if it is gouging wear you will find that their compressive strength as well as their fracture resistance is very important; polishing wear it is the hardness and that typical microstructure which is important. Then cavitation wear again toughness alloy composition as microstructure and corrosion resistance property is important, innosive wear you will find that hardness and kind of phases which are there in the material is important.

Fretting wear you will find that toughness and hardness important, galling wear again hardness is very important, adhesive wear composition as well as hardness is important like that in different wears different material properties are important and this is this acts as a kind of guideline to choose the material for coating application.

So, whenever you are interested to tailor any kind of wear property or wear resistance, you have to take these all factors into consideration to choose proper material and so, that it gives you the proper properties onto the surface.

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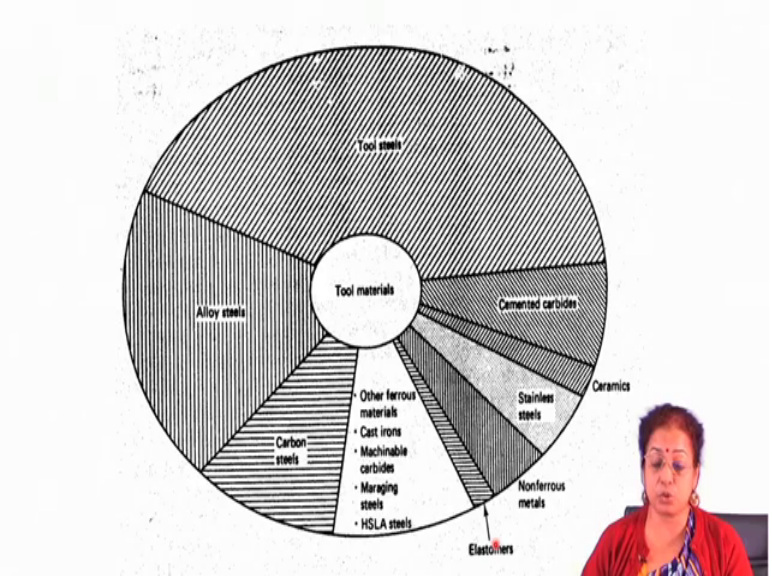

And depending on the material you choose naturally you have to choose the proper technique which you were applying for the spraying purpose. Like tool materials if you see there are different tool materials available, tool steels, alloy steels, carbon steels, then stainless steel cemented carbides is different tools are available.

So, different tools that are mixed are available non ferrous materials are available, elastomers are available. So, different materials can be quoted for tool purpose tool making purposes and here basically this is very important because again depending on the application you have to choose the proper material and then proper coating technique.

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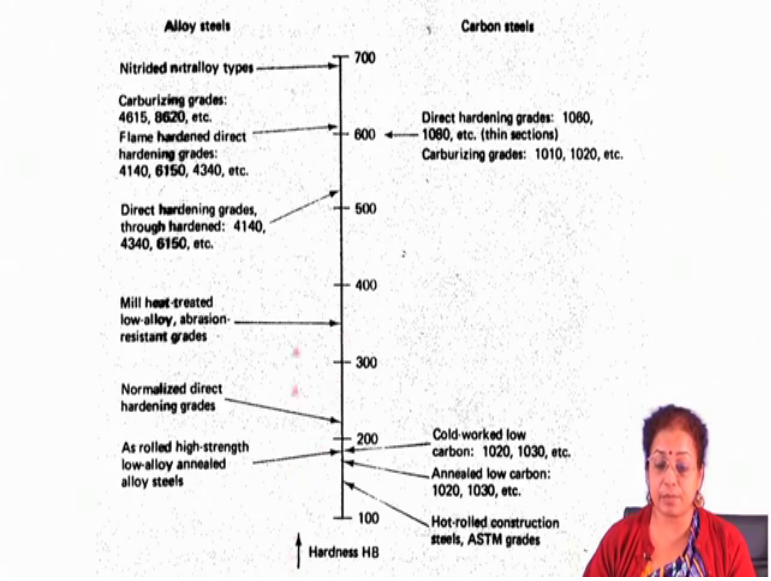

Then as I mentioned you hardness is an important parameter. So, you will find that large numbers of materials are available which are having lot difference in hardness like starting from typical normal steel cold worked low, carbon steel to like nitralloy or carburized grades steel. So, you can go from 100 to around 700 is be show different hardness values are there for different materials. Again for material selection for a particular application you choose the material based on your required hardness for the required application.

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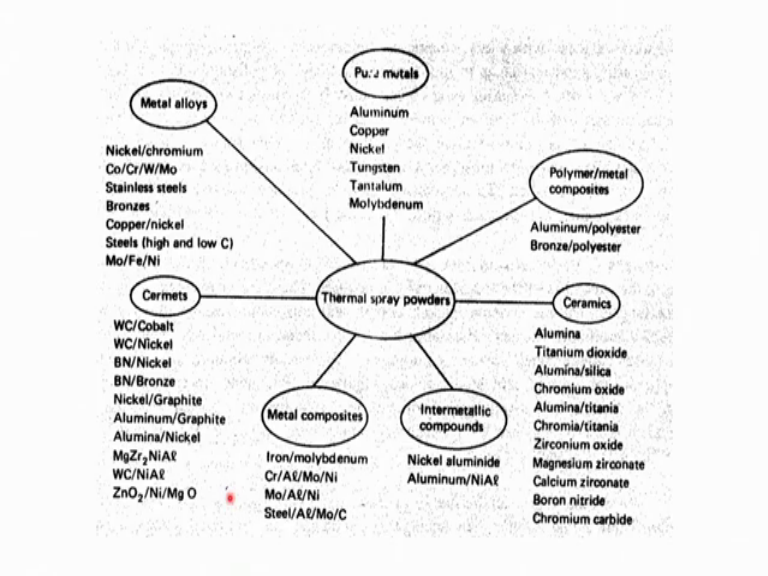

So, whenever you talk about the wear resistance, you can choose the proper material with the desired hardness. Now if you see that different types of materials again, it may be pure metal with different hardness. So, if it is for example, if you are interested to develop a coating which should have very good antifriction property, then you go tin coating as tin coating and pure metal tin you use for coating material.

If you are interested to develop a coating or high temperature oxidation resistance application use aluminium as coating, you can use tungsten or nickel as coating where you require both corrosion resistance as well as erosion resistance. Tantalum may be used as coating material and molybdenum also may be used as coating material.

So, different pure metals are available in nature alloys are available like nickel bases alloy, chromium, stainless steel, bronzes, steels and iron, nickel, molybdenum, nickel alloys. There are different types of cremets available which are basically ceramic based and this particular cermets offered very good hardness as well as it is having little higher toughness than that of ceramic materials.

Metal composition composites are available, intermetallic compounds are available which offer high strength as well as high temperature oxidation resistance and ceramics are available different types of ceramics which offer very high hardness and for some of the wear application where you do not need much toughness for erosion resistance purpose for corrosion resistance purpose you can use ceramic coating. And polymers are

also available which are mostly applied for anti friction property enhancement and also sometimes also for improving the study erosion property enhancement we just use polymeric composite coating.

So, these are different materials available in practice which may be thermal spray deposited because there is no bar as I mentioned you thermal spray deposition is a very much versatile technique. So, you can use any material as the precursor for thermal spray deposition process.

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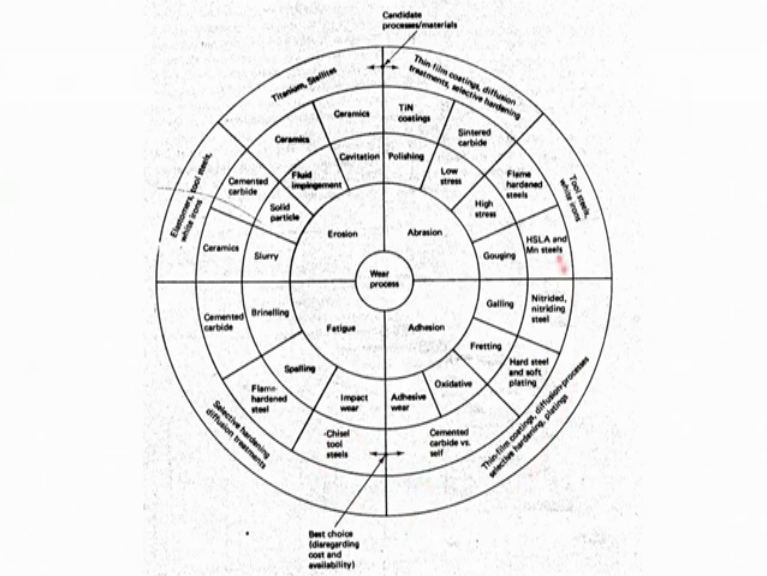

And this is the applications of these particular areas application areas of the coating where you need to have very good wear resistance for wear resistance for example, it is in and different material. So, this is a chart actually which is very important and acts as a guideline for choice of proper material for different purposes actually and accordingly you can have the different coating techniques for these particular applications.

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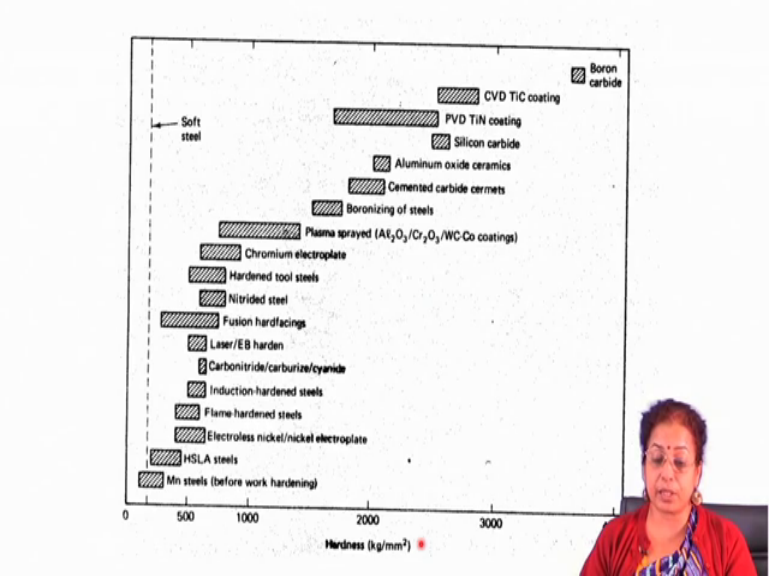

Again this is for a typical hard hardness chart which is available which are all documented.

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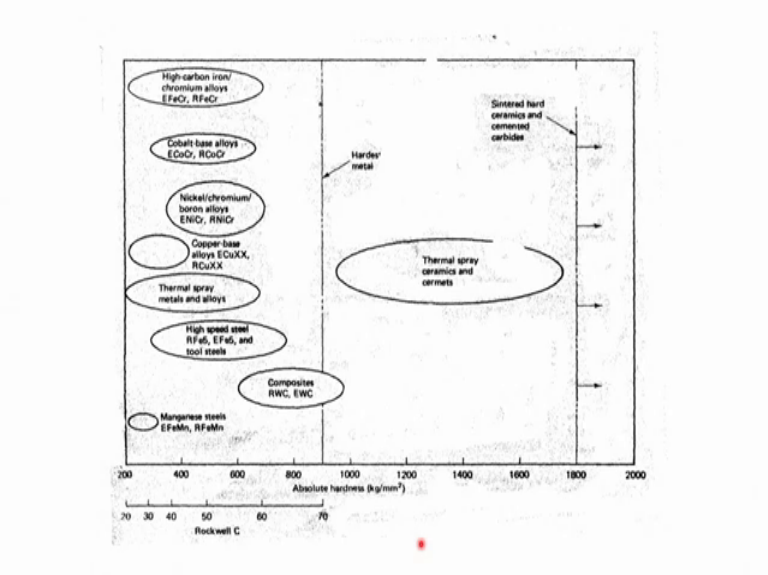

So, these all are documented things so, these acts as a kind of guidelines for the proper choice of material for specific applications so, but what is important here is that when you choose the material for specific application, naturally you have to choose the proper technique which is again equally important. So, if it is metallic system you have to go for that frame spraying deposition technique or if it is for example, metal matrix composite

you have to go for plasma spray deposition technique, if it is ceramic or cermets you have to go for the plasma strain deposition technique, if it is for example, nano structured material or bulk metallic glass you have to go for kinetic strain technique.

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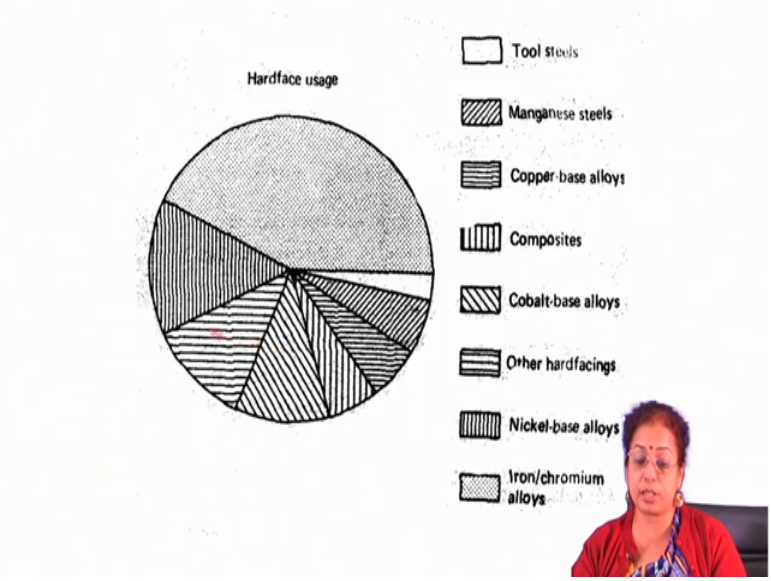

So, depending on the kind of material which you are going to use for strain you have to choose proper techniques. So, this is typical hardface alloys the applications. So, you will find that maximum alloys which reduced as hardface there iron and chromium based alloys and apart from that there are manganese steel is very much applied for that tool application, then copper based alloys can be applied quite nicely composites can be applied nickel based and other materials.

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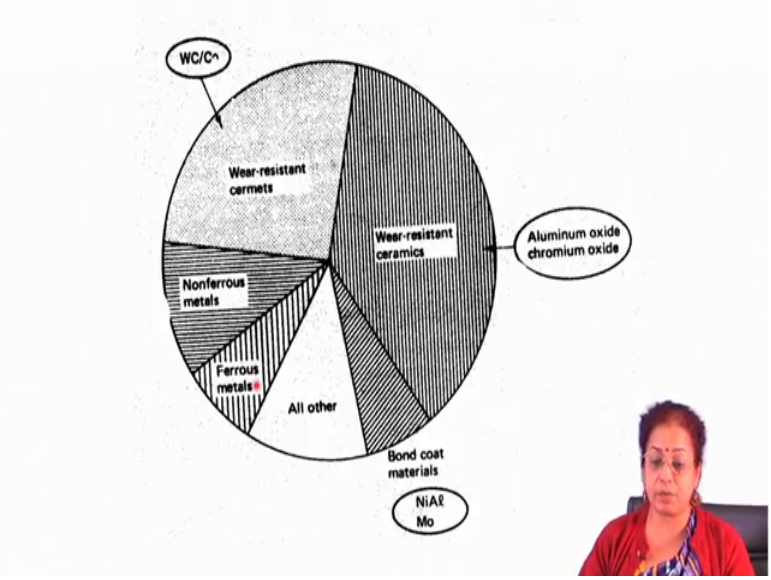

Is a nothing, but the bar chart depending on the statistical value or statistical applicable statistical analysis of application of different materials.

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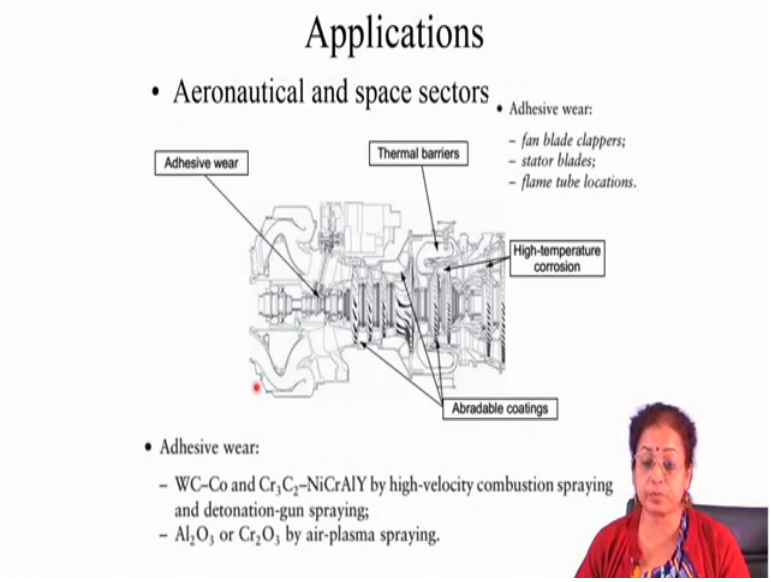

So, now if you particularly go through the application in different sectors, you will find that in aeronautical or space sectors there are major applications of thermal spray deposition technique. They may be applied for adhesive wear applications improval adhesive wear enhance property enhancement, then maybe for thermal barrier property

enhancement, they may be for abrasion wear resistance application or high-temperature corrosion application.

So, we will find that different parts can require or can demand different properties. So, depending on the properties which you are looking for a particular purpose you have to choose the materials for coating. For example, if you are interested to develop a coating for improved adhesive wear resistance, then there you should have higher hardness and you should also have very low coefficient of friction in addition to that you should have the top coating.

So, for adhesive wear resistance application you can apply tungsten carbide cobalt their cermets, you can use chromium carbide and nicraly composite, you can apply the alumina or chromium oxide and the techniques are usually plasma spraying technique specially when it is ceramic materials, but when it is cermets you can use high-velocity oxyfuel technique or maybe detonation gun spraying technique.

So, for adhesive wear purpose you have to have a very tough and hard coating on the surface. Whenever it is for example, abrasive wear that are typical application or components which are subjected to adhesive were their fan blade, clappers, state stator blades and flame tube locations.

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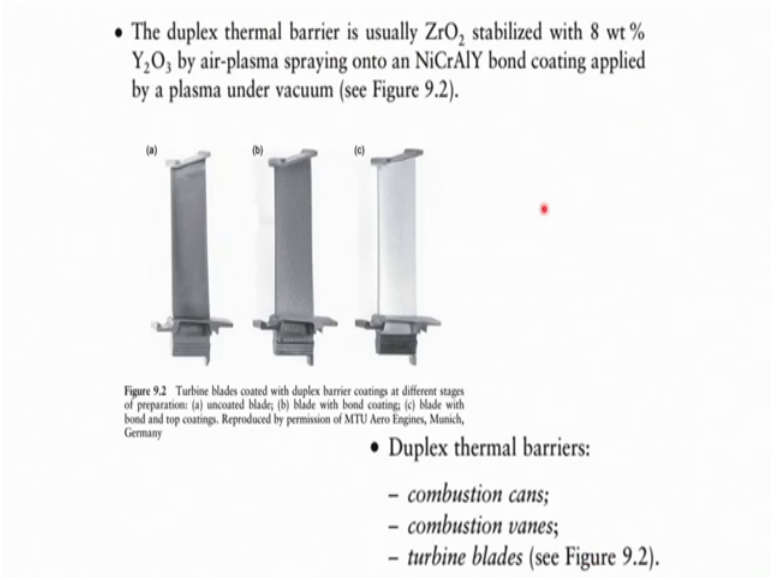

So, whenever you talk about the adhesive abrasive wear.

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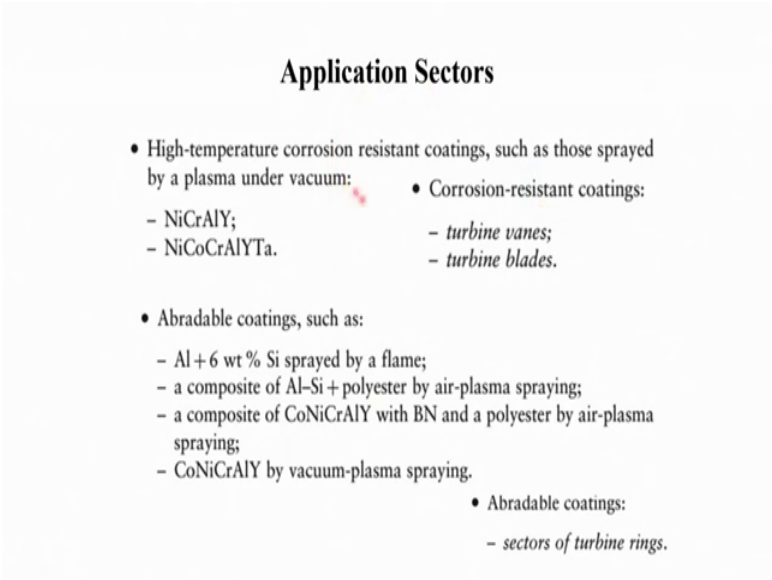

Usually for abrasive wear you basically apply aluminum silicon spray which is sprayed by flame spraying operation there alumina silicon plus polyester by air plasma spraying operation composite of CoNiCrAlY and boron nitride by air plasma spraying again CoNiCrAlY vacuum plasma spray plasma spraying. So, this is applied again in turbine ring.

So, when you talk about high temperature corrosion resistance, then you have to look for the materials which offers high temperature corrosion distance for example, NiCrAlY should NiCrAlY etium titanium then these all things are applied on turbine vanes, turbine blades those particular components there are sub j which are subjected to high temperature corrosion there you have to look for the corrosion resistance coating.

Now thermal barrier coating is another phase of application of this particular thermal spray deposition technique particularly for the thermal barrier coating, you have to apply the plasma spray air plasma spray deposition unit. Because thermal barrier coatings are basically oxide based ceramic coating mostly they are (Refer Time: 14:16) or zirconia. And they are not directly applied onto the surface of the substrate because if they applied directly onto the surface of the substrate there will be chance of solution.

So, usually they are applied on the bond coat prior to application of this particular thermal barrier coating, you have to apply a very thin bond coating which is CoNiCrAlY as bond coating because CoNiCrAlY is having the coefficient of thermal expansion between metal and that of ceramics. So, it basically reduces the stress at the interface to a large level and it also offers very good high temperature oxidation resistance property.

So, usually these particular the component parts which are subjected to this particular thermal barrier coating their turbine blades, their combustion cans, combustion vanes and these are the component which are basically subjected to this particular thermal barrier coating. So, this is duplex because CoNiCrAlY coating is applied on top of the bare parts after sandblasting and then they are subjected to typical thermal barrier coating.

So, it is important that you prepared the parts very nicely prior to that prior to plasma spraying or thermal spraying operation. Then if you talk about the ship building and naval sectors there are a lot of problems of erosion, corrosions and cavitation erosion. So, there is a lot of applications of the thermal spray deposition technique.

Particularly in c profiler your c file you will find that this particular c file is subjected to marine particularly whenever it is in marine environment, you will find that there will be problem of corrosion particularly pitting corrosion there is also the problem of carbonations erosion corrosion, there will be also the problem of the microbial corrosion.

So, these c files are basically cladded with the or sometimes they are sprayed with the copper nickel alloy so, that they are the antibacterial property is increased antibacterial corrosion resistance is increased and they are also coated with cermets and also metal matrix composite by zero strain. So, that you get very good wear resistant surface and also you can add chromium in addition to that so, that you get very good corrosion resistance property in the aqueous environment.

Similarly, is there steam valve stems, there are non-skid helicopter flight deck and then marine gas turbine engines these all are the areas where these are the components where there is lot of applications of the thermal spray deposition techniques. So, in general we can say that this particular technique is lot of techniques are there and it can be applied for metallic coating, ceramic coating or metal matrix composite coating, but proper choice of material is very important so, that you get proper properties on the surface.

And if you are interested to develop the coating for typical aqueous corrosion resistance application, you have to look for you can look for either barrier coating like you can deposit typical polyester coating onto the surface of the any material which is subjected to very low temperature so, that you get you do not it does not really corrode in normal environment or otherwise you can also go for sacrificial coating like zinc coating.

So, usually if you talk about zinc coating aluminum coating these coatings are done by wire strain technique or arcs strain technique because, in both the techniques you end up with a very good structure and their efficiency is quite high. Because if you talk about wire arc spraying then you will find that its efficiency is quite high, because there is no loss at all if you have optimize the parameters in contrast to that of powder frames spray process where a lot of powder is lost in the air because of the low efficiency of the process and also because powders can fly away when you do spraying.

So, for low melting material deposition for corrosion resistance purpose, you do flame spraying or maybe you do that arc spraying operation. Whenever you are interested to develop the typical barrier coating you can go for tin coating for example, again this is low melting temperature coating there you can go for flame spraying operation for coating purpose.

So, another type of coating which may be applied for corrosion resistance where application is for example, if you have a very cheap mild steel substrate or mild steel

based on top of which you are interested to have very good corrosion resistance in the marine environment particularly, you can go for the say AISI refers to a or 316 stainless steel coating, you take the stainless steel powder and then deposit it by flame spraying process. And but one of the biggest limitation of these particularly spraying based technique is that in this spraying base technique you end up with lot of porosities on the surface.

Though those are not interconnected, but again surface porosity can lead to accumulation of the aqueous media on the surface. So, if are interested to get rid of this particular problem you have to go for either sealing operation. So, wax sealing you can do or otherwise you can also go for surface melting operation. It has been observed that if you just want develop the plasma spray of processing and coating by plasma spray processing and subsequently you do built it using high-power laser beam you end up with a structure which is a pro free and as well as which is very nice and having improved corrosion resistance property on the surface.

For example it is observed that AISI 304 when it is subjected to thermal spray deposition of molybdenum, you will get deterioration in the pitting corrosion resistance property, but when the same coating is melted using the laser beam you get very high pitting corrosion resistance of this particular coating. So, you can always go on combining the two or three techniques to get the best result in terms of the desired properties on the surface.

It has also been observed that nickel chromium silicon boron nickro (Refer Time: 21:24) coating is very much interesting coating which is self fluxing alloy and which can be applied for wear resistance application as well as can be applied for hot corrosion resistance application when it is deposited by (Refer Time: 21:36) spraying technique though it is completely dense having 98 to 99 percent density and offers very good corrosion resistance. And also wear resistance when it is subjected to laser melting you will find that there is microstructure definment homogenization and formation of nano boride dispersed phase onto the surface of the substrate.

And when it is done naturally you end up with a very good wear resistance even superior corrosion resistance property on the surface of the coating. So, hybrid coating technology

and its application is the gradual swift of this particular technique, where you are basically a two or three different techniques to get the best result onto the component.

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So, after this all things I would like to say some of a examples of the application of this coating on two different sectors.

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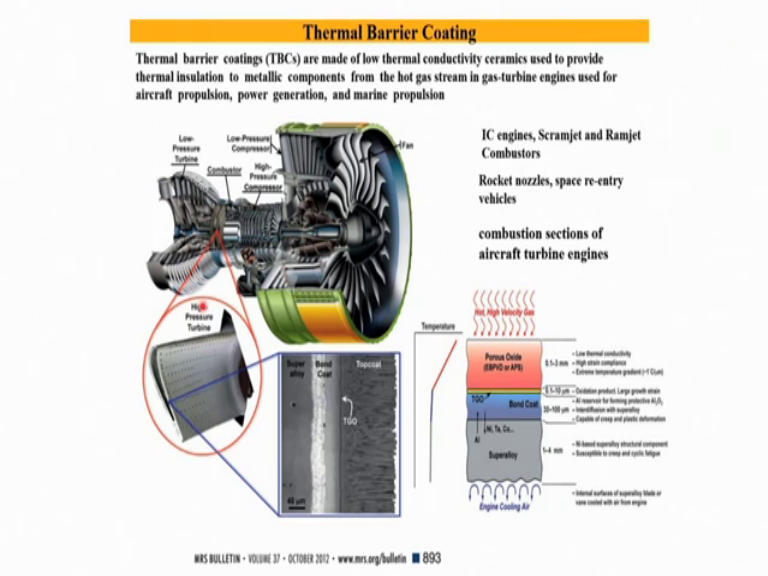

One is that high temperature oxidation resistance purpose that is thermal barrier coating, another one is for biological property enhancement purpose bio implant in bio implant for applications the application of thermal spray deposition.

So, as I mentioned you thermal barrier coating is a kind of oxide based coating which when applied onto the surface of the substrate, it offers the high temperature oxidation resistance property significantly, but thermal barrier coating itself does not offer oxidation resistance property, but it acts as a kind of insulating barrier for insulating barrier onto the surface of the substrate. So, actual temperature experienced by the substrate is reduced to a great level.

So, for example, where the application of (Refer Time: 23:29) thermal barrier coating, the temperature infrared temperature experienced by these particular nickel based or iron based super alloy can be reduced by 50 to 100 degree Celsius. So, this reduction is say in temperature is very much helpful because of the reduction in temperature naturally you will find that the overall oxidation or overall the service life of the component increases to a large extent.

So, usually you find that this thermal barrier coating is there ceramic in nature. So, they are basically applied by plasma spray deposition technique. So, but it consist of three different components; one is bond coat, another one is that top coat and third one is the thermally grown oxide layer. So, when you talk about the this particular thermal barrier coating usually it is applied onto the surface of the substrate and prior to application of the coating you have to apply a very thin bound coat.

So, thin means thickness is around 40 to 50 micron. So, these bond coat usually is having different can have different composition. Whenever you talk about the aerospace applications high temperature oxidation resistance applications where the there is no humidity there it is cobalt CoNiCrAlY based coatings. On the other hand if it is having high level of humidity then your chromium content in the coating increases to a large extent. So, depending on the kind of coating you are applying kind of applications the coating is your bond coat composition also varies.

But basic purpose of the bond coat is to have a kind of to increase the adherence of the topcoat by reducing the coefficient of thermal expansion or in between so, that the less stress is generated at the interface between the coating and substrate. Because you usually bound coat is having the coefficient of thermal expansion between top coat and that of a substrate and another purpose of applying bound coat is that, when you apply

bond coat the bond coat offers the oxidation resistance or corrosion resistance property of the substrate.

Because as I mentioned you top coat is not really the coating for oxidation resistance purpose but it is the coating for acting as a kind of insulating barrier. But bond coat is the coating which basically offers a high temperature oxidation resistance or aqueous corrosion resistance of the substrate.

So, usually whenever you have the bond coat and top coat you will find that gradually when you expose the whole combination into environment, you will find that the bond coat get oxidized and because of the transportation of the oxygen through the top coat; top coat is usually porous in nature porosities are desired in the top coat because the whole combinations are usually subjected to thermal cyclic stress.

So, whenever it is subjected to thermal cyclic stress lot of stress is arrested in the coating. So, you should have lot of defects in the coating so, that the stress is accommodated in the defected side. So, but defects are also not good because of presence of defects there is chance of oxygen engrace, to that oxygen usually reacts with the bond coat surface and then forms thermally grown oxide layer.

So, thermally grown oxide layer is also part of the whole system. So, whenever you just expose the system to air or maybe the aqueous media we will find that depending on the media whatever it may be there will be oxide layer formation and that is got thermally grown oxide layer.

And thermally grown oxide layer basically protects the surface again further from oxidation, but it also is not really constant thickness it increases with the time. As you go on increasing the time thermally grown oxide layer thickness grows and it increases its thickness and you will find that when the thermally grown oxide layer reaches a thickness of 5 to 6 micron there will be the damage of the coating the coating fails actually.

So, controlling the thickness or kinetics of the thermally grow grown oxide layer is a major tricks in enhancing the life time of the component. So, for that it is important that you design the top coating composition, you choose proper material for the top coating and also proper coating technique. So, this is the thermal barrier coating where there is

lot of applications of the plasma spray position technique as well as (Refer Time: 28:32) deposition (Refer Time: 28:34) strain deposition technique, usually top coat is applied by plasma strain technique, but the bond coat is applied by (Refer Time: 28:41) strain technique. So, that there is no not much porosity or flaws in the bond coat, but in top coat there has to be some flaws or some porosity so, that the stress relaxation is possible in the top coat.

Top coat can also be developed by electron wear physical vapour deposition technique, but plasma spraying is also a kind of technique where which can be applied for development of the top coat. So, this particular thermal barrier coating is usually applied in IC engine, Scramjets and Ramjet combustor, then rocket nozzles space re entry vehicles, combustion sections of the aircraft turbine engines these all sectors.

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References

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So, now that is all and thank you very much in the next slide I will discuss about the details about and also the future direction of research on the development of the thermal barrier coating.