

AN OVERVIEW OF HARDFACED COATINGS FOR INDUSTRIAL USE

by

Edward R. Buchanan

President

Holtgren, Incorporated

Kenilworth, New Jersey



Edward R. Buchanan is President of Holtgren, Incorporated, of Kenilworth, New Jersey, following his purchase of the company in April, 1985. Prior to this, he was Vice President of the Chromalloy Research and Technology Industrial Products Department, of Orangeburg, New York.

Dr. Buchanan received his B.S. degree from Lehigh University in 1960 and his Ph.D. degree in 1968, from the University of Florida. Both degrees are in Metallurgical Engineering. Dr. Buchanan was an Assistant Professor at Lehigh University from 1968-1970, when he joined the General Electric Corporate Research and Development Center. In 1973, he became head of the Coatings Program for the G.E. Gas Turbine Division.

Dr. Buchanan has published a number of papers and holds eleven patents. He is a member of ASM and ASME.

ABSTRACT

The wear of critical pump components costs the industry millions of dollars annually. This loss can be mitigated by the use of hardfacing to minimize wear. The correct selection of a hardface coating requires an understanding of the different techniques and compositions available to a user.

An overview is presented of available hardface techniques, including interstitial diffusion coatings, metallizing, Stellite, plasma-transfer-arc, plasma spray, the spray and fuse braze coatings, and the detonation gun. Several recent developments including a vacuum plasma spray, graded coatings, laser coatings, and ion implantation, will be discussed.

INTRODUCTION

Hardface coatings are any hard coating applied to the surface of a component for the purpose of increasing its resistance to wear or erosion. Hardface coatings are therefore used extensively in the pump industry. The purpose herein is not to describe the different types of pump design and the components contained therein, which are coated to minimize wear or erosion. Suffice it to say that most major manufacturers of one type of pump or another routinely coat wear rings, shaft sleeves, bushings, impellers, repellers, pistons, shafts, plungers, and valves for enhanced wear or erosion protection. In some instances, coatings are applied to obtain a specific set of properties not otherwise obtainable. For example, some pump components used in the mining industry require both a high degree of abrasion resistance and impact resistance. This can be achieved by applying a wear resistant hardface coating to an impact resistant substrate alloy. In other instances, coatings are used to enable a designer to use a less-expensive material for a given application. In one instance, a manufacturer used a sleeve design composed of a nickel-chromium-tungsten carbide hardface on an AISI 1018 steel

substrate. This design replaced an earlier design which was an uncoated, expensive high-alloy material. This change is said to result in savings of tens of thousands of dollars annually to the manufacturer.

Hardfaced coatings fall into one of two categories, diffusion coatings and overlay coatings. Most hardfaced coatings are overlays, and these will be the subject of greater interest here. The different types of hardfaced coatings are categorized in Table 1.

Table 1. Coatings for the Hardface Industry.

Diffusion coatings

- Carbide coatings
- Nitride coatings
- Boride coatings
- Combinations (carbonitrides, etc.)

Overlay coatings

- Metallized coatings
- Stellite
 - oxy-acetylene gas welding
 - Heliarc welding
- Plasma-transfer-arc (PTA)
- Spray-and-fuse braze coatings
- Plasma spray
 - air plasma
 - vacuum plasma
- High velocity processes
 - the detonation gun
 - Jet Kote
 - Gator Gard
- Laser coatings
- Ion implantation

Diffusion Coatings

Diffusion coatings are those which form as the result of a chemical reaction between the base metal and some external vapor source. In this regard, a diffusion coating, unlike the overlay coatings to be discussed, becomes an intrinsic part of the base metal. A diffusion coating is thus adherent, and can be safely specified for environments in which a tensile load is anticipated across the coating-base metal interface. On the other hand, diffusion coatings are limited in thickness relative to overlay coatings, because the coating, as it forms, becomes a physical barrier which separates the base metal from the external vapor. The rate of formation of the coating thus decreases asymptotically with time.

Carburized, nitrided, and borided case hardened coatings all fall into the category of diffusion coatings. These coatings are those hardened by the interstitial elements carbon, nitrogen, or boron. These elements, all with small atomic radii, occupy spaces

between individual atom sites in a parent lattice, hence the term "interstitial." The effect of such placement within the lattice is to distort or strengthen the crystal lattice more than a "substitutional" replacement, as might occur with an atom of larger atomic radius. Therefore, carbon, nitrogen, and boron have a significant hardening and strengthening effect on most parent base metals, rendering them more resistant to erosion and wear than they would otherwise be. In addition, interstitial diffusion coatings are inexpensive to apply and reliable.

Interstitial diffusion coatings are usually only applied to low alloy or plain carbon steels. Carbon, nitrogen, and boron are all chemically reactive, and, as such, chemically react with many alloying additions. For example, stainless steel will result in the massive precipitation of chromium carbide, removing the chromium from solid solution and markedly reducing the corrosion resistance of the base alloy. Nitrogen and boron have a similar effect. While there are occasional instances where high alloy materials are surface hardened by an interstitial diffusion process, these instances are not common. In addition, a potential user should be cautious about specifying the use of interstitial diffusion coatings at elevated temperatures. The thermal mobility of interstitial atoms within a parent lattice is so high that thermal diffusion will reduce the surface hardness in relatively short periods of time.

Interstitial diffusion coatings do not see much usage in the pump industry, in part because the diffusion mechanism by which they are formed prevents them from being developed to the thickness required to be effective in a wear or abrasive environment. However, because overlay coatings are applied by a line-or-sight process, there are instances where components with re-entrant angles, such as impellers, can only be coated by a diffusion coating.

Another reason diffusion coatings do not see wide usage in the pump industry is because the heterogeneity of their structure precludes their being machined after the coating is applied. A sketch of the cross-section of a hard outer surface area is presented in Figure 1. It can be seen that the coating comprises several different phases, representing the individual intermetallic phases across the span of a multi-component phase diagram. In a diffusion coating, the phase at the surface is the one highest in the external substance being diffused, which for an interstitial coating would, of course, be carbon, nitrogen, or boron. This phase is usually the hardest and most wear resistant. The phase just under this is the second hardest and most wear-resistant, and so on. Thus, any machining operation following application of a diffusion coating, even if it is only a skim cut, can remove much of the hard outer surface layer.

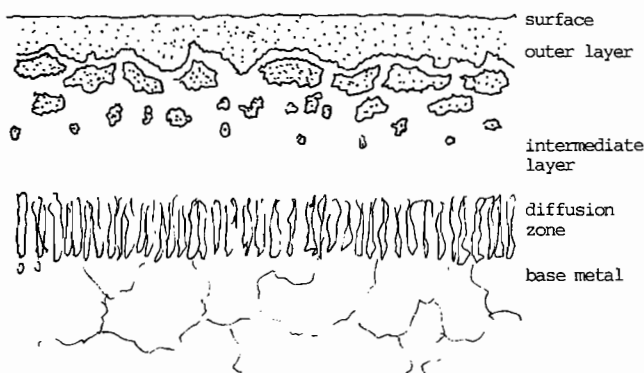


Figure 1. Cross-section of Typical Diffusion Coating, Showing Structural Gradations.

Overlay Coatings

Overlay coatings are those which are applied by some totally external source, such as vapor deposition, plasma or flame spray, cladding, electroplating, or any of a number of other such techniques. As a general rule, overlay coatings are thicker and less adherent than diffusion coatings. They also usually have a homogeneous composition which, unlike diffusion coatings, can be tailored to some specific set of properties (the composition of a diffusion coating is the end product of a diffusion reaction, and is not always the most wear-resistant composition which could be devised).

Overlay hardfaced coatings can be applied by a number of techniques. Some of these are as described in the following paragraphs.

Metallizing

The first coating process used to enhance wear resistance was the metallizing process developed in Switzerland by Max Shoop in 1910. This process consists of injecting coating powder or wire at a controlled rate into the orifice of an oxy-acetylene torch. The flame temperature, on the order of 3,000°F to 4,000°F, softens the coating substance, which is then expelled out the gun orifice to impact the surface of the part to be coated. Metallized coatings can be built to ¼ in thick or more.

There are both advantages and disadvantages to metallizing. The process is fast, economical, and can be used to apply a wide variety of compositions. Another important advantage is that the base metal is only minimally heated (200°F to 400°F), and the temper or hardness of a hardened base alloy can be thus retained. This is an important consideration when attempting to re-build a heat treated component such as a worn shaft, and is a major reason that metallizing is still widely used as a repair process for industrial machinery, since metallized coatings can be machined and ground.

The two major disadvantages of metallizing are that a) the applied coatings are only 60 percent to 80 percent dense when sprayed, and b) the bond across the coating interface is not a metallurgical bond but a mechanically locked bond with bond strengths capable of sustaining only 1,000-2,000 psi across the interface.

The porosity contained in metallized coatings can be used to advantage in instances where lubrication is required. In this sense, metallized coatings act in a manner similar to self-lubricating bearings, retaining lubricant in the pores until drawn out by frictional heat. In instances where such porosity is not desirable, various sealers are often used to make the coating solid or impervious. However, in instances where such sealers are not acceptable and greater density is required, the user is urged to select an overlay coating process which has greater density.

The mechanical bond between the coating and the base metal is usually not of concern for compressive load applications such as shafts, housings, bearing races, etc. In instances where the load across the interface is tensile in nature, the user should proceed cautiously. Similarly, in instances where thermal fluctuations are anticipated, spalling can result. Some powder manufacturers have developed self-bonding exothermic coating materials which improve the nature of the interface bond.

Even in site of the improvements in metallizing spray techniques which have been developed over the past few decades, metallizing of industrial machinery components is used primarily as a repair procedure rather than as one used to hardface original equipment manufacturer (OEM) components. Designers usually select a coating process with better bond strength and density when specifying a technique to hardface such components. There are, however, exceptions. One major pump manufacturer specifies manufacture of an investment cast AISI 304 pump sleeve which is then hardfaced by the application of a metallized

AISI 410 hardface. It should be apparent that the major advantage of such a design is economic.

Stelliting

Stelliting refers to a class of cobalt-chromium-tungsten carbide alloys, invented by Elwood Haynes in 1914. It is important to recognize the distinction that metallizing refers to a technique of application, while Stelliting refers to a class of alloy. It is possible to apply Stellite coatings by plasma spray, cladding, metallizing, or any of a number of techniques, but it has been applied by welding for so long that most people think of Stelliting as a welding process because of the wider usage of this process.

Stellites are extremely hard, strong, and both erosion and corrosion resistant. When applied by welding, they are extremely adherent. The disadvantages of Stellites are that they are expensive and somewhat lacking in ductility and impact strength.

Two welding processes are used to apply Stellites; heliarc welding and oxy-acetylene gas welding. The effect on the hardfaced surface of welding by the two techniques is markedly different. Heliarc welding is a true welding process in which the base metal is melted and inter-mixing between the weld metal and base metal is achieved. Oxy-acetylene gas welding is not a true welding process, but more akin to a braze, in that there is very little melting of the base metal.

As might be expected, heliarc welding achieves a metallurgical bond with the base metal. Dilution of the hard solid solution elements into the base metal is a potential problem, particularly when welding is done by hand. "Soft spots" in the hardfaced surface, representing areas where dilution is excessive, can occur. The hardness loss in such cases can be deleterious to wear and erosion resistance.

A second possible negative aspect of heliarc-welded Stellite surfaces are those characteristic of many welded structure—entrapped slag, blowholes, thermal shock, residual stress, cracking, and the myriad problems associated with dealing with a molten material having a melting point in excess of 2500°F. However, these difficulties are not insurmountable and can be dealt with if attacked in a systematic and logical manner.

Oxy-acetylene gas welding is, as previously mentioned, a braze process rather than a weld process in that the base metal is not truly melted. The bond between the base metal and the Stellite is, however, a metallurgical bond. Dilution is minimal, and thermal shock is lessened.

The major disadvantage of oxy-acetylene welding Stellite alloys is the introduction of carbon into the melt. This can result in the precipitation of chromium from solid solution in the form of chromium carbide. Gas welding is also a difficult and "dirty" process due to the presence of soot and the lack of fluidity of the weld metal.

Stellites are also applied by most of the other techniques which will be discussed in subsequent sections, and, in fact, the percentage of hardfaced Stellite surfaces applied by heliarc or gas welding relative to these other techniques is decreasing as improvements are made in these less-mature techniques. The advantages and disadvantages of Stellites when applied by these other techniques become, for the most part, the advantages and disadvantages of the techniques used to apply them. These will be discussed in detail in subsequent sections.

Plasma-Transfer-Arc (PTA)

The plasma-transfer-arc (PTA) process, not to be confused with plasma spray, is a welding process which has been successfully used to hardface numerous components. The PTA process consists of an electrode contained within a water-cooled copper orifice, as shown in Figure 2. An inert gas such as argon is bled through the orifice such that when an arc is struck between the electrode and the base metal, the gas is ionized and becomes

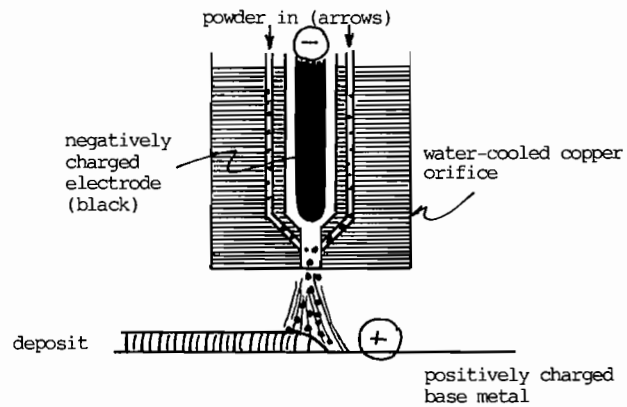


Figure 2. Cross-section of Plasma-transfer-arc Hardfacing System. Base metal is positively charged with respect to electrode.

conductive. The hardfaced powder is metered into the orifice space, becomes molten, and is expelled onto the molten base metal surface, forming a fused hardfaced coating.

There are many advantages to the PTA process. It is clean, forms a dense coating which is metallurgically bonded to the basemetal, has a high deposition rate, is relatively energy efficient, and can be used to apply most electrically conductive powder compositions. There is also less dilution than with heliarc welding.

The disadvantages of the process are that very high thermal gradients and cooling rates are introduced, and both the base metal and coating must have enough ductility to withstand the stresses which are introduced by rapid heating and cooling. The PTA process is also difficult to control unless automated, and cannot be considered a hand process. As such, it is usually not economical for small number of parts. It is also difficult to adapt the PTA process to complex shapes or geometries.

Spray and Fuse Coatings (Braze Coatings)

The most widely used coatings in the pump industry are the spray and fuse braze coatings. Spray and fuse braze coatings are two-phase eutectic alloys which are sprayed onto a surface and then "fused" by the application of heat to densify them and bond them to the base metal. The fusing operation is in reality a controlled melting in which the rate of liquation is determined by the rate at which the two coating phases alloy with each other. The objective is to fuse the two phases together to a point just short of complete melting of the coating. This achieves a 100 percent dense coating which is metallurgically bonded to the base metal. These coatings have achieved wide usage throughout the pump and valve industry because they have good corrosion resistance as well as good wear resistance. They are also less expensive to apply than other types of coating which are sometimes specified.

The first spray and fuse coating was developed by two engineers named Cole and Edmonds in 1936, who sold their patent rights to the Wall Colmonoy Corporation. The original patents have long since expired, and variations of the original alloys are now available through a large number of coating manufacturers.

Cole and Edmonds recognized that the melting points of nickel-chromium alloys could be lowered by as much as 300° to 400°F by the addition of boron. Furthermore, if boron were added to the base metal alloy in the form of chromium boride, the excess chromium boride intermetallic phase made the alloy very wear and erosion resistant, being exceptionally hard and wear resistant.

The primary advantage of the braze alloys is their low cost. The nickel and boron in the coatings is much less expensive than the cobalt and tungsten in Stellite coatings. The other advantages of these coatings are their metallurgical bond and minimal dilution with the base metal. They are homogeneous, 100 percent dense, and can be applied to virtually any desired thickness. The base metal is not heated to the melting point, as is the case with Stellite and the PTA process.

The disadvantages of the spray and fuse braze coatings are that they can only be applied to materials with melting points in excess of 2300° to 2400°F. This excludes aluminum, magnesium, copper, and all other low-melting materials, but not, of course, ferritic materials, on which they see most of their useage. A second disadvantage of coatings of this type is that they do not have the same engineering wear qualities as the tungsten carbide-containing Stellite alloys, although their lower cost in some instances outweighs this disadvantage. The tensile strength of tungsten carbide is on the order of 80,000 psi, while that of chromium boride is about 30,000 psi. Coating development engineers have compensated for this lower strength by back adding tungsten carbide. At present, a wide range of nickel and cobalt-base spray and fuse alloys are available which contain up to about fifty percent by weight of tungsten carbide. These alloys in some instances actually out perform the tungsten carbide-containing Stellite alloys.

The metallurgy of the spray and fuse braze alloys is quite interesting. The coating is first deposited by one of the various spray techniques such as flame or plasma spray. In the as-deposited form, the coating is 80 percent to 90 percent dense and is joined to the base metal only by a mechanical bond. The coating is then formed into a dense, metallurgically sound and adherent entity by the fuse operation, which can be done either in a furnace or with a hand torch. Many people in the field feel that sound coatings can be more consistently achieved by torch fusing than furnace fusing. The heat-to-heat variation in melting point of different lots of coating powder causes variations in fusing from one heat of alloy to another. An underfused alloy will have less than 100 percent density and adherence, and an overfused alloy will melt and run off the part being coated. A skilled technician can observe the degree of liquation in the braze alloy coating and can stop the fuse at exactly 100 percent fusion.

The as-sprayed alloy, before fusion, will contain two primary phases, the nickel-chromium gamma phase and the intermetallic Cr_3B_2 phase. The melting points of these two phases are considerably higher than the melting point of the eutectic aggregate, which is typically 1900° to 1950°F. The two phases begin to alloy with each other during the fuse operation. The gamma phase begins to acquire boron through the process of interdiffusion, and the chromium boride phase begins to acquire nickel and chromium (the latter is unimportant with regard to the fuse operation). The melting point of the gamma matrix phase begins to decrease as alloying occurs, and the fuse technician can sense this by the glistening or "sweating" that occurs on the component surface, and can stop the fuse just before complete liquation. In this manner, a 100 percent dense coating is achieved, and, because interdiffusion is occurring between the gamma phase and the base metal at the same time the gamma phase is alloying with the chromium boride phase, a metallurgical bond is achieved.

Plasma Spray

Plasma spray coatings have come into wide useage since World War II, because they are cleaner, denser, and more well-bonded to the base metal than flame spray or metallized coatings. The major difference between flame spray and plasma spray is that the heat used to soften or melt the spray powder is generated in an electric arc rather than an oxy-acetylene flame.

Temperatures generated in an electric arc can reach 30,000°F, while those in an oxy-acetylene flame are on the order of 3,000°F to 4,000°F.

The term "plasma," as used both for the plasma spray process and the plasma-transfer-arc weld process, refers to a carrier gas which is so super-heated that it is stripped of its electrons and, hence, becomes electrically conductive. The plasma provides another major benefit besides its conductivity. An ionized plasma gas has heat transfer characteristics which are vastly superior to an un-ionized counterpart. When a coating powder particle is injected into a plasma stream and collides with a gas ion, the ion gives up energy to the powder particle. The amount of energy is determined in part by the energy given up by the electron in going from its excited level to its rest level. The recombinant energy of an electron which has been stripped from the atom nucleus is much higher than one which has been merely raised to some excited state.

The cross-section of a typical plasma spray gun is shown in Figure 3. It is quite similar to a plasma-transfer-arc system in appearance. The difference between a plasma spray system and a PTA system is that in the former, the electrical bias is contained entirely within the gun, as the tungsten cathode is negatively charged with respect to the water-cooled copper anode, while the bias in the PTA system is "transferred" from the electrode to the base metal. In this sense, plasma spray is "non-transfer-arc" in nature.

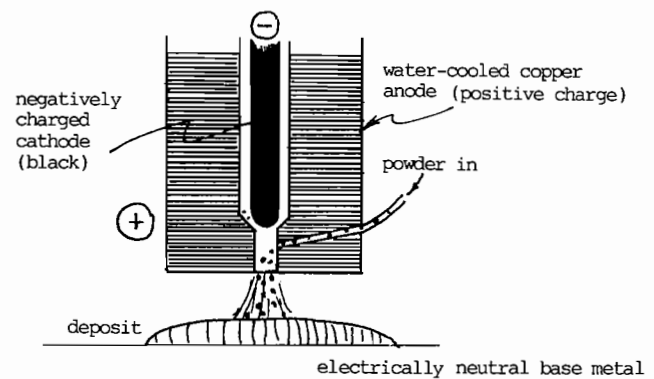


Figure 3. Cross-section of Plasma Spray System. Base metal is electrically neutral with respect to plasma gun (non-transfer arc).

Powder is injected into the gun orifice, or just in front of it, depending on the particular type of gun design. It becomes molten and is expelled from the gun in the direction of the base metal. Powder velocities on the order of 800 ft to 1,000 ft/sec per second are achieved, or about twice that of flame spray processes. The heat-softened powder impacts the base metal, building a denser and more adherent coating than is achieved by flame spray.

The advantages of plasma spray include a high rate of deposition, an absence of dilution, and the ability to spray uniformly thick, homogeneous coatings. The disadvantages of plasma spray are the relatively high cost of the process, the fact the bond is still mechanical in nature rather than metallurgical, and the high energy useage. Plasma coatings are typically applied using 40 kW to 80 kW.

Because plasma is so much hotter than flame spray, it is possible to spray a wide variety of materials, including ceramics. These high-melting point materials are only minimally softened by heat in an oxy-acetylene flame, and deposition efficiencies are often too low to be commercially viable, because the ceramic tends to bounce off the base surface. In addition, because ceramic powders are only marginally softened in an oxy-

acetylene flame, the coating densities achieved are sometimes unsatisfactory.

Ceramics in many regards are the ultimate coating material. Many ceramics have hardnesses which approach those of diamond. In addition, they have outstanding oxidation and chemical resistance. Chromium oxide, titanium oxide, and aluminum oxide are all routinely sprayed using plasma spray.

The major disadvantage associated with the use of ceramic materials is the poor adherence. Diffusion coefficients for ceramic materials are low, so even on a microscopic scale, little diffusion occurs across the interface. The bond is totally mechanical in nature. In addition, ceramics have little capability for plastic deformation or strain accommodation. They cannot fully deform to the shape of the base metal at the interface, and internal stresses in thick ceramic coatings are a problem.

Thin (up to 0.008 in) ceramic coatings are usually sprayed directly onto the base metal without an intermediate bond coat. Thicker coatings are usually applied with a self-fusing bond coat.

A recent innovation which improves ceramic adherence is the use of a graded coating. A photomicrograph of such a coating is presented in Figure 4. The bond coat is first deposited onto the base metal. By using two powder feeder hoppers, subsequent layers contain an ever-increasing percentage of ceramic, and an ever-decreasing percentage of metallic bond coat. The end result is an outer surface which is totally ceramic, and thereby impervious to wear, erosion, and chemical attack, without the limitation of poor adherence. Such a coating is also superior for useage where thermal fluctuations occur.

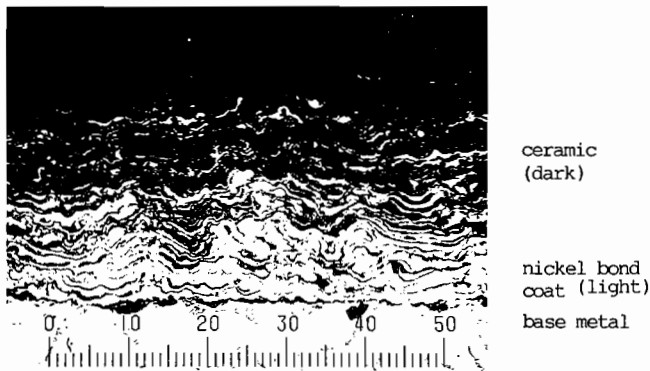


Figure 4. Photomicrograph Showing Graded Ceramic Coating Used to Enhance Bonding. 300x.

The Detonation ("D") Gun

The detonation or "D" gun process was developed by Union Carbide, and is available only through them. The "D" gun is not a plasma spray process, but provides very high quality, adherent coatings because of the high powder velocities achieved. In the "D" gun process, metal powder, oxygen, and acetylene are injected into the base of a 4 ft long gun barrel. The mixture is detonated by the spark from a spark plug, and the metal powder is expelled from the open end of the barrel at very high velocities. The powder impacts the base metal at high velocities which can be as high as Mach III, thus building up a dense and adherent coating. The "D" gun system has been used with good success to apply hardface coatings to millions of components. It is a further advantage that the substrate is kept below 300°F during the spray process, by spray of liquid nitrogen to the area surrounding the spray area. This permits inexpensive hardened steels to be coated without destroying the temper. It is also possible with the "D" gun process to coat low melting materials.

The major disadvantages of the "D" gun process are the high cost and the fact that combustion products are included in the coating.

Shrouded Spray Techniques

There have been a number of attempts in recent years to develop an inexpensive process having the superior density and adherence of the "D" gun process. One of these is the "Gator Gard" system developed by Pratt and Whitney. This system uses an annular envelope of an inert gas such as argon to shroud the powder spray and minimize oxidation. The system appears to minimize oxidation effectively, but because powder velocities are lower than "D" gun powder velocities, it cannot be expected to develop the same density and bond strength as a supersonic system. The patent rights to the "Gator Gard" system have been sold to Sermatech, and coatings are only available through them.

Cabot Corporation markets a spray process called "Jet Kote." This process utilizes what is effectively a small rocket engine. Metal powder is metered into the "exhaust" in the usual manner. The writer has no first-hand knowledge of this process, but has been told by individuals familiar with the process that the applied coatings are comparable in quality to those applied by the "D" gun. As with the "D" gun, the products of combustion are contained in the coating.

As of this writing, the supersonic "Jet Kote" process is too recent a development to be a major force in the hardface business. However, if the process provides "D" gun quality coatings without the necessity to ship parts to a proprietary service center, the process could be a significant market entry (unlike Union Carbide and Sermatech, Cabot has made the strategic decision to market the coating equipment rather than the coating services).

Vacuum Plasma Spray

Another recent spray development is the vacuum plasma spray (VPS) process, in which a plasma spray system is installed in a vacuum chamber. Powder velocities in a plasma system are related to the ratio of the gas pressure inside the gun to the gas pressure outside the gun. Very high gas velocities can be achieved by operating the plasma spray system in a near-vacuum (0.1 Torr) because the ratio of pressure inside the gun to outside is very high. Plasma velocities in a vacuum system achieve Mach III, or equivalent to those generated in the Union Carbide "D" gun process and the Cabot "Jet Kote" process. The major advantage the VPS has over the other two supersonic processes is the minimization of oxidation resulting from the use of the vacuum environment. The microstructure of the same coating material as sprayed both in air and in vacuum is compared in Figure 5. The difference between the two coatings is obvious. Such a system makes possible the spray application of oxidation-prone materials difficult to apply in an air environment.

Another aspect of the VPS system is the incorporation into the system of a transfer-arc booster. The plasma spray system, as has been described, is a non-transfer-arc mode of operation in that the plasma gun is electrically neutral with respect to the substrate. In the VPS system, however, a low-level (20 kW) transfer arc bias is applied in addition to the primary (80-120 kW) non-transfer-arc mode. During spray operation, the transfer-arc mode melts the surface to provide a thin skin of molten material to enhance bonding. In other words, the VPS system combines plasma spray and the plasma transfer-arc processes into one process.

A further unique feature of the VPS system is the capability to reverse the polarity of the transfer-arc before deposition begins. This generates a "sputtering" or "glow discharge" effect which atomistically cleans the base metal surface before powder deposition begins. This further enhances bonding.

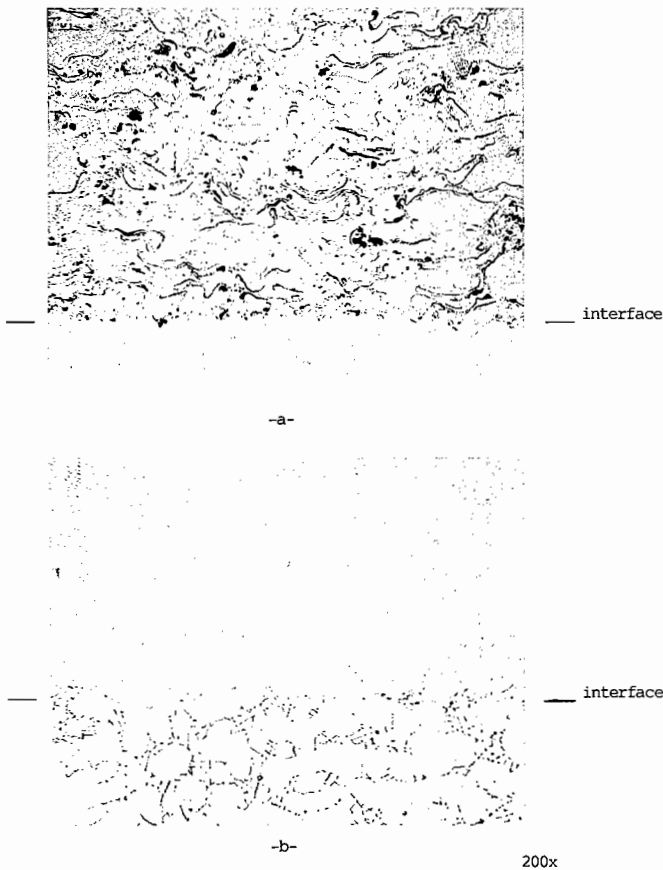


Figure 5. Photomicrograph Illustrating Microstructure of Plasma Coating Deposited on Nickel-base Superalloy a) in Air, and b) in Vacuum.

The major disadvantage of the vacuum plasma system is the high capital cost and high unit coating cost. As was once remarked, "if you can't hold it in your hand, and if it's not worth several hundred dollars, it's probably not economical to VPS coat it." To date, the only pump parts vacuum plasma system coated were some sleeves coated with tantalum for use in a hydrochloric acid environment.

Laser Coatings

Lasers offer engineers the capability to apply a source of heat to a surface with minimal disruption to the underlying base metal. In this sense, laser coatings offer the promise of much potential to the pump industry.

Laser coatings fall into two categories, one which hardens the base metal surface (laser glazing) and one which melt and fuse an external filler material onto the component surface. In the former category, the surface of hardenable materials such as 400-series stainless steels can be quickly heated and cooled without significant conduction of heat to the substrate. In the latter category, a hardface coating material is applied to the base metal surface by spraying, cladding, plating, or any of a number of other such application techniques, and then bonded to the base metal surface with the laser. In this sense, the process is not unlike the plasma-transfer-arc process, using the laser as a source of energy in place of the plasma arc. The major difference between laser coatings and PTA process is that the laser beam is a more concentrated and localized source of energy.

The laser coating process has not yet generally been used on a production basis for hardfacing of pump components. The major concerns are the possible loss of fatigue strength and the high initial cost of the equipment. However, the process has so many attractive aspects that it is likely that coatings applied by laser will, in some future year, be a mainstay of the pump hardfacing business.

Ion Implantation

Ion implantation is one of the most promising and highly-publicized surface treatment techniques developed in recent years. In the ion implantation technique, the substrate surface is embedded with ions which have been accelerated to high velocity through an electrical field. The embedded ions become an integral part of the substrate surface, and coating adherence is equal or even superior to that of diffusion coatings.

The major limitation of the ion implantation technique is that the coating is thin, usually on the order of 0.0005 in or less. For this reason, ion implantation has been used mostly in conjunction with other surface hardening techniques. Extremely high surface hardnesses have been reported, but there have been some reports of fatigue life decrease. The process does, however, offer the potential to extreme improvements in surface wear resistance.

SUMMARY

A wide range of coatings are available to a user for improved wear and erosion resistance, ranging from the low-cost metallizing process to the high-tech, high-cost processes such as the "D" gun, vacuum plasma spray, laser coatings, and ion implantation. The final decision as to which process should be used must be based on economics and field performance. The correct selection can be extremely cost-effective to the end user.

ACKNOWLEDGEMENT

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