Hard Chrome vs. Thermal Spray/ HVOF Coatings

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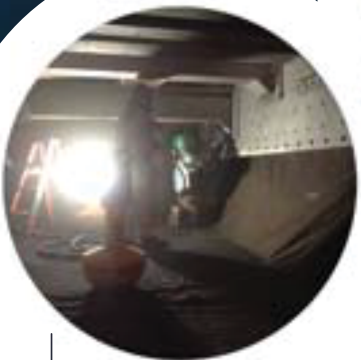

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Hard Chrome Replacement for Industrial and Consumer Machine Components

Although replacing hard chrome plating with thermal spray HVOF and plasma arc thermal spray metallic and ceramic coatings is not new to industry, it has gained momentum in recent years due to the tightening of federal and state environmental standards for the exposure to hexavalent chromium also known as Hex Chrome or Chrome 6. Besides the environmental concerns behind hard chrome plating, economic and performance benefits are driving the move to thermal spray coatings as well. Manufacturers continue to look for new technologies such as thermal spray to improve component life and performance in the face of rising fuel prices, increasing stringent government regulations and the need to continuously improve total cost of operation of their machines. For a slightly higher initial cost, thermal spray coatings offer longer wear life, improved corrosion protection, and higher fatigue lives when compared to hard chrome plate.

Environmental

In 2006 OSHA published a new standard which lowered the allowable limits for hexavalent chromium (Cr6+) exposure to industrial workers by a factor of 10.[i] The dangers of chrome 6 exposure to workers are well documented. During the chrome plating process vapors from chromic acid containing hex chrome are released to the surrounding environment which could expose workers to harmful levels. Thermal spray dust/fumes also can contain hex chrome. However, thermal spray is done inside noise abatement enclosures and all the dust/fumes are captured and exhausted through dust collectors. These collectors have an efficiency of 99.99% for particles of 0.5 microns or greater. To further improve filtration efficiency many thermal spray suppliers supplement their cartridge collectors with Hepa filters which improve efficiency down to 0.3 micron particles. Filtering the exhaust through a high efficiency dust collector prevents hex chrome from entering the plant or surrounding environment. Furthermore, overspray dust collected in the collector hoppers is sent to material recyclers who in turn sell the materials to manufacturers of stainless steel, and other products. Many environmentally conscience thermal spray shops have zero landfill contributions. Everything including spent dust cartridges and powder bottles can be recycled into other products safe for consumers, workers and manufacturers. For instance powder bottles are ground into pellets which are then compressed into 6" cubes. These cubes are then used as the energy absorbing component in guard rails along interstate highways.

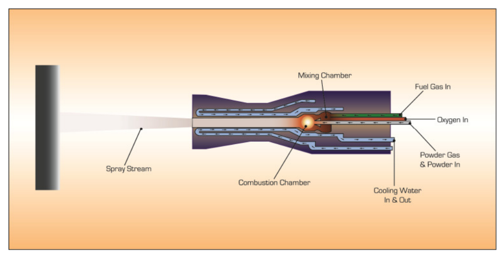
The European Union Parliament published that automakers after 2003 were prohibited from putting cars on the market containing lead, cadmium, mercury and hexavalent chrome. Because of the added environment restrictions and safety equipment necessary for plating hard chrome, the cost of chrome has risen in recent years. Estimated costs of the new regulations are predicted by the Small Business Administration to be much higher than OSHA had stated in its justifications.[ii] The capital costs for establishing a new chrome plating facility are substantially more compared to a new thermal spray operation. Disposal costs for chrome

plating are significant. The left over plating chemicals must be disposed of as hazardous waste. Trucking and disposal are large costs which must be taken into account.

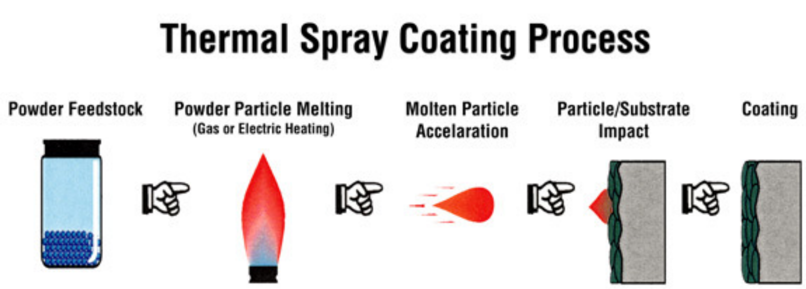
Economics

While chrome plating can look like a less expensive option because of the lower initial cost, ROI calculations demonstrate the overall lower cost of using thermal spray coatings. Thermal spray coatings have proven to be more wear and corrosion resistant than hard chrome. **Field and lab data confirm tungsten carbide, chrome carbide, and chrome oxide coatings can last 3 to 5 times longer than hard chrome plating**. Savings are realized not only when the part lasts longer – and therefore does not need to be replated or recoated - but also in reducing or eliminating machine downtime. Downtime in a typical manufacturing operation can cost $1000 per hour or more. Downtime in batch processing operations such as chemical and plastics production can cost tens of thousands of dollars per hour. Downtime for offshore or subsea oil and gas operations will run into hundreds of thousands or millions of dollars per day. So whenever calculating the return on investment to compare the cost of chrome plating verses thermal spray coating downtime it is important to include the cost of downtime as part of the equation. Reducing total cost of operation is the goal.

Thermal Spray Basics

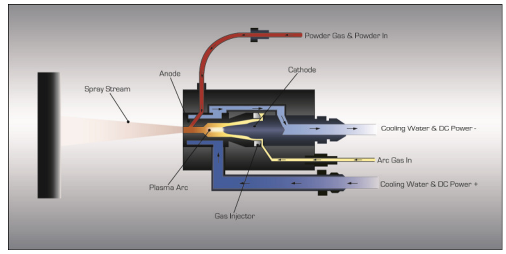


High velocity oxy fuel (HVOF) is the coating process most often used for chrome replacement. Tungsten carbide cobalt chromium (WC Co Cr) and chrome carbide, CrC-NiCr are two of the most common powder materials used to replace chrome. HVOF was invented in the early 1980's. It involves using a spray device pictured adjacent, into which the metal powder, oxygen and a fuel gas such as kerosene, propane or propylene or natural gas is introduced. The gas is ignited, heating and accelerating the powder particles which are sprayed onto the work piece at high velocity. The sprayed powder particles impact the work piece and form splats which are built up to make the coating in layers. The bond between the coating and the work piece is a mechanical bond with bond strengths of greater than 10,000 psi. Tensile tests are performed in accordance with ASTM C633. HVOF coatings have porosities of less than 1%. The density of HVOF coatings is the reason for their excellent corrosion resistance. Chrome has fair corrosion resistance but the presence of micro cracking provides a path for corrosive fluids to reach a ferrous substrate. Crevice corrosion leads to flaking and delamination.



[iii]

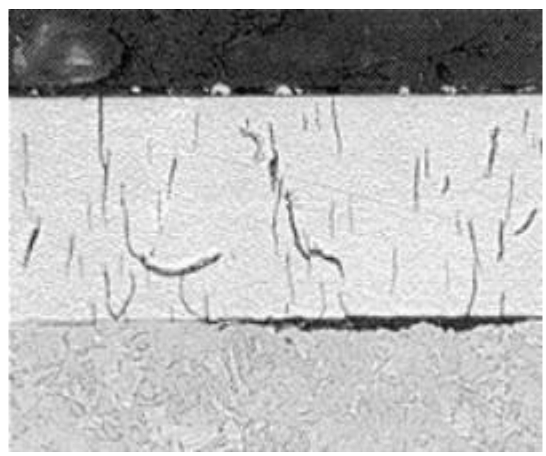
Another option for chrome replacement is plasma arc spray. Plasma arc is best suited for spraying ceramics materials like chrome oxide Cr_2O_3 and alumina oxide Al_2O_3. Both ceramics provide excellent wear resistance. However, ceramics may not be the best choice if extreme corrosion is present. Ceramic coatings have slightly higher relative porosities than HVOF coatings. But you cannot beat ceramics for hardness and sliding wear resistance. Plasma arc spray is also capable of spraying WC and CrC coatings. The cost to apply WC and CrC is slightly less than using HVOF but the bond strength, hardness and density of plasma sprayed WC or CrC will be lower than coatings sprayed with HVOF due to the lower particle velocities of plasma arc.



Thermal spray coatings are a line of sight process. Therefore, coating around corners or into small ID bores is not possible. Thermal spray coatings are applied in sound enclosures in order to contain the high frequency noise (126 dBA and up) and overspray dust. All the dust is captured in high efficiency dust collectors to prevent release into the surrounding plant and environment.

Performance: Comparing Hard Chrome to Thermal Spray Coatings

How do thermal spray coatings compare physically to hard chrome plating? Let's take a look at their properties. Thermal spray coatings are significantly denser than chrome plating. Plus chrome plating has micro cracking within the plating layer which allows corrosive agents with high or low pH to penetrate the plating and attack the substrate. Micro cracking can be seen in the adjacent photomicrograph. If the substrate is ferrous, this leads to crevice corrosion and ultimately the failure of the plating by flaking and delamination. The porosity of HVOF coatings is less than 1 percent and is not interconnected. As such, thermal spray coatings provide a much stronger corrosion barrier than hard chrome plate.



Customizing the coating design such as using a bond coat, increasing the coating thickness, or modifying the coating material composition (adding chromium or nickel to the powder mix), or using a post coating sealer can all further increase the corrosion barrier strength of a coating.

Attribute	Hard Chrome Plate	Thermal Spray Coatings
Wear Life	Moderate	Excellent
Corrosion Barrier	Weak	Excellent
Fatigue Resistance	Low	Excellent
Cost	Low	Moderate
Environment Friendly	Poor	Excellent
Damage Resistance	Poor	Good
Anti-fretting resistance	Good	Good

Thermal spray coatings have a good deal of ductility as well and have excellent fatigue strength properties. Bend tests as described in ASTM D522 specify coatings must resist cracking or flaking when bent over a mandrel. Fatigue resistance of thermal spray coatings is much higher than that of chrome plating.[iv] Because HVOF coatings impart a compressive load to the substrate, they actually increase the life of components against fatigue failure by resisting crack initiation. Chrome plating introduces tensile loading to the substrate surface which initiates crack formation and possibly leading to premature failure.

Measure	**Hard Chrome Plate**	**Thermal Spray WC or CrC**
Bond Strength	6000 psi	>10,000 psi
Micro Hardness HV	900	1200
Porosity	Microcracking	Less than 1%
Corrosion	55 Hours	720 Hours
Temp Limits	750° F	1600° F
Friction Coefficient Dry	0.22	0.25
Friction Coeff Lubricated[v]	0.12	0.11

Chrome plating does have its advantages. One benefit of chrome plating is that it is a dip process. So it is generally easier and more efficient to fully encapsulate a component with a dip process than with a line of sight process such as thermal spray. Since thermal spray is a line of sight process all surfaces must be visible to the spray head during coating application. For components with complex geometries multiple set ups are necessary if more than one surface is to be coated.

Conversely for components with multiple areas to be coated and adjacent areas where coating is not allowed, thermal spray maybe the most economical solution. Masking areas where the plating is not allowed or needed is much more difficult and expensive with chrome plating. Masking thermal spray is as easy as placing a shield in front of the spray gun when coating an area where coating is not desired. It is generally easier to automate masking for thermal spray than it is with chrome plating. Masking for chrome plating is for the most part a labor intensive manual operation. Furthermore, advances in spray devices now allow deep ID bores to be coated. Deep ID bores as small as 3" can be coated with plasma arc spray.

Common Applications

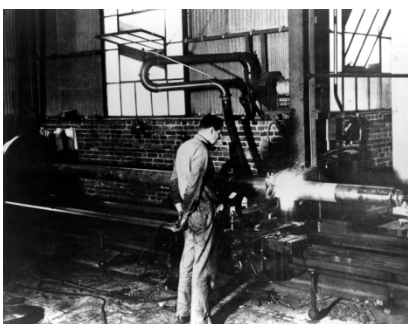
Thermal spray coatings have been used for years to replace chrome across a wide variety of industries. The aircraft engine and airframe industry took the lead early on replacing chrome with thermal spray coatings because of the increased component life. Coatings resistance to fretting, wear, fatigue and corrosion make thermal spray coatings an economic and performance winner over hard chrome plating. Many other industries have quickly followed the aerospace lead. Some examples are mining, chemical and plastics processing, oil and gas exploration, printing, power generation, agriculture, and heavy machinery. Pump parts, diesel engine components, printing cylinders, and all kinds of rolls are coated with tungsten carbide and other similar metals instead of chrome.

Landing gear for aircraft once 100% chrome plated now are mostly thermal spray coated with chrome carbide HVOF coatings.[vi]

- Landing gear
- Print and Blanket Cylinders
- Remanufactured components
- Centrifuge Bowl Ends
- Tension Bars
- Hydraulic Cylinders
- Feedscrews for injection molding and plastics compounding
- Gate Valves
- Progressive Cavity Pump Rotors
- Ball Valves
- Cylinder Heads
- Piston Rings

Remanufactured Components

Seventy percent of the material cost and 80% of the energy costs are recovered when remanufacturing a component instead of replacing it with a new component.[vii] While chrome has been the standard process by which repair shops restore dimension to worn or damaged parts, thermal spray is now offering a bigger bang for the buck. By using thermal spray tungsten carbide or stainless steel material instead of chrome, the components remanufactured will last longer and perform better. In some cases using tungsten carbide instead of chrome will mean the part will never need to be repaired again. It is always important to engineer the coating material to meet the application's performance needs. In some cases it may be better to use a less expensive material like CrC or stainless steel because the life of the component would not support the cost of tungsten carbide.



Remanufacturing components also provides the benefit of faster delivery. Some OEM replacement parts can take weeks or months before the part arrives from the factory. Local thermal spray shops with machining capabilities can frequently return a fully remanufactured component in weeks or in some cases days.

Summary

If your goal is to have machines running longer and at higher efficiencies, you should consider whether thermal spray coatings is an option for you. Consult a thermal spray technical sales engineer to see what would be the best material and process to improve performance. By engineering the right material and process you can expect longer life and better performance from your components. Coatings can cut the overall cost of operation and help meet always increasing customer expectations. Replacing hard chrome plating with thermal spray coatings is *good for business, good for the earth!*

Written by Scott McLaughlin

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References

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[i] US Department of Labor Website News Release. 06-342-NAT. February 27, 2006.

[ii] SBA Report, ALTERNATIVES To OSHA'S DRAFT PROPOSED HEXAVALENT CHROMIUM STANDARDS FOR GENERAL INDUSTRY,MARITIME OPERATIONS, and CONSTRUCTION, Jack Faucett Associates, page 4, 3-29-04.

[iii] ITSA website, www.thermalspray.org

[iv] Material Science and Engineering, Fatigue and deformation of HVOF sprayed WC–Co coatings and hard chrome plating. A. Ibrahim, CC Berndt. http://www.ewp.rpi.edu/hartford/~leahem/EP/SupportingMaterials/Research/HVOF%20Characteristics/ibrahim.pdf

[v] HVOF Coatings as an Alternative to Hard Chrome for Pistons and Valves. JA Picas, A. Forn, G. Matthaus. www.sciencedirect.com. January 23, 2006.

[vi] SAE article, Use of HVOF Thermal Spray Coatings for Hard Chrome Replacement in Landing Gear Applications, A-5 Aerospace Landing Gear Systems Committee, 2-22-07.

[vii] Business Week article. "Everything Old is New Again. September 25, 2006.