TECH SPOTLIGHT

High velocity oxygen fuel (HVOF) tungsten carbide coatings are among the most promising alternatives to hard chromium coatings.

HVOF tungsten carbide coatings are applied to a wide range of aircraft landing gear components.

Tungsten carbide coatings replace chromium

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For more than 70 years, hard chromium coatings have been "the gold standard" to impart resistance to wear, impact, and corrosion to components in aviation, transportation, industrial, and consumer products. However, in recent years, several performance limitations associated with hard chromium have driven the engineering community in both the military and civilian aerospace sectors, as well as many industrial sectors, to seek better coating materials, as well as more cost-effective methods to apply them.

Among the most promising alternatives are high velocity oxygen fuel (HVOF) tungsten carbide coatings. Extensive performance testing and an increasing number of successful commercial applications are proving the performance advantages of HVOF tungsten carbide coatings for a variety of aviation engine and airframe components. These include aircraft landing gear, hydraulic actuators, jet engine bearings and bearing housings, turbine shafts, and even some dynamic components such as helicopter drive trains and propeller assemblies. Able to provide improved wear, impact and fatigue resistance, and equal or better corrosion resist-

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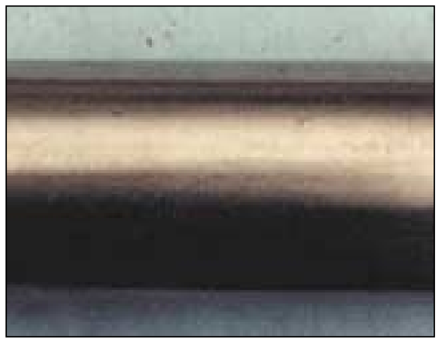
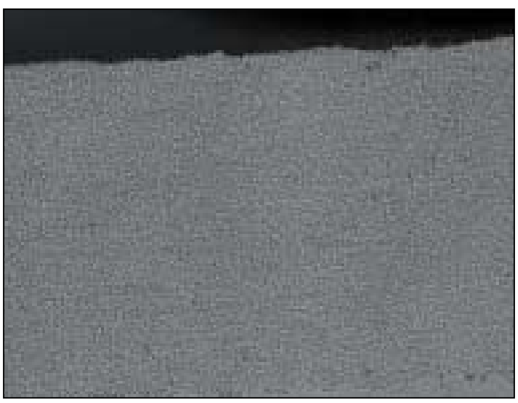
Coating characteristics and performance results

Property	HVOF tungsten carbide coating	Hard chromium plate
Macrohardness, HRC	>70	60 – 70
Microhardness, DPH 300	>1050	750 – 850
Bond strength, MPa (psi)	>80 (10,000)*	~41 (6,000)
Porosity	<1%	Inherently cracked
Coating thickness, mm (in.)	>0.08 (0.003)	< 0.13 (0.005)
Surface finish, Ra	<4	<4
Corrosion test (ASTM B117), hours	720	55
Surface temperature limits, °C (°F)	550 (1025)	400 (750)

**Results exceed strength limit of epoxy needed for tensile test.*

The left image shows a hard chromium coating; the right image shows the much smoother tungsten carbide coating applied by HVOF.



HVOF tungsten carbide has a bonding strength to the substrate of 80 MPa (10 ksi).

ance, these new coatings are replacing conventional hard chromium coatings in many demanding applications.

In addition to the performance advantages that the HVOF tungsten carbide coatings can provide in the face of punishing operating conditions, the HVOF coating process is easier to carry out than conventional electrolytic chrome plating baths. In fact, a variety of previously published technology assessments (many of them joint projects between the private and military sectors) have concluded that HVOF thermal spray of tungsten carbide is a viable technology for hard chrome replacement. To date, extensive lab and prototype testing, and increasingly far-reaching commercial experience, have demonstrated comparable or superior performance to chromium plating in terms of wear, corrosion, and heat resistance; application feasibility; and overall lifecycle costs and process economics.

A better deposition method

HVOF coatings are deposited by thermal spray. During this process, fuel gas and oxygen are pre-mixed, and fed at high pressure into a combustion chamber, where they burn to produce a hot, high-pressure gas stream. Tungsten carbide powder particles are injected directly into this combustion region of the gun under automatic control. As the high-velocity gas stream (containing semi-molten powder particles) is directed toward the substrate, the impact and deposition of the particles on the surface creates a dense, uniform coating, typically with less than 1% porosity, an oxide content of less than 1%, and a bond strength in excess of 80 MPa (10 ksi). The HVOF coating process is carried out in a spray booth, with a robotic apparatus.

The HVOF deposition process is faster than conventional chrome plating. Typical tungsten carbide coatings are applied in an hour or two, versus 24 hours or more required for hard chrome plating. Furthermore, unlike hard chrome coatings, HVOF tungsten carbide coatings do not undergo hydrogen embrittlement, so the time and cost required for embrittlement-relief treatment is eliminated.

All of these factors work in tandem to reduce the frequency of repairs and facilitate faster turnaround during overhaul and maintenance activities. The result is reduced out-of-service time, and generally reduced overall lifecycle costs associated with critical industrial engine and aviation parts.

As shown in the table, the macrohardness of HVOF tungsten carbide coatings is greater than 70 Rc (Rockwell scale), compared with typical values of 60 to 70 Rc for hard chrome plating. Microhardness values for the tungsten carbide coating are on the order of 1050 DPH 300 (Diamond Pyramid Hardness), compared with values of 750 to 850 DPH that are typical of hard chrome plate.

As mentioned above, greater bond strength and lower porosity can also contribute to the formation of durable coatings. As summarized in the table, HVOF tungsten carbide coatings have also demonstrated considerably greater corrosion resistance than hard chrome coatings (720 hours, compared with 55 hours, using ASTM B117 testing protocols), and have endured higher surface temperature limits (1025°F, as opposed to 750°F).

Gaining in commercial acceptance

HVOF tungsten carbide coatings are already protecting many landing gear and airframe components. For example, Engelhard applies HVOF tungsten carbide coatings on a wide array of components for both military and commercial aircraft, including landing gear and actuators.

As the U.S. Dept. of Defense, the U.S. Air Force, the U.S. Navy, and a growing list of private-sector jet engine and airplane manufacturers continue to recognize the ability of HVOF tungsten carbide coatings to impart superior resistance to abrasion and wear, fatigue failure, and corrosive attack, and to help operators sidestep the costs associated with using electrolytic chrome plating processes, the use of these advanced coatings is expected to take off.

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