HIGH VELOCITY OXY-FUEL SPRAY TECHNOLOGY

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The rapid advancement of **H**igh **V**elocity **O**xy-**F**uel (HVOF) spray coating technology since its introduction over 10 years ago has led to many diverse applications. These applications range from the aircraft and automotive industries, to paper and petroleum. DresserRand is evaluating this technology by establishing its first HVOF thermal spray cell at the Engine Process Compressor Division (EPCD) plant in Painted Post, New York. This work group, or Cell as it is known, is dedicated to the production of high-quality, **T**ungsten-**C**arbide coated compressor piston rods to combat wear and corrosion that is often encountered in gas field and petrochemical compression service. The experience gained in developing and operating this HVOF Cell will boost Dresser-Rand's capability to develop future coating applications including the rebuilding of worn components. This article describes HVOF technology and the development of the process at Painted-Post.

INTRODUCTION

As Dresser-Rand Company approaches the next century, manufacturing technology along with product development must be explored to increase product reliability. For the past several years, Dresser-Rand's Engine Process Compressor Division (EPCD) in Painted Post, New York, has concentrated much effort and talent on capitalizing on the rapidly advancing thermal spraying field. As a start, Dresser-Rand has established its first HVOF (High Velocity Oxy-Fuel) thermal spray cell in Painted Post to coat compressor piston rods with a Tungsten-Carbide Cobalt Chromium blend. This coating has proven effective in combating wear and corrosion often encountered in gas field refining and petrochemical compression service.

HVOF spraying theory is quite basic. Hot combustion gases are channeled and combined with a fine metal powder and accelerated down a nozzle. In the case of Dresser-Rand's TC_3 (Tungsten Carbide Cobalt Chromium) compressor rod coating, hydrogen and oxygen are combined and combusted producing the means to melt and accelerate the Tungsten-Carbide Chromium-Cobalt powder to deposit on the packing and scraper travel portions of the piston rod body. The combustion temperature is approximately 5000 degrees F with exhaust velocities up to 4500 feet/second. The powder particles impact the work piece where they are deformed and quenched. This method of thermal spraying provides coating properties that exhibit high density and uniformity.

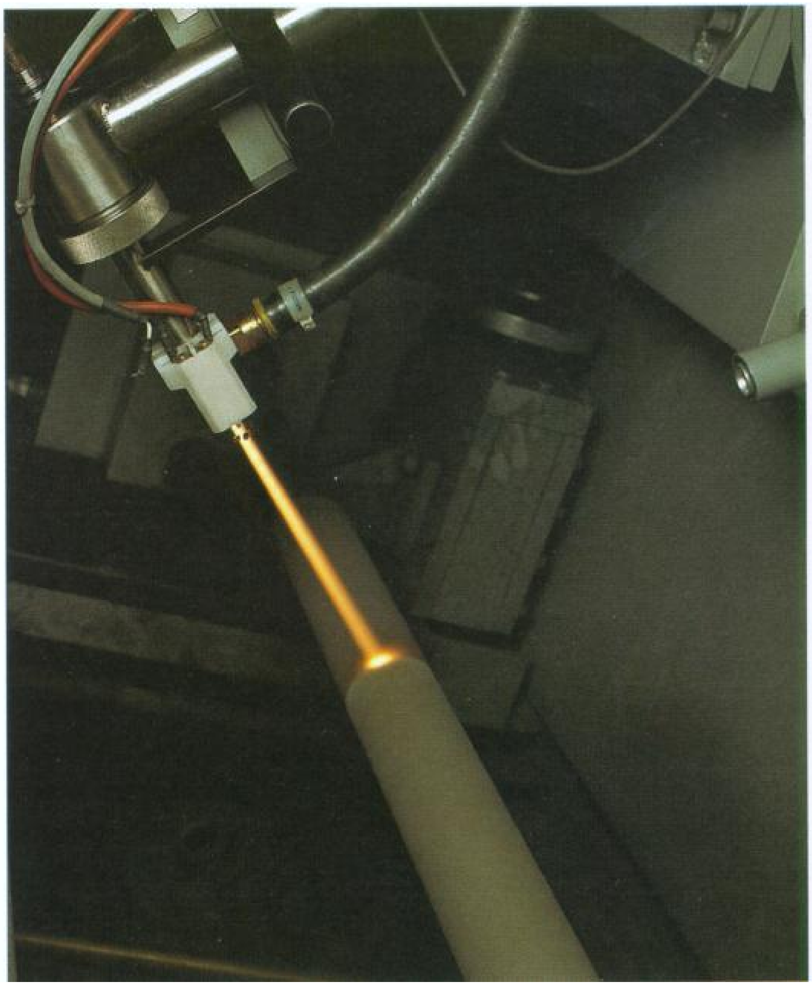
MARKETING ASPECTS

For years, the compressor industry has recognized the benefits of a Tungsten-Carbide coated compressor rod. Tungsten-Carbide is an extremely hard material with a rating of nine on the Moh scale, surpassed only by diamond which has a rating of ten. HVOF coating, a technology that has only been used in industry the past ten years, provides the answer to a cost-effective, hard face coating. Tungsten-Carbide coatings produced using HVOF systems are equal or better than previously supplied coatings when evaluated for bond strength, density, and oxide content. These properties give an HVOF Tungsten-Carbide coating superior hardness; this leads to excellent wear resistance which is the key performance characteristic for a compressor rod application. The addition of Chromium to the powder blend provides the corrosion resistance required in today's many corrosive compressor applications.

Many factors were considered in making the decision to enter such a competitive market. With 60-70% of compressor business covered by API 618, the fourth edition will require use of a continuously coated compressor rod in the piston rod packing and oil wiper travel area with a wear resistant material (API 618 section 2.8.4). Even without API requirements, market tracking shows a significant increase in compressor rods being purchased through EPCD Painted Post with coating requirements. In reality, this number is much higher since many users have reclaimed worn compressor rods with tungsten carbide or had soft steel compressor rods coated before service. With requirements increasing and just-in-time (JIT) engineering and manufacturing becoming standard, the use of original equipment manufacture (OEM) subcontractors is becoming more and more difficult due to additional lead time of shipping parts in and out of the plant and increased inspection costs. Therefore, the project was funded in order to meet customers demands not only for cost, but for product delivery.

PROGRAM DEVELOPMENT

The decision for Dresser-Rand to enter the tungstencarbide coating market was an easy one, compared to the work required to develop the equipment and skills for producing a high quality repeatable coating in a production OEM environment. The Painted Post plant's biggest strength in overcoming this obstacle was inhouse materials and engineering expertise. The primary requirement was that the Painted Post coating would need to meet or exceed current coating industry quality standards in order to be competitive. Early on the need to develop an internal coating quality control system was recognized. This was required since ASTM or other material organizations have yet to publish standard guidelines for coating evaluation. We needed to understand and measure standard coating properties such as porosity, oxides, micro hardness, and be able to recognize unmelted or foreign particles in the coating microstructure. Bond line strength and contamination also needed to be a focus, along with base material characteristics. Since Dresser-Rand has used various coating suppliers, programs were set up to receive sample sprayed coupons with each production compressor rod sent out for coating. Coupons were also given to coating suppliers to evaluate various tungsten-carbide-cobalt-chromium blends. The results unfortunately were not as conclusive as was hoped. Many variables started to appear that were not at first recognized: surface preparation on coupons had to be consistent; main fuel gas properties and quality had to be consistent; cooling temperatures had to be controlled. This, in addition to variables such as powder feed rates, gas flow rates, HVOF torch configurations, and gun temperature contributed to varying coating quality. Since all these variables could not be controlled through multiple suppliers, the evaluations were limited to one powder supplier, where we could specify and provide coupon material, powder, equipment used, and cooling rates. This supplier was invaluable in providing numerous iterations to determine various coating characteristics and the impact from parameter changes. It was quickly learned that for this application, hydrogen gas versus propylene gave hotter combustion and higher velocity which provided a denser Tungsten-Carbide coating structure with fewer unmelted particles. Optimizing hydrogen and oxygen flow rates then became a priority. This optimization process had to incorporate many important variables such as compressor rod temperature during spraying and cost considerations.



State-of-the-art computer controlled HVOF system applies high density Tungsten- Carbide Coating to typical compressor rod in controlled environment in Painted Post manufacturing facility.

Throughout this process of evaluation, the material engineering team gained the knowledge to evaluate coatings by consistently mounting, polishing and evaluating sample coating coupons. Coupon geometry became important for consistently mounting the coupon perpendicular in the epoxy mount. Coupon size was limited so a diamond cut-off saw was not required to section the sample before mounting, thus eliminating chances of fracturing the brittle tungsten-carbide coating. Polishing was automated by the use of state-of the-art polisher which can identically prepare each sample. Many iterations of various combinations of different grades of polishing disks, intensity and duration of polish were tried to ensure a true reflection of coating properties. Aggressive polishing could produce pullout of the coating which could be interpreted as apparent porosity. Yet other techniques could smear the coating sample and show little to no porosity. It was found that even a trained metallurgist could prepare the same sample manually and get remarkably different results. Internal documentation of procedures used at each evaluation step was critical. The materials team benchmarked their ability to prepare coating samples for evaluation by comparison with samples prepared by the powder suppliers. Sample coupons were sprayed in sets then sent out for independent evaluations. ASTM standards for micro hardness evaluation were followed giving consistency from sample to sample. Once consistent results were achieved, we started to evaluate the present compressor rod coating supplier for further data in coating selection. Cross-sectioning of actual compressor rods was required to determine actual correlation between test coupons and a compressor rod. Tests such as a bend and twist test on a flat strip were developed and evaluated for a "quick and dirty" bond line strength test. Twisting a strip sprayed with 0.005 inch thick Tungsten-Carbide is an extreme test for such a brittle material, yet provides valuable insight as to the coating bond line integrity.

PRODUCTION ASPECTS

Once the proper blend of powder for the coating was determined, a new challenge appeared: Could the powder be manufactured on a consistent basis by a supplier? An understanding of powder manufacturing processes became important to realize certain limitations and cost impact. Analysis of each coating batch would be required using standard sieve analysis and chemical composition. A simple requalification of the coating system each time a new batch of powder is used became standard for internal qualification. Internal standards were written for evaluation in both as-received and sprayed conditions.

It was then necessary to translate the desired coating properties to the Dresser-Rand coating system. The system selected was engineered and built specifically for compressor rods. Since the system would be in a production environment, many safeguards were added to the system logic to ensure coating quality. Additional interlocks of powder flow and gas flow with part rotation were designed to eliminate operator error in applying the coating. This led to the development of an advanced computer controlled system that integrates part programming with spraying parameters. This gives the cell a high degree of repeatability in coating properties. This is the key to dedicated production with quick change time to meet the needs of JIT manufacturing. Although the thermal spraying was the core of the development work, there were other factors equally important to producing the highest quality coating. Surface preparation is very important to ensure good mechanical bond of the coating. Given the great length of some compressor rods, a highly uniform method of blast preparation was required to guarantee bond over the entire coated surface of the rod. Therefore, a computer-assisted suction blast was selected. This system gives the capacity to blast a compressor rod body up to 120 inches long. The system is equipped with blow-off nozzles, reducing the amount of bond line contamination from embedded blast particles. The blast system recycles and sizes blast media ensuring uniform surface preparation.

Grinding of the coating is the third and final step in producing a tungsten-carbide coated compressor rod. Diamond wheels were tested for optimum infeed and table travel. Various factors such as dressing and trueing of the diamond wheel had to be implemented. Coolant not only reduced the heat in the work piece but served to wash the work wheel and improve grinding surface finish. A balance had to be obtained between the rod surface being too smooth versus being too rough. A surface that is too smooth would lead to poor oil retention, thus overheating the rod in the packing. A surface too rough could decrease pressure packing life from wear and affect compressor performance.

The result of extensive development and careful equipment selection is a world-class production cell where finished machined compressor rods can be masked, blasted, coated, ground, sealed and inspected. However, equipment and coating evaluation is all for naught until personnel can be trained to effectively use equipment, and identify and resolve problems. The training program developed internally at Dresser-Rand models many similar programs in industry. As with all programs, a certification of competence is required to spray production components. Continuation of training and certifications are critical to success. Process standards were written to ensure qualification of the HVOF system was accomplished on a consistent basis and operators understood limitations of thermal spraying. Documentation of all processes is stressed at Painted Post since International Standards Organization (ISO) certification in 1992. This is reflected in detailed process sheets which show all critical gun parameters, console settings and program variables. Dimensional checks are recorded at each stage (blast, spray and grind) to ensure final coating thickness. A coated rod can be tracked both by the base material and by the coating batch heat number. Microstructure samples are also kept with each record, along with process sheets. Internal training of product engineering, marketing and manufacturing was required to ensure that all requirements of compressor rod coating are understood.

SUMMARY

The development of the HVOF Cell in Painted Post has provided the opportunity to better understand the complexities of the coating industry and better apply coating technology to both production and service requirements. Understanding of requirements for coating analysis along with repeatable manufacturing processes, were required to launch program. These requirements, in addition to operator training and documentation, completed this stage of the program. The Dresser-Rand coatings program will continue to grow. Advancements in the coating industry are monitored for future applications. For example, Nickel base coatings may prove to be the answer for severe corrosion applications where tungstencarbide has not been historically used. Other parts that can also benefit from HVOF coating technology are being evaluated. The next installation of a thermal spray system is in the Dresser-Rand Tulsa repair center. This will position Dresser-Rand to use HVOF coatings for various repairs and rebuilds right in the backyard of many users. This will further develop applications for future thermal sprayed product.

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