POWER Engineering

The Art and Craft of Applying Thermal Barrier Coatings to Improve Life Expectancy

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Thermal barrier coatings (TBCs) protect turbine components from oxidation and corrosion and effectively provide greater durability and reliability to turbine engines. The importance of protecting turbines from the degradation caused by high temperature and wear is fully understood and has been a design goal for some 40 years. This effort continues today.

The demand for improved turbine performance inevitably leads to increasingly sophisticated component configurations. This results in a more demanding coating application process. The TBC process transfers a material onto a component in the form of a coating. As the components become more complex so does the challenge to create a consistent coating every time.

FIGURE 1 THERMAL SPRAY FLAME COATING CONVEX SIDE OF THE AIRFOIL BETWEEN THE TWO VANES

While the benefits of TBC materials are established, the importance of spraying and applying TBCs effectively is not fully understood and appreciated. No matter how advanced and effective the TBC material, it must be applied consistently and repetitively over many thousands of uniquely shaped parts to achieve the desired performance characteristics. Vanes, blades and other critical engine components require consistent thickness and structure if the turbine's integrity is to be sustained.

An example of this challenge is coating complex airfoils. It is difficult to coat consistently the area between a convex and concave airfoil, as shown in Figure 1.

At a recent ASME meeting, Purush Sahoo and Peter A. Sobieski presented a paper titled "Performance Characteristics of Thermal Barrier Coatings: A Case Study."[1] They reported a "wide variation in process control even among experienced coaters" during a blind test by a major manufacturer. Inconsistency in application "appeared to have the single biggest impact" on the life expectancy of the TBC, it was reported. The paper concluded that in many cases attention to the minutiae of process is often "significantly more important than choosing the 'right' materials or process."

Maintaining tight thickness standards and structure control[2] improves the life expectancy of the turbine component. Therefore, effectively applying TBCs and using best practices for controlling thickness and structure when coating complex turbine components is imperative.

Figure 2 shows a cross-section of a TBC on a turbine part. The rough surface finish of the bond coat and uniform distribution of porosity in the top coat are evident. Maintaining consistency of these coatings is critical for long TBC life and durability.

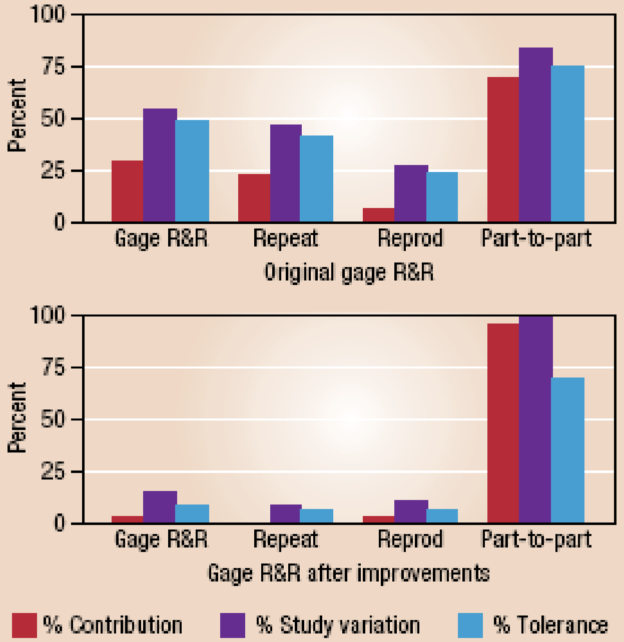
Establishing Process Controls

The first step to improving coating consistency is to verify the measurements are repeatable. Without repeatable measurements, it is considerably difficult to improve process consistency. One of the best techniques to do this is "Gage R&R." The Gage R&R measures how well the gage repeats the value and how well the operator using that gage reproduces the value when measuring the same characteristic at the same location on the same part, as well as from part to part.

FIGURE 2 CROSS SECTION OF A TBC ON A TURBINE PART.

Gage R&R makes it possible to review the results of individual coating applicators and verify that they are obtaining the exact same results every time they measure and/or collect data measurements. This ensures data consistency and stability. Every inspection measuring system is carefully examined and

Figure 3 GAGE R&R COMPARISON - BEFORE AND AFTER MEASURING SYSTEM IMPROVEMENTS



measured in the Gage R&R process.

When BASF Catalysts LLC performed a Gage R&R on the existing measuring system (a standard used by industry), the results showed the gage was not sufficiently accurate to produce dependable readings. The total gage variation was 54.66 percent. A measuring system with a variation greater than 30 percent is considered unreliable. Thirty percent or less is acceptable and 10 percent or less is ideal. Improvements were made to the measuring system and a Gage R&R was repeated. The results showed the measuring system had significant improvements, with variation at 13.58 percent. As Figure 3 illustrates, most of the variation is between the parts and not with the gage.

Based on this technique, BASF Catalysts implemented a couple of key improvements to increase process control.

Automated Coating

Imparting the specified coating to a single part in a specific spray booth is an achievement in itself. But consistently coating thousands of parts of different shapes and sizes in different spray environments raises the bar to greater heights.

To establish uniformity (also known as transparency) in the TBC coating process, BASF Catalysts have found that robots are a critical tool. Robots execute the most repetitive tasks and they perform them consistently by following the spray pattern set by the human hand. Robot technology minimizes human fatigue factors and dramatically reduces variations.

While robots tirelessly repeat the same strokes that would inevitably fatigue the most diligent of human sprayers, the human hand and mind remain quite indispensable. Setting the robotic sprayer to do its job requires a proper human touch and a reliable system of measurements.

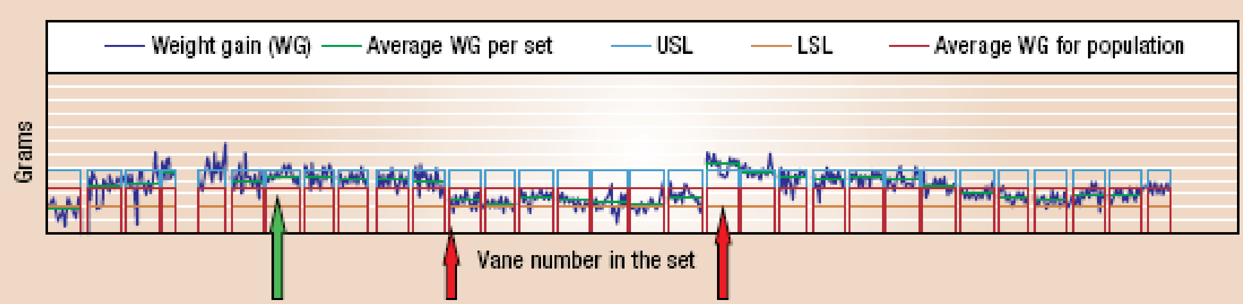
In addition, BASF Catalysts implemented an integrated auxiliary axis between the part and the robot to enable the sprayers to manipulate both the torch and the part. This further increases the consistency of the coating process.

Automated Measurements

BASF Catalysts also implemented a system of automated measurements to improve process control. Using proprietary eddy current technology, computers identify and provide data monitoring for each part being sprayed. Instantaneous reports chart the actual thickness values being achieved on all surfaces. Convex, concave, straight or angled, all parts are carefully measured for uniform coating.

The computer monitors the weight gain of each part being sprayed. This important data, which is stored on a data collection system, demonstrates whether the coating process is stable, unstable, in control or out of control. Basically, weight gain gives a unique view of the coating process. In Figure 4, the green arrow to the far left points to the time when process improvements were implemented. Prior to that, the process was unstable and the variations between the readings were large. The two red arrows point to process shifts. These shifts can be attributed to powder size distribution from lot to lot. Without monitoring the weight gain, these shifts would not be seen or understood. Figure 4 depicts 800 parts over a one-year period.

Figure 4 DATA COLLECTED THROUGH WEIGHT GAIN MONITORING



Surface finish for both the bond coat and top (TBC) coat is another measured characteristic. To increase the performance of the two-layer system, the industry has raised the surface finish of the bond coat in an effort to minimize spalling between the two coatings (Figure 5). This is measured real time throughout the coating process.

FIGURE 5 PHOTO OF INCREASED SURFACE FINISH FOR BOND COAT.

All this collected data—eddy current, weight gain, surface finish and micrometer readings—are fed into a single data collection system, which in turn creates histograms, capability studies and reports as needed. Quality control, quality assurance and engineering personnel can monitor this system real time from their respective stations as the data is collected, allowing for heightened awareness and control of the production process.

Conclusion

Thermal barrier coatings' thickness and structure may be as important as the TBC materials. To achieve consistent thickness and structure specifications, it is essential that thermal spray coaters utilize modern equipment and computers to calibrate and monitor their application processes. With modern techniques, proper thickness and structure can be consistently maintained on virtually all surfaces, leading to improved life expectancy of the turbine components.

Some BASF Catalysts customers have found that life expectancy increases as control tightens; even if the original control was within "spec." It is critical, therefore, that manufacturers select a coater with state-of-the-art process control.

References

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BASF Catalysts provides a full range of thermal spray services to meet the coating needs of customers in the manufacture of high-quality gas turbine engines for both OEM and overhaul and repair applications. Our coatings impart essential material characteristics to blades and housings. We also offer catalysts to control emissions from power plants. Our catalyst technology offers an efficient, cost-effective solution for gas or oil fired turbines and boilers to meet these regulations.

BASF's portfolio ranges from chemicals, plastics, performance products, agricultural products and fine chemicals to crude oil and natural gas. As a partner to virtually all industries, BASF's intelligent system solutions and high-value products help our customers to be more successful.

BASF develops new technologies and uses them to open up additional opportunities. We combine economic success with environmental and social responsibility, thus contributing to a better future.

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