JTTEE5 14:313-314
DOI: 10.1361/105996305X62220
1059-9630/$19.00 © ASM International

Accepted Practices of Thermal Spray Technology

This column presents short reports from the Thermal Spray Accepted Practice Committees. The mandate of these committees is to develop and to make known practices of various elements of thermal spray technology. This includes the collection of information, the unbiased evaluation of this information, the generation of useful accepted practices, achieving consensus within the committee, approval of the ASM TSS Board, and publication of the final practices. Contact: Lori Sobota at lori.sobota@asminternational.org.

Metallographic Preparation and Testing of Thermal Spray Coatings: Sectioning

TSS Committee on Accepted Practices
J.P. Sauer, Sauer Engineering, Cincinnati, OH

The evaluation of thermal spray coatings can be a challenging task for thermal spray shops and laboratory personnel. This article and a series to follow on mounting, grinding, polishing, and microstructural interpretation will strive to provide information on a variety of techniques and equipment, and assist companies in meeting this challenge. Some actual accounts of metallographic preparation problems are discussed and critical parameters identified in suggested methods for time and cost efficiency. With the aid of this information, shops should be able to formulate well-written and documented testing procedures that provide consistent reproducible results, allowing good production decisions on the shop floor.

Sectioning

To obtain a sample of the thermal sprayed coating for evaluation, it is usually necessary to section or cut the sprayed article. Sometimes, a small coupon sprayed early in the day as "booth release," or a representative sample sprayed along with the parts in question, will be sectioned. To avoid the many sectioning issues described in the following paragraphs, and perhaps save time and money by eliminating an entire step in the preparation sequence, many companies will spray coupons that are small enough to be mounted directly. It is important that the base metal and coating thickness be representative of the parts. Other laboratories may cut the specimen, but then mount the "as-sprayed" end on the viewing plane to stay away from cutting damage. In either case, it is critical to remove a sufficient amount of material during planar/rough grinding to move beyond "edge effects" of the coated sample.

Sectioning equipment is available in several formats, including manual-feed abrasive saws, automatic abrasive cutters, low-speed precision diamond saws, and larger high-speed precision cutters. Regardless of the system, it is important to review the sectioning process and consider the process parameters outlined in Table 1. Ideally, the resulting sectioned surface should be as planar as possible, burn free, exhibit minimal deformation, and have low surface roughness.

When sectioning coated coupons, the primary concern is to keep the coating in compression that prevents delamination. This requires orienting the specimen such that the coating is being pushed into the substrate during cutting (Fig. 1). Although the coating should be well bonded to the substrate, a substantial force is being exerted under the blade as it is "forced" through the specimen. The contact or cutting area varies from a minimum at entry and exit, up to a maximum through the largest section of the specimen. Unless the coating orientation is favorable, delamination may sometimes be initiated under these circumstances.

Clamping systems must be given consideration prior to the sectioning of coated specimens. The ability to correctly orient the coating may be limited if the specimen is large, or the clamping system is inadequate. Thus, the correct orientation is the one in which the coating is being compressed for the majority of the cutting cycle. Clamping on the coating can be acceptable, but care must be taken with brittle materials or delicate coatings. A rubber pad or wooden shim may be used to "cushion" the coating from direct contact with the metal clamps.

Table 1 Sectioning issues

Parameter	Considerations
Thickness of blade	Use a thin blade if possible. Thinner blades present less contact area to the specimen, leaving less deformation on the sectioned surface. And, thinner blades minimize material loss. When possible, a relatively thin blade (<0.1 in.) should be used. Thinner blades cause less deformation of the coating and generate less heat.
Fixturing	The specimen should be oriented to present the smallest cross-sectional area, while at the same time allowing for the coating to be in compression during sectioning. When sectioning curved or distorted specimens, the coatings should be oriented so that the blade starts at the crown. Lastly, the blade must be normal to the coating/substrate interface
Coolant	Proper use of a coolant will dissipate the heat generated during sectioning, thus preventing alteration of the coating structure, including spallation, cracks, and other untrue effects. Coolants normally consist of a mixture of the cooling agent, rust inhibitor, and possibly a biological inhibitor to prevent bacteria growth. The coolant is positioned and directed so it follows the edge of the wheel through the cut, while providing an adequate flow for effective cooling.
Precision blades	Precision wafering blades are thin metal blades containing diamonds or CBN (cubic boron nitride) in a continuous band around the blade perimeter. The abrasives are usually hot pressed into the metal blade and are available in several abrasive sizes and concentrations. Wafering blades are rigid and long-lasting and deliver accurate quality cuts.
Abrasive blades	Abrasive cut-off wheels commonly contain aluminum oxide or silicon carbide particles of various grit sizes, in varying densities. The bonding agent is a combination of phenolic resin and/or rubber of varying densities. Metallurgical quality sectioning of hard materials requires that a soft-bonded grade of abrasive wheel be used. As the wheel cuts, it releases the abrasive grains when they become dull, and continuously presents new sharp grains. Conversely, the sharp grains are not as critical to cutting soft materials, and a harder bonded wheel will last longer. Thin blades in this format are delicate and require that careful attention be paid to all process parameters.
Speed and force of cut	Excessive cutting pressure can cause "burning" on the cut face, spalling of the coating, or wheel breakage. In manual cutting, the operator can significantly influence the quality of the cut, by varying the speed, the applied pressure, and by not compensating for changes in the contact area.

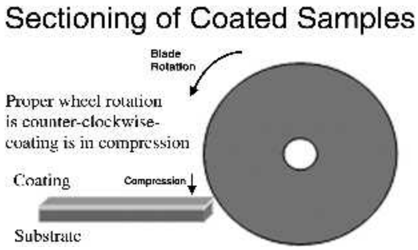

Fig. 1 Coating orientation for sectioning

Some systems provide only one clamp to hold the specimen. Others provide a dual-clamp system, which applies clamping pressure to the material on both sides of the blade. It is suggested that the primary clamp be tightened and the other clamp be snug only. This is especially critical with test specimens that have distorted during the coating process. The specimen likely contains residual stresses that may be relieved during sectioning, causing the specimen to shift, which can pinch the blade or crack the coating. Figure 2 shows a resultant transverse crack, a sectioning artifact, in an HVOF tungsten carbide-cobalt coating.

When considering the choice of sectioning equipment, the attributes of each unit must be considered. With manual cutting, an inexperienced operator may not be able to sense the difference in cutting area, and this may result in higher pressure at entry and exit. Likewise, it is difficult to apply a constant force manually, and possible burning or cutting damage can result. Constant load sectioning machines will apply an even load throughout the cycle, but again do not compensate for differences in contact area. The best and most reliable option for abrasive cutting are automatic constant-feed systems, which supply constant cutting pressure (not load) during the process, resulting in uniform sectioning conditions and uniform cut surface quality.

A low-speed diamond saw will provide a clean cut, even on brittle materials, with minimal damage to the coating. Precision saws with diamond or CBN blades can be automated with either an inexpensive constant load device, or the more expensive constant force and constant cutting speed controls, freeing the operator to perform other tasks.

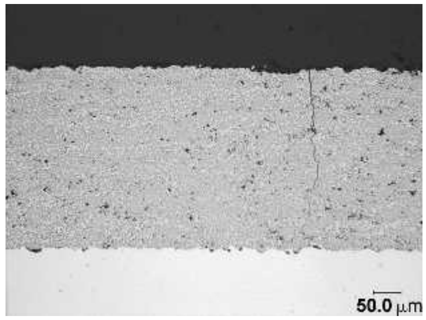

Fig. 2 HVOF WC/Co coating sample that suffered damage during sectioning. Courtesy of TSS Accepted Practices Committee on Metallography

When time is critical, as in the case of booth qualification, high-speed automated precision saws will outperform any other approach. The cutting cycle is short, the process is not operator dependent, and the high quality of the cut eliminates the need for lengthy planar grinding. As with all steps in metallography, the type of sectioning process used should be dictated by the coating types and parts being analyzed to provide the most cost- and time-efficient method for that laboratory.

Blade selection is also critical with respect to the hardness of the material being cut. Although conventional wisdom suggests "soft" wheels that will break down and supply fresh cutting particles/grains to section many of the harder coatings, a diamond blade with hard diamond particles may be necessary when cutting coatings such as ceramic composites. Each individual situation must be ultimately reviewed for proper wheel/blade selection.

Special Sectioning Issues

When parts are coated on both sides or around the entire circumference, it becomes more challenging to section the specimen and still maintain the coating in compression during most of the cutting process. Two options are listed below to address these issues:

Waterjet Sectioning

Waterjet sectioning involves impinging a high-pressure waterjet (approximately 55 ksi, or 380 MPa) with an entrained garnet abrasive onto the workpiece. Precise movement of the jet is accomplished by CNC controls. A word of caution with waterjet sectioning: the abrasive particles from the system can become embedded in the sample. This may interfere with any subsequent microprobe analyses for composition.

Traveling Wire EDM

Electrical discharge machining (EDM), otherwise known as "spark erosion," is a nonconventional thermal machining process that uses a continuously moving wire to remove material, by means of rapid controlled repetitive spark discharges. A dielectric fluid is used to flush the detached particles, regulate the discharge, and keep the wire and workpiece cool. The wire and workpiece must be electrically conductive. Precise control of the EDM process is accomplished by CNC controls.

Conclusions

The foundation for consistent metallography, in sectioning as with all other metallographic preparation steps, is identification of process variables, and adequate procedures to control those parameters. It is critical for the laboratory to understand the types of coated specimens to be processed, the equipment and consumables that are available to them, and the time constraints imposed by their facility or their customer.

In spite of the many sectioning variables, some laboratories adopt one sectioning policy for all coating/substrate combinations. With high precision equipment and experienced personnel, this could be a viable option. Others with less experience and limited equipment may choose different methods for soft versus brittle or hard coatings due to the product mix in the shop. Process understanding and documented procedures will provide the tools for consistent and reproducible sectioning of thermal spray coatings.