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Accepted Practices of Thermal Spray Technology

In this column, we present 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.

The Preparation and Evaluation of Thermal Spray Coatings: Fine Grinding & Polishing

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Abstract

This is the fourth and final article in a series of articles dealing with the metallographic preparation and evaluation of thermal spray coatings. Previous articles have covered variables and best practices for the sectioning, mounting, and coarse grinding of coated components. In this article, the relationship between fine grinding and polishing practices, consumables, and resultant plasma spray coating structure are discussed.

Fine Grinding

A survey of a room full of metallographers would likely yield a variety of answers to the question "when does grinding stop and polishing begin?" Traditional metallographic recipes rely heavily on silicon carbide (SiC) abrasive paper to perform both planar and fine grinding. Polishing is generally limited to one step, which consists of a napped cloth charged with 1 μm diamond particles. This method requires a long polishing time on the final cloth, which tends to produce edge rounding and coating artifacts. Modern methods developed within the past 20 years minimize the use of SiC paper. As an alternative, multiple steps are performed using coarse to fine diamond particles on a variety of fine grinding discs and cloths. Instead of a single final polishing step, modern methods rely more heavily on diamond polishing. Table 1 provides an example of traditional and modern methods.

For the purpose of this paper, fine grinding is defined as those steps which use coarse diamond (6 to 15 μm) in combination with either grinding discs or hard, low resilience polishing cloths. Grinding discs, such as the Struers Largo, Allegro, or Buehler Hercules discs, are essentially rigid metallic plates containing a systematic array of composite pads on the surface of the plate. Out of the box, these plates do not contain any type of abrasive. However, diamond applied to the disc will embed itself in the composite pads during use, leading to a fine grinding action. Cloths used for fine grinding are generally characterized by a hard woven appearance. In combination with coarse diamond, these cloths produce good removal rates with minimal edge rounding.

Polishing

The final step(s) in the metallographic preparation of thermal spray coatings typically has the greatest influence on the final structure of the coating. The polishing process must remove any smearing or deformation that has taken place in previous steps. However, polishing must not remove phases inherent to the coating structure. Careful selection of polishing variables and consumables is critical for ensuring an accurate microstructure.

In order to be consistent with the authors' previous definition, polishing is defined as those steps that use fine diamond (1, 3, or 6 μm) or submicron-sized oxide abra-

Table 1 Sample traditional (top) and modern (bottom) preparation recipes

Step	Disc/cloth	Abrasive	Force (per sample), N	Time
1	SiC paper	180 grit SiC	35	0:60 (repeat until planar)
2	SiC paper	240 grit SiC	35	0:60
3	SiC paper	320 grit SiC	35	0:60
4	SiC paper	400 grit SiC	35	0:60
5	SiC paper	600 grit SiC	35	0:60
6	SiC paper	800 grit SiC	35	0:60
7	Nap cloth	1 μm diamond	25	4 minutes
Step	**Disc/cloth**	**Abrasive**	**Force (per sample), N**	**Time**
1	SiC paper	180 grit SiC	35	0:60 (repeat until planar)
2	DGD	9 μm diamond	35	4:30
3	Fine woven cloth	3 μm diamond	35	4:00
4	Nap cloth	1 μm diamond	25	3:00
		or		
4	Chem cloth	0.05 μm SiC_2	10	0:60

Note: 35 N is equal to approximately 7.5 lb. SiC steps use a base speed of 300 rpm, while all polishing steps are performed at 150 rpm.

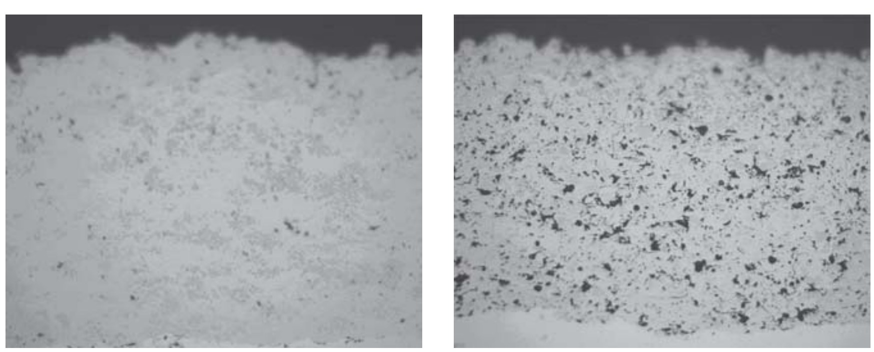

Fig. 1 Identical WCCo plasma spray samples, prepared using traditional (left) and modern (right) metallographic techniques. Courtesy of Pratt & Whitney

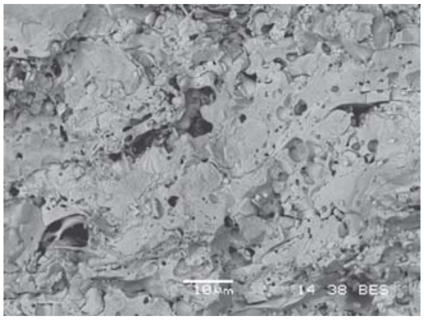

Fig. 2 SEM micrograph showing a cryogenic fracture surface of the WCCo sample shown previously in Fig. 1. From this surface, a qualitative assessment of the inherent porosity of this coating can be made. Courtesy of Pratt & Whitney

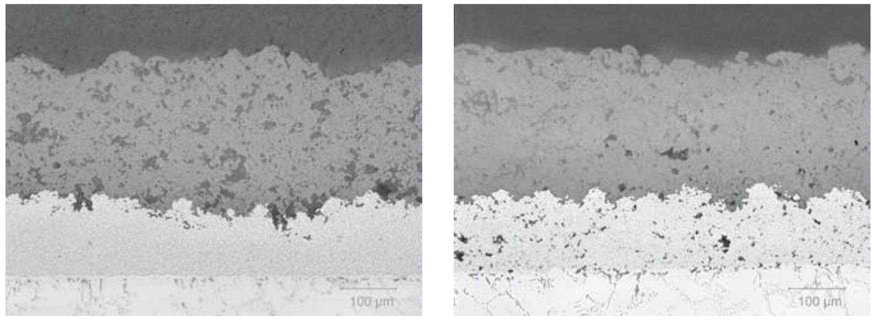

Fig. 3 Plasma sprayed TBS over LPPS NiCoCrAlY coating, prepared using traditional (left) and modern (right) metallographic techniques. Please note that vacuum impregnation was not used on the traditional sample and has resulted in exaggerated porosity levels within the TBC coating.

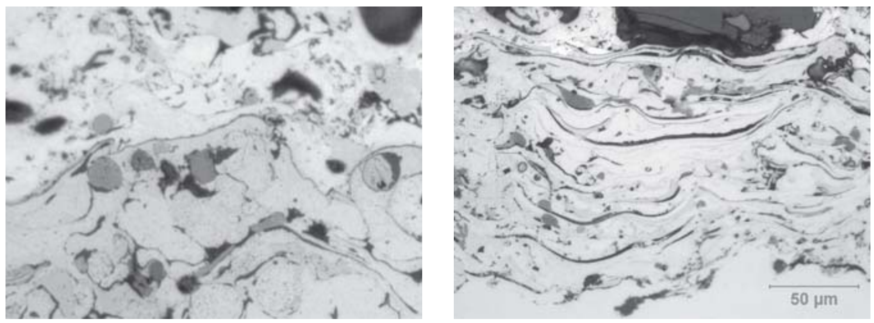

Fig. 4 Plasma sprayed Metco 450NS bond coat prepared using modern metallographic methods. The sample on the right was polished using a fine, napped cloth in combination with 1 μm diamond. This sample appears to have induced porosity (consistent with delaminations) between the individual splat particles.

sive (SiO_2, Al_2O_3) in combination with a specific polishing cloth. Modern metallographic methods commonly use more than one polishing step, as shown in Table 1. Because of its propensity to cause edge rounding on soft polishing cloths, the use of 3 or 6 μm diamond is generally limited to hard, finely woven cloths. Final polishing (1 μm diamond or <1 μm silica or alumina) is used in combination with a soft chemotextile cloth. Napped cloths are generally not recommended for surface examination and/or thermal spray coatings because of their propensity to cause erosion of oxides and mechanical damage such as pull-out (enlargement of apparent porosity).

Artifacts in Thermal Spray Coatings

Many common coatings have been found to be particularly sensitive to metallographic preparation methods. In this paper, WCCo, LPPS NiCoCrAlY, and Metco 450NS (Ni5Al) are used to illustrate this point. All three of these coatings are somewhat ductile in nature and are susceptible to smearing during grinding and polishing operations.

Figure 1 shows different sections from a plasma sprayed WCCo coating coupon, prepared using recipes similar to those outlined in Table 1. From these images, it is clear that the preparation recipe used has played a significant role in the apparent porosity of the coating. In this case, cryogenic fracture surface analysis (Ref 1) of this coating using a scanning electron microscope (SEM) provides a referee method to determine the amount of porosity present (see Fig. 2). Based on this analysis, it appears that the traditional method has led to smearing of the cobalt phase within this coating, resulting in artificially low apparent porosity.

Figure 3 shows a thermal barrier coating (TBC) over low-pressure plasma spray (LPPS) NiCoCrAlY system prepared using the same traditional and modern methods. These samples were removed from a single vane in the region of the airfoil to platform radius. Of primary interest in these samples is the appearance of the bond coat. Once again, the extended use of SiC papers has led to a smearing of the coating. As a result, the bond coat now appears to be nearly fully dense. In reality, this coating typically exhibits elevated porosity levels in the vicinity of this radius, which are more accurately revealed by extended diamond polishing. It should be noted that differences in TBC porosity in Fig. 3 are due to mounting methods and are not the result of polishing methods.

Figure 4 shows two images of a Metco 450NS bond coat. While both samples were prepared using modern methods, one sample used 0.05 μm silica and a chemotextile cloth for the final polish, while the other sample used 1 μm diamond on a fine napped cloth. While the differences are very subtle, the sample prepared using the napped cloth was found to exhibit more features consistent with delaminations. One possible explanation is that the napped cloth exaggerates particle boundaries by either pulling out oxides present at these interfaces or eroding and enlarging the inherent porosity between particles.

Summary

Thermal spray coatings represent one of the most challenging systems for a metallographer. Coatings can be brittle or ductile, porous or dense, and are often used in combination on a given component. As a result, modern metallographic techniques can lead to more accurate and consistent results.

Four papers have been presented that highlight the importance of sound metallographic techniques for the preparation of thermal spray coatings. Within each paper, best practices have been identified that should enable the metallographer to ensure an accurate and representative coating structure. Regardless of the experience level of the individual interpreting the microstructure of a coating, that interpretation is meaningless if features have been induced into the coating during metallographic preparation. Only through proper sectioning, mounting, grinding, and polishing techniques can the true coating structure be revealed.

Acknowledgments

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Reference

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