JTTEE5 15:31-32
DOI: 10.1361/105996306X92703
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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.

The Preparation and Evaluation of Thermal Spray Coatings: Grinding

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Abstract

This article is the third in a series of articles dealing with the metallographic preparation and evaluation of thermal spray coatings. Previously, critical parameters and best practices for the sectioning and mounting of coated components were discussed. In this article, different methods and consumables for material removal by grinding are discussed.

Abrasive Papers

During the metallographic preparation of thermal spray coatings, a great deal of damage can be induced into the sample. Sectioning of the specimen or coupon can cause localized cracking, delamination, and/or separation of the coating. As a result, the plane of evaluation must be at a point beyond this induced damage. While the depth of damage will vary depending on the operator and equipment used, most specifications call for the removal of at least 0.060 in. of material prior to polishing. This initial step, designed to quickly remove material, is referred to as planar grinding.

The most common consumable for planar grinding and also for a number of subsequent fine grinding steps is abrasive papers. These papers primarily use silicon carbide (SiC) as the abrasive, although alumina (Al_2O_3) and zirconia (ZrO_2) are used to a lesser extent. SiC papers can be purchased over a range of grit sizes (60-1200 ANSI/P60-P2500 FEPA), while Al_2O_3 and ZrO_2 papers are generally used only for planar grinding and therefore fall within the 60-120 grit range. Traditional metallographic preparation methods use a series of papers ranging from coarse to fine in order to flatten and grind a mounted specimen.

Despite their wide use and popularity, there are a number of drawbacks to SiC papers. A significant drawback is the lack of standardization for SiC papers and for most consumables used in the metallographic laboratory. SiC papers can be manufactured by a number of methods and as a result can vary significantly in terms of lifespan and material removal rates. Figure 1 shows scanning electron microscope (SEM) images of the surfaces of two sheets of 180 grit SiC paper. While both papers are marketed alike (180 grit, C-weight paper, etc.), a cursory examination reveals differences between the papers in terms of abrasive particle density. By using a higher magnification to continue this comparison (Fig. 2), differences in the orientation of the abrasive particles become apparent. In this case, one of the papers is manufactured using an electrostatic process that causes the abrasive particles to stand up when subjected to an electric field. The other paper does not use this manufacturing step.

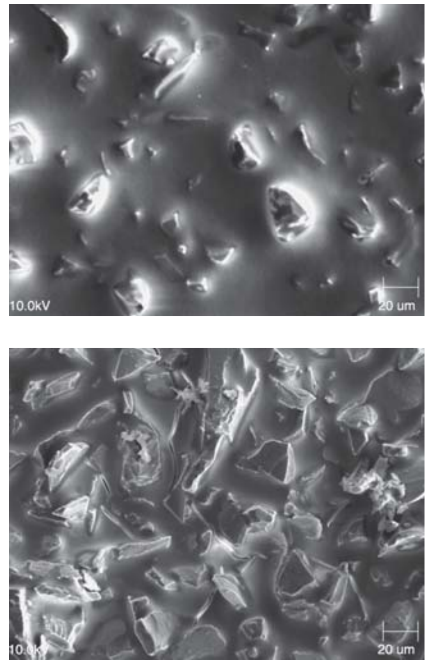

Fig. 2 Same SiC samples as shown in Fig. 1. At higher magnification, differences in abrasive particle orientation due to the manufacturing process can be more readily seen.

As reported by Samuels (Ref 1), the mechanics of material removal are quite complicated and are based on properties such as material hardness, abrasive spacing (density), and abrasive particle orientation. Effective material removal (referred to as "cutting") relies on abrasive particle orientation at angles close to normal to the material. As this angle deviates from 90°, less cutting and more plowing takes place. Referring back to Fig. 2, the paper produced by electrostatic methods contains the majority of its particles oriented normal to the paper. In comparison, the standard paper has a significant percentage of the particles lying flat, as evidenced by the visible profile of these particles.

In order to quantify the effect of abrasive particle orientation, several trials were performed using carbon steel bar stock to measure material removal rates. Six 1 in. tall by 1 in. diam samples were cut from the same bar. These samples were weighed using an analytical balance to create a baseline and subsequently ground on 180 grit abrasive papers using identical conditions (30 N per sample, complimentary rotation, 300 rpm, 60

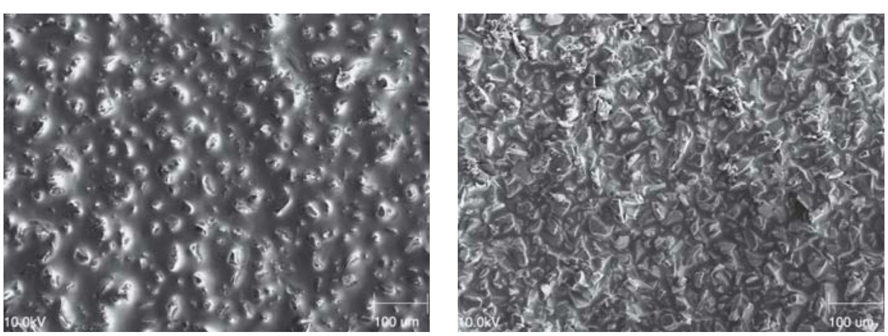

Fig. 1 SEM micrographs of two sheets of 180 grit SiC abrasive paper, produced by electrostatic (left) and standard (right) methods. In these images, differences in abrasive density are apparent.

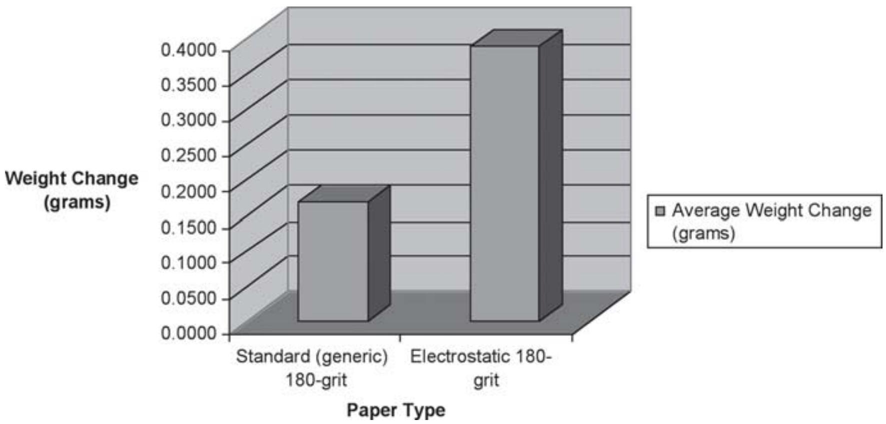

Fig. 3 Graphical representation of the results of weight-change studies for the two types of SiC paper

s/paper). Following each trial, the samples were re-weighed to determine weight loss (material removal) for each run. Several trials were performed for each type of abrasive paper (electrostatic and standard). The result of these trials revealed that for the 180 grit SiC paper from two different manufacturers, the electrostatic papers resulted in material removal rates more than twice as high as the standard papers (see Fig. 3). Additional trials were performed to measure material removal rates as a function of times. These trials revealed that the lifespan of both electrostatic and standard SiC papers was essentially 30 s. After that point, the amount of material removed over the next 30 s was a small fraction of the material initially removed.

Planar grinding can also be performed using a diamond grinding disc; however, these discs are designed for repeated use instead of single use and therefore are a different type of consumable.

Stone Grinding

In many cases, the use of abrasive papers is not practical for planar grinding. This is often the case for samples such as turbine blade airfoil sections. When limited to the use of SiC papers, an operator may easily go through 15 to 20 papers in an effort to remove the required amount of material. As mentioned in the first article of this series, large samples that require the use of abrasive blades for sectioning will contain induced features to a greater depth. Therefore, the removal of a full 0.060 in. or more is required to ensure an accurate coating structure.

Stone grinding uses 14 in. or larger aluminum oxide discs that operate at very high speeds (~1400 rpm). Different grit sizes are available; however, 60 to 80 grit is common for this grinding step. Stone grinding is generally only performed on special laboratory equipment, as more traditional polishing equipment is typically not designed to meet the size or speed requirements for stone grinding.

While this method of planar grinding is very efficient, the operator needs to be aware that stone grinding can induce damage into a thermal spray coating. As a result, subsequent grinding and polishing operations need to remove any damage induced during planar grinding. Typically, this can be accomplished by using a single sheet of coarse SiC paper. Once again, features such as cracking, delaminations, separations, and even excessive porosity may indicate that the sample contains residual damage from the sectioning or planar grinding operation.

Surface Grinding

Occasionally, some laboratories rely upon nonconventional equipment such as surface grinders to perform planar grinding. Unfortunately, a number of new variables come into play when equipment from outside the metallography lab is utilized. Heat generation during grinding can lead to coating damage, particularly since most industrial grinding machines are not designed to properly cool a mounted specimen. Furthermore, because of the design (and aggressive nature of these machines), a great deal of additional damage may be introduced into the sample.

Conclusions

Planar grinding is an essential step in the metallographic preparation of thermal spray coatings. Regardless of what equipment has been used prior to this point, planar grinding can be used to create a plane of evaluation beyond any induced damage. For large abrasive chop saws, this may require a minimum of 0.060 in. of material removal. For small precision saws, the amount of material that needs to be removed is much smaller.

While silicon carbide abrasive papers offer a simple method to remove material, the operator needs to be aware that variations in paper quality can lead to inconsistencies in the effectiveness of the paper. Consider a fictitious laboratory that has developed internal procedures that call for the use of 120 grit SiC paper for planar grinding. At the time when these procedures were developed, three sheets of electrostatically deposited paper were specified as being sufficient to remove 0.060 in. of material. However, because there is no standardization or specifications for SiC paper, switching to a new vendor in the future may mean that two to three times the number of sheets may now be required to remove the same amount of material. If the laboratory fails to recognize the difference in paper quality and continues with their established procedures, samples may begin to exhibit remnants from the sectioning operation. This is because far less than 0.060 in. of material is now being removed during the initial planar grinding step.

The bottom line is that laboratories must weigh the cost-benefits of any consumable used in the laboratory. In many cases, seemingly equivalent products may yield signification variations in quality and consistency.

Reference

1. L.E. Samuels, *Metallographic Polishing by Mechanical Methods,* 4th ed., ASM International, 2003