MATERIALS CHARACTERIZATION AND NONDESTRUCTIVE TESTING

Optimizing Speed, Accuracy and Reproducibility in Metallographic Preparation of Heat-Treated Materials

August 3, 2018

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KEYWORDS hardness testing / heat treatment / metallography / microstructure / sample mounting

The microstructure of a material represents its fundamental properties, and most heat treatments are performed to tailor these properties to a specific need. Good metallographic preparation allows faster and more-accurate quality control – whether a microstructural inspection or performing specific tests such as case-depth analysis.

The process of metallographic preparation is basically straightforward. A series of sequential stages, such as those shown in Figure 1, are used to produce a sample that has been

ground and polished sufficiently to:

- See the microstructure of the material through etching and imaging
- Make measurements
- Perform hardness testing

It is not uncommon to find that the people performing these steps are not specifically trained in the process, however, or the process has been inherited from decades ago and is applied with limited review. The net result is that we often find that it would be possible to perform a higher-quality preparation more quickly and often at a lower cost.

Both direct and indirect consequences of poor preparation approaches (Table 1) need to be recognized, and the value of reviewing this process becomes much more apparent. The extent of potential improvement may seem surprising, but technologies change. Even incremental improvements over a significant time period can make a big difference.

The purpose of this article is to review some key considerations in the metallographic process that may allow the reader to identify these opportunities in their own process.

Preparation Needs

When hardened materials are sectioned or ground heavily, residual heat may alter the microstructure or affect hardness results. These can be important factors in quality control, so it is important that any induced damage of this kind is removed in the subsequent stages. Each stage needs to remove the damage from the previous stage until the remaining damage is small enough not to interfere with analysis.

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A high proportion of the problems we find in specimen preparation originate with the sectioning method. Most applications will use a metallographic saw with an abrasive blade (Fig. 2). These are preferred because more-aggressive processes such as band saws can leave very deep damage on the sample, extending preparation times considerably.

Blade choice is simplified by the manufacturers, who will typically provide lookup tables that allow you to select abrasive blades by material type and hardness. For harder materials, a blade that wears down more quickly is needed (soft-bonded). The faster wear keeps the blade "sharp" by exposing fresh abrasive more quickly.

It is tempting to use a blade with slower wear (harder-bonded) to save cost, but this will often result in either slower cutting or the use of higher cutting loads and, therefore, more damage to the cut surface. It is far better, in most cases, to select the correct blade for your needs and simply cut at a slower rate if extended blade life is needed. This ensures the best compromise between quality, speed and cost.

Any movement in the specimen during the process will cause problems, from an uneven sample face to broken blades. It is recommended to secure the sample firmly during cutting, and supporting the sample on both sides of the cut will dramatically reduce burrs. In addition, cooling should be even and applied close to the cut to make sure that heat and debris are carried away effectively. Regular maintenance of both the machine and the coolant itself greatly improve consistency and quality.

Sample Mounting

The purpose of mounting samples prior to metallographic preparation is twofold: to protect the specimen and to make the samples easier to handle. Not all applications require the specimen to be mounted, and fixtures can often be used in semiautomatic machines to allow the preparation of

unmounted samples. In most cases, mounting is preferred, however, especially where there is a need to examine the edges of specimens.

There are two main methods of encapsulating (mounting) samples prior to metallographic preparation.

1. Castable mounting: Place the sample in a mounting cup, mix two or more liquid and powder components, and pour over the sample. Cures in 5 minutes to 8 hours, depending on the resin used.
2. Hot-compression mounting: Place the sample in the machine, add powder, close and start the machine. Cures in 7-12 minutes, depending on sample size.

The highest-quality mounts are made using a hot-compression mounting machine (Fig. 3). These machines use high pressures and temperatures to encapsulate samples. The largest barrier to their use is typically the purchase price. The mounting compounds for hot-compression mounting are inexpensive compared with castable mounting, however, so the longer-term economics can often make these a cost-effective purchase (Fig. 4).

The use of edge-retention mounting material is particularly important when examining coatings and surface layers (e.g., nitride layers and case layers) and checking for potential problems such as decarburization. Typically, a mineral-filled epoxy such as EpoMet is chosen for these applications.

Sample Preparation

The use of a semiautomatic grinder/polisher allows more-reproducible and consistent preparation. To get the specimens as flat as possible, the use of planar grinding, diamond grinding discs (DGD) and no-nap cloths are recommended. Central-force grinding (where specimens are locked into a holder for the entire process) helps to ensure uniform grinding and maximize planarity. It is also important

to minimize the amount of time polishing on soft cloths because this can cause edge rounding. So, final polishing steps should be optimized and not excessively long. If the finish is not good enough after the last stage, go back and repeat earlier stages rather than polish longer.

A recommended preparation route for typical heat-treated materials is given in Table 2. Further information can be found in the "Solutions" section at www.buehler.com. In typical semiautomatic grinding machines, six or more specimens can be prepared at once using these methods. Compare the times with your current methods. Is there opportunity to improve your efficiency?

Many older preparation routes rely on multiple stages of silicon-carbide (SiC) paper. Manual preparation can be a quick approach for one sample at a time, but it's likely that costs are comparatively high, and the variability between users can cause significant problems with quality and high repreparation rates. In some cases, the cost of consumables for sample preparation can be as much as halved by changing from a manual SiC-based approach to semiautomatic preparation methods such as those in Tables 2 and 3.

The advantages of refining the metallographic process don't stop at the polishing stage. An improvement in preparation provides many advantages in etching and analysis, including:

- More-accurate hardness-test measurement
- Increased success rate of automated hardness-testing systems
- Better definition of microstructures during etching
- Faster and more-effective with a lower-strength etchant. This has the benefit of shortening etching time, improving confidence in the analysis of structures, and reducing health and safety risks for operators.

Conclusion

Sometimes the simplest observations are also the most

powerful. Metallographic preparation is a critical step in many quality-control activities. Just like any other part of the manufacturing route, it is best applied with understanding and control. Proper use of equipment and methods can improve efficiencies and reduce costs. At the same time, it can ensure improved reproducibility and reliability of results. In the highly focused world of heat treatment, and in rapid-paced environments such as automotive manufacturing, this can be enough to provide a competitive edge to help ensure your success.

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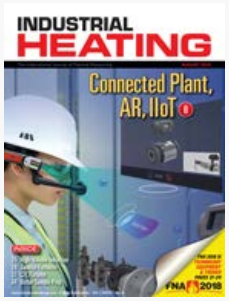

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