Fastener Metallography for Today!

Fastener Quality Act Is Here!
The 1980's were tough times for U.S. fastener manufacturers with a substantial loss of business due to aggressive competition from offshore suppliers, resulting in plant closings and massive downsizing. Then, fastener users were shocked when they discovered that many fasteners they purchased did not meet stated properties for their grade. Furthermore, bogus bolts were found to be the cause of some well documented service failures. This prompted a full blown investigation by the Committee on Oversights and Investigations of the Committee on Energy and Commerce of the U.S. House of Representatives. Losing business and jobs was a serious problem but dumping counterfeit products using falsified documents stirred Congress into action. The 61 page report published by the committee in 1988 revealed numerous incredible violations that placed the U.S. military, aerospace, space program and the entire manufacturing industry in jeopardy. The Fastener Quality Act of 1990, PL 101-542, was passed mandating strict adherence to established fastener test protocols and methods and tough penalties for violators, foreign or domestic. The original form of the law was found to be unenforceable and after six years of committee meetings President Clinton signed PL 104-113 in March of 1996 (the May 27, 1996 date of compliance has been postponed).

The purpose of this issue of BUEHLER Tech-Notes is to illustrate how those who will conduct the various metallographic procedures required under the terms of this law can be assured of the highest quality of compliance.

The Role Of Metallography
Table 1 lists various possible tests that might be required by a manufacturer of fasteners or any other company that alters fasteners for sale. Remember that the law applies to certain grade-marked fasteners mainly sold or used in the United States. Distributors are exempt from testing as long as the fasteners are not altered before reselling. Further information about the new law is provided in an article by Joseph Greenslade in the American Fastener Journal, Jan./Feb. 1997, Vol. 14, No. 1. Also, be aware that all tests are not required by all fastener specifications. Each fastener specification will call out the specific tests that are required.

Metallographic Specimen Preparation Of Fasteners - Sampling/Sectioning
Fastener specifications nearly always require that representative fastener specimens be sectioned longitudinally to reveal the profile of the head, threads and a minimum length of shank as illustrated in Figure 1. The most effective way to accomplish this is to cut slightly off-center to allow sufficient material for loss during the subsequent abrasive grinding and polishing. Smaller fasteners are usually mounted and ground to plane rather than sectioned before mounting.

Metallographic cutters and holding chucks are usually designed for general applications and are not well suited to handle the various fastener sizes and shapes. A small accessory chuck is available to secure fasteners and is clamped in the larger cutter vise. A better alternative is the use of the ISOMET™ 2000 Precision Cutter, shown in Figure 2, and a special fastener vise. This cutter is uniquely suited for fastener sectioning because it is automatic and provides a high degree of control over the cutting conditions including precise location of the cut to be made. Furthermore, using the thinner abrasive wheels designed for this precision cutter, accurate low kerf loss cuts may be made with a surface superior to that produced by conventional metallographic cutters.

Table 1: Metallographic Tests for Grade Marked Fasteners

<table>
<thead>
<tr>
<th>Flaw Detection or Verification</th>
<th>Qualitative Analysis</th>
<th>Quantitative Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Identification, Location, Extent</td>
<td>Microstructural phases, Grain Flow, Presence of decarburization, Presence of retained austenite, Inclusion identification</td>
<td>Bulk hardness, Microindentation hardness, Decarburization depth, % Retained austenite, Inclusion type, size, distribution, Microdimensions</td>
</tr>
</tbody>
</table>

Figure 1: Scheme for longitudinal sectioning

Figure 2: ISOMET™ 2000 Precision Cutter
Mounting Cut Specimens

A correctly sectioned fastener reveals the profiles of the threads so that rejectable defects may be discovered when examined in the as-polished condition at a low magnification. Various specifications include a drawing, such as Figure 3, that shows the pitch diameter with the most critical defect area being below this line including the thread root that is of primary concern to the analyst. Since potentially rejectable defects usually occur at the edges of the threads, it is essential that these edges are not rounded during preparation, making the specimen edge difficult, if not impossible, to accurately analyze. Edge rounding is caused by wrong choices made in mounting and in the subsequent abrasive surface preparation.

Three steps that assure maximum edge retention are:

- Specimens must be cleaned thoroughly to remove particles and oily films that prevent the mounting media from mechanically adhering to the surface of the fastener specimen. Ultrasonic cleaning is highly recommended. A more labor-intensive alternative is to scrub the specimens with a fine brush soaked with warm water and detergent. The cleaned specimens should be thoroughly dried before mounting.
- For best edge retention use EPOMET® Mounting Resin, an epoxy compression mounting resin that adheres well to a clean surface. Since it is more expensive than other mounting materials, use EPOMET resin only to protect the specimen itself and add the softer less expensive phenolic resin as the bulk material as shown in Figure 4.
- Keep mounts under pressure during cooling to prevent the mounting material from pulling away from the fastener specimen due to dissimilarities in the coefficients of expansion and contraction of the metal and the resin, Figures 5a and 5b. Never remove the mount from the press hot and place in cold water. A mounting press such as the SIMPLIMET® 2000 shown in Figure 6 which automatically heats and cools the specimen mounts under pressure contributes greatly to the production of shrinkage-free mounts.

Specimen Surface Preparation

The ability to obtain an accurate analysis of fastener specimens requires both the selection of an effective preparation procedure and the equipment that produces well prepared specimens rapidly, economically, and as flat as possible. The typical procedure shown as Table 2 works for a wide range of ferrous fasteners.

The Role of Automation

Automation is not a luxury in the abrasive surface preparation of fasteners but offers the following key advantages:

- Superior results both in finish and flatness
- More uniform, repeatable results
- Greater productivity – more specimens per shift
- Less manual skilled required – skill dependency eliminated

Table 2. Typical Procedure for Preparing High Quality Polished Fastener

<table>
<thead>
<tr>
<th>Step</th>
<th>Surface</th>
<th>Abrasive Type/ Size</th>
<th>Speed (rpm)</th>
<th>Time (min.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planar Grind</td>
<td>CARBIMET® SiC Paper 120 grit</td>
<td>120</td>
<td>Until Plane</td>
<td></td>
</tr>
<tr>
<td>Specimen integrity</td>
<td>CARBIMET SiC Paper 240 grit</td>
<td>120</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Specimen integrity</td>
<td>ULTRA-PAD® Polishing Cloth</td>
<td>9 micron Diamond*</td>
<td>120</td>
<td>2-4</td>
</tr>
<tr>
<td>Specimen integrity</td>
<td>TEXMET® 1000 Polishing Cloth</td>
<td>3 micron Diamond*</td>
<td>120</td>
<td>2</td>
</tr>
<tr>
<td>Final Polish</td>
<td>MICROCLOTH® Polishing Cloth</td>
<td>0.05 micron Alumina**</td>
<td>120</td>
<td>1</td>
</tr>
</tbody>
</table>

*METADAIN® SUPREME Diamond Suspensions
**MASTERPREP® Alumina

Figure 3: The location of the pitch diameter of the threads

Figure 4: (left) Dual resin mounting

Figure 5a: (top) Shrinkage gap (arrow) in a phenolic resin mounted fastener surface (ejected hot) Figure 5b: (bottom) Tight adherence (arrow) of EPOMET® Mounting Resin

Figure 6: (right) SIMPLIMET 2000 Automatic Press

Automatic specimen preparation machines utilize either 8” or 12” diameter formats and may be classified as semiautomatic or...
fully automatic. The PHOENIX® 4000 preparation system shown in Figure 7 (page 4) will produce excellent results using either central force application (full holder) or individual load application (one or more specimens).

**Results of Quality Fastener Specimen Preparation**
Well-prepared fastener specimens should be examined in the as-polished condition, preferably after a light etch and brief repolish to remove any residual superficial deformation (smear) that may hide a fine crack. Figure 8 shows a fine crack in the root of a fastener in the as-polished condition. If this specimen would have been etched without examination in the as-polished condition, observation of the crack may have been masked by flow lines in the root. Figure 9 (page 4) shows serious defects near the root of this A-286 fastener, clearly shown after light etching. Figure 10 reveals a shallow total decarburized layer containing fine oxides in this heat-treated alloy steel fastener at 400x after being originally detected at 100x.

**Tech-Tips**

**Question:** I have read about a number of techniques for edge retention. How useful are they?

**Answer:** Edge retention was a more difficult problem in the days of manual polishing. The switch from hot ejecting thermosetting type phenolic mounts (which people often cooled in water) to cooling under pressure after curing has virtually eliminated the shrinkage gap problem, especially with mounting compounds like EPOMET® compression mounting epoxy. Further, use of automatic polishing devices and the newer “hard” cloths make relief relatively easy to control. Years ago, people used canvas and other “softer” cloths, including some with a nap, which inherently produce relief, regardless of the polishing equipment. Electroless nickel plating does give the ultimate in edge retention, but it is time consuming. Adding various filler materials (like cast iron or alumina shot) to a mount is unnecessary today. These filler materials added little benefit and could make polishing or etching very difficult.

**Question:** When I use epoxy, I often get “gassy” mounts full of bubbles and I sometimes have problems getting the mount to cure so that it is hard. What am I doing wrong?

**Answer:** First, all liquid resins have a certain shelf life and with time beyond the normal shelf life, curing can become a problem. With any liquid mounting system, it is important to follow the instructions carefully. Most systems work best when the resin and hardener are weighed to the specified amounts before mixing. This works better than mixing on a volumetric basis, although it is less convenient. When you mix the epoxy, you should gently stir the fluids for about a minute. Vigorous stirring traps air in the liquid which produces the bubbles, which may not float out depending on the viscosity of the epoxy. Some epoxy systems require curing at a temperature other than room temperature, while others simply cure faster at elevated temperatures. Curing faster may not always be beneficial, however. Fast curing epoxies are more difficult to control. In general, higher exotherm temperatures obtained during curing increase the risk of shrinkage problems. Many users of epoxy mix and fill mounts at the end of the day and take them out of the molds the next morning.