No. 12

LECO MET-TIPS Ideas for Metallographic Procedures

Sectioning

Nine times out of ten, material received in a metallographic laboratory in preparation for microscopic examination is either too big or too small to handle conveniently. Most of the time, material will fall into the too-big category. So, something must be done to obtain a piece small enough to handle. This usually entails the use of some type of sectioning equipment.

Sectioning is the first step in the overall process of specimen preparation. It is a step that should be given considerable thought and care. Where the sectioning should be placed and the proper equipment to use should each be considered. Too often, the prime concern is getting the sample cut and not how cutting it will affect the sample. The result can be a severely damaged specimen that no amount of subsequent metallographic procedures can correct.

There are several methods available to the metallographer to obtain a smaller piece from a large section: fracturing, sawing, or abrasive wheel sectioning.

Fracturing

Fracturing a piece can be accomplished by applying repeated blows or steady pressure; however, this method is not recommended for several reasons. First, fracturing seldom follows desired directions unless the sample is pre-notched; second, the fractured-surface usually requires significant coarse grinding to obtain a flat surface. Moreover, damage from fracturing can also mask inherent features seen microscopically.

Sawing

Sawing is perhaps the oldest met lab method of sectioning that is still used today. It can be accomplished with a hand-held hacksaw, a band saw, or an oscillating power hacksaw. Of the three methods hand-held hacksaws and band saws are preferred. Frictional heat from power saws can alter the microstructure.

Although coolants should be used in any type of sectioning, band saw cutting can be done without it due to the slow speed. Coolants are used to decrease the depth of deformation introduced by the method of sectioning.

Saw-cut surfaces are very rough. Coarse grinding is required to first obtain a flat surface. Fine grinding can then be started.

Abrasive Wheel Sectioning

The most popular method of sectioning is with abrasive cut-off wheels. Wheels utilizing silicon carbide, aluminum oxide, and diamond abrasives are used in the sectioning process. With this type of sectioning, the metallographer has more control over the conditions used. For example, he can choose silicon carbide or aluminum oxide with three types of bond: (1) rubber, (2) resin, or (3) resinoid (a rubber-resin composition). The selection of abrasive used is more important than the bond. Choice of bond is usually based upon objections to the odor of burning rubber as the wheel degrades.

Each abrasive particle contained in an abrasive cut-off wheel acts as a miniature cutting tool that removes a very definite chip of material. The many thousands of particles contacting the material in rapid succession and at very high speeds serve to "section" the material.

Two terms used in the selection of abrasive cut-off wheels are "hard" and "soft". These terms do not refer to the hardness of the abrasive grains but to the manner in which the wheel breaks down. Actually, there is very little difference between the hardness of Al_2O_3 and SiC—Al_2O_3 is approximately 2000 on the Vickers scale and SiC is about 2400.

The manner in which the wheel breaks down is dependent upon the type of bond used. Generally speaking, resin and resinoid bonded wheels break down (wear away) more rapidly than rubber bonded wheels. The rubber bond is more tenacious in retaining abrasive particles. The result is slower wheel wear and more cuts per wheel; the rubber also forms a solid bond (i.e. there are no pores). On the other hand, resin sets up in a polymerization process, with small, minute pores throughout the wheel which may or may not be intimate with abrasive grains. As a consequence, when resin bonded wheels are used, they wear away more rapidly but always present a fresh cutting surface because each abrasive grain is ejected before it becomes dull.

Most metals processed through the metallographic laboratory can fall into two categories: hard or soft. Hard metals include metal carbides; metal borides; hardened tool steels; and ceramics such as Al_2O_3, BeO, and MgO; and cermets, which are metal-ceramic composites. Soft metals include carbon steel alloys; alloy steels; cast irons; and nonferrous alloys. When sectioning hard materials, a soft wheel (usually silicon carbide) should be used. As previously mentioned, a soft wheel is one that breaks down more rapidly, thus always presenting a fresh cutting surface. Conversely, when sectioning softer materials, a hard wheel (usually Al_2O_3) should be selected. A diamond-rimmed cut-off wheel is recommended when sectioning metal carbides, borides, ceramics, and cermets. A good rule to follow is "soft wheels for hard materials and hard wheels for soft materials". This is not to imply that soft wheels will not cut soft materials, but since soft wheels break down faster, fewer cuts are realized, and more wheels are used.

Abrasive wheel sectioning should always be done with a coolant. For specifics, see Met Tip #10.

Improper wheel selection can cause short wheel life; burning of the material even in the presence of a coolant; wheel breakage; and the wheel not being able to cut the material.

Short Wheel Life

Short wheel life is a result of the wheel breaking down too rapidly. Cuts are very good, but the number of cuts per wheel is drastically reduced. Selecting a harder wheel (a rubber bonded Al_2O_3 for example), will yield more cuts per wheel without a sacrifice in quality.

Burning

The main reason for burned cuts is the result of sectioning without a coolant. However, burning can occur even in the presence of a coolant if the wheel is forced too hard into the material. Slower feeding of the wheel will correct this problem. If burning still persists, it may be caused by too hard a wheel causing a taper effect on the cutting edge. As the wheel edge becomes a sharp taper, and as the kerf (thickness of the cut) reaches the thickness of the wheel, binding will occur. The result is burning and/or wheel breakage. Selecting a softer wheel (different bond) will correct this problem.

Wheel Breakage

Obvious wheel breakage can be caused by several reasons—the initial wheel/material contact is made with too much force, or the sample being sectioned has compressive stresses that pinch in on the wheel as these stresses are relieved. One of the reasons could be that the cutting edge of the wheel is taking on a chisel effect. Chisel effect is caused by improper application of the coolant. Perhaps one of the coolant hoses is partially blocked. In either case, more coolant is being introduced to one side of the wheel and the result is uneven wear on the cutting surface. The chisel point tends to take the edge of the wheel in a deviate direction while the wheel flanges try to perform their designed purpose by making the wheel run true. Undue stresses are imposed on the wheel and breakage occurs. Checking to insure that the coolant is evenly applied to both sides of the wheel will eliminate the chisel effect.

Wheel Not Cutting

Cut-off wheels that start to cut then seem to stop cutting are usually rubber bonded Al_2O_3 wheels that are being used to cut extremely hard materials. Since the rubber bond tends to hold the Al_2O_3 particles longer, the abrasive particles become dull and soon form a glaze around the cutting edge. The edge feels smooth to the touch and looks glassy. Selecting a bond that breaks down more rapidly will eliminate glazing.

If a rubber-bonded wheel must be used for hard materials, placing a piece of softer material with the hard material so that the wheel cuts into the softer material first should correct the problem.

Rubber Bond Versus Resin Bond

There is no doubt to those who use rubber bonded wheels that there is an offensive odor of burning rubber given off as the wheel degrades. To some, this is a "necessary evil" that one must become accustomed to in order to accomplish sectioning. It also seems that the strongest objections come from personnel not directly associated with the laboratory.

To eliminate the burning rubber odor, one can select a wheel with a resin or resinoid bond. The quality of the cuts will be the same as with rubber bonded wheels; however, the number of cuts per wheel may be reduced. Wheels with a resinoid bond, which is a composite of resin and rubber, have all the good qualities of a rubber bond but without the odor, and tend to yield longer wheel life than an all resin bond.

If a laboratory is locked into using rubber-bonded wheels for some reason or another, using a coolant with an odor-mask additive can drastically reduce the odor. An odor mask is simply perfume that has been added to the coolant to mask the burned rubber odor. It is very effective.

If in doubt as to the type of wheel bond (rubber or resin), holding a lighted match to the wheel edge will differentiate this. A rubber-bonded wheel will flame, burn, and give off an odor of burning rubber. A resin-bonded wheel will not flame or give off an odor.

Many abrasive wheel manufacturers will stamp their wheels in a code for easy identification. A typical analysis for an A90K2R30 wheel is as follows.

A Abrasive	90 Grit Size	K Grade	2 Density	R Bond	30 Manufacturer's Code
A-Al_2O_3 C-SiC	12 (coarse) to 240 (fine)	G (soft) to X (hard)	1 (dense) to 15 (open)	R-Rubber B-Resin or Resinioid	

Cut-off wheels having grit sizes ranging from 60 to 120 are recommended for sectioning metallographic specimens. The surface finish is such that coarse grinding is not necessary, and the grinding sequence can usually start with a 180-SiC grit size.

Shelf Life

Rubber bonded wheels have a definite shelf life. The shelf life can vary from lab to lab depending on storage and climatic conditions. Generally speaking, the shelf life will be between 12 and 18 months for rubber bonded wheels. The rubber has a tendency to harden and become brittle. Storing abrasive wheels in an extremely warm area will hasten the degradation of the rubber, further cutting down on the shelf life. Abrasive wheels should be removed from their shipping containers and laid flat on a rigid surface in a relatively dry environment. They should never be hung on a wall or stored on edge because warping can occur.

Many abrasive wheel manufacturers will date their wheels when they make a particular wheel type, and the date will appear in grouped numbers. For instance, 1008 or 3/09 means October 2008 and March 2009. If rubber bonded wheels fragment easily even after checking for other conditions that contribute to short wheel life, look for a stamped date on the wheel. If the shelf life has been exceeded, they can be returned to the distributor for exchange. Sometimes distributors do not practice the "first-in, first-out" rule when they place their inventory in bins to fill customer orders.

Resin bonded wheels should be stored in the same manner as rubber bonded wheels and in particular, in a dry atmosphere. A high humidity area can lead to early disintegration of the resin bond. Resin absorbs moisture and absorption weakens the bond.

Diamond Wheel Sectioning

Diamond wheel sectioning is usually reserved for the sectioning of extremely hard materials—metal carbides, metal borides, ceramics, and/or cermets. Diamond cutoff wheels do not have their abrasive on the kerf edge of the wheel but are concentrated on either edge of a bronze or aluminum wheel. The concentration of the diamonds can be low, medium, or high, and the wheels are priced accordingly.

Sectioning should be slow and with a copious flow of coolant. The wheel should not be forced into the material because it can fracture the material. Diamond cut-off wheels should be dressed periodically to remove metal debris and swarf that accumulates in the interstices between the diamond particles. A dressing stick usually accompanies a diamond cut-off wheel.

The initial wheel-material contact should be made as gently as possible to avoid deflection of the wheel. After a small groove has become apparent, slightly more pressure can be applied.

Reinforced Wheels

Reinforced wheels are made with layers of fiberglass cloth molded into the wheel. They are available in either rubber or resin bonded wheels. Reinforced wheels are not unbreakable but are break resistant. The fiberglass only serves to prevent pieces from flying about in case of breakage. They should never be used to circumvent safety features such as wheel guards, safety glasses, and other normal operator protection accessories.

Coolants

Water alone should not be used as a coolant for wet sectioning. A water-soluble oil with a rust inhibitor additive coolant should be selected. The inhibitor serves to protect the moving parts of the cut-off machine from rusting, minimizing the possibility of burning. It will also give better quality cuts. Some, but not excessive, foaming of the coolant is desirable.

The ideal cooling condition is submerged sectioning, where the entire piece is under water. Submerged sectioning is recommended for heat sensitive materials that undergo microstructural changes at low temperatures. (For example, as-quenched alloy steels having an untempered martensitic microstructure can readily transform to tempered martensite with the frictional heat developed.) The quality of the submerged cut is excellent, and the specimens produced will not require extensive grinding procedures.

Where aluminum is being sectioned on a continuing basis, a nitrite-free coolant is recommended to avoid the formation of sodium hydroxide. Sodium hydroxide will cause pitting of the exposed metal parts (vises, sump pump areas, T-slot tables, etc.).

Abrasive cutting is indispensable to the laboratory. To the metallurgist, the quality of the cut is paramount and wheel life is secondary. To the manager, just the opposite may be true. With all the options that are readily available regarding types of abrasive and bonds, a happy compromise can be reached. A well-equipped metallography laboratory should have a variety of wheels available for different applications.

Cut-Off Wheel Selection Guide

Material To Section	Approximate Hardness	Abrasive - Bond
Nonferrous (Cu, Al, Ti, etc.)	All	SiC - Resin/Rubber
Medium-Soft Steels	20 to 35 R_c	Al_2O_3 - Resin or Rubber
Medium-Hard Steels	30 to 45 R_c	Al_2O_3 - Resin or Rubber
Hardened Steels	45 to 60 R_c	Al_2O_3 - Resin or Rubber
Hardened Steels	> 60 R_c	Al_2O_3 - Resin or Rubber
Multi-Purpose	All	Al_2O_3 - Rubber
Ceramic	> 1200 Vickers	Diamond - Sintered Metal

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