SUMNotes
PUBLISHED BY BUEHLER, A DIVISION OF ILLINOIS TOOL WORKS
VOLUME 4, ISSUE 1

CUTTING EDGE HARDNESS TESTING

Executive Summary

Inspection of manufactured goods has increasingly become standard practice to ensure products meet more and more demanding specifications. In some cases, this can mean that long established methods of quality control need to be pushed to their limits. One example is the heat treatment of steel. Hardness testing has been used to check heat treatments for more than 100 years. As applications have become more specific, and technical developments more refined, the test methods have developed further alongside technology. In the highly competitive cutting blades industry, it is vital for the blade to have sufficient hardness to retain an edge, while too hard can cause brittle failure. When hardened materials are ground, residual heat may alter the microstructure and soften the blade edge. By design, the blades have little mass, so control of residual heat during the final finishing process is also critical. Accurate testing for hardness is therefore vital to ensure a high quality product. Testing the hardness of the cutting blades becomes challenging as indents must be made and measured accurately, using low loads and correspondingly small indents. This requires proper specimen preparation and careful use of hardness testing equipment. This article will review a guide to metallographic preparation and microhardness test processes for this application, although the principles are relevant to the use of Vickers testing for any hard material applications.

Challenges

Before diving in to specimen preparation, it is important to select methods appropriate to the specimen material and expected hardness. For our blade example, the expected Vickers Hardness (HV) value may be upward of 700HV and can easily extend into 1200HV range. For such a hardened part, the inspection sample will need to be mounted, ground and polished while maintaining a flat edge. Flatness is of paramount importance for obtaining valid symmetrical hardness indentations, as tilt or rounding in the specimen can cause significant errors in measurement.

The ASTM-E384 Standard for Knoop and Vickers hardness testing recommends that any indent shall be 2.5X its diagonal size away from any edge or other indent. Placing an indent close to the blade tip therefore requires low loads, such that the expected indent diagonals will be very small, i.e. 4 to 5 μm diagonal length. With such a small indent size, accurate measurement would be very difficult if the hardness tester does not have high magnification objectives. Even with a 100X objective, measuring such small indents manually with an eye-piece can vary significantly between operators. These factors affect repeatability and reproducibility of hardness test results.

Metallographic Preparation

Detailed focus on specimen preparation can reduce processing time and increase accuracy of test results. Sectioning cutting blades is best done using a precision saw with cubic boron nitride blades. This enables sectioning very close to the area of interest without inducing excess mechanical and thermal damage. Abrasive cutters may be used, though such machines are usually unnecessarily large for this application. The cut should be a short distance from the hardness test plane, taking into account material removed during grinding and polishing (commonly a few millimeters).

It is essential to clean and dry samples well prior to mounting. This, in conjunction with excellent quality mount media, will ensure there are no gaps between the media and sample.

Cutting blade samples exhibit high aspect ratio, which lends to molding multiple samples into one mount. Such an arrangement increases efficiency of both sample preparation and hardness testing. Specimen support clips are often necessary to maintain orientation of the sample during molding. Compression mounting is highly recommended, cast mounting may be performed, but is inferior to compression mounting for hardness testing. The highest quality compression media on the market is EpoMet. EpoMet is available in EpoMet G (granular) and EpoMet F (fine) variants. EpoMet F is preferred in this application as granular powders can shift samples in the mount during molding, resulting in loss of proper orientation for hardness testing.

The SimpliMet 4000 mounting press has a pre-load function. Pre-load applies a small amount of pressure at the beginning of the mold cycle to liquify the mount media prior to full application of pressure. This aids in maintaining the orientation of thin sheet type samples including cutting blades by ensuring un-melted media does not settle and shift samples about during initial stages of the mold cycle.

Table 1: Metallographic Preparation Method

Step No.	Surface	Abrasive	Lubricant/ Extender	Force (Per Specimen)	Time (min:sec)	Platen Speed (rpm)	Head Speed (rpm)	Rotation
1	DGD Yellow	35 µm Diamond	Water	6lbs (27N)	Till Plane	250	60	>>
2	DGD White	15 µm Diamond	Water	6lbs (27N)	05:00	250	60	>>
3	TriDent	3 µm Diamond	-	6lbs (27N)	04:00	150	60	>>
4	ChemoMet	0.05 µm Alumina	•	6lbs (27N)	02:00	130	60	>>

*>> Comp • Last 15-20 seconds flush platen with water * 1.25" mount, scale load by specimen mount diameter*

Automated grinding and polishing is preferable to manual work as automation provides reduced processing time and labor is not operator-dependent. The AutoMet and EcoMet 30 polishers enable programming of the preparation process, ensuring the same method is performed each time regardless of operator. To get the specimens as flat as possible, diamond grinding discs (DGD) and no-nap cloths are recommended. Central force grinding was also used to ensure uniform grinding and maximize planarity. With preparation of very hard material, it is important to minimize the amount of time polishing on soft surfaces, as this can also cause edge rounding, so polishing steps should be optimized and not be excessive. If the finish is not good enough after the last stage, rather than polish longer, go back and repeat earlier stages. The polishing route used is outlined in Table 1. A series of Apex DGD grinding discs were used to planarize the sample, and sequentially reduce scratches. Diamond discs are far superior to silicon carbide paper for retaining flatness. The TriDent cloth used for 3 µm diamond and the ChemoMet used for the 0.05 µm final polishing step were both selected for attaining best flatness in the sample.

Microhardness Testing

Selecting the proper set-up for microhardness testing on cutting blade specimens is critical. Proper system configuration is also important. For low load microhardness testing, the tester should be isolated from environmental vibration. If vibration is an issue, inaccurate load application can occur. Given that the test area is limited to the blade tip, repeating an indentation may require re-preparing the specimen. Therefore, an indent to be placed at the blade tip leaves no room for error. The hardness tester needs to be accurate and repeatable at low loads. A load cell tester allows highly accurate application of load, whereas drop-weight testers can be prone to slight overloads. Regardless of which type of tester is selected, the tester must be accurate, repeatable and in compliance.

When measuring low load indents, a 100X objective is a must. ASTM-E384 addresses the inherent difficulties with making and measuring indents below 20 µm due to the various possible measurement error. A 10% error (0.4 µm) in measuring 4 µm size indent at 100X through an eye-piece may not be uncommon, as the limits of optical resolution are being reached. Measurements made on a monitor improve accuracy and are re more repeatable repeatable than those measurements taken through a filar eye-piece, due to improved visibility. When diagonals are down to 4 µm size, a digital image makes measuring such small indents easier. The option of digital magnification would further improve measurement repeatability and accuracy.

Today's automatic hardness systems use computers and integrated software to control the hardness tester. It becomes an intelligent tester using sophisticated measurement algorithms to capture an indent's image and measure its diagonal lengths automatically. Auto-measurement allows fast, accurate and repeatable results and will convert the measured diagonals directly to a hardness value without requiring an operator to perform any calculation or use a look-up table. All of these functions help to significantly reduce the error and variance between operators.

The tester needs to be capable of locating and placing indents at designated points. An automatic tester will allow programming of hardness traverses with multiple indents at designated locations. The more intelligent software system allows specimen tracing and indent placements over created templates. For high volume quality verification testing, multi-sample testing can significantly reduce testing operation time. Time studies on automated hardness testing have shown a time-saving of over 80% compared to manual testers. Of course, the test process will vary for each situation; but, actual time-saving are generally significantly.

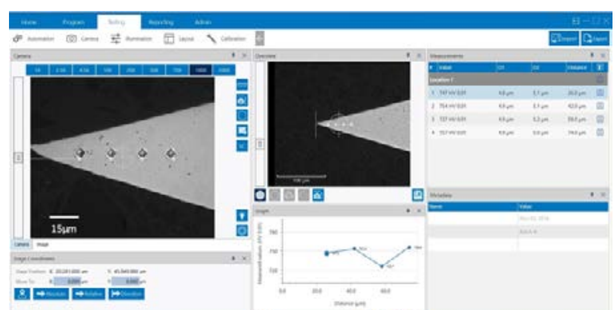

Figure 1: Microhardness indent performed on Knife Blade Tip, HV10gf 747 @ 26µm from blade tip. Tester: VH3300 automatic hardness tester with DiaMet software.

Summary

Quality assessment of cutting blades has its challenges, but these can be overcome. Technique and attention to details with specimen preparation is a key factor to success. Having the specimen flat with no edge rounding will allow an indent to be placed near the blade tip. The use of semi or fully automatic grinder/polishers will provide uniform, reproducible specimens.

The use of automatic hardness testers with integrated software systems and high quality optics is the other key factor. They reduce operator error and variance between different operators. Auto-measurement of indents is quick and accurate; indent placement is precise and repeatable, and the total hardness test time is significantly reduced.

BUEHLER

BUEHLER Worldwide Headquarters
North America-South America Offices
41 Waukegan Road
Lake Bluff, Illinois 60044-1699 USA
P: 800 BUEHLER (800-283-4537)
P: (847) 295-6500
www.buehler.com | info@buehler.com

European Headquarters
BUEHLER Germany
info.eu@buehler.com

BUEHLER France
info.eu@buehler.com

BUEHLER United Kingdom
info.eu@buehler.com

BUEHLER China
info.cn@buehler.com

BUEHLER Japan
info.japan@buehler.com

BUEHLER Asia-Pacific
info.asia@buehler.com