COMMON PROBLEMS IN MICROHARDNESS TESTING

Inherent to microhardness testing are the problems of accuracy, repeatability, and correlation. However, by using properly maintained and calibrated equipment, trained personnel, and appropriate testing environments, testing error and variability can be minimized.

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Vickers and Knoop testers are prolific. They are found everywhere from research labs to quality control laboratories. The sheltered environments in which they are typically housed (i.e. laboratory vs. shop floor) generally insure a long service life.

These methods of hardness testing are valuable tools in determining "shallow layer hardness," such as surface hardness, coating hardness, and case depth. Additionally, selective testing of particular grains or constituents could not be performed without these tests.

Most Vickers and Knoop testers are very accurate in applying the test force, as well as measuring distance. However, when most people think of microhardness testing, three terms often come into their mind: finicky, subjective, and time consuming. That having been said, in most cases, all three of these negative connotations are deserved for several reasons. However, advances in computer technology have reduced, if not eliminated, these unflattering adjectives.

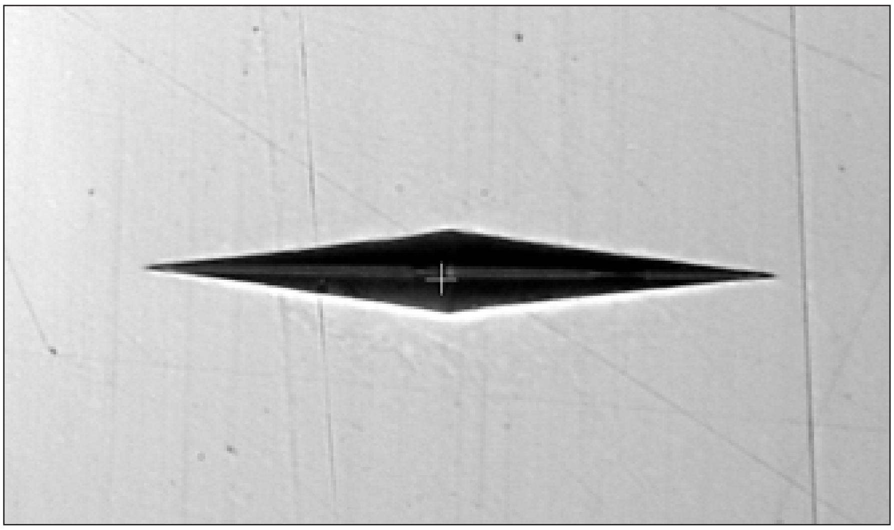
Microhardness testers are delicate instruments. Extremely light forces (typically from 10 –1,000 g.) must be accurately applied, and the resultant impressions (some as small as 10 microns) must be precisely measured under high magnification. A number of problems are inherent to these stringent requirements.

Three Basic Problems

Typically, microhardness testing problems can be separated into three categories — accuracy, repeatability, and correlation — and traced to five main causes — machine, operator, environment, sample preparation, and calibration.

Before discussing the causes, it is important to define the problems:

• **Accuracy —** The ability of the instrument to read in linear fashion on recognized hardness standards (certified test blocks), and its ability to



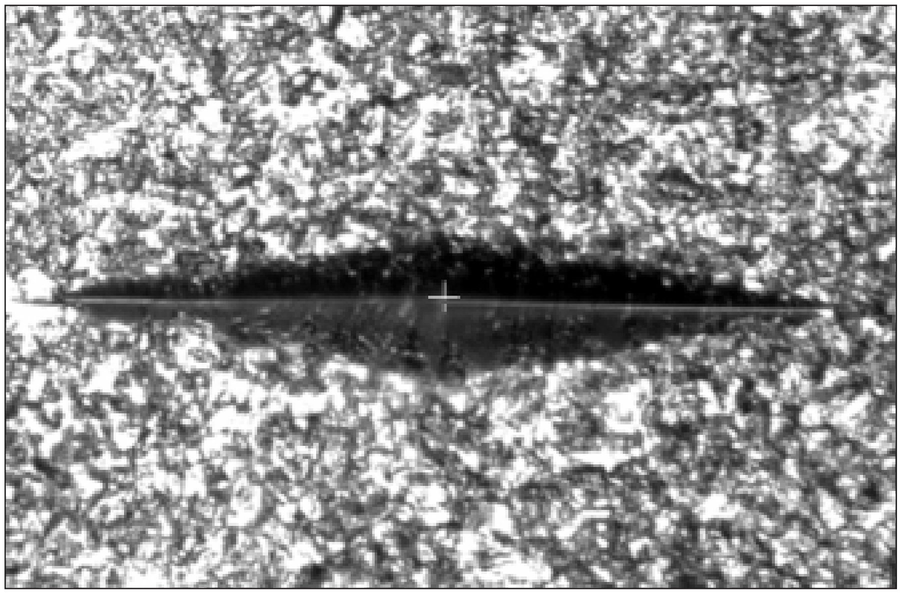
A Knoop indentation, as it appears on a smoothly polished surface, showing good tip definition.

transfer this accuracy onto test specimens.

• **Repeatability —** A measure of how well the instrument is able to duplicate its results on recognized hardness standards.

• **Correlation —** The ability of the instrument to produce results similar to those produced by another "properly calibrated" instrument; or the ability of two operators to measure the same impression using the same machine and achieve similar results.

With an understanding of these problems, we can better relate to their causes. While there are really only five major causes, there are numerous issues encompassed by each of them, the most common of which are discussed here.



A Knoop indentation, as it appears on an etched surface, showing poor tip definition - especially comparing the right side to the left.

The Machine

Microhardness testers use dead weights to create force. Unlike Rockwell hardness testers, these light loading devices (10-2,000 gf) stack the dead weights directly on top of the indenter. This eliminates the error of magnification and a lot of other negatives, such as knife-edges and hanging weights. Other units utilize screw drives to apply force, and load cells to control the amount of force applied. These types have their own set of repeatability and durability issues. Generally, these force application systems are robust. However, issues of indenter stroke can create erroneous loads.

With most machines, load application is done in two speeds — a "fast speed" to bring the indenter close to the test piece, and a "slow" speed to contact the work and apply the load. The "stroke" of the indenter is usually set with a measuring device. Once this "indenter tip to test surface" distance is set, the high power objective is focused on the test surface. Now, once properly focused, the operator will be assured that the work piece is contacted at the proper speed, and that impacting of the load has not occurred. It takes approximately 30 seconds for an instrument to make an impression, considering ASTM E384 standard dwell time of 15 seconds. This is part of the "slow" problem mentioned previously.

Alignment of the indenter with the objectives is critical when measuring case depths or just trying to accurately place an impression on a specific spot. Although the accuracy of the hardness value is not affected by this error, if the operator is measuring effective case depth, the distance from the edge of the sample may be wrong and ultimately result in an erroneous measurement. Also, if the operator is attempting to make an impression on a particular grain, or in the center of a thin coating, misalignment can make this difficult, if not impossible, to accomplish. Usually, knocking the indenter or the objective with the sample causes this misalignment, so care must be taken when loading samples or rotating the turret.

The Operator

No other discipline of hardness testing is as influenced by the operator as microhardness. Although this is true for both Vickers and Knoop testing, Knoop, with it's fine, seemingly endless tips, is the most susceptible of all. In general, the ability of an operator to accurately and repeatably resolve the ends of these impressions is most often the cause of error. Getting two operators to agree exactly, when measuring the same impression, is indeed a rarity.

This problem is often masked by users performing daily verifications of their machines. Here, operators can take their time measuring these impressions on test blocks of a known hardness whose test surfaces are typically in the optimal condition. There are two operative phrases here: "take their time" and "known hardness." In production environments, operators are sometimes rushed to perform tests and get parts out the door. All the care that was taken to insure the proper results on the Hardness Standard is nowhere to be found. Additionally, it can be a mundane and tiring task looking through the eyepiece for any period of time.

Often, the operator mentally knows the proper dimension of the impression and, when he goes to measure it, he "sees" that value. It's human nature.

Proper focus is a critical factor in achieving accurate results. As blurriness increases, so does perceived image size. Consistency of focus will help increase consistency of results. Be sure that *the surface of the sample, not the bottom of the impression, is the focus plane.* Most automated systems feature some means of focusing automatically, virtually eliminating this concern.

Recording and converting results from microns to Vickers or Knoop hardness numbers is another common source of error. A measurement of 32.3 microns can easily become 33.2 microns. We've all done it. When dialing a phone number we simply get the wrong person, but when converting hardness numbers, you get the wrong hardness value!

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Digital microhardness testers that utilize optical encoders to assist with measuring eliminate this. However, they do not find the impression ends. To help eliminate these problems, cameras can be attached to virtually any microhardness tester, as well as most of the "vintage" models still running everyday. These cameras feed an image to a computer, which enables the operator to view the image on the computer's monitor. Here, Vickers and Knoop impressions can be measured manually by clicking the mouse on the corners of the impression, or in more sophisticated software, the computer will perform a form of gray scaling to automatically determine the tips of the impression, and will display the hardness value, converted scale (HRC, etc.) and typically the average diagonal.

The enhanced magnification afforded by the camera and the monitor enable the operator to more precisely resolve the tips of the impressions. Also, viewing impressions on the monitor is far more comfortable and relaxing than squinting through an eyepiece, thereby reducing operator fatigue.

Depending upon the amount and type of studies being performed, various levels of sophistication are provided. Most basic forms provide for the ability to manually "click" on the tips of the impression, and the computer will display the hardness values, and in many cases, a converted secondary hardness value (i.e. HRC). Various levels of sophistication and automation spur from these basic systems.

The Newage CAMS (Computer Assisted Measuring System) is a modular system that can grow from a basic "click on the tips" type of a system, all the way through to full automation. This enables users to seek the sophistication level that best matches their needs and, should the requirements change, allows their system to grow. Operating in a Windows environment, CAMS also collects, files, and stores all the data, eliminating errors of transposition or data co-mingling.

Automatic measuring is one of the most popular features of the CAMS system. Operator influence over the measurement of impressions is eliminated, as is the sometimes time-consuming process associated with measuring. Once the operator clicks on the "measure" icon, the image is captured, and the impression is measured in a blink of the eye. Actual diagonal length, hardness value, and converted scale are displayed on the screen, and can be saved to a file.

The Environment

Because of the light loads utilized in microhardness testing, vibration can be a contributor to loading accuracy. Even if the part is not impacted during loading, the oscillation of the indenter or the test specimen can cause the indenter to work its way deeper into the part, creating a softer result. Microhardness testers should always be placed on a dedicated, level, sturdy, table that is free standing. Often, machines are placed on appropriate tables, but which are inappropriately located, such as against a wall or an adjoining table or counter. This scenario can lead to inaccurate results caused by a slamming lab door that sends movement down the wall, or by someone working on the adjoining table creating movement that is translated through the table.

High magnification optical systems are utilized in microhardness testers to assist the operator in defining the small tips of the impressions. Dirt in the optical path (the ocular, optical encoder, tube, or objective) can obscure the impression or the measuring lines, making bad enough worse. A clean environment will help diminish the chances of this occurring. Common sense goes a long way here: don't cut, grind, or polish samples in the immediate area of the hardness tester. It is this fine particulate that is most apt to find its way into the instrument.

Sample Preparation

In most cases, samples are sectioned and mounted in bakelite or epoxy mounts prior to testing. Once sectioned and mounted, the samples are ground, sanded, and polished to provide a test surface that is free of scratches and surface texture that could otherwise interfere with the operator's ability to discern the tips of the impression.

In production laboratories the demands of production sometimes do not enable the operator to spend the time necessary to realize a proper finish. Often this results in undulating surfaces, rounded edges that are difficult to discern, and surface imperfections that make it difficult to accurately measure the tips of the impression.

When etching samples, the surface of the part is chemically corroded, providing metallographic contrast. Although etching of samples helps define grain structure, heat affected zones in welds, total case depths, and decarb layers, it lessens the contrast between the test surface and the tips of microhardness impressions. In many cases this diminished contrast can create difficulty or the total inability to measure the impression. If microhardness testing is to be performed on an etched sample, etch to the minimum required to visually discern the desired attribute.

Although most automated microhardness testing systems can automatically measure Vickers and Knoop impression repeatedly on finely prepared samples, many are fooled by surface anomalies and changes in contrast. Typically, systems that utilize "thresholding" techniques to determine the impression size are the most susceptible to these issues, and will exhibit the greatest amount of variation and error.

A Vickers indentation, as it appears on a rougher ground surface, showing potential for tip identification problems from grind marks

Calibration

Most microhardness testers lead a charmed life in comparison to Rockwell and Brinell testers. Because of the previously discussed environmental concerns, these instruments usually wind up in laboratory environments, free from the dirt and oil that can plague other hardness testers. Consequently, microhardness testers tend to have a long useful life, with little to go wrong between calibrations.

Fortunately, most microhardness testers are very consistent in their ability to apply force. With the exception of load cell units, this is rarely ever an issue when it comes to calibration.

The measuring systems in microhardness testers vary widely, ranging from micrometer heads on an ocular, to optical encoders attached to a digital readout. One thing they have in common is they are dependent upon being at a specific magnification, or distance (the ocular slides in/out to increase/decrease magnification) from the objective. To directly verify the measuring system, a stage micrometer is placed on the anvil, and the instrument's measuring lines are place at a known distance on the stage micrometer. This distance is then compared to the unit's measuring system. If they agree, all is well. If not, the ocular is moved in/out to increase/decrease the measuring distance. The point of all of this is that if you are not careful of the ocular position, the *measuring* accuracy can be compromised.

Microhardness testers are usually indirectly verified against Standard Hardness Blocks. As the resultant impressions are extremely small, these standard blocks can appear to last forever. On one hand this is true, but on the other, improperly handled blocks can become scratched, making them difficult to read. In severe cases, improper handling on softer materials, work or age hardened, can change the value of the block. This emphasizes the need for checking multiple Standard hardness blocks.

Since microhardness testers' impressions reside in very thin sections of the test surface, it is significant that test blocks are calibrated in the forces that are typically used. Test block values should only be considered at the forces at which they were calibrated. This means that it is inappropriate to use Rockwell blocks and convert them to Vickers or Knoop values. Tempting as this may be, it may yield erroneous results, and is prohibited by ASTM E 384. Test blocks can be calibrated at several forces to minimize the number of test blocks needed.

Conclusions

The unrivaled source of error in microhardness testing is that induced by the operator. This gets compounded when surface preparation is poor and when the "heat of the battle" is on. The mundane nature of measuring multiple impressions also contributes to fatigue and subsequent errors.

How do we then minimize this effect?

In sporadic testing situations, be sure the operator is properly trained, has the proper tools to prepare the test surface, the instrument is properly calibrated and in proper working condition, and that he has time to do the

Computer-based microhardness testing systems, like Newage's CAMS (Computer Assisted Measuring System), reduce the operator's influence on measurements and speed up testing.

job properly. With a conscientious operator error will be minimized.

Where there is a need for more frequent or higher volume testing, some level of computer assistance will help. Most microhardness testers, regardless of age, can be adapted. With today's technology, impressions can be read in a much more repeatable manner by computers, and in a fraction of the time. And the computers don't get bored or tired, they have a greater sensitivity for shifts in contrast, and they can repeat their measurements. Additionally, these systems can be fully automated to include automatic focus, automatic table positioning, data collection, and charting. Automation further eliminates sources of error.

Other instruments, such as our MT90 system, utilize the Rockwell principle of testing with microhardness-appropriate loads. As these devices are measuring depth, they are not influenced by the operator, and can read on far rougher surfaces. Test cycle times are also reduced dramatically.

Used and maintained properly, microhardness testers can be invaluable tools in the lab and for process control. Taking the time to review some of the recommendations made in this article will lead to more credible results and better process control.

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