COMMON PROBLEMS IN

ROCKWELL HARDNESS TESTING

Problems related to accuracy, repeatability, and / or correlation usually can be traced to one or more of five causes: machine, operator, environment, sample prep, and calibration.

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As manufacturers of hardness testing equipment, we're often called upon to help users with problems associated with testing. As is typical with most customer support roles, it seems that the same difficulties arise time and time again, and this also is true for Rockwell hardness testing. The purpose of this article is to address the more common problems associated with Rockwell hardness testing, and hopefully prevent them from occurring in the reader's facility.

Three basic problem types

Typically, most Rockwell hardness 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 a linear fashion on recognized hardness standards (certified test blocks), and it's ability to transfer this accuracy onto hardness test specimens.
- *Repeatability:* A measurement 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.

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.

Testing machine-related causes

The most common problem we hear is, "My machine is reading high." This always raises the "bad indenter" flag. In the case of testing hardened steels, diamond indenters are required to penetrate the material. Diamonds are used because of their hardness and ability to maintain their geometrical form. However, the very trait that enables diamonds to penetrate steel — high hardness — is also their Achilles' heel. A diamond's hardness renders it brittle, and an impact or shock can cause it to break, changing it's dimensional form from a radiused tip to a flat or other non-spheroconical shape. This new shape will offer more surface area to the test specimen, increasing its resistance to penetration,

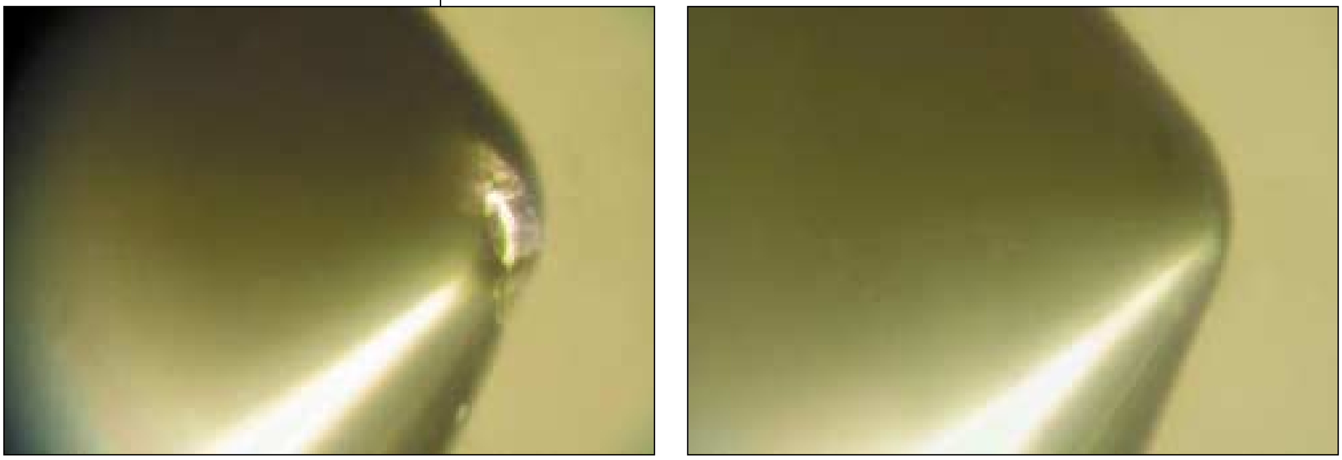

Fig. 1 — Left: Broken Rockwell diamond indenter. Note interrupted radius and angle, which will create greater resistance to penetration. Right: Unbroken diamond indenter. Note nicely formed radius and smoothed edges to form angle.

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Fig. 2 — Proper support of parts is critical. Some machines, such as this one, are capable of clamping parts prior to the application of loads, providing a stable test piece.

Fig. 3 — Rockwell hardness testers are often asked to perform in harsh environments. In these cases, says the author, the elevating screw and its bearings should be cleaned during every servicing of the instrument.

and therefore yielding an incorrect higher hardness value. Examples of broken and unbroken indenter tips are shown in Fig. 1.

Inspectors have been known to compound this problem. To avoid admitting to breaking the diamond, they may "forget" the traumatic incident, allowing others to unknowingly continue testing with a damaged indenter.

Ball indenters: The same holds true for ball indenters. ASTM E18, the specification that covers Rockwell hardness testing, still permits the use of high-speed steel balls. One test on a very hard piece of steel ($\geq$58 HRC) will put a flat on the ball and produce high readings for the same reason that a broken diamond indenter does. (ASTM E18 is a copyrighted document of American Society for Testing and Materials, www.astm.org.)

The current version of E18 recommends the use of carbide ball indenters to eliminate the problems associated with flattening of high-speed steel balls. The next version of E18 will mandate the use of carbide balls for routine work, but will allow for the use of steel balls with prior agreement from other parties involved. By the way, if you aren't already using carbide balls, it's not too early to prepare for the switch. An existing penetrator can be used with the simple addition of a carbide ball. However, because of the difference in deflection between carbide and steel balls, it is imperative that machines using carbide balls be verified with test blocks that were calibrated with carbide balls.

Deflections: Machine deflection caused by dirt, grease, burrs, and other sources is also a significant contributor to machine errors. Most Rockwell-scale testers are unable to compensate for deflection (or movement) under load. (The Newage Versitron is an exception.) Poor maintenance, sample preparation, or wear are the typical culprits here.

Part deflection is another issue that can cause more than erroneous results. Adding insult to injury, it often can cause diamond indenters to break.

A major cause of part deflection is improper fixturing. With the exception of testers that clamp parts into place prior to the application of loads, such as the Versitron (Fig. 2), it is rarely, if ever, appropriate to cantilever a test specimen off of the anvil . The specimen should always be firmly supported prior to the application of loads. Only rarely does holding the part by hand suffice. To get a sense of the importance of having a stable test specimen, consider that each Regular Rockwell point is equal to 0.0008 in. (0.02 mm), and each Superficial Rockwell point is equal to 0.0004 in. (0.01 mm).

Anvils: An often overlooked source of error is the anvil. Rough or gouged anvil surfaces, anvil surfaces that have been inadvertently hardness tested, and anvil surfaces that are worn or ground to a taper can all spell disaster. In addition, the seating surface of the anvil and the anvil mating surface on the elevating screw also can be culprits in conventional Rockwell testers. These surfaces should be lapped together every few service visits to ensure that they are flat and burr-free.

Operator-related causes

It is no surprise that operators often can be the source of problems in Rockwell hardness testing. Training operators to be competent in the discipline means that they should understand the theory of the test method, the proper operation of the instruments they are responsible for running, and the surface preparation requirements and fixturing techniques for the parts they are responsible for testing. By gaining an understanding of these areas, the operator will acquire sensitivity to the test method and the abstract thinking required to prevent some of these problems from occurring. In most cases, training operators properly once will eliminate rework, and will help to protect the investment made in the testing instrument.

Environment-related causes

Dirt and vibration are without a doubt the most often encountered causes of errors in Rockwell hardness testing. Unless your hardness tester has "test surface referencing" — the ability to establish and maintain a referencing relationship between the indenter, the indenter shroud, and the test surface — dirt in the elevating screw nut, in bearings, or under the anvil can wreak havoc with all but a few machines. As mentioned previously, the deflection caused by dirt typically will result in low readings.

A little bit of housekeeping, combined with common sense will help to minimize these problems. For example, grinding samples in the immediate vicinity of the Rockwell tester (especially grinding in the direction of the instrument) should be discouraged. If the environment cannot be improved, then the instrument should be covered when not in use.

Vibration also can lead to softer than expected results, especially with deadweight machines. Gross vibration can cause the weights to bounce, resulting in impacts that increase the amount of force applied to the parts. Also, the vibration or impact caused by a nearby drop-forge hammer can cause the part to move, resulting in the same type of erroneous reading. Again, bear in mind that we're talking about a measuring resolution in the millionths of an inch.

Surface preparation-related causes

Rough surfaces cause rough results. If you're only interested in knowing roughly how hard a part is, a rough surface will work. But if you're interested in accurate, consistent test results, always test a shiny surface. Even though the Rockwell method begins its hardness measurement beneath the surface of the part, the inherent variability of a rough surface can and will cause inconsistent results.

Surface coatings or hardened layers also can provide deceptive results. If you want to test the hardness of a coating or surface layer, use a load / indenter combination that will ensure that the measurement is taken in the coating or layer. Remember the 10X rule: the thickness of a part or coating must be 10X greater than the maximum depth of penetration. On the other hand, if you are interested only in the hardness of the substrate and not that of the coating, the coating or surface layer must be removed using a suitable surface preparation technique.

Scale and decarburized surfaces also will deliver erroneous results. In these cases, it is imperative to remove all of the scale, and to grind to below the decarb layer before conducting a hardness test.

An important note: Unless you're using an instrument that features test surface referencing, surface preparation applies to the underside of the test specimen as well. Remove any loose scale, oil, or grease because they also will cause deflection and erroneous results as previously described.

Fig. 4 — Competence of service organizations varies dramatically. Minimally ensure that you are dealing with a source accredited to ISO/IEC 17025.

Calibration-related causes

"The soup is only as good as the ingredients you put in it." The same is true for instrument maintenance and calibration. If your service agency is doing no more than "throwing the blocks on the machine" — something you could do yourself — then it's high time to look for a new service agency.

The most important part of a calibration visit should be the preventive maintenance performed on the hardness testing machine. In most shop environments, the minimum that should be done is cleaning the elevating screw and its bearings. In dirty environments (Fig. 3), this should be done at every servicing. In a laboratory environment, which typically is much cleaner, every other servicing typically suffices.

A dirty machine may read appropriately when the verification is performed, but readings often change as the foreign matter is compressed and densified. (This foreign matter may actually be compensating for another error elsewhere in the loading / measuring mechanism.)

Your next servicing also would be a good time to make the switch to carbide balls if you're still using high-speed steel balls.

Lastly, investigate service providers that are accredited to ISO / IEC 17025 (Fig. 4). In *most* cases, accreditation of conformance to this specification can provide reasonable assurance of the provider's competence.

Importance of training

It should be evident that many of these common problems can be avoided if operators are properly trained. Proper training goes beyond just showing the operator how to "test this part." It includes an appreciation of hardness testing theory, an understanding of environmental implications, and knowledge of proper surface preparation and machine maintenance techniques.

This is not meant to imply that operators cause all problems. The instrument is not infallible, but in many cases, a lack of maintenance or mechanical or electrical problems with the instrument will cause machine failure and not erroneous readings. Even so, problems like these will become apparent in test block readings. However, this should in no way diminish the need for regular maintenance by a competent service provider. **HTP**

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