

Practical Considerations for Successful Hardness Testing

By Alan Stone, Aston Metallurgical Services, Inc., and Daniel H. Herring, The HERRING GROUP, Inc.

Everyone knows how to perform a hardness test, or do they? Hardness testing is made more complex by such real world factors as a hard case over a soft core, hard particles, soft inclusions, and soft layers over hard cores to name a few. Part size, shape, and weight are other test challenges. Selection of the best test method, use of proper procedures, and a keen awareness of what and where to test are needed.

Hardness testing is one of the most common quality control checks performed. It is often used to determine the success or failure of a particular heat treatment operation or to understand the material's current condition. Hardness testing is one of the easiest tests to perform on the shop floor or in the laboratory, but it can be one of the hardest tests to do properly.

Hardness is a property determined by measuring the resistance to deformation from an applied load. Alignment of the indenter to the sample surface is crucial to correct hardness measurements. The penetration is measured by either depth or area, which is then translated into a hardness number. It is important to realize that all conventional hardness-testing methods involve sampling some volume of material. The amount of material actually sampled is

a function of the indenter selected, the applied load and the material properties. If the sampled volume is limited by the physical size of the piece to be tested, then you may actually be sampling the underlying anvil or pushing out beyond the edge of the sample.

The most commonly used indentation hardness tests are the Brinell, Rockwell, Rockwell Superficial and microhardness methods. The Brinell test is used primarily for inhomogeneous materials such as forgings and castings, particularly cast iron. The Rockwell test (Table 1) is used for both ferrous and nonferrous materials, which have been annealed, hardened, case hardened or tempered. Sheet materials in heavier gages and cemented carbides can also be tested. Rockwell Superficial is used where lighter loads are required for testing thin case hardened surfaces, decarburized layers and sheet material in thin gages.

Microhardness tests are typically used for very small, intricate shapes, thin parts and for case depth determination.

Types of Indenters & Test Methods

Brinell testing uses larger indenters (e.g. 10 mm) and heavier loads (e.g. 3000 kg) to minimize localized feature effects such as graphite flakes or voids in castings. Common indenters for Rockwell testing include diamonds and steel or carbide balls (although steel is being phased out). Applied testing loads range from 15kg for the Rockwell superficial scales to 150kg for the "C" scale.

To illustrate the concepts of hardness testing, imagine a pen being pushed into a small cubic chunk of clay and then retracted (Figs. 1, 2, 3). You are left with a hole where depth is dependent on the force applied load and the resistance of the



Fig. 1

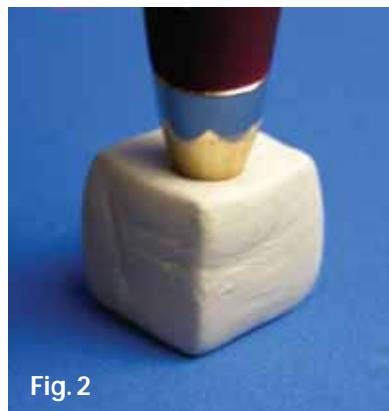


Fig. 2

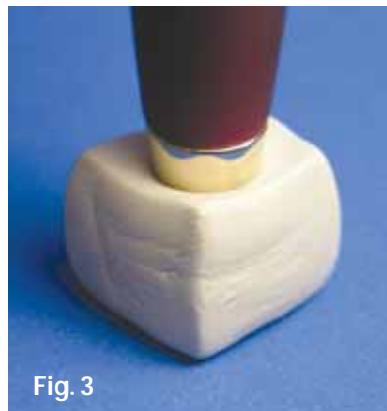


Fig. 3



Fig. 4

Fig. 1. Large Pen Indenter Applying Initial Load into Clay Cube. Fig. 2. Large Pen Indenter Applying Intermediate Load into Clay Cube. Fig. 3. Large Pen Indenter Applying Excessive Load Bulging Sides of Clay Cube. Fig. 4. Small Pen Indenter Applying Load to Clay Cube with Minimal Side Distortion

clay to the indentation. A different sized or shaped pen (Fig. 4) produces a different type of indentation. As shown, the heavy loads produce deeper indentations and sample more volume of material. The higher the hardness of the material, the more resistant it is to penetration and the shallower the resultant indentation.

From this explanation, hardness testing sounds pretty simple. That is, until you factor in real world considerations. What happens if there is a hard case (e.g. nitriding, carburizing, and plating) over a soft core? Or a soft layer over a hard core (e.g. decarburization)? Or soft inclusions for machinability? Or hard particles such as carbides? What if the shape is complex and you don't have flat parallel surfaces? Or you can't get your indenter to the region of interest? One of the most common problems we see is that the material is too thin, too soft or too irregularly shaped to allow for Rockwell testing. Another common problem is that the method specified or the individual performing the test fails to account for the three dimensional aspect of the part, and the test does not truly sample the appropriate volume of material.

Indenter for microhardness testing (Fig. 5) include Knoop and Vickers with applied loads ranging from 1 gram to 1000 grams. The indentations are typically measured optically at magnifications from 400 to 1000x. High quality optics is critical especially when using magnifications of 500x and greater. Accurate measurement of the indentation boundaries, especially when using lighter loads, is mandatory

Microhardness testing is ideal for precise sampling of a small region, for a very thin part (Figs. 6, 7), a soft sample, or a material with either hard or soft particles you wish to include or exclude from the field of measurement. The Knoop and Vickers indenters have different aspect ratios. Knoop indenters are elongated and better suited for more precise measurements of layers or for measurements at specific depths. Vickers indenters are more symmetric and better suited for particle hardness measurements.

The key to microhardness testing is that it requires more sample preparation and operator skill, as well as more elaborate testing equipment. Unlike Rockwell scales,

microhardness numbers are affected by the applied load. For example, a Knoop hardness value of 100 taken with a 500-gram load ($HKN_{500} 100$) is not equivalent to a Knoop hardness value of 100 taken with a 50-gram load ($HKN_{50} 100$). Hence it is critical to report the applied load along with the test

result. It is also important to know that ASTM E140 only recognizes microhardness conversions with minimum loading of 500 grams. Consequently, conversions to Rockwell scales produce errant values at increasingly lighter loads (Fig. 8).

Microhardness testing is sensitive to a

Table 1 Typical Rockwell Scale Applications^[1]

Scale Symbol	Typical Application of the Scale
A	Cemented carbides, thin steel and shallow case hardened steel.
B	Copper alloys, soft steels, aluminum alloys, malleable irons.
C	Steel. Hard cast irons, pearlitic malleable iron, titanium, deep case hardened steel, and other materials harder than HRB 100.
D	Thin steel and medium case hardened steel and pearlitic malleable iron
E	Cast iron, aluminum and magnesium alloys, bearing materials.
F	Annealed copper alloys, thin soft sheet metals.
G	Phosphorous bronze, beryllium copper, malleable irons and materials softer than HRG 92.
H	Aluminum, lead, and zinc.
K, L, M, P, R, S, V	Bearing materials and other very soft or thin materials. Use the smallest ball and heaviest load that does not give anvil effect.
N	Applications similar to the A, C, and D scales but of thinner gage or shallower case depth.
T	Applications similar to the B, F, and G scales but of thinner gage.
W, X, Y	Very soft materials.

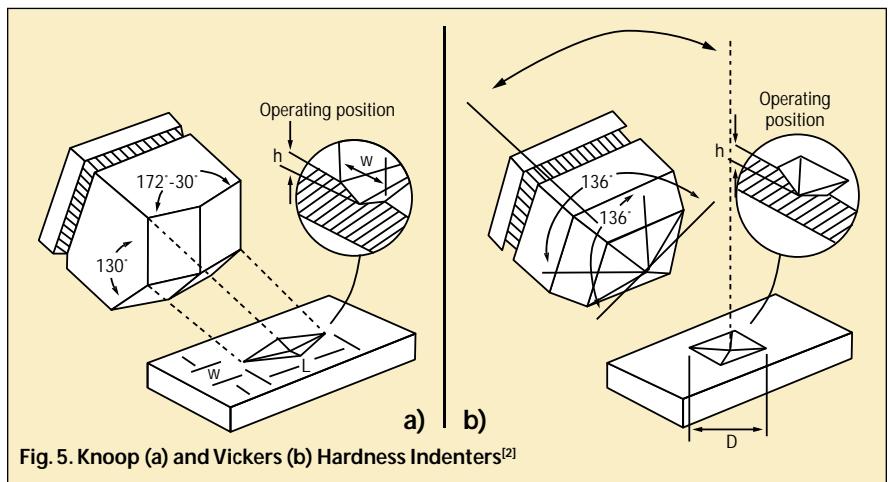


Fig. 5. Knoop (a) and Vickers (b) Hardness Indenters^[2]

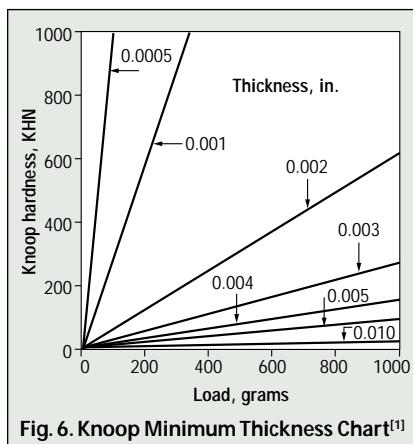


Fig. 6. Knoop Minimum Thickness Chart^[1]

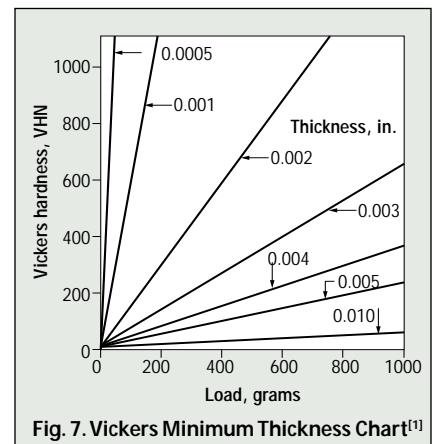


Fig. 7. Vickers Minimum Thickness Chart^[1]

number of variables such as indentation spacing (Fig. 9), material segregation, inclusions, edge effects and cold working.

Summing Up

Most people need not be experts in all the intricate details of hardness testing.

Should you find yourself in a dispute regarding hardness and hardness testing methods, the first item to confirm is that the specified hardness is appropriate for that material. Next, investigate how the hardness was measured and if it was a suitable method for that sample. While there can be shades of gray and varying levels of uncertainty between hardness testing machines or laboratories, expect some level of consensus if the methods are correct.

ASTM guidelines^[3] state the Rockwell readings should be reported to the nearest integer.

Everyone involved with hardness testing should have and be familiar with the

appropriate ASTM specifications. These address proper sample preparations, selection of loads and penetrators, sample geometry, minimum sample thickness considerations, roundness corrections, spacing and edge considerations, and conversions between scales. **IH**

References

1. Lysaght, Vincent E., and DeBellis, Anthony, *Hardness Testing Handbook*, American Chain and Cable Company, 1969.
2. Wilson Instruments Division, Instron Corporation, Norwood, MA (www.wilsoninstruments.com)
3. ASTM Specification Nos. E3, E10, E18, E103, E140 and E384 (www.astm.org).

Additional related material may be found by searching for these (and other) key words/terms via BNP Media LINX at www.industrialheating.com: Hardness testing, Rockwell, Rockwell superficial, Knoop, Vickers, microhardness, indentors, ferrous, nonferrous, material properties

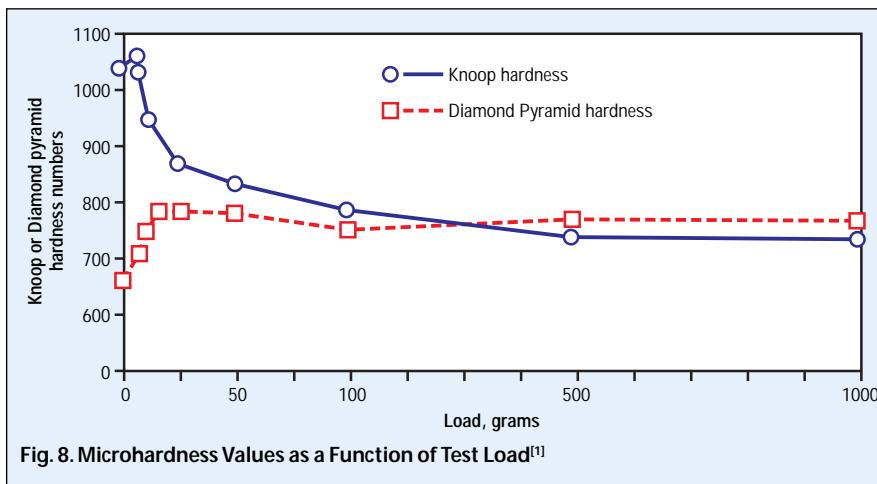


Fig. 8. Microhardness Values as a Function of Test Load^[1]



Fig. 9. Knoop Indentation Causing Localized Work Hardening

PROTECT YOUR PROFITS

CERAM-GUARD®

METALLURGICAL COATINGS

- INCREASE YIELD
- REDUCE SCALING
- CONTROL DECARB
- RESIST GAS ABSORPTION
- FORGING LUBRICATION

AT TEMPERATURES TO 2300°

PROTECTS DURING PROCESSING OF...

- High Carbon Steels
- Stainless Steels
- Tool Steels
- Titanium
- Nickel Alloys
- Molybdenum

A. O. SMITH
PROTECTIVE COATINGS
DIVISION

A DIVISION OF A. O. SMITH CORPORATION

www.hotwater.com

For Information
call
859-727-3500
or write
8160 Holton Dr.
Florence, KY 41042

Info # 80 or www.IHainfo.cc