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Microindentation Hardness Testing of Materials Using ASTM E384

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The origins of ASTM date back to the end of the 19th century. At this time two of the largest industries in America were the railroads and the steel industry. While the railroads linked the nation, the steel purchased from one mill for a particular application could have greatly different properties than a similar alloy purchased from another mill. Establishing voluntary, consensus, conformance standards in the steel industry was one of the driving forces for the creation of ASTM. With this in mind, it seems obvious that the first ASTM committee to be formed was A01, Steel. As standards for steel alloys were being developed, the next logical progression was the development of standard methodologies to test materials; hence, committee E01 on test methods was formed. In 1916 committee E04 was spun off from committee E01. While the first focus of E04 was to develop a set of standard magnifications to use for evaluating steel microstructures, with time the scope became much broader. The current name "On Metallography" was adopted in 1921. Today ASTM International has over 30,000 members from more than 100 countries, and is responsible for over 11,000 standards. Committee E04 is currently responsible for 36 standards concerning metallography and similarly related topics. Standard E384, Standard Test Method for Microindentation Hardness of Materials is one of the standards in Committee E04's charge [1].

The concepts of "hardness" and "softness" are as old as they are ambiguous. Defining the term hardness is nearly impossible because the definition depends on the method of measurement, and that determines the hardness scale. The methods of measuring hardness are dependent on several different properties of the material being tested. The elastic and plastic deformation characteristics of the material, the elastic limit, elastic modulus, yield strength, tensile strength and brittleness of the material all effect a hardness measurement. Standard hardness tests such as the Brinell test involve the application of single loads as high as 3,000 kgf (29.4 N). The hardness of the material is related to the diameter of the ball that is forced into the material being tested. Where as the Rockwell type of tester applies a minor load and then a major load. The hardness scale is related to the differential change in penetration caused by the indenter after removal of the major load.

Microindentation hardness testing involves much smaller forces than those used in a conventional hardness test. As describe in ASTM E384, the forces used in these tests range from approximately 1gf to a maximum of 1000gf ($9.8*10^{-3}$ to 9.8 N). Two types of testing are covered by this standard, the Knoop and the Vickers test. The difference between the two tests is related to the geometry of the indenters. The Knoop indenter is a rhombic-based pyramidal-shaped diamond indenter with edge angles of $\angle A = 172° 30'$, and $\angle B = 130° 0'$, Figure 1. The long diagonal of the Knoop indenter is approximately 7.14 times the length of the short diagonal. The Knoop hardness number is based upon the force divided by the projected area of the indentation. The Vickers indenter is a square based pyramidal-shaped diamond indenter with face angles of 136°, Figure 2. The Vickers hardness number is based upon the force divided by the surface area of the indentation. The material hardness are calculated by using the following equations:

$$HK = \frac{14229 * P}{d_k^2} \quad \text{and} \quad HV = \frac{1854.4 * P}{d_v^2}$$

For the Knoop hardness equation, 14229 is related to the indenter constant, P is the test load and d_k is the length of the long Knoop diagonal. For the Vickers hardness equation, 1854.4 is a geometrical constant, P is the applied load and d_v is the average length of the two Vickers diagonals. For these equations, the loads are in gram-force and the diagonal lengths are measured in micrometers (μm).

This presentation will discuss the major aspects of the different sections of the standard. The standard describes in detail how the testing is to be performed, the details regarding the apparatus used to perform the tests, the proper test specimen to use when conducting the test, the method for reporting the test results and a Precision and Bias statement. The Precision and Bias statement contains information regarding factors that can effect the results of the test. In addition, the Precision and Bias statement is supported by the results of an interlaboratory set of tests on ferrous and nonferrous specimens. The interlaboratory test results were used to determine the Repeatability and reproducibility of the test procedure. Currently, E04 is conducting an inter-laboratory test to assess how test results obtained by manual methods compare to results obtained by automated video procedures.

The standard contains two annexes. These sections contain information regarding direct and indirect verification of the testing machines and procedures for the calibration of standardized hardness test blocks used to verify microindentation hardness testing machines. Other information contained in two appendices regarding the interlaboratory tests conducted for this standard, and recommendations for light force microindentation hardness testing will be discussed.

Reference

[1] ASTM E384-00 Test Method for Microindentation Hardness of Materials, American Society for Testing and Materials International, Volume 03.01, W. Conshohocken, PA, 2003.

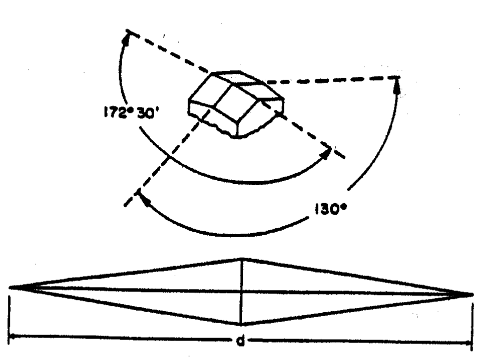

Figure 1. Geometry of the Knoop indenter and the Knoop indent.

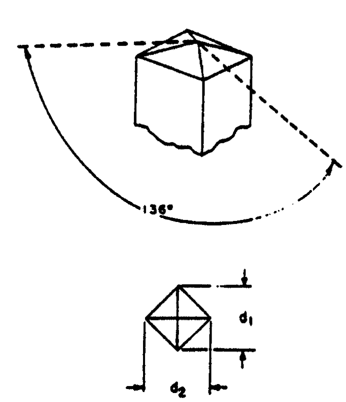

Figure 2. Geometry of the Vickers indenter and the Vickers indent.

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