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Introduction

HARDNESS IS AN IMPORTANT PROPERTY WHEN JUDGING THE QUALITY and possible applications of a material. It can also give indications concerning the tensile strength, ductility, or wearing quality of the material.

Beginning in approximately 1822, quantitative evaluation of hardness was carried out based on the hardness scale developed by F. Mohs. He ordered known minerals so that the harder mineral scratched the one preceding it.

TABLE 20.1—Mohs Hardness Scale.

Mohs Scale	Mohs Standard Mineral	Equivalent Knoop Hardness Number
1	Talc	2
2	Gypsum	32
3	Calcite	120
4	Fluorite	150
5	Apatite	400
6	Feldspar	560
7	Quartz	700
8	Topaz	1300
9	Corundum	1800
10	Diamond	6000

It must be noted that the differences in hardness between the individual steps of the scale are not equal. For example, the difference between steps 9 and 10 is substantially greater than that between 1 and 9.

Around 1900, further testing procedures were developed for technical purposes. In these procedures, hardness is not determined by scratching, but rather by indenting the material to be tested with very hard objects of a specified size and shape. The Brinell, Rockwell, Vickers, and Knoop hardness testing procedures are the best known of these techniques.

Already in 1900, Martens suggested the following definition of hardness for technical purposes:

Hardness is the resistance of a material to penetration by another (harder) material.

This simple conceptualization remains the basis of our understanding of hardness even today.

20.1 Indentation Hardness

Figure 20.1 schematically shows the significant elements of indentation hardness testing. A particular indenter (1), attached to the lower end of a press, is pressed into the

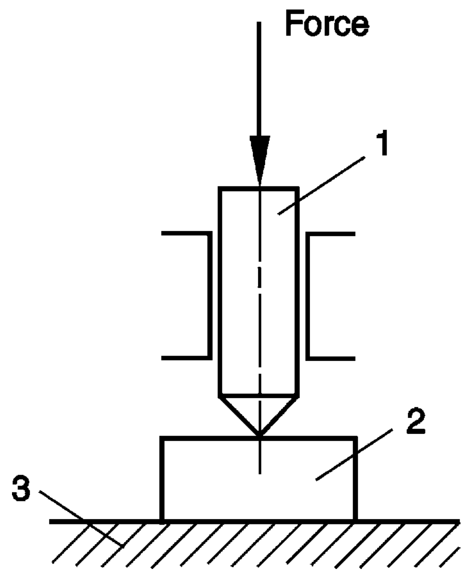

Fig. 20.1—Schematic drawing of hardness tester indicating force, indenter (1) specimen (2) and support (3).

specimen surface (2) with a particular test force (in N or kgf) and then pulled back. The indentation that is created can then be measured.

The shape and size of the indenter are decisive for indentation resistance. With ball-shaped indenters, the specimen material is pushed away sideways and downwards through plastic and elastic deformation. Angular or needle-shaped indenters can, in addition to the deformation, cause separation processes like cracks, especially in brittle materials (ceramics).

Depending on the characteristics of the material being tested, various mostly non-homogeneous deformation processes with multiple axes and varying degrees of elasticity and plasticity occur with penetration.

The speed of penetration also influences the behavior of the material being tested. For these reasons, the guidelines for the hardness testing procedures, including equipment construction, indenter, penetration speed, optical system, and evaluation are of particular importance.

Hardness is a distinguishing feature of a material. It is usually measured quantitatively according to the following general relationship:

$$\text{Hardness value} = \text{Test force/indentation size} \quad (1)$$

Beginning in 1940, hardness testing procedures in which the penetration depth is measured during application of a test force and then used to determine hardness were developed. These procedures quickly gained in importance.

We differentiate among:

Hardness testing procedures with static load action.

Hardness testing procedures with dynamic load action.

Special hardness testing procedures.

The most important of these will be shortly described below.

20.2 ASTM Standards

To be able to compare hardness values, the equipment, testing procedures, testing method, and evaluation must correspond to particular standards. The following ASTM standards describe the various hardness testing procedures. See Section 12.4.2 for more standards on hardness.

Standard Practices for Force Verification of Testing Machines (E 4)

Standard Test Method for Brinell Hardness of Metallic Materials (E 10)

Standard Test Methods for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials (E 18)

Standard Test Method for Rapid Indentation Hardness Testing of Metallic Materials (E 103)

Standard Test Method for Indentation Hardness of Metallic Materials by Portable Hardness Testers (E 110)

Hardness Conversion Tables for Metals (Relationship Between Brinell Hardness, Vickers Hardness, Rockwell Hardness, Rockwell Superficial Hardness, Knoop Hardness and Scleroscope Hardness) (E 140)

Standard Practice for Scleroscope Hardness Testing of Metallic Materials (E 448)

Standard Test Method for Microindentation Hardness of Materials (E 384)

Standard Test Method for Vickers Hardness of Metallic Materials (E 92)