HARDNESS TESTS OF CERAMICS

Hardness is resistance of material to Plastic deformation caused by indentation. Sometimes hardness refers to resistance of material to scratching or abrasion.

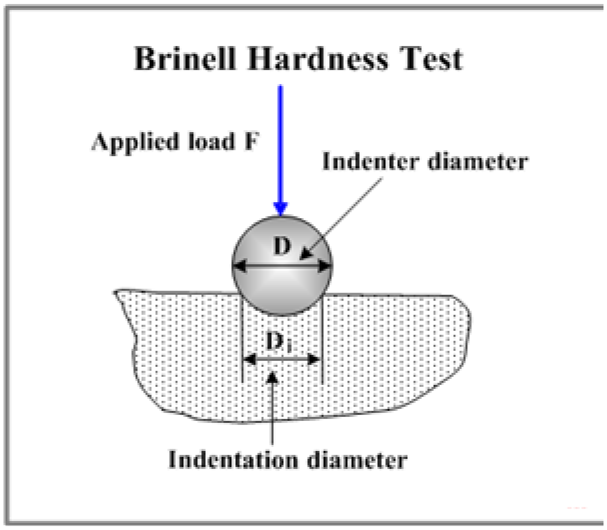
In some cases relatively quick and simple hardness test may substitute tensile test.
Hardness may be measured from a small sample of material without destroying it.

There are hardness methods, allowing to measure hardness onsite.

Principle of any hardness test method is forcing an indenter into the sample surface followed by measuring dimensions of the indentation (depth or actual surface area of the indentation).
Hardness is not fundamental property and its value depends on the combination of yield strength, tensile test and modulus of elasticity.
Hardness of ceramics is determined by their chemical compositions and microstructure characteristics: porosity, grain size, grain-boundary phases.
Depending on the loading force value and the indentation dimensions, hardness is defined as a macro- , micro- or nano-hardness.

Macro-hardness tests (Rockwell, Brinell, Vickers) are the most widely used methods for rapid routine hardness measurements. The indenting forces in macro-hardness tests are in the range of 50N to 30000N.
Micro-hardness test (micro-Vickers, Knoop**)** is applicable when hardness of coatings, surface hardness, or hardness of different phases in the multi-phase material is measured. Small diamond pyramid is used as indenter loaded with a small force of 10 to 1000gf.
Nano-hardness test uses minor loads of about 1 nano-Newton followed by precise measuring depth of indentation.
Hardness of ceramic materials is usually tested by Vickers or Knoop Methods, using diamond indenters.

Brinell Hardness Test



In this test a hardened steel (or tungsten carbide for extremely hard materials) ball of 2.5, 5 or 10 mm in diameter is used as indenter.

The loading force is in the range of 300N to 30000N (higher loading forces from the range are used for harder materials).

The Brinell Hardness Number (HB) is calculated by the formula:

$$HB = F/ (\pi D/2*(D-(D^2 - D_i^2)^{1/2}))$$

Where

F - applied load, kg
D – indenter diameter, mm
D_i– indentation diameter, mm.
In order to eliminate an influence of the specimen supporting base, the specimen should be seven times (as minimum) thicker than indentation depth for hard alloys and fifteen times thicker than indentation depth for soft alloys.

Rockwell Hardness Test

In the Rockwell test the depth of the indenter penetration into the specimen surface is measured. The indenter may be either a hardened steel ball with diameter 1/16", 1/8" or a spherical diamond cone of 120º angle (Brale).

Loading procedure starts from applying a minor load of 10 kgf (3kgf in Rockwell Superficial Test) and then the indicator, measuring the penetration depth, is set to zero. After that the major load (60, 100 or 150 kgf)is applied. The penetration depth is measured after removal of the major load.

Hardness is measured in different scales (A, B, C, D, E, F, G, H, K) and in numbers, having no units (in contrast to Brinell and Vickers methods).

Aluminum alloys, copper alloys and soft steels are tested with 1/16” diameter steel ball at 100 kgf load (**Rockwell hardness scale B**).
Harder alloys and hard cast iron are tested with the diamond cone at 150 kgf (**Rockwell hardness scale C**).
An example of Rockwell test result: 53 HRC. It means 53 units, measured in the scale C by the method HR (Hardness Rockwell).

Rockwell Superficial Test is applied for thin strips, coatings, carburized surfaces.
Reduced loads (15 kgf, 30 kgf, and 30 kgf) as a major load and deduced preload (3kgf) are used in the superficial test.

Depending on the indenter, two scales of Rockwell Superficial method may be used: T (1/16” steel ball) or N (diamond cone).

62 R30Tmeans 62 units, measured in the scale 30T (30 kgf, 1/16” steel ball indenter) by the Rockwell Superficial method (R).

Vickers Hardness Test

The principle of the Vickers Hardness method is similar to the Brinell method.

The Vickers indenter is a 136 degrees square-based diamond pyramid.

The impression, produced by the Vickers indenter is clearer, than the impression of Brinell indenter, therefore this method is more accurate.

The load, varying from 1kgf to 120 kgf, is usually applied for 30 seconds.

The Vickers number (HV) is calculated by the formula:

$$HV = 1.854 * F / D^2$$

Where

F -applied load, kg
D – length of the impression diagonal, mm
The length of the impression diagonal is measured by means of a microscope, which is usually an integral part of the Vickers Tester.

Knoop Hardness Test

A diamond pyramid indenter with angles 130º and 170º30’ is used in this method.

The Knoop Hardness Test is applied for testing soft material and thin coating, since the penetration depth is very small (about 1/30 of the impression length).

The loading force in the Knoop method are usually in the range of 10 gf to 1000gf (micro-hardness range).

The Knoop number (HK) is calculated by the formula:

$HK = 14.229*F/ D^2$

Where

F -applied load, kg
D – length of the impression, mm

Shore Scleroscope

The Shore Scleroscope hardness is associated with the elasticity of the material.

The appliance consists of a diamond-tipped hammer, falling in a graduated glass tube from a definite height. The tube is divided into 140 equal parts.

The height of the first rebound is the hardness index of the material.

The harder the material, the higher the rebound.

The Shore method is widely used for measuring hardness of large machine components like rolls, gears, dies, etc.

The Shore scleroscope is not only small and mobile, it also leaves no impressions on the tested surface.

Source : http://www.substech.com/dokuwiki/doku.php?id=hardness_tests_of_ceramics