Vickers Hardness Testing http://www.calce.umd.edu/TSFA/Hardness_ad_.htm **for details of hardness test**

The **Vickers hardness test method**, also referred to as a microhardness test method, is mostly used for small parts, thin sections, or case depth work. The Vickers method is based on an optical measurement system. The Microhardness test procedure, ASTM E-384, specifies a range of light loads using a **diamond indenter** to make an **indentation** which is measured and converted to a **hardness value**. It is very useful for testing on a wide type of materials as long as test samples are carefully prepared. A square base pyramid shaped diamond is used for testing in the Vickers scale. Typically loads are very light, ranging from a **few grams** to one or **several kilograms**, although **"Macro"** Vickers loads can range up to **30 kg** or more. The Microhardness methods are used to test on **metals, ceramics, composites** - almost any type of material.
Since the test indentation is very small in a Vickers test, it is useful for a variety of applications: testing very thin materials like foils or measuring the surface of a part, small parts or small areas, measuring individual microstructures, or measuring the depth of case hardening by sectioning a part and making a series of indentations to describe a profile of the change in hardness. The Vickers method is more commonly used. The sample preparation is usually necessary with a microhardness test in order to provide a small enough specimen that can fit into the tester. Additionally, the sample preparation will need to make the specimen's surface smooth to permit a regular indentation shape and good measurement, and to ensure the sample can be held perpendicular to the indenter. Usually the prepared samples are mounted in a plastic medium to facilitate the preparation and testing. The indentations should be as large as possible to maximize the measurement resolution. (Error is magnified as indentation sizes decrease) The test procedure is subject to problems of operator influence on the test results.

The **Vickers hardness test** was developed in **1921** by **Robert L. Smith and George E. Sandland** at Vickers Ltd as an alternative to the Brinell method to measure the hardness of materials.[1] The Vickers test is often easier to use than other hardness tests since the required calculations are independent of the size of the indenter, and the indenter can be used for all materials irrespective of hardness. The basic principle, as with all common measures of hardness, is to observe the questioned material's ability to resist plastic deformation from a standard source. The Vickers test can be used for all metals and has one of the widest scales among hardness tests. The unit of hardness given by the test is known as the **Vickers Pyramid Number** (**HV**) or **Diamond Pyramid Hardness** (**DPH**). The hardness number can be converted into units of pascals, but should not be confused with pressure, which also has units of pascals. The hardness number is determined by the load over the surface area of the indentation and not the area normal to the force, and is therefore not pressure.

It was decided that the indenter shape should be capable of producing geometrically similar impressions, irrespective of size; the impression should have well-defined points of measurement; and the indenter should have high resistance to self-deformation. A diamond in the form of a square-based pyramid satisfied these conditions. It had been established that the ideal size of a Brinell impression was 3/8 of the ball diameter. As two tangents to the circle at the ends of a chord 3*d*/8 long intersect at 136°, it was decided to use this as the included angle of the indenter, giving an angle to the horizontal plane of 22° on each side. The angle was varied experimentally and it was found that the hardness value obtained on a homogeneous piece of material remained constant, irrespective of load.[2] Accordingly, loads of various magnitudes are applied to a flat surface, depending on the hardness of the material to be measured. The HV number is then determined by the ratio F/A, where F is the force applied to the diamond in kilograms-force and A is the surface area of the resulting indentation in square millimeters. A can be determined by the formula.

$$A = \frac{d^2}{2\sin(136^\circ/2)},$$ which can be approximated by evaluating the sine term to give

$$A \approx \frac{d^2}{1.8544},$$ where d is the average length of the diagonal left by the indenter in millimeters. Hence,[3]

$$HV = \frac{F}{A} \approx \frac{1.8544F}{d^2}$$, where F is in kgf and d is in millimeters.

The corresponding units of HV are then kilograms-force per square millimeter (kgf/mm²). To calculate Vickers hardness number using SI units one needs to convert the force applied from kilogram-force to newtons by multiplying by 9.806 65 (standard gravity) and dividing by a factor of 1000 to get the answer in GPa. To do the calculation directly, the following equation can be used:[4]

$$HV = \frac{F}{A} \approx \frac{0.01819F}{d^2},$$

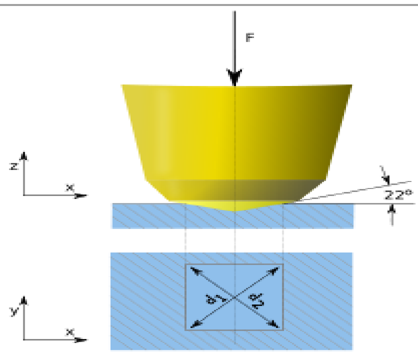
where F is in N and d is in millimeters.
Vickers hardness numbers are reported as **xxxHVyy**, e.g. **440HV30**, or **xxxHVyy/zz** if duration of force differs from 10 s to 15 s, e.g. 440Hv30/20, where:

- **440** is the hardness number,
- **HV** gives the hardness scale (Vickers),
- **30** indicates the load used in kgf.
- **20** indicates the loading time if it differs from 10 s to 15 s

Vickers values are generally independent of the test force: they will come out the same for 500 gf and 50 kgf, as long as the force is at least 200 gf.[5]For thin samples indentation depth can be an issue due to substrate effects. As a general rule of thumb the sample thickness should be kept greater than 2.5 times the indent diameter. Alternatively indent depth can be calculated according to:

$$h = \frac{d}{2\sqrt{2}\tan\frac{\theta}{2}} \approx \frac{d}{7.0006},$$

Examples of HV values for various materials[6]



Material	Value
316L stainless steel	140HV30
347L stainless steel	180HV30
Carbon steel	55–120HV5
Iron	30–80HV5
Martensite	1000HV
Diamond	10000HV

Mohs scale of mineral hardness: It is a qualitative ordinal scale that characterizes the scratch resistance of various minerals through the ability of a harder material to scratch a softer material. It was created in 1812 by the German geologist and mineralogist Friedrich Mohs and is one of several definitions of hardness in materials science, some of which are more quantitative.[1] The method of comparing hardness by seeing which minerals can visibly scratch others, however, is of great antiquity, having been mentioned by Theophrastus in his treatise *On Stones*, c. 300 BC, followed by Pliny the Elder in his *Naturalis Historia*, c. 77 AD.[2][3][4] While greatly facilitating the identification of minerals in the field, the Mohs scale is not suitable for accurately gauging the hardness of industrial materials.[5]

Minerals: The Mohs scale of mineral hardness is based on the ability of one natural sample of mineral to scratch another mineral visibly. The samples of matter used by Mohs are all different minerals. Minerals are pure substances found in nature. Rocks are made up of one or more minerals.[6] As the hardest known naturally occurring substance when the scale was designed, diamonds are at the top of the scale. The hardness of a material is measured against the scale by finding the hardest material that the given material can scratch, and/or the softest material that can scratch the given material. For example, if some material is scratched by apatite but not by fluorite, its hardness on the Mohs scale would fall between 4 and 5.[7] "Scratching" a material for the purposes of the Mohs scale means creating non-elastic dislocations visible to the naked eye. Frequently, materials that are lower on the Mohs scale can create microscopic, non-elastic dislocations on materials that have a higher Mohs number. While these microscopic dislocations are permanent and sometimes detrimental to the harder material's structural integrity, they are not considered "scratches" for the determination of a Mohs scale number.[8]

The Mohs scale is a purely ordinal scale. For example, corundum (9) is twice as hard as topaz (8), but diamond (10) is four times as hard as corundum. The table below shows the comparison with the absolute hardness measured by a sclerometer, with pictorial examples.[9][10]

Mohs hardness	Mineral	Chemical formula	Absolute hardness[11]	Image
1	Talc	$Mg_3Si_4O_{10}(OH)_2$	1	
2	Gypsum	$CaSO_4{\cdot}2H_2O$	3	
3	Calcite	$CaCO_3$	9	

Mohs hardness	Mineral	Chemical formula	Absolute hardness[11]	Image
4	Fluorite	CaF_2	21	
5	Apatite	$Ca_5(PO_4)_3(OH^-,Cl^-,F^-)$	48	
6	Orthoclase feldspar	$KAlSi_3O_8$	72	
7	Quartz	SiO_2	100	
8	Topaz	$Al_2SiO_4(OH^-,F^-)_2$	200	
9	Corundum	Al_2O_3	400	
10	Diamond	C	1600	

On the Mohs scale, a streak plate (unglazed porcelain) has a hardness of 7.0. Using these ordinary materials of known hardness can be a simple way to approximate the position of a mineral on the scale.[1]