**EXPERIMENT 4**

**A) EXPERIMENT NAME： Microhardness Test**

**B) THE AIM OF THE EXPERIMENT:**

To study and evaluation of surface hardness of different materials using Micro-Hardness testing Equipment, Vicker Methods. The hardness test is a mechanical test for material properties which are used in engineering design, analysis of structures and materials development. The principal purpose of the hardness test is to determine the suitability of a material for a given application or the particular treatment to which the material has been subjected.

**C) EXPERIMENTAL SETUP AND APPARATUS**

Selected samples will be selected to be tested by Vickers hardness test, the results are given to students in the class lab by the SHIMADZU HMV microhardness tester in Fig.1. In this laboratory experiment some of the different material samples can be tested as shown in the Fig. 2.

**Figure 1: SHIMADZU HMV Microhardness Tester**


**Figure 2: Test Specimens**

## D) THEORY

Several test methods, using different indenter materials and shapes, have been developed to measure the hardness of materials. The most commonly used hardness tests are described below.

**Brinell Test:** Introduced by J.A. Brinell in 1900, this test involves pressing a steel or tungsten-carbide ball 10 mm in diameter against a surface, with a load of 500, 1500, or 3000 kg (Fig. 3). The *Brinell hardness number* (HB) is defined as the ratio of the applied load, *P*, to the curved surface area of the indentation. The harder the material tested, the smaller the impression; a 1500-kg or 3000-kg load is usually recommended in order to obtain impressions sufficiently large for accurate measurement of hardness.

The indenter, which has a finite elastic modulus, also undergoes elastic deformation under the applied load; as a result, hardness measurements may not be as accurate as expected. One method for minimizing this effect is to use tungsten-carbide balls; because of their higher modulus of elasticity, they distort less than steel balls do. Tungsten-carbide balls are usually recommended for Brinell hardness numbers greater than 500.

**Rockwell Test:** Developed by S.P. Rockwell in 1922, this test measures the depth of penetration instead of the diameter of the indentation. The indenter is pressed onto the surface, first with a minor load and then with a major load; the difference in the depths of penetration is a measure of the hardness of the material. Some of the more common Rockwell hardness scales and the indenters used are shown in Fig. 3. Rockwell superficial hardness tests using the same type of indenters, but at lighter loads, have also been developed.

**Knoop Test:** This test, developed by F. Knoop in 1939, uses a diamond indenter in the shape of an elongated pyramid (Fig. 3), with applied loads ranging generally from 25 g to 5 kg. The Knoop hardness number is indicated by HK. Because of the light loads that are applied, the Knoop test is a microhardness test; therefore, it is suitable for very small or very thin specimens, and for brittle materials such as carbides, ceramics, and glass. This test is also used for measuring the hardness of the individual grains and components in a metal alloy. The size of the indentation is generally in the range from 0.01 to 0.10 mm; consequently, surface preparation is very important. Because the hardness number obtained depends on the applied load, Knoop test results should always cite the load used.

**Vickers Test:** This test, developed in 1922 and formerly known as the diamond pyramid hardness test, uses a pyramid-shaped diamond indenter (Fig. 3) and a load that ranges from 1 kg to 120 kg. The Vickers hardness number is indicated by HV. The impressions obtained are typically less than 0.5 mm on the diagonal. The Vickers test gives essentially the same hardness number regardless of the load, and is suitable for testing materials with a wide range of hardness, including heat-treated steels. More recently, test procedures have been developed to perform Vickers-type tests in atomic force microscopes and nanoindenters, to estimate hardness at penetration depths as low as 20 nm.

İZMİR KÂTİP ÇELEBİ ÜNİVERSİTESİ 2010

| Test | Indenter | Shape of indentation | | Load, $P$ | Hardness number |
|---|---|---|---|---|---|
| | | Side view | Top view | | |
| Brinell | 10-mm steel or tungsten-carbide ball | $D$; $d$ | $d$ | 500 kg<br>1500 kg<br>3000 kg | $HB = \frac{2P}{(\pi D)(D - \sqrt{D^2 - d^2})}$ |
| Vickers | Diamond pyramid | 136° | $L$ | 1–120 kg | $HV = \frac{1.854P}{L^2}$ |
| Knoop | Diamond pyramid | $L/b = 7.11$<br>$b/t = 4.00$<br>$t$ | $b$; $L$ | 25 g–5 kg | $HK = \frac{14.2P}{L^2}$ |
| Rockwell<br>A<br>C<br>D | Diamond cone | 120°<br>$t$ = mm | | 60 kg<br>150 kg<br>100 kg | HRA<br>HRC<br>HRD $= 100 - 500t$ |
| B<br>F<br>G | 1.6-mm diameter steel ball | $t$ = mm | | 100 kg<br>60 kg<br>150 kg | HRB<br>HRF<br>HRG $= 130 - 500t$ |
| E | 3.2-mm diameter steel ball | | | 100 kg | HRE |


| Test | Indenter | Shape of indentation | | Load, $P$ | Hardness number |
|---|---|---|---|---|---|
| | | Side view | Top view | | |
| Brinell | 10-mm steel or tungsten-carbide ball | $D$; $d$ | $d$ | 500 kg<br>1500 kg<br>3000 kg | $HB = \frac{2P}{(\pi D)(D - \sqrt{D^2 - d^2})}$ |
| Vickers | Diamond pyramid | 136° | $L$ | 1–120 kg | $HV = \frac{1.854P}{L^2}$ |
| Knoop | Diamond pyramid | $L/b = 7.11$<br>$b/t = 4.00$<br>$t$ | $b$; $L$ | 25 g–5 kg | $HK = \frac{14.2P}{L^2}$ |
| Rockwell<br>A<br>C<br>D | Diamond cone | 120°<br>$t$ = mm | | 60 kg<br>150 kg<br>100 kg | HRA<br>HRC<br>HRD $= 100 - 500t$ |
| B<br>F<br>G | 1.6-mm diameter steel ball | $t$ = mm | | 100 kg<br>60 kg<br>150 kg | HRB<br>HRF<br>HRG $= 130 - 500t$ |
| E | 3.2-mm diameter steel ball | | | 100 kg | HRE |


**Figure 3: General characteristics of hardness-testing methods and formulas for calculating hardness**

For most standard hardness tests, a known load is applied slowly by pressing the indenter at 90° into the metal surface being tested. The indenter is withdrawn from the surface after the indentation is made. An empirical hardness number is then calculated or read off a dial, which is based on the cross-sectional area or depth of the impression. The four common hardness tests are Brinnell, Vickers, Knoop and Rockwell. In this experiment, Vickers microhardness test (sometimes also called diamond pyramid) will be used. The basic principles of operation of the Vickers hardness test are illustrated in *Figure 4* where it can be seen that the load is applied to the indenter by a simple weighted lever. In older machines, an oil filled dash pot is used as a timing mechanism - on more modern equipment this is done electronically.

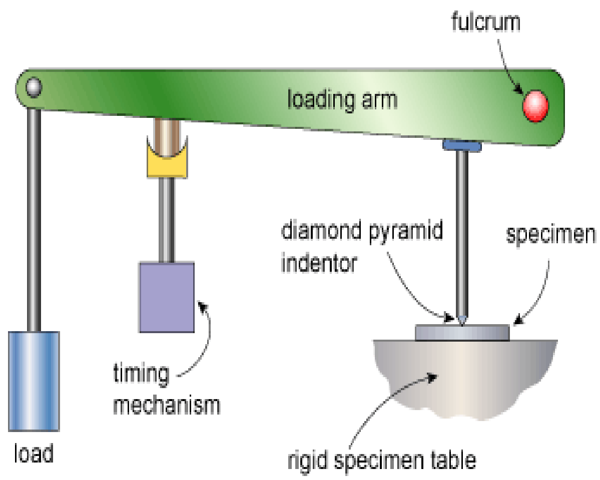


**Figure 4: Schematic principles of operation of Vickers hardness machine**

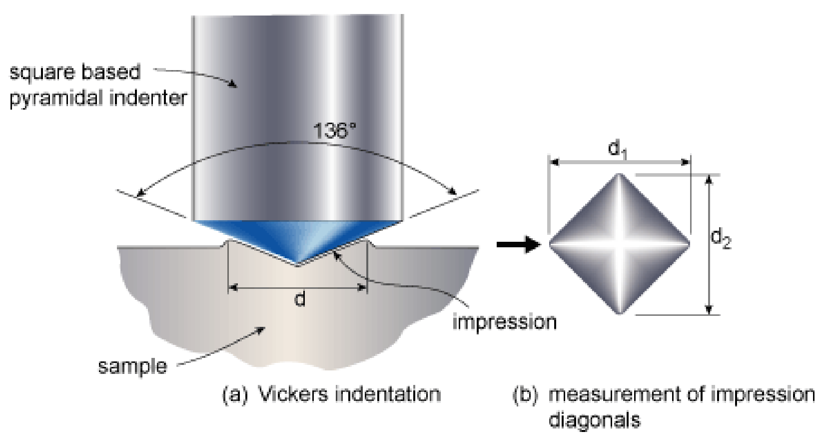


**Figure 5: Vickers Hardness Test representation**

**Calculations**

Vickers hardness number is designated by HV,

$$HV = \frac{1.854\,P}{d^2}$$

where P= Load in kg and $d$ = Arithmetic mean of the two diagonals, $D_1$ and $D_2$ in mm.

## E) EXPERIMENTAL PROCEDURE:

The hardness tests are carried out under the supervision of the lab instructor.

General procedure:

1. The specimen was placed on the vice.
2. The indenter was lowered until it just touches the specimen surface.
3. The appropriate load (F = 1kgf) was set for the indenter for 10 seconds.
4. The indenter was allowed to penetrate the specimen surface.
5. Load was removed and indenter was raised from specimen surface.
6. The appropriate parameter (diameter) of the indentation was measured.
7. The hardness value was computed.
8. The above steps were repeated for different materials for 3 times at different locations on the specimen and the average value was computed.

## F) ASSIGNMENTS

1. Note that the values you measured during the experiment and calculate the average hardness values.

**Results for Sample 1**

| Parameters | First Reading | Second Reading | Third Reading |
|---|---|---|---|
| $D_1$ (µm) | | | |
| $D_2$ (µm) | | | |
| Hardness (HV) | | | |
| Average Hardness (HV) | | | |

**Results for Sample 2**

| Parameters | First Reading | Second Reading | Third Reading |
|---|---|---|---|
| $D_1$ (µm) | | | |
| $D_2$ (µm) | | | |
| Hardness (HV) | | | |
| Average Hardness (HV) | | | |

2. Calculate Vickers hardness values by using the formula.
3. What are the advantages of Vickers test against other test methods?