ESTABLISHMENT OF HARDNESS MEASUREMENT LABORATORY AT ULUSAL METROLOJI ENSTITÜSÜ (UME)

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Abstract

As a fast developing country Turkey needs to compete with other developed countries in science and technology. It is the high time that Turkey raised its measurement standard up to the international level. Here in UME we are going to establish a Primary standard hardness measurement laboratory. In this paper we tried to discuss about hardness metrology, our plan of the laboratory and our goal in the near future in this field

1. INTRODUCTION

The diffusion of Quality Assurance concept, and consequently of its methods and practice, is rightly considered to be perhaps the most important event in the industrial history at the end of the 20th century.

One of the corner stones of Quality Assurance systems, as clearly defined by EN 29000 standards, is the traceability of any measurement operation to recognized and commonly accepted standards. It is possible and reasonable to compare and correctly evaluate measurements only if they are carried out with calibrated and certified equipment. Moreover, this aspect becomes more and more important when trade relationships spread beyond national boundaries and quality systems are to be established over an international basis.

Among the various metrological quantities of industrial interest, hardness plays a singular and characteristic role, since, unlike other quantities like velocity, force, energy, etc., cannot be directly traced to the fundamental quantities of SI system (Length, Mass, Time, Electrical Current). In other words, the availability of [or the traceability to] SI units standards is a necessary, but not sufficient, condition to establish a hardness reference standard.

For this reasons, it is clear that any program for the development and growth of industrial production, especially if export-oriented, cannot neglect two fundamental principles:

– the availability of specific metrological references for hardness testing, to be compared with the relevant references of other countries;

– the availability of a system for the dissemination of such references at industrial level. Only if these basic requirements are fulfilled it is possible to certify, and consequently to qualify objectively, the production of instruments and accessories according to standards that are now accepted internationally and assumed by most countries[1].

2. DEFINITION OF A HARDNESS REFERENCE SYSTEM

On this basis, the configuration of a reference metrological system for hardness testing can be defined, provided with the following features:

– traceability to reference standards for primary quantities (as much as it is possible and meaningful);

– comparability with similar references maintained by Primary metrological laboratories of other countries;

– capacity to generate by itself secondary standards for dissemination at industrial level.

After the growing diffusion and application of EN 29000, a considerable increase in the demand for calibration and certification is being registered in most countries.

Consequently, there is evidence that an industrialized country can not entrust one only metrological laboratory with both reference maintenance together with all the activities of calibration and certification of measuring equipment for industry. The solution to this problem is the constitution of a national calibration service.

Like in other industrialized countries, a calibration service is working in turkey also for hardness testing, based on:

– a primary metrological laboratory, responsible for the development and maintenance of the hardness reference standards and for the international comparisons;

– a network of secondary calibration centers, responsible for the dissemination of secondary hardness references in the industrial environment.

With this organization, the primary laboratory is left free from routine calibration activities and can concentrates its efforts in warranting the availability of first-line references and in harmonizing with the other national primary laboratories; while calibration centers, under the supervision of the primary laboratory, are incharged for the diffusion of the references at industrial level, thus warranting manufacturers the metrological support for product calibration, in the spirit of EN2900.

Next to visual examination and dimensional measurements, hardness testing is probably the tool most widely used for quality control of metal parts. In summary, the purpose of hardness testing is to determine physical properties, and the uniformity of such properties, in a manner which causes only minimal destructive effect.

Before proceeding, it is important that we try to understand what this property "hardness" really is and how it can be defined. In so doing, we will readily see that it is perhaps the most complicated property dealt with in physical testing. It is more properly a combination of various physical properties. Its true definition has been pondered down through the ages. Before this subject becomes too confusing, a few standard definitions from various sources are in order:

"Hardness – the resistance which matter offers to the penetration of a solid body."

• American Society for Metals.""

"Hardness – resistance of metal to plastic deformation, usually by indentation."

•American Society for Testing and Materials.""

"Indentation Hardness – a number related to the size of the impression made by an indenter of a specific size and shape under a known load. Note – the term indentation hardness has no quantitative meaning except in terms of a particular test in which the size and shape of the indenter, the indenting load, and other conditions of the tests are specified."

It becomes apparent that hardness is an important physical property that actually represents a complexity of other properties and that is represented by a dimensionless number. What is actually being measured is the strength of a material under compression loading, which produces permanent deformation by slip or plastic flow. Such measurements are made using an assortment of types of equipment. The indenters used vary from small diamond points of various shapes to round balls nearly 3/8 in. in diameter. The loading conditions vary from 1 g to 3 Mg. The rate of load application also varies. So, the quantitative values of hardness are determined to be:

1. The load applied.
2. The manner of load application.
3. The duration of load application.
4. The configuration of the penetrator.

3. HISTORY OF INDENTATION HARDNESS TESTING

The first indentation hardness tester was developed in 1856. In 1900 a Swedish metallurgist, John August Brinell, exhibited a hardness tester at the Paris Exposition. In 1919 Stanley P. Rockwell, a New England metallurgist, invented the Rockwell Hardness Tester. These two instruments, in their various forms, are the most common in use today. Each will be discussed in some detail.

Through the years, a need gradually developed for a low-load or microhardness test. Very thin materials, highly localized areas, brittle-friable materials, and certain very hard materials could not be tested by the standard (macro-) hardness testing techniques. The earliest reference to such low-load hardness testing appeared in the National Physical Laboratory report of 1932.''' Two widely accepted test procedures were developed from this concept: the Vickers or DPH (Diamond Pyramid Hardness) procedure and the Knoop hardness method. These procedures, which differ principally in the type of indenter used, will be discussed in detail later.

An arbitrary definition of macro- and microhardness is in order and is proposed as follows: [2]

4. TYPES OF HARDNESS TESTING

Hardness types are mainly classified on the basis of the load being used.

Test type	load utilized
Macro hardness testing	Over 1 Kg
Micro hardness testing	1 Kg or less

Figure shows the relative sizes of various commonly used hardness test impressions.

4.1 Macro Hardness Testing

Macro hardness tests are mainly used in the factories and laboratories. So we will give more emphasis on this class..

4.1.1 Brinell hardness testing.

4.1.2 Rockwell hardness testing.

4.1.3 Vickers harness testing.

4.1.4 Shore scleroscope hardness testing.

4.1.5 Ultrasonic hardness testing.

4.1.5 Leeb hardness testing.

4.1.1 Brinell Hardness Testing:

The Brinell test is the hardness test most often used on large parts, especially castings, structures, and forgings, but is not limited to such parts. It makes a rather large indentation, which may be deleterious to appearance, but averages the hardness over a greater area than does any other hardness testing method. Test loads and indenters can be varied, the combination most often used being a 3000-kg load on a 10-mm steel ball indenter. Test equipment varies from small, portable units to large, automated, direct-reading, high-production units. Brinell testers cannot be used on very thin or very hard materials.

Preparation for testing is simple, and results are very repeatable from operator to operator. The Brinell test may be the most widely used hardness test.

4.1.2 Rockwell Hardness Testing

Regular Rockwell tests use a 10-kg minor load, and major loads of 60, 100, and 150 kg. The superficial test uses a 3-kg minor load and 15-, 30-, and 45-kg major loads. The indenters used comprise a diamond cone of 120° and hardened steel balls 1/ 16, 1/8, 1/4, and 1/2 in. in diameter. The hardness value obtained is based on the difference between the depths of penetration by the indenter resulting from application of the minor and major loads. The Rockwell test is a rapid, direct-dial-reading test. It is adaptable to many sizes and types of materials due to the various loads and indenters available (see Tables 9 and 10). A reasonably smooth surface is necessary. Additional information can be found in ASM and SAE handbooks, as well as in the references cited in this chapter, and listed in the bibliography at the end of this book. The most widely used specifications are found in ASTM Standards E-18, E-140, E-4, and A-370.

The depth-measurement device is verified over at least three ranges including the lowest and highest hardnesses used. This measurement shall be accurate within <0.001 mm for standard Rockwell testing, or within $+0.0005$ mm for superficial Rockwell testing.

4.1.3 Vickers Hardness Testing:

In the Vickers hardness test, a square- based diamond pyramid is substituted for a ball in order to provide geometrical similitude under different test force. The angle between the opposite faces at the vertex of pyramid indenter is ideally 136°

The Vickers hardness number (HV) is obtained by deviding the test force by the contact area (sloping area) of the indentation

HV= F/S

where F-The test force

S- The contact area

According to the different ranges of test forces, the Vickers hardness can be classified in 3 types:

(1) Vickers hardness test(HV5-HV100 with the test force of 49.03N-980.7N

(2) Low load Vickers hardness test(HV0.2 to HV5) with test force 1.961N to 46.03N

(3) Vickers microhardness test (HV0.2 to 1.961N)

The standard tester adopts the deadweight loading type.

4.1.4 Shore Scleroscope Hardness Testing

There are many varieties of hardness test involves dropping a 1/4 -in. diam, 3/4-in.-long diamond -tipped (spherical or blunt) object weighing less than 0.1oz through a distance of 10 in. The hardness value is then determined by measuring the height of the rebound. This is test is very portable and can be used where other tests cannot. It is sensitive to surface conditions and requires careful, experienced operation. [3]

4.1.5 Ultrasonic Hardness Testing

Ultrasonic hardness testing is a unique method that leaves virtually no mark. A magnetostrictive diamond-dropped rod is ultrasonically induced to vibrate at its natural resonant frequency. The frequency of vibration changes with the depth of penetration and is read on a meter and compared with readings from standard test blocks. The total depth of penetration is 0.0003 to 0.0005 in. the test is very rapid, but requires very good surface preparation.

4.2 Microhardness Testing

Microhardness testing involves the principles previously described for Brinell and Rockwell hardness testing-- that is, an indenter is impressed into the test surface under a measured applied. The difference is that in microhardness testing the loads are very low and the indenters are more precise. The loads generally range from 1g to 1 kg. Two types of indenters are commonly used-- the knoop indenter and the DPH (Diamond Pyramid Hardness) indenter. Both are diamond indenters. After the indentation has been made, it is measured using a suitable microscope. The microhardness value is defined as the ratio between the force acting on the indenter and the area of the indentation produced by plastic deformation.

5. HARDNESS SCALE IN ULUSAL METROLOJI ENSTITÜSÜ (UME)

Our main purpose of establishing hardness laboratory is to calibrate the hardness blocks and control the hardness testing machines used by numerous companies throughout the country. Every coming day Turkish industrial environment is entering a big horizon which starts from Europe to America and Asia to Africa.

So in order to keep international standards in our products from our industries. The measurement and the properties of the products should follow a reference standard. Until now we are trying to keep pace with international standards(ISO) and Europe standards(EN).

Due to the crying need of the hardness test control in Turkey intensive work is going on to establish a primary standard hardness testing lab in National metrological Institute. Our first preferences will be to have a lab. having the facilities given below.

-Primary standard dead-weight hardness testing machine;

-Primary standard dead-weight microhardness testing machine;

-Diamond indenters characterization equipment.

-Reference hardness test blocks

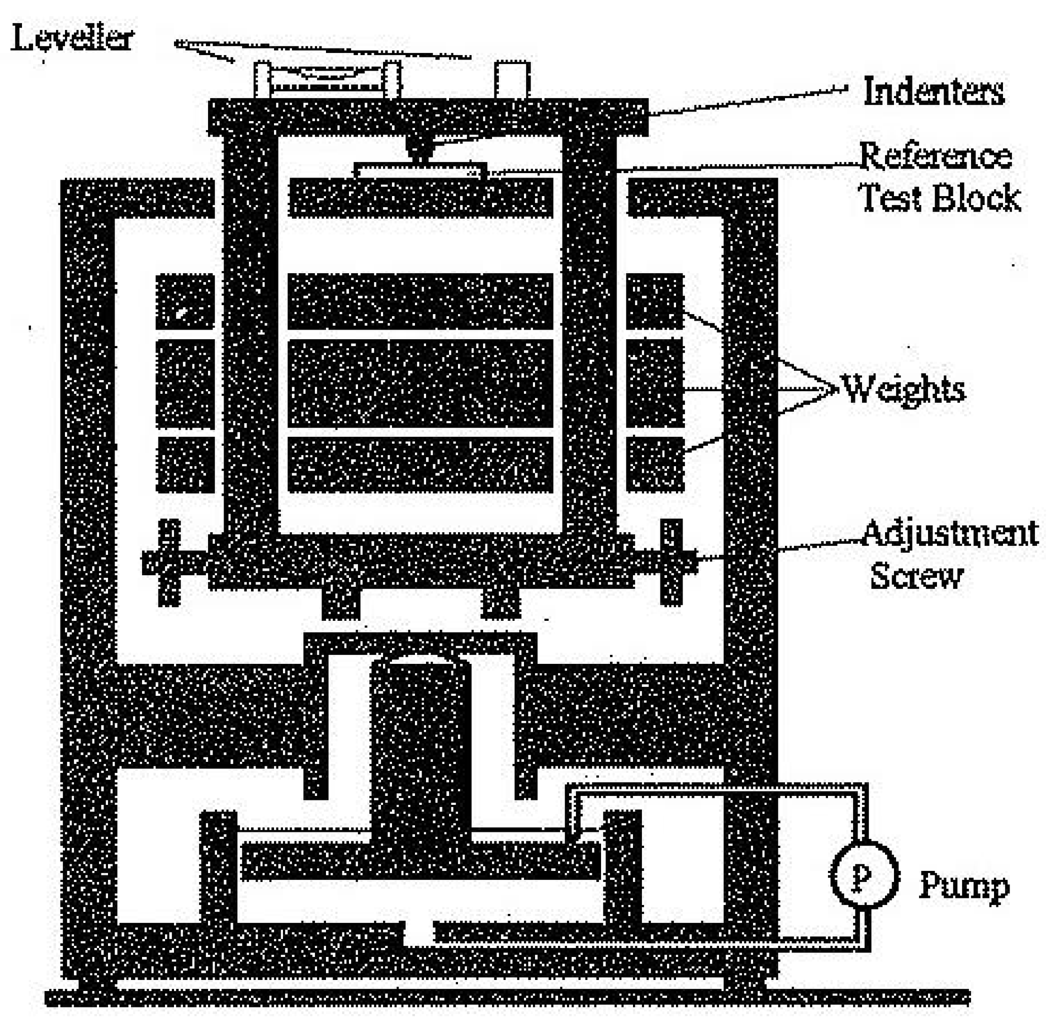
5.1 Primary Standard Dead-weight Hardness Testing Machine

The design and metrological characteristics of the dead weight machine have been conceived to obtain repeatable hardness measurements and long term measurement stability within the performance parameters stated below.

The machine structure, based on a 3-column frame, is developed to be symmetric and stable at each phase of the test cycle, avoiding hyperstatic conditions as far as possible.

Total test force ranging from 98.07N to 1839N can be applied, with uncertainty of less than 50 ppm. Laser interferrometric system will be installed which allows indentation depth to be measured with an uncertainty of less than 0.1μm.

There will be servo controlled feed back system.



Schematic drawing of the Hardness testing machine

5.2 Primary Standard Dead-weight Microhardness Testing Machine

Two sources of uncertainty mainly affect microhardness testing results: friction in load application and human error in indentation measurement. As a consequence , commercial microhardness testers are free from complying, both for accuracy and long term stability.

So we will try to establish high accuracy machines. Ball bushing guides will be replaced by air bearings.

This machine is expected to have the facilities like

-dead weight load application system

-automatic computerized indentation measuring system
-motorized x-y stage sample holder
-motorized z-axis translation stage
-user friendly operation and data management

5.3 Diamond Indenters Characterization Equipment

It is very important that indenter is one of the most frequent cause of results difference in the laboratory. A correct geometrical characterization of diamond indenter is a necessary condition. To carry out angle measurement on both Rockwell and Vickers indenters, an interferrometric sine-bar system will be realized allowing angle characterization also for standardizing to be used on calibration machines. A rotating table with air bearing guidance will also be installed.

5.4 Reference HardnessTest Blocks

Test blocks are the means to calibrate and test other existing machine with a standard machine. Considering our lab as a primary Lab. We will carry on testing the other machines and maintain international standards. Test block must have some specific characteristics. Five hardness readings are made on each block. The difference between the highest and lowest value should not exceed the repeatability value. The difference between the average of the five values and the test-block value represents the error. This should not exceed the error noted on the test block.

At least one routine test should be made each day. This test is best made on the scale or scales being used. A routine test involves making five hardness tests on one test block and ensuring that they fall within the tolerance range of that block. It is best to make several preliminary test impressions (at least three) prior to making verification tests. This allows proper seating of the anvil and the indenter, and smooth movement of all mechanisms.

6. CONCLUSIONS

After establishing of primary level hardness laboratory at UME in one year period, Turkish industry can find the opportunity to compete with other developed countries in production and technology because of harmonization with other developed primary level laboratories.

REFERENCES

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