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DESIGN AND DEVELOPMENT OF HARDNESS INDENTATION MEASUREMENT SYSTEM AT TÜBİTAK UME

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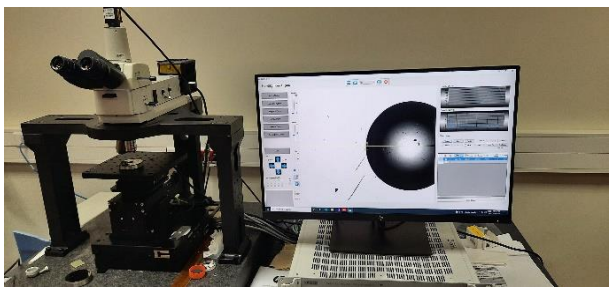
Abstract:
Developments in reference standards in Hardness Laboratory of TÜBİTAK UME (National Metrology Institute of Türkiye) and the demand received from calibration and testing laboratories forced us to develop a new hardness indentation measurement system (HIMS) that covers all Brinell, Vickers and Knoop hardness indentation measurements. In this design it has been aimed at automatization of measurements, constitution of different methods for determination of border of indentation and in turn measurement of the size (diameter and diagonal length) of indentations. In this paper design, installation and metrological characterization of HIMS developed by TÜBİTAK UME Hardness Laboratory is explained in detail.

Keywords: Brinell hardness; Vickers hardness; Knoop hardness; indentation; measurement

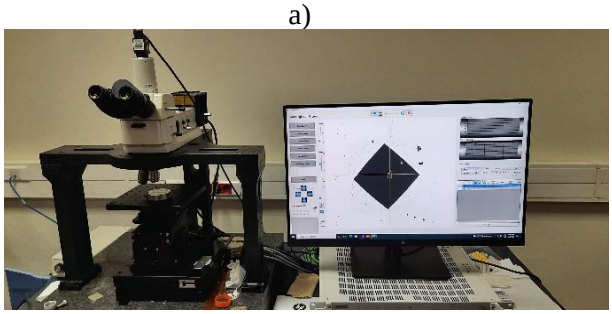
1. INTRODUCTION

Improvements in TÜBİTAK UME Hardness Laboratory infrastructure and demand received from calibration and testing laboratories as well as hardness testing machine producers and other users made it very significant for us to develop a hardness indentation measurement system at TÜBİTAK UME Hardness Laboratory. After successful implementation of two hardness calibration machines at TSE (Turkish Standards Institution) in Rockwell and Brinell-Vickers hardness separately and other two hardness standardizing machines in Hardness Laboratory of TÜBİTAK UME (Rockwell-Brinell-Vickers hardness standard machine [1] and high load Brinell hardness standard machine [2]) it had been decided to develop an indentation measurement system by improving the one present in this laboratory within the scope of an internally funded project. It is realized via designing a new system aiming at improving the degrees of freedom, automatization of measurement and some possibilities to make a fully automatic measurements of *n* number of indentations randomly located on the surface of hardness reference blocks. For this reason, a 4-axis motorized stage is used, combined with a light microscope through a sturdy mechanical body and anti-vibration plate. Auto-focusing, automatic edge detection via image processing, automatic indentation size measurements and sequential indentation measurements via special algorithm are all possible in this design. Beside automatic measurements, manual measurements where the decision of the border of indentation is made by the operator is also possible for all size of indentations.

All possible Brinell, Vickers and Knoop indentations' measurements can be made with this system. Various measurement methods are also available for indentations that can take place in the field of view of the microscope and the ones much bigger than this field by movements of the stage from one side of the indentations to the other side both in X and Y_directions. The designed system with Brinell and Vickers indentations viewed on the screen of the PC is shown in Figure 1.



a)



b)

Figure 1: a) and b) Hardness indentation measurement system designed by TÜBİTAK UME Hardness Laboratory

Beside indentation size measurements, calibration of the lenses and the motorized stage is also possible

by making use of a line scale, and inversely this system is useful for calibration of the line scales if the system has a traceability with higher accuracy trough a laser interferometer optic system.

2. PRODUCTION AND INSTALLATION

The machine body was designed to be rigid and sturdy and eliminating vibration to minimize side effects during movement of the motorized stage and placement of the hardness reference blocks with small size and big Brinell hardness reference blocks with weights range from 20 g to more than 3 kg. A granite plate used as a base for the system and seated on anti-vibration material. The 4_axis motorized stage is placed and mounted on the granite plate and a three-armed plate is placed on top of the motorized stage via three legs to carry the optical microscope, letting movement of the motorized stage in X, Y, Z and Rotational directions. During the measurement the samples (hardness reference blocks) are movable underneath the microscope used to view the indentation border and high-resolution camera is mounted to the microscope to transfer the magnified image to screen of PC for evaluation of border and size of indentation.

The system is controlled through the specially prepared software and with a specially prepared virtual joystick. All mechanical parts, equipment and software are combined together to constitute the system letting the operator to make all adjustments via the user interface and perform measurements via a screen. The construction of the system can be seen clearly in Figure 2.

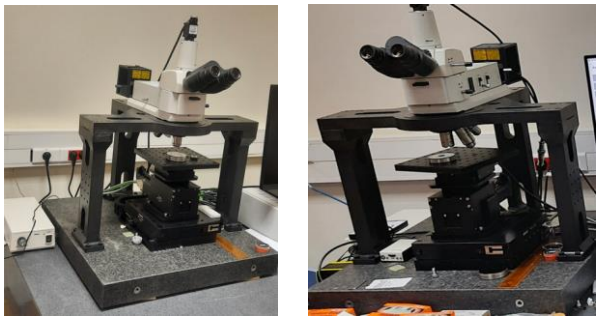


Figure 2: Construction of the mechanical part together with the equipment used for indentation analysis and measurement.

3. INDENTATION MEASUREMENT

The system is equipped with 4_Axis motorized stage, optical microscope, high resolution camera and a specially prepared software letting the system measure size of indentations for all possible Brinell, Vickers and Knoop hardness indentations. High accurate movement stage is used to measure the diameter and diagonal length of the indentations by movement of the stage in the X and Y_directions. 360º Angle rotation is possible for adjustment of indentation when needed. The Z_motorized stage is used for manual and/or automatic focusing of the indentation. Automatic corner determination of Vickers indentations is given in Figure 3.

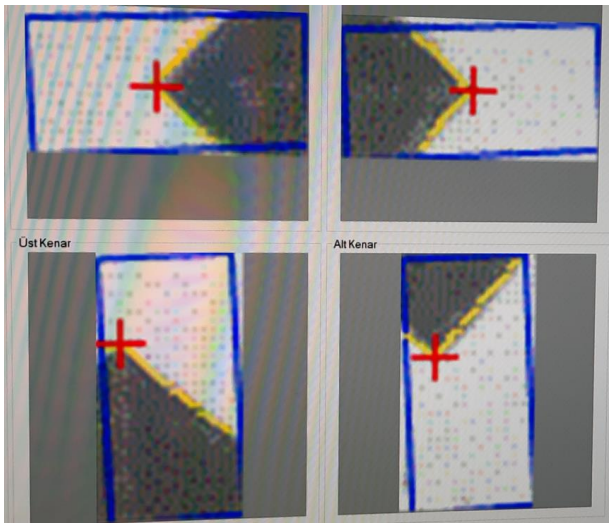


Figure 3: Hardness indentation automatic measurement

The optical microscope with 6 lens turret is used for magnification of the indentation border. The turret is used manually, and the suitable lens is adjusted at the beginning of measurement. Light and filter adjustment is possible when needed during the measurement.

A high-resolution camera is used to transfer the magnified indentation (border) to the screen of a PC for evaluation of the border and in turn the size of indentation.

A specially prepared software is used for analysis of the border of indentation and measurement of its size. Different measurement methodology is possible with this system and the software. Automatic measurements where the border of indentation is determined by the software is possible for high quality indentations and for indents where enough contrast is received from the image. Manual measurements is possible by the operator's decision about the border of indentations. All possible indentations, in regard to their size are able to be measured.

3.1. Small Indentations

If the indentations are in the field of view, it is possible to measure the indentation size at one time in both directions as can be seen easily in Figure 4. It is also possible to perform the measurements of these indents by determination of the first corner (for Vickers) or the first arc of the indents (for Brinell) and move the stage to the other corner or the arc of the indents and calculate the size of indentations taking the movement value of the stage into consideration.

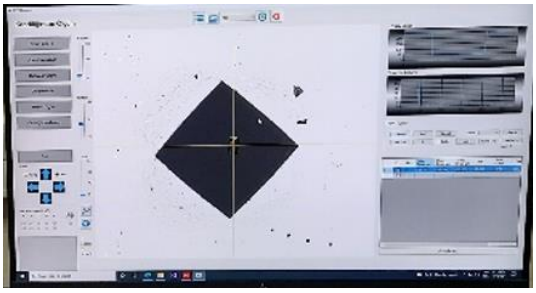


Figure 4: Small size hardness indentation measurement

3.2. Large Indentations

If the indentations are bigger than the field of view it is possible to measure the indentation size by determining one corner of the square shaped indentation and move the opposite corner underneath the microscope and determine the second point and calculate the total distance between the two points that give us the diagonal length or diameter of a circular indentation. As the system has in X and Y direction measurement capability this measurement can be done in both direction with the same accuracy. Another important advantage of this system is the indentations alignment that is not critical and can be measured in any direction. Some examples for large indentations are given in Figure 5.

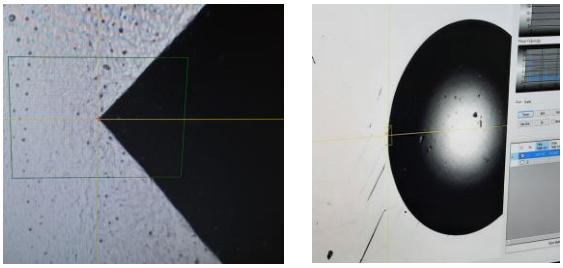


Figure 5: Big size hardness indentation measurement

3.3. Manual Measurement

In this measurement method the operator can decide the border of indentation and perform the measurement by point or line measurement method. It is possible for small and big size of indentations and work just like the first two methods, by analysing each border/corner or the indent as a whole, only the border of indentation is decided by the operator. Manual measurement by lines in bot X and Y_directions can be seen in Figure 6.

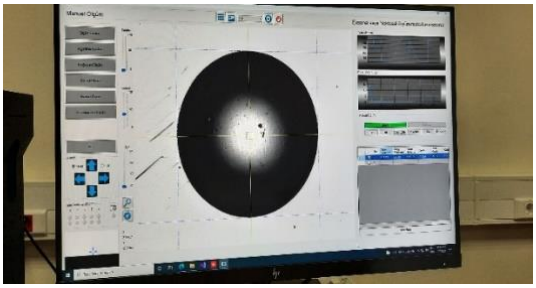


Figure 6: Manual measurement

3.5. Automatic Measurement

In this methodology the border of indentation is determined by the software specially prepared for this system. The edge detection algorithm is used to determine the border of indentation as well as the diameter and diagonal points of the indents and the measurement is performed with the automatic movement of the motorized stage. The measurement property of the stage in both X and Y directions is used. In all measurement option the alignment of the indentation is not critical and i.e. it is not requested to be in the horizontal direction. An example for automatic indentation measurement is given in Figure 3.

3.6. Stage micrometer calibration

The system traceability is constituted via a certified stage micrometer (line scale). There is an automatic calibration capability to make the calibration of the system via the stage micrometer. There is another option, if the system is calibrated with a laser interferometer system its accuracy will be enough the make the calibration of the stage micrometers and this option is embedded in the software of the system. Below in Figure 7 the calibration of the stage micrometer made automatically by the software is seen.

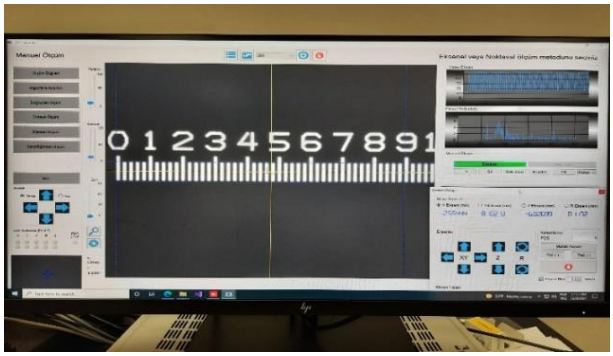


Figure 7: Calibration of the stage micrometer

4. PERFORMANCE OF THE MACHINE

After mounting and automation of the system it was calibrated by making use of a laser interferometer optic system and relevant corrections were made. The system performance is in accordance with the relevant ISO hardness standards [3]-[8]. Also certified dummy indentations were used for the verification of the system and the results were in compliance with the certificates values of the indentations. For a preliminary verification of the system for two lenses a certified stage micrometer is used. The lenses used in this system for indentation measurement for the time being on are the 20X and the 50X lenses. For preliminary verification of the system three series of measurements were made and the measurement results were compared with the

stage micrometer certified values. The graphical representation of the measurement results are given in Figure 8 and Figure 9 for 20X and 50X, respectively.

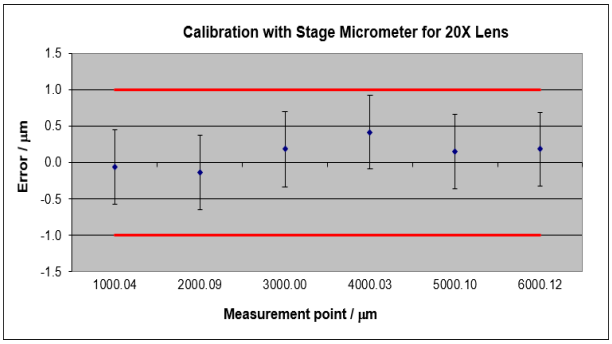


Figure 8: Calibration of the system with stage micrometer for 20X lens

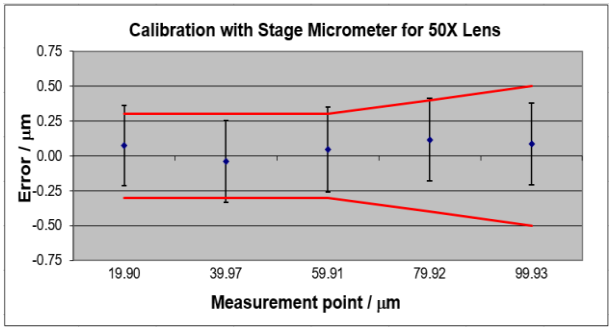


Figure 9: Calibration of the system with stage micrometer for 50X lens

5. SUMMARY

At the end of this project an indentation measurement system is designed, produced, installed and activated for first time by TÜBİTAK UME Hardness Laboratory in Türkiye. It has the capability of indentation measurements for all possible Brinell, Vickers and Knoop hardness scales present in the relevant hardness standards. The calibration and verification results were satisfactory and complying with the certified values.

6. REFERENCES

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