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INSTALLATION AND METROLOGICAL CHARACTERIZATION OF HIGH LOAD BRINELL HARDNESS STANDARD MACHINE AT TÜBİTAK UME

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Abstract:

Improvements in quality assurance in the field of hardness testing and demand received from calibration and testing laboratories as well as hardness testing machine producers and other users made it inevitable to develop a high load Brinell hardness standard machine (HLBHSM) at Hardness Laboratory of TÜBİTAK UME (National Metrology Institute of Türkiye). Design of such a national standard was made for high load Brinell hardness scales within the scope of an internally funded project. In this paper installation and metrological characterization of HLBHSM with dead weight force application system developed by TÜBİTAK UME Hardness Laboratory is explained in detail.

Keywords: Brinell hardness; hardness standard machine; indentation; measurement; dead weight.

1. INTRODUCTION

Improvements in quality assurance in the field of hardness testing and demand received from calibration and testing laboratories as well as hardness testing machine producers and other users made it inevitable to develop a HLBHSM at Hardness Laboratory of TÜBİTAK UME. After successful implementation of two hardness standardizing machines at TSE (Turkish Standards Institution) in Rockwell and Brinell-Vickers hardness separately and attaining good results with the use of dead weight force application systems for realization of indentation it had been decided to improve TÜBİTAK UME Hardness Laboratory capability at high load Brinell hardness scales. It is realized via designing [1] and developing a deadweight type Brinell HSM within the scope of an internally funded project to provide traceability to Brinell hardness measurements covering the range 187.5 kgf – 3000 kgf. In this newly installed HLBHSM the force application system was considered to comprise mass stacks realizing force under the gravitational acceleration and a frame to transfer the realized force to the tip of the indenter, a well-known deadweight force application principle. As a first and unique application in the world the frame is guided via two air bearings to prevent any rotational and pendulum motion during realization of indentation. A picture of the HLBHSM is given in Figure 1 after its installation and activation.

Figure 1: High Load Brinell Hardness Standard Machine of TÜBİTAK UME

An indentation measurement system is needed to be used for diameter measurement for Brinell hardness indentations. It is designed and developed within the scope of another project and installed in TÜBİTAK UME Hardness Laboratory. The indenters to be used for realization of indentation are purchased from producers and certified at TÜBİTAK UME in terms of diameter requirements.

The measurement cycle is realized by making use of a force measurement device (force transducer) to which the whole force application system (the frame and the mass stacks as a whole) is mounted and force application times are figured out.

2. PRODUCTION AND INSTALLATION

The machine body was designed to be rigid and sturdy to minimize side effects during force application and realization of indentation, and every component constituting Brinell hardness is considered to be with the highest accuracy to attain the best outcome quantity hardness.

2.1. Body of the Machine and Mass Stacks

It is very important to have a rigid and strong enough body that will not affect the measurement results. For this reason, the machine body was designed and produced to comprise the minimum number of parts and each part having precise dimensional measurements and tight tolerances, special material and production methods. The body is composed of two main parts; the plates and the columns (legs). The plates are made of steel and the columns are made of cast iron with one part each and having precise dimensions and tolerances for a high quality mounting. Pictures of the main body and mass stacks are given in Figure 2.

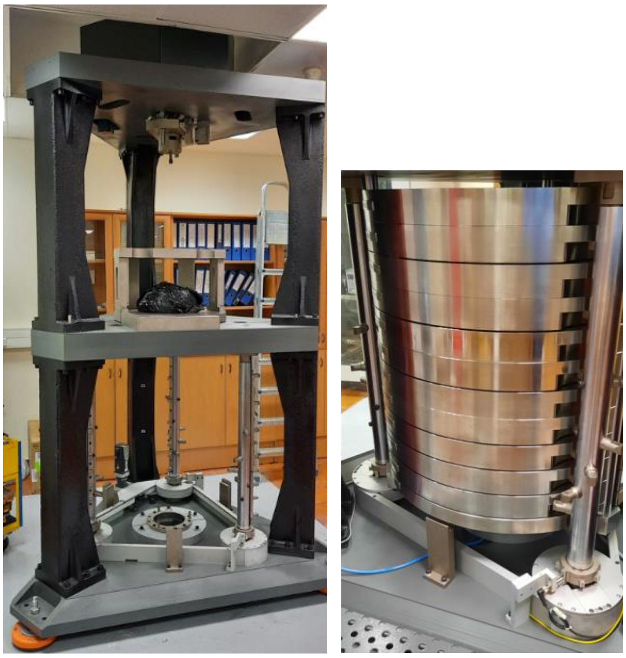

Figure 2: HLBHSM Body & Stainless Steel Mass Stacks

The mass stacks were mentioned to have long term stable material as the weights to be used for force application and stainless steel is used and the mass stacks were produced with 795 mm diameter and 67 mm thickness. Each regular mass stack corresponds to 250 kgf, only the lowermost one is 62.5 kgf that is the one used to constitute the 250 kgf scale together with the 187.5 kgf frame. The sequence of the masses from bottom to the top and the frame constitute the first scale which is HBW 2.5/187.5.

2.2. Force Application System

To realize the force with the highest accuracy and stability, deadweight type force application principle is preferred. It comprises mass stacks made up of stainless steel and a frame to constitute the first load and transfer the other loads to the tip of the indenter. The mass stacks are one 62.5 kgf and eleven 250 kgf that make a total of 3000 kgf together with the frame which is 187.5 kgf by itself.

2.3. Measurement Cycle

The measurement cycle is realized with application of force with a predefined indenter approach speed and force application rates with respect to time. To figure out the measurement cycle of force application, a force measurement device is equipped onto the machine and data from this device is recorded and instantaneous force application is plotted as the force is applied. The force measurement device (force transducer) is an accurate one and can be used for force measurements where it is needed. The picture of the upper side of the force application mechanism is shown in Figure 3 below.

Figure 3: HLBHSM Force Application Mechanism; the force transducer and the frame

3. AUTOMATION OF THE MACHINE

The machine is equipped with two servomotors, one (M_1) for movement of the dead weights up-and-down direction to realize the indentation and the other one (M_2) is for selection of the relevant mass according to the scale. Other automation sensors are the force measurement device, laser interferometer (when necessary) and other limiting switches and sensors necessary for automatic activation of the machine. A user-friendly software is specially prepared for activating the machine and performing all measurement stages automatically. The picture of the user interface is shown in Figure 4.

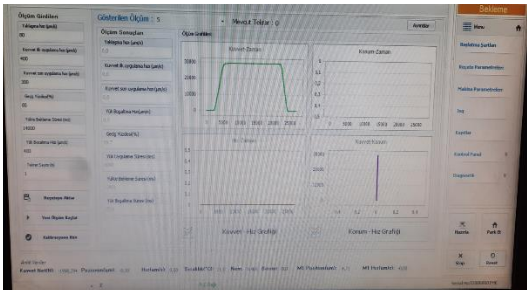

Figure 4: User interface software of the HLBHSM

With the user interface software it is possible to set all measurement parameters like approach speed of the indenter, force application and removal speeds, information belonging to the hardness reference block subject to calibration etc. At the end of the realization of indentation, a list of the realized values of the parameters set before the measurement is listed. For instance the force application and dwell times of the measurement cycle is measured and given on the screen.

4. PERFORMANCE OF THE MACHINE

High load Brinell hardness standard machine is used only for realization of indentation for Brinell scales between 187.5 kgf and 3000 kgf. With the measurements made so far repeatable results were attained in terms of force application and measurement cycle parameters such as force application and dwell times. The software gives the possibility to figure out the force application and comparison of force with the reference value as well as the tolerances requested. Below in Figure 5 to Figure 7 you can see force application cycle and the information extracted from the force measurement device during realization of indentation.

The force applied, time, the reference force value with the tolerances requested (grey area) and the uncertainty of the force measurement information can be seen as a label at any instant. As shown in Figure 6 and Figure 7 visual interpretation of the force applied being within the tolerances is demonstrated on the graphical interpretation of measurement cycle.

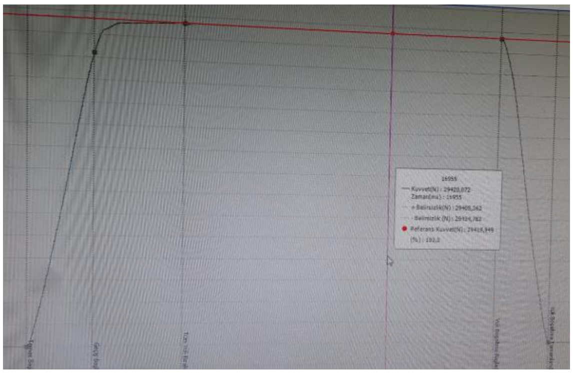

Figure 5: Force application with HLBHSM

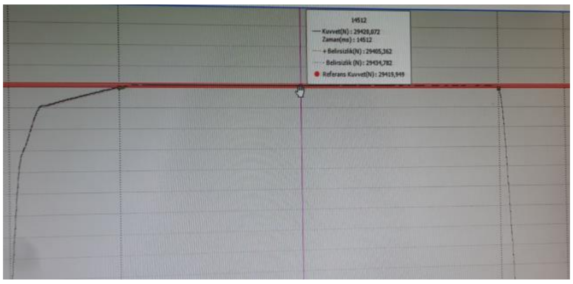

Figure 6: Force application with HLBHSM

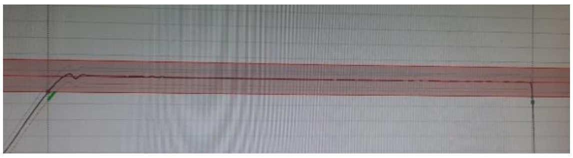

Figure 7: Force application with HLBHSM

5. METROLOGICAL CHARACTERISATION

As mentioned in the entire paper this primary machine is developed for only realization of indentations in regard to Brinell hardness scales. Its metrological characterisation is related to only the components taking part in realization of indentations such as force, measurement cycle and indenter. Indentation measurement is not part of this study and its characterisation will be the scope of another work in the near future.

5.1. Force Application

Force is generated with mass stacks under the gravitational acceleration. The mass stacks are calibrated with uncertainty level of $1 \cdot 10^{-6}$ while the local gravitational acceleration is measured with an uncertainty of some parts in $1 \cdot 10^{-8}$. After calculation the force generation is accepted to be at uncertainty level of $1 \cdot 10^{-5}$ (k = 1). The verification/calibration of force was made via a calibrated force transducer traceable to TÜBİTAK UME Force Standard Machine. Some of the results attained in force calibration/verification are as follows (see Table 1 to Table 5).

Table 1: Force measurement results for 187.5 kgf

187.5 kgf	Mean	u_{REPE}	u_{RES}	u_{REPR}	u_{REF}	U (k=2)	U (k=2)
N	N	N	N	N	N	N	%
1,839.12	1,839.25	0.09	0.00	0.33	0.02	0.69	0.04
1,839.06							
1,839.43							
1,839.45							
1,839.17							

Table 2: Force measurement results for 500 kgf

500 kgf	Mean	u_{REPE}	u_{RES}	u_{REPR}	u_{REF}	U (k=2)	U (k=2)
N	N	N	N	N	N	N	%
4,904.88	4,904.81	0.10	0.01	0.35	0.05	0.74	0.02
4,904.94							
4,904.80							
4,904.46							
4,904.98							

Table 3: Force measurement results for 1000 kgf

1000 kgf	Mean	u_{REPE}	u_{RES}	u_{REPR}	u_{REF}	U (k=2)	U (k=2)
N	N	N	N	N	N	N	%
9,808.54	9,808.73	0.19	0.01	0.58	0.10	1.24	0.01
9,808.83							
9,808.49							
9,809.35							
9,808.44							

Table 4: Force measurement results for 1500 kgf

1500 kgf	Mean	u_{REPE}	u_{RES}	u_{REPR}	u_{REF}	U (k=2)	U (k=2)
N	N	N	N	N	N	N	%
14,712.20	14,712.56	0.18	0.02	0.51	0.15	1.12	0.01
14,713.09							
14,712.72							
14,712.34							
14,712.44							

Table 5: Force measurement results for 3000 kgf

3000 kgf	Mean	u_{REPE}	u_{RES}	u_{REPR}	u_{REF}	U (k=2)	U (k=2)
N	N	N	N	N	N	N	%
29,425.56	29,425.85	0.20	0.04	1.36	0.29	2.81	0.01
29,426.29							
29,425.61							
29,426.26							
29,425.56							

In the force uncertainty calculations repeatability (U_{REPE}), resolution (U_{RES}), reproducibility (U_{REPR}) and reference (U_{REF}) effects were taken into consideration.

5.2. Measurement cycle

Another important component is the cycle through which the measurement is realized. In regard to the cycle some velocities and durations should be controlled. To make such a control the force measurement device is used to measure the time period during which the force is applied and kept applied on the indenter. An example is given below in Table 6 and Table 7.

Table 6: Force application time

	Mean	u_{REPE}	u_{RES}	u_{REF}	u_{RESP}	U (k=2)
s	s	s	s	s	s	s
7.350	7.530	0.111	0.087	0.000	0.014	0.282
7.450						
7.850						
7.350						
7.650						

Table 7: Force dwell time

	Mean	u_{REPE}	u_{RES}	u_{REF}	u_{RESP}	U (k=2)
s	s	s	s	s	s	s
13.950	13.770	0.164	0.087	0.000	0.014	0.372
13.650						
14.200						
13.350						
13.700						

In the measurement cycle uncertainty calculations repeatability (U_{REPE}), resolution (U_{RES}), response time of the transducer (U_{RESP}) and reference (U_{REF}) effects were taken into consideration.

5.3. Indenters

The indenters used for realization of indentation is not part of this project, but all of them are calibrated in accordance with ISO 6506-1:2014 [2] and 6506-3:2014 [3].

6. SUMMARY

At the end of this project a deadweight type HLBHSM with air bearings is designed, produced, installed and activated for first time by TÜBİTAK UME Hardness Laboratory. It comprises all scales in the range 187.5 kgf – 3000 kgf. Very good results were attained in terms of force application and testing cycle realization functioning properties, and user-friendliness from design and automation point of view. Very good repeatability in terms of force application as well as measurement cycle parameters were attained. The system can also be used for Instrumented Indentation Test and the calibration of the force transducer used for calibration/verification of measurement cycle parameters.

7. REFERENCES

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[3] EN ISO, 6506-3. Metallic Materials - Brinell Hardness Test - Part3: Calibration of Reference Blocks, 2014.