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DESIGN AND DEVELOPMENT OF BRINELL-VICKERS HARDNESS STANDARD MACHINE

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Abstract – A dead weight type Brinell-Vickers hardness standard machine was designed for TSE (Turkish Standards Institution) in the scope of TÜBİTAK (The Scientific and Technological Research Council of Turkey) Project* with project number 111G068. The scope of this project is mainly based on covering the requirements of a government agency by making R&D in the related field and it is funded by the TÜBİTAK.

A Brinell-Vickers hardness standard machine had been previously designed and established at UME (National Metrology Institute of Turkey) Hardness Laboratory as a National Standard to provide traceability for realization of indentation for Brinell and Vickers hardness scales to be used as a reference standard in Brinell and Vickers hardness reference blocks calibration. In the new TÜBİTAK Project it is aimed to design a new machine for the TSE with at least similar metrological performance to and more automatic hardness measurement capability than UME machine.

Traceability of each component constituting Brinell and Vickers Hardness scales such as force application and realization of testing cycle to national standards is provided by direct calibration. The indentation measurement system will be provided by the TSE. To realize performance tests of the machine as a whole, hardness reference blocks calibrated by the PTB (National Metrology Institute of Germany) and UME were planned to be used. In this paper Brinell-Vickers Hardness Standard Machine designed by TÜBİTAK UME Hardness Laboratory for the TSE is introduced and its performance test results performed so far are interpreted.

Keywords: Brinell, Vickers, Hardness Standard Machine, Hardness

1. INTRODUCTION

With the demand of the TSE and in turn accredited calibration and testing laboratories a Brinell-Vickers hardness standard machine had been decided to be redesigned and established to provide traceability in the field of Brinell and Vickers Hardness measurements. In this new design 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 very well known dead weight force application system. The frame was supposed to generate the 5 kgf which corresponds to the force value to HV5 and HBW 1/5 scales. There are 8 mass stacks to be added to the frame for realization of the other Brinell scales up to 250 kgf and Vickers scales up to 100 kgf.

An indentation measurement system will be needed for diagonal and diameter length measurement for Vickers and Brinell hardness, respectively. The indentation measurement system is not in the scope of the project, it will be provided by the TSE.

Testing cycle is managed by making use of a load cell to which the whole force application system is mounted. The force application durations are sensed by measuring the force on the load cell instantaneously during load application and comparing the measured force values with the nominal values belonging to the scale and Force - Time relationship is recorded. The indenter approach speed will be adjusted by calibrating the main servomotor which will be used for realization of the testing cycle and penetration speed are measured via the change in the load cell value in time.

2. DESIGN OF THE MACHINE

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

The machine was also designed to realize hardness indentations as automatic as possible. For this purpose a motorized XY_stage is mounted onto the machine body and integrated to the control panel and in turn it is aimed to realize a series of indentations automatically at marked locations before starting the block calibration. Also a camera is adapted to the system to place locations of indentation to

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be realized on the screen of the control pc through the automation software of the system. In Fig. 1 a complete view of the machine is given.

Fig. 1. Brinell-Vickers Hardness Standard Machine Designed for the TSE

2.1. Force Application System

To realize the force with the highest accuracy and stability, deadweight type force application principle was preferred. It comprises mass stacks made up of stainless steel and a frame made of Aluminium to constitute the first load. The force values and scales to be realized are given in Table 1 below.

Table 1. Hardness Scales to be Realized by The Brinell-Vickers Hardness Standard Machine

Hardness Scale	**Indenter**	**Force (N)**
HV5 HV10 HV20 HV30 HV50 HV100	Square based pyramid diamond indenter	49,3 98,07 196,1 294,2 490,3 980,7
HBW1/5 HBW1/10 HBW1/30	1 mm Tungsten Carbide ball	49,3 98,07 294,2
HBW2,5/62,5 HBW2,5/187,5	2,5 mm Tungsten Carbide ball	612,9 1839
HBW5/62,5 HBW5/250	5 mm Tungsten Carbide ball	612,9 2452
HBW10/100 HBW10/250	10 mm Tungsten Carbide ball	980,7 2452

The frame is adjusted to apple 5 kgf and the mass stacks will be in additional order to constitute the other force values and scales. The other mass stacks are 5 kgf, 10 kgf, 10 kgf, 20 kgf, 12,5 kgf, 37,5 kgf, 87,5 kgf and 62,5 kgf, a total of 250 kgf including the frame itself. To prevent the frame from any pendulum and rotational motions during load application which will affect penetration performance of the indenter, it was guided by two air bearings at the two ends. One of the two air bearings is square and the other is cylindrical shaped, both are working with (4-6) bar air pressure. The 8 mass stacks and the frame constituting the first 5 kgf is shown in Fig. 2.

2.2. Indentation Measurement System

The indentation measurement system is not part of this project. It was provided by the TSE. It is used for dimensional measurements.

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Fig. 2. The 8 Mass Stacks and the Frame, a Total of 250 kgf

2.3. Testing Cycle

Beside the force applied on the indenter by the frame and mass stacks, the cycle through which the indentation is realized is also critical and has effects on measurement results. For this reason, indenter speed and force application durations should be controlled. To make such a control and necessary adjustments a load cell is equipped on to the machine and by making use of this load cell force application times are recorded. With a very fast data acquisition the instantaneous force application can be viewed on the screen of a PC by a Force - Time graph. The cycle can be applied manually and automatically, also it can be open loop or closed loop controlled. The final load application speed and the percentage of force at which the speed is changed also can be changed.

3. AUTOMATION OF THE MACHINE

The machine is designed to perform the action from the scale selection to performing the hardness indentation automatically for all scales. Under this circumstances there are two main servo-motor integrated with the mechanical parts and controlled with a software; one for selection of masses and the other one for realization of indentation which moves the masses in the up and down direction for force application. A motorized XY_stage is used to move the hardness block on the anvil for the next indentation at the predefined location, as many times as requested at the beginning of the test.

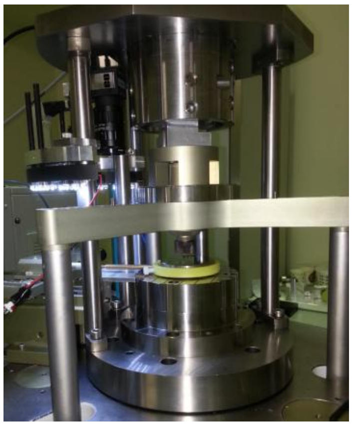

Fig. 3. Motorized XY_Stage and Camera System

A camera as shown in Fig. 3 is mounted on the machine located just on top of the XY_stage to view the block surface and select the number and locations of the indentations prior to the realization of indentations. Once the selection of as many indentations as requested on the PC screen and calibration is started, all indentations are realized automatically.

4. CALIBRATION OF THE MACHINE AND CALIBRATION RESULTS

4.1. Force Calibration – Testing Cycle Verification

Mass stacks used in Brinell-Vickers Hardness Standard Machine were calibrated at UME Mass Laboratory at $1x10^{-5}$ level of uncertainty and the local gravitational acceleration where the machine will be located is measured with a better level of uncertainty. After mounting the machine the force at the tip of the indenter was supposed to be calibrated/verified by high accuracy reference load cell force measurement devices. Two load cells are used by locating them instead of the hardness blocks and the measurement cycle is applied just as applied for the blocks, for all scales and hardness levels. Besides force the speed is also possible to view on the same graph. The very preliminary testing cycle results are given below in Fig 4.

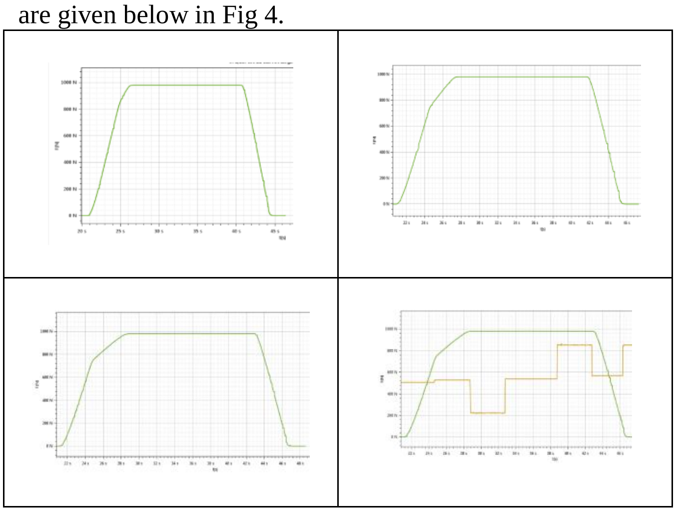

Fig. 4. Testing Cycles with Different Final Load Application Speed and Percentage of Force at which Speed is Changed

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Below force calibration/verification of three scales are given as an example in Fig. 5 to Fig. 8 for HV5, HV10, HV20 and HV30, respectively.

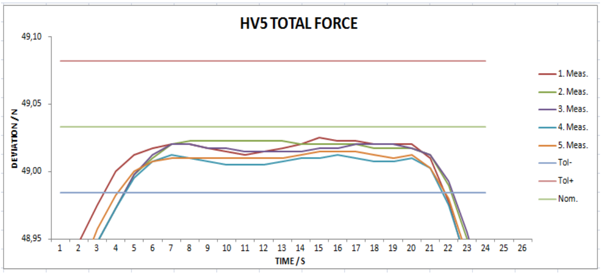

Fig. 5. Testing Cycles and Force Application for HV5

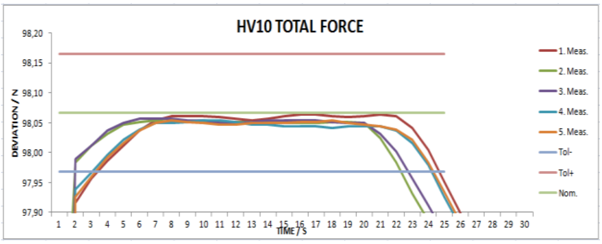

Fig. 6. Testing Cycles and Force Application for HV10

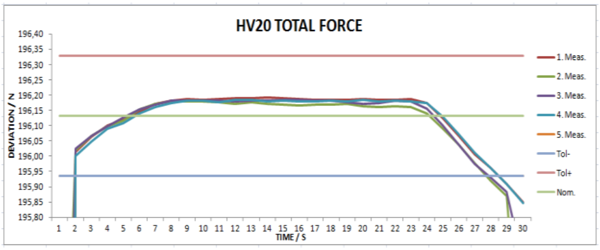

Fig. 7. Testing Cycles and Force Application for HV20

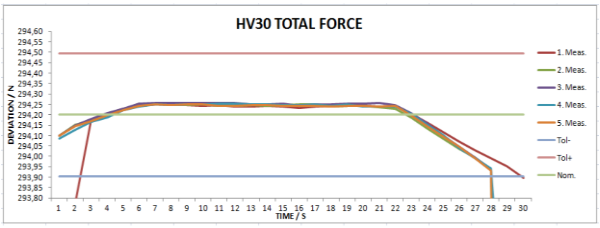

Fig. 8. Testing Cycles and Force Application for HV30

4.2. Indenters

Tungsten carbide ball and square based pyramid diamond indenters in accordance with EN ISO 6506-3 [4] standard and EN ISO 6507-3 [5] standard were used. The ball indenters with 1 mm, 2.5 mm, and 10 mm diameter and square based pyramid diamond indenters were all calibrated at UME in accordance with EN ISO 6506-3 [4] and 6507-3 [5].

4.3. Calibration By Hardness Reference Blocks

After calibration/verification of each component constituting Brinell and Vickers hardness scales, the hardness machine should be checked by hardness reference blocks to figure out its performance including non-measurable effects. For the very preliminary measurement two scales are performed for HV10 and HV30 with blocks measured by UME and the new designed TSE machine.

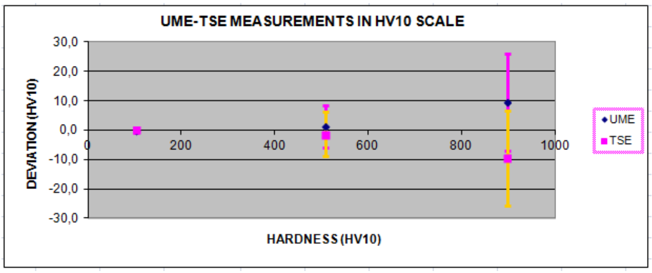

Fig. 9. UME-TSE Block Measurements in HV10 Scale

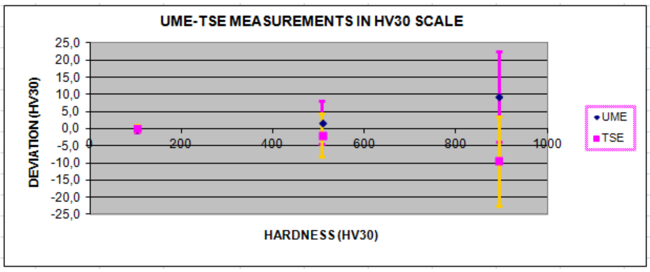

Fig. 10. UME-TSE Block Measurements in HV30 Scale

6. CONCLUSION

At the end of the work explained above we attained the following conclusions;

- We have designed and established a new Brinell-Vickers Hardness Machine for realization of indentation in accordance with EN ISO 6506-1 and EN ISO 6506-3 for Brinell scales and in accordance with EN ISO 6507-1 and EN ISO 6507-3 for Vickers scales.
- Indentation realization for Vickers Hardness scales HV5 to HV100 and most important Brinell Hardness scales between 5 kgf to 250 kgf are possible.
- In this new design, performing scale selection, measurement cycle, performing a series of indentation realization and selection of the location of indentations through a camera all can be done automatically.
- In this new design all forces can be applied through different measurement cycles, i.e. approach speed, force application and final load application speed, different load application speeds in one cycle is possible.

8. REFERENCES

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