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## INVESTIGATION OF TEST FORCE OF REFERENCE HARDNESS STANDARD OF CROATIA

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**Abstract** – Reference hardness standard with HV1 – HV50 measuring range was installed at LIMS (Laboratory for Testing Mechanical Properties) at the end of 2007 with the aim of providing continuous improvement of the metrology infrastructure of Croatia. The load is realised by means of weights and a lever. Measurements of test forces, both axial and radial, were carried out. In this paper the results of the measurements are presented and discussed.

**Keywords:** reference hardness standard, force, measurement uncertainty

### 1. SCOPE

A reference hardness machine has been provided to represent the hardness reference standard in Croatia. The machine was made by Indentec, England, type 5030TKV Std. with hardness scale for Vickers.

Hardness reference machine 5030TKV was installed in the Laboratory for Testing Mechanical Properties at the Faculty of Mechanical Engineering and Naval Architecture. The load is realised by means of weights and a lever. By definition, force is defined with the expression  $F=m \cdot g$ . Therefore, the gravimetric measurements on the location of the reference hardness machine installation were needed in order to achieve the appropriate load by means of weights. The acceleration of gravitation  $g = 98066333,7 \cdot 10^{-08} \text{ ms}^{-2} \pm 4,7 \cdot 10^{-08} \text{ ms}^{-2}$  was obtained by analysis and calculation. On the basis of that value the weights were produced. The estimation and calculation of the measurement uncertainty was carried out in accordance with the EN ISO 6507-2 [1], EN ISO 6507-3 [2] and document EURAMET/cg-16/v.01[3]. On the basis of indirect calibration results it can be concluded that the expanded measurement uncertainty of the reference hardness machine will be in the range  $\pm 1 \%$  HV for the entire measuring range of the machine.

After two years of monitoring of a test force certain changes were determined. One of the questions at Vickers hardness method is axiality of the test force. If we consider a design of a load transmission from weights over lever to a test

specimen it is clear that there are some influential factors on axiality of test force as follows:

- deviation between axis of pyramid holder and axis of indenter peak which should be parallel
- geometrical construction of indenter peak
- deviation of axis of driver
- deviation of perpendicular ( driver- hardness table)
- plan parallel of test specimen or hardness block
- deviation of perpendicular of cylinder on which is table of hardness standard.

### 3. TEST FORCE

Measurements of test forces, both axial and radial, were carried out.

#### 3.1 Test axial force

The applied force was calibrated with force transfer standard (load cells). Such a system leads to two main error sources:

- measurement of the applied force;
- measurement of the maintenance of the applied force.

Several series of measurements were carried out in accordance with the recognized standards. The maintenance of the applied force was assessed by analysing the data obtained during force calibration.

Loading forces were checked by the portable standard of force of class 00 in accordance with EN ISO 376 standard. They were calibrated at PTB (Physikalisch-Technische Bundesanstalt), Germany, using national standards of force (deadweight machines) of measuring capability  $\leq 0,002 \%$ . The expanded measurement uncertainty of their calibration was  $\leq 0,03 \%$ . For each loading two different portable standards of force were applied.

The uncertainty of measurement of the test force is evaluated in two steps:

- determination of the combined relative standard uncertainty of the reference value of the force transfer standard:

$$u_{FRS} = \sqrt{u_{TS}^2 + u_T^2 + u_S^2 + u_D^2} \quad (1)$$

$u_{TS}$  - relative uncertainty of the transfer standard

$u_T$  - relative uncertainty due to the temperature deviation

$u_S$  - relative long term stability,  
 $u_D$  - relative interpolation deviation.

- determination of the measurement uncertainty of each force.

The uncertainty of measurement of the test force is calculated by using the following formula:

$$u_F = \sqrt{u_{FRS}^2 + u_{FHTM}^2 + u_{main}^2} \quad (2)$$

$u_{FHTM}$  – uncertainty of measurement of the test force  
 – normal distribution  
 $u_{main}$  – uncertainty of maintenance of the test force  
 – rectangular distribution

Expanded uncertainty:

$$U_F = k \times u_F \quad (3)$$

Each force was measured three times in three different indentation positions.

Certain difficulties were noted during investigation of the real test force which is calculated and realized by means of weights. Investigations were carried out in four positions of the indenter where the test force is measured five times in each position. Deviations of the test forces for the measuring method HV10 for two different portable force standards with approximately the same measurement capability is presented on figure 1.

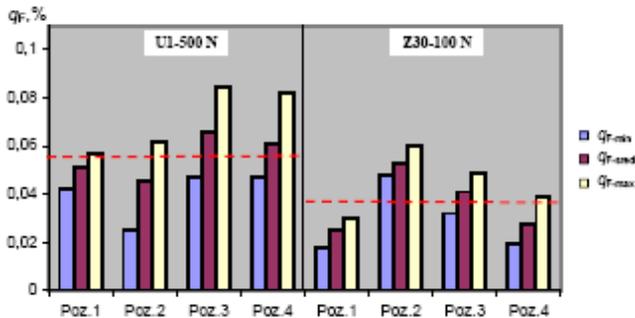


Figure 1. Deviation of the test force for HV10 with two different portable force standards

Investigations for the different loads were also carried out with two different portable force standards (manufactures: HBM, Germany and GTM, Germany) which were previously calibrated in PTB, Germany. Measurement capability of the portable force standards are approximately the same and comply all requirement for reference hardness standards according to EN ISO 6507-2 and 3. Obtained deviations are presented on the figures 2 and 3. From the results can be concluded that all deviations are in the range 0,1%. The influence of the potable force standard design and the way of the contact between potable force standard and reference hardness machine on measurements results were noted by determination of the real force value. Mentioned has significant influence if the real force value is directly calculated in the expression for the hardness determination.

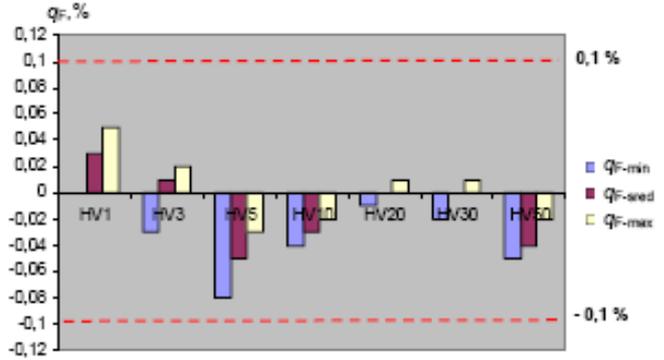


Figure 2. Deviations of the test forces obtained by the HBM portable force standards

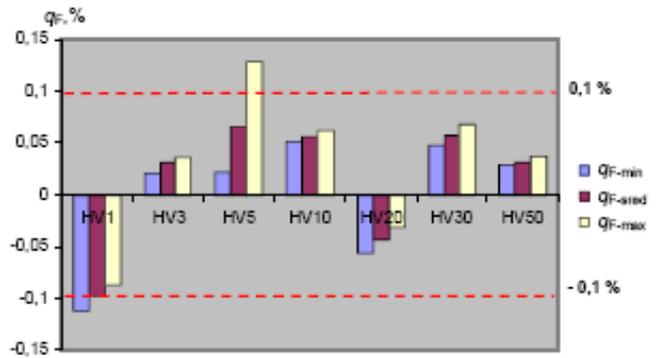


Figure 3. Deviations of the test forces obtained by the GTM portable force standards

The biggest deviation of the test forces at hardness reference machine 5030TKV are perceived at measuring methods HV1 and HV5. As well at mentioned measuring methods repeatability of measurements was the biggest (see Table 1).

Table 1: Repeatability of the test forces

F, N	b, %			
	Position 1	Position 2	Position 3	Position 4
9,807	0,100	0,048	0,031	0,102
29,42	0,014	0,005	0,027	0,014
49,03	0,007	0,116	0,073	0,092
98,07	0,015	0,037	0,037	0,012
196,1	0,025	0,031	0,034	0,056
294,2	0,015	0,018	0,017	0,065
490,3	0,041	0,020	0,051	0,048

One of the indicators that there are certain problems with the values of the real force is repeatability of the measurements' results. Source of mentioned problem can be devices for the contact between indenter and portable force standard and the design of the reference hardness machine and is also uncertainty component and has to be included in uncertainty budget. On the basis of test force investigation of reference hardness tester 5030TKV the real force determination and uncertainty calculation was carried out. Results are shown in Table 2.

Table 2: Results of force measurement uncertainty

$F$ , N	$F_{sr}$ , N	$\Delta F_{rel}$ , %	$U_F$ , %
9,807	9,813	0,061	0,057
29,42	29,432	0,041	0,046
49,03	49,049	0,039	0,067
196,1	196,198	0,050	0,052
294,2	294,314	0,039	0,053
490,3	490,350	0,010	0,037

$F_{sr}$  - mean value of the measured forces,  
 $\Delta F_{rel}$  - relative deviation of the test force,  
 $U_F$  - relative expanded uncertainty of the test force;  $k=2$ .

### 3.2 Test radial force

Testing of the radial test force was carried out with a view to determination of a possibility of the radial forces measurement and their meaning. Special equipment for mentioned was needed. In last few years there was a huge development of force transducers which can measure both axial and radial forces which create certain torques. Positioning of the force transducer on the table of the reference hardness standard and a direction of test forces are shown in Figure 4.

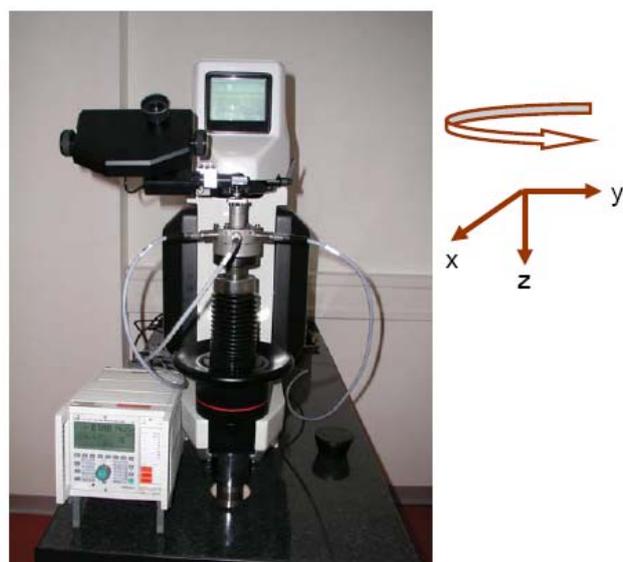


Figure 4. Measurement of the radial test force

Testing of radial test forces in directions x and y with measuring method HV 50 were carried out. At the same time test forces at indenter indentation in hardness block were measured. The first and the third series of measurements were carried out without moving of the hardness block from the hardness table. At the second measurement series the hardness block was moved from the hardness table at each measurement point. Results of radial force measurement on the hardness block IN40452G with the nominal value 417,3 HV50 are presented in the Table 3.

Existence of the radial test force with very good repeatability is seen from the measurement results. The real values of the radial test forces are questionable since calibration of the portable force standard in direction y and z haven't been carried out.

Table 3: Results of radial force measurement

Hardness block 417,3 HV50	Measurement series	$F_z$ N	$F_x$ N	$F_y$ N
Series 1	1.1	490,3393	23,533	-3,522
	1.2	490,3643	23,609	-3,672
	1.3	490,3143	23,534	-3,823
	1.4	490,3892	23,834	-3,797
	1.5	490,3643	23,609	-3,748
Series 2	2.1	490,3643	22,935	-3,673
	2.2	490,6461	23,484	-3,273
	2.3	490,2893	22,710	-3,498
	2.4	490,4142	22,260	-3,198
	2.5	490,3892	22,485	-3,373
Series 3	3.1	490,4392	22,985	-3,448
	3.2	490,3143	22,785	-3,373
	3.3	490,3892	22,935	-3,248
	3.4	490,3643	22,985	-3,173
	3.5	490,3643	22,860	-3,273

Extra investigations of the radial test forces were carried out in which portable force standards were rotated for 60 after every measurements. Results are presented on figure 5.

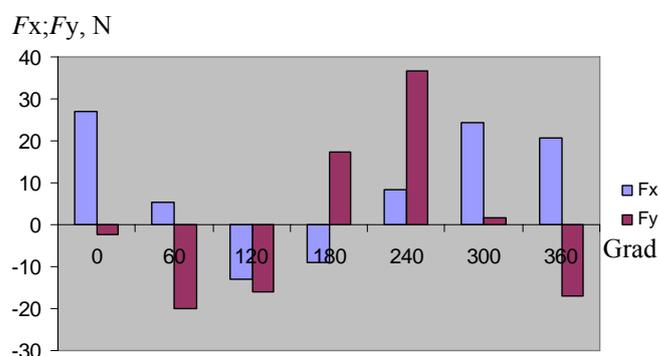


Figure 5. Measurements of the radial test forces at rotation of the portable force standard

On the basis of carried investigations is determined that the values of the radial test forces amounts maximal 25 N. As well their graphical sum is approximately the same. Repeatability of the measurements was in the range to 10% In order to obtain certain conclusion is needed to carry out more measurements and to estimate influential factors which are source to uncertainty.

### 4. CONCLUSION

On the basis of carried investigations on the reference hardness machine 5030 TKV can be concluded that the test forces and the uncertainty components influence on the hardness measurements. Mentioned has significant influence

if the real values of the force is directly calculated in the expression for the hardness determination. Special attention at hardness measurement has to be on the design of the hardness machine or more precisely on contact between on the loading fitting of the portable force standard and the indenter. Therefore it would be recommended to carry measurements with more different portable force standards. In the calculation of the measurement uncertainty has to be included the uncertainty of the repeatability of the test force measurements which is indicator if the load transition has unwished changes. As well the number of test forces measurements at one position has to decrease on at least five.

Influence and quantity of the radial test forces are a field of investigation which have significant influence on the

improvement of the measurement capability of the reference hardness machines in the future.

#### REFERENCES

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