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INVESTIGATION OF THE INFLUENCE OF DURATION OF PRELIMINARY AND TOTAL FORCES FOR MEASUREMENT OF HARDNESS

The article describes the works on researching the effect of indentation time in the measurement of the hardness using Rockwell scales. The sensitivity coefficients are determined at different times of indentation applied to the hardness blocks. The dependence of the measured hardness from the load application time is obtained. The influence of the load time application to expanded uncertainty in the measurement of hardness in the range of 20-30 HRC, 40-50 HRC, 60-70 HRC and 80-86 HRA is shown. The works were carried out on the national primary standard of Ukraine of hardness units (DETU 02-04-99).

Keywords: *hardness, preliminary and total test forces, sensitivity coefficient, budget of uncertainty.*

Introduction

When analyzing the results of international comparisons it is often necessary to give reasons for over- or underestimated values in the hardness measurement. Determination of hardness values depends on the result of measurement of the large number of different parameters such as the load of weight, radius and angle of spheroconical indenter, the penetration depth of the indenter, the duration of the preliminary and total test forces. The algorithm of measurement of hardness and the hardness reference blocks used for transfer the hardness unit must comply with the [1 – 3]. The work shows the influence of the sensitivity coefficient for the time of applying the preliminary test force and the total test force on the expanded uncertainty.

In [4] the effect of increasing the duration of the preliminary test force time for HRB and HRC ranges is determined. The effect of hardening and softening effects on the measurement result is discussed. Comparisons of measurement uncertainty at various hardness levels are provided.

Methods and procedures

Taking into account the methodology of determining the uncertainty (using sensitivity coefficients) for hardness standards, the following components for the uncertainty budget are indicated:

- the preliminary test force, F_0;
- the total test force, F;
- radius and angle of spheroconical indenter, α_m, R_α;
- the length measuring system, h;
- speed of additional load application, V_{fis};
- duration time of preliminary test force, T_p
- duration of the total force, T_{df};
- deformation of frame, d.

These values determine the equation of the hardness measurement in implicit form:

$$HR = f\left(F_0, F, \alpha_m, R_\alpha, h, V_{fis,}, T_p, T_{df}, d\right). \quad (1)$$

The ratio of changes of the measured hardness values ΔH to the measurement of each parameter Δx_i, which are the components of budget uncertainty, is defined as the sensitivity coefficient c_i:

$$c_i = \frac{\Delta H}{\Delta x_i}. \quad (2)$$

The sensitivity coefficient is a value ranging the modes tolerances of the standard.

The problem of determining the sensitivity coefficient reduces to the measurement of hardness reference blocks in different variations of the components of uncertainty budget for each of the hardness range reproduced by the standard.

According to [3], the duration of the preliminary test force action must not exceed 3 s ($T_p \le 3$ s), the shift from the preliminary test force to the total test force load must be at least 1 s, but no more than 8 s (1 s $< t_{apply} <$ 8 s), the duration of the total test force T_{df} should be between 4 s ±2 s.

The depth of indentation is measured after removal of the base load, and the indicated depth of imprint (final reading stabilization time, t_{post}) should be from 3 s to 5 s. It is also important to follow the indentation speed when applying the total load in the range of 20 μm/s $< V_{fis} <$ 40 μm/s.

The similar works on the study of speed indentation for Superficial-Rockwell scales are described in [5, 6].

In the experiment, the time of the duration of the preliminary test force and the total force was changing in the range from 1 s to 10 s, but other components (the preliminary test force, the total test force, the indenter geometry, the final indentation speed of additional load

application, the length measuring system) were taken as constant and acceptable to [1-3].

Works were carried out on the national primary standard of Ukraine of hardness units (DETU 02-04-99) (Fig. 1).

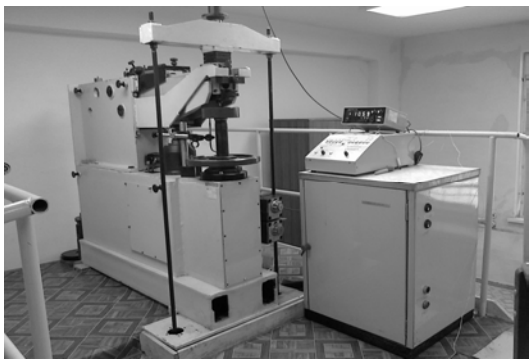

Fig. 1. National primary standard of hardness units

The hardness blocks manufactured by Centre "MET" Ltd (Russia) were used for researches (see Fig. 2).

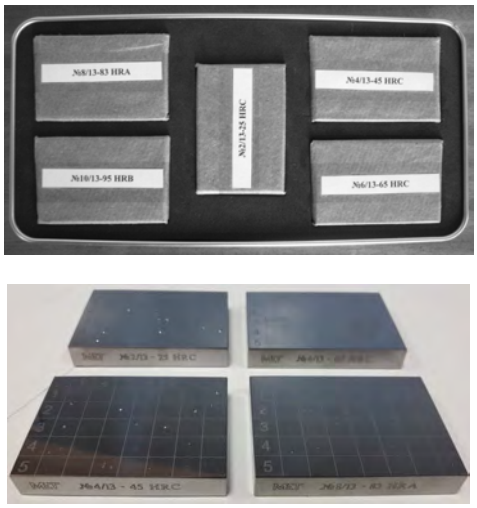

Fig. 2 Rockwell set of hardness reference blocks

The upper surface of the block, which is the measurement surface, is finished. The measurement area is defined to be within marked grid. The grid (7×7 mm^2) is drawn on the block surface in order to define the coordinates of the test locations. The sizes of the test area and grid allow 35 possible test locations.

Results and discussion

The figures 3 – 6 show the dependence of the measured hardness values from the duration of the preliminary test force for the four ranges 20-30 HRC, 40-50 HRC, 60-70 HRC, and 80-86 HRA.

Then we determine the equation of a straight line and the resulting coefficient of sensitivity for each of the four ranges.

The obtained results shown in Figures 2-5 are consistent with the experimental data from [4].

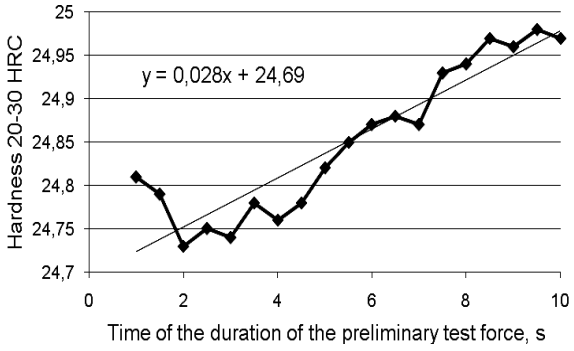

Fig. 3. The dependence of the measured hardness values from the duration of the preliminary test force for the range of 20-30 HRC

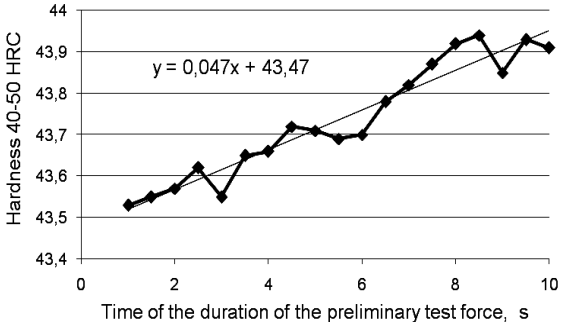

Fig. 4. The dependence of the measured hardness values from the duration of the preliminary test force for the range of 40-50 HRC

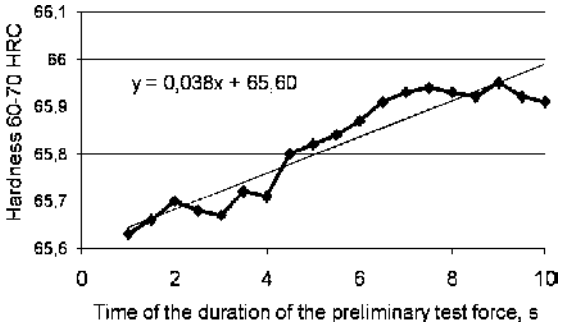

Fig. 5. The dependence of the measured hardness values from the duration of the preliminary test force for the range of 60-70 HRC

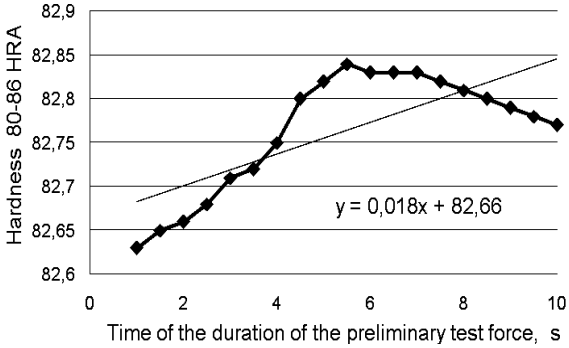

Fig. 6. The dependence of the measured hardness values from the duration of the preliminary test force for the range of 80-86 HRA

We perform the similar measurements with increased time T_p of preliminary force F_0 and increased time T_{df} of total test force F .

The Figures 7, 8, 9 and 10 show the dependence of the measured hardness values from the duration of the total test force for the four ranges 20-30 HRC, 40-50 HRC, 60-70 HRC, and 80-86 HRA.

The equations of the lines allow determining the sensitivity coefficients for each range.

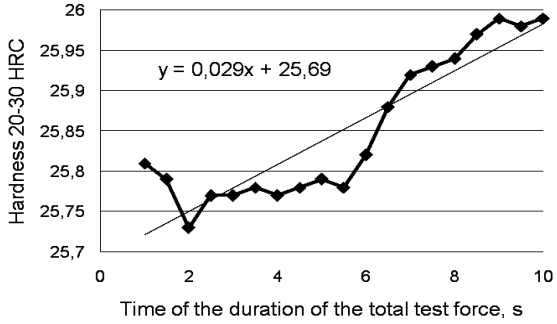

Fig. 7. The dependence of the measured hardness values from the duration of the total test force for the range of 20-30 HRC

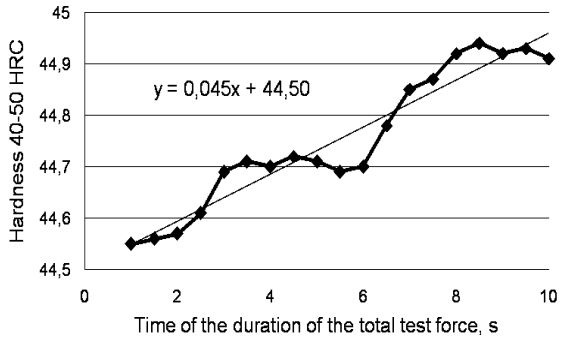

Fig. 8. The dependence of the measured hardness values from the duration of the total test force for the range of 40-50 HRC

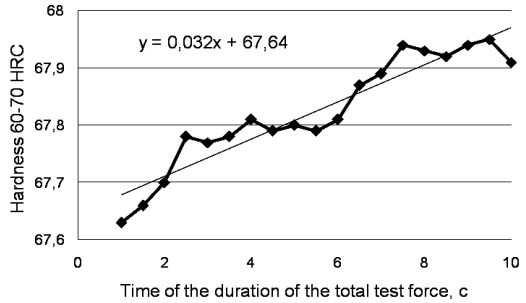

Fig. 9. The dependence of the measured hardness values from the duration of the total test force for the range of 60-70 HRC

We compare the sensitivity coefficients at different time load applications T_p and T_{df} (Table 1).

The values of sensitivity coefficients for $T_p \le 3$ and $2 \le T_{df} \le 6$ seconds correspond to the time of the applying of the load in international comparisons [7].

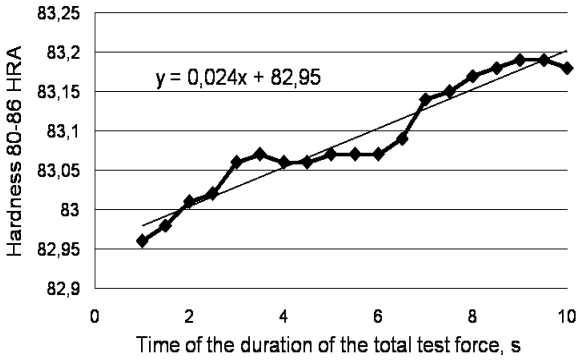

Fig. 10. The dependence of the measured hardness values from the duration of the total test force for the range of 80-86 HRA

Table 1

Evaluation of uncertainty of sensitivity coefficient

Time of the duration of the test forces, s	Sensitivity coefficient, $c_i = \frac{\Delta H}{\Delta x_i}$			
	20-30 HRC	40-50 HRC	60-70 HRC	80-86 HRA
$T_p \le 3$	0,009	0,030	0,029	0,011
$2 \le T_{df} \le 6$	0,010	0,029	0,029	-0,011
$1 \le T_p \le 10$	0,028	0,047	0,038	0,018
$1 \le T_{df} \le 10$	0,029	0,045	0,032	0,024

In order to determine the expanded uncertainty of measurement results for each of the test range, we substitute the sensitivity coefficients into the respective budgets of uncertainty.

The values of the expanded uncertainty of measurement results are shown in Tables 2-5, respectively.

Table 2

Evaluation of uncertainty measurement for 20-30 HRC

Time of the duration of the test forces, s	Sensitivity coefficient	Maximum hardness variation	Expanded uncertainty
$T_p \le 3$	0,009	0,28	0,25142
$2 \le T_{df} \le 6$	0,010	0,32	
$1 \le T_p \le 10$	0,028	0,25	0,25159
$1 \le T_{df} \le 10$	0,029	0,28	

Table 3

Evaluation of uncertainty measurement for 40-50 HRC

Time of the duration of the test forces, s	Sensitivity coefficient	Maximum hardness variation	Expanded uncertainty
$T_p \le 3$	0,030	0,35	0,37696
$2 \le T_{df} \le 6$	0,029	0,38	
$1 \le T_p \le 10$	0,047	0,41	0,37713
$1 \le T_{df} \le 10$	0,045	0,37	

Table 4

Evaluation of uncertainty measurement for 60-70 HRC

Time of the duration of the test forces, s	Sensitivity coefficient	Maximum hardness variation	Expanded uncertainty
$T_p \leq 3$	0,029	0,29	0,39080
$2 \leq T_{df} \leq 6$	0,029	0,31	
$1 \leq T_p \leq 10$	0,038	0,32	0,39083
$1 \leq T_{df} \leq 10$	0,032	0,28	

Table 5

Evaluation of uncertainty measurement for 80-86 HRA

Time of the duration of the test forces, s	Sensitivity coefficient	Maximum hardness variation	Expanded uncertainty
$T_p \leq 3$	0,011	0,28	0,26745
$2 \leq T_{df} \leq 6$	-0,011	0,24	
$1 \leq T_p \leq 10$	0,018	0,21	0,26752
$1 \leq T_{df} \leq 10$	0,024	0,16	

Conclusions

By analyzing the results of hardness measurements using the scales of hardness in the range of 20-30 HRC, 40-50 HRC, 60-70 HRC, and 80-86 HRA, it can be concluded, that the possible over- or underestimated values of the measured hardness depend marginally (4-5 decimal point) on the duration (exposure) time of the preliminary and/or the total force. Determination of the sensitivity coefficients that are the most influencing ones on the expanded uncertainty is a reason for further investigation.

The reference hardness test blocks were used for the investigation. Measurements were carried out all over the area of hardness test blocks. The dependence of the hardness values obtained from the pre-load applying time demonstrates the plastic properties of metal. Depending on the hardness of the metal, the softening or hardening of the material is observed. When carrying out the researches, the main load plateau is observed in the hardness range of exposure times from 2 seconds to 6 seconds.

The duration of total force T_{df} is equal to 4 s ± 2 s and defined in the documents for the international comparisons.

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ДОСЛІДЖЕННЯ ВПЛИВУ ЧАСУ ДІЇ ПОПЕРЕДНЬОГО ЗАВАНТАЖЕННЯ ПРИ ВИМІРЮВАННІ ТВЕРДОСТІ

В.В. Скляров, Я.С. Довженко

У статті описуються проведені роботи по дослідженню впливу часу індентування при вимірюванні твердості за шкалою Роквеллу. Визначені коефіцієнти чутливості при різних тимчасових інтервалах дії індентора на міру твердості. Отримані залежності зміряної твердості від часу додатку навантаження при використанні сфероконічного індентора. Показаний вплив часу додатку навантажень на розширену невизначеність при вимірюванні твердості в діапазонах 20-30 HRC, 40-50 HRC, 60-70 HRC і 80-86 HRA. Роботи проводилися на державному первинному еталоні України одиниць твердості (ДЕТУ 02-04-99).

Ключові слова: *твердість, час дії попереднього і основного завантажень, коефіцієнти чутливості, бюджет невизначеності.*

ИССЛЕДОВАНИЕ ВЛИЯНИЯ ВРЕМЕНИ ДЕЙСТВИЯ ПРЕДВАРИТЕЛЬНОЙ ЗАГРУЗКИ ПРИ ИЗМЕРЕНИИ ТВЕРДОСТИ

В.В. Скляров, Я.С. Довженко

В статье описываются проведенные работы по исследованию влияния времени индентирования при измерении твердости по шкале Роквелла. Определены коэффициенты чувствительности при различных временных интервалах воздействия индентора на меру твердости. Получены зависимости измеренной твердости от времени приложения нагрузки при использовании сфероконического индентора. Показано влияние времени приложения нагрузок на расширенную неопределенность при измерении твердости в диапазонах 20-30 HRC, 40-50 HRC, 60-70 HRC и 80-86 HRA. Работы проводились на государственном первичном эталоне Украины единиц твердости (ДЕТУ 02-04-99).

Ключевые слова: *твердость, время действия предварительной и основной загрузок, коэффициенты чувствительности, бюджет неопределенности.*