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Features of the production and calibration of reference hardness test blocks

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This article provides an information about the production of reference hardness measurements on the Brinell scales (type MTB-K), Rockwell A, B, C (type MTR-K), Superficial Rockwell N and T (type MTSD-K), brief information about the state of production of hardness measures in the world and the research conducted at this institute in the development and improvement of manufacturing technology. The physical and chemical properties of the studied measuring instruments are given. Hardness measures are intended for setting, calibration or verification according to standardized hardness scales of stationary and portable hardness measuring instruments, for example, software. Reference hardness measures are manufactured in accordance with GOST 9031-75 «Exemplary hardness measures. Specifications» made of carbon and alloy steels, passing through the stages of mechanical and heat treatment, have a rectangular, triangular or round shape. Reference hardness measures in accordance with the law «On Ensuring the uniformity of measurements in the Republic of Kazakhstan» are calibrated. Primary and periodic verification of hardness measurements is carried out by the bodies of the metrological service accredited for the right to verify hardness measuring instruments. The verification interval is 2 years in accordance with the interstate standard GOST 8.335-2004 «Standard hardness measures. Verification method».

Keywords: hardness measurement, hardness test blocks, number of hardness, hardness scales, heat treatment, production.
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1 Introduction

In modern production, the assessment of the physical properties of metal products, as well as the solution of issues related to the control of technological processes in industry, are inextricably linked with mechanical testing of materials and, in particular, with hardness measurements. Hardness measurements are distinguished by simplicity and high productivity, the ability to test, without the manufacture of special samples, directly on the surface of the product, while slightly violating its shape and physical characteristics. The hardness of materials is determined by scales corresponding to the measurement method [1-4, 7].

Hardness measurements are used in engineering, metallurgy, mining, transport, and energy enterprises. For verification/calibration, as well as setting up stationary and portable devices for measuring hardness on the Brinell, Vickers, Rockwell and Super-Rockwell scales, reference hardness measures are used. Verification of these devices is carried out according to various methods of verification, incl. on [6, 8, 9].

In Kazakhstan, there was historically no production of hardness measures, they were imported in the vast majority from Russia (PO «Tochpribor», CPCR «MET»). Thus, the production of hardness blocks in the Republic of Kazakhstan is a new and promising direction in the production of measuring instruments, while the need for enterprises to use hardness blocks is high, and moreover, a further increase in demand is expected due to the opening of new production facilities.

Reference hardness measures [5], which are produced in the KF RSE «KazStandard», undergo metrological certification on state standards of hardness according to the Brinell, Vickers, Rockwell and Super-Rockwell scales. Calibration and measurement capabilities of the above standards are confirmed by international comparisons within COOMET and published on the BIPM website [10,11].

The main objective of this production is to increase the level of metrological support for verification / calibration of working hardness measuring instruments used at industrial enterprises of the Republic of Kazakhstan.

2 Development of production technology

The main requirement for a measure of hardness is the uniformity of the working surface and the stability of physical and mechanical properties over time. The homogeneity criterion is the range of hardness numbers. The arithmetic mean of the results of measurements of five prints applied evenly over its surface is taken as the actual value of the hardness of the measure.

When developing the technology, the factors affecting the uniformity of hardness measures were considered, and on the basis of research work, grades and assortment of steels were selected.

In all countries, in the production of hardness blocks, various technologies for their manufacture are used. The production technology of each manufacturer is unique, incl. differences in the steels used. National standards have their own steel grades and requirements for the assortment, their chemical composition and structure. Table 1 shows the chemical composition of the steels used in the production of test blocks in some countries.

In the process of developing the technology for the production of hardness blocks, a chemical and microstructural analysis of the hardness blocks produced by the Tochpribor software, manufactured in 1989, was carried out. The results of the analysis are shown in table 2.

Table 3 shows the requirements for the chemical composition of U8A-U10A, KhG, KhVG steels used for the production of hardness measures.

Table 1 – The chemical composition of steels used in various states

Manufacturer country	Steel designation	Chemical composition of steel, %									Analogue of the steel grade according to the RD of the RK
		C	Mn	Si	P	S	Cr	Ni	W	V	
Japan	SK4	0,9	0,36	0,25	0,013	0,007	0,04	-	-	-	U9A
Japan	JWP9	0,87	0,33	0,32	0,018	0,009	0,04	0,13	-	-	U8-U9A
USA	01	0,95	1,27	0,24	0,026	0,015	0,5	-	-	-	HGC
Great Britain	2S31	1,0	1,2	0,2	0,03	0,01	0,6	0,5	0,2	0,4	HBG

Table 2 – Studies of hardness measures produced by PO «Tochpribor»

Number, hardness scale	Chemical composition, %			steel grade	macrostructure	microstructure
	C	Mn	Si			
25 HRC	0,96	0,33	0,32	У10	1 score	Uniform sorbitol
61 HRC	Steeloscope			У10		Trostite hardening
104 HB	0,11	0,60	0,33	Ст10		Uniform ferrite-pearlite
203 HB	1,00	0,30	0,22	У10		Uniform sorbitol

Table 3 – Requirements for the chemical composition of steels

steel grade	Chemical composition of steel, %							Source
	C	Mn	Si	P	S	Cr	W	
У8А	0,75-0,84	0,17-0,28	0,17-0,33	0,025	0,018	-	-	GOST 1435-99
У9А	0,85-0,94	0,17-0,28	0,17-0,33	0,025	0,018	-	-	GOST 1435-99
У10А	0,95-1,09	0,17-0,28	0,17-0,33	0,025	0,018	-	-	GOST 1435-99
ХГС	0,95-1,05	0,85-1,25	0,4-0,7	-	-	1,3-1,65		GOST 5950-2000
ХВГ	0,9-1,05	0,8-1,1	0,1-0,4	-	-	0,9-1,2	1,2-1,6	GOST 5950-2000

Conducted studies and subsequent analysis show that carbon and alloy steels are used in most cases for production.

The range of steels used in the production of hardness tests is also individual. In Japan, hardness test blocks are made from forged billets, in Switzerland (HMT company) powder metallurgy technology is used, the rest of the countries use mainly rolled strip.

Heating for hardening in the Russian Federation, Great Britain, Poland is carried out in salt baths of various compositions, and in Japan, the Czech Republic in electric furnaces. Quenching media also differ: for alloy steels – oil, carbon steels – water or aqueous solutions of caustic soda or sodium chloride. After hardening, some manufacturers use cold treatment. Vacation is carried out in oil baths (Russia, Japan), salt baths (Poland, USA) or in electric furnaces (Great Britain, Russia) with artificial circulation of the medium.

In order to reduce costs in the production of hardness blocks, manufacturers use the smallest possible range and the cheapest steel grades.

In the production of hardness blocks, the conversion of hardness numbers according to various hardness scales is used, for example, hardness blocks of 25 HRC correspond to a hardness level of 200 HB. Figure 1 shows the ratio of the levels of various scales and methods of measuring hardness to HV30 [12].

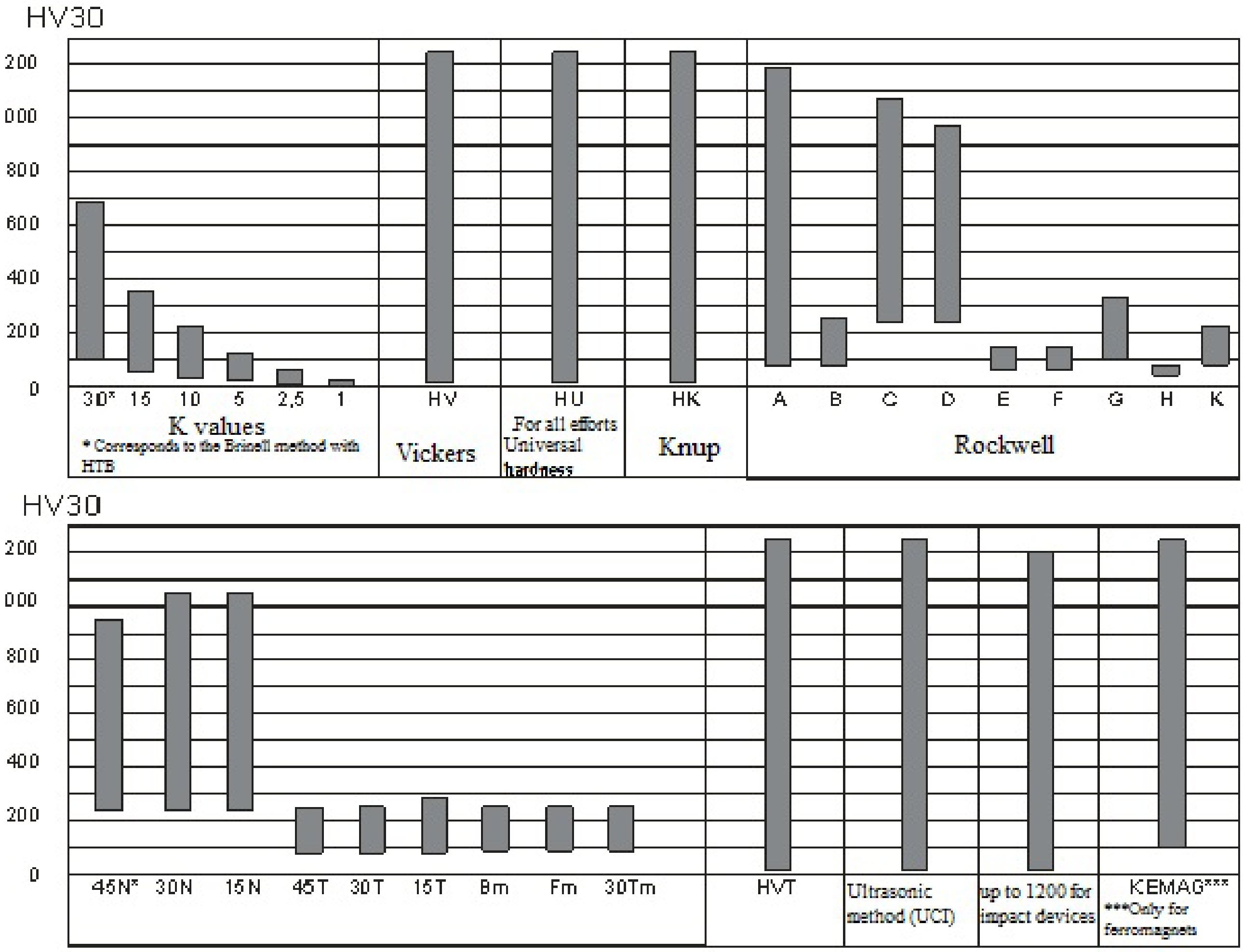

Figure 1 – The ratio of the levels of various scales and methods of measuring hardness to the Vickers hardness scale HV30

The developers of various portable and stationary, electronic devices for measuring hardness are also forced to use the conversion of hardness numbers [13], [14], [15].

Based on the information obtained in the study of hardness measures and pilot production of hardness samples, the main factors influencing the heterogeneity of hardness measures were determined, which include:

composition and grade of steel;

metallurgical production at the smelting stage (quality of steels, additional processing by remelting with slag, grain size, etc.);

assortment of rolled metal products, i.e. rolling method affecting the structure;

method of machining workpieces (cutting, milling);

heat treatment [16], [17];

finishing surface treatment of workpieces (grinding, polishing).

The method of steel smelting affects the purity of steels from impurities, the structure of grain boundaries. The use of steels, in the production of which electroslag remelting or vacuum holding of steel was used, makes it possible to increase the uniformity of hardness measures. Vacuum remelting frees steel from hidden impurities – nitrogen, oxygen, hydrogen and non-metallic inclusions. Vacuum pumps pump out gaseous oxides of CO, CO2 and H2O and reduce the oxygen content in steel. Electroslag remelting frees steel from non-metallic inclusions – sulfur, phosphorus, etc. In this process, the crystallization of the metal bath is slowed down from the bottom up, which allows you to clean the steel from gases, harmful impurities and non-metallic inclusions.

In [18], it is recommended to use rectangular hardness test blocks made from strips that are rolled with a high degree of reduction, which has a positive effect on uniformity. Also, the strip for the workpiece is selected as close as possible to the thickness of the workpiece, because the thinner the strip, the greater the degree of compression it undergoes.

According to [19], during grinding of parts, burns and surface stresses, the formation of a secondary hardened layer, and an inhomogeneous decrease in hardness can occur if the depth of cut during grinding goes beyond certain limits and measures are not taken to ensure sufficient cooling of the parts.

The technology for the production of hardness blocks as reference measuring instruments is complex and time-consuming. The technology for the production of hardness blocks as reference measuring instruments is complex and time-consuming.

3 Stages of development of own production

In 2010, for the first time in the Republic, RSE «KazStandard» on the basis of a branch in Karaganda, mastered small-scale production of hardness measures according to Brinell, Rockwell and Super-Rockwell scales. Technical and metrological characteristics of the produced hardness test blocks are presented in tables 4 and 5.

Table 4 – Technical and metrological characteristics of Brinell hardness test blocks MTB-K

Hardness scale HB (HBW)	Intervals of hardness numbers, HB (HBW)	Range of hardness numbers, no more, %	Weight, no more than, kg
10/3000	(400 ± 50); (200 ± 50)	3,0	1,6
10/1000	(100 ± 50)	4,0	
5/750	(400 ± 50); (200 ± 50)	3,0	

Table 5 – Technical and metrological characteristics of hardness test blocks according to Rockwell MTP-K and Super-Rockwell MTSR-K

Hardness scale	Intervals of hardness numbers, HR	Range of hardness numbers, no more, HR	Overall dimensions, (length × width × height), not less than, мм	Weight, no more than, kg
HRA	83 ± 3	0,6		
HRB	90 ± 10	1,2		
HRC	25 ± 5 45 ± 5 65 ± 5	1,1 0,8 0,5		
HRN15	92 ± 2	0,6	60×40×6	0,24
HRN30	80 ± 4 45 ± 5	0,6 1,1		
HRN45	49 ± 6	1,1		
HRT30	76 ± 6 45 ± 5	1,2 1,8		

In 2017, a pilot batch of reference hardness tests according to the Vickers MTV-K scales was produced, which are manufactured in accordance with [5]. The developed technology did not allow obtaining hardness measures due to the existing high level of defects. It is required to conduct research in order to adjust the technology. Vickers hardness measures are subject to higher requirements for the roughness of the working surface (roughness parameter Ra is not more than 0.04 μm [5], [14]) compared to measures of other scales, which significantly increases the complexity of their production [17]. Table 6 is given below with the metrological characteristics of Vickers hardness testers of the 2nd category [5].

Figure 2 shows a general view of the hardness blocks manufactured by the KF RSE «KazStandard».

Table 6 – Metrological characteristics of hardness measures according to Vickers

Test load, H	Hardness number	Range of hardness values, %, no more
1	450 ± 75 800 ± 50	5,0
5, 10	450 ± 75 800 ± 50	3,0
20, 30, 50	450 ± 75 800 ± 50	2,0

Figure 2 – General view of hardness measures

4 Conclusions

In 2020, the share of Kazakhstani content of hardness test blocks KF RSE «KazStandard» increased from 61.1% (as of 2016) to (97.2-98.4)% for hardness testers MTR-K and MTSR-K and (81 .0-89.7) % for MTB-K hardness test blocks.

Since 2010, the volume of production of hardness blocks has grown 4 times. The distribution of sales volumes until 2021 is shown in Figure 3.

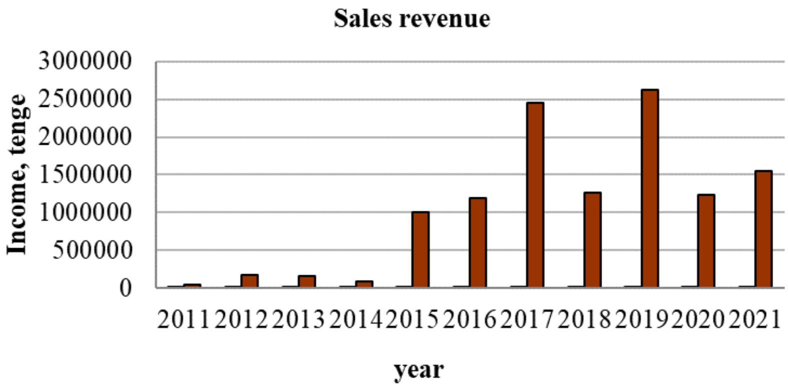

Figure 3 – Volumes of implementation of hardness measures

In the process of production of hardness blocks, problems arise regarding the dependence on third-party enterprises when they perform subcontracting work – cutting blanks, milling, grinding [25], which leads to a significant increase in the cost of manufacturing hardness blocks.

In order to optimize the activities for the production of reference hardness blocks and reduce costs on an ongoing basis, experimentally, some technological operations are being revised during the heat treatment of a batch of blanks of reference hardness blocks, depending on the results of metrological certification. Thus, this will provide the domestic market of Kazakhstan with a sufficient number of hardness measures at prices acceptable to users.

Prospects for the development of production include the following steps:

purchase of technological equipment;

continuation of work related to improving product quality.

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