SELECTION OF THE METHOD OF HARDNESS TEST

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Abstract. The paper gives classification of the hardness tests in dependence on the measured physical parameters. There is hardness of the reference specimen evaluated by practically widely used hardness measurement techniques and methods and the measurement accuracy calculated. The most appropriate methods for research of hardness and strength changes of the pellet torch body in the burning area are selected. The hardness of samples, cut from the pellet torch, as well as pellet torch body is measured by Mobil tester M-295. It is clarified, that for hardness test of small size flat samples the best methods are Rockwell, Brinell and Vickers methods, however, Mobil tester M-295 is more appropriated for scientific researches because the absolute value of the hardness figure has not relevant importance, but the character of changes of this value in dependence on different factors is important.

Key words: hardness, hardness test, accuracy.

Introduction

Hardness tests are one of the faster and less expensive methods for definition of mechanical properties of materials, as well as the tested product is practically not destroyed in the testing process. Hardness is not physical constant; the value of it is dependent not only on the tested material, but on the testing method also. Hardness depends on the mechanical properties of the material – plasticity, limit of elasticity, module of elasticity, strength, etc. When hardness is defined by different methods, the impact of the mechanical properties is different. This is a reason, why it is very important to choose the method, which gives comparable and credible results, as well satisfies the demands for further data using.

The methods of hardness tests by the shape of indenter and measured physically parameter can be divided in several groups [1]:

1. Hardness is defined by measuring of the value of plastically deformation that occurs in the material from slowly pushing in a steel or sintered-carbide ball (Brinell method) or square-shape diamond pyramid (Vickers method), or diamond cone (Rockwell method);
2. Hardness is defined by measuring of the value of plastically and elasticity deformations that occur in the material from pushing a standard-type indenter (Marten's method);
3. Hardness is defined by measuring of the value of elasticity deformation that occurrs in the material from pushing a standard-type indenter (Shore's method);
4. Hardness is defined by scratching in the material with indenter from harder material (Moss method, Meyer method);
5. Hardness is defined by the ability of the material to be treated by cutting, boring or grinding;
6. Hardness is defined for nano - materials by using of nano-hardness definition methods;
7. Hardness is defined by measuring of the parameters that describe pendulum motion.

Several hardness definition methods request to use indenters with different sizes (Brinell method) and/or different shapes (Rockwell method) with the aim to extend the range of hardness measuring.

It is possible to make a hardness definition by using of mobile equipment. The mobile hardness definition methods request to make dynamic influence of the indenter on the material, for example, the Poldy method as well as the Shore's method (Ceroscopy); as well as with ultrasound influence (ultrasonic micro hardness).

The selection of the hardness test method and acquired results are dependent on hardness of the item surface, roughness, dimensions, shape, microstructure, processing type before measuring and the conditions of exploitation. Important factors are the aims for the results using as well the value of the necessary accuracy.

Selection of the type of the hardness test is significantly affected by the rate of surface hardness. For softest metals and alloys the most appropriate and accurate hardness definition method is the Brinell method. Implementation of this method is possible on the specimen with not a very high value of surface roughness. Smooth and very high smooth surface is necessary when the Rockwell and

Vickers methods are used. Greater surface roughness is allowable when the value of the hardness figure is defined by the mobile hardness tester.

Selection of the type of hardness test is dependent on the dimensions of the item researched. With Brinell, Rockwell, Vickers methods it is possible to define hardness for small dimension detail surfaces. For hardness definition of large dimension detail surfaces mobile testers are used, the Poldy method as well the Moss method and ultrasound.

The shape of the surface as well as the rate of homogeneity of the material properties also are affected by the value of the hardness figure; because when hardness is defined always measurements of the diameter have to be made as well as of square diagonals of impress in two perpendicular destinations. When hardness is defined for incurved and curved details, the results of measuring are made more accurate by using of correction coefficients.

The value of the hardness figure is affected by the structure of the item researched. When hardness is defined for graphitized cast iron as well as materials with non homogeny density it is not allowed to use the Rockwell method with diamond cone as well as the Vickers method.

The previous mechanical or thermal treatment of the researched item can significantly affect the value of the hardness figure ant this must be taken into account when the measuring method is selected, the same, it must be noticed when the specimen is prepared for researching by grinding, buffing.

The researched item can be operated before testing in conditions with elevated temperatures as well as into the environment with a high level of influence of chemical elements; as the result of the mentioned below, the surface can become hardened, annealed or charred and its properties are different from the properties of the researched item. In case, if this surface is grinded – its mechanical properties change.

Before selection of the hardness test it is important to know the purpose of further data using as well as what accuracy is necessary. When item hardness is defined for expertise needs, often the accuracy of the hardness figure definition is extremely significant. In some researches it is possible to use the results of hardness tests, when the absolute value of the hardness figure has not relevant importance, but the character of changes of this value in dependence on different factors is important.

Hypothesis: hardness tests can be used for appreciation of: strength of material and products, deterioration, changing of the structure and shape as well as other parameters, when direct measuring is not possible or measuring cannot be done without the item damage.

The aim of the research: to compare the accuracy of different hardness tests and select the most appropriate method for research in the hardness and strength changes of the pellet torch body in the burning area.

The tasks of the research: to examine either the hardness of reference does not change in the length of time, to define how the hardness figure of flat reference specimen changes, when that is defined by practically widely used hardness measurement techniques and methods; as well as to select the most appropriate methods for research in hardness and strength changes of the pellet torch body in the burning area.

Materials and methods

Usually measuring equipment appreciates accuracy of hardness measuring by comparing of reference specimen testing results with parameters, which are pointed on the inspected reference specimen.

For hardness testing of the items examined Wilson Hardness press Brinell BH 3000 (manufactured in 2012), Brinell press TIII-2M (manufactured in 1978 in Russia), Wilson Instrument press Rockwell 574 (manufactured in 2012), TK-2M press Rockwell (manufactured in 1971 in Russia), Wilson Hardness Tester Micro-Vickers Model 402 MVD (manufactured in 2012) as well Wilson Hardness Tester M-295 (manufactured in 2012) were used. The amount of measures for one item was from 5 to 10. The mean and dispersion of the hardness figures are determined.

There were used incurved and curved specimen surfaces for definition of the hardness figure.

For flat specimen hardness testing and value changing in time by using of different methods there was used reference specimen of Brinell press N 10228 with hardness 389 HBS $_{10/3000/10}$, dimensions 115x75x17 and roughness of surface *Ra* 1.6 (manufactured in 1959).

This measuring item was selected because in the mentioned range it is possible to measure hardness by all methods.

For research in the changes of the grain pellet torch body hardness and strength we selected a used grain pellet torch body, cut 250 mm long fragment from it, one of the ends of this fragment was gutted by fire.

The parameters of the selected sample: thickness of walls is 9 mm, width – 70 mm, length – 140 mm, radius of curvature 50 mm, and material – malleable cast iron GJMW 700 – 2. Tensile strength *Rm* of the material is defined by using expression [2] *Rm* = 3.5×HB, where 3.5 is the coefficient, HB – Brinell hardness figures.

For comparing of the material hardness figure, which was defined by different testing methods, we used the conversation cart of Wolpert Wilson tool, the data are obtained by using the standard method DIN EN ISO.

Results and discussion

The hardness of the reference specimen defined with Brinell BH 3000 press, by using of 10 mm sintered-carbide ball and load 3000 kgf; in the result arithmetical mean from 10 measures is HBW $_{10/3000/10}$ 387.7 [3].

If hardness of the reference specimen defined with Brinell TIII-2M press, by using of 10 mm sintered-carbide ball and load 3000 kgf; in the result arithmetical mean from 10 measures is HBS $_{10/3000/10}$ 386.6. When 2.5 mm hardened steel ball and load 182.5 kgf are used, arithmetical mean from 10 measures is HBS $_{2.5/182.5/10}$ 364.

When hardness of the reference specimen defined with Rockwell 574 press, by using a diamond cone and load 150 kgf – arithmetical mean from 10 measures is HRC 41.13 [4].

After measuring of hardness of the reference specimen in 10 points with TK-2M press, by using a diamond cone, HRC scale and load 150 kgf – the value of arithmetical mean is HRC 37.6.

When hardness of the reference specimen defined with Micro-Vickers Model 402 MVD press, by using a diamond pyramid and load 2 kgf – arithmetical mean from 6 measures is HV 410.8 [5].

The examination results of measuring as well as the data from the conversation cart are summarized in Table 1.

Table 1

Hardness measuring results of reference specimen (HB 389)

<table>
<tr><th>Data from conversion card</th><th colspan="2">HB 390</th><th colspan="2">HRC 41.8</th><th>HV 410</th><th colspan="2">HV 410</th></tr>
<tr><th>Allowable deviations</th><td colspan="2">2 %</td><td colspan="2">2 %</td><td>4 %</td><td colspan="2">4 %</td></tr>
<tr><th>Press</th><td colspan="2">BH 300, TIII-2M</td><td colspan="2">Rocw 574, TK-2M</td><td>402 MVD</td><td colspan="2">M-295</td></tr>
<tr><th>Measuring result</th><td>HB 387.7</td><td>HB 386.6
HB 364</td><td>HRC 41.1</td><td>HRC 37.6</td><td>HV 410.8</td><td>HV 375</td><td>HV3 80</td></tr>
<tr><th>Deviation from nom.</th><td>-0.33 %</td><td>-0.62 %
-6.43 %</td><td>-1.67 %</td><td>-10 %</td><td>+0.2 %</td><td>-8.5 %</td><td>-7.3 %</td></tr>
</table>

After measuring of hardness of the reference specimen in 5 points with Mobil Hardness Tester M-295 (measuring detail is based on a massive wooden table) the result is got in Vickers scale units and the acquired value of mean is HV 375.4.

After measuring of hardness of the reference specimen in 5 points with Mobil Hardness Tester M-295 (measuring detail is based on massive metal background) the result is got in Vickers scale units and the acquired value of mean is HV 380.4.

The results of measuring give evidence that working with Mobil Hardness Tester M-295 the value of the hardness figure of one and the same sample changes in dependence on torpidity of the surface to be based.

Comparing the results of testing with hardness of the reference specimen we come to a conclusion that in 53 year period hardness of the reference specimen practically had not changed.

However, hardness figures, obtained with some separated methods are different from the reference specimen as well as the data from the Conversion Chart, deviations go out from the allowable range only in separate cases – if measured with Rockwell TK-2M press, Mobil Hardness Tester M-295 as well with Brinell TIII-2M press, by using of 2.5 ball mm.

The results obtained in the research below serve as the background for selection of the most appropriate methods for research of hardness and strength changes of the pellet torch body. Fig. 1 shows a pellet torch gutted by fire before and after cutting out the sample for the research.

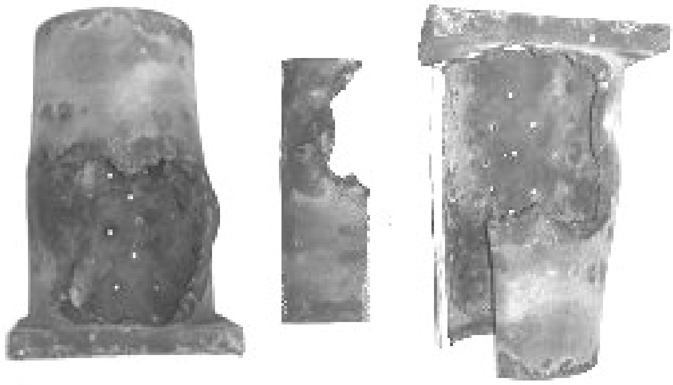

Fig. 1. **Body of gutted by fire pellet torch before and after cutting out the sample for the research**

The researched sample has curved, where flatness is disparate in incurved and curved sections, the reason is – the incurved section is under high temperature flame and heated gases conditions. The attempts to clean the incurved section surface until clear metal were unsuccessful. Moreover, for checking of the pellet torch in the exploitation conditions as well as access to inner part is difficult, because for hardness measuring the curved surface was prepared. Fig. 2 shows the curved surface after measuring.

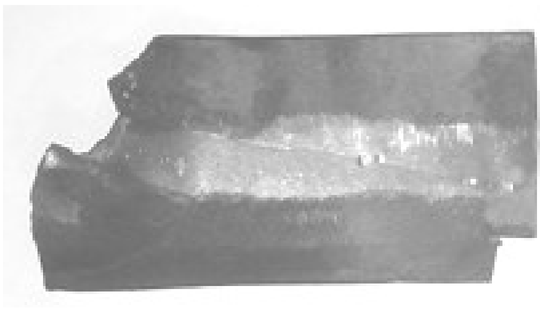

Fig. 2. **Grinded curved surface of pellet torch body after hardness measuring**

For measuring of hardness of the fragment of the pellet torch body the most appropriate method is Brinell, because there is not necessary to provide extremely high surface flatness, as well as from Brinell hardness figure by using the expression mentioned below it is possible to calculate the value of tensile strength. It was not possible to define hardness by using a 10 mm ball, because the sample hardness was too low. Therefore, hardness was defined with a 2.5 mm ball. The measuring began from the section, which was not gutted by fire and continued with hardness measuring $HB_{2,5/182,5,10}$ after each 10 mm. At the same time there is made similar measuring by using tester M-295, as well as with the micrometer is measured the thickness of the sample from both sample sides. The results are presented in Tab. 2.

Table 2

Results of measuring of hardness and thickness of fragment of pellet torch body

Distance from the end, mm	Hardness HB by Brinell method	Hardness HB with tester M-295	Sample thickness, k, mm	Sample thickness, l, mm	Calculated tensile strength, MPa
10	HB 228	HB 217	8.83	8.83	787
20	HB 221	HB 196	8.83	8.52	762
30	HB 219	HB 181	8.70	8.23	756
40	HB 205	HB 169	8.55	8.18	742
50	HB 196	HB 133	8.26	8.27	742
60	HB 186	HB 124	8.16	8.30	731
70	HB 173	HB 110	8.14	8.32	597
80	HB 155	HB 111	7.67	8.03	535
90	HB 144	HB 97	7.50	8.02	497
100	HB 141	HB 90	7.50	7.62	486
110	HB134	HB 90	7.50	7.60	464
120	HB 128	HB 88	7.48	7.60	442

Findings demonstrate that most quick changes of sample hardness and thickness begin approximately in the length 40-60 mm from the ending surface. Roughly in the same place on the researched item incurved surface also the effect of influence of high temperature can visually be observed – here can be seen scales of lamina and the burned area as well as thickness of these increases in the direction to the area gutted by fire.

The values of the hardness figure of the sample defined with Brinell methods and Mobil tester M-295 change similarly. The hardness figure which is got by Mobil tester has lower absolute value because hardness figures got by this equipment are always lower. It can be explained with the circumstance that measuring by tester is substantially affected by the impact of the sample mass – the thicker and lighter the measured item, the greater the difference between real hardness and measured with tester hardness. From the data in the table it can be seen that the value of the hardness figure tested with Mobil tester is on average 1.5 times lower. The advantage of Mobil tester is in the circumstance that it can define hardness of the item without making damages that is why this method is useful for appreciation of the rate of gutting by fire of the operated pellet torch as well as for forecasting of duration of operating.

Definition of hardness of the torch body is made in all length proximally in 70 mm from the area gutted by fire. The length of the torch from the flap to the ended surface is 240 mm. The values of the hardness figure HB as well as the changes of this in dependence on the distance from the ended surface of the torch are shown in Fig. 3. The maximum of hardness is proximally in the same distance from the torch end as the center of gutting by fire.

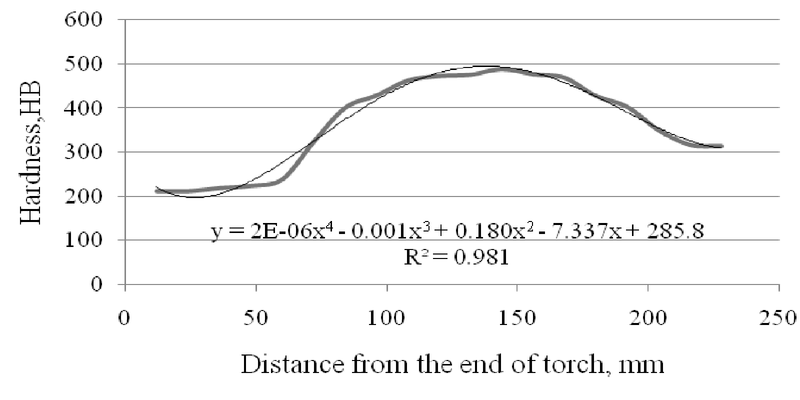

Fig. 3. **Hardness HB in dependence on distance from ended surface of torch**

The findings demonstrate that in the period of operation of the torch the mechanical properties as well as the structure of the material are substantially changed by the influence of high temperature and gas environment. In appearance that a hole is burned out into the torch, we can conclude that temperature was more than 1300 ºC, as well as at the area near the hole temperature protractedly is achieved proximally 900 ºC. In similar temperatures graphite cast iron is hardened with cooling by water till HRC 50, it complies with HB 487.

Conclusions

1. It is clarified that the hardness of reference practically does not change in the length of time.
2. It is clarified, that for the hardness test of small size flat samples the best methods are Rockwell, Brinell and Vickers methods as well as more appropriate method for accurat hardness measuring of medium hard meterials is the Brinell method. Using of Rockwell and Vickers methods is appropriate only for samples with homogeneous structure and very smooth surface.
3. Mobil tester M-295 is more appropriate for hardness measuring of gross dimension flat and relatively rough surfaces as well as curved surfaces.
4. Mobil tester M-295 is appropriate for scientific researches because the absolute value of the hardness figure has not relevant importance, but the character of changes of this value in dependence on different factors is important.

References

1. Гогоберидзе Д.Б. Твердость и методы ее измерения. Москва-Ленинград, Машгиз, 1952. 320 стр.
2. Fundamentals of Materials Science and Engineering. William D. Callister, Jr.&David G. Rethwisch. John Wiley &Sons, 2008. 884. p.
3. EN ISO 6506-1. Metallic materials – Brinell hardness test – Part 1: test method.
4. EN ISO 6508-1. Metallic materials – Rockwell hardness test – Part 1: test method.
5. EN ISO 6506-1. Metallic materials – Vickers hardness test – Part 1: test method.