RESEARCH REGARDING THE HARDNESS TESTS UNDER HIGH TEMPERATURES

Amalia Ana DASCĂL
"POLITEHNICA" University of Timişoara, Engineering Faculty of Hunedoara
e-mail: amalia.dascal@fih.upt.ro; amaliadascal@yahoo.com

Key words: Brinell hardness ,high temperature, thermal-resistent steel grade.

Abstract: The hardness determining test is one of the methods most frequently used in estimating the behavior of metallic materials under wear and plastic deformation. In the case of materials to be used under high temperatures, the test (not nationally standardized) is carried out under the same conditions, but at exploitation temperatures. The paper introduces the results of experimental studies carried out on one steel grade used under various exploitation temperatures.

1. GENERAL CONSIDERATIONS

Hardness is a conventional magnitude with a complex character, offering data obtained in a relatively short time with respect to the deformability of a material at the level of its superficial layers, under well-determined work conditions.

Hardness is defined as the property of a material of resisting static or dynamic contact strains, which lead to a localized deformation or/and deterioration of the surface of a body (element of resistance).

The static methods used in determining hardness differ as to the penetrating element used, the work conditions and the way of appreciating hardness according to the characteristic dimensions of the prints (traces). The most widespread used methods of static trial of hardness are: **Brinell, Rockwell** and **Vickers**.

The hardness characteristic can be used to appreciate the quality of some thermal, thermo-chemical or mechanical treatments applied to the respective type of material.

The methods used in determining hardness are standardized and refer to the hardness trials carried out at room temperature. Some of these methods can also be used at high temperatures, maintaining the principle of the method and using an oven that has to meet the following requirements: temperature can be increased to the desired temperature; leveling the temperature in the entire mass of the test rod and keeping it constant all along the trial.

In choosing the trial method to be used for tests at high temperature it is important to consider elements such as:

- if the surface of the resistance element can be explored for hardness traces;
- the nature of the material under tests;
- the domain of probable hardness;
- the precision of the hardness tests;
- the heating means (the oven, the system of temperature regulation and maintenance).

Out of the static methods used to determine hardness at high temperatures, one that can be used is Brinell, as the harness meters allow the selection of certain pressing charges (1,839 kN; 2,452 kN; 4,903 kN; 9,807 kN; 14,71 kN şi 29,42 kN)), thus achieving various values for the **strain amount** $\mathbf{k = 0.102\ F/D^2}$; (2.5; 5; 10; 15 or 30). Under certain conditions, when the endowment of the laboratory allows it, one can also use method Rockwell or Vickers to carry out trials at high temperatures.

We have to point out that, until now, the hardness trials at high temperatures have not been standardized at national or European level. The few researches we met in the reference literature [9] aim at establishing correlations between the hardness characteristic at high temperatures and other mechanical material characteristics obtained at the same temperatures (for instance: the correlation between hardness and the traction resistance or the resilience at high temperatures)

Hardness testing according to Brinell method [8], [11], consists in pressing, perpendicularly to the flat, polished surface of the test rod (the body to be examined) of a

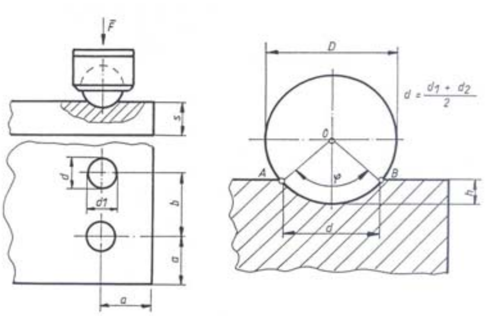

Fig. 1. ***The principle diagram of the Brinell hardness trial***

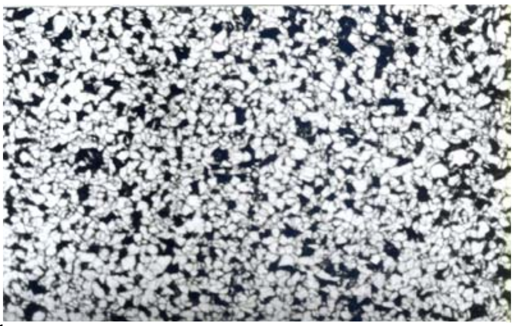

Fig. 2. ***The initial structure of OLT35K steel***

penetrating element (tempered steel ball or ba the diameter **D,** with a force **F** applied statically anc ı of time (10… 15 s). After the trial force has been rei ace of the test rod, in the shape of a spherical calotte the ball). On the surface of the test rod the print has ɘan value between two diameters of the print, meas The basic diagram of the hardness trial by Brinell meth

On establishing the parameters of the trial ad in view the regulations given in ***SR EN 10003-1:1997 Brinell harness trial Part 1: Method of trial*** that replaces ***STAS 165-83.***

The test rods used in the hardness trial were analyzed from the metallographic point of view on delivery and then after the thermal treatment, the initial structures being given in fig. 2. The reactive used was nital 2% and the samples were studied after having been 100 times magnified.

The metallographic study showed that OLT 35K steel has a ferrito-pearlitic structure with a real grain ranked 7-6 according to SR ISO 643-93.

2. TRIALS

The experiments have been carried out on a of thermal-resistant steel grade, belonging to the category of those used in steam pipes, namely OLT 35K.

We used a hardness meter Brinell produced by “Balanta” Sibiu, and for the trials we had to alter the charging head as well as to build some additional parts.

The heating of the test rods was done in an oven of original conception. The tempered test rods were tried at room temperature and at high temperatures, up to $+500^0$C. For each temperature level we used three test rods.

Temperature gauging was done by means of a chrome-aluminum thermo-coupling. By means of a data acquisition board we transferred the temperature values to the computer, using the thermal-electromotive voltage variation of the thermal-coupling; the correction and maintenance of the trial temperature was kept within accepted tolerance limits by means of a power variator (alternating voltage), connected to the computer. The work interface of the temperature monitoring and regulation program was done under Labview.

After the test rods were tried, we measured two perpendicular diameters to each print, calculating the mean diameter and out of the standard we obtained the value of Brinell hardness.

3. RESULTS AND CONCLUSIONS

In fig. 3 we gave the OLT 35K test rods after the hardness trials for the temperatures: +20^{0}C; +100^{0}C; +200^{0}C; +300^{0}C; +400^{0}C; +500^{0}C.

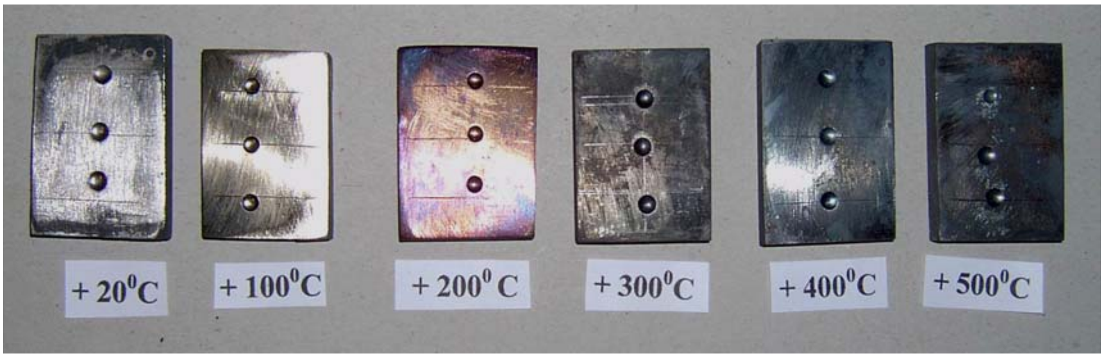

Fig. 3. ***Set of test rods made of OLT 35K, unused material, tried at high temperatures***

The results of the measurements, the calculated values and the magnitude of the hardness are given in table 1.

With the hardness values given in the table we drew the variation curves according to the trial temperature given in figure 4.

Table 1. Brinell hardness at high temperature of OLT 35K steel, after tempering

No.	Trial temperature [^{0}C]	d	Diameter [mm]				Brinell hardness HBS]			
			Print			Mean	Print			Mean
			1	2	3		1	2	3	
1	+20	d_1	5,14	5,18	5,16	***5,18***	134	132	133	***132***
		d_2	5,18	5,22	5,20		132	130	131	
		d_m	**5,16**	**5,20**	**5,18**		**133**	**131**	**132**	
2	+100	d_1	4,71	4,67	4,69	***4,676***	162	165	164	***164,33***
		d_2	4,73	4,61	4,65		161	170	167	
		d_m	**4,72**	**4,64**	**4,67**		**161**	**167**	**165**	
3	+200	d_1	4,54	4,51	4,61	***4,533***	175	178	170	***176***
		d_2	4,48	4,52	4,55		180	177	174	
		d_m	**4,51**	**4,51**	**4,58**		**178**	**178**	**172**	
4	+300	d_1	4,78	4,80	4,76	***4,765***	157	156	158	***158***
		d_2	4,75	4,78	4,74		159	157	161	
		d_m	**4,476**	**4,79**	**4,74**		**158**	**156**	**160**	
5	+400	d_1	4,92	4,86	4,98	***4,923***	148	152	144	***147,66***
		d_2	4,95	4,90	4,93		146	149	147	
		d_m	**4,935**	**4,88**	**4,955**		**147**	**150**	**146**	
6	+450	d_1	5,17	5,17	5,18	***5,156***	133	133	132	***133,66***
		d_2	5,14	5,10	5,20		134	137	131	
		d_m	**5,15**	**5,13**	**5,19**		**134**	**135**	**132**	

An analysis of figure 4, the point graph, shows that Brinell hardness increases with temperature, and stays constant for values ranging between 200°C and 260°C, after which it decreases again.

If we draw the graph of 2nd degree polynomial function for the values we obtained, we obtain the equation of this function, the correlation coefficient being $R^2 = 0.8856$.

We can therefore conclude that hardness depending on trial temperature observes a law of 2nd degree polynomial variation, namely: $Y = -0.0008x^2 + 0.3729x + 129.31$.

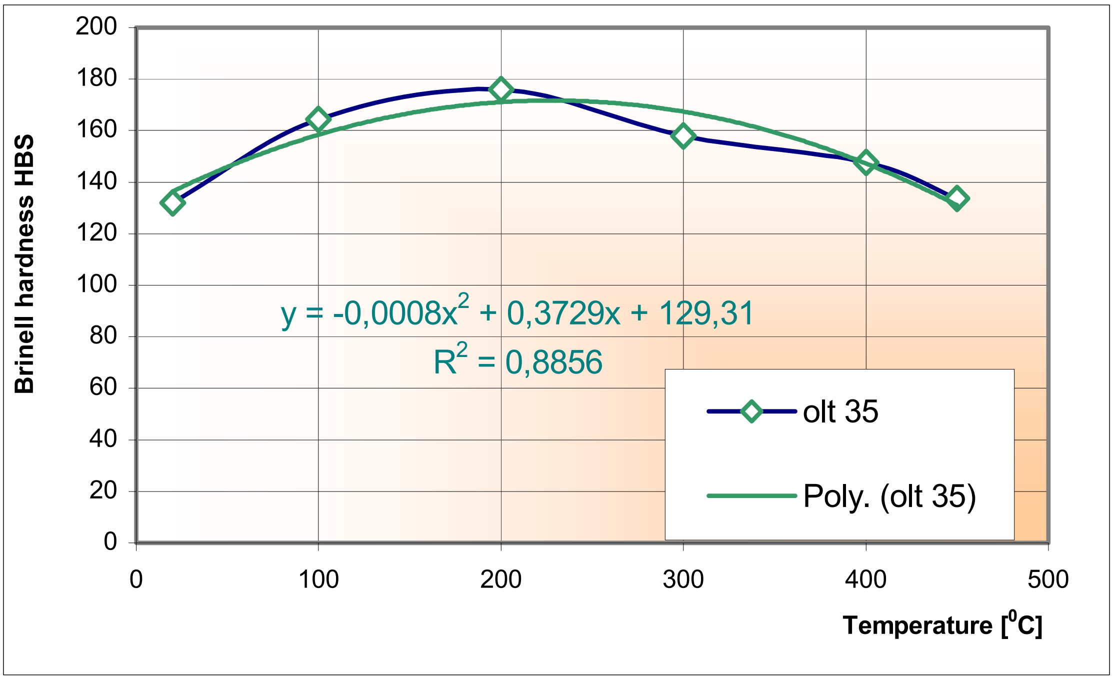

Fig. 4. ***The variation of Brinell hardness depending on trial temperature for OLT 35K steel***

It is also to be noticed that all the values we obtained are higher than 133 HB. For the steel under study it is particularly useful to know these values, because it is used in making parts that work under high pressure and temperature.

REFERENCES:

[1]. Asavinei, I., Niculescu, C. - *Ghid pentru utilizarea termocuplurilor în măsurări industriale*, Editura Tehnică, Bucureşti, 1981.
[2]. Cheşa, I., ş.a. - *Alegerea şi utilizarea oțelurilor*, Editura Tehnică, Bucureşti, 1984.
[3]. Dieter, G.F. - *Metalurgie mecanică*, Editura Tehnică, Bucureşti, 1970.
[4]. Geru, N., Gurgu, C., Cosmeleață, G. - *Analiza structurii materialelor metalice,* Editura Tehnică, Bucureşti, 1990.
[5]. Lemaitre, J., Chaboche, J.L. - *Mecanique des materiaux solides*, Editura Dunod, Paris, 1988.
[6]. Lăpuşan, A. – *Contribuții la studiul comportării oțelurilor la temperaturi ridicate*, Teză de doctorat, Timişoara, 2004.
[7]. Marchidan, D.I., Ciopec, M. - *Temperatura - scări, metode şi mijloace de măsurare*, Editura Ştiințifică şi Enciclopedică, Bucureşti, 1977.
[8]. Mocanu, D.R., ş.a. - *Încercarea materialelor*, vol. I. *Încercări distructive ale metalelor*, Editura Tehnică, Bucureşti, 1982.
[9]. Nădăşan, Şt., ş.a. - *Încercări şi analize de metale*, Editura Tehnică, Bucureşti, 1965.
[10]. Pănoiu, A.N.- *Cazane de abur,* Editura Didactică şi Pedagogică, Bucureşti, 1982.
[11]. SR EN 10003-1:1997 - *Materiale metalice. Încercarea de duritate Brinell.Partea 1: Metodă de încercare.*