RESEARCH STUDY OF HARDNESS VALUES OBTAINED WITH DYNAMIC HARDNESS TESTER PROTOTYPE DD01

Severin Traian-Lucian[1], Băncescu Nicolai[2], Dulucheanu Constantin[3], Severin Lucian[4]

[1,2,3,4] *Stefan cel Mare University of Suceava, Romania, Faculty of Mechanical Engineering, Mechatronics and Management, e-mail: severin.traian@fim.usv.ro*

Abstract: *The paper submitted for publication is a comparative study of the hardness values recorded on metallic and non-metallic samples, values that been taken over with a standardized hardness tester Shimadzu HMV-2T, respectively Dynamic Hardness Tester Prototype DD01.Dynamic Hardness Tester Prototype DD01 is a device for determining dynamic hardness of metallic and non-metallic materials, device that was built starting from the proposal became patent Durimetru DinamicRO 126704/2011.The analysis of experimental results shows that the average value of dynamic hardness obtained with Dynamic Hardness Tester Prototype DD01 are closely approximates to the value determined by standardized devices, surprisingly good results to an significant costs in terms of series production.*

Keywords: *heat treatments, polished, hardness, hardness tester.*

1. Introduction

The hardness generally means resistance that opposes the test material from indentation of a harder corps from outside. This resistance is calculated using the surface trace of indenter or according to the depth of it, under a certain constant load. When testing the dynamic hardness addition this expression is the possibility of recoil energy expression as a measure of elastic response of the material tested, [1, 2].

With the hardness help is characterized the material respectively its condition, it cannot be measured directly. Hardness value is deducted from the primary quantities such as depth of indentation, force, energy elastic recoil. Comparison of hardness test results is possible only when a test was made through the same procedures with compliance to all test parameters, [1, 2, 5].

Dynamic hardness test appeared as means of behavior appreciation of metallic and nonmetallic materials during in the same period in which were set bases of static hardness test. However it is less used, the reason being obtaining of weaker reproducible of the results than the static hardness test. Dynamic hardness test method based on measuring the elastic deformation energy of elastic recoil is based on links between elastic recoil energy of mobile equipment containing the indenter and the hardness of material tested. It is obvious that besides material hardness, recoil is dependent on the material elasticity tested, the mass of mobile device, its geometry and sample tested. Also should be taken in mind that with increasing of specific impact energy achieved by increasing the height of the fall, increasing mass of mobile equipment, the height and mass, decrease the size of indenter recoil relative height is decreases, which actually corresponds to increasing the plastic component against elastic, [3,6,7].

$$\overbrace{\underbrace{W_i}_{1} + \underbrace{W_{p1}}_{2}}^{before\ impact} = \overbrace{\underbrace{W_{el}}_{3} + \underbrace{W_{pl}}_{4} + \underbrace{W_v}_{5} + \underbrace{W_{p2}}_{6}}^{after\ impact} \quad (1)$$

Practical appreciation of hardness by this method uses a kinetic energy balance, relationship 1, [1].

2. Devices and materials used for the comparative study of the hardness determination

In order to achieve the research study were used 7 metallic materials *C45*, *C22*, *20NiCrMo2*, *42MoCr11*, *40CrMnMo7*, *X210Cr12*, *100Cr6*, *S235JR* and *6* nonmetallic materials *Al*, *AlCu4.4Si1*, *AlCu4Mg1Mn*, *Cu99.97*, *CuSn10*, *CuAl10Fe5Ni5*.

Heat treatments (table 1) applied to lots of metal samples were cooled after quenching in medium of mineral oil *TT22* (STAS 12195-84, 10) currently used in industrial practice and water. For each steel were produced several heat treatments to obtain more hardness values.

For heat treatments is used for heating a furnace CARBOLITE ELT 1100 °C, oven that meets the following specifications: maximum operating temperature of 1100 ° C, room capacity of *23l*, rolled radiating elements on both sides of the chamber to ensure temperature uniformity, fast heat up to operating temperature to a quarter of traditional ovens, ceramic hearth and power supply interruption when the door opens, double-wall construction allows convection cooling airflow to outer casing according to *EN61010* safety standard.

As shown in table 1, the same thermal treatment regimens have been tested on several types of steels, except austenite quenching temperatures were different depending on the type of steel used.

Table 1 -Heat treatments applied to steel samples

Steel brand	Normalization (T1)		Quenching in water (T2)		Quenching in oil (T3)		Quenching in oil and low recovery (T4)	
	Heating °C	Cooling	Heating °C	Cooling	Heating °C	Cooling	Heating °C	Cooling
C45	840	air	840	air	840	oil	150	air
C22	860	air	860	air	860	oil	170	air
20NiCrMo2	850	air	850	air	850	oil	-	-
42CrMo4	880	air	880	air	880	oil	-	-
X210Cr12	980	air	-	-	980	oil	230	air
40CrMnMo7	850	air	850	air	850	oil	150	air
100Cr6	880	air	880	air	880	oil	150	air

Table 1- Heat treatments applied to steel samples - continuation

Steel brand	Quenching in oil and low recovery (T5)		Quenching in water and low recovery (T6)		Quenching in oil and high recovery (T7)		Quenching in oil and medium recovery (T8)	
	Heating °C	Cooling	Heating °C	Cooling	Heating °C	Cooling	Heating °C	Cooling
C45	840	air	-	-	-	-	-	-
C22	850	air	-	-	850	air	-	-
20NiCrMo2	-	-	-	-	-	-	-	-
42CrMo4	600	air	-	-	-	-	-	-
X210Cr12	-	-	-	-	-	-	440	air
40CrMnMo7	-	-	150	air	600	air	-	-
100Cr6	850	air	-	-	-	-	-	-

For *100Cr6* steel the quenching in water heat treatment is not provided in STAS, same thing is applies to *40CrMnMo7* steel for the quenching treatment of low and high water recovery. These treatments were performed to have a higher hardness range for hardness testing.

After heat treatment, the samples were polished applying a wet process [STAS 4203-74], which was performed under flowing water using hydrophilic metallographic papers. Both processes sanding and polishing of samples was performed on a device manufactured by Metkon, model FORCIPOL *2V*, and parameters used are presented in table *2*.

Table2 Sanding parameters and metallographic type of paper used.

Item no.	Granulation of metallographic paper					
	400	600	800	1000	1500	2000
Time for sanding sample (~min.)	4	4	3	3	3	3

Mechanical polishing of samples was performed on a velvet rotating disk in order to remove the last traces left after sanding and getting a flat mirror gloss. During polishing disc was impregnated with a suspension of fine alumina (Al_2O_3) in water [STAS 4203-74].

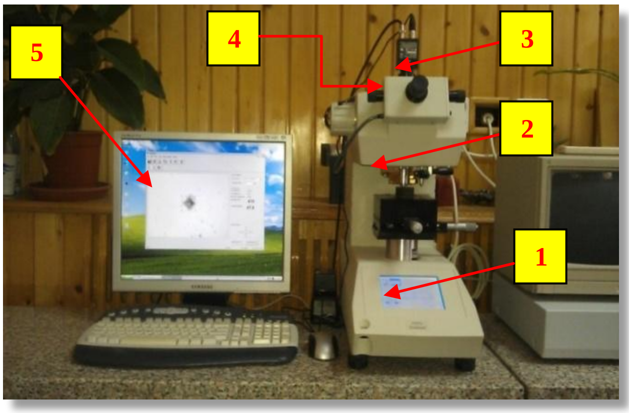

Figure 1. – *Hardness TesterHMV – 2T Shimadzu (1), automatic system automatic indentation and mark visualization (2), optic mark visualization (3), video CCD image acquisition system (4), hardness measurement and inspection software (5).*

To determine the hardness in the first stage was used standardized hardness tester Shimadzu *HMV-2T* (fig. 1), which is equipped with a diamond pyramid indenter and the follow obtained is viewing to the optical microscope with magnification of *400x.*

For taking image the device is equipped with a video camera, model: *XC-ST30*. Type of hardness determined with this device is hardness based on the Vickers principle.

The second device for determining hardness is the Dynamic Hardness Tester Prototype DD01, device which is part also from the objective of our research.

The operation of Dynamic Hardness Tester Prototype *DD01* is based on the principle explained in the patent RO 126704/2011, namely the determination of hardness on horizontal-vertical surface the hardness tester is placed with base and screw in horizontally or vertically surface on the test material and turn on action button which unloading the indenter perpendicular to tested material (fig.2,3).

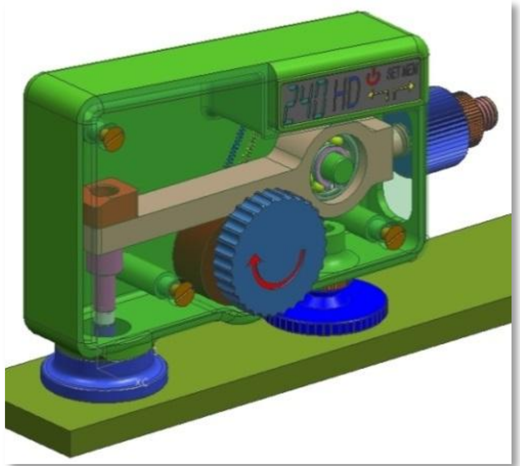

Figure 2 -*Hardness tester for determining hardness on horizontal surfaces, virtual designed.*

During impact piezo-electric sensor for dynamic force send a voltage signal (U) which evolves over time. Maximum voltage (U_{max}) depending on the resistance of the material tested (hardness), the height of the fall and the amount of counterweight adjustable. In terms of a specific adjustable counterweight, maximum voltage (U_{max}) is an expression of dynamic hardness H_d, which is calculated by the microcontroller after relationship 2 [4,9].

Constant (K) is determined using a hardness standard reference for measuring it with hardness tester value (U_{max}). Voltage (U_{max}) is determined automatically by the microcontroller, the derived voltage (U) on the time (t), derived that the maximum voltage is zero.

$$H_d = K \cdot U_{max} \quad (2)$$
$$H_d = 176,53 \cdot U_{max} \cdot K_H - 730,07 \quad (3)$$
$$H_d = 176,53 \cdot U_{max} \cdot K_V - 730,07 \quad (4)$$

where: U_{max} is the maximum recorded value in volts through piezoelectric sensor;

K_H - factor for determining the hardness in horizontal position;

K_V- factor for determining the hardness in vertical position.

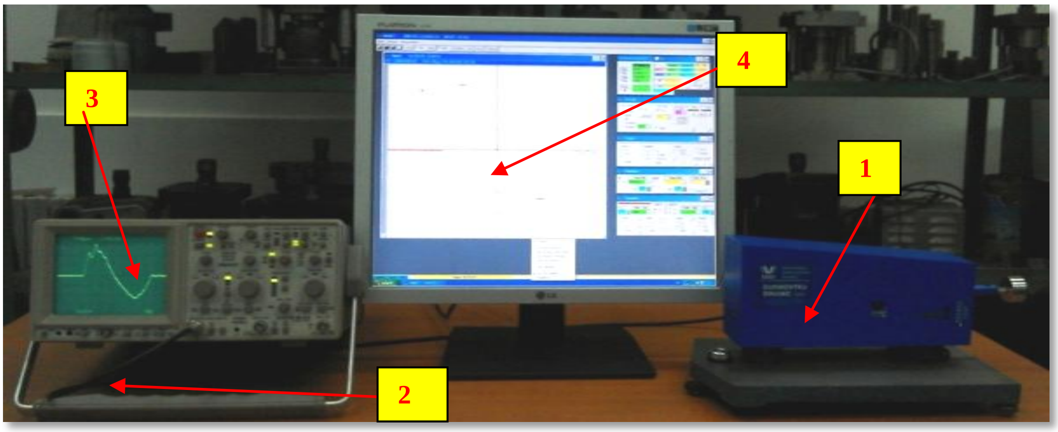

Figure 3-*Dynamic Hardness Tester Prototype DD01 system .*
(1) –Dynamic Hardness Tester Prototype DD01, (2)- coaxial cable for transferring hardness signal, (3)- memory oscilloscope HAMEG HM407, (4)- PC data processing system.

3 Interpretation of the values obtained with the two types of devices

In this subchapter are presented and compared values obtained with Dynamic Hardness Tester Prototype *DD01* with the values recorded on the same samples with standardized device Shimadzu *HMV-2T*.

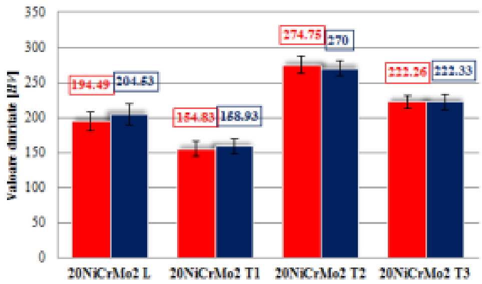

Figure 5 - *Variation of the average hardness 20NiCrMo2 steel samples with different heat treatments, obtained with Dynamic Hardness Tester Prototype DD01 (red) and standardized Hardness Tester Shimadzu HMV-2T (blue).*

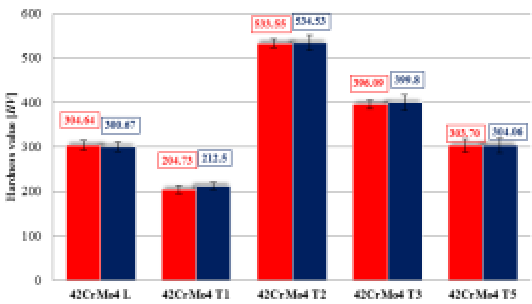

Figure 6 - *Variation of of the average hardness 42CrMo4 steel samples with different heat treatments, obtained with Dynamic Hardness Tester Prototype DD01 (red) and standardized Hardness Tester Shimadzu HMV-2T (blue).*

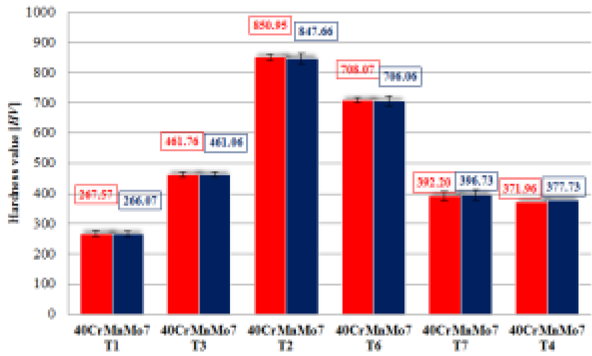

Figure 7 - *Variation of the average hardness 40CrMnMo7 steel samples with different heat treatments, obtained with Dynamic Hardness Tester Prototype DD01 (red) and standardized Hardness Tester Shimadzu HMV-2T (blue).*

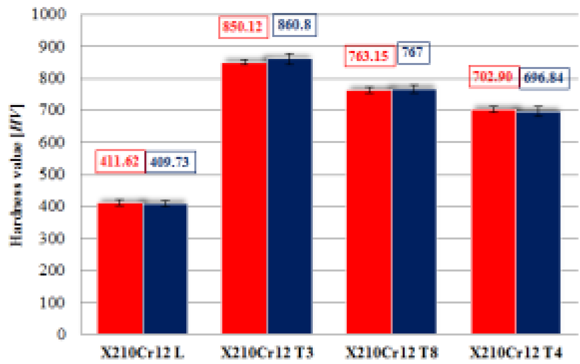

Figure 8 - *Variation of the average hardness X210Cr12 steel samples with different heat treatments, obtained with Dynamic Hardness Tester Prototype DD01 (red) and standardized Hardness Tester Shimadzu HMV-2T (blue).*

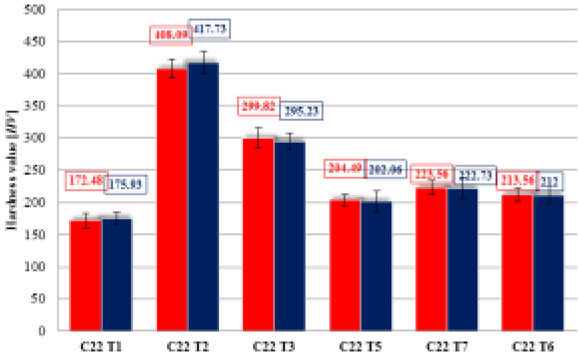

Figure 9 - *Variation of the average hardness C22 steel samples with different heat treatments, obtained with Dynamic Hardness Tester Prototype DD01 (red) and standardized Hardness Tester Shimadzu HMV-2T (blue).*

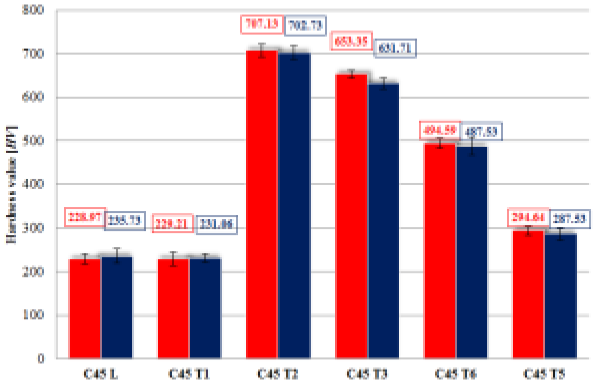

Figure 10 - *Variation of the average hardness C45 steel samples with different heat treatments, obtained with Dynamic Hardness Tester Prototype DD01 (red) and standardized Hardness Tester Shimadzu HMV-2T (blue).*

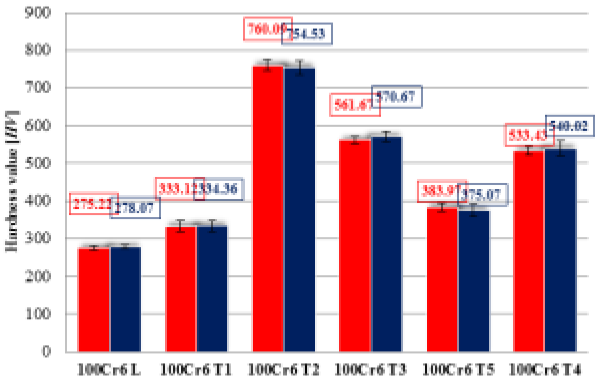

Figure 11 - *Variation of the average hardness 100Cr steel samples with different heat treatments, obtained with Dynamic Hardness Tester Prototype DD01 (red) and standardized Hardness Tester Shimadzu HMV-2T (blue).*

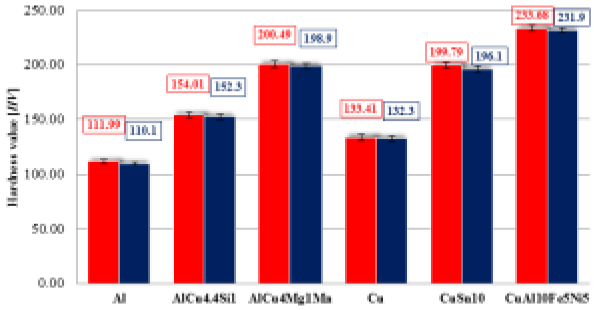

Figure 12 - *Variation of the average hardness on nonmetallic samples obtained with Dynamic Hardness Tester Prototype DD01 (red) and standardized Hardness Tester Shimadzu HMV-2T (blue).*

Experimental determination of hardness by dynamic method performed with Dynamic Hardness Tester Prototype *DD01* shows a good agreement with the hardness obtained with Hardness Tester Shimadzu *HMV-2T* which is based on static principle method.

4. Conclusion

According to these graphical representations (fig. 5 - 12) hardness variation of the same types of samples obtained with Dynamic Hardness Tester Prototype *DD01* (red columns) or with standard Hardness Tester Shimadzu *HMV-2T* (blue columns) can be distinguished two main conclusions:

- the first is that the average value of hardness obtained on the experimental samples are very similar when using the two devices
- the second conclusion is that the graphics variation of the standard deviation of hardness values obtained with Dynamic Hardness Tester Prototype *DD01* are included within the standard deviation of hardness value when using standardized Hardness Tester Shimadzu *HMV-2T*.

Therefore Dynamic Hardness Tester Prototype *DD01* can be used to retrieve the value of hardness for ferrous and nonferrous materials whose hardness varies between 48 and *980 HV*, values to which this device was calibrated and the final hardness value after at least *5* repetitions on the same sample can record an error of *1.07 %.*

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