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ANALYSIS OF St. 42 STEEL HARDNESS AFTER BEING HEATED TO 8000C AND QUICKLY COOLED WITH FRESH WATER BY APPLYING ROCKWELL METHOD

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Abstract. The hardness of machine components which, in operation time, collide and rub against each other and are made of St.42 steel needs to be found out. Therefore, research on the hardness of St.42 steel especially those which are heated needs to be carried out so that it can be chosen as machine component properly. This research tests the change of the surface hardness by applying Rockwell method and is the continuation from a former research. Steel is a technical material which is often used as machine components, so that its strength against external loads is really needed to be known. External loads which are often occurred on machine components are friction load, torsion load, tensile load, bent load and mash load. This research aims to find out how much the change of the hardness of standard St.42 steel surface after being heated at temperature of 800^0C and quickly cooled by using fresh water which is carried out in laboratory of material testing, Department of Mechanical Engineering, State Polytechnic of Bali. The result shows that the hardness of the surface of steel which is heated until 800^0C and quickly cooled by using fresh water is more lenient than the standard St.42 steel, although it is tested by applying either Rockwell B (HRB) or Rockwell C (HRC) methods. The change of the strength based on Rockwell B method shows the decrease in surface hardness until 19,81%; from 29,93 (Kgf/mm^2) to 24,0 (Kgf/mm^2). In Rockwell C method there is also decrease in surface hardness which is equal to 20,23%; from 54,7(Kgf/mm^2) to 43,63 (Kgf/mm^2).

Keywords : Hardness, steel, heat treatment

1. INTRODUCTION

Hardness is the ability of metal to not change in shape and size permanently if an outside load is given. There are three methods of hardness measurement namely: penetration, elastic hardness, and abrasion hardness. Penetration method is applied by pressing harder metal on the test specimen with certain time, load, and size. This testing is done in hardness testing machine (Brinnle, Rockwell, and Vickers). Elastic hardness method is applied by measuring the rebound height of a poly hammer dropped from a certain height to a test object in a measuring tube, then the height of the rebound data is entered into a formula. The harder the tested material, the higher the rebound will be, and vice versa. Abrasion method is applied by scratching the test object with a type of object that is standardized from hard to soft. If one can cause scratches, it can be determined empirically rather than the hardness of the metal [1].

The hardness of material, steel in this case, is measured based on the depth of maximum penetration occurred on test specimen, then it is calculated by using relevant formulas based on the testing method applied [2]. To find out the hardness of steel, hardness testing should be administered. The execution of hardness test in this research is in collaboration with mechanical engineering students in fourth semester using the material hardness testing machine of *Precision Hardness Tester-GNEM OM-150* in the Laboratory of Material Testing and

Metrology, Mechanical Engineering Department, Bali State Polytechnic. Every class of the fourth semester students is divided into four groups.; Each group consists of six to seven students. Hardness test is a mechanical properties test which is aimed at finding out the material hardness. The testing is administered by pressing the surface of test specimen using standard penetrator with the load time of 10 seconds. This hardness test is obviously based on test standard which has been specifically set in form of indicator of test performance achievement [3].

For the next, research data collection is continued by filling table format which is used as the primary data of hardness result. In order to be able to administer hardness test, the practitioners have learned about material technology and attend necessary training. The test has to pay attention to and obey the rules applicable in laboratory of material test and metrology beside health and safety factors which are indeed required for each test kit [4].

Material hardness is one of mechanical properties of materials which are mostly affected by carbon element and its compounds. Mechanical properties of steel is really needed to be known so that, when it is used, it can hold loads and safe to be used, so the function of steel or other materials can be effective. Carbon element in steel obviously affects the quality and strength of steel which can be achieved by heat treatment, for example. Mechanical properties of steel can be known through some processes of test in laboratory of material test. Tests of steel strength in general are testing of tensile, twisting, surface hardness and bending which can provide information on the mechanical properties of steel, [5].

Reliable machinery or equipment is a machine / tool system that can produce a safe work process for the operator and its environment when operated, the sustainability in maintenance and repairs is guaranteed, produce competitive products in the market, [6]. To fulfill the above criteria, the selection of materials for machine components / tools must be in accordance with the designation and resistance to loads based on their mechanical properties.

This study analyzed the hardness of standard St.42 steel surface compared to St.42 heat treated steel. Especially the steel is heated to 800^0C and cooled quickly using fresh water. Steel hardness testing can provide information about the maximum ability of steel to penetrate other standard materials, [4]. Material or steel hardness is the ability of a material or steel to withstand a compressive load or penetration of a certain surface area. The tensile strength of the material including the hardness of a material or steel is largely influenced by the elements of its compounds. Carbon in iron or steel definitely affects the quality or hardness of steel surfaces, [3].

This hardness testing process is done in machine which is specially designed to be able to administer test of steel hardness. The surface hardness test machine used is *Precision Hardness Tester-GNEM OM-150*, [7,8]. The test administered by using this machine can determine the surface hardness of a material especially metal or steel through testing in accordance with the standard procedure.

Aims of this research are: (1) Being able to measure changes in surface hardness that occur in St.42 steel based on the theory of heat treatment. (2) Being able know for sure the value of the change in hardness of the steel surface of St. 42 with heat treatment.

Results of this research are beneficial, such as: (1) For the researcher himself, this research is very useful for developing and deepening knowledge in the field of material technology, as well as adding skills in the implementation and operation of materials testing tools. (2) For Bali State Polytechnic institutions, this research is useful to introduce to the parties so that it can be used as a source and comparison of relevant research results. (3) For the community especially those who are dealing with the design and selection of steel materials, the results of this study can be used as a consideration in choosing technical materials or steel, especially the St. 42.

2. METHODS

Research Process and Location

Testing of this hardness is done using Rockwell method, where there are two types of Rockwell hardness testing, namely: testing using a standard press or spherical dedentor and the other using a cone-shaped press. For the two test methods above, the testing procedure is the same, only the use of the type of dedentor is different, so each of these tests produces a valid standard of hardness, namely Rockwell B which is abbreviated as HRB, and Rockwell C which is abbreviated as HRC, [9].

The standard testing process carried out is: ground level before the specimen is installed on the hardness testing machine; make sure the available voltage is 220 Volts. Install the penetrator or dedentor according to the type of test that will be carried out correctly, set the amount of load that must be given. Turn on the Precision Hardness Tester-GNEM OM-150 engine by pressing the switch on the On button, the test engine's focus lamp lights up, leave it for about five minutes as initial preparation. Next, turn the loading handle according to the instructions so that the hardness value can be read correctly on the hardness indicator. Thus the hardness testing process is repeated according to the number of specimens to be examined, which are 30 times each [3].

The process of this research is carried out through two stages. The first stage is the preparation of the test object including giving heat treatment to the test object and the second stage is the data collection on the hardness testing machine. The preparatory work is intended to have the surface of the test material smooth and flat, while

the heat treatment of the test object in the heating kitchen is intended to harden or soften the test object compared to the standard specimen [7,8].

Research sites; This research was conducted in collaboration with students who conducted material test practical activities in the fourth semester at the Materials Test and Metrology Laboratory, Mechanical Engineering Department, Bali State Polytechnic. Students are divided into five groups and each group consists of four to five students. Each group is given both types of specimens, namely standard and hardened specimens, one unit of each. The results of the test data for each group are averaged according to the type of specimen that the data is taken as the data put in this study table [10].

The Parameter Observed

Hardness test using the *Precision Hardness Tester-GNEM OM-150* machine with the Rockwell method is the most practical one compared to using two other methods namely Brinell method and Vickers method, because the hardness value of the test object can be read directly on the measuring instruments contained in the test machine. So, the Rockwell method does not use any formulas like the Brinell method or the Vickers method. Hardness test using the Rockwell method, besides being faster, is also more accurate because the engine directly shows the hardness value of the test object. However, the three methods of testing the hardness mentioned above are still acknowledged and the results are valid, as long as they are carried out with standardized testing standards.

Research on the hardness of similar specimens using the Brinell and Vickers methods has been reported in the research report in the July 2016 LOGIC journal and the March 2017 LOGIC journal. Therefore, this study is very necessary to report the results of the hardness test using Rocwell B and Rocwell C methods through LOGIC journal, Research and Community Service Center, Bali State Polytechnic.

3. RESULTS AND DISCUSSION

Test Results

Tests were carried out carefully and systematically starting from the testing of standard St.42 and St.42 perimeter (hardening) specimens. The results of testing carried out by each student group for each type of test object using a diamond ball and cone shaped penetrator. The data obtained is then put into format and table as follows.

Test object (round shape) : St.42 (Standard) and (Hardening)
Test object thickness : 8.4 mm
Diameter of test object : 9 mm
Ball penetrator diameter : 1/16 inch
Loading : 100 kgf
Loading time : 15 seconds
Test type : Rockwell B

Table 1. Data of Standard and Hardening St.42 Steel Hardness (Rockwell B)

No	HRB St.42Standar (Kgf/mm^2)	HRB St.42Hardening (Kgf/mm^2)	Hasil Rerata HRB (Kgf/mm^2)
1.	34	28	
2.	27	25	
3.	31	24	
4.	28	26	
5.	29	27	
6.	32	24	HRB Standar = 29,93
7.	33	23	
8.	31	22	
9.	33	21	
10.	32	20	
11.	31	28	
12.	28	25	
13.	34	24	
14.	27	26	
15.	31	27	

No	HRB St.42Standar (Kgf/mm^2)	HRB St.42Hardening (Kgf/mm^2)	Hasil Rerata HRB (Kgf/mm^2)
16.	32	24	
17.	33	23	
18.	29	22	
19.	33	21	
20.	32	20	HRB Hardening = 24,00
21.	34	28	
22.	27	25	
23.	31	24	
24.	28	26	
25.	29	27	
26.	32	24	
27.	33	23	
28.	31	22	
29	30	21	
30.	33	20	

Source: Data of the Standard St.42 Hardness Test

Next is the test result of standard and hardening St.42 steel which gets heating and quick cooling with fresh water, tested using a cone-shaped diamond penetrator with a peak angle of 110^0 resulting in the hardness of Rockwell C.

Test object (round shape) : St.42 (hardening and standard)
Test object thickness : 8.4 mm
Diameter of test specimen : 9 mm
Cone diamond penetrator : 1200 (peak angle)
Loading : 150 kgf
Loading time : 15 seconds
Test type : Rockwell C

Table 2. Data of Standard and Hardening St.42 Steel Hardness Test (Rockwell C)

No	HRC St.42standar (Kgf/mm^2)	HRC St.42hardening (Kgf/mm^2)	Hasil Rerata HRC (Kgf/mm^2)
1.	55	44	
2.	52	47	
3.	64	43	
4.	62	40	HRC Standar = 54,70
5.	50	42	
6.	63	46	
7.	61	45	
8.	51	41	
9.	53	48	
10.	54	43	
11.	55	43	
12.	52	40	
13.	64	42	
14.	62	46	
15.	50	45	
16.	63	41	
17.	61	48	
18.	51	43	HRC Hardening = 43,63
19.	53	44	
20.	54	47	
21.	55	43	
22.	52	40	
23.	64	42	
24.	62	46	
25.	50	45	
26.	63	41	
27.	61	48	
28.	51	43	
29.	55	43	
30.	53	40	

Source: Data of Hardening St.42 hardness test

Discussion

Furthermore, from each data in the hardness test table above, it can be read the standard St.42 test object hardness and the hardness of St.42 hardening steel. In testing using the Rockwell B method, the standard hardness of St.42 is 29.93 kgf / mm^2, while in St.42 Hardening, the hardness shows a decrease which is equal to 24.0 kgf / mm^2. So, the hardness of St.42 steel, after being heated to 800^0C and cooled using fresh water, was decreased by 19.81%. Furthermore, Rockwell C testing is carried out by replacing the ball-shaped penetrator with cone-shaped diamond penetrator and the loading is set at 150 kgf, while the loading time is the same; it is 15 seconds.

The test used the Rockwell C method, the standard hardness of St.42 was 54.70 kgf / mm2, whereas for St.42 Hardening, the hardness showed a decrease which was 43.63 kgf / mm2. So, for the St.42 steel after being heated to 800^0C and cooled using fresh water, the hardness decreased by 20.23%.

Hardness testing using the Rockwell method is according to standard procedures, this study uses a spherical penetrator with a diameter of 1/16 inch and a load of 100 kgf for testing Rockwell B hardness. Meanwhile, Rockwell C hardness testing uses a cone penetrator with a peak angle of 1200 and a load of 150 kgf.

The data from the research results of the two types of specimens above show a difference in hardness, such as a change in one of the mechanical properties of the specimen, especially St.42 hardening steel with 800^0C heating and quick cooling using fresh water. In fact, the test data of St.42 steel specimens which were heat treated and cooled quickly using fresh water, the hardness decreased by about 20% compared to the standard St.42 steel test hardness.

4. CONCLUSION

Based on the results of the research and the data analysis, it can be concluded that: (1) Rockwell B hardness test, namely St.42 Hardening Steel hardened by heating to 800ºC and quick cooling using fresh water turned out to have lower hardness compared to the standard St.42 steel. It was proven from the hardness data of Hardening HRB St.42 which equals to 29,93 kgf / mm^2, while the Standard HRB St.42 hardness = 24.00 kgf / mm^2. (2) Testing of Rockwell C hardness is: St.42 Hardening Steel which is hardened by heating to 800ºC and quick cooling using fresh water turns out to have lower hardness compared to standard St.42 steel. It was proven from the hardness data of Hardening HRB St. 42 = 54.70 kgf / mm^2, while the hardness of Standard HRB St.42 = 43.63 kgf / mm^2. (3) There is a match between the results of the Rockwell B and Rockwell C hardness studies, with the same results of steel hardness study using the Vicker method as well as hardness testing using the Brinell method, which has been carried out before and has been published in the LOGIC Journal of Bali State Polytechnic.

5. SUGGESTION

Based on result and discussion above, suggested that: (1) It is necessary to test the same specimen by gradually changing the heating temperature to a certain extent in the next research, (2) It is very necessary to test the same specimen with different loading times in the next research.

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