Hardening Of Iron St 37 With Various Heat Treatments Using Cooling Crude Palm Oil (Cpo)

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Abstract: Hardening of iron st 37 is a process carried out to improve the mechanical properties of the strength of the material it has. With good strength, it can withstand the compressive loads received by the material. The hardening process carried out to improve the mechanical properties of the ST 37 material is by the Quencing method using Crude Palm Oil (CPO), where the ST 37 material is heated from a temperature of 200 ^{o}C, 400^{o}C, 600^{o}C, 800^{o}C and 965^{o}C and immediately cooled them. The hardening process carried out with each experiment uses 5 pcs of workpieces and after the quencing process is done, the testing process presses on the workpiece. The results obtained from the hardening of the ST 37 workpiece, resulted in several parameters of the increase in the value of the hardness that occurred from the specimens that had been heated and quenching CPO in the 200^{o}C heating specimen was 24.4% (49 HRC) against the untreated specimens (37 HRC), increase in the hardning of specimens carried out by heating 400^{o}C, 600^{o}C, 800^{o}C, 965^{o}C is as much as 36.6% (59 HRC), 31.9% (55 HRC), 9.7% (41 HRC) and 29.9% (53 HRC). So the most superior hardness value is in specimens that use 400^{o}C heating by quenching CPO.

Index Terms: quenching, heating, crude palm oil

1 INTRODUCTION

Iron is widely used by the wider community in daily life to do a job. Iron is a mixture of ferro and carbon materials carried out by the heating process in the formation process. Test material with classification of ST 37 is iron with a tensile strength of 37 kg/mm^2 which is widely used for materials with sufficiently low strength. ST 37 which has equality with AISI 1045 material, which has a chemical composition is 0.5% C, 0.8% Mn, and 0.3% Si. To meet the needs of the work process that is quite heavy, then the materials used must use materials that have good strength and toughness, so that they are not easily damaged, rust, and wear. In the process of improving the strength of the material, several treatments can be carried out such as heat treatment, aging, hardening, tempering, and quenching [1-3].In the process of hardening test specimens, various testing methods can be carried out according to the requirements of the material that wants to be hardened. Quenching is a rapid cooling process using liquid materials / media, such as: water, oil, brine, molten salt and polymer sequences [4-5]. Hardening ST 37 to improve the strength of the material it has; can use the heat treatment process with rapid cooling using liquid media. This cooling process is called quenching. The effect of heat treatment with quenching media on brine and oil on spring steel AISI 3165 gives a considerable hardness value and forms ferrite phase, residual austenite and tempered martensite which is more tightly and evenly spread [6-7].

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The use of quenching is also used on Smaw welding specimens which increase the hardness of the ST37 material using the quenching method [8]. Quenching using acid and alkaline solutions (soapy water and vinegar water) can affect the hardness of ST 37 steel [9]. In aluminum alloy materials using several variations of quenching media provide mechanical properties of tensile strength testing and the hardness of the material possessed increases [10]. Hardness metallurgy is the resistance of a material to the penetration of the emphasis given to the specimen [11]. Testing the hardness is used to find out how tough the test object is pressed by several methods. The most common methods used in conducting hardness testing are Vickers, Brinell, and Rockwell. Vickers hardness testing is a test of hardness of the specimen with a pendulum / suppressor / penetration is square diamond, testing using the Brinell method is a test using steel ball identor, while the Rockwell test is a test using a reading scale that can be seen directly the value of hardness.

2 LITERATURE STUDY

2.1 Carbon Steel (diagram Fe-C)

ST 37 is a metal material containing 0.5% carbon which is included in the medium carbon steel category. In the process of forming the ST 37 material, there are several phases that will form the core/material ST, namely: at 0 - 210^{o}C experiences the ferrite phase. At a temperature of 210^{o}C the object will change from magnetic to Fe3C. These changes continue from α + Fe3C until it reaches a temperature of 727^{o}C which makes the change of objects from austentite to pearlite. When the temperature of 727^{o}C - 760^{o}C is formed ferrite + austentite. Addition of temperature up to ± 1.480^{o}C all objects underwent austentite phase, then below the temperature of 1.492^{o}C the phase formed is austentite + liquid, fiber above temperature of 1.492^{o}C is the liquid phase. The graphic image of the Fe - C balance can be seen in the Figure 1.

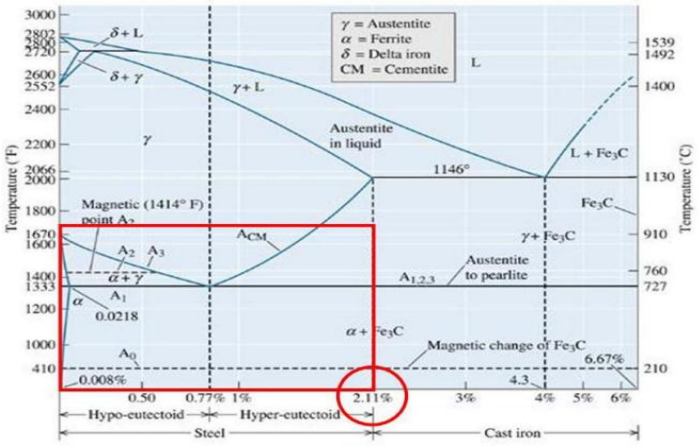

Figure 1. Fe-C diagram [7]

2.2 Quenching

The quenching process is carried out with the aim of obtaining better materials for the physical strength of the material that is owned, where first heating and then quenching with liquid media (media that can accelerate cooling). Some methods for quenching [3] are divided into: Direct quenching method, where the test object is held at a temperature for a certain period of time, then quenched directly into the liquid medium. The method of martempering, where the test object is heated to the temperature of hardening, then quenched liquid media is maintained conditions above the temperature of Ms or 250°C, The austempering method, where quenching from the austenizing temperature into liquid salt with a little temperature is in the range of Ms. Holding Quenching method, where heated specimens are removed from the furnace and left before quenching. Time quenching method, where specimens are quenched from diquenched temperature into oil to be cooled into the air. The die quenching method, which is carried out on thin plates, gears, small cross section, and complicated workpieces that can be easily distorted if quenched into a conventional medium. The following is a graph of quenching on eteuctoid carbon steel material.

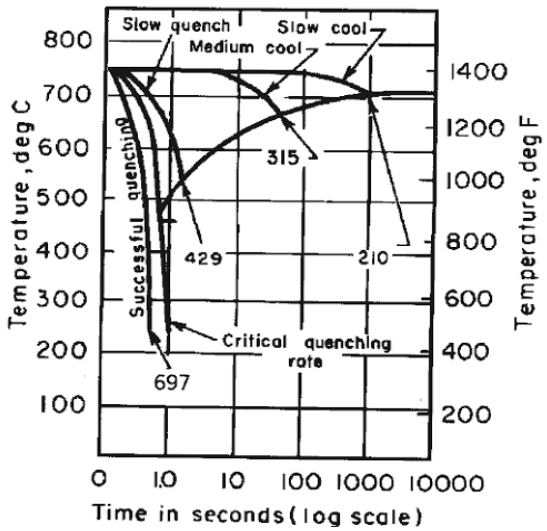

Figure 2. Effect of Cooling Materials of Eutectoid Carbon Steel [3]

2.3 Heating

Furnace is a unit that is used to increase the temperature of ST 37 specimens which will be tested for surface hardness of material by Rockwell method. The furnace with the Noberthem brand can raise the temperature of 4 levels, from 0 - 1000°C, and can hold a temperature hold on the specimen as many as 4 holding times. The process is very easy, with the first step entering the specimen to be heated and arranged in a regular manner, the second setting the temperature to be warmed and setting the time for holding for 1 minute (for even distribution of heating on the specimens). After the specified temperature has been reached (200°C, 400°C, 600°C, 800°C, 965°C), then the test object is taken from the furnace and inserted into the cooling medium (Crude Palm Oil (CPO)).

2.3 Hardness Testing

According to [11] Testing of hardeness is done with two considerations, namely to determine the characteristics of a new material and see the quality to ensure a material has certain quality specifications. Based on the usage is divided into: Testing of hardeness with emphasis (indentation test), this test is carried out to conduct testing of hardness on metal where in determining its strength is done by analyzing indentation or stress marks on the test object as a reaction from press loading Testing of hardness with scratches (sratch test) is a test of hardness on objects (metal) where in determining the hardness is done by looking for comparison of the material that becomes standard. An example is testing the MOH'S method Dynamic hardness testing (dynamic test) is a hardness test by measuring the reflection height of a steel ball or diamond (hammer) dropped from a certain height.

Compressive Strength of Hardness Rockwell (HRC)

Rockwell is the most commonly used method because it is simple and does not require special skills. It is used a combination of indenter variations and loads for metal materials and mixtures ranging from soft to hard materials. Hardness testing using the Rockwell method aims to determine the hardness of a material in the form of material resistance to specimens in the form of steel balls or diamond cones which are emphasized on the surface of the test material.

Indenter

Hard steel balls, size: 1/16 , 1/8 , 1/4 , 1/2 inci (1,588; 3,175; 6,350; 12,70 mm). Diamond cone, Hardness number is determined by the difference in indenter penetration depth, by giving a minor load followed by a larger major load Based on the large minor and major loads, the Rockwell hardness test is divided into 2: Superficial Rockwell and Rockwell for thin materials. Load Rockwell hardness test is divided into 2, namely: minor loads: 10 kg and major loads: 60, 100, 150 kg. The Rockwell superficial hardness test is divided into 2, namely: minor loads: 3 kg and major loads: 15, 30, 45 kg on Table 1.

Table 1. Scale of Rockwell hardness

SYMBOL	INDENTER	MAJOR LOADS (KG)
A	Diamond	60
B	Ball 1/16 inch	100
C	Diamond	150
D	Diamond	100
E	Ball 1/8 inch	100
F	Ball 1/16 inch	60
G	Ball 1/16 inch	150
H	Ball 1/8inch	60
K	Ball 1/8 inch	150

The scale commonly used in Rockwell testing is: HRa (For very hard material) HRb (For soft material). The identity is in the form of a steel ball with a diameter of 1/16 inch and a test load of 100 Kgf. HRc (For materials with medium hardness). Indentor is a diamond cone with a peak angle of 120 degrees and a test load of 150 kgf.

2.5 Crude palm oil (CPO)

Crude Palm Oil CPO is the product of processing / pressing from the Fresh Fruit Sign (FFB) of oil palm trees which can be used as vegetable oil, biodiesel, refeneration of beauty ingredients, food, etc.. FFB that has been piped and boiled, then pressed to get crude palm oil. The process is then clarified to purify crude palm oil. According to Ketaren, 1986, CPO has a chemical formula $C_3H_5(COOR)_3$ with characteristics namely: Molecular Weight : 847.28 g/mol Boiling point : 298ºC Freezing point : 5ºC Specific Gravity : 0.9 Density : 0.895 g/cm3 Heat Type : 0.497 kal/gºC Appearance : Yellow Orange Liquid Purity : 98% Impurities : 2 % Water In this case CPO is used as a quenching material from the test object by heating the furnace by 200ºC, 400ºC, 600ºC, 800ºC, 965ºC. This rapid cooling process will have the effect of changing the strength and hardness of the specimen.

3 RESEARCH METHOD

The following is a flow of research conducted in accordance with Figure 3.

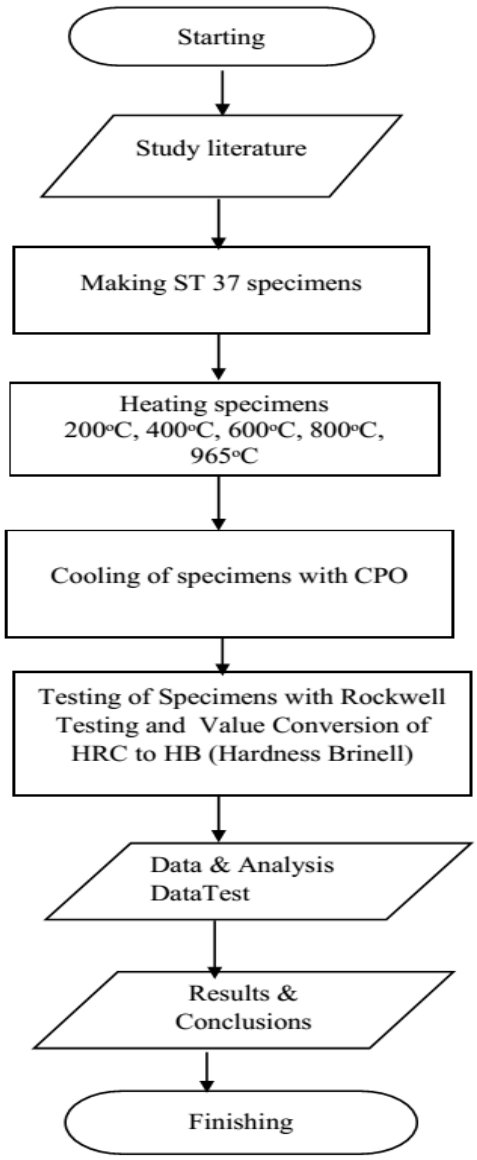

Figure 3. Flowchart of this research

4 RESULTS AND DISCUSSION

ST 37 specimens in the hardness testing process use Rockwell method hardness testing (HRC) with cone identifier and 150 kg load (1471 N). During the Rockwell hardness testing process, the workpiece is placed on a base, and a hard pressure is applied to the specimen. Then the specimen that has been given the pressure of hardening can be read directly the value of hardness (HRC). The value of Rockwell hardness that has been read can be converted into Brinell (HB) hardness value. The process of testing the hardness carried out on each specimen is 3 times, as well as in the heating and quenching treatment using 5 samples of test specimens. Below is a graphic image of the test object without heating and quenching on Figure 4.

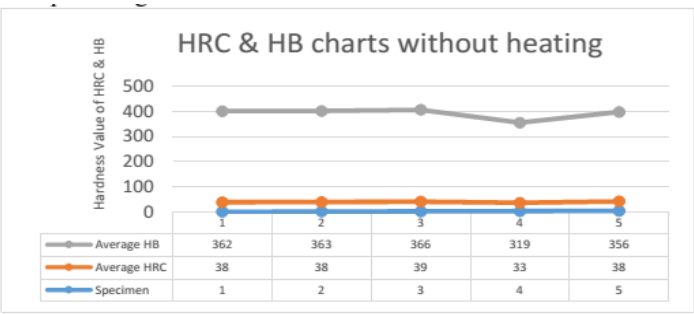

Figure 4. Graph of Specimen Without Treatment

In Figure 4, the value of the specimen shows that the average value of HRC hardness is between 38 HRC and 39 HRC, and the smallest is on specimen 4 of 33 HRC. The value of Brinell hardness in succession specimens 1,2,3,4 and 5 are 363 HB, 363 HB, 366 HB, 319 HB and 396 HB.

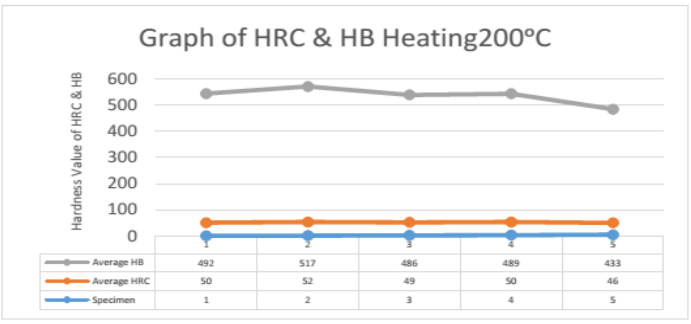

Figure 5. Graph of HRC and HB Hardness Value Heating Specimens of 200°C Quenching CPO

The test specimens carried out by heating are up to 200°C which can be seen in Figure 5. It is seen that the average value of hardness of Rockwell testing is higher than the test object without treatment, where the value of HRC on the specimen 1, 2, 3, dan 4 is 50 HRC, 52 HRC, 49 HRC, 50 HRC, and 46 HRC. While the value of Brinell's hardness conversion in specimens is 1, 2, 3, and 4 that is :492 HB, 517 HB, 486 HB, 489 HB, and 433 HB. Specimens with 200°C heating, look bright silver.

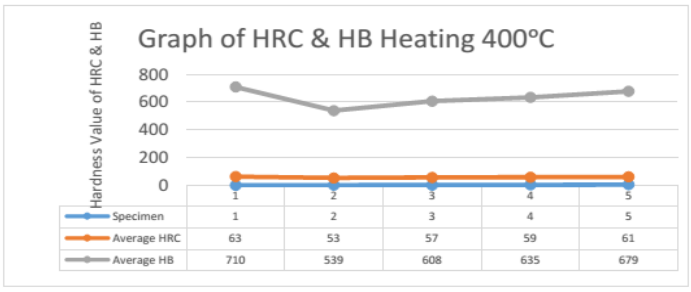

Figure 6. Graph of Hardness Value of HRC and HB Heating Specimen 400 °C Quenching CPO

In Figure 6, it can be seen the hardness value of HRC in specimens 1, 2, 3, and 4 which has been carried out by heating 400°C, i.e: 63 HRC, 53 HRC, 57 HRC, 59 HRC, and 61 HRC. The value of this hardness can be converted to Brinell hardness, that is : 710 HB, 539 HB, 608 HB, 635 HB, and 679 HB. This specimen changes color to black when quenching CPO.

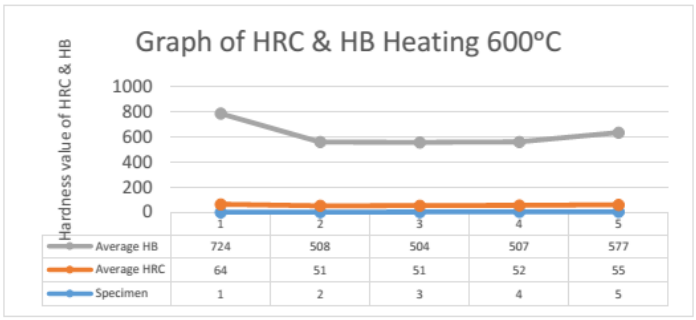

Figure 7. Graph of HRC and HB Hardness Value Specimen of Heating 600°C Quenching CPO

In Figure 7. there is a graph that shows the hardness value in the Rockwell test which in specimens 1, 2, 3, and 4 are as follows: 64 HRC, 51 HRC, 51 HRC, 52 HRC, 52 HRC, and 55 HRC. For the conversion of Brinell hardness values, that is : 724 HB, 508 HB, 504 HB, 507 HB, and 577 HB. The specimen at 600°C increases the hardness value to 31.9% compared to untreated specimens. The specimen turns to be black.

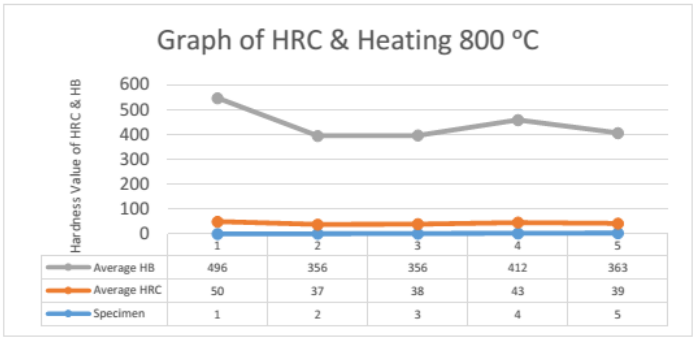

Figure 8. Graph of Hardness Value of HRC and HB Specimen of Heating 800°C Quenching CPO

The specimens at 1, 2, 3, 4, have an increase of 9.7% with the value of Rockwell hardness, namely: 50 HRC, 37 HRC, 38 HRC, 43 HRC, and 39 HRC. The specimen became softer compared to the specimens carried out by heating 200°C, 400°C, 600°C. The specimen goes to be black. For Brinell hardness values are as follows: 496 HB, 356 HB, 356 HB, 412 HB, and 363 HB.

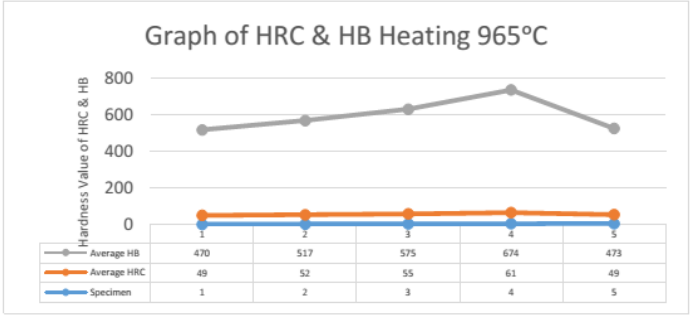

Figure 9. Graph of HRC and HB Hardness Value Heating Test Objects 965°C of Quenching CPO

In Figure 9, we can see a graph of the hardness values of Rockwell and Brinell from specimens 1, 2, 3, 4 as follows 29 HRC, 52 HRC, 55 HRC, 61 HRC, 49 HRC (470 HB, 517 HB, 575 HB, 674 HB, 473). Specimens provide hardness that increases with changes in color to black and crust which can be separated from the test object.

Table 2. Hardness Test Data for HRC On ST37 Without Treatment

No	Treatment Heating (°C)	Quenching	Specimen	Point 1		Point 2		Point 3		Average	
				HRC	HB	HRC	HB	HRC	HB	HRC	HB
1	Room temperature 30	Without Quenching	1	36	341	44	415	35	331	38	362
2			2	39	369	39	369	37	350	38	363
3			3	41	388	40	379	35	331	39	366
4			4	30	294	32	303	38	360	33	319
5			5	35	331	39	369	39	369	38	356
6	200	CPO	1	54	555	50	488	46	434	50	492
7			2	52	517	47	451	56	583	52	517
8			3	45	425	56	583	47	451	49	486
9			4	45	425	54	555	50	488	50	489
10			5	47	451	44	415	46	434	46	433
11	400	CPO	1	63	710	61	670	66	750	63	710
12			2	50	488	55	565	55	565	53	539
13			3	57	602	55	565	60	656	57	608
14			4	63	710	59	639	54	555	59	635
15			5	60	656	63	710	61	670	61	679
16	600	CPO	1	65	739	64	722	63	710	64	724
17			2	55	565	50	488	49	470	51	508
18			3	49	470	53	525	52	517	51	504
19			4	49	470	53	525	53	525	52	507
20			5	59	639	49	470	58	621	55	577
21	800	CPO	1	56	583	41	388	52	517	50	496
22			2	28	275	43	405	41	388	37	356
23			3	41	388	35	331	37	350	38	356
24			4	50	488	38	360	41	388	43	412
25			5	37	341	40	379	39	369	39	363
26	965	CPO	1	49	470	49	470	49	470	49	470
27			2	48	461	49	470	58	621	52	517
28			3	61	670	58	621	46	434	55	575
29			4	60	656	63	710	60	656	61	674
30			5	45	425	49	470	53	525	49	473

In conducting hardness testing using the Rockwell method is to use type C, with a load of 150 kg (1471 N). Specimens that have been heated in the furnace cause the specimen to change color, which is red by increasing its temperature. And the quenching process uses CPO to be more black on the specimen. Data on Rockwell hardness test (HRC) and Brinell (HB) hardness value conversion can be seen in table 2. There are 30 specimens that are used in testing Rockwell hardness and 25 specimens are gradually heated from 200°C - 965°C. Then the hardness value data that has been tested is made an average value that is the hardness value of Rockwell and Brinell.

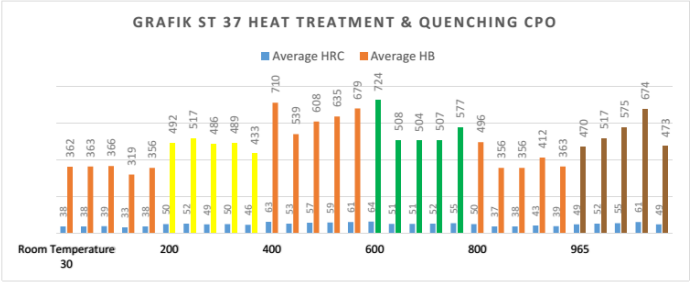

Figure 10. Graph of HRC and HB Hardness Value in Room Temperature Heating Specimen - 965°C Quenching CPO

In Figure 10, there is an increase in the hardness value of the specimens that have been heated and quenched using CPO. The greatest hardness value occurs at a heating temperature of 400°C and the lowest is 800°C.

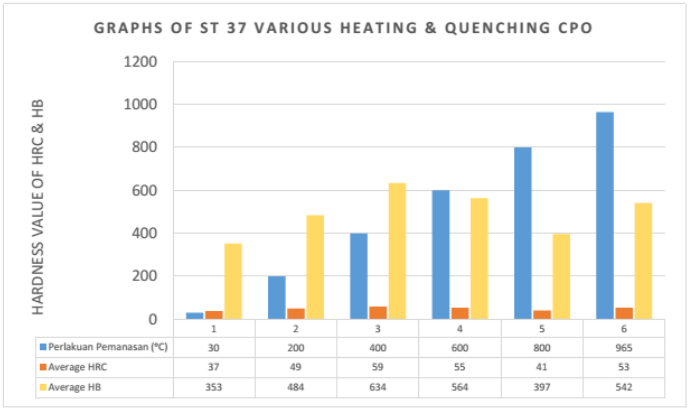

Figure 11. Graph of Average Hardness Value of HRC and HB Heating Specimen 30 - 965°C Quenching CPO

In Figure 11, it is seen a graph of the average hardness valueof HRC and HB in the heating specimens from room temperature (30°C) to 965 °C. The increase in the value of the hardness that occurs from specimens that have been heated and quenched by CPO is as follows: in the 200°C heating specimen 24.4% of the specimens were not treated. The increase in the value of the hardness of the specimens carried out by heating 400°C, 600°C, 800°C, 965°C is as much as 36.6 %, 31.9%, 9.7% and 29.9%. So the most superior hardness value is in specimens that uses 400°C heating by quenching CPO.

3 CONCLUSION

From the results of testing that has been done, heating and quenching on the specimen can be concluded, namely: By increasing the temperature of the specimens and quenching with CPO, the hardness value will increase compared to the test object which is not treated. The increase in the value of the hardness that occurs from the specimens that have been heated and quenched CPO in the heating specimen 200°C is 24.4% (49 HRC) to the specimens not treated (37 HRC), the increase in the hardness of the specimens carried out by heating 400°C, 600°C, 800°C, 965°C is as much as 36.6% (59 HRC), 31.9% (55 HRC), 9.7% (41 HRC) and 29.9% (53 HRC). So the most superior hardness value is in specimens that use 400°C heating by quenching CPO.

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