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Effect of Austenization and Repeated Quenching on The Microstructures and Mechanical Properties of Wear-Resistant Steel

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Cover Page Footnote

The author would like to thank the management and staff at the Research & Development Division of PT Krakatau Steel which has assisted in this research process.

Effect of Austenization and Repeated Quenching on The Microstructures and Mechanical Properties of Wear-Resistant Steel

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Abstract. This study was focused on determining the effect of repeated austenitization and quenching on mechanical properties and microstructure. The experiment was carried out in a rolled quencher facility with a heat treatment process of one to two times, with parameters of an austenitizing temperature of 9500C and quenching at a temperature of 8500C with pressurized water media. Testing of specimens, including microstructure observations and hardness testing. The repeated heat treatment process showed an increase in hardness of 0.79% on one-time repeated heat treatment and 1.65% on two repeated heat treatments. This occurs due to the presence accompanied by refinement of the prior austenite grains and the martensite structure. In addition, the hardness value decreases in the surface area 17.9 HV and 24.9 HV due to the deeper accumulation of decarburization 0.06-0.10 mm followed by thicker iron oxide growth 0.04-0.07mm.

Keywords: Repeated austenization; Repeated quenching; Heat treatment; Manufacture; Martensite

INTRODUCTION

The issue of flatness quality has become a standard in fulfilling the quality of wear-resistant steel. Problems occur in some of the output of domestic wear-resistant steel products, which have a flatness beyond the standard, wavy or curved. This occurs when the heat treatment process takes place in the facility's rolled quenchers. An alternative that has been done at this time is to improve flatness by doing the heat treatment process again by adding roll force on the roll leveler. The repair process is repeated once to twice during heat treatment [1].

Technically, the reheat treatment process is possible because iron (Fe) is allotropic in that it has two or more transformable forms of the atomic arrangement of the unit cell with temperature changes. Martensite, which has a Body Center Tetragonal (BCT) crystal structure when austenized, will turn into a Face Center Cubic (FCC) crystal structure, and when quenched, it will re-form BCT structure. Many studies related the repetition of austenitization and quenching processes and some of its effects on the final mechanical properties. Research conducted by Zhaoxi Cao

stated that the second austenitization and quenching significantly increased strength, tensile and toughness, and the limit of rotating bending fatigue strength (RBF) [2]. Process repetition austenitization and quenching can refine the prior austenite grain size by up to 50%, affecting the toughness increase of up to 23% compared to one process [3]. The formation of austenite priors significantly affects the alloy content of the steel. In the austenitization and quenching process, making Soluble carbides thus significantly affects the prior austenite grain refinement. It increases the hardness value of the carbides, which dissolve in the first austenitization (precipitate), becoming the trigger grain refinement on the second austenization [4] as well as the research conducted by Kseer showed that double quenching on low carbon steel increases wears resistance compared to single quenching [5].

Apart from the increase in mechanical properties, it is also reviewed from the martensite microstructure formed, with repetition of the process can increase lath size and grain refinement [6,7]. Therefore, this research aims to know the effect of repeated austenitization and quenching on properties, mechanics, and microstructure in KSTA500 wear-resistant steel.

MATERIAL AND METHODS

Materials

The sample used is KSTA500 low alloy steel which is the production of a steel manufacturer nationally applied as wear-resistant steel, with an alloy chemical composition including chromium, nickel, and molybdenum, as shown in Table 1. The sample size was 8.5x40x400 mm, with the same size for each specimen.

TABLE 1. Typical Composition of Wear Resistance Steel KSTA500

Element	**C**	**Mn**	**Cr**	**Ni**	**Mo**
%	0.28	1.4	0.8	0.3	0.25

Methods

The research method was carried out using a rolled quencher heat treatment facility. Sample by size 8.5 x 40 x 400 mm is welded to the dummy plate, which has made a hole in the center, as shown in Figure 1. The setup was different from conventional heat treatment using a muffle furnace which sample placement could affect the microstructure [1, 8]. The research uses the existing production parameters by heating to a temperature of 950°C and holding for 21 minutes with a steel plate that moves back and forth, driven by a roller on the table in the reheating furnace. Furthermore, the steel plate comes out of the reheating furnace to the transition table within 21 seconds, accompanied by a decrease in temperature of 100°C, so that the temperature when entering the process area of the quencher 850°C which was then quenched with water at a pressure of 5 bar. A schematic of this heat treatment process is shown in Figure 2, with the heat treatment process carried out one time with a green plate and repetition of the process 1 and 2 times, then each process is characterized.

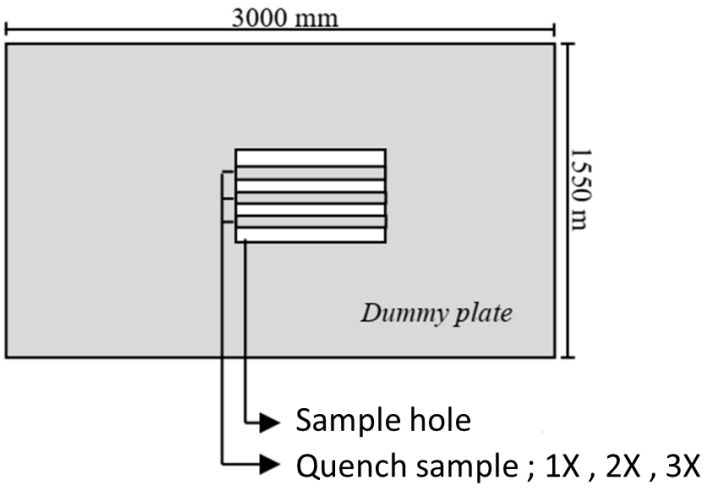

FIGURE 1. Sample Preparation Scheme on Heat Treatment Process in Rolled Quencher Facility

The characterization of the hardness and hardness tests was carried out with metallography to find out the results of the heat treatment process. The hardness test was carried out using the Vickers microhardness test, indenting 0.1 mm from the surface and then indenting 0.40 mm to a depth of 4 mm from the steel surface. Furthermore, microstructure observations were carried out to identify the final structure using an optical microscope, measuring the depth of decarburization, iron oxide thickness, and austenite grain size.

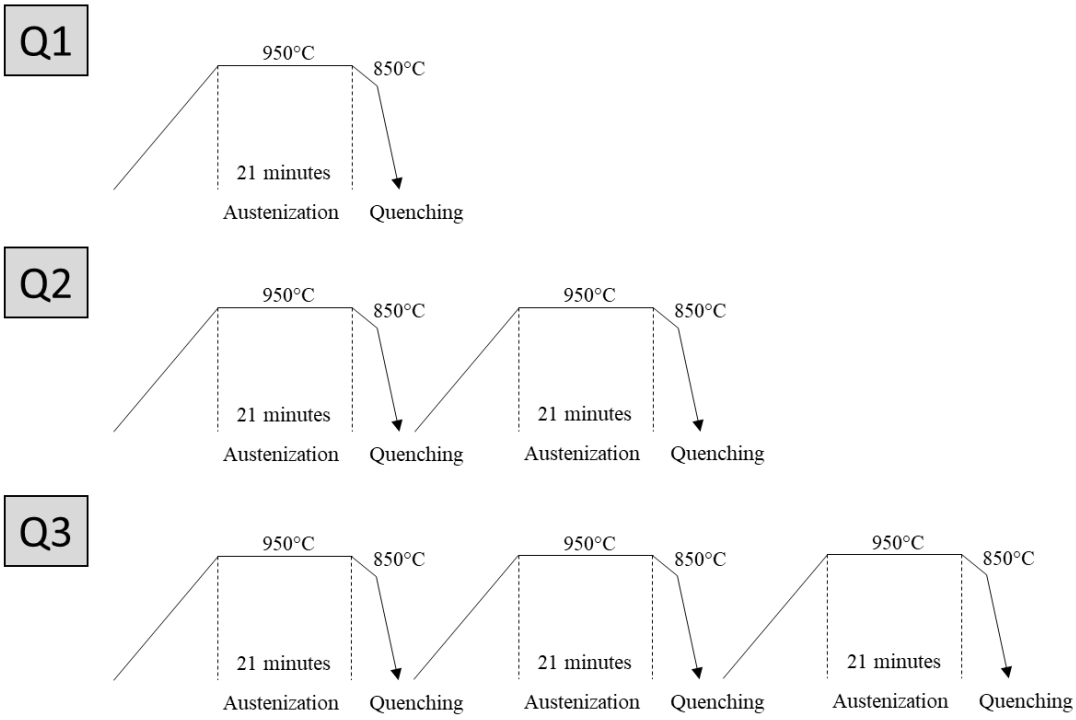

FIGURE 2. Heat Treatment Parameter Cycle for Austenization and Quenching

RESULT AND DISCUSSION

Based on the results of microstructural observations using 3% nital etching and 500x magnification, it can be seen in Figure 3. Prior austenite grain observation of the Q1 specimen has a grain size of 28.3 µm, the Q2 specimen with a grain size of 26.6 µm, and in Q3 with a grain size of 23.8 µm. This shows a grain refinement process at each repetition of the austenitization and quenching processes. Qualitative observation of changes in the morphology of the martensite structure in Figure 4. also shows a refinement of the structure martensite in Q2 and Q3 specimens compared to Q1. This grain refinement is caused by grains of austenite formed in the first austenitization, which is a soluble precipitate carbide, and into the formation of second austenite grains after re-austenization so that the carbide solubility will be higher. The smaller austenite grains make the width of the martensite block smoother so that it can serve as a barrier to crack propagation, increasing ductility and toughness [3].

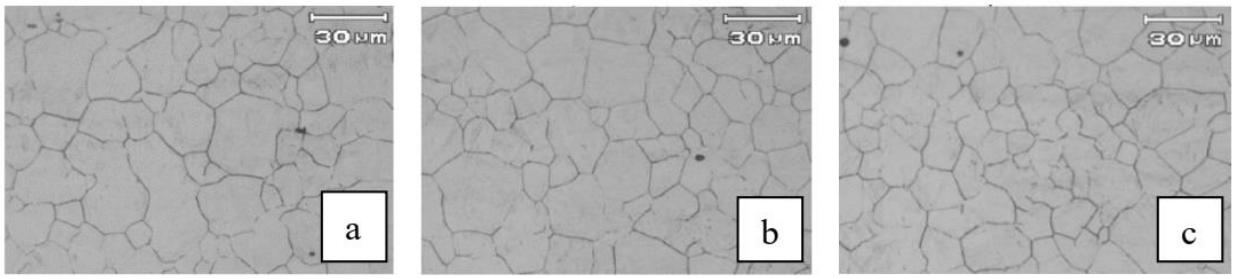

FIGURE 3. Prior Austenite Microstructure. (a) Q1, (b) Q2, (c) Q3.

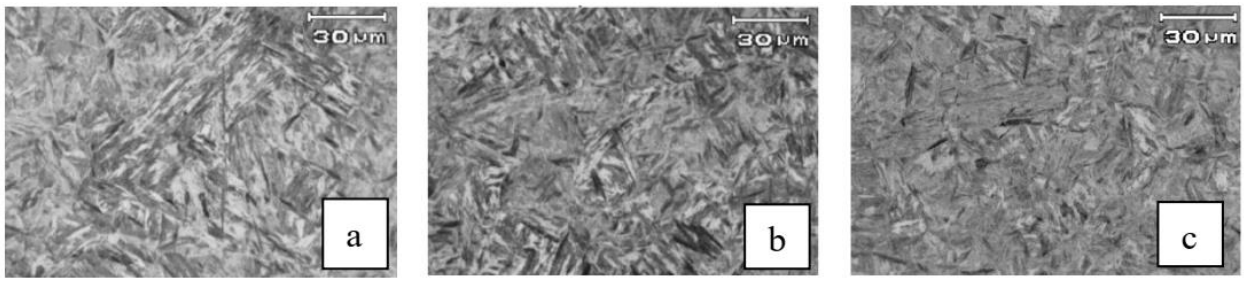

FIGURE 4. Martensite Microstructure. (a) Q1, (b) Q2, (c) Q3.

The formation of iron oxide (scale) will always form when the austenitization process takes place in reheating furnace. The metallographic observations in Figure 5 show the scale's thickness on the Q1 specimen of 0.03 mm, Q2 of 0.04 mm, and Q3 of 0.07 mm. The increase in scale thickness is accumulated due to the repetition of the heat treatment process. Thicker scale formation is considered in the repetition of this heat treatment process because the formation of scale automatically will reduce the thickness of the product and will measure the actual thickness of the steel when the final stage is carried out, namely, the de-scaling process with the sandblasting method.

In addition, in Figure 5. it is also identified that there is a decarburization process on the steel surface caused by the oxidation process in the reheating furnace. From the results of metallographic observations on the surface area, Qualitative measurements in the decarburization area on the Q1 specimen have a decarburization depth of 0.02 mm, in Q2 of 0.06 mm, and Q3 of 0.10 mm. Decarburization depth is getting deeper along with increasing repetitions of the heat treatment process. This is because the steel surface is directly exposed to the atmosphere in a reheating furnace oxidative.

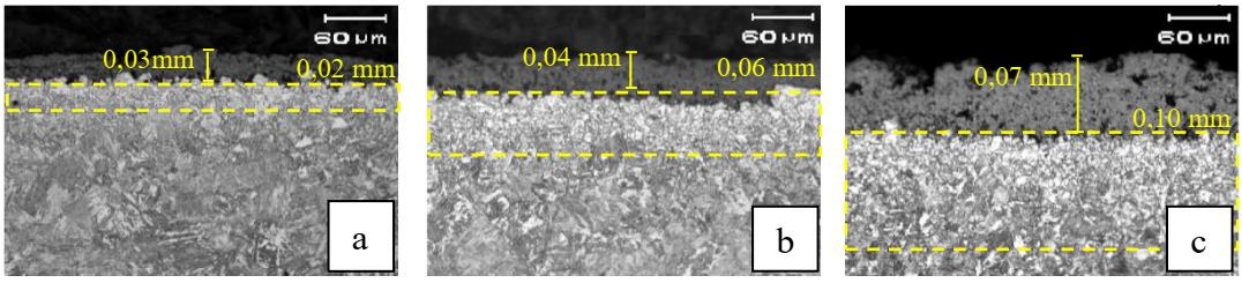

FIGURE 5. Microstructure Observation on the Surface Area. (a) Q1, (b) Q2, (c) Q3.

The hardness test results in Table 2 show that the sample surface is at a depth of 0.1 mm and has the lowest hardness value. The comparison of hardness test values at 0.1 mm below the sample surface decreased with the repetition of the process. From observing the microstructure, the deeper decarburization was caused by the repeated heating process. The relationship between the depth of decarburization and the hardness value is shown in Figure 6(b). The deeper the decarburization, the lower the hardness value. However, on the indentation point is 0.4 - 4.0 mm below the surface, the hardness value increases with the distance of the indentation point from the decarburized area. It identifies a difference in the hardness value of each process repetition. Figure 6 (a) illustrates a deviation of hardness values in Q1, Q2, and Q3. In the Q2 sample, the hardness test value increased by an average of 3.87 HV at each point compared to the Q1 sample. In the Q3 sample, the hardness test value increased even more, with the average increase in each point being 8.13 HV compared to the Q1 sample or 4.16 HV compared to the Q2 sample. From the results of the hardness test, it is explained that the material has undergone a conventional process of quenching and is then re-processed. Grain refinement will occur, which will affect the mechanical properties [4, 9].

TABLE 2. Vickers Hardness Result

Distance from Surface (mm)	Vickers Hardness (HV)		
	Q1	Q2	Q3
0.1	413.1	395.2	388.2
0.4	152.7	465.1	469.3
0.8	482.4	488.2	490.3
1.2	482.4	493.4	468.1
1.6	482.4	481.4	490.3
2	482.4	490.3	494.7
2.4	492.4	492.3	495.1
2.8	505.1	506.6	511.7
3.2	510.1	512.1	515.1
3.6	510.1	512.3	515.1
4	513.1	511.1	514.7
Average	491.31	495.28	499.44

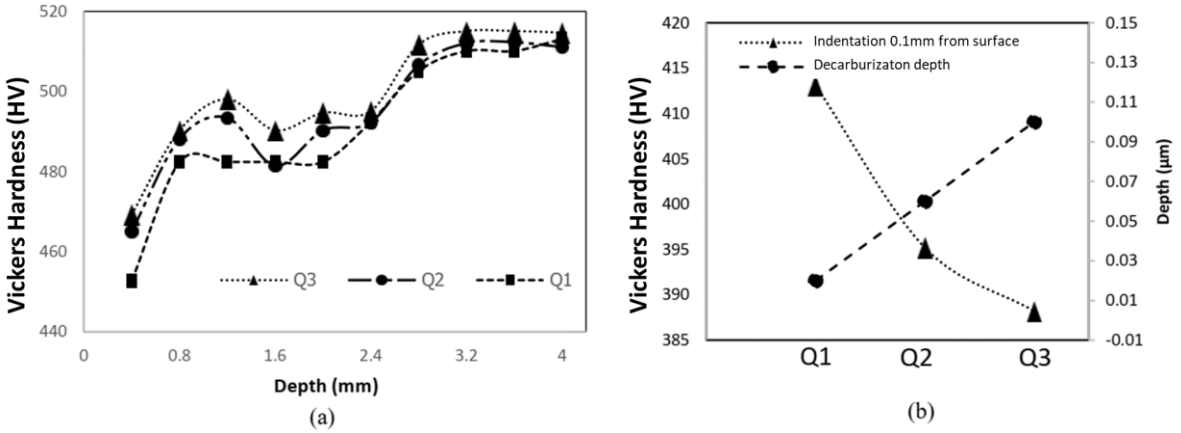

FIGURE 6. (a) Hardness in Different Surface Depth, (b) Hardness Value comparison with Decarburization Depth.

CONCLUSION

From the results of this study, it can be concluded that:

1. From the microstructure observation, the final structure of martensite formed during austenitization and quenching the second and third times has a finer structure accompanied by refinement of the prior's austenite and improved mechanical properties [10].
2. From the hardness test results, the second austenitization and quenching (Q2) and the third time (Q3) experienced an increase in the average hardness value of 3.87 HV and 8.13 HV compared to the austenitization-quenching process one-time.
3. The formation of the decarburized area accumulates deeper with each repetition of the maximum process depth of 0.10 mm at Q3. The hardness test results in the decarburized area experienced a decrease in hardness value of 24.9 HV in sample Q3 compared to Q1.
4. The growth of scale accumulates thicker at each repetition of the process until it reaches 0.07 mm on austenitization – quenching the third time (Q3).
5. Repeat austenitization and quenching processes generally do not change the mechanical properties but a significant decrease in surface hardness due to the deeper decarburization and accumulation of thick scale into consideration in this process.

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