Effect of Heat Treatment on Mechanical and Microstructure Properties from 0.21C-0.44Mn-0.65Cr-1.2Ni Lateritic Steel

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Abstract. Nowadays, along with the era that moves forward, the utilization of steel is developing rapidly in the infrastructure industry. It has been researched about laterite steel, which becomes alternative steel materials. Because of the laterite steel is the alternative material, the heat treatment process has been chosen to know about mechanical properties and microstructures that can be formed in the laterite steel. In this research, laterite steel, who has 0.21%C, 0.44%Mn, 0.65%Cr, and 1.2%Ni as the main composition, be heated on austenite temperatures that are 800ºC for 30 minutes. After that, the quenching process is carried out in water and oil as the cooling medium required. And the final process is tempering process to complete this study with the tempering temperature 100 and 200ºC for 45 minutes. The result shows that heat treatment process increased mechanical properties for laterite steel with the value of the tensile strength, hardness, and impact toughness are 14.88 N/mm^2 for UTS and 10.27 N/mm^2 for YS; 830 HV; and 0.047 J/mm^2. Similarly, the microstructures formed is dominated by 62.74% of martensite structure.

INTRODUCTION

The industrial world is now growing very rapidly. Further research is also continuing to get the right ferrous material. Lateritic steel is a finished product made from laterite ore and will produce 1-3 percent nickel content. According to previous research, the content of nickel alloys is high enough to produce good quality steel that is needed for infrastructure in Indonesia[1].

Because lateritic steel is an alternative material in steel production, laterite steel needs to be developed with a variety of metal functions, one of which is the heat treatment process. The heat treatment process involves heating the steel to a certain temperature, maintaining it at a certain time, and cooling it to a certain medium as well. The heat treatment has the aim of increasing ductility, eliminating internal stresses, smoothing crystal grains, increasing hardness, and tensile stresses of metals[2]. These objectives will be achieved if you consider the factors that influence it, such as heating temperatures and the cooling media used[3].

Therefore, the steel needs to be done further processes, namely the tempering process. The tempering process will reduce agility, tensile strength, and hardness to meet the conditions of use, while tenacity and toughness increase[4].

After the hardening process is carried out, several test materials will be tested to determine hardness, tenacity, microstructure that occurs in the test material, which can later be used as infrastructure applications and steel made from local raw materials using the term laterite steel[5].

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EXPERIMENTAL SETUP

The sample used is plain reinforcing steel. The sample will be subjected to heat treatment and tempering process. Plain reinforcing steel samples are cylindrical and 25 mm in diameter. Samples were cut 100 mm in length for the tensile test sample (ASTM E8 standard)[6] and 55 mm in length for the impact test sample (ASTM E 23 standard)[7]. After that, the sample is heated to a temperature variation of 800, 850, and 950°C with holding time adjusted to the thickness of the sample. Furthermore, the cooling process is carried out with different variations of the cooling media. The variation of cooling media used is water and quenching oil. After going through the cooling process, the sample will be tempered with a temperature of 100 and 200 °C for 45 minutes. As for the tests conducted on samples, including hardness test with the Vickers method, impact test with Charpy method, tensile test with TT-HW2-600-S universal servo-hydraulic testing machine, and metallography using optical microscopy.

RESULT AND DISCUSSION

Chemical Composition Testing

TABLE 1. Composition of Plain Reinforced Steel Laterites (% by weight)

Element	C	Si	S	P	Mn	W	Ti	Sn	Al	Pb
Composition	0.211	0.247	0.035	0.032	0.442	<0.0001	0.006	0.0125	0.0413	0.0004
Element	Cr	V	Cu	Nb	Zr	Ni	Zn	Mo	Fe	
Composition	0.653	0.0059	0.0264	0.0041	0.00097	1.202	0.0018	0.0022	97.07	

From the results of testing the chemical composition, it can be seen that the main chemical composition contained in laterite steel is iron (Fe) = 97.07%, Fe is the main constituent element. From the results of this test, the carbon content (C) = 0.211% with a carbon content of this magnitude can be concluded that this steel is categorized in low carbon steel, low carbon steel that is steel containing carbon elements <0.3%.

Impact Test

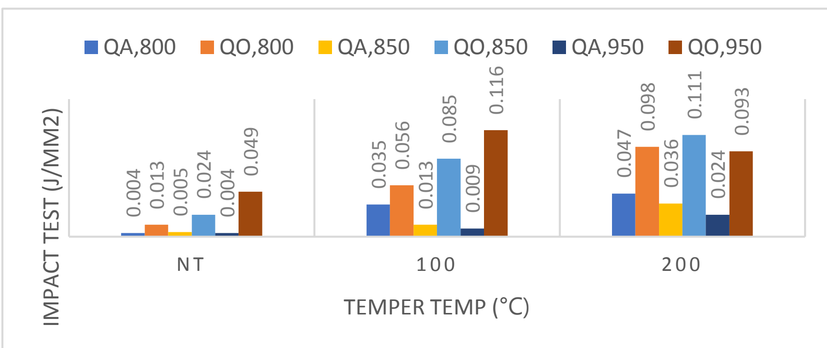

FIGURE 1. Relationship of the Tempering temperature with the impact properties

It can be seen from the graph above the impact price results from the heat treatment process. All samples experienced an impact price increase with increasing tempering temperatures. The biggest increase occurred in samples heated at a temperature of 800°C and then cooled with water media and carried out the tempering process at a temperature of 200°C with a value of 0.004 J / mm^2 to 0.047 J / mm^2. This proves that the previously hardened sample will become soft with the tempering process, which removes residual stresses due to rapid cooling. C. Sun et al. also believes that the tempering process removes internal stresses from the sample due to heating at low temperatures or below 200°C [4,8]. So it can affect the impact price, which increases due to increased tempering temperatures and loss of internal stress.

Hardness Test

Hardness testing obtained data by the Vickers method as follows:

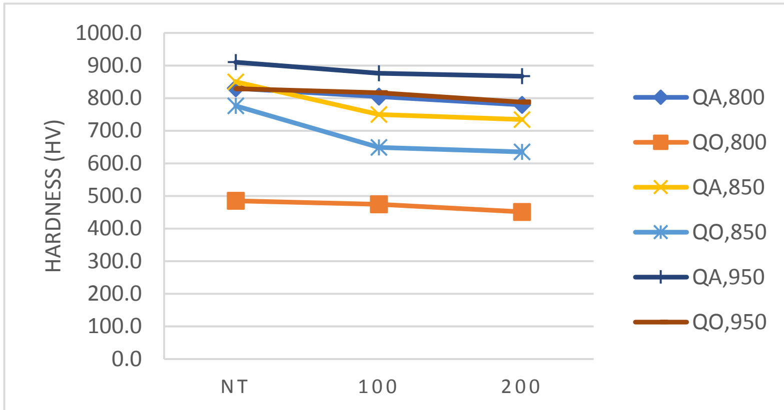

FIGURE 2. The Relationship Temper temperature and Hardness Properties

The graph above presents data obtained from a hardness test of a sample that has been subjected to a heat-treatment process. Media quenching is very influential in increasing the value of violence. The biggest increase occurred in the sample carried out quenching on water media from 184.8 HV to 830.0 HV. After the tempering process is complete, the sample experiences a decrease in hardness value. The hardness value in the sample decreases with the increase in tempering temperature caused by the loss of internal stress formed during rapid cooling in the quenching process.

From the analysis of hardness test data, it can be concluded that the sample experienced an increase in violence after the heat treatment process. But when the sample undergoes a tempering process, the hardness value will decrease with increasing tempering temperature.

Tensile Strength Test

Tensile testing uses the TT-HW2-600-S universal servo-hydraulic testing machine. Here is a figure from tensile testing:

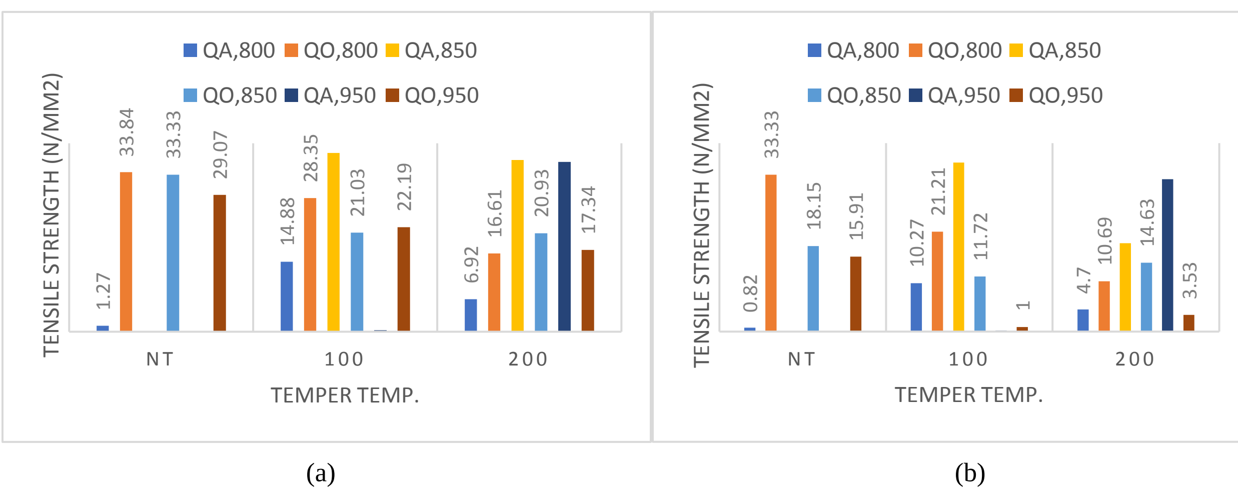

FIGURE 3. Relationship between Reduction Variations (a) UTS (Ultimate Tensile Strength) and (b) YS (Yield Points)

The graph above presents the results of the tensile test on the UTS and YS values that were previously heat treated. It can be seen that there is a decrease in the value of UTS and YS in the tempering process. The significant reduction occurred in samples that were heated at 850°C and cooled with water media then tempering at 100ºC. The values obtained were 14.88 N / mm^2 to 6.92 N / mm^2 for UTS and 10.27 N / mm^2 to 4.7 N / mm^2 for YS. From the results of the analysis of the tensile strength test, it can be concluded that the value of the tensile strength decreases with increasing tempering temperature and different cooling media[9].

Metallographic Test

Metallographic testing was carried out as a complement to see the microstructure formed in the sample.

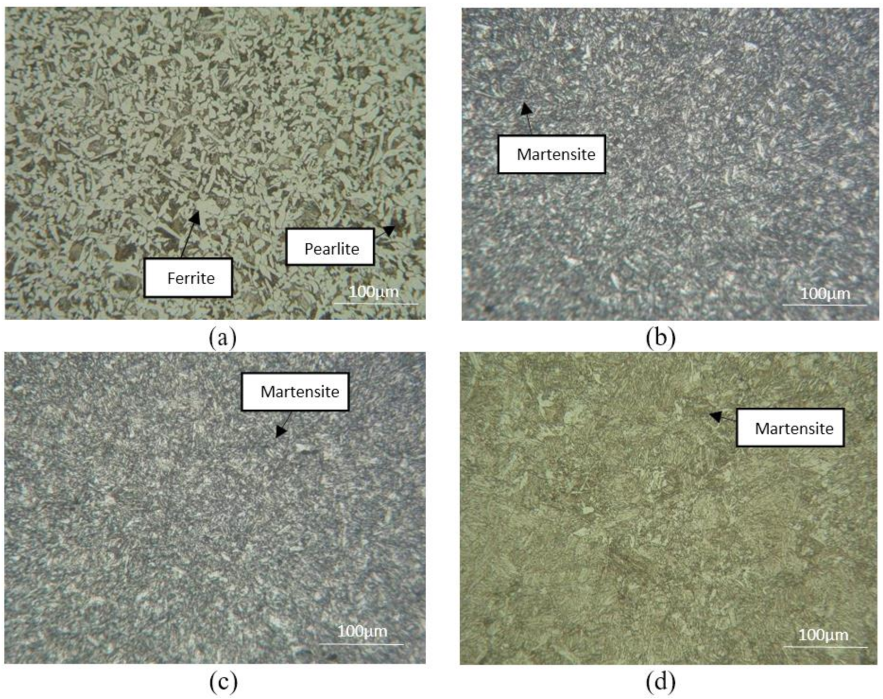

FIGURE 4. Metallographic Test Results with a magnification of 200x: (a) Raw; (b) QO800; (c) QO800+T100; (d) QO800+T200

Fig 4. shows the changes in the microstructure that occur in the heat treatment process of austenitization temperature of 800°C. The resulting phase is the martensite ferrite phase. By using ImageJ software, it can be seen. Then the sample is tempered and still produces the martensite phase. Using ImageJ software, it can be seen that the levels of the martensite phase decreased from 68.68% to 63.92% and continued to decrease to 55.07%.

Figure 5 shows the microstructure of the raw sample, which is pearlite ferrite, which turns into a martensite phase after being heated at an austenitization temperature of 950°C and cooled with a water cooling medium. The formed phase remains the martensitic phase. By using ImageJ software, it can be seen that the martensite phase levels decreased to 62.08% and 59.69% which caused a decrease in the hardness value and increased impact strength due to reduced residual stress and caused greater energy absorption compared to samples that were not carried out tempering process[9-11].

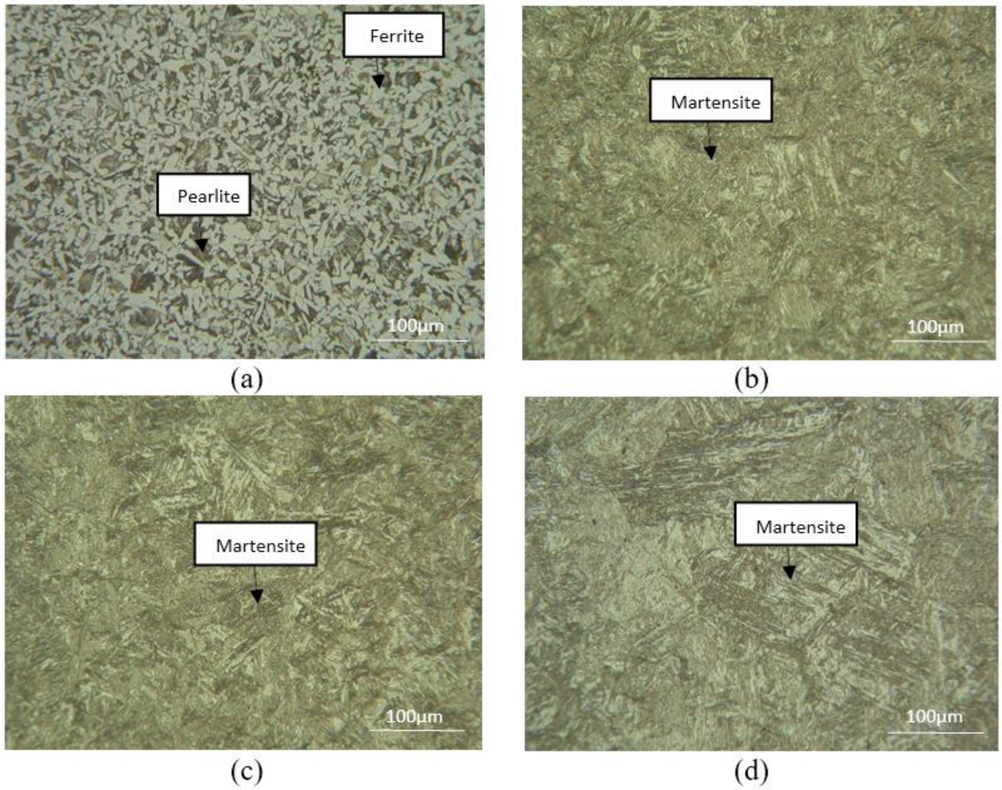

FIGURE 5. Metallographic Test Results with a magnification of 200x: (a) Raw; (b) QA950; (c) QA950+T100; (d) QA950+T200

CONCLUSION

The influence of the cooling media is more dominant than the austenitization temperature and tempering temperature on changes in mechanical properties, which have a hardness value of 830 HV with water cooling media or an increase of 451% of the sample without heat treatment. For the impact test, the parameter that has a deep influence is the tempering temperature parameter with a temperature of 200°C, which has an impact of 0.047 J / mm^2 or an increase of 1175% from the sample without tempering process. And for tensile strength, the parameter which has a great influence is the tempering temperature also with a temperature of 100°C with a tensile strength value of 14.88 N / mm^2 for UTS and 10.27 N / mm^2 for YS or an increase of 1171.1% and 1252 4%.

The results of observing the microstructure of laterite steel used as a sample, the structure formed is dominated by 62.74% martensite structure in water media. Whereas in the oil media, the martensitic structure formed was 13.49% less than the water media. So that the cooling process with water media is harder than the oil media. Whereas in the air conditioner media, the structure formed is pearlite ferrite.

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