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## Mechanical and microstructure properties of the Ni-Cr-Mo modified steel by heat treatment process

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# Mechanical and microstructure properties of the Ni-Cr-Mo modified steel by heat treatment process

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**Abstract.** The development of Iron and steel is the fundamental essential needs for a construction. Indonesia should seek local raw materials for steelmaking production to cooperate with industrial markets. In this research, a new innovation in the manufacturing of bucket teeth components using laterite steel by optimizing the nickel alloy content reaches 1.5-3% and other alloys with special heat treatment process. The best results of optimization abrasion wear resistance and hardness properties on 1Cr1Mo steel with quenching oil treatment resulted in hardness of 43.60 HRC and had a good abrasive resistance of 0.16 gr/cm<sup>2</sup> weight loss. In morphological analysis of microstructure showed that the grain boundaries become more flattened and sharpened into martensite phase transformation.

## 1. Introduction

Iron and steel manufacturing industries are very rapidly developing and also material innovation has been carried out in the development of bucket teeth product using laterite steel by optimizing the nickel alloy content which reaches 1.5-3%[1]. It is expected that laterite steel can be a new alternative in the production of bucket teeth with a value of mechanical properties and a longer lifetime. In this study will be discussed about the mechanical study of materials especially on the nature of hardness and wear resistance abrasion through a tempering process using metallographic observation methods, abrasion testing, chemical composition testing, and hardness testing which is useful to determine the price of hardness in bucket teeth.

Laterite steel is steel that has much better formability and mechanical properties compared to carbon steel and stainless steel because it has a Ni content of 0 to 3.0% and Cr is 0 to 2.5%. In addition to Fe and Ni content, laterite steel also contains other elements, namely Cr and Mn, where both elements will have an impact on the properties of steel weldability, surface hardness, and corrosion resistance[2]. Low alloys steel is widely used as the main material in piping systems, hydroelectric power plants, petrochemical industries and nuclear power because of its long service life, corrosion resistance, and economical[3].

Abrasion wear is a mechanism of hard material collides with a soft surface and usually leaves wear fragments. A heat treatment approach that can modify phase and microstructures and also modify steel surfaces by applying coatings is a way to increase abrasion wear resistance. Tempering process with the addition of Mo-Cr has no effect on the carbide morphology at low tempering temperatures but can increase wear resistance when the temperature is above 350°C[4].



This goal will be achieved as desired to the factors that influence, such as tempering temperature and cooling media also variations in the material composition. Heat treatment has an influence on the microstructure and mechanical properties of variations in cast steel of Ni-Cr-Mo alloy, tempering temperature can change the microstructure and abrasion resistance and surface hardness of laterite steel.

## 2. Experimental Method

This experiment starts with cutting the test sample with various composition (Ni, Cr, Mo) to get the specimens ready for abrasion, hardness and metallography testing so as not to be affected by the machining process after heat treatment. The heating process at 950°C with 60 minutes holding time then quench using oil media and tempering at a temperature of 500°C.

Furthermore, heat treatment samples were tested for hardness using rockwell hardness method, and abrasion testing using ASTM G 132-96 standard, ADAMEL LHOMARGY abrasion rotary on cylindrical sample with 2-3 cm<sup>2</sup> surface area where the sample was placed under sandpaper grid size 120 rotating at a speed of 100 rpm as many as 1000 rounds with a load of 1 kg at room temperature of about 30 °C. The results of abrasion testing are weight loss in units of mg / cm<sup>2</sup> which shows the abrasion resistance. Metallographic testing with an optical microscope with grinding preparation, polishing to etch with 2% nital concentrate to analyze the shape, grain boundary and phase formed.

## 3. Results and Discussion

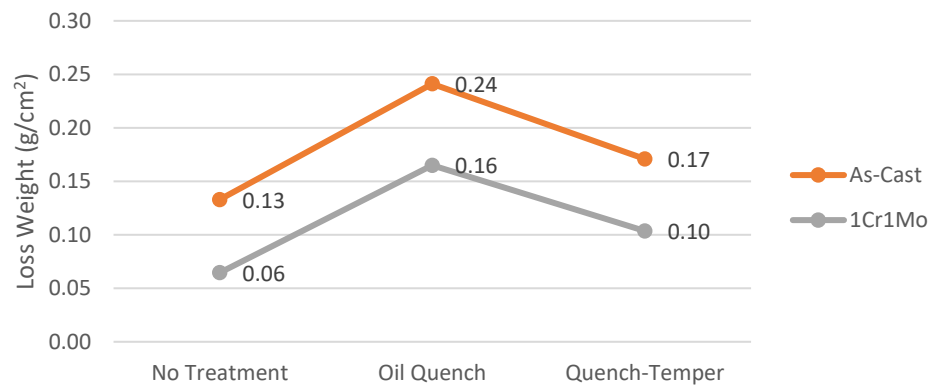
Chemical composition testing is carried out to determine the content of chemical elements contained in laterite-based alloy cast steel resulting from the casting process with material balance calculations.

**Table 1.** Chemical composition of the experimental steel

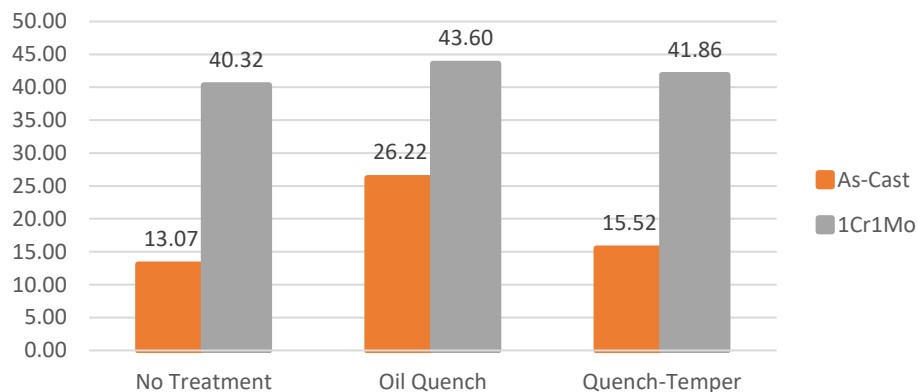
Type	Chemical Element								
	C	Si	Mn	P	S	Cr	Ni	Mo	Fe
<b>As-Cast</b>	0.2	0.6	0.47	0.0005	0.0003	0.02	2.4	0.006	Bal.
<b>1Cr1Mo</b>	0.2	0.4	0.5	0.0005	0.0003	1.074	2.2	0.981	Bal.

The chemical composition testing of alloy steel, it can be seen that the main chemical composition contained in the laterite steel samples of As-Cast is (Ni) = 2.483 %, Ni is the main constituent element. From the results of this test the carbon content (C) = 0.1556 % with this carbon content can be concluded that this steel is categorized in medium carbon steel and low alloy steel, medium carbon steel that is steel containing carbon elements from 0.10 % - 0.30 % approached the modified steel standard AISI 4140[5], [6].

Abrasive resistance testing aims to determine the effect of variations of Ni-Cr-Mo alloy in laterite steel and variations in heat treatment of abrasive resistance. Bucket teeth have the main function as soil and rock crushing with wear resistance and toughness to obtain bucket teeth have an optimum service life.



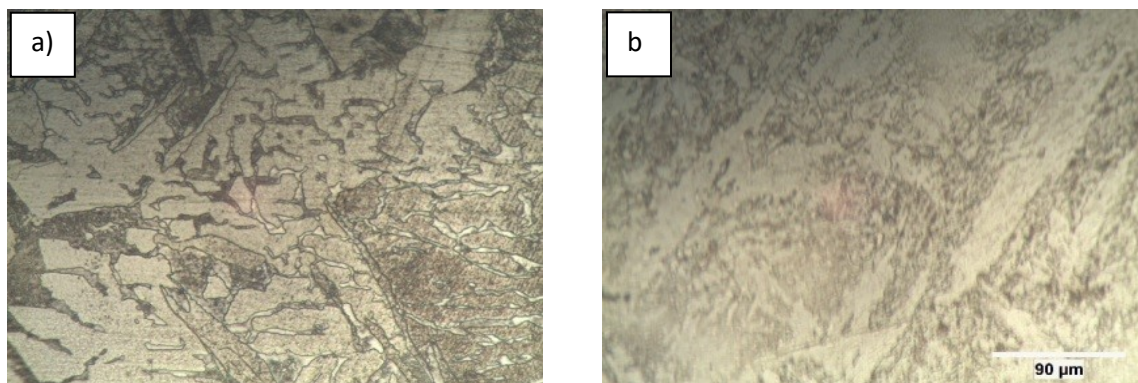
**Figure 1.** Abrasion test result

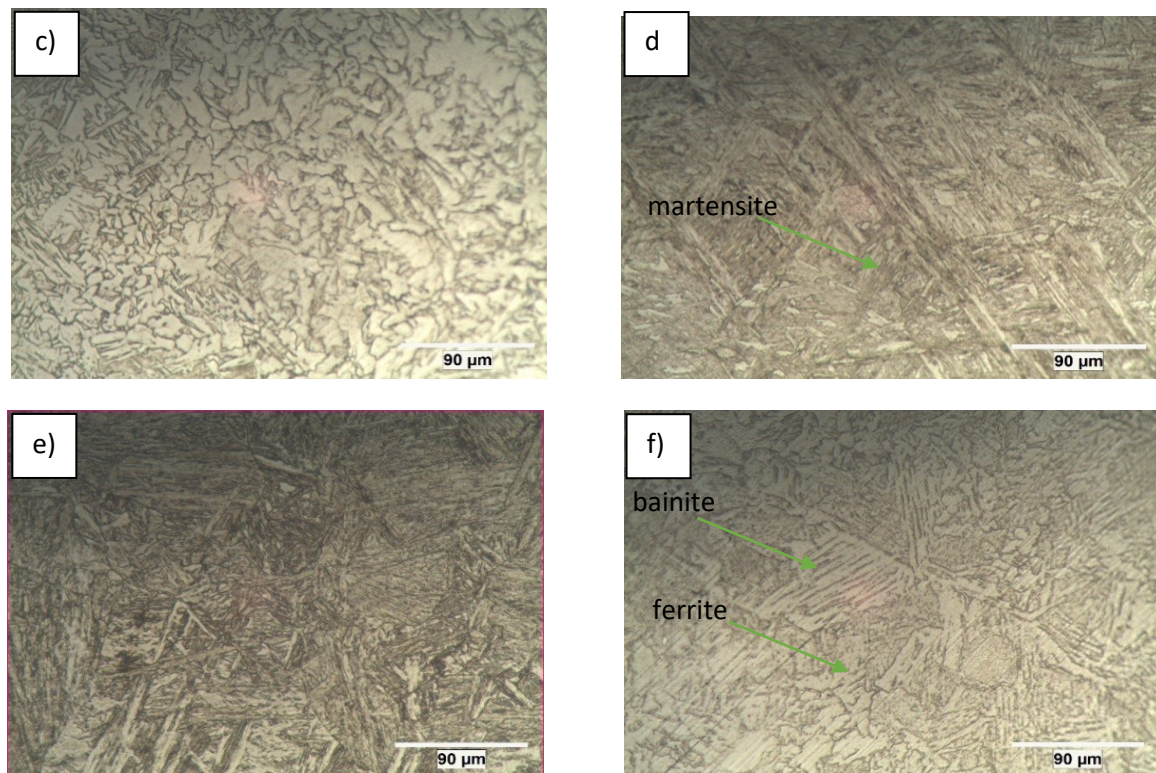


**Figure 2.** Hardness Rockwell test result

In Figure 1 and 2 showed that the effect of heat treatment on material variations with abrasive resistance values and hardness properties. It can be seen in Figure 1 and 2 on the graph that weight loss and hardness on surface area shown in the untreated 1Cr1Mo sample was  $0.06\text{g}/\text{cm}^2$ ; 40.32 HRC, then at the oil quench the abrasion resistance oil increased by  $0.16\text{g}/\text{cm}^2$ ; 43.60 HRC and when at quench-temper the abrasion resistance was stable at  $0.10\text{ g}/\text{cm}^2$ ; 41.86 HRC respectively.

Abrasive resistance is strongly dependent on the value of hardness where the higher hardness value also the good abrasive resistance value. But the graph above where different abrasive resistance values are due to the influence of the value of hardness and microstructure formed during the heat treatment process in variety of material[7][8].





**Figure 3.** The microstructure of lateritic alloy steel a) as-cast no treat b) 1Cr1Mo no treat c) as-cast quench oil d) 1Cr1Mo quench oil e) as-cast quench-temper f) 1Cr1Mo quench-temper

Figure 3 show the microstructure of 1Cr1Mo material obtained from heating at a temperature of 950°C and cooling using oil media showed that the microstructure were increasingly flat and the phase transformed into martensite with visible residual austenite. The martensite phase will made the sample stronger and harder but tend to be brittle. The microstructure of sample which heated at 950°C follow with quench temper showed quench tempering after heat treatment the formation of tempered martensite phase, bainite and ferrite phase with the success of eliminating retained austenite. This increasingly tenacious microstructure supported by the presence of Cr-Mo alloys[9], [10] .

#### 4. Conclusions

1Cr1Mo treated laterite steel has the good characteristics compared as-cast or non-treatment, the highest hardness properties in this study had 1Cr1Mo material with quenching oil treatment produces hardness of 43.60 HRC and has a wear resistance of 0.16 g/cm<sup>2</sup> significantly. It can be projected that Ni-Cr-Mo alloy cast steel can be applied for the development of bucket teeth material which refers to AISI 4140 specifications with 40 HRC hardness. In metallographic testing, the grain boundaries are increasingly flat and the phase is transformed into martensite-tempered and with a pearlite phase.

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