

# **Analysis of quenching heat treatment, martemper on structure micro and hardness in SCMn<sub>3</sub> steel.**

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**Abstract.** Microstructure analysis and hardness analysis has been carried out on cast steel for components of soil digging machines due to heat treatment of quench, and martemper. The presence of residual austenite causes wear resistance and reduced fracture strength in the earth quarry component to function as a support for the designed arm. In its manufacture, it uses metal casting technology and heat quenching treatments and templates in suitable cooling media, to meet standard requirements. The temperature treatment of austenite 875 ° C temperature was held for 90 minutes, and then quenched with variations in the cooling media of water, oil, and salt bath. Furthermore, the martemper process at 425 ° C for 90 minutes is cooled to air to room temperature. Microstructure testing and weight percent composition using SEM-EDX and Brihnell scale hardness test. The analysis shows that the hardness value (388 HB) of cast steel quenched in salt bath media is greater than ordinary water (299 HB) and oil (260 HB). However, after the martemper process the value of hardness drops to (342 HB) in the salt water medium, which remains larger than ordinary water (264 HB) and oil (233 HB). This is due to the faster cooling speed in brine and produces martensitic microstructure and residual austenite after being observed with SEM-EDX. The results of this study meet the quality requirements according to the JIS G5111 standard where the minimum hardness value is 222 HB, to be used as a component in excavator.

## **1. Introduction**

Medium carbon steel has carbon content (0.30 - 0.60) % C, has a greater hardness and tensile strength than low carbon steel, but the total strain possessed is lower. Because of these properties, medium carbon steel is very suitable for use as a component of motorized vehicles, heavy equipment, agricultural equipment, gear and other components that require high strength, durability and hardness but are not easily broken. [1]

SCMn<sub>3</sub> cast steel is steel that has a production process by means of casting which is the way of producing objects that are directly obtained through the pouring process in the mold. This process is based on the reason for producing objects that have a special shape that is difficult to do with the process of heat or cold (forging and so on). In addition, the casting work is also carried out for large sizes. Strength and plasticity will be the same in all directions compared to forged steel which has unequal strength in different directions because it has a multilayered structure. [1, 2]

The balance diagram of the iron-iron carbide ( $\text{Fe}_3\text{C}$ ) phase can be seen in Figure 1. This diagram results in a slow cooling process. Steel and cast iron are mostly in the form of iron alloys with carbon, where the carbon is an interstitial compound (cementite /  $\text{Fe}_3\text{C}$ ).

Sementit is a metastable metal structure. In addition to the carbon elements in iron and steel there are approximately 0.25% Si, 0.3-1.5% Mn and other impurities such as P, S, and others. Because these elements do not provide a major influence on the phase diagram, the phase diagram can still be used regardless of the existence of these elements. Through the equilibrium diagram of Fe- $\text{Fe}_3\text{C}$  in general the steel can also be grouped as follows:

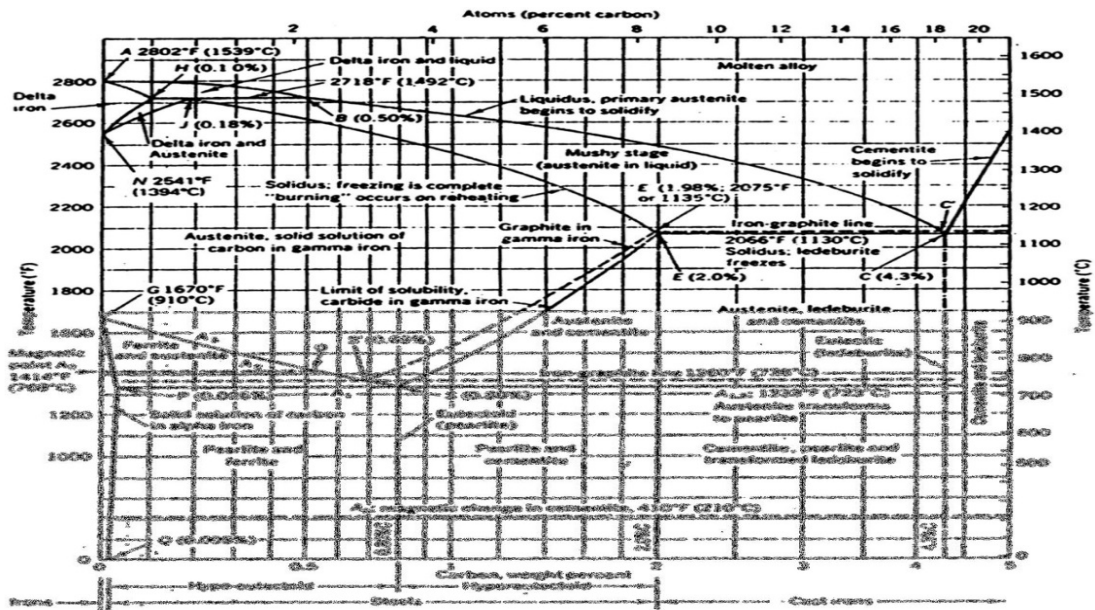


Figure 1. Diagram of phase iron (Fe) –  $\text{Fe}_3\text{C}$ . [2]

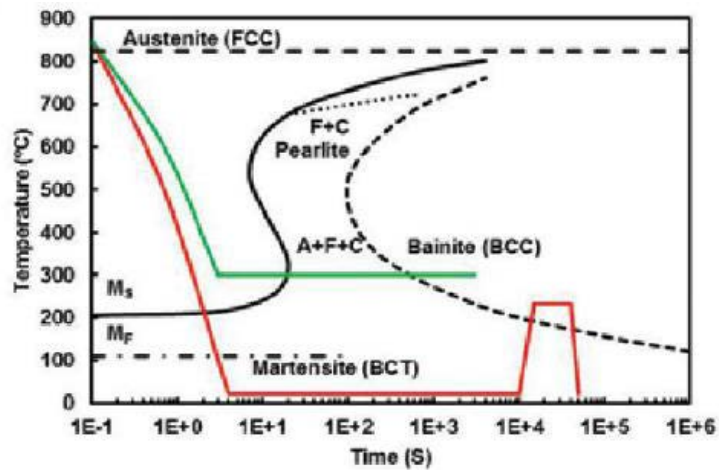


Figure 2. Schem of TT diagram describing the process austempering, quenching and martempering. [2]

Heat treatment process can change the nature of iron or steel from easily broken to stronger or can also change the nature of steel from soft to very hard and so on. In addition, it is also a combination of heating and cooling of metals or alloys in a solid state for a certain period of time intended to obtain certain properties in metals or alloys.

Austempering can be applied to several classes of high strength steel which must have certain toughness and tenacity. Components that undergo this process will have higher toughness, better impact strength, fatigue limit and tenacity increase compared to the same hardness resulting from conventional quench processes.

Austempering is done by quenching the steel from its austenizing temperature into molten salt, the temperature of which is slightly above the  $M_s$  temperature. The length of the barrier in the liquid salt is so that all austenite transforms into bainite. After that the steel is cooled in the air to room temperature as shown in Figure 2 above, with the holding time varying from 5 to 30 minutes or 1 hour at austempering temperature 250-270°C. but the appropriate treatment temperature and length of holding must be determined from the transformation diagram corresponding to the steel to be austempered. The hardness of bainite obtained from transformation in certain conditions is roughly identical to the hardness of martensite which is tempered at the same temperature. Bainite hardness is influenced by the chemical composition of steel and by the temperature of the salt fluid, so the austemper process can be adjusted by adjusting the temperature of the austemper 250-270°C. But the appropriate treatment temperature and length of holding must be determined from the transformation diagram corresponding to the steel to be austempered. The hardness of bainite obtained from transformation in certain conditions is roughly identical to the hardness of martensite which is tempered at the same temperature. Bainite hardness is influenced by the chemical composition of steel and by the temperature of the salt fluid, so the austemper process can be adjusted by adjusting the temperature of the austemper.

The formation of these traits is very necessary to obtain industrial materials that are truly in accordance with their needs and functions. After heat treatment on the austenite phase then quenching cooling in salt water media can increase the hardness value of medium carbon steel, but the weakness is very brittle. Through the martempering process, the hardness and brittleness values can be reduced to meet the usage requirements. In cast steel the hardness value decreases, the tensile strength will decrease as well, but the ductility and toughness of the cast steel increases. Based on the above background, the writer needs to conduct a research study on the effect of quenching cooling media variations before the heat treatment of martempering on medium carbon steel from the casting product, to determine the effect that occurs so that the results can be made possible in more optimal use in some applications in manufacturing.

## **2. Research Method**

### **Procedure**

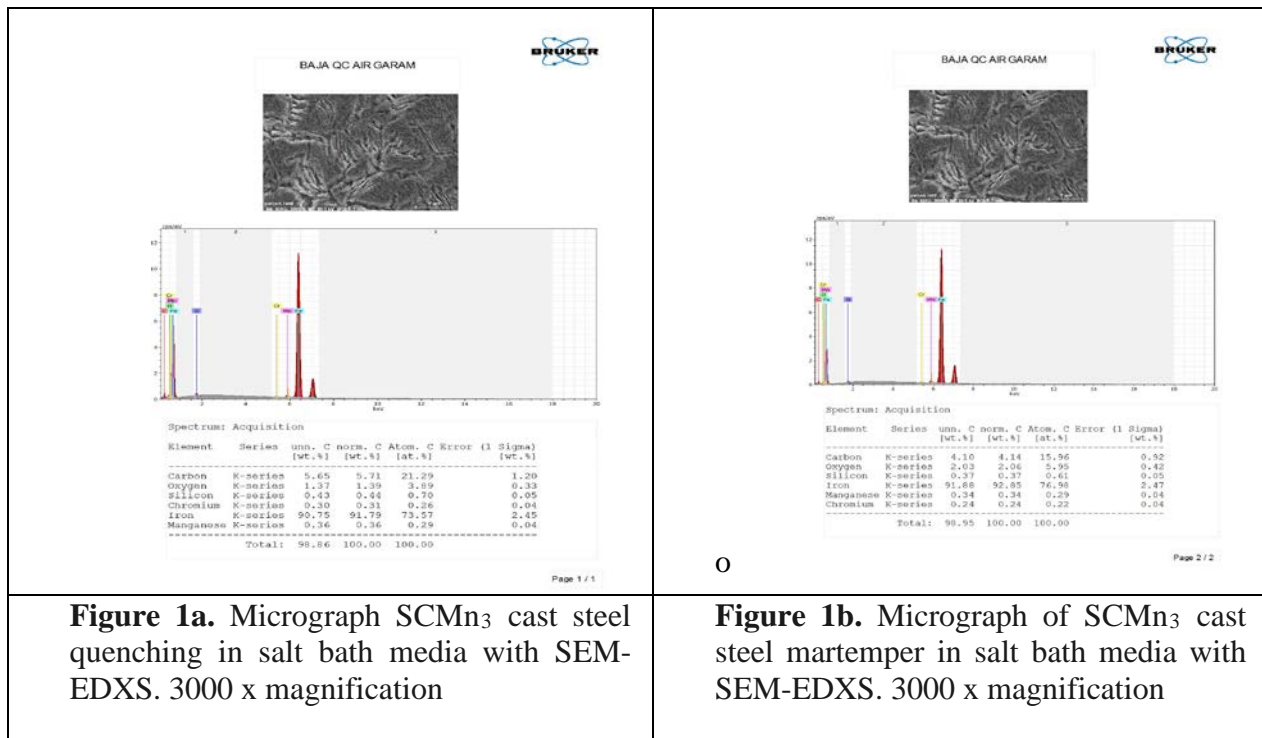
The commercial material used in this study is SCMn<sub>3</sub> Cast steel from a company in Jakarta. The SCMn<sub>3</sub> cast steel material is cut into a laboratory scale into 21 parts with a size of 2 cm x 2 cm x 0.5 cm and complete metallographic material. Original footage is separated as a reference for comparison of samples given austenite heat (Temperature 875°C) held for 90 minutes, followed by rapid dipping (quenching) of salt water, oil and water media. Martemper heating (Temperature 425°C, for 90 minutes) and cooled to room temperature. Then these specimens

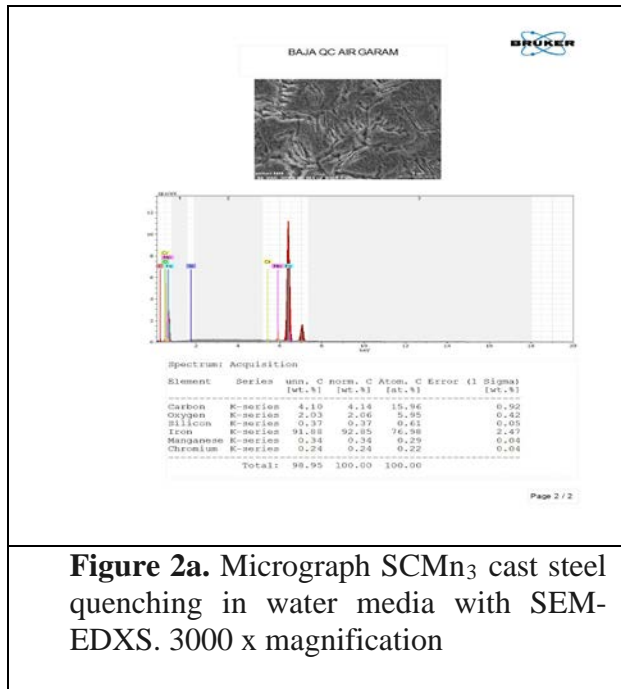
were characterized by Brihnell scale hardness, and microstructural observations and semi-quantitative chemical composition using SEM-EDXS (Scanning Electron Microscope-Energy Dispersive X-ray Spectroscopy)). Before testing all samples were carried out metallography (cutting, grinding, polishing, starting from sandpaper to alumina liquid, and etching).

### 3. Result and Discussion

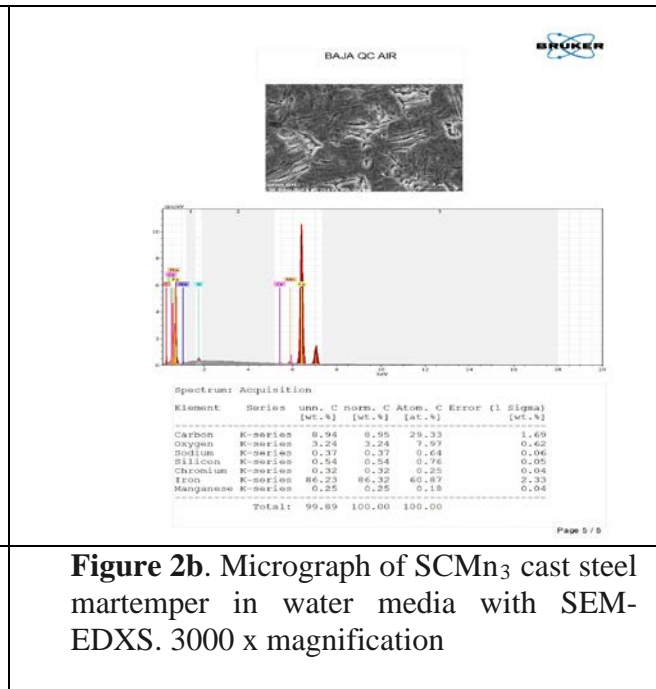
The results of testing the chemical composition of SCMn<sub>3</sub> cast steel materials with Optical Emission Spectrometers contained the following elements: C (0.37% by weight), Mn (2.65% by weight) Si (0.16% by weight), P (0.016% by weight), and Fe (balance).

#### a. Analysis of Microstructure

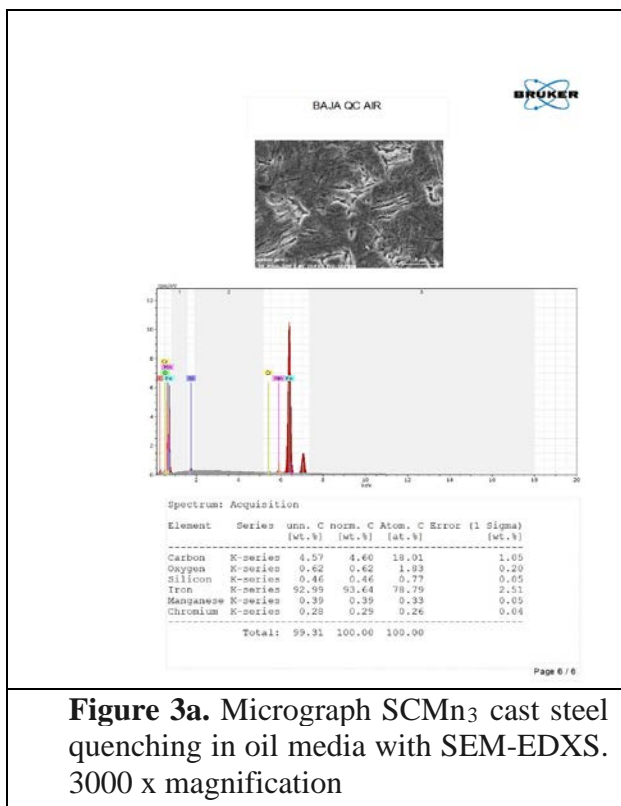




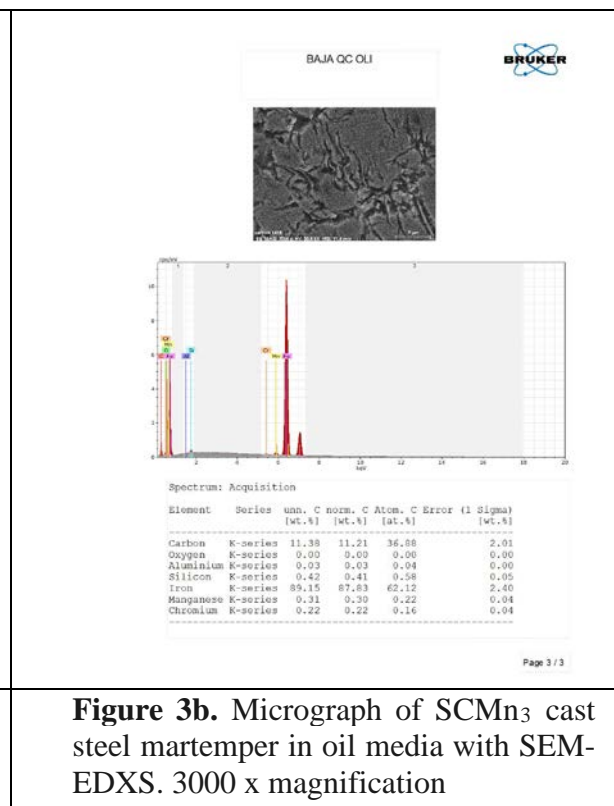
**Figure 2a.** Micrograph SCMn<sub>3</sub> cast steel quenching in water media with SEM-EDXS. 3000 x magnification



**Figure 2b.** Micrograph of SCMn<sub>3</sub> cast steel martemper in water media with SEM-EDXS. 3000 x magnification



**Figure 3a.** Micrograph SCMn<sub>3</sub> cast steel quenching in oil media with SEM-EDXS. 3000 x magnification



**Figure 3b.** Micrograph of SCMn<sub>3</sub> cast steel martemper in oil media with SEM-EDXS. 3000 x magnification

Figures 1a, 2a, and 3a show micrographs of  $\text{SCMn}_3$  cast steel after quenching in the form of salt water, oil and water prepared to study micro changes. From figure 1a, it shows the microstructure of quench specimens of salt water media, which consists of longitudinal black blades with good distribution. These black blades are interpreted as the presence of martensite in the structure and residual austenite. And in Figure 1b, the micrograph of the martempered sample structure looks the same as the results after quench. When compared with figures 2b, and 3b, it is seen that the number of martensite phases is less, which changes only by the percent weight quantity of the chemical elements in  $\text{SCMn}_3$  cast steel. By observing the surface morphology, micro hardness tester, and crystalline structure to determine its microstructural changes. The results showed that the lowest amount of residual austenite in the microstructure was obtained in specimens cooled by oil media after quench (hardness 260 HB) and martemper (hardness 233 HB). Because the transformation of austenite into martensite during the process results in a change in volume in austenite which results in the formation of residual stress at the austenite-martensite boundary, such defects (grain boundaries) where appropriate for crack nucleation occur and hence, reduce the durability of  $\text{SCMn}_3$  cast steel specimens. In addition, the increase in areas close to grain boundaries and enter dendritic contains more alloying elements caused by micro separation

#### b. Analysis of Hardness

The results of the Brinell scale hardness test from medium carbon steel cast material are then seen in Table 1 below,

**Table 1.**Data of result hardness scale of Brinell Investigation

Brinell (HBN)		Condition of Heat Treatment		
Standar JIS G5111	Media of quench	Austenite	Quenching	Martemper
Queching 875°C, Martemper 425°C hold time 90 min,	Water	213	299	264
	Oil	213	260	233
	Salt bath	213	388	342

Table 1 shows that there are differences in the value of hardness resulting from differences in cooling media after quenching.  $\text{SCMn}_3$  cast steel samples hardness value of austenite 213 HB condition, after quenching in salt water media the hardness value of 388 HB increased by 82%. This is because the residual martensite and austenite phases are formed and residual stress occurs, also due to the changing shape of the crystal structure from the body center cubic (BCC) to the tetragonal (BCT) body center. After the martemper process temperature of 425°C, the hardness value is reduced by 11% (342 HB), according to the previous researchers' opinion that due to the quenching process on carbon steel the hardness value increases, but the weakness is brittle, to reduce the hardness and increase the ductile treatment tempering heat. From table 1, it shows that the highest salt water cooling media is compared to oil and water media. This concludes that the use of salt water (NaCl) can accelerate the rate of copying so that the more formed martensite microstructure and affect the hardness of the  $\text{SCMn}_3$  cast steel.

#### 4. Conclusion

The results of research and analysis can be summarized as follows:

1. The martemper process on SCMn<sub>3</sub> cast steel can reduce the hardness value and on hard brine media (371 HB) greater than ordinary water (264 HB) and oil (233 HB).
2. The results of the microstructure observations show the formation of the martensite phase and residual austenite which is reduced after the martemper process. This is indicated by a value hardness decreased.

### References

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