

The heat treatment of austenisation analysis of medium carbon steel to the hardness, microstructure, and tensile strength

Budiarto^{1,*}, Dikki A.H.¹, Adiman², Ochrandhy Danang Fajar²

¹Department of Mechanical Engineering, Faculty of Engineering, Indonesian Christian University Jl. Mayjen Sutoyo no.2 Cawang Jakarta Timur 13630

²Department of Mechanical Engineering High School of Bina Tunggal Technology Jl. Wahab Affan Medan Satria Bekasi West Java

*budidamaz@gmail.com

Abstract. The research has been carried out on the effect of austenization process on hardness, microstructure, and tensile strength on carbon steel while SAE 1050 and SAE 1552. The aim of the study was to determine the tensile strength and hardness due to austenization process on motor chain components from medium carbon steel SAE 1050 and SAE 1552. The process of austenizing heat treatment at a temperature of 850°C and held for 40 minutes, then quenched into a temperature of 600°C oil medium, then tempered at a temperature of 260°C for 60 minutes. The results of the hardness test showed that carbon steel was SAE 1552 experiencing an increase in hardness of 4.25% compared to SAE 1050. The results of SAE 1552 medium carbon steel tensile strength test were 1781.04 N / mm² and SAE 1050 1711.43 N / mm², tensile test results SAE 1552 material is higher than SAE 1050. The results of microstructural observations show the formation of the martensite phase and the remaining austenite phase.

1. Introduction

Indonesia is the largest motorcycle market in Asia, but Indonesia has not been able to produce motorcycles with its own brand, so many motor manufacturers from other countries such as China, Japan and Italy throw their production into Indonesia. The motorcycle market in Indonesia in 2016 is expected to continue to grow as the population increases and the welfare of the community increases. National motorcycle production in 2017 is predicted to reach 12 million units or increase from last year's only 10 million units. As the largest motorcycle market in Asia, the increase in motorcycle consumption will certainly have an impact on the increasing demand for motorcycle components. One component of the motorcycle is a chain. The chain material uses SAE 1050 and SAE 1552 alloy steel, which is this type of steel; hard, resilient, high corrosion resistance and has the ability to harden. Because SAE 1050 and SAE 1552 alloy steels have the ability to be hardened, this type of steel is often applied to the manufacture of products with heat threatening processes, which will later get products that have hard mechanical properties on the surface (tough, friction resistant, wear resistant) but soft (ductile / not easily broken) inside. Heat treatment has the aim of increasing ductility, eliminating internal stress, smoothing crystal grain size and increasing metal hardness or tensile stress. Some factors that can affect heat treatment, namely heating temperature, time required at heating temperature, cooling rate and atmospheric environment. Heat treatment is a combination between the heating or cooling process of a metal or its alloy in a solid state to get certain traits. To get this, the cooling speed and temperature limit are very decisive. [3]

Some of the goals of heat treatment include [3]: Increase tenacity; eliminating internal stress; Refinement of grain size; Increases hardness or tensile strength and achieves changes in the chemical composition of metal surfaces as in hardening cases. The advantages of heat treatment include: Increasing machine ability, changing magnetic properties, modifying electrical conductivity; Increased toughness and developed a recrystallization structure in cold-worked metal. Factors or variables that can affect the heat treatment process include: Temperature heat treatment; Holding time; Heating rate; quenching process. Some examples of heat treatment processes are:

a. Hardening

Hardening is the process of heating metals until temperatures above the critical point (the austenite region), are held for a moment according to the resistance time needed so that all work pieces have austenitic structure and then cooled down suddenly. The purpose of this process is to obtain a martensitic crystal structure. Martensite is a structure that steel must possess in order to obtain a very large increase in violence. Martensite has a needle structure because the atomic network is tetragonal.

b. Quenching

Quenching is a process of steel hardening by means of steel being heated to reach the austenite limit and then followed by a process of rapid cooling through water, oil, or salt water cooling media, so that the independent phase is transformed partially to form a martensitic structure. The main purpose of this quenching process is to produce steel with high hardness properties.

c. Tempering

Tempering is the process of reheating a metal that has been hardened through a quenching process at a temperature below its critical temperature for a certain amount of time and slowly cooled down. The purpose of this process is to reduce internal stress, change the arrangement, reduce hardness and increase metal tenacity so that the right combination of hardness and tenacity of the test metal is obtained.

d. Full annealing

It is the process of heating steel to a certain temperature then it is cooled slowly through its transformation temperature in the furnace. The purpose of this process is to smooth the grain, soften, to improve the magnetic properties and electrical properties.

e. Spheroidizing

It is a process of heating steel slightly below the lower critical temperature so as to produce small spherical carbides (spheres) in matrix ferrite. The purpose of this process is to improve the machinability of steel.

f. Stress-relief annealing

It is the process of heating steel under its critical temperature around 1000°F - 1200 °F. The purpose of this process is to reduce the residual stress due to cold working.

g. Normalizing

It is a heating process of 100 °F above the critical temperature above about a temperature of 1000 °F - 1250 °F. The purpose of this process is to produce stronger and harder steel compared to the full annealing process steel, so the application of the normalizing process is used as a final treatment.

Austenitic low carbon steel is a material that is widely used in industry, because it has corrosion resistance, plastic properties and good mechanics. This type of steel is mass produced. Structurally this steel can be divided into stable austenitic structures, steel

having an instable austenitic structure (capable of transforming to the martensitic phase during plastic deformation) and austenitic- ferritic mixed steel structures. [1-3]

One such effort is to innovate to determine the material to be used in the product in the hardening method carried out through the transition of conventional heat treatment methods in the form of normal hardening. The reason for the transition of SAE 1050 material to SAE 1552 is because this material has several advantages in mechanical properties, namely hardness and tensile strength compared to SAE 1050 material because it has higher manganese content.

2. Research Method

The materials used are carbon steel being formed through a cold forming process from sheets with dimensions of 1mm thickness, 23mm length, and 10mm width for medium carbon steel SAE 1050 and SAE 1552, and materials for complete metallography and 2-3% Christmas etching solutions.

Equipment used: Mesh Belt Furnace, Rockwell method hardness test ASTM E 18 standard, Tensile strength test equipment with standard JIS Z 2201; 1998, and the optical microscope tool method ASM handbook Vol. 9

Procedure

In the process of normal hardening or austenization, samples with the number of SAE 1050 specimens (1 fruit and SAE 1552 (15 pieces) are carried out on the surface coating process which occurs due to loss of carbon atoms due to the atmosphere containing a lot of O₂, so that carbon atoms react with the environment at austenization, forming CO₂ which causes many C atoms to leave the surface of the sample The material then undergoes austenization treatment at a temperature of 850⁰C for 40 minutes in the Mesh Belt Furnace, then quenched into oil media temperature 60⁰C, then tempered (260⁰C) for 60 minute.

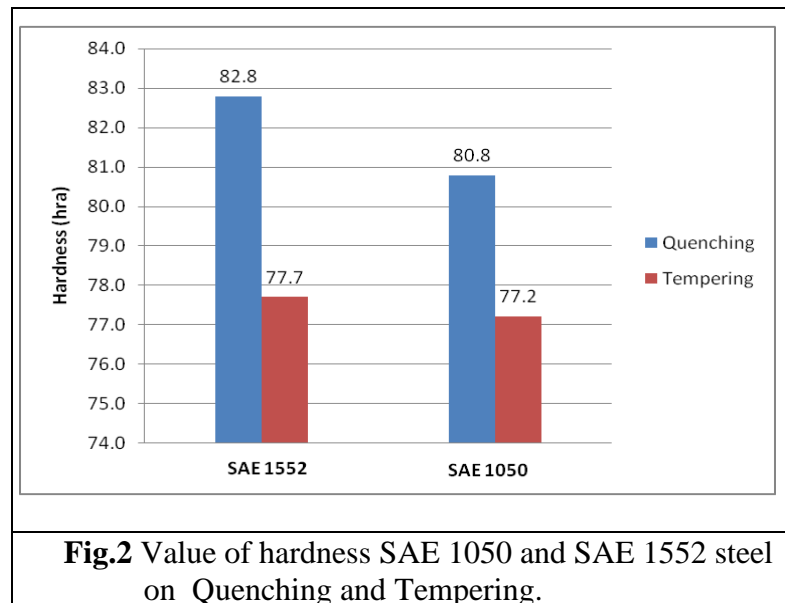
3. Results and Discussion

The results of measuring the composition of elements in both carbon steel samples are SAE 1050 and SAE 1552 can be seen in Table 1 below.

Table 1. Data from measurements of chemical element composition from Carbon Steel is SAE 1050 and SAE 1552

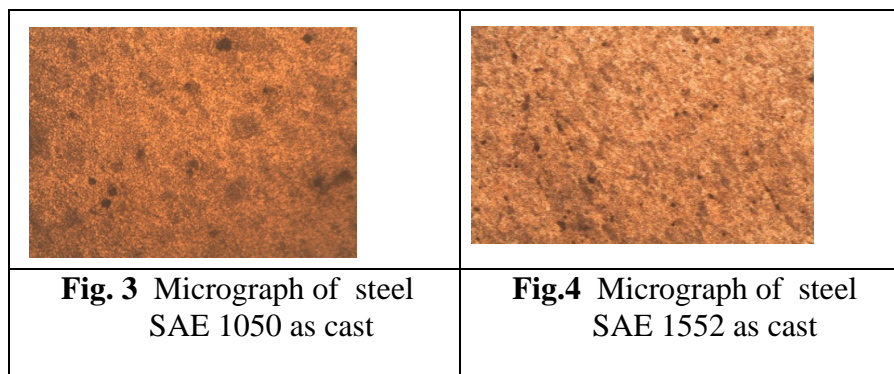
No	Element	1050 (%)	AISI 1050 (%)	1552 (%)	AISI 1552 (%)
1	C	0,47	0,48-0,55	0,50	0,47-0,55
2	Mn	0,78	0,6-0,9	1,43	1,2-1,5
3	Cr	0,15	Max 0,2	0,10	Max 0,2
4	Mo	<0,002	-	<0,002	-
5	Si	0,004	0,15-0,35	0,003	0,15-0,35
6	Al	0,02	-	0,02	-
7	Fe	98,3	96-99	97,6	96-99
8	S	0,002	Max 0,035	0,005	0,05
9	Cu	0,008	Max 0,3	0,008	0,02
10	Ni	0,007	Max 0,2	0,003	0,01

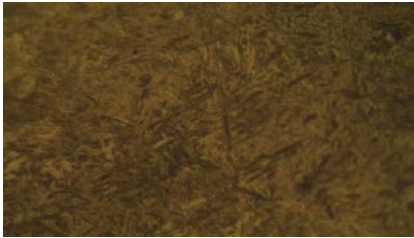

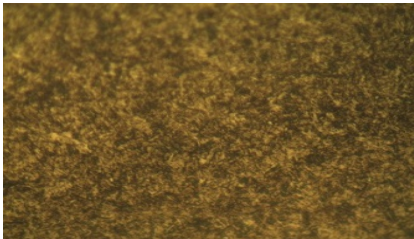

a. Analysis of Hardness



The hardness value achieved by SAE 1552 (82.8 HRA) steel material is higher when compared to the hardness value of SAE 1050 (80.8 HRA) steel material with the difference in the average value of both 2 HRA, this is due to the value of the manganese content lies in SAE 1552 steel material 0.75% higher than SAE 1050 steel material because MnS compounds are formed. In addition, the martensite phase has formed with the shape of the Tetragonal Body Center crystal structure (BCT) and residual stress occurs. After the tempering process the hardness test results decreased to 77.2 HRA in both SAE 1050 steel and SAE 1552 steel.

b. Analysis of Microstructure



	
Fig.5 Micrograph of steel SAE 1050 after quenching	Fig. 6 Micrograph of steel SAE 1552 after quenching
	
Fig.7 Micrograph of steel SAE 1050 after tempering	Fig. 8 Micrograph of steel SAE 1552 after tempering

In figure 3 and 4, the microstructure shown in the raw material sample between SAE 1552 steel and SAE 1050 steel before the heat treatment both have the same phase, namely Ferrite phase and pearlite phase. Figure 5-8, microstructure was shown in conventional quench samples using and 2-3% etching. The material has undergone a quench heat treatment process from austenization time of 40 minutes and a temperature of 850⁰C with cooling media in the form of oil at 60⁰C. It is seen that the micro structure in the form of austenite phase is bluish white (bright) and scattered and the martensite phase. The phase is residual austenite which gives the effect of increasing the value of hardness in the sample. In addition there are carbide deposits in the form of small black particles in the form of cementite and MnS inclusions. This martensite structure before temper looks very rough and firm. This indicates that very high violence reached 82.8 HRA. Figure 8 is a surface microstructure of SAE 1552 steel material which is isotropic resulting from homogenization and quenched to room temperature, taken by optical microscope. The phase α -Fe derived from γ -Fe metastable still contributes to the minor phase of the material and is localized at the grain boundary. Black coagulation or lumps scattered throughout the surface of the material is Fe₃C phase which is formed from the saturation of the solid reaction process (solid state reaction). After the tempering process of the micro structure can be seen in Figure 7 and 8. The appearance of a very fine grain structure as a matrix with deposits in the form of black particles scattered among them. When martensite is tempered at 260⁰C, martensite will become invisible and will be replaced by a structure consisting of ferrite and very fine dispersed cementite. This structure does not contain pearlite at all and is called tempering martensite. There are also structures such as white dots which are residual austenites.

c. Analysis of Tensile Strength

The tensile test results of specimens taken after the normal hardening and tempering process are as follows. Tensile Testing uses the standard JIS Z 2201; 2010, the test results data are seen in the Graph below.

Based on the results of the raw material tensile test conducted by the author at PT Astra Otoparts - EDC, data obtained for the average ultimate stress material of SAE 1552 is 877 Mpa and for SAE 1050 the ultimate stress value is 876 Mpa. Both materials have the ultimate stress value which is almost the same because the material has not passed the Heat Treatment process so that the ultimate stress value is the same.

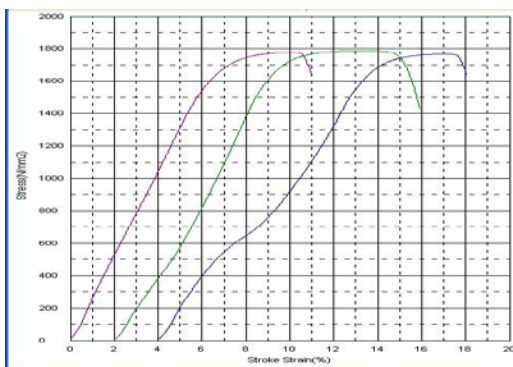


Fig. 9 Graphic of the test results data of tensile of SAE 1050 steel.

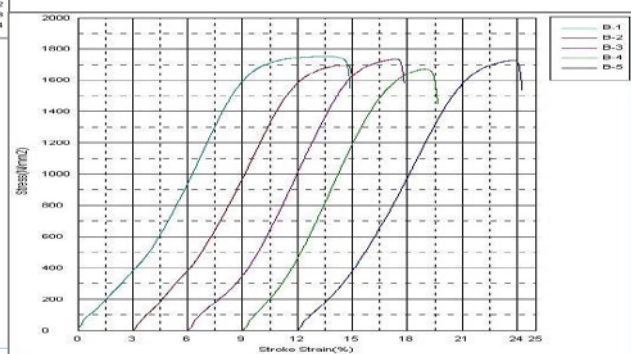


Fig. 10 Graphic of the test results data of tensile of SAE 1552 steel.

Next, the writer presents a graph of the tensile test of raw material SAE 1552 with SAE 1050. From graph 4.11 above, it can be seen that SAE 1552 carbon steel material is better than SAE 1050 material. It can be seen from the breaking value of SAE 1552 at 670 Kgf, while SAE 1050 material only reaches a breaking load of 555 Kgf.

4. Conclusion

Based on the testing conducted by the author, the conclusion of this final assignment is:

1. The average hardness of SAE 1552 material after the hardening process is 77.7 HRA higher than SAE 1050 whose hardness value only reaches 77.2 HRA.
2. Microstructure analysis shows that the grain structure of SAE 1552 material is better than SAE 1050 material grain because the grain in SAE 1552 material is finer which influences the toughness of a material.
3. From the results of the tensile test conducted by testers using specimens, the SAE1552 material tensile test values were 1781.04 N / mm² and SAE 1050 1711.43 N / mm², the value of the SAE 1552 tensile test results was higher than SAE 1050.

References

- [1]. ASM Metals Handbook, Vol 04 *Heat Treating*. ASM International ; USA, 1991 p.p 295
- [2]. <http://www.process-heating.com/articles/84799-tips-hot-oil-systems>.
- [3]. Callister, W.D, Materials Science and Engineering an Introduction 7ed – hal 355, 358

- [4]. <http://blog.ub.ac.id/okkyardiansyah/2012/03/20/heat-treatment/>
- [5]. <http://www.alatuji.com/article/detail/3/what-is-hardness-test-uji-kekerasan-#.WBJvBV7Y200>
- [6]. <http://www.infometrik.com/2009/09/mengenal-uji-tarik-dan-sifat-sifat-mekanik-logam/>
- [7]. JIS HANDBOOK Ferrous Material & Metallurgy I; 2010 hal 496
- [8]. Anonymous, (2014). *Iron-Carbon Phase Diagram* (a review), see Callister Chapter 9, MSE 300 Materials Laboratory Procedures, University of Tennessee, Dept. of Materials Science and Engineering, pp. 1-34. Retrieved 11 February 2014.