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Mechanical Properties Analysis of Medium Carbon Steel Heated at 850°C by Quenching in NaOH Solution

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Abstract. The aim of this study is to analyze the mechanical properties of carbon steel medium by quenching in NaOH solution. Heating medium of the carbon steel in a heating furnace is 850°C. The cooling process in NaOH solution was varied in concentration of NaOH (5%, 10%, 15%, 20%, 25%), and the sample was allowed to reach room temperature (27°C). The original medium carbon steel hardness value is 9.4 HRC and the tensile strength value is 656.85 MPa, while for materials with heat treatment processes and cooling processes with different concentrations of NaOH (5%, 10%, 15%, 20%, 25%) resulted in hardness values of 57 HRC, 58.3 HRC, 58.5 HRC, 60 HRC, 57.5 HRC and tensile strength values of 728.50 MPa, 835.99 MPa, 987.26 MPa, 1035 MPa, and 855 MPa for different concentrations of NaOH (5%, 10%, 15%, 20% , 25 %). Analysis of XRD crystalline structure on medium carbon steel with intermediate carbon steel from the three highest peaks of each test sample was found that its orthorhombic crystal structure in which lattice parameters *a*, *b*, and *c*.

Keyword: medium carbon steel, quenching, mechanical properties, crystal structure.

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1 Introduction

The need for metal materials in the manufacture of tools and means of life is increasing. Starting from the simplest equipment to the most complex equipment, such as household furniture, bridges, buildings, vehicles, and aircraft construction. In increasing the hardness of these materials can be done with a heat treatment process. Heat treatment is a process that heats a metal in a solid state to a certain temperature and then cools it to give the metal more perfect physical or mechanical properties. By means of heat treatment, it is also possible to change the size and shape of the metal grains [1-3]. Hardness can be defined as resistance to penetration or the ability of a material to withstand scratching, indentation or penetration. The hardness value is related to the tensile or yield strength of the metal because during the assessment, the metal undergoes plastic deformation so that a certain percentage of strain occurs. Hardness is also related to the wear resistance of the metal [4-6]. After paying attention to the results and

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conclusions of the studies above, the authors are interested in conducting research about mechanical properties analysis of 850°C heated medium carbon steel with quenching in NaOH solution.

2 Methods

The tools used and the materials used in this study are as follows: Tensile testing machine: strength testing machine (STM), Hardness testing machine: Rockwell Hardness Optical microscope Furnace heating capacity 1200°C, Lathe and XRD, with ingredients NaOH solution: concentration 5%, 10%, 15%, 20%, 25% and Medium carbon steel: 1045. Provide 12 pieces of test material with details: 6 pieces for hardness testing, 6 pieces for tensile testing, while for testing the microstructure taken from hardness testing materials.

3 Result and Discussion

Testing of the mechanical properties of several test materials has been carried out by varying the concentration of NaOH for medium carbon steel. The results of the tests that have been carried out are hardness (hardness), tensile strength (tensile strength), observation of microstructure and observation of crystal structure with various concentrations of NaOH as a cooling medium for medium carbon steel [7-10]. The data obtained from the test results are obtained by calculations and the results are listed in the following table:

Table 1. Test results for medium carbon steel tensile strength with $d = 8$ mm, $l_0 = 8$ mm, $A = 50.24\ \text{mm}^2$

No	Quencing on Solution NaOH (%)	Maximum Load (N)	Tensile Strength (MPa)
1	0	33,000	656.85
2	5	36,600	728.50
3	10	42,000	835.99
4	15	49,600	978.26
5	20	52,000	1035.03
6	25	43,000	855.89

The hardness value of the test material from the measurement results can be seen in table 1, where the hardness value can be seen on the hardness tester which directly measures the hardness of the test material based on the measured depth. The test results data below are tested once for each test material. Below we can see the relationship between NaOH concentration and hardness of medium carbon steel, as shown in the graph.

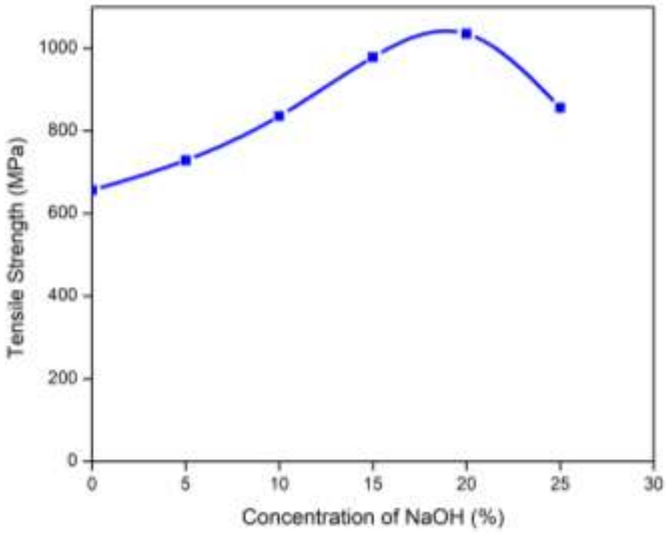

Figure 1. Graph of the relationship between NaOH concentration and tensile strength of steel medium carbon

From the graph above, it can be seen that the increase in the tensile strength value of medium carbon steel after heat treatment and cooling with NaOH solution. The value of tensile strength continues to increase from the smallest concentration and maximum value at a concentration of 20%, but at a concentration of 25% the tensile strength value decreases.

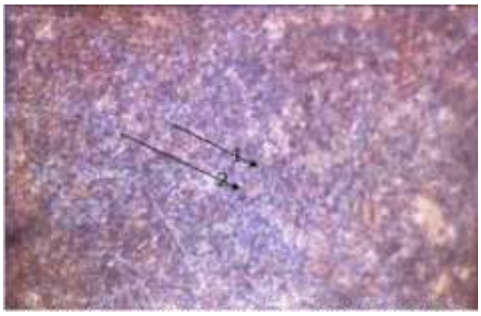

Figure 2. Microstructure of medium carbon steel without heat treatment process, 500x magnification

The microstructure above shows the structure of ferrite and pearlite, where at Number 1 is Ferrite and Number 2 is Pearlite which is coarse in shape and large in size, where the hardness and tensile strength are low.

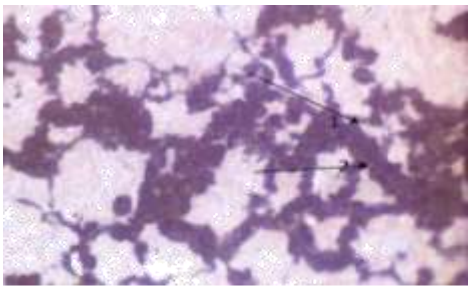

Figure 3. Microstructure of medium carbon steel after heat treatment process 850°C with quenching NaOH 20%, magnification 500x

The microstructure above is Martesite and Pearlite, where at No. 1 is pearlite in the form of a dark line which is less in number than the 15% NaOH. The structure of ferrite and pearlite is seen in medium carbon steel without heat treatment process with coarse grain structure and large size [11]. This shows that the hardness and tensile strength are low, while the pearlite and martensitic structures are seen in medium carbon steel which is heat treated and cooled into NaOH solution at concentrations of 5%, 10%, 15% with a fine grain structure and small size which showed that the hardness and tensile strength increased. And finer grain structure and smaller size seen on cooling into NaOH solution with a concentration of 20% which indicates that the value of hardness and tensile strength is greater. While the value of hardness and tensile strength decreased on cooling into a NaOH solution with a concentration of 25%. The data below is the result of XRD testing on medium carbon steel, where the test sample is without treatment (original), and the addition of NaOH concentrations of 5%, 10%, 15%, 20%, and 25%. Below is a graph of the results of X-Ray Diffraction.

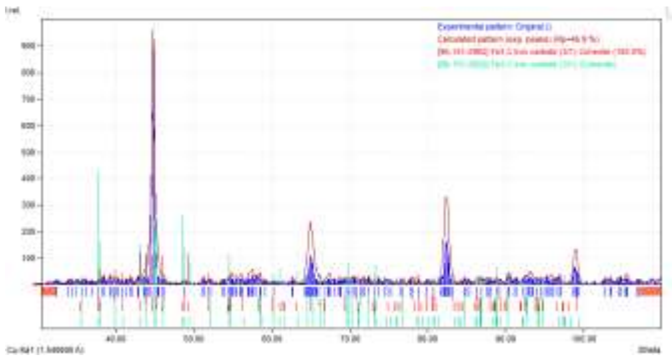

Figure 4. Diffraction pattern of medium carbon steel (Fe3C) with $T = 850°\text{C}$ original

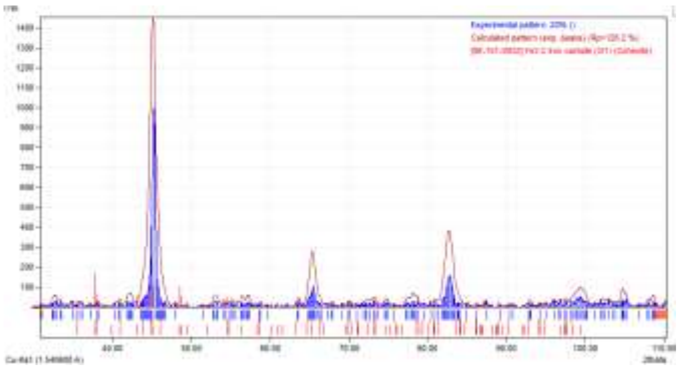

Figure 5. Diffraction of medium carbon steel (Fe3C) with T= 8500C, Quenching 20% NaOH

In the Original medium carbon steel of the three highest peaks, it was found that the crystal structure was orthrocombic where the lattice parameters $a = 4.5130$ Å, $b = 5.0480$ Å, and $c = 6.7310$ Å and density is $7.77700\ \text{g/cm}^3$. In medium Carbon Steel with 5% NaOH where from the three highest peaks it was found that the crystal structure is orthrocombic where the lattice parameters $a = 4.5170$ Å, $b = 5.0700$ Å, and $c = 6.7300$ Å and density is $7.73800\ \text{g/cm}^3$. In medium Carbon Steel with 10% NaOH where from the three highest peaks it is found that the crystal structure is orthrocombic where the lattice parameters $a = 4.5180$ Å, $b = 5.0690$ Å, and $c = 6.7360$ Å and density is $7.73000\ \text{g/cm}^3$. In medium Carbon Steel with 15%

NaOH where from the three highest peaks it is found that the crystal structure is orthrocombic where the lattice parameters $a = 5.0920$ Å, $b = 6.7410$ Å, and $c = 4.5270$ Å and density is $7.67400\ \mathrm{g/cm^3}$. In medium carbon steel with 20% NaOH where from the three highest peaks it is found that the crystal structure is orthrocombic where the lattice parameters $a = 4.5310$ Å, $b = 5.0480$ Å, and $c = 6.7310$ Å and density is $7.77700\ \mathrm{g/cm^3}$. In medium Carbon Steel with 25% NaOH where from the three highest peaks it is found that the crystal structure is orthrocombic where the lattice parameters $a = 4.5144$ Å, $b = 5.0787$ Å, and $c = 6.7360$ Å and density is $7.72900\ \mathrm{g/cm^3}$ [12-20].

4 Conclusion

Based on the results of research and discussion of the effect of NaOH concentration as a cooling medium on the tensile strength of medium carbon steel, it can be concluded as a heat treatment process (heat treatment) and sudden cooling (quenching) on medium carbon steel into 5%, 10%, 15%, 20%, 25% NaOH solution to produce a hardness of 57 HRC; 58.3 HRC; 58.5 HRC; 60 HRC and 57.5 HRC for different concentrations of medium carbon steel. The hardness and tensile strength of medium carbon steel reached a maximum value of 60 HRC and 1035.28 Mpa when heated and cooled into NaOH solution with a concentration of 20%. From the results of XRD analysis on medium carbon steel with heat treatment of 850°C with the results of the test sample without treatment (original) and with the addition of NaOH concentration 5%, 10%, 15%, 20%, 25%. In the original where the highest three were found that the crystal structure was othorcombic. Ferrite and pearlite structures are seen in medium carbon steels without heat treatment processes (heat treatment) and pearlite and martensitic structures seen in medium carbon steel with heat treatment processes (heat treatment) and the cooling process suddenly (quenching). The visible pearlite and martensite structures show the hardness and tensile strength of medium carbon steel increasing or decreasing.

REFERENCES

[1] D. S. Agustina, "Effect of NaCl Concentration as a Cooling Medium on the Mechanical and Physical Properties of Medium Carbon Steel," *Thesis*, Medan: Unimed, 2007.

[2] H. Amanto and Daryanto, Ilmu Bahan, Jakarta: Bumi Aksara, 1999.

[3] G. Love, Metal Work Theory and Practice, third edition, translated by Harun A.R, Jakarta: Erlangga, 1982.

[4] E. Bruno, G. Chiari and A. Facchinelli, "Anorthite Quenched from 1530°C, I. Structure Refinement," *Acta Crystallographica Section B: Structural Science, Crystal Engineering and Materials*, vol. 32, pp. 3270-3280, 1976.

[5] M. Dalil, P. Adhi and I. Ismet, “Pengaruh Perbedaan Waktu Penahanan Suhu Stabil (Holding Time) Terhadap Kekerasan Logam, *Jurnal Natur Indonesia II*, vol. 1, pp. 12-17, 1999.

[6] Rajagukguk, J., Pengaruh Media Pendingin Pada Proses Perlakuan Panas Terhadap Kuat Tarik Baja Karbon Sedang, Thesis, Unimed,2005.

[7] G. E. Dieter, Metalurgi Mekanik Jilid 2, translation: S. Djaprie, Jakarta: Erlangga, 1992.

[8] R. E. Smallman, Metalurgi Fisik Modern Edisi Keempat, translation: S. Djaprie, Jakarta: Gramedia Pustaka Utama,1991.

[9] Sumanto, Pengetahuan tentang Bahan, Yogyakarta: Andi Offset,1996.

[10] T. Surdia and S. Saito, Pengetahuan Bahan Teknik, Jakarta: Pradnya Paramita,1999.

[11] N. D. Anggraeni, "Analisa SEM (Scanning Electron Microscopy) dalam Pemantauan Proses Oksidasi Magnetite menjadi Hematite," in *Seminar Nasional-VII Rekayasa dan Aplikasi Teknik Mesin di Industri, Kampus Itenas, Bandung, 28-29 October 2008,* pp. 50-56, Itenas, 2008.

[12] H. D. Megaw, Crystal Structures: A Working Approach, Philadelphia: Saunders, 1973.

[13] B. Huang, H. Wu, X. Shu and E. G. Burdette, "Laboratory Evaluation of Permeability and Strength of Polymer-Modified Pervious Concrete," *Construction and Building Materials*, vol. 24, no. 5, pp. 818-823, 2010.

[14] J. J. Pluth, J. V. Smith and J. Faber, "Crystal Structure of Low Cristobalite at 10, 293 and 473 K: Variation of Framework Geometry with Temperature Sample: T=293 K Locality: Synthetic," *Journal of Applied Physics*, vol. 57, pp. 1045-1049, 1985.

[15] H. Shelton, B. Tiange, E. Zurek, J. Smith and P. Dera, "Cristobalite XI: A Bridge Between Low and High Density Silica Polymorphs," in *American Geophysical Union, Fall Meeting 2017, Abstracts, New Orleans*, 2017.

[16] S. Pascal, A. Alliche and P. Pilvin, "Mechanical Behaviour of Polymer Modified Mortars," *Materials Science and Engineering: A*, vol. 380, no. 1-2, pp. 1-8, 2004.

[17] P. J. Heaney, C. T. Prewitt and G. V. Gibbs, Silica: Physical Behavior, Geochemistry, and Materials Applications, USA: Walter de Gruyter GmbH & Co KG, 1994.

[18] R. J. Angel, M. A. Carpenter and L. W. Finger, "Structural Variation Associated with Compositional Variation and Order-Disorder Behavior in Anorthite-rich Feldspars," *American Mineralogist*, vol. 75, no. 1-2, pp. 150-162, 1990.

[19] S. Bijaksana, "Rock Magnetic Methods for Environmental Studies," in *ASEANIP Regional Seminar on the Physics of Metals and Alloys*, 1996.

[20] S. Lee and H. Xu, "Using Powder XRD and Pair Distribution Function to Determine Anisotropic Atomic Displacement Parameters of Orthorhombic Tridymite and Tetragonal Cristobalite," *Acta Crystallographica Section B: Structural Science, Crystal Engineering and Materials*, vol. 75, no. 2, pp. 160-167, 2019.