THE EFFECT OF HOLDING TIME ON THE QUENCHING PROCESS IN COOLING WATER CIRCULATED ON AISI STEEL 1045

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ABSTRACT

Quenching is a material cooling system to obtain certain desired properties. Quenching is carried out to maintain the mechanical properties associated with the crystal structure which will be lost on slow cooling. The method used is quenching in circulating cooling water media with specimens that have been prepared in the form of AISI 1045 steel. The results obtained are the hardness of AISI 1045 steel after going through the 850°C quenching process with holding times of 30, 45, and 60 minutes, an increase of 300% from the raw material. The application of AISI 1045 steel that has been quenched shows results or hardness values that are the main raw materials for gears, crankshafts, and light vehicle spare parts.

Keywords*: quenching, AISI 1045 steel, circulating cooling.*

1. INTRODUCTION

In this modern era, all lines have developed rapidly, both in terms of technology and information. Like medium carbon steel, medium carbon steel is a type that is often used in the world of light vehicle engineering, motorcycles, and business. This type of steel has sufficient capability to be said to be qualified, easy to obtain, easy to machine machining and the price is relatively cheap. Carbon steel is a category of steel with a carbon content of 0.12 to 2%. AISI 1045 is medium carbon steel designed to function in areas requiring greater strength and hardness. These steels have excellent sizing accuracy, concentricity, and straightness that allow for minimal wear in high-speed applications. AISI 1045 can be formed into shafts and plates (Akhyar and Sayuti, 2015).

Components or engine parts for motorcycles and light vehicles such as gears, pressure, and friction that occur repeatedly and continuously can result in failure or wear of certain parts. This deficiency can be prevented by increasing the mechanical properties of AISI 1045, both hardness and wear resistance which is tested under working conditions. Several treatments applied to the specimen will increase the service life of the engine components when operating (Aghaei *et al.,* 2019). The treatment applied also plays an important role in reducing failure and damage that occurs when the component is in high heat conditions. The expected superior properties such as hardness and wear resistance are obtained by heat treatment. A combined heating and cooling process can produce superior properties. The heat treatment method that can be used to obtain superior properties such as hardness and wear resistance of AISI 1045 steel is a very fast cooling method or better known as quenching (Basori *et al.,* 2019).

Research conducted by (Cong *et al.,* 2021) quenching in molten alkali salt and oil bath media, and the results were seen in the form of microstructure and surface properties of AISI 1045 steel. The salt quenching medium used in this study contained 40% NaOH and 60% KOH with the addition of 5 wt.% water at 205°C. Hardening of AISI 1045 in this medium resulted in an almost uniform microstructure, consisting of fine martensite and bainite. For comparison, the microstructure of the samples quenched with oil media was martensite, ferrite, and pearlite. Cooling in a salt medium causes an increase in surface properties, i.e., a decrease in surface roughness Research (Esfahani *et al.,* 2021) carried out the quenching process on AISI 1045 steel using pure water as a cooling medium and a salt solution. The austenization process was carried out at a temperature of 850°C with a holding time of 15 and 30 minutes. The samples were then quenched in a salt solution cooling medium with concentrations of 0, 10, and 23%. The results showed that the quenching process on AISI 1045 steel promotes phase transformation from a mixture of ferrite and pearlite to martensite. Increasing austenitization holding time and salt concentration level resulted in higher martensite intensity and hardness. On the other hand, an increase in austenitizing holding time and a salt concentration level results in lower toughness.

Then the research conducted by (Mulyadi *et al.,* 2022) quenching was carried out on salt and oil cooling media. Cooling in an aqueous salt medium to a temperature of 205°C produces high hardness and the hardness is well distributed over the entire surface. The microstructure of salt media specimens with and without water consists of martensite and bainite (Perez *et al.,* 2018); The microstructure of the oil media specimen consists of martensite, pearlite, and ferrite. Salt cooling medium has a more uniform type of microstructure than oil cooling (Raygan *et al.,* 2009). The impact energy of the salt medium specimen is higher than that of the oil medium specimen. When observing the microstructure there are some of the same mechanical properties.

The use of certain media for quenching such as water, salt water, and oil is expected to increase the hardness number so that the wear resistance value will also be good (Rassizadehghani *et al.,* 2006). This research will focus on how the cooling medium is fully circulated and tested in the form of mechanical testing. Based on the explanation above, the authors are interested in researching"The Effect of Holding Time on the Quenching Process in Circulating Cooling Water Media on AISI 1045 Steel". Analysis of the number of HD wear resistance is carried out after the material is tested to explain the mechanism and properties that occur during the test.

2. METHODS

AISI 1045 steel purchased in the market with dimensions of 20 mm x 20 mm x 10 mm was used in the study, as shown in figure 1.

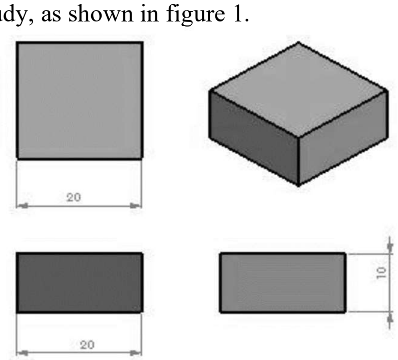


Figure 1. AISI 1045

A furnace or combustion furnace is used for Hardness Test a sample heater with the highest temperature point of the specimen is 850^{o}C with adjustable heating time. The basic principle of the Vickers Hardness test is very simple, namely the indenter in the form of a pyramid pressing the material or object being tested and then evaluating the surface part of the object or material that is indented after being given an emphasis that has set the magnitude of the force.

3. RESULTS AND DISCUSSION

3.1 Hardness Test

From testing conducted so obtained some data which will be explained are as follows.

Table 1. Hardness Vickers Test

Cooling	*Holding Time (Min)*	No. Test	Hardness Vickers	Average HV	STD
Raw Material	30	HRM1	211,54	211,67	1,3
			213,03		
			210,32		
	45	HRM2	212,35	213,72	1,4
			213,21		
			215,10		
	60	HRM3	210,99	212,35	1,3
			212,05		
			213,72		
Water	30	HO1	580,91	587,13	4,26
			587,33		
			593,44		
	45	HO2	579,88	586,08	4,75
			586,13		
			589,22		
	60	HO3	581,94	588,17	4,28
			588,12		
			594,51		
Circulated Water	30	HA1	632,42	639,49	5,7
			639,52		
			647,88		
	45	HA2	633,59	640,68	5,38
			640,21		
			644,26		
	60	HA3	634,76	641,87	5,49
			641,44		
			687,12		

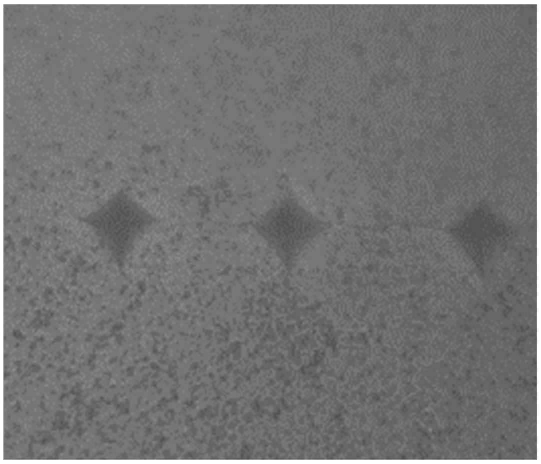


Figure 2. Vickers indentation on raw material (50X)

Vickers test cross-section images like Figure 2 were viewed with an optical microscope. For raw materials, the hardness value tends to be the same as the certificate purchased commercially, on the written certificate the hardness of AISI 1045 steel ranges from 160 - 220 HB, if it is converted into a Vickers unit, namely HV, the test result value is still within the range stated in the certificate. Because of this suitability, AISI 1045 steel was continued in the next testing stage. When viewed from the results of the hardness test, the raw material has a standard deviation of around 1.044%, meaning that a small standard deviation value, can minimize the error value that occurs during the testing process.

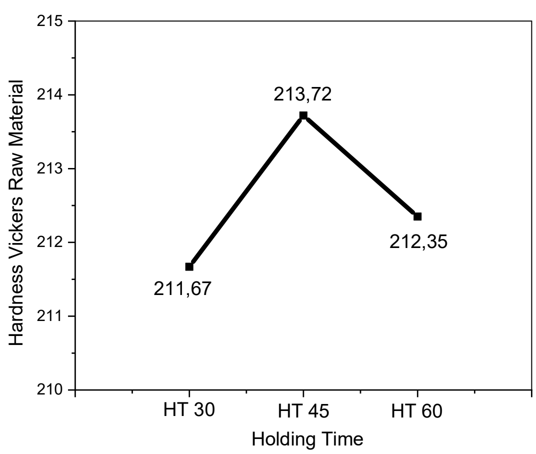


Figure 3. Vickers indentation results on raw material

Then the raw material was tested by quenching heat treatment with two different cooling media. The first cooling medium is water media, and the second is circulating water with a full valve opening. During the heat treatment process the optimum temperature given ranges from ~850ºC in the furnace. It can be seen in Figure 3 that hardness results are almost the same in all. Then steel AISI 1045 which has been quenched with water cooling media, with the code names HO1, HO2, and HO3. In the first sample, HO1 with a holding time of 30 minutes resulted in a hardness value of 587.13 HV. The second sample HO2 with a holding time of 45 minutes resulted in a hardness value of 586.08 HV and the last sample HO3 with a holding time of 60 minutes resulted in a hardness value of 588.17 HV, from the three data obtained an average of 587.13 HV. The heat treatment applied to the sample proves that the quenching heat treatment process can increase the hard value of a material, the increase in the hardness value has something to do with the martensitic structure of a material (Singh *et al.,* 2006). Martensite is an element that makes the hardness value of a metal material high but tends to be brittle. The standard deviation of AISI 1045 steel for cooling water is 1.045%.

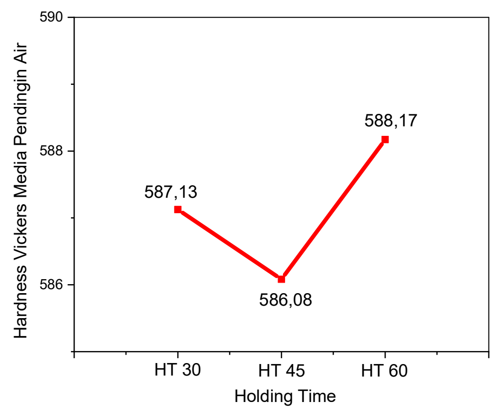


Figure 4. Results of quenching steel Vickers indentation with water cooling media

After that, the AISI 1045 steel which had been quenched with water cooling media with a full valve opening, was codenamed HA1, HA2, and HA3. In the first sample, HA1 with a holding time of 30 minutes resulted in a hardness value of 639.40 HV. The second sample HA2 with a holding time of 45 minutes produced a hardness value of 640.68 HV and the last sample HA3 with a holding time of 60 minutes produced a hardness value of 641.87 HV, from the three data obtained an average of 640.68 HV.

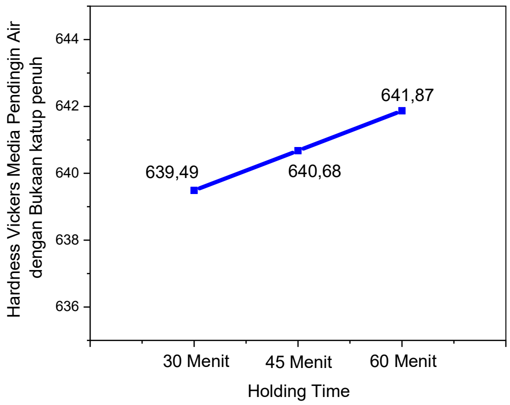


Figure 5. Results of indentation of steel Vickers quenching medium circulating water with full valve opening

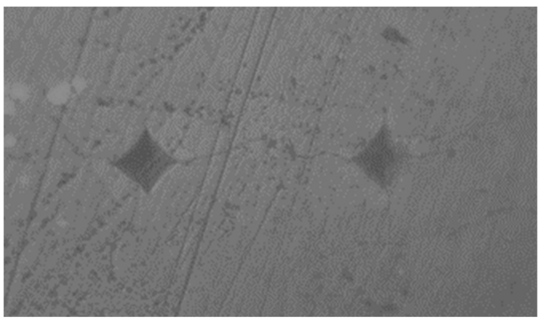


Figure 6. Indentation trail of quenched steel Vickers circulating water medium with full valve opening (50X)

The results of the indentation with water cooling media with full valve opening are shown in Figure 6. The standard deviation of AISI 1045 steel for water cooling media is 1.191%. Based on data from the three materials that have been tested for indentation, it can be seen that the highest hardness value is found in circulating water media with a full valve opening. It can be seen that a fully opened valve affects the results of the hardness values and Figure 7 is an amalgamation of the hardness values of all specimens that have been tested.

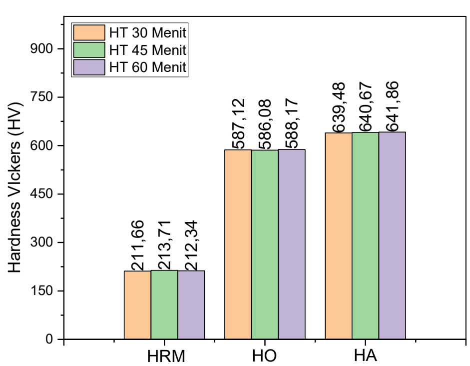
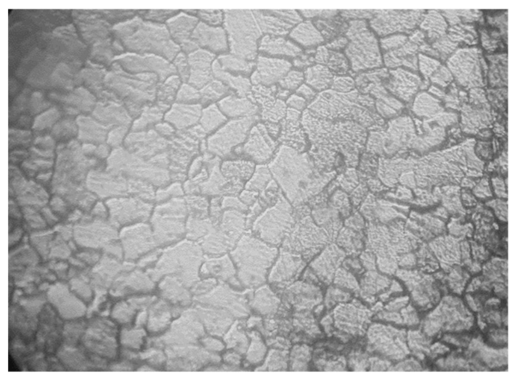


Figure 7. Results of Vickers indentation

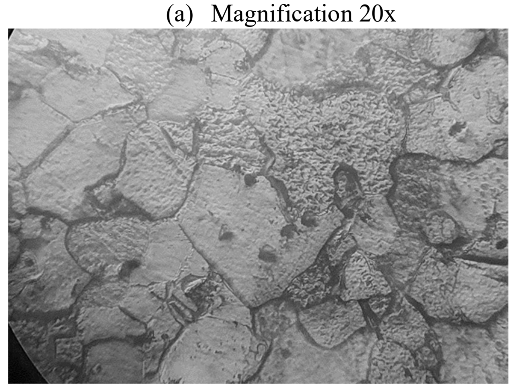
When viewed directly the difference is very visible in the results of the hardness test of the indentation method on cooling media using water and fully circulated water. The highest hardness is found in AISI 1045 steel samples with circulating water media, and martensite phase which will increase the hardness of a material. This event or change is also the result of more phase changes from the pearlite phase and the ferrite phase to the austenite phase and then converted to the martensite phase by the quenching method or rapid cooling. In theory, the martensite hardness is more than 500 HV. Based on Figure 7, we can conclude that circulating cooling media with a full valve opening will have a greater effect both in terms of hardness value and other properties.

Microstructure Observation

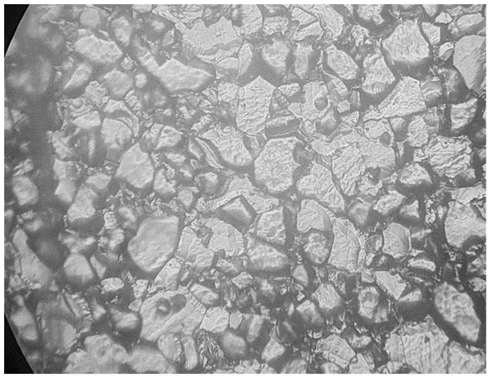
Magnification in Figure 8 (a, c, and e) uses 20x magnification, while Figure 8 (b, d, and f) uses 100x magnification with the etching solution used: Nital, Nitric Acid, Alcohol in a ratio of 1:4.



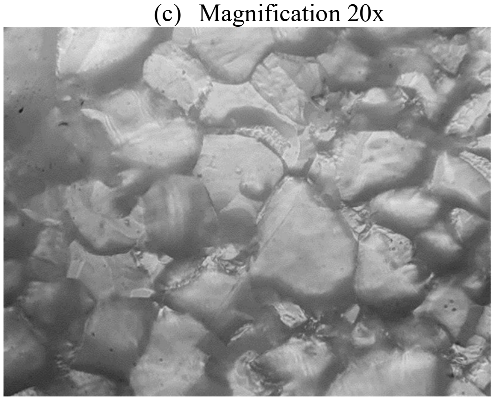
(a) Magnification 20x



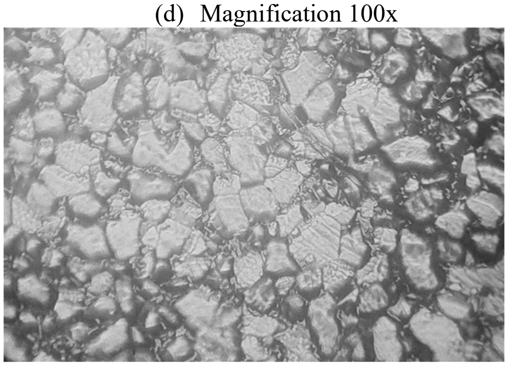
(b) Magnification 100x



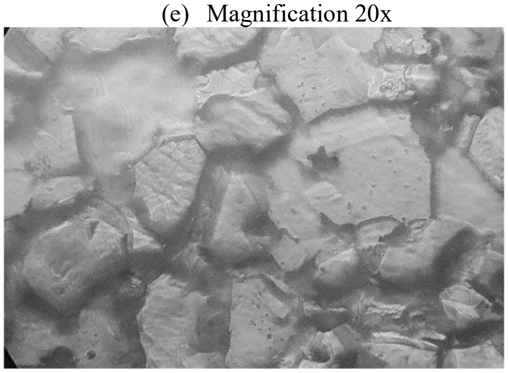
(c) Magnification 20x



(d) Magnification 100x



(e) Magnification 20x



(f) Magnification 100x

Figure 8. The quenched AISI 1045 microstructure (a, b) HT 30 (c, d) HT 45 and (e, f) HT 60.

After the quenching process, the steel is molded with resin to facilitate the sanding process, sanding using sizes 100, 200, 400, 1000, and 2000, after polishing the next step is etching with Nital solution on the AISI 1045 steel test specimen, the microstructure is observed through a microscope with magnification 20x and 100x. Figure 8 shows the microstructure of the quenched specimen from AISI 1045 with HT 30, 45, and 60. The microstructure of the HT 30, 45, and 60 specimens is the microstructure under temperature conditions of 850^{o}C with quenched conditions. According to the reference microstructure photo from the reference, in this condition, the specimen consisted of two phases, namely pearlite and pro eutectoid (pro eutectoid ferrite). Dark colored pearlite and light pro eutectoid. Pearlite itself is composed of carbide (Fe3C) and eutectoid (eutectoid ferrite) (Zordao *et al.,* 2019). The martensite microstructure formed with increasing agitation flow rate is getting better and more evenly distributed. The distribution of the microstructure of martensite is characterized by a random shape and shaped like a lath needle. The microstructure of eutectoid (eutectoid ferrite) is getting less and less, it is estimated that the cooling rate when viewed with the help of CCT diagrams only slightly passes through the pearlite formation region. However, further analysis cannot be carried out because the magnification used is only 100x. When viewed at 100x magnification martensite tends to be less visible. For more analysis, a scanning electron microscope (SEM) should be used.

4. CONCLUSION

There was an increase in the hardness value of AISI 1045 steel after going through a quenching process of 850^{o}C with holding times of 30, 45, and 60 minutes. The difference in cooling method affects the hardness value. Based on the test results, the circulating water cooling media has the highest hardness value, which is 640.68 HV. During the testing and rapid cooling process, AISI 1045 steel experienced an increase in hardness of about 300% of the raw material. The stationary water-cooling medium is slightly lower than the circulating water. The application of quenched AISI 1045 steel shows results or hardness values that match the main raw materials for gears, crankshafts, and light vehicle spare parts

REFERENCES

Akhyar, I., & Sayuti, M. (2015). Effect of heat treatment on hardness and microstructures of AISI 1045. In *Advanced Materials Research* (Vol. 1119, pp. 575-579). Trans Tech Publications Ltd.

Aghaei, M., Nazari, F., & Honarpisheh, M. (2019). Effect of cooling system on the mechanical properties and residual stress of steel AISI 1045 in quenching heat treatment. *Modares Mechanical Engineering*, *19*(12), 2979-2986.

Basori, I., Pratiwi, W. D., & Dwiyati, S. T. (2019, December). Effect of Salt quenching on the microstructures and mechanical properties of AISI 1045 steel. In *Journal of Physics: Conference Series* (Vol. 1402, No. 5, p. 055102). IOP Publishing.

Cong, M. A. O., Peihao, C. A. I., Yongle, H. U., Zhong, Y., Jishuang, W. E. I., Zhuming, B. I., ... & Zhang, M. (2021). Effect of laser-discrete-quenching on bonding properties of electroplated grinding wheel with AISI 1045 steel substrate and nickel bond. *Chinese Journal of Aeronautics*, *34*(6), 79-89.

Esfahani, A. K., Babaei, M., & Sarrami-Foroushani, S. (2021). A numerical model coupling phase transformation to predict microstructure evolution and residual stress during quenching of 1045 steel. *Mathematics and Computers in Simulation*, *179*, 1-22.

Mulyadi, M., Tafrant, D., Hendradinata, H., & Zainuddin, Z. (2022, February). The Effect of Quenching Media on the Hardness of AISI 1045 Steel. In *5th FIRST T1 T2 2021 International Conference (FIRST-T1-T2 2021)* (pp. 66-71). Atlantis Press.

Pérez Ruiz, E. A., Negrín Hernández, L. I., Llano, J. F., & Ravagli, J. S. (2018). Effect of machining fluid like quenching media on the friction and wear behavior aisi 1045 steel.

Raygan, S., Rassizadehghani, J., & Askari, M. (2009). Comparison of Microstructure and Surface Properties of AISI 1045 Steel After Quenching in Hot Alkaline Salt Bath and Oil. *Journal of Materials Engineering and Performance*, *18*(2), 168-173.

Rassizadehghani, J., Raygan, S., & Askari, M. (2006). Comparison of the quenching capacities of hot salt and oil baths. *Metal Science and Heat Treatment*, *48*(5), 193-198.

Singh, S., Samir, S., Kumar, K., and Thapa, S., 2021. Effect of heat treatment processes on the mechanical properties of AISI 1045 steel. Materials Today: Proceedings, 45, pp.5097-5101.

Zordão, L. H. P., Oliveira, V. A., Totten, G. E., & Canale, L. C. (2019). Quenching power of aqueous salt solution. *International Journal of Heat and Mass Transfer*, *140*, 807-818.