

Effect of Variation of Quenching Process Cooling Media on Hardness and Microstructure of AISI 1020 Steel Subjected to The Pack Carburizing Process Using Graphite and Eggshell Carbon Media

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Abstract: AISI 1020 steel is a low-carbon steel known for its affordability compared to medium-carbon steel, high-carbon steel, and alloy steel. This material is commonly used in construction and is widely applied in machine and structural components, such as gears and shafts subjected to relatively small loads. The objective of this study is to enhance the hardness of AISI 1020 steel. The pack carburizing process was conducted using graphite carbon and eggshells as the carburizing media at a temperature of 850 °C. This process effectively increases the material's hardness. The highest hardness value was achieved using a brine cooling medium (457.111 BHN), followed by water cooling (319.345 BHN) and oil cooling (248.204 BHN). The results indicate that optimized pack carburizing and cooling methods can improve the mechanical properties of AISI 1020 steel, making it more suitable for applications requiring enhanced wear resistance, such as automotive components, industrial machinery, and tools.

Keywords: quenching; pack carburizing; eggshell, AISI 1020, graphite

1. Introduction

AISI 1020 steel is a low carbon steel that has a low selling price compared to medium carbon steel, high carbon steel, and alloy steel. It is used as a general construction material. AISI 1020 steel has high ductility and is easily formed, but its hardness is low. The chemical composition of AISI 1020 steel is 0.17-0.23% C, 99.08-99.53% Fe, 0.30-0.60% Mn, <0.040% P, <0.05% S, 0.0031% [1]. AISI 1020 steel is generally widely used and applied to engine components and construction components such as gears and shafts with relatively small loads. relatively shorter when subjected to dynamic or repetitive loading. One way to improve surface properties and hardness values is the pack carburizing process [2]. The carburizing process is a chemical heat treatment process carried out by heating the specimen to austenite temperature in a space containing carbon temperature [3]. This

process is carried out by heating steel at a certain temperature, maintaining it for a certain time, and cooling it using certain media. This process is carried out at a temperature of 900°C - 950°C in an environment that gives up carbon and then left for some time at that temperature, then cooled [4].

Other research was also conducted by Adi, et al (2018) on the effect of pack carburizing on commercial steel hardness. This study used a variation of carbon donor media, teak wood charcoal, coconut shell charcoal, and graphite by 90% with a 10% barium carbonate catalyst mixture at 950°C with the hardness value of each donor being teak wood charcoal of 715.5 HV coconut shell charcoal of 815.39 HV and graphite of 343.975 HV. [5].

Based on the description above, the research conducted will use graphite as a carbon source, eggshells as a catalyst and variations in cooling media in the form of oil, water, and salt water. While the material used in this research is AISI 1020 low carbon steel.

2. Materials and Methods

2.1. Test Speciment Creation

Plate-shaped AISI 1020 specimens were cut to the specified specimen specifications with a lathe. The number of specimens made was 13 specimens. Specimens that have been cut are then smoothed with sandpaper (see Figure 1) and the chemical composition (see Table 1).



Figure 1. AISI 1020 steel

Table 2. Chemical composition of AISI 1020 steel [3]

Component Elements	Metric
Carbon, C	0.17 - 0.23 %
Iron, Fe	99.08 - 99.53 %
Manganese, Mn	0.30 - 0.60 %
Phosphorus, P	<= 0.040 %
Sulfur, S	<= 0.050 %

2.2. Carburizing Process

The carbonizing process is carried out using graphite powder media and a pulverized and sieved eggshell catalyst. Stages of carburizing process:

1. Mixing 90% carbon powder (graphite) with eggshells (CaCO₃) from a composition of 500 grams and then mixed equally.
2. The test object (AISI 1020) is placed in a cementation box filled with a mixture of carbon (graphite) and eggshell (CaCO₃) until it covers the entire surface so that the carburizing process occurs and the two powder mixtures are completely fused on the surface of the test object.
3. Put the cementation box into the heating furnace, and the furnace is closed, turn on the heating furnace see the initial temperature of 30°C. Wait until the final heating temperature of 850°C, with a heating holding time of 1 hour.
4. Turn off the furnace, open the furnace and remove the cementation box from the furnace.

5. Lift the test specimen (AISI 1020) from the cementation box using tongs and put it into cooling media in the form of water, salt water, and oil, let it cool down.
6. Remove the test specimen (AISI 1020) from the cooling media and wipe it dry with a fine cloth, then sand one side until it is clean (shiny) for the hardness and microstructure testing process.
7. After the carburizing process, all test specimens (AISI 1020) were taken for their hardness value in the hardness testing process using a hardness testing machine, and microstructure observation using an optical microscope.

2.3. Test Equipment

In this research, the tool used for testing is a furnace machine model L64/14, frequency 50 Hz, maximum temperature capacity 1400 °C with 13.0 W power and 16/16/28 A current available at the Material Laboratory of the Mechanical Engineering Dept., University of Lampung (see figure 2).



Figure 3. Furnace Machine

3. Results and Discussion

3.1. Hardness Test

Hardness testing was carried out using the brinell method at a load of 1838.74 N (187.5 kg) using a steel ball indenter with a diameter of 2.5 mm. Each test material was tested 5 times from the center point of the material with a distance of approximately 5 mm from the center point. Brinell hardness test data can be seen in Figure 3.

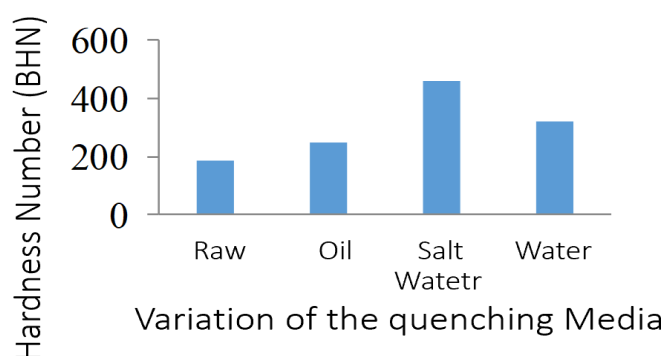


Figure 4. Hardness value graph of AISI 1020 steel

In the hardness testing graph above the difference in cooling variations affects the hardness value of the specimen. Raw has an average hardness value of 187.69 BHN then in 3 variations of cooling media has an average hardness value, namely, 248.2 BHN for oil, 457, 11 BHN for salt water, and 319.34 BHN for water. In the cooling process there are several influential factors such as density and viscosity. The higher the density value, the faster the cooling rate while the higher the viscosity, the slower the cooling rate.

3.2. Composition Test

The hardness value is influenced by how much the carbon element is contained in a material; to find out how much the addition is carried out chemical composition testing that we have done. The result of our chemical composition test data is presented in table 2.

Table 2. Chemical composition of AISI 1020 steel

	C	Si	Mn	P	S	Fe
RAW	0,17	0,22	0,71	0,012	0,0031	98,8
PACK	0,31	0,15	0,72	0,0054	0,0011	98,8

This chemical composition is in a good agreement with other published studies [3,5].

3.3. Microstructure Observation Results

Observation of raw material microstructure with 500x magnification using an optical microscope on each test specimen. From this observation we can find out the shape of ferrite and pearlite.



Figure 5. Microstructure of AISI 1020 steel raw material magnification 500x

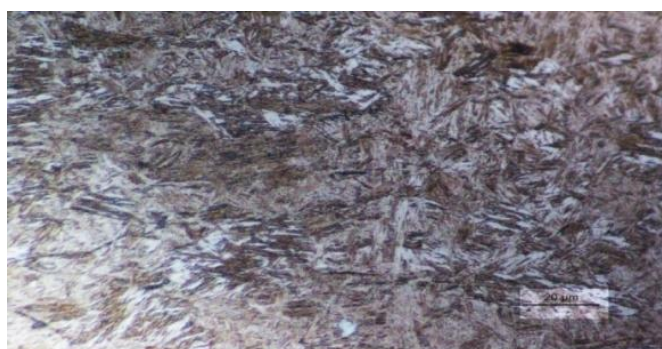


Figure 6. Microstructure of AISI 1020 steel quenching water media 500x magnification



Figure 7. Microstructure of AISI 1020 steel quenching oil media 500x magnification.

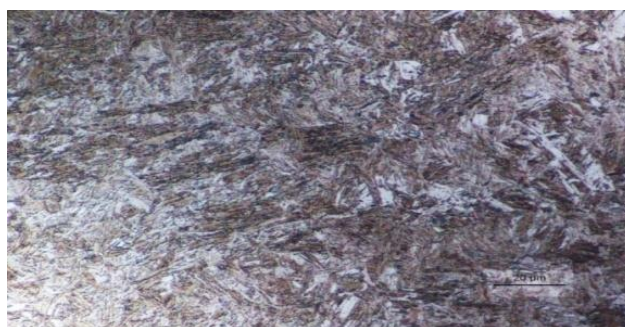


Figure 8. Micro structure of AISI 1020 steel quenching 500x magnification

4. Conclusions

Based on the results of the research and data analysis that has been carried out, several conclusions can be drawn that the heat treatment using the pack carburizing process with eggshell media as a catalyst can increase the hardness value and affect the microstructure of AISI 1020 steel. Of the several cooling media used in this study, salt water cooling media is the best media to increase the hardness value. The microstructure observation of the samples shows that martensite is more dominant in salt water so that it affects the hardness value.

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