The study of low carbon steel pack carburizing using cow bone and coconut shell

To cite this article: Miswanto et al 2019 IOP Conf. Ser.: Mater. Sci. Eng. 478 012037

View the article online for updates and enhancements.
The study of low carbon steel pack carburizing using cow bone and coconut shell

Miswanto\textsuperscript{1}, T O Rajaguguk\textsuperscript{1}, and S Sumardi\textsuperscript{2}

\textsuperscript{1}Department of Mechanical Engineering, Malahayati University, Lampung 35144, Indonesia
\textsuperscript{2}Research Unit for Mineral Technology, Indonesian Institute of Sciences, Lampung 35361, Indonesia

Email: slametsumardi99@gmail.com

Abstract. Despite of the ability of cow bone and coconut shell to be able to be processed into a charcoal, so far these have been only used as fuel or left aside becoming waste, in order to improve the economy value of cow bone and coconut shell waste, it requires processing into a charcoal. The cow bone and coconut shell can be obtained from copra farmers and cow slaughtering house farmers. In this research cow bone and coconut shell charcoal were used as carbon sources to improve low carbon steel hardness. The objective of this research was to find out the influences of temperature and charcoal composition to low carbon steel hardness. A process to use in this research was pack carburizing by using cow bone and coconut shell charcoal and applied temperatures of 900\degree C, 950\degree C, and 1000\degree C during 3 hours of retention. After pack carburizing, the \%C content was improved between 0.710\% and 1.20\%. This improvement was followed by hardness value up to 64.04 kgf/mm\textsuperscript{2} at 900\degree C, 64.20 kgf/mm\textsuperscript{2} at 950\degree C, and 64.30 kgf/mm\textsuperscript{2} at 1000\degree C.

1. Introduction
Damage is often found in metal material, and some of its causes are low carbon percentage and incompatibility between the metal characteristics and desired strength [1,2]. This may cause that the casting industry reduces carbon level at steel casting, so that it influences hardness score and steel classification [3]. Hence, the objectives of this research were to improve metal carbon level and hardness.

This research used pack carburizing method by using cow bone [4] and coconut charcoal media. In this method, carbon was added to the low carbon material by using cow bone and coconut shell charcoal media. Cow bone and coconut charcoal were selected because of its abundant availability. Data from National Statistical Bureau in 2015 showed that the cow meat productions in Java, Sumatera, Sulawesi, Kalimantan, Bali/Nusa Tenggara, Maluku/Papua islands were 297,063 kg/year; 99,251 kg/year; 34,063 kg/year; 31,334 kg/year; 32,735 kg/year; and 10,373 kg/year respectively. The highest and the lowest cow productions were in Java Papua islands respectively. The high cow production in Indonesia affects the environment because of large amount of cow bone waste.

Culinary business in Indonesia has been using cow been so far, and some industries also use cow bone as adsorbent. However this cow bone usage does not influence significantly the amount of cow bone waste in Indonesia, because the cow meat consumption increase each year in Indonesia while it is not followed by using the waste from cow slaughtering houses. Based on this problem, to help government in overcoming waste in Indonesia, the author used cow bone and coconut shell charcoal as the carbon source in the pack carburizing. Cow bone has sufficient carbon element to use as media in pack carburizing.

2. Experimental Procedures

2.1. Charcoal Making
Charcoal making was done in a controlled air supply system, where the burning process was controlled by controlling air supply to the burning chamber. In the part where charcoal has been burnt up into charcoal, the air supply ventilation hole was closed and the holes in upper line were opened so that the burning process would only go to the opened ventilation holes. This process was repeated until the last ventilation hole on the upper line was closed. In this process the material used for carbon addition was inserted into the can or container which has been ready with the flames, and then it was piled up again with charcoal as burner medium and then the container was closed tightly until the desired temperature and retaining time, or until all of the material has became charcoal.

In this research the author used cow bone and coconut shell charcoal media. To make a coconut shell, the coconut shells were first cracked and then were burnt into charcoal. The same process was applied for the cow bone. The cow bone was collected, cleaned, and dried under sunrays at 30°C temperature for 16 hours. After drying, the cow bone was crashed to facilitate burning process and charcoal making. The flow chart of making charcoal can be seen in Figure 1 and Figure 2.

2.2. Carbon content analysis of the charcoal
The following analyses are required to calculate the total carbon content of the charcoal.

a) Analysis of total water content (SNI 13-376-1994)

\[ m_{w} \, (\%) = \frac{m_2 - m_3}{m_2 - m_1} \times 100 \]

\( m_1 \) = empty dish weight (gram) \\
\( m_2 = \) dish + sample weight (gram) \\
\( m_3 = \) dish + sample weight after heated (gram) \\
\( m_{ar} \) = total water content in the sample

b) Analysis of moisture in the air (SNI 13-3477-1994)

\[ mad \, (\%) = \frac{m_2 - m_3}{m_2 - m_1} \times 100 \]

c) Analysis of volatile matter: (SNI 13-3999-1995)

\[ volatile \, (\%) = \frac{m_2 - m_3}{m_2 - m_1} \times 100 - mad \]

d) Analysis of ash content (SNI 3478: 2010)

\[ ash \, content \, (\%) = \frac{m_3 - m_1}{m_2 - m_1} \times 100 \]

e) Analysis of fixed carbon: (SNI 13-3479-1994)

\[ Fc \, (\%) = 100 - (mad + ash \, content + volatile) \]
2.3. Filtering charcoal particle size  
In this stage, charcoal was sieved to obtain desired particle size according to the need for pack carburizing [4,5].

2.4. Carburizing specimen making  
Steps in making specimen are follows. Specimens were cut in a striped plate of 70 mm x 20 mm x 3 mm by using cutting. After specimens were cut into desired dimension, specimens were then polished by sanding process with polishing machine.

2.5. Container making  
In the solid material carbonizing (pack carburizing), a box or container was required to place the specimen and charcoal. The container box was made of 2 mm thick steel plate which was cut and welded in to the dimension of 100 mm long x 90 mm wide x 50 mm height. The container box cover was made precisely according to the container box dimension to ease opening while the container box was still hot.

2.6. Specimen cleaning  
The specimen was cleaned impurities attached to the specimen, such as impurities that might be attached at polishing process to remove rust and to get flat surface. The objective of this stage was to have good process of diffusion in the carbonizing process and to get good testing results. The sample cleaning processes were as follow. The physical cleaning process was done by sanding with grinding machine to make smooth the uneven-surface and to remove scratch and chips on the specimen surface.

3. Results and discussion  
3.1. Charcoal Making Result  
Table 1 show that the time required to burn 9 kg of cow bone into charcoal was 330 minutes to produce 2.5 kg charcoal. The yield from cow bone burning was 27.78%. It took 279 minutes to burn 8 kg coconut shell into 1.16 kg charcoal. The yield was 29.12%.

| Burning          | Initial weight (kg) | Charcoal product (kg) | Time (t) | Yield (%) |
|------------------|---------------------|-----------------------|----------|-----------|
| Cow bone         | 9                   | 2.5                   | 330      | 27.78     |
| Coconut shell    | 8                   | 1.16                  | 279      | 29.12     |

Table 1. The yield result of charcoal making

Some analyses on the coconut shell to use as pack carburizing media were done. The result can be seen in Table 2. The average score of total of water content is 6.5%, moisture is 0.33%, volatile matter is 14%, and ash content is 3%. The total carbon in fixed carbon analysis is 82.67% C.

The same analyses were done to the cow bone charcoal. Table 3 shows that the average score of total of water content is 1.55%, moisture is 0.35%, volatile matter is 16.50%, and ash content is 80.00%. The total carbon in fixed carbon analysis is 3.15% C.

Total carbon of the cow bone charcoal shows the lowest score of %C, but cow bone contains of high content of calcium phosphate and calcium carbonate. Both calcium phosphate and calcium carbonate are used as energizer in the pack carburizing process (Pramuko and Purboputro, 2006). Table 2 presents chemical composition of cow bone.
Table 2. Chemical composition of the charcoal

| Chemical composition | Cow bone charcoal | Coconut shell charcoal |
|----------------------|-------------------|-----------------------|
| Total of Water content | 1.55% | 6.50% |
| moisture | 0.35% | 0.33% |
| Volatile matter | 16.50% | 14.00% |
| Asch content | 80.00% | 3.00% |
| total of carbon | 3.15% | 82.67% |

3.2. Chemical composition test

Table 3 shows that the higher carburizing temperature, then the higher the carbon (C) addition is to the specimen. This can be seen from the increase of % C in each respective temperature variation. It increases up to 0.89% at 900°C form 60% coconut shell charcoal + 40% cow bone charcoal. 1.12% C increase also occurs at 950°C temperature with 100% cow bone charcoal. It is followed 1.12% C increase at 1000°C with 100% coconut shell charcoal. This carbon increase is influenced by the higher temperature during carbonizing process, where carbonizing media at higher temperature is degraded into CO and then degraded into active carbon is able to diffuse into specimen, so that the carbon content in the specimen increases [6].

Table 3. The metal content of specimen before and after pack carburizing process.

| Temperature (°C) | Time (Hour) | Charcoal Composition | Metal Element (%) |
|------------------|-------------|----------------------|-------------------|
| RM               |             | 100% AB              | Fe  C  Si  Mn  P  S  Cr |
| 900              | 3           | 97.6                 | 0.776 0.148 0.695 0.069 0.076 0.096 |
|                  |             | 80% AB + 20% AT      | 97.6 0.710 0.157 0.762 0.012 0.051 0.108 |
|                  |             | 60% AB + 40% AT      | 97.7 0.897 0.146 0.664 0.018 0.026 0.092 |
|                  |             | 40% AB + 60% AT      | 97.6 0.886 0.153 0.690 0.018 0.020 0.099 |
|                  |             | 100% AT              | 97.6 0.846 0.139 0.701 0.090 0.057 0.106 |
|                  |             | 100% AB              | 97.5 1.00 0.148 0.683 0.013 0.016 0.106 |
|                  |             | 80% AB + 20% AT      | 97.5 1.05 0.153 0.656 0.013 0.015 0.100 |
|                  |             | 60% AB + 40% AT      | 97.4 1.08 0.151 0.672 0.014 0.017 0.112 |
|                  |             | 40% AB + 60% AT      | 97.4 1.09 0.147 0.666 0.016 0.017 0.094 |
|                  |             | 100% AT              | 97.4 1.12 0.159 0.686 0.016 0.024 0.105 |
|                  |             | 100% AB              | 97.4 1.20 0.152 0.669 0.011 0.019 0.097 |
|                  |             | 80% AB + 20% AT      | 97.3 1.15 0.145 0.639 0.026 0.017 0.091 |
|                  |             | 60% AB + 40% AT      | 97.4 1.12 0.154 0.667 0.017 0.020 0.102 |
|                  |             | 40% AB + 60% AT      | 97.4 1.14 0.153 0.685 0.011 0.016 0.102 |
3.3. Rockwell hardness test result

Rockwell hardness test was conducted at the base material before the same test was conducted to the pack carburizing specimen. The Rockwell hardness test at the base material was done in the spherical steel ball with initial load of 10 kg and total load of 150 kg with Rockwell B hardness test (HRB). The result is shown in Table 4.

**Table 4. Rockwell Hardness Test (HRB) to the Raw Material**

|     | A  | B  | C  | D  | E  | Average |
|-----|----|----|----|----|----|---------|
| 100% AT | 57.2 | 58.5 | 57 | 57 | 55 | 56.8 |
| 97.3 | 1.15 | 0.152 | 0.730 | 0.018 | 0.016 | 0.113 |

The Rockwell hardness test (HRB) at the base material, which is shown in the Table 5, obtained the average score of hardness of 57.15 kgf/mm².

**Table 5. Rockwell Hardness Test (HRC) by using varying charcoal composition**

| Temperature (°C) | Time (Hour) | Charcoal Composition | Rockwell Hardness Test (HRC) |
|------------------|-------------|----------------------|-----------------------------|
| 900              | 3           | 40% AT               | 62.24                       |
|                  |             | 40% AB +             |                             |
|                  |             | 60% AB +             |                             |
| 950              | 3           | 40% AT               | 62.72                       |
|                  |             | 40% AB +             |                             |
|                  |             | 60% AB +             |                             |
| 1000             | 3           | 40% AT               | 63.21                       |
|                  |             | 40% AB +             |                             |
|                  |             | 60% AB +             |                             |

*Note: AB = coconut shell charcoal, AT = cow bone charcoal*
Data of Rockwell hardness test (HRB) shows that the base material hardness score is 57.15 kgf/mm². Data in the Rockwell hardness test (HRC) in the material undergoing pack carburizing shows hardness improvement. It could be seen in the indenters used in the Rockwell hardness test. Steel ball indenter was used in the Rockwell hardness test (HRB) of base material, while diamond cone indenter of the material undergoing carburizing was used in the Rockwell hardness test (HRC).

Table 5 shows that the hardness score at 900°C temperature shows significant hardness to the material (64.04 kgf/mm²) at charcoal composition of 100% AT (cow bone charcoal). The 950°C temperature with 100% AB (coconut shell charcoal) show highest hardness improvement at 64.20 kgf/mm², while at 1000°C highest improvement with 100% AB is 64.3 kgf/mm².

4. Conclusion
The method used in this research was the controlled air supply system. Coconut shell charcoal making took 279 minutes at 450°C, while cow bone charcoal making took 330 minutes at 746°C. The higher the temperature, the higher was the score of %C between 0.710 %C to 1.20 %C. At 900°C, the charcoal composition of 60% AB (coconut shell charcoal) + 40% AT (cow bone charcoal) produced the best hardness carbon improvement of 0.897 %C. 100% AT produced best carbon improvement of 1.12 %C at 950°C. While at 1000°C, 100% AB produced the best carbon improvement of 1.20 %C. Therefore, the higher the temperature was the higher the score of %C. The initial low carbon steel hardness score was 57.15 kgf/mm². After the carburizing process, it increased up to 64.04 kgf/mm², 64.20 kgf/mm², 64.30 kgf/mm² at 900°C, 950°C, and 1000°C respectively. Therefore, the higher temperature was the greater the hardness at both composition of 100%AT (cow bone charcoal) and 100%AB (coconut shell charcoal).

Acknowledgment
The authors would like to thank the Research unit for Mineral Technology and Malahayati University that has facilitate for this research.

References
[1] Smallman R E 1991 *Metalurgi Fisik Modern* PT Gramedia Pustaka Utama, Jakarta
[2] Surdia T 1996 *Teknik Pengecoran Logam* Pradnya Paramitha, Jakarta
[3] Callister 2009 *Materials Science and Engineering: an Introduction* Eight Editian Wiley, USA
[4] Ihom A P 2013 *African Journal of Engineering* Vol. 1 97-101
[5] Pramuko I dan Purboputro 2006 *Jurnal Media Mesin* 7(1) 9-16
[6] Mujiyono dan Arianto L S 2008 *Jurnal Teknik Mesin* 10(1) 8-14