

THE INFLUENCE OF PARTICLE SIZE AND VOLUME FRACTION ON SURFACE HARDNESS OF C16 STEEL.

ABSTRACT

This work examines the effect of carburizing variables such as time, volume fraction and particle sizes of energizer (sea shell) and charcoal on the hardness values of carburized mild steel for improved performance. A carburizer consisting of charcoal was used for research with sea shell as energizer. Samples were carburized using different percentages of energizers (10, 20, and 30%) of particle sizes of 212 μ m, 425 μ m and 600 μ m respectively. The process was carried out at carburizing temperature of 950 $^{\circ}$ C, soaked for 4, 6, and 8 hours and quenched in oil and water. The samples were tempered at 200 $^{\circ}$ C for 1 hour, cooled in air and quenched in water. The hardness values of the carburized mild steel were measured with a micro hardness tester. The results of the study showed that hardness values of the carburized steel increased with influence of soaking time, volume fraction and particle sizes of energizer. The optimal carburizing effect was achieved at 90% charcoal and 10% seashell (energizer) of 212 μ m particle size at 8 hrs soaking time when quenched with water.

Key words: carburizer, energizer, carburizing time, cooling media, particle sizes, hardness

1.0 INTRODUCTION

Steels are alloys of iron and carbon containing up to 1.5% of carbon. There are many forms of steel each of which is designed to serve most effectively for a particular application in the field

24 of engineering. The surface engineering of components to improve the life and performance of
25 parts used in automobiles and aerospace is an active area of research [1]. Various forms of steel
26 are used in the manufacture of both major and minor machine parts. Bolts, cams, screw and
27 cutting tools are among the essential engineering components usually made out from steel. The
28 addition of carbon to the surface of low-carbon steels at temperatures within the austenitic
29 region of the steel concern is called carburizing, which usually is between 850°C and 950°C for
30 mild steels. Within this austenite temperature range, there is high solubility for carbon which is
31 the stable crystal structure. When the subsequent high-carbon surface layer is quenched to form
32 martensite hardening is accomplished so that a high-carbon martensitic case with good fatigue
33 and wear resistance is superimposed on a tough, low carbon steel core [2, 4, 6].

34 Mild steel, by reasons of its dominance and workability among the classes of steel [3], has
35 found a broad relevance in the production of engineering components like cams, gears, shafts,
36 pinions, keys, hand tools, agricultural equipment, etc. These components require the
37 mechanical properties of impact strength, hardness and tensile strength for their safe and
38 durable purposes. The inward diffusion of carbon takes place at a rate which depends on the
39 chemical composition of the steel, the carburizing temperature and the chemical composition of
40 the carburizing mixture [5, 7, 9, 11]. For a successful carburization, a control of all these
41 parameters; the carburizing temperature, carburizing time, and chemical composition of the
42 carburizing compound must be achieved [8, 10, 12].

43 Case hardening is a process in which an alloying element, most commonly carbon or nitrogen,
44 diffuses into the surface of a metal. The resulting interstitial solid solution is harder than the
45 base material, which improves wear resistance without sacrificing toughness [13]. A great
46 concern in manufacturing environments is optimum structural material, where there is demand
47 for high performance in mechanical properties such as hardness. If the temperature of
48 carburization is between 900°C and 950°C as is usually the practice – then the rate at which
49 the case is produced depends on the characteristics of the carburizing compound employed. For

50 some steel components to meet the service conditions requirements, they must have high
51 surface wear resistance, and tough shock resistant cores. These properties are conferred by the
52 process of carburization, the effectiveness of which is determined by the properties of the
53 carburizing medium employed and characteristics of the cooling media. Thus, the evaluation of
54 particle sizes, volume fractions of energizer, different media and variation of time with
55 temperature becomes imperative.

56 The use of sea shell as an energizer in case carburization of mild steel was investigated by Ogo
57 and Ette [14]. The result showed that the addition of sea shell (Oyster shell) to charcoal
58 produced a significant increase in the carburization rate and hardness of mild steel. The
59 addition of sea shell to charcoal produced a significant increase in the tensile strength of mild
60 steel [15, 16]. Seashell also compared favourably with BaCO_3 as energizer, giving relative
61 efficiency of 72.5%. However, there is limited report on the effect of grain sizes of energizers
62 and cooling media

63 The study of process parameters in metals during heat treatment has been of considerable
64 interest for some years [7, 8, 10, 17] but there has been relatively little work on process
65 variables during the surface hardening process [18] since controlling parameters in
66 carburization is a complex problem. The major influencing parameters in carburization are the
67 holding time, carburizing temperature, carbon potential and the quench time in oil [19].

68 The aim of this research work is to improve the hardness of the mild steel applicable in
69 automobiles, machines, gears and springs by pack carburization using sea shell as an energizer
70 and by optimizing volume fraction of energizer, particle sizes of energizer and soaking time.

71

72

73

74

75 **2.0 EXPERIMENTAL PROCEDURE**76 **2.1 MATERIALS AND PREPARATION**

77 A flat bar of mild obtained was analyzed and its nominal chemical composition is given in
78 Table 1.

79

80

81 Table 1: Chemical Composition of AISI 1016 Mild Steel.

C	Si	Mn	P	S	Cr	Ni	Cu	Fe
0.16%	0.215	0.51%	0.022%	0.005%	0.02%	0.02%	0.09%	BALANCE

82

Al	Mo	Co	Nb	V	Sn
0.031	0.0043	0.0092	0.0047	0.0027	0.0034

83 Pack carburizing process was carried out in a Muffle furnace. The prepared mild steel samples
84 were embedded in the carburizing box, which was first filled with the carburizing agent with
85 appropriate carburizing mixture (Charcoal/Sea shell) which was then tightly sealed with clay
86 cover to prevent unwanted furnace gas from entering the carburizing box during heating. The
87 furnace temperature was adjusted to the required temperature (950°C), and the loaded steel
88 carburizing box was charged into the furnace. When the furnace temperature reaches the
89 required carburizing temperature, it was then soaked at the temperature for the required time
90 (4, 6 and 8hours). The material was held at the specified time, the steel carburizing box was
91 removed from the furnace and the material was quenched in oil while some samples were also
92 quenched in water. The carburizing process was carried out in various batches in accordance
93 with volume fraction set.

94 The carburized test samples were tempered at a temperature of 200°C held for an hour and then
95 cooled in air. Rockwell Hardness test was measured on the carburized and tempered mild steel.
96 For each of the sample, tests were carried out 3times, and the average of all the samples was
97 taken as the observed values in each case.

98

99 **3.0 RESULTS AND DISCUSSION**

100

101

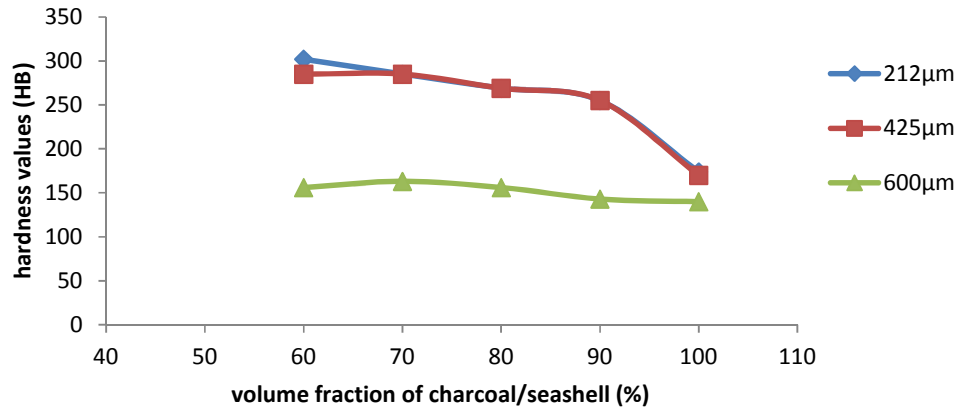


Figure 1: The relationship between hardness and volume fraction of different particle sizes after 4hrs at 950°C. (cooling medium: water)

102

103

104

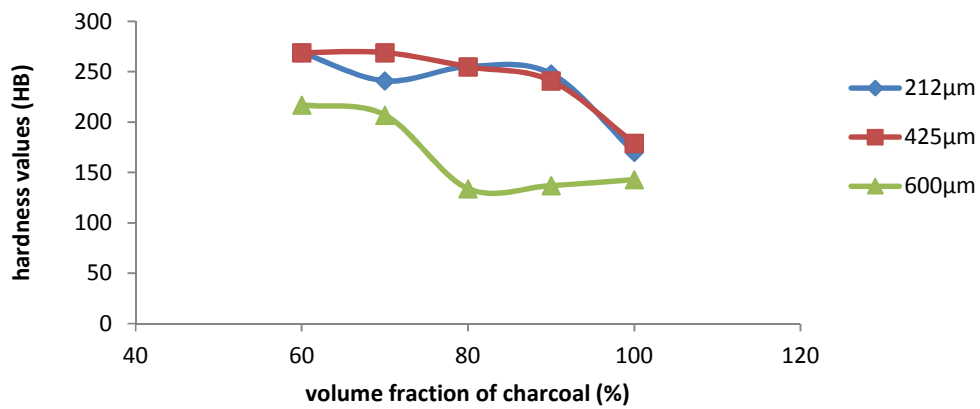


Figure 2: The relationship between hardness and volume fraction of different particle sizes after 4hrs at 950°C. (cooling medium: oil)

105

106

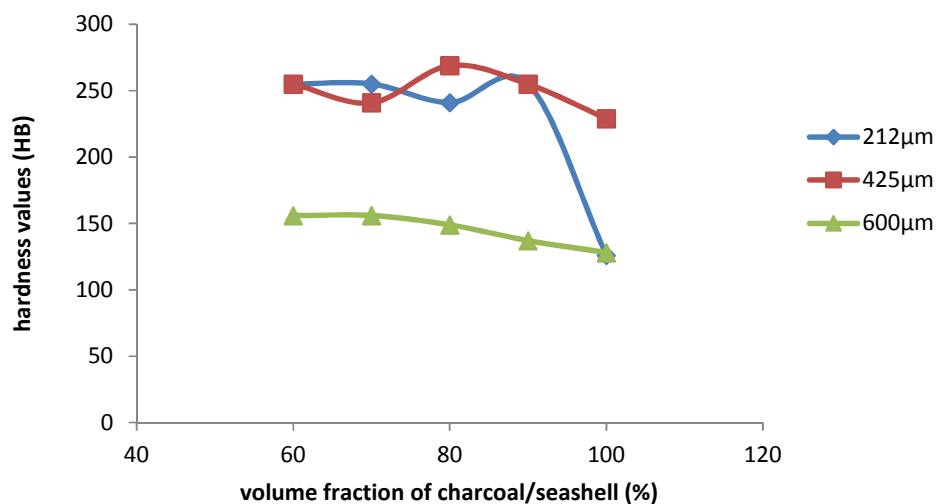


Figure 3: The relationship between hardness and volume fraction of different particle sizes after 6hrs at 950°C. (cooling medium:water)

107

108

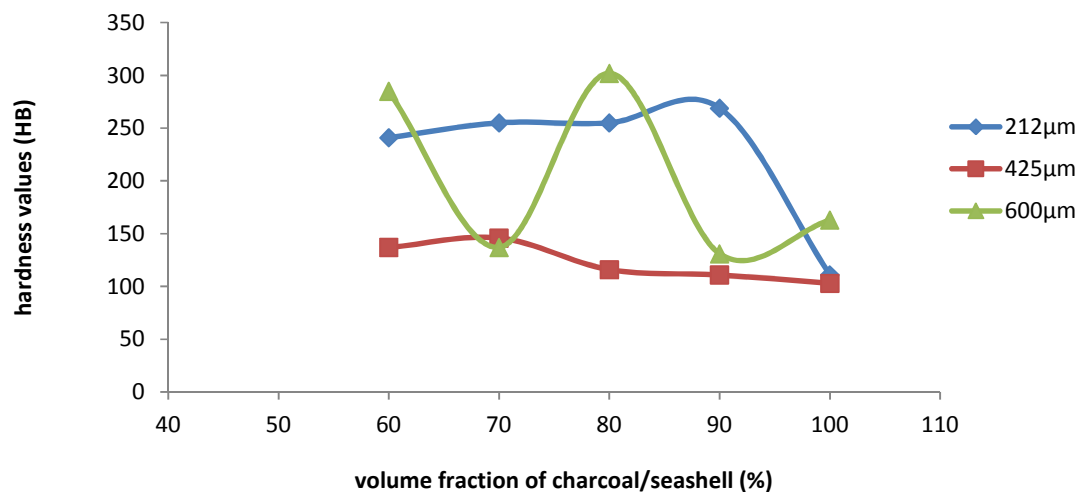
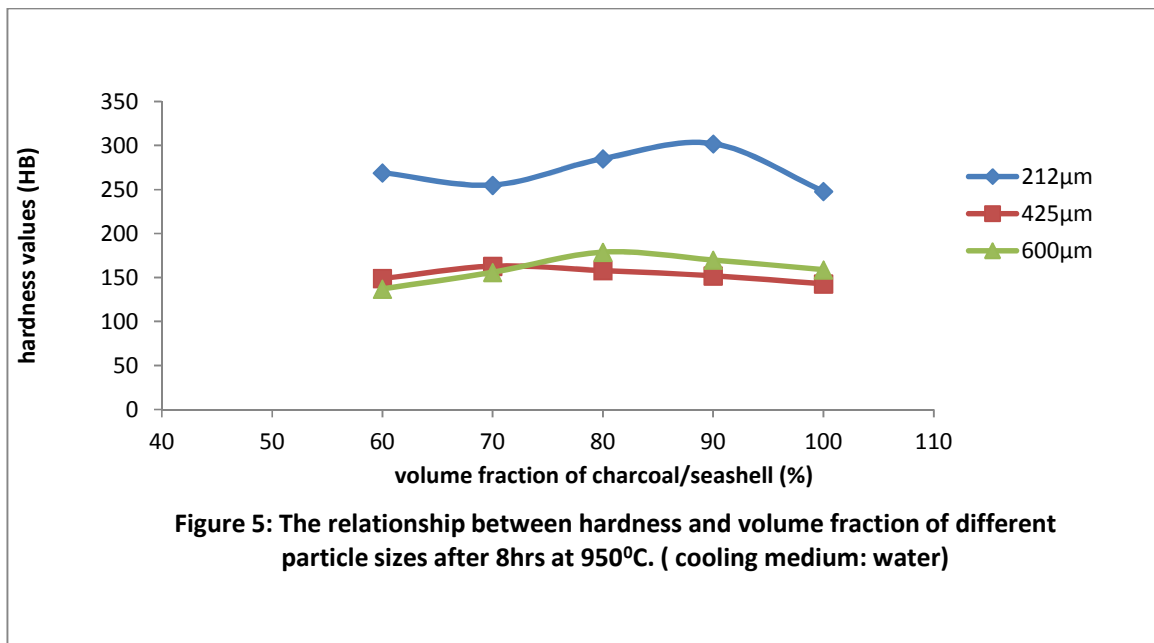


Figure 4: The relationship between hardness and volume fraction of different particle sizes after 6hrs at 950°C. (cooling medium: oil)

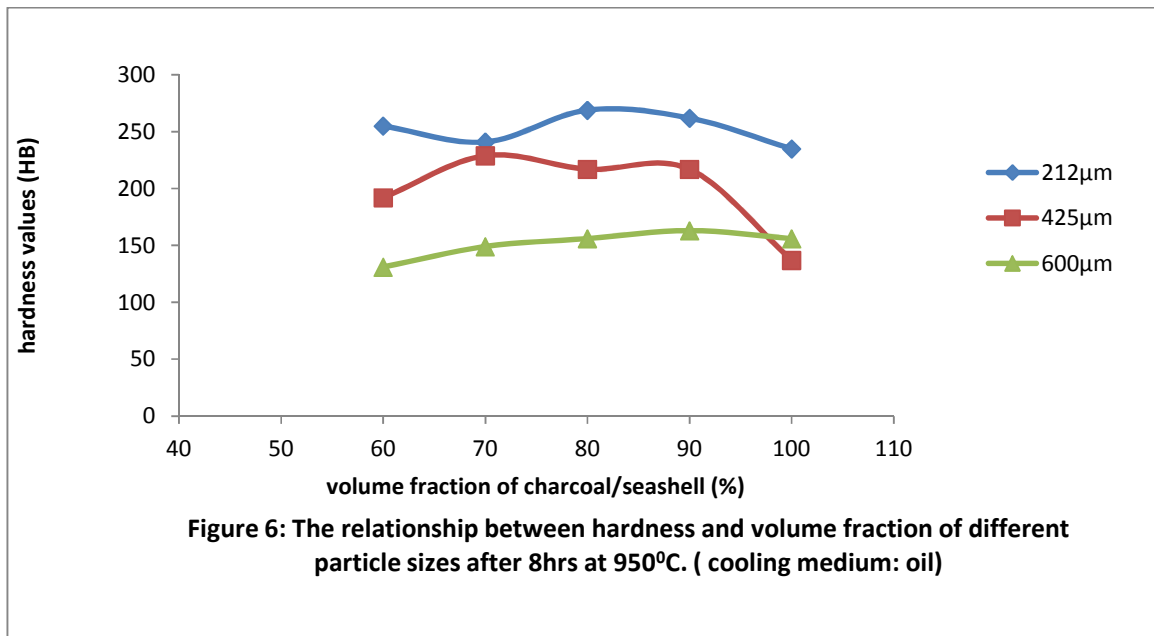
109

110



111

112



113

114

115 From fig.1, after heat treating for 4 hours at 950°C, the steel sample that was cooled in water
 116 and heat treated with solid carburizing media of particle size 212μm had the highest value of
 117 300HRB at a composition ratio of 60%charcoal and 40%energizer. The next to highest
 118 hardness value was obtained at particle size of 425μm, and the least hardness value was

119 obtained with particle size 600 μ m. It shows that the finer the grain size of the energizer the
120 better the hardness of the sample.

121 In fig.2, with the same holding time and furnace temperature but oil as the cooling medium,
122 steel sample heat treated with particle size of 212 μ m still had the optimum hardness value of
123 269 HRB which was low compared to using water as cooling medium. The trend followed in
124 fig.1 with a sample heat treated with particle sizes 425 μ m and 600 μ m having the next to the
125 highest and the least hardness value respectively. The finer grain size had influence on the
126 hardness of steel with increase carburizing time [19].

127 From fig.3, after heat treating for 6 hours with carburizing temperature of 950⁰C, the steel
128 sample that was cooled in water with particle size of 425 μ m had the highest value of 269HRB
129 at a composition ratio of 80% charcoal, 20% energizer. After this, the hardness values started
130 going down with increased volume fraction. The next highest value of hardness was obtained
131 from steel carburized with energizer of particle size of 212 μ m while the least was obtained
132 from 600 μ m.

133 From fig.4, after heat treating with the same condition as fig.3, but quenched in oil, particle
134 size of 600 μ m picked at value of 301HRB at a volume fraction of 80% charcoal, 20%
135 energizer, although there was a drastic drop in hardness values at some other composition
136 ranges. 212 μ m particle size started slowly and peaked at 262HRB before decreasing with an
137 increase in volume fraction, and in this case the least hardness was obtained from 425 μ m
138 particle size.

139 From fig.5, after heat treating for 8 hours with a furnace temperature of 950⁰C, the steel sample
140 cooled in water and heat treated at particle size of 212 μ m had hardness values of 302HRB far
141 above the other particle sizes at a volume fraction of 90% charcoal, 10% energizer. There was
142 fluctuation between 425 μ m and 600 μ m hardness values at different volume fractions.

143 Fig.6 produced the optimum hardness value of 304HRB with particle size of 212 μ m at volume
144 fraction of 90% charcoal, 10% seashell. Particle size 425 μ m had a slight increase in hardness
145 value while 600 μ m had a decrease in hardness values with an increase in volume fraction of
146 energizer respectively.

147 Therefore, particle size of 212 μ m yielded the optimum hardness values of 304HRB at volume
148 fraction of 90% charcoal and 10% seashell. It implies hardness increases with decreasing
149 particle size.

150

151 4.0 CONCLUSION

152 The followings can be deduced from the results:

- 153 ❖ There is a significant increase in the carburization rate of low carbon steel by the
154 addition of seashell to charcoal. This can be seen in the difference between the hardness
155 values of carburized steel for 100% charcoal (as received) and samples which had sea
156 shell energizer added for equal holding time, particle size and quenching media. The
157 100% charcoal samples had lowest hardness values than the energized samples.
- 158
- 159 ❖ The optimal carburizing effect was achieved at 90% charcoal and 10% seashell for
160 212µm particle size at 8hrs holding time when quenched with water. This yielded
161 optimum hardness values of 304HRB. It implies hardness increases with decreasing
162 particle size. It indicates the best condition under which sea shell should be used as an
163 energizer for the carburization of mild steel.
- 164 ❖ Better efficacy might be derived using longer furnace holding times and finer grain
165 sizes of seashell. The longer holding times suggest longer periods for the carbon
166 diffusion to occur in the furnace which will increase the case depth and hence hardness
167 of the carburized samples. The finer grain sizes on the other hand, indicate a larger
168 surface area which is a precursor for a faster reaction rate.

169

170 5.0 REFERENCES

- 171 [1] Oyetunji A., Adeosun O.S. (2012): "Effects of carburizing process variables on mechanical
172 and chemical properties of carburized mild steel." Journal of Basic and Applied Science, 8, pp.
173 319-324.
- 174 [2] Gupta R.C., Kumar M.O (1995): "Abrasive wears characteristics of carbon and low alloy
175 steels for better performance of farm implements." Journal of Material Science and
176 Technology, 11: pp.91-96.
- 177 [3] Kanisawa H.O., Koyasou Y.K (1995): "Development of high strength carburized steels for
178 automobile gears." Nippon Steel Technical Report, 65: pp.234-237.

- 179 [4] Tucas J.O (2010): "Tribology of 316L austenitic stainless steel carburized at low
180 temperature." M.sc, Case Western Reserve University.
- 181 [5] Wang S.W., Lin Y.C., Chen T.M (2002): "A study on the behavior of hardened medium
182 carbon steel." Journal of Materials Processing Technology., 120: pp.126-132.
- 183 [6] Osma A.U (2009): "Effect of high temperature gas carburizing on fatigue bending strength
184 of SAE 8620 steel." Materials and Design. 30 (15), pp.1792-1797.
- 185 [7] Gupta R.C (2009): "Effect of carburizing temperatures on the mechanical and wear
186 behavior of mild steels." M.sc. thesis, National Institute of Technology Rourkela, India.
- 187 [8] Aramide F.O., Ibitoye S.A., Oladele I.O. (2009): "Effects of carburizing time and
188 temperature on the mechanical properties of carburized mild steel, using activated charcoal as
189 carburizer." Material Research, 12(4):pp.483-487.
- 190 [9] Muhammad H.J (2000): "Effect of various heat treatments on microstructure and
191 mechanical properties of low carbon steel." ISIJ Int., 34(3): pp.34-38.
- 192 [10] Atanda P.O., Umoru L.E., Adeyeye A.D. (2009): "Effects of carburizing variables on the
193 case properties of C2R steel." Journal of Minerals and Materials Characterization and
194 Engineering, 8(2):pp.79-92.
- 195 [11] Kumar M.O (1994): "Studies on the abrasive wear of carburized mild steels." Trans.
196 Indian Inst., Metals, 47: pp.417-420.
- 197 [12] Sarkar S (2008): "Two dimensional mathematical modeling in cylindrical coordinate for
198 simulating the pack carburization process." ASM International, 39A: pp.46-48.
- 199 [13] Yang C.F., Chiu L.H., Wu J.K (1995): "Effect of carburization and hydrogenation on the
200 impact toughness of AISI 4118 steel." Surface and Coating Technology, 73: pp.18-22.
- 201 [14] Ogo D.U.I., Ette A.O. (1994): "The use of river clam shell as an energizer in case
202 carburization of mild steels." ISIJ Int., 44(5): pp.865-868.

- 203 [15] Ogo D.U.I., Ette A.O., Iyorchir A.I (2007): "Feasibility of sea and coconut shells as
204 substitute to barium carbonate in small scale foundry and heat treatment shop in Nigeria."
205 ISIJ Int., 35(2): pp.203-209.
- 206 [16] Ekeshili C.K (1991): "The influence of particle size and firing temperature on burnt
207 properties of sea shell/clay mixture." B.sc. thesis, University of Agriculture, Markudi.
- 208 [17] Ohize E.J (2009): "Effects of local carbonaceous materials on the mechanical properties of
209 mild steel." AUJ. 13(2): pp.107-113.
- 210 [18] Preciado M.J., Bravo P.M (2006): "Effect of low temperature tempering prior cryogenic
211 treatment on carburized steels." Journal of Material Processing Technology, 176: pp.41-44.
- 212 [19] Aramide F.O., Ibitoye S.A., Oladele I.O. (2010): "Pack carburization of mild steel using
213 pulverized bone as carburizers." Leonardo Electronics Journal of Practices, 16:pp.1-12.