Materials Science and Metallurgy Engineering, 2014, Vol. 2, No. 3, 31-34
Available online at http://pubs.sciepub.com/msme/2/3/1
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DOI:10.12691/msme-2-3-1

The Effect of Holding Time on the Hardness of Case Hardened Mild Steel

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Received February 07, 2014; Revised August 20, 2014; Accepted September 16, 2014

Abstract The study "the effect of holding time on the hardness of mild steel case hardened with carburizing material energized by cow-bone" has been x-rayed. The mild steel specimens used for the study were carburized in the furnace at 900°C at various holding times of 2 hrs, 4 hrs, 6 hrs, and 8 hrs, using 65% charcoal / 35% cow-bone as carburizing material. Hardness values were obtained using Vickers Micro-hardness Tester Machine, from the hardness values, hardness profiles were plotted. The result of the study clearly showed that the hardness of the carburized steel increased with increase in holding time. The hardness profile results were higher for higher holding time (surface hardness: 830 Hv for 2 hrs, 850 Hv for 4 hrs, 900 Hv for 6 hrs and 1000 Hv for 8 hrs) and also the plot of the profile for 8 hrs holding time was higher than that of 6 hrs, and that of 6 hrs was higher than that of 4 hrs, and in that order. This clearly showed that holding time has effect on the hardness of case hardened steel.

Keywords: *effect, holding time, hardness, steel, carburizing material*

Cite This Article: Ihom P. Aondona, and Aniekan Offiong, "The Effect of Holding Time on the Hardness of Case Hardened Mild Steel." *Materials Science and Metallurgy Engineering*, vol. 2, no. 3 (2014): 31-34. doi: 10.12691/msme-2-3-1.

1. Introduction

The need to establish control parameters in the shop floor for effective case hardening of mild steel cannot be overemphasized. This is because the parameters determine the outcome of the heat treatment. The appropriate use of the control parameters in case hardening saves energy, time, and material. It also results in the production of well case hardened products [1].

In our highly competitive world of today where a heat treatment shop's inability to provide quality service is an advantage to another shop, care must be taken to remain competitive in the business. A heat treatment shop that satisfies the customers will be the one that will be patronized. From the author's experience at the National Metallurgical Development Centre, Jos, heat treatment shop, a customer who is not satisfied with the heat treatment services rendered on his component hardly comes back again. A gear component was brought to the shop for case hardening, unfortunately such parameters as composition of the gear, heating temperature, holding time, efficacy of the carburizing material used and the quenching and post-quenching treatment were not adequately considered; at the end of the case hardening the gear component did not meet the specified hardness value given by the customer. The customer never came back again [2]. The above experience stresses the importance of control parameters in case hardening operation.

In a work carried out by Aramide, et al [3], the authors investigated the mechanical properties of mild steel subjected to pack carburization treatment using pulverized bone as the carburizer. The carburization was done at 850°C, 900°C, and 950°C with the soaking time of 15 minutes and 30 minutes and quenched in oil, and tempered at 550°C. The authors observed that the mechanical properties of the mild steel were found to be strongly influenced by the process of carburization, carburizing temperature, and soaking time at the carburization temperature. In another work carried out by the author he observed that carbon potential is very important in attaining high hardness value, however, carbon potential depend on the nature of the carburizing material used, the carburizing temperature, and holding time just like the diffusion of the carbon into the surface of the mild steel [4].

The objective of this work is to clearly establish the effect of holding time on the hardness of mild steel case hardened with carburizing material energized by cow-bone.

2. Materials and Method

2.1. Materials

The materials used for the work included, RST 37 grade steel rods of 16 mm diameter obtained from Delta Steel Company, Aladja, acetone, water, clay, and carburizing compound. The composition of the steel used is shown in Table 1 and the composition of the carburizing compound used was 65% charcoal and 35% cow-bone.

Table 1. Mild Steel Composition used

C	Si	Mn	P	S	Cr	Mo	Ni	Sn	Cu	V
0.13	0.15	0.47	0.043	0.006	0.01	0.01	0.01	0.001	0.03	0.002

2.1.2. Equipment

The equipment used were, heat resisting steel pack carburization boxes, a large muffle electric furnace with a temperature sensitivity of ± 5°C, lathe machine, hack saw, grinders and polishing disc, and Vickers Micro-hardness testing Machine model MHT-1 No: 8331 made by Matsuzawa Seiki Co. Ltd. of Japan.

2.2. Method

2.2.1. Material Preparation

The steel samples for carburization were cut from RST 37 grade steel rods of 16 mm diameter. Each sample measured 30 mm in length. These 30 mm long rods were thoroughly washed in acetone and dried and their faces (ends) coated with ceramic clay. This was done to remove foreign material from the samples to avoid the occurrence of soft spots and to prevent carburization from occurring at the ends.

To make a pack for carburization, a 20 mm thick layer of the compound was first poured into the box, and the steel specimens were placed in position inside the box and the box filled up with the compound. The lid was then sealed with clay in order to make the box air tight and eliminate possibility of air ingress during pack carburization process.

2.2.2. Pack Carburization Process

A large muffle electric furnace with a temperature sensitivity of ± 5°C was used. The temperature distribution in the furnace over the 800°C – 1000°C range was first established and it showed the existence of a uniform temperature within the central region of the furnace extending over an area of 320 x 320 mm and up to 150 mm high from the furnace floor. The pack boxes were introduced into the muffle furnace within the uniform temperature zone which had already attained the carburizing temperature. The heating-up time needed to make up for the sudden temperature drop which followed the introduction of the packs into the furnace was less than 10 minutes and was therefore negligible compared to the carburizing time. Pack carburization runs with the carburizing compound was carried out at 900°C for 2 hours, 4 hours, 6 hours, and 8 hours. At the end of a carburization time the specimens were taken out and quenched in water. It was then tempered at 150°C for 1 hour.

2.2.3. Hardness Testing and Effective Case Depth Determination

Steel discs of 10 mm thick were cut from the central region of each of the carburized rod specimens and labeled. They were then prepared and polished for hardness measurement on a micro-hardness indenter. Micro-hardness measurements on all the specimens were carried out on Vickers Micro-hardness Testing Machine Model MHT-1 No: 8331 made by Matsuzawa Seiki Co.Ltd., of Japan. The machine had a maximum test load of 1000 gf with a load holding time of 5-30 seconds. Indentations were made starting 0.2 mm from the edge end, at an interval of 0.2 mm to a distance of 4 mm towards the middle and was repeated when specimens were turned at right angles from the first measurement. From the hardness values obtained for each specimen, hardness profiles were plotted and effective case depths at various times were extracted.

3. Results and Discussion

3.1. Results

The results of the work are as presented in Table 2 and Figure 1-Figure 5.

Table 2. Average Case Depth of Mild Steel using 65% Charcoal and 35% Cow-bone Mixture

Carburizing compound	Effective case depth dc (mm)				Average case depth
	2 hrs.	4 hrs.	6 hrs.	8 hrs.	
65% Charcoal and 35% Cowbone	1.8	1.8	1.92	2.56	2.02

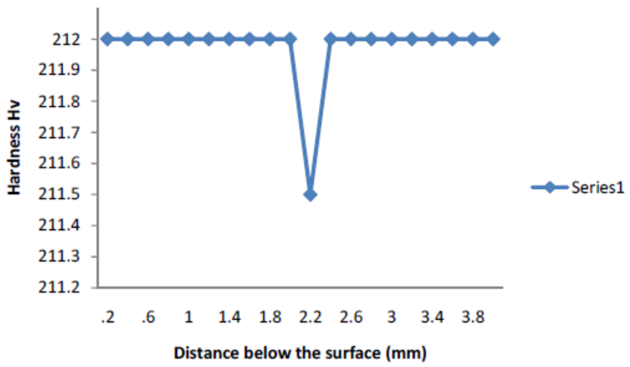

Figure 1. Hardness Profile of the Un-carburized Mild Steel

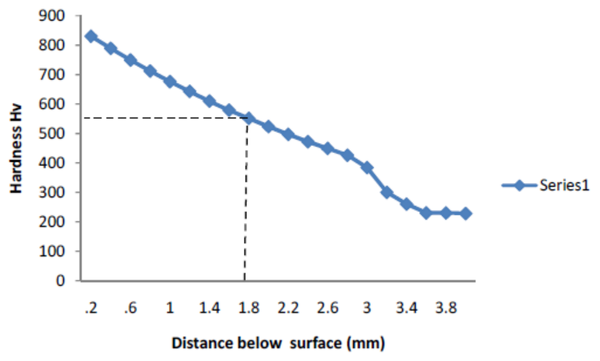

Figure 2. Hardness Profile of Carburized Mild Steel using 65% Charcoal and 35% Cow-bone for 2 Hours at 900°C

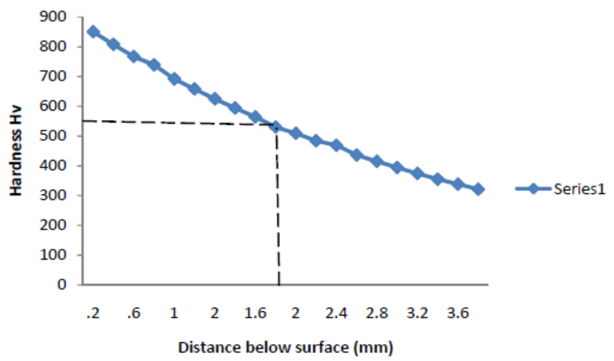

Figure 3. Hardness Profile of Carburized Mild Steel using 65% Charcoal and 35% Cow-bone for 4 Hours at 900°C

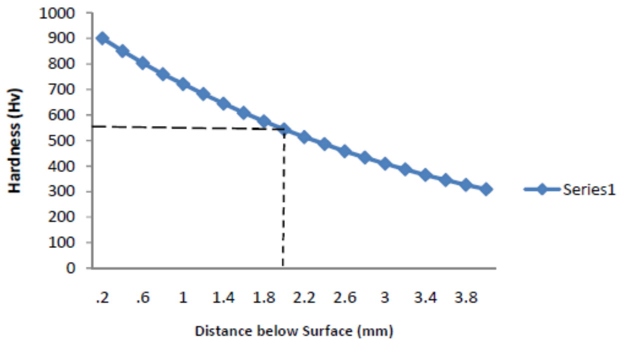

Figure 4. Hardness Profile of Carburized Mild Steel using 65% Charcoal and 35% Cow-bone for 6 Hours at 900°C

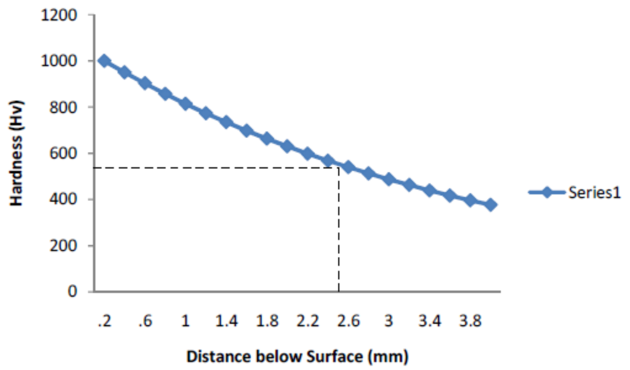

Figure 5. Hardness Profile of Carburized Mild Steel using 65% Charcoal and 35% Cow-bone for 8 Hours at 900°C

3.2. Discussion

Table 1 gives the composition of the steel used for the work. The composition clearly indicates that the steel is mild steel with carbon content of 0.13% carbon [5].

Table 2 shows the effective case depths obtained at the various holding times and the average case depths using 65% charcoal / 35% cow-bone. 2 hrs holding time gave an effective case depth of 1.8 mm, 4 hrs holding time also gave 1.8 mm, however 6 hrs holding time gave 1.92 mm and 8 hrs holding time gave 2.56 mm showing a consistent increase, it therefore implies that something must have happened between 2 hrs and 4 hrs to affect the reading at 4 hrs holding time. Previous works by several authors have indicated that the effective case depth increases with holding time [6,7,8]. This pattern is seen in the result except at 4 hrs of holding time. A temperature fluctuation or reading error may be responsible, since the carburizing material was the same in all the carburizing boxes.

Figure 1 is the hardness profile of the un-carburized steel specimen. The profile is horizontally straight except for a simple deviation from the consistent values of hardness. This is normal because of the presence of impurities which may occur in the steel in the form of inclusions (oxide inclusions) this tend to lower the hardness of the steel at that point [1,7].

Figure 2 shows the hardness profile of the mild steel carburized at 900 ^{O}C for 2 hrs using 65 wt.% charcoal / 35 wt% cow-bone as carburizing material. The hardness profile decreases towards the core of the steel specimen and is indicated by the descending graph. The highest value of 830 Hv occurred at 0.2 mm and the lowest value of 228 Hv occurred at 4 mm towards the core. This profile is typical of a case hardened steel specimen that has a hard case and a soft core [8]

Figure 3- Figure 5 all have the same shape of hardness profile just as Figure 2, rising from the left and descending towards the right as the hardness measurement is taken towards the core of the steel specimen. The hardness profile at 4 hrs is higher than that at 2 hrs, and the hardness profile at 6 hrs is higher than that at 4 hrs and so is the hardness profile at 8 hrs higher than the hardness profile at 6 hrs. The hardness profiles have clearly demonstrated that as the holding time is increasing so also is the hardness of the carburized steel increasing. It can also be seen from the hardness profiles (Figure 2- Figure 5) that at 0.2 mm the hardness value is 830 Hv at 2 hrs, 850 Hv at 4 hrs, 900 Hv at 6 hrs and 1000 Hv at 8 hrs. This is a proof that as the holding time increases so also the hardness of the carburized steel increases. This assertion had equally been confirmed by several researchers [8-13]

4. Conclusion

The study has shown that holding time has effect on the hardness of carburized mild steel. It has clearly proven that as the holding time increases the hardness of the carburized steel also increases. The holding time also affects the effective case depth. The study pointed out that as the holding time is increased the effective case depth also is increased. Therefore it can be concluded that for higher hardness of carburized steel a longer holding time should be used

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