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INVESTIGATION OF THE EFFECT OF TEMPERATURE AND TIME OF CASE HARDENING ON THE MECHANICAL PROPERTIES AND MICROSTRUCTURE OF LOW CARBON STEEL (AISI 1020)

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Abstract

The main objective of this paper is experimental study of pack carburizing of carbon steels (AISI 1020) by using two parameters (holding time and carburizing temperature). This study was conducted by using electrical furnace. This process is carried out at temperatures of 950°C for durations time 90 minutes. From the experiment, the surface hardness and thickness of carbon layer was different according to the parameters used. The quenching medium that uses in this experiment is water, oil, sea water and air. For carburizing temperature at 950°C, the highest of surface hardness value for air is 128 HV that carburized for 90 minutes, the highest of surface hardness value for water is 224 HV that carburized for 90 minutes. For carburizing temperature of 950°C, the highest of surface hardness value for sea water is 166.9 HV that carburized for 90 minutes and for carburizing temperature at 950°C which is the highest of surface hardness value for oil is 126 HV. The thickness of carbon layer was between 40μm to 120μm. The result indicates the carburizing process accelerates the diffusion of carbon atoms into the surface, thus increasing the thickness of carburized layer as well as the surface hardness.

Keyword. *Carburizing; Hardness; Temperature; Low Carbon Steel; and Quenching.*

I. INTRODUCTION

Low-carbon steel AISI 1020 is widely used as a construction material and for manufacturing **of** machine parts. Improving the mechanical and surface properties of this steel has been an important research field in materials science in the last decades because of its technological use. Usually, thermochemical heat treatments such as carbo-nit riding or bronzing have been used to improve the tribological behavior of AISI 1020 steel [1, 2]. However, the use of severe plastic_deformation (SPD) processes have shown important results in improving properties. Case hardening-also known as "pack carburizing"-involves putting carbon (or a combination of carbon and nitrogen) into the surface of the steel to make it a high carbon steel which can be hardened by heat treatment, just as if it were tool steel or any other high-carbon steel. Only the outer skin of the steel gets hard in case hardening, while the center remains tough and malleable. This makes for a strong part with a very tough, durable surface such as the hardness for this type of material [3, 4]. Carburizing is a case-hardening process by which carbon is added to the surface of low-carbon steel [5].

This results in carburized steel that has a high-carbon surface and a low-carbon interior. When the carburized steel is heat-treated, the case becomes hardened and the core remains soft and tough. Two methods are used for carburizing steel. One method consists of heating the steel in a furnace containing a carbon monoxide atmosphere. The other method has the steel placed in a container packed with charcoal or some other carbon rich material and then heated in a furnace [6, 7].

The major influencing parameters in carburization are the holding time, carburizing temperature, carbon potential and the quench time in oil[9]. The present work is focused on the effects of carburizing temperature and holding time on the mechanical properties of carburized mild steel [8].

II. EXPERIMENTAL WORK

The material used in this study was low carbon steel (AISI 1020) with chemical composition illustrate in table (1). The specimen cylindrical shape of diameter of (10mm) and length of (100mm).

Table 1 shows the chemical composition of mild steel (AISI 1020).

Element	C	Si	Mn	S	P	Ni	Cu	Cr	Fe
wt %	0.20	0.149	0.547	0.0271	0.0113	0.163	0.271	0.157	Bal

Table2 illustrate the carburizing temperature (950C^{o}) with constant time (90 minutes) and different questioning media for the carburizing process.

Table 2: The carburizing conditions

Condition	carburizing	carburizing	carburizing	carburizing	tempering
Temperature, °C	950	950	950	950	550
Holding time, minutes	90	90	90	90	30
Cooling medium	Water	Sea water	oil	air	Air

III. RESULTS AND DISCUSSION

The effect of carburizing process on the mechanical properties such as micro-hardness toughness, impact test, ultimate tensile strength and percentage elongation.

1. Analysis Of Micro-Hardness Test Results

From hardness test using hardness Vickers method, find the following results as shown in table (3) and the relationship between carburized samples No. and hardness Vickers. Results of hardness Vickers No. for carburized samples from out to core as shown in table (3,4,5 and 6). the relationship between Radius of specimen from out to core and hardness Vickers No. for carburized specimen at temperature of 950°C and durations time of 90 minutes.

Respectively, the comparison of hardness Vickers No. between the temperature of 950°C and durations time 90 minutes, that can be explained that the surface hardness for samples is decrease toward the center which is keeping its toughness and this means that the carburization treatment makes the part hard in outer surface resistant to scratching.

Table 3. Illustrate the hardness test values for the water quenched sample

Temperature C°	Time Minutes	Specimens	Hardness HV	quenching medium
950	90	A	224	water
950	90	B	198	water
950	90	C	123	water

Table 4. Illustrate the hardness test values for the oil quenched sample

Temperature C°	Time Minutes	Specimens	Hardness HB	quenching medium
950	90	A	125	OIL
950	90	B	126	OIL
950	90	C	118	OIL

Table 5. Illustrate the hardness test values for the sea water quenched sample

Temperature C°	Time Minutes	Specimens	Hardness HV	quenching medium
950	90	A	164.9	Sea water
950	90	B	166.9	Sea water
950	90	C	164.9	Sea water

Table 6. Illustrate the hardness test values for the air quenched sample

Temperature C°	Time Minutes	Specimens	Hardness HV	quenching medium
950	90	A	123	Air
950	90	B	128	Air
950	90	C	118	air

2. Analysis Of Impact Test Results.

The results which obtained from the impact test shown in table 7, it is clear that the analyses of impact are varied between the maximum value of the impact test for oil is 65J quenching and the minimum value of the impact test for water quenching is 45J for the soaking time of 90 minutes of mild steels at carburized temperature of 950^{0}C. So, it is concluded that the carburization process decreases the impact of the mild steels, this result is expected. It is also obtained from the impact test results that as the quenching media change from one to another, there is a large increase in the impact values from 65J to 45. This is also shown graphically in the figure 1.

Table 7.the result of impact test for different quenching media

Temperature C°	Time Minutes	Impact J	Impact angle	quenching medium
950	90	46	120	water
950	90	50	120	sea water
950	90	65	120	oil
950	90	60	120	air

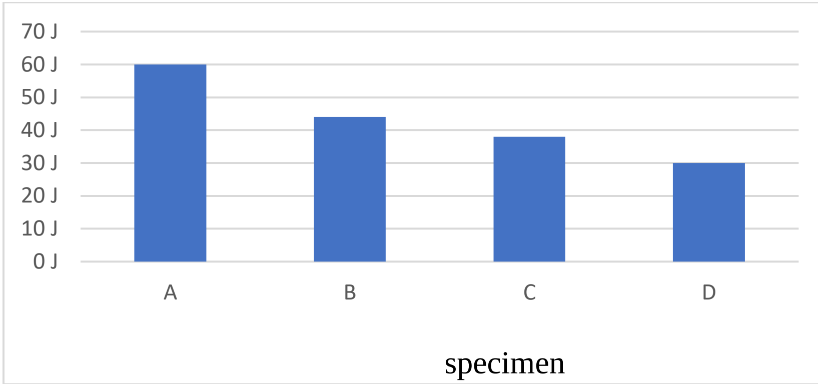

Figure 1. Illustrate the chart graph for the impact test for different quenching media

3. Analysis of tensile strength results

The effect of carburizing on the mechanical properties (ultimate tensile strength and hardness of the treated and untreated samples of AISI 1020 low carbon steel is shown in table (8,9,10 and11). The water quenched sample showed the highest tensile strength (230 N/mm^2), and the lowest tensile strength 219 N/mm^2 and the elongation (21%) and toughness. The decrease in tensile strength can be associated with the formation of soft ferrite matrix in the microstructure of the sample by water cooling. The mechanical properties of the water quenching sample is illustrated in figure 2.

Table.8. Tensile strength test values for the water quenched sample

Temperature C°	Time minutes	Specimen No	Rpy(Nmm^2	R(Nmm^2	Fm(kN)	Fb(kN)	Elongation
950°C	90	A	161	230	25.48	19.52	20%
950°C	90	B	156	219	24.76	12.29	20%
950°C	90	C	158	223	25.20	19.81	21%

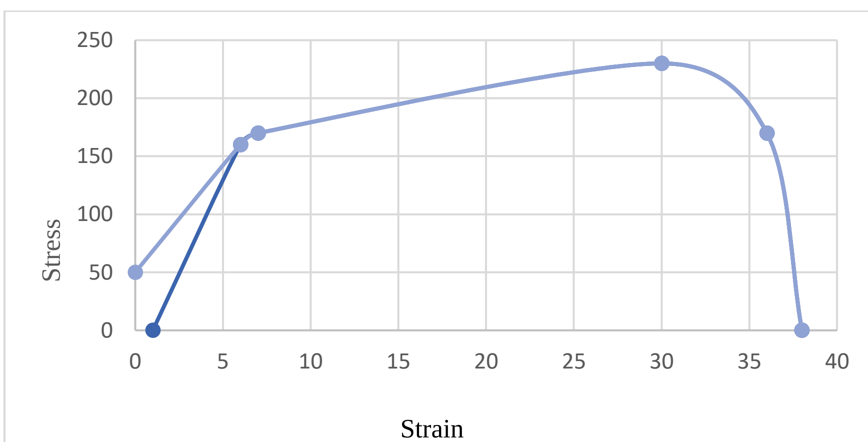

Figure 2. Illustrate the graph of tensile strength test for the water quenched sample.

The mechanical properties of the oil quenching sample revealed that it had the highest value of tensile strength 240 N/mm^2 and highest elongation 24% were obtained. This carburizing process increased the tensile strength. The results explain that the tensile strength varied directly with the carburization time and temperature. This concluded that with the increase in the carburization time and temperature, the tensile strength increases linearly.

Table.9. Tensile strength test values for the oil quenched sample

Temperature C^o	**Time minutes**	**Specimen No**	**Rpy(Nmm^2**	**R(Nmm^2**	**Fm(kN)**	**Fb(kN)**	**Elongation**
950^{o}C	90	A	163	240	25.48	24	24%
950^{o}C	90	B	160	236	24.76	21	22%
950^{o}C	90	C	159	227	25.20	19	21%

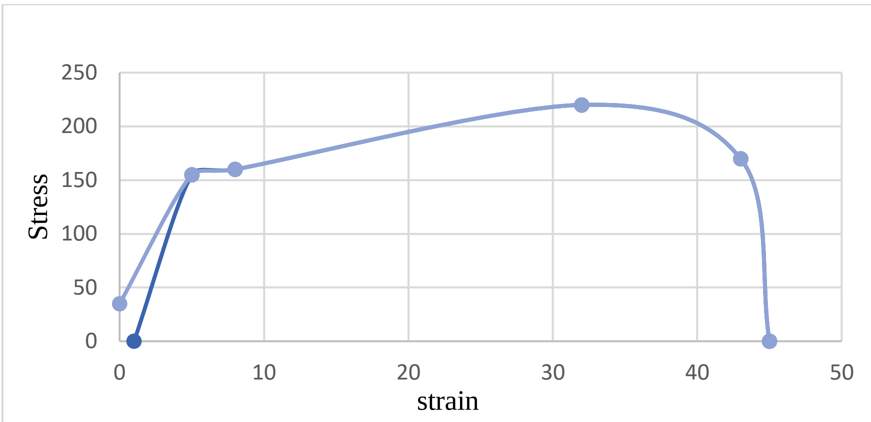

Figure 3. Illustrate the graph of tensile strength test for the oil quenched sample

The strength of sea water quenched sample value is 225 N/mm^2 and the elongation 20%. This was attributed to its relatively high C value, because carbon was the strongest element for martensitic strengthening in steel. To indicated that the contribution of the extra carbon to the strengthening effect should be significant.

Table.10. Tensile strength test values for the sea water quenched sample

Temperature C^o	**Time minutes**	**Specimen No**	**Rpy(Nmm^2**	**R(Nmm^2**	**Fm(kN)**	**Fb(kN)**	**Elongation**
950^{o}C	90	A	160	225	25.48	19.52	21%
950^{o}C	90	B	156	221	24.76	12.29	20%
950^{o}C	90	C	154	219	25.20	19.81	19%

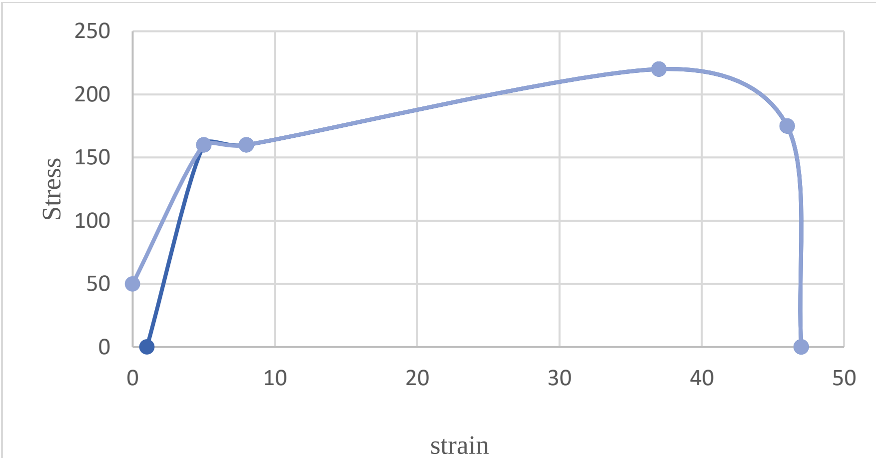

Figure 4. Illustrate the graph of tensile strength test for the sea water quenched sample

Figure 5 illustrate that the strength first increases to a maximum and then keeps on decreasing. The curve is almost overlapping, indicating that there is only a marginal effect due to the difference in the carburizing sequence. Maximum tensile strength of about 230 N/mm^2 occurs at tempering of 950°C for the air-quenched. It should be noted that ultimate strength variation has almost the same pattern as hardness variation. This confirms that there is an almost direct relationship between hardness and strength,

Table.11. Tensile strength test values for the air quenched sample

Temperature C°	**Time minutes**	**Specimen No**	**Rpy(Nmm²**	**R(Nmm²**	**Fm(kN)**	**Fb(kN)**	**Elongation**
950°C	90	A	161	230	25.48	19.52	20%
950°C	90	B	156	219	24.76	12.29	20%
950°C	90	C	158	223	25.20	19.81	21%

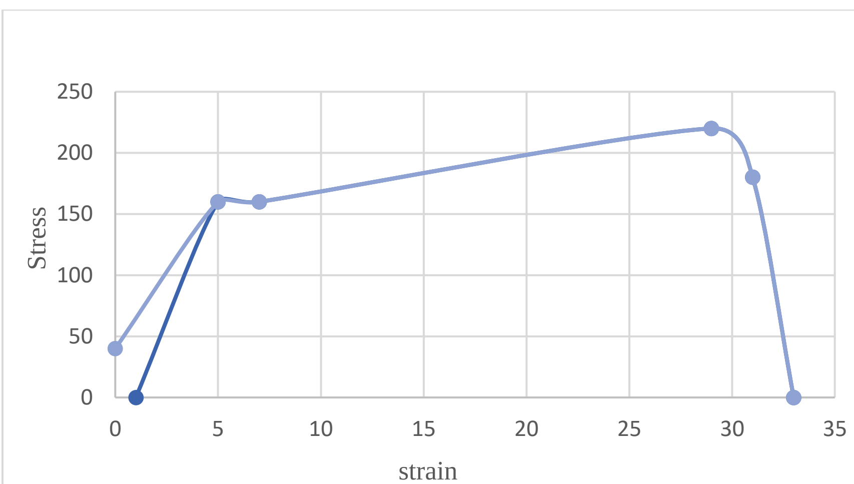

Figure 5. Illustrate the graph of tensile strength test for the air quenched sample

4. Microstructure Examination

Microstructure examination of the treated and untreated samples was carried out. Each sample was carefully grounded progressively on emery paper in decreasing coarseness. The grinding surface of the samples were polished using Al203 carried on a micro clothe. The crystallinestructure of the specimens was made visible by etching using solution containing 2% Nitric acids and 98% methylated spirit on the polished surfaces. Microscopic examination of the etched surface of various specimens was undertaken using a metallurgical microscope with an inbuilt camera through which the resulting microstructure of the samples were all photographically recorded with magnification of 400. Figure 6 showing optical micrographs of water quenching sample at carburized at 950°C for 90 minutes.

Figure 7 shows the microstructure and the transform the surface of low carbon steel to the core after carburized and quenched. The case with dark and bright structure is martensite between case and core are martensite and ferrite. It has been observed that variety of case hardening range from(12-36 µm) as shown in figure (7) and this may due to irregular in temperature graded. This indicates a lack of homogeneity for the carburizing layer. It can explain due to forming of a layer martensite in some areas and the pearlite and martensite in other areas. While the variation in core is very few due to the reason have not to change the crystal structure from ferrite and pearlite. While at the core, the variety is very little between different positions in core, this may be due to the microstructures remain the same as the original, pearlite and ferrite

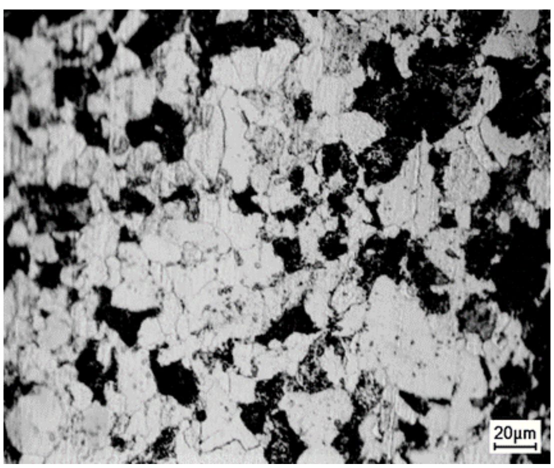

Figure 6

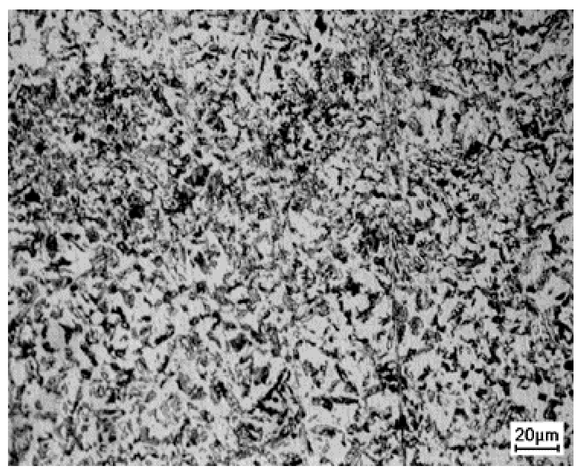

Figure 7

Figure 8 showing optical micrographs of oil quenching sample at carburized at 950°C for 90 minutes. As it can be seen in figure 13, the ferrite grains had undergone complete recrystallization and these constituted the major portion of the microstructure the carburized low carbon steel with stress free matrix. At 950^{o}C the deformed structure was fully homogenized and during the slow cooling from austenizing range to room

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temperature the final microstructure consisted of fine ferrite grains in which the pearlite was more uniformly distributed.

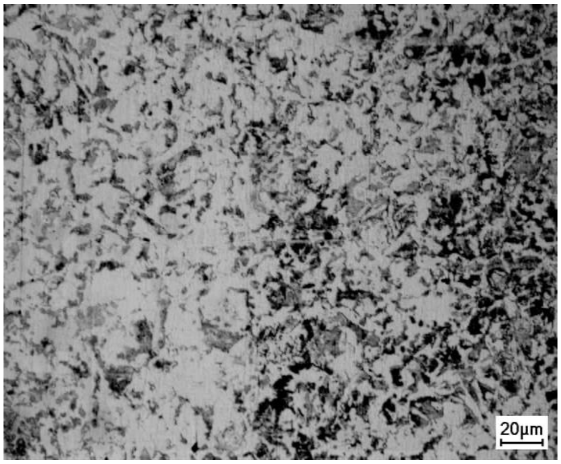

Figure 9

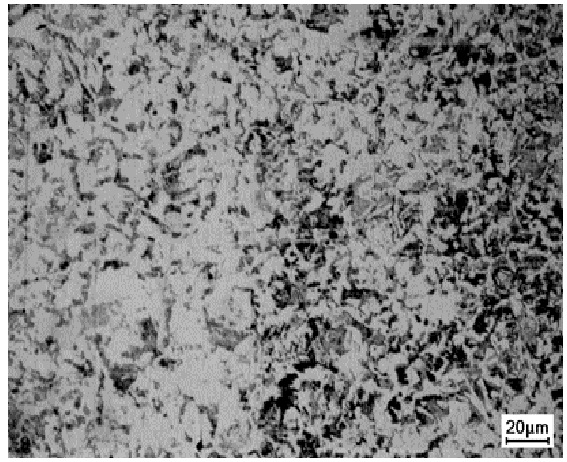

Figure 10

Figure 9 shows the microstructure of the carburized sample at temperature of 950°C for 90 minutes. The carburized sample showed that the shape and size of the original austenite grains were influenced to a remarkable extent. The sample revealed a pearlitic matrix in which shorter graphite flakes than in the carburized sample at temperature of 950°C for 90 minutes existed. It was observed that there were many short graphite flakes surrounded with patches of uniformly distributed pearlite grains.

Figure 10 shows the massive martensite structure of carburized sample at temperature of 950°C for 90 minutes, when the carburized low carbon steel is rapidly quenched from its austenite temperature to room temperature, the austenite will decompose into a mixture of some low carbon steel, martensite and fewer pearlite as a result of this microstructure which is hard, hence, a highly recrystallized ferrite grains (white dotted areas) with some secondary graphite site was observed.

IV. CONCLUSIONS

This study aimed to experimental study of pack carburizing of carbon steels (AISI 1020) by using two parameters (holding time and carburizing temperature. The low carbon steel AISI 1020 rod was examined at temperature of 950°C for 90 minutes.

The mechanical properties such as tensile strength, impact and hardness of low carbon steels were found to be strongly influenced by the process of carburization. The results shown the comparing between different quenching media for carburization temperatures of 950°C for 90 minutes, it reveals that the highest tensile strength value of 240 N/mm^2 and highest elongation 24% was obtained from oil quenching samples and the lowest value 225 N/mm^2 and lowest elongation 19% was obtained from sea water quenching sample.

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