IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

Impact Of Carburizing Parameters On The Mechanical Properties Of Carbon Steel Alloy (AISI 1025)

[1] S. Dabbashi

[1]Faculty of Engineering, Sabratha University, Libya

Abstract: This paper investigates the effect of temperature and soaking time of carburizing process on the mechanical properties of low carbon steel alloy. This practical study includes defining the process conditions, which leads to achieve the optimum combination of mechanical properties.

The pack carburizing process was carried out to investigate their effect on mechanical properties of the surface of low carbon steel AISI 1025 using different temperatures; (850, 900, and 950˚C) with different soaking time cases; (1,2,3 and 4 hours). The micro hardness of the surface of each sample was measured and impact tests was conducted. The results showed the formation of a significant hardened case due to the formation of martensite, while the core retained its original ferrite-carbide microstructure and was softer and tougher. Tempering was carried out at 500ºC for one hour in order to stress relieve the quenched samples and to increase the toughness of the steel case with an acceptable reduction in hardness.

The mechanical properties of AISI 1025 steels were found to be strongly influenced by the carburizing temperature and soaking time with different weight for each factor. It was concluded that the optimum combination of mechanical properties is achieved at the carburizing temperature of 900 ºC and time of 4 hours.

Index Terms **- carburizing, carbon steel, hardness, martensite, soaking time.**

1. INTRODUCTION

Low-carbon steel used in many mechanical components is tough, but also soft and ductile. However its surface is susceptible to battering and wear. Generally, surface treatment processes will apply to produce ductile but tough components with hard surface to resist wear [1].

Case hardening is ideal for parts that require a wear-resistant surface and must be tough enough internally to withstand heavy loading and vibration. Steel types best suited for case hardening are the low-carbon and low-alloy series because in high-carbon steels the hardness penetrates the core and causes brittleness. In case hardening the surface of the metal changes chemically by introducing a high carbide or nitride content where the core remains chemically unaffected. When heat-treated, the high-carbon surface responds to hardening, and the core remains tough. Typical applications for case hardening are gear teeth, cams, shaft, bearing, fasteners, pins, automotive clutch plates, tools, and dies [2].

Case hardening also known as "pack carburizing" that involves putting carbon (or a combination of carbon and nitrogen) into the surface of the steel in high temperature to make it 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 [3].

Automobile components such as rack and pinion, gears, cam shaft valve rocker shafts and axles, which require high fatigue resistance, are normally case hardened by carburizing. The carburizing furnaces are either gas fired or electrically heated. The carburizing temperature varies from 870 to 940 ºC the gas atmosphere for carburizing is produced from liquid or gaseous hydrocarbons such as propane, butane or methane.

The study of process parameters in metals during heat treatment has been a considerable interest for many years. However, there has been relatively little work on process variables during the surface hardening process since controlling parameters in carburization is a complex issue. The major influencing parameters in carburization are the holding time, carburizing temperature, carbon potential and the quench time in oil. The present work focuses on the effects of carburizing temperature and holding time on the mechanical properties of carburized mild steel (AISI 1025).

2. LITERATURE BACKGROUND

2.1 Classification of Carbon Steel Alloys

There are several systems by which steel alloys can be classified. For example, steel alloys can be classified according to; the major applications (e.g. heat-resistant, corrosion-resistant, structural, or tool steels), production or finishing methods (wrought, cast, killed, semi killed. However, steel alloys are more commonly classified based on their chemical compositions. In this context, steel alloys are classified according to the percentage of their carbon contents (e.g. low, medium or high carbon alloys) or to the total amount of alloying elements additions (e.g. plain, micro, low, medium or high alloyed steels) [4].

2.1.1 Plain carbon steel

Plain carbon steel is essentially an alloy of iron-carbon, which usually contains less than 0.2 % wt. carbon. However, manganese and traces amounts of other residual elements may also present after the refining processes of plain carbon steel. According to the American Iron and Steel [5].

In general, plain carbon steel usually possesses a good formability and weldability with adequate levels of toughness and ductility and good hardness and wear resistance. On the other hand, the aging response of plain carbon steel to hardening heat treatment "hardenability", without having significant loss in toughness and ductility, is also known to be limited due to its lower carbon contents. Further, the mechanical properties of plain carbon steel can be highly deteriorated (loss of strength and impact resistance) in severe working conditions (e.g. high/low-temperature or corrosive environments). Plain carbon steel is also known to exhibit a poor corrosion resistance at aqueous environments and high oxidizing tendency at elevated temperatures.

2.1.2 Low carbon steel

Mild steel is the most common form of steel as its price is relatively low while it provides material properties that are acceptable for many applications. Low carbon steel contains approximately 0.05–0.15% carbon and mild steel contains 0.16–0.30% carbon. Mild steel has a relatively low tensile strength, but it is cheap and malleable; surface hardness can be increased through carburizing. It is used where ductility or softness are important

2.1.3 Medium carbon steels

Commercial medium carbon steels with 0.3% - 0.55% C, are relatively cheap engineering alloys, which are characterized by desirable mechanical properties such as high strength and toughness.

Consequently, medium carbon steels are the most commonly engineering alloys steel that are applied. Typical Applications Axles, bolts, connecting rods, studs, rams, pins, rolls, spindles, ratchets, crankshafts, torsion bars, sockets, worms, light gears, guide rods etc. Medium carbon steel whose carbon content is 0.45% has structure as fine lamellar pearlite (dark) and ferrite (light) as shown in Figure (2.1) [6].

Figure 2.1: Microstructure of 1025 Steel Bar [23]

2.1.4 High carbon steel

Carbon content in this type ranges from 0.50 to 1.05%. There are also high alloy steels, with approximately 5–10 % by weight consisting of alloying elements other than carbon. Though high carbon steels are used in the smallest amounts, these are specialty steels, often referred as tool steels, which are generally heat treated. Adding alloying elements can increase the depth of hardening and therefore larger sections can be heat treated to reach required hardness and strength.

Figure. 2.2 shows, the Fe-C equilibrium diagram in which various structure (obtained during heating and cooling), phases and microscopic constituents of various kinds of steel and cast iron are depicted. The main structures, significance of various lines and critical points are discussed as under.

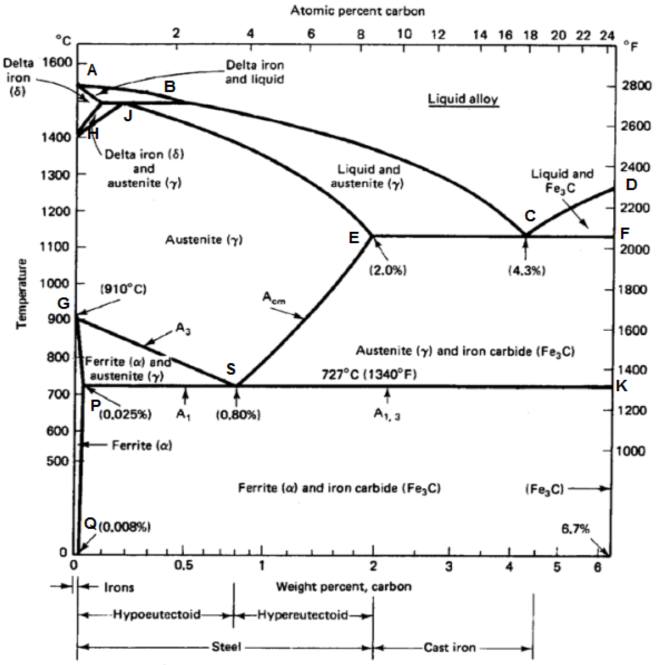

Figure. 2.2: Fe-C Equilibrium Diagram

2.2 Heat Treatment of Steel

Heat treatment is heating and cooling process of a metal or an alloy in the solid state in order to change their properties such as softness, hardness, tensile-strength, toughness etc. It consists of three main phases namely; (i) heating of the metal (ii) soaking of the metal and (iii) cooling of the metal. The theory of heat treatment is based on the fact that a change takes place in the internal structure of metal by heating and cooling which induces desired properties in it. The rate of cooling is the major controlling factor. Rapid cooling the metal from above the critical range, results in hard structure. Whereas very slow cooling produces the opposite affect i.e. soft structure [7].

2.2.1 Hardening

Hardening is a process of cooling a metal at a rapid rate. This is most often done to produce a martensite transformation. In ferrous alloys, this will often produce a harder metal. To harden by quenching, a metal (usually steel or cast iron) must be heated above the upper critical temperature and then quickly cooled.

Liquids may be used for rapid cooling, due to their better thermal conductivity, such as oil, water. Upon being rapidly cooled, a portion of austenite (dependent on alloy composition) will transform to martensite, a hard, brittle crystalline structure. The quenched hardness of a metal depends on its chemical composition and quenching method [8].

For every different steel alloy there is a specific relationship between its mechanical properties and its cooling rate. A steel alloy that has a high hardenability is one that hardens, or forms martensite, not only at the surface but also to a large degree throughout the entire interior. In other words, hardenability is a measure of the degree to which a specific alloy may be hardened [9].

2.2.2- Tempering

Is a process in which previously hardened or normalized steel is usually heated to a temperature below the lower critical temperature and cooled at a suitable rate, primarily to increase ductility and toughness, but also to increase the grain size. Steels are tempered by reheating after hardening to obtain specific values of mechanical properties and also to relieve quenching stresses and to ensure dimensional stability. Tempering usually follows quenching from above the upper critical temperature; however, tempering is also used to relieve the stresses and reduce the hardness developed during welding and to relieve stresses induced by forming and machining.

2.2.3- Case hardening

Case hardening is a simple method of hardening steel. This technique is used for steels with low carbon content. Carbon is added to the outer surface of the steel to a depth of approximately 0.03mm. This hardening process includes a wide variety of techniques used to improve the mechanical properties and wear resistance of surface without affecting the tough interior of the part. This combination of hard surface and resistance and breakage upon impact is useful in parts such as a cam or ring gear that must have a very hard surface to resist wear, along with a tough interior to resist the impact that occurs during operation. Furthermore, the surface hardening of steels has an advantage over through hardening because less expensive low-carbon and medium carbon steels can be surface hardened without the problems of distortion and cracking associated with the through hardening of thick sections. One advantage of this method of hardening steel is that the inner core is left untouched and so still processes properties such as flexibility and is still relatively soft.

2.2.4- Carburization

Carburization is simply defined as the addition of carbon to the surface of low carbon steel at high temperature (generally between 850-950o), which is most widely used for surface hardening. It consist of enrichment of surface layers of low carbon / mild steel (C less than equal to 0.30%) with carbon up to 0.8 % to 1% by this way the good wear and fatigue resistance is superimposed on a tough low carbon steel core. usually have base-carbon contents of about 0.2%, with the carbon content of the carburized layer generally being controlled at between 0.8 and 1% C. However, surface carbon is often limited to 0.9% because too high carbon content can result in retained austenite and brittle martensite [10]. Figure 2.2 shows the microstructure of surface carburized sample. The brown area is pearlite that represents an area of carbon pickup.

Figure 2.2: Microstructure of surface carburized sample

Types of carburization:-

1. Solid carburization
2. Gaseous carburization
3. Vacuum carburization
4. Plasma carburization and salt bath carburization

Solid carburization

The solid or pack carburization involves heating the steels parts embedded in powdery mixture of 85% coal and 15% $BaCO_3$ at a temperature in range 900-950 degree Celsius. The residual air in the box combines with carbon to produce Co gas. Carbon monoxide gas is unstable at the process temperature and thus decomposes upon contacting the iron surface by reaction.

$2CO = C + CO_2$

The atomic carbon enters the steel through the following reaction.

$Fe+2CO = Fe(C) + CO_2$

The addition of $BaCO_3$ enhances the carburizing effect. $BaCO_3$ decomposes and evolves CO_2 which react with coal to form carbon monoxide. $C+CO_2 = 2CO$ solid carburization is a time consuming procedure. Typical carburizing time to obtain a case depth of 1-2 mm is around 6-8 hours. Higher speed can be obtained by carburizing in gaseous medium [11].

Gaseous carburization

The gaseous carburization is carried out at temperature in range 900-950 degree Celsius. Carbon monoxide and various hydrocarbon are used as a carburizers. They decompose at the process temperature and form atomic carbon according to the following reaction.

$2CO = C + CO2$

$Cn + Hm = nC + mH$

It is very essential to accurately control the composition and flow rate of carburizing gas. Gas carburization is the main process in mass production, while the simpler solid carburization is economically more effective in small scale production.

Vacuum carburization

In efforts required to simplify the atmosphere, carburizing in an oxygen-free environment at very low pressure (vacuum carburizing) has been explored and developed into a viable and important alternative. Although the furnace enclosure in some respects becomes more complex, the atmosphere is greatly simplified. A single-component atmosphere consisting solely of a simple gaseous hydrocarbon, for example methane, may be used. Furthermore, because the parts are heated in an oxygen-free environment, the carburizing temperature may be increased substantially without the risk of surface or grain-boundary oxidation. The higher temperature permitted increases not only the solid solubility of carbon in the austenite but also its rate of diffusion, so that the time required to achieve the case depth desired is reduced.

Although vacuum carburizing overcomes some of the complexities of gas carburizing, it introduces a serious new problem that must be addressed. Because vacuum carburizing is conducted at very low pressures, and the rate of flow of the carburizing gas into the furnace is very low, the carbon potential of the gas in deep recesses and blind holes is quickly depleted.

Unless this gas is replenished, a great non uniformity in case depth over the surface of the part is likely to occur [12].

Plasma and salt bath carburization

A method that overcomes both of these major problems yet retains the desirable features of a simple atmosphere and permissible operating temperature is plasma or ion carburizing.

These methods introduce carbon by the use of gas (atmospheric-gas, plasma, and vacuum carburizing), liquids (salt bath carburizing), or solid compounds (pack carburizing). All of these methods have limitations and advantages, but gas carburizing is used most often for large-scale production because it can be accurately controlled and involves a minimum of special handling.

Vacuum carburizing and plasma carburizing have found applications because of the absence of oxygen in the furnace atmosphere. Salt bath and pack carburizing arc still done occasionally, but have little commercial importance today [13].

2.2.5 Nitriding

Nitriding is a surface-hardening heat treatment that introduces nitrogen into the surface of steel at a temperature range (500 to 600°C) while it is in the ferrite condition. Thus, nitriding is similar to carburizing in that surface composition is altered, but different in that nitrogen is added into ferrite instead of austenite. Because nitriding does not involve heating into the austenite phase field and a subsequent quench to form martensite

$NH3 = 3H + N$

The atomic nitrogen thus formed diffuses into the steel,the nitride layer increases the corrosion resistance of steel in moist atmosphere

Practically only alloy steels are subjected to nitriding [14].

2.2.6 Carbonitriding and cyaniding

Carbonitriding is a modified form of gas carburizing, at a temperature range between 850 – 900 Co.

The modification consists of introducing ammonia into the gas carburizing atmosphere to add nitrogen to the carburized case as it is being produced. Nascent nitrogen forms at the work surface by the dissociation of ammonia in the furnace atmosphere; the nitrogen diffuses into the steel simultaneously with carbon. Typically, carbonitriding is carried out at a lower temperature and for a shorter time than is gas carburizing, producing a shallower case than is usual in production carburizing.

In its effects on steel, carbonitriding is similar to liquid cyaniding. Because of problems in disposing of cyanide-bearing wastes, carbonitriding is often preferred. In terms over liquid cyaniding of case characteristics, carbonitriding differs from carburizing and nitriding in that carburized cases normally do not contain nitrogen, and nitrided cases contain nitrogen primarily, whereas carbonitrided cases contain both [15].

2.2.7 Flame hardening

This is the simplest form of heat treatment process. The workpiece is heated by means of a gas torch (oxy-acetylene flame) followed by a water spray on the heated parts. The heat from the torch penetrates only to small depth on the surface and consequently the steel in the outer layers gets quenched to martensite and bainite. Case depth up to 3mm can be achieved by this process.

This process can be followed by heating to about 200 0 C for the purpose of stress relieving. The surface hardness is not appreciably affected by these reheating operations. This process is suitable for any complex shape of component such as crank shaft, large gears, cam, etc. with carbon This process can be followed by heating to about 200 0 C for the purpose of stress relieving. The surface hardness is not appreciably affected by these reheating operations. This process is suitable for any complex shape of component such as crank shaft, large gears, cam, etc. with carbon percentage ranging from 0.3 to 0.6%. Though high carbon steel can also be flame hardened, greater care is needed to avoid surface cracking [16].

2.2.8 Induction hardening

This is similar to flame hardening process where the heating of component surface is achieved by the electromagnetic induction. The workpiece such as crank shaft is enclosed in the magnetic field of an alternating (10 kHz to 2MHz) current conductor to obtain case depth of the order of 0.25 to 1.5 mm. This causes induction heating of the workpiece, the heated workpiece then quenched by water spray. The induction heat penetrates only outer surface of the workpiece as a result only the skin gets hardened by the quenching process. The whole process is very fast (5s to 4 minutes) and result in hard outer surface (50 to 60 Rc) [17].

3. Experimental work

3.1 Material and method

Sample of low carbon steel (AISI 1025) with round bar of 12 mm diameter and 10 m long was purchased from a local market. The chemical composition of the steel sample was determined as given in Tables 3.1. Samples were subjected to different period of soaking time (1,2,3 and 4 hours) and a temperature of 850oC,900oC and 950oC. The heat treatment which have been used in this study was pack carburizing and then the samples were subjected to tempering of 550oC for one hour accordance to ASM International Standards.

3.1.1 Materials Selection

The chemical composition of low carbon steels AISI (1025) by (wt %) is given in table (3.1).

Table 3.1: Chemical composition of mild steel AISI (1025)

Element	C	Si	Mn	S	P	Ni	Cu	Cr	Fe
wt %	0.25	0.149	0.547	0.0271	0.0113	0.163	0.271	0.157	Bal

3.2 Heat Treatment

Samples of 1cm length were cut from the AISI (1025) steel, 12 mm Ø rods and subjected to the following heat treatment processes (carburizing and tempering) using a Gallen Kamp laboratory electrical furnace according the conditions presented in Table 3.2.

Table 3.2: Heat treatment conditions

Condition	Carburizing	Carburizing	Carburizing	Carburizing	Tempering
Temperature, °C	850	850	850	850	500
Temperature, °C	900	900	900	900	500
Temperature, °C	950	950	950	950	500
Holding time, hour	1	2	3	4	1
Cooling medium	Oil	Oil	Oil	Oil	Air

3.2.1 Quench Hardening

Samples were loaded into a pre-heated furnace at 600˚C and then rapidly heated to the ferrite + pearlite → austenite transformation region at 850˚C, 900˚C and 950˚C. Samples were allowed to be soaked at this temperature for different periods of time; 1, 2, 3 and 4 hours and then rapidly removed from the furnace and quenched at room temperature.

3.2.2 Tempering

Some of the water quenched samples were reheated to 500˚C for one hour, then removed from the furnace and allowed to be air cooled to room temperature on a ceramic base.

3.3 Coal selection and preparation

The vasundhara coal is taken for this purpose and it is crushed into -52 mesh size with the help of crusher and test sieve. About 4 kg of coal is prepared for this purpose and this coal is used for the pack carburization of the mild steel samples.

3.3.1 Proximate analysis of Vasundhara coal

Analysis for moisture, volatile matter, ash and fixed carbon contents in vasundhara coal were carried out on samples ground to pass through -72 mess B.S. test sieve by the method given below.

Moisture determination

One gram of air dried coal powdered sample of size -72mess was taken in a borosil glass crucible and then kept in the air oven maintained at the temperature 110°C.The sample was soaked at this temperature for one hour and then taken out from the furnace and cooled. Weight loss was recorded using an electronic balance. The percentage loss in weight gave the percentage moisture content in the sample.

Volatile matter determination

One gram of air dried coal powdered sample of size -72 mess was taken in a volatile matter crucible (made of silica) and kept in the muffle furnace maintained at the required temperature of 925°C.The sample was soaked at this temperature for seven minutes and then crucible was taken out from the furnace and cooled in air. Weight loss in the sample was recorded by using an electronic balance. The percentage loss in weight – moisture present in the sample gives the volatile matter content in the sample.

Ash determination

One gram of air dried powdered sample of size -72mess was taken in a shallow silica disc and kept in the muffle furnace maintained at the temperature of 775-800°C.The sample was kept in the furnace till complete burning. Weight of ash formed was noted down and the percentage ash content in the sample was determined.

Fixed carbon determination

The fixed carbon content in the sample was determined by using the following formula:
Fixed Carbon Content (Wt. %) =100-Wt %(Moisture + Volatile matter + Ash)

Carburization of mild steel samples

The different test specimen samples made up of low carbon steel AISI (1025) for mechanical and were subjected to pack carburization treatment as shown in figure 3.1. In this process the low carbon steel AISI (1025) samples were placed on the thick bed of carburizer kept in a stainless steel container and fully covered from all sides, the top of the container was covered with a steel plate. The container was then introduced into the muffle furnace and then maintained at the required carburization temperature of 850˚C,900˚C and 950ºC with different times of 1hr, 2hr, 3hr, 4hr by this way the mild steel samples gets carburized. The hardening was affected immediately after carburization.

Fig. 3.1: Carburizing process

3.3 Determination of Mechanical Properties

Mechanical properties of the treated and untreated samples were determined using standard methods. For hardness testing, oxide layers formed during heat treatment were removed by stage-grinding and then polished. Average Vickers Hardness (VH) readings were determined by taking three hardness readings at different positions on the samples, using a Vickers hardness tester.

3.3.1 Hardness testing

For hardness testing, samples of 1 cm length were cut from the AISI (1025) 12 mm Ø rods, and subjected to the various heat treatments regimes employed in the present study (i.e. hardening, tempering, normalizing and annealing). Prior to hardness measurements, the surface of all tested samples were cleaned with emery papers, washed with ethanol and air dried to remove thick oxides and any hydrocarbon deposits that may have formed on the surface during heat treatment. Vickers hardness values for each of the heat treated samples were then measured at the center of the top side of the cylindrical samples using a digital Mitutoyo hardness tester model MVK-HVL equipped with VL-101 video line micrometer. All hardness measurements were conducted at room temperature under a static load of 1 kg, which was maintained for 15 seconds. The average of 7 measurements for each type of heat treated samples was calculated and taken as a hardness value

3.3.2 Impact testing

Impact tests are designed to measure the resistance to failure of a material to a suddenly applied force. The test measures the impact energy, or the energy absorbed prior to fracture. Test samples (10*10*55 mm) according to the design as shown in Figure 3.2 were machined using milling CNC machine. Three specimens of each regime as shown in figure (3.3) were tested to ensure the repeatability from which the average is calculated.

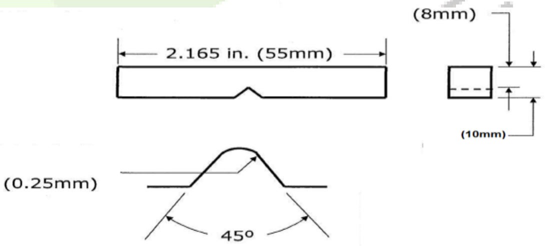

Figure 3.2: Impact test specimen dimensions

Figure 3.9: Specimen for impact test

4. Results

4.1 Proximate analysis of Vasundhara coal

The results of proximate analysis of vasundhara coal is shown in table (4.1). This analysis is performed to find out the percentage (wt %) of moisture, volatile matter, ash and carbon content in the given coal sample. From the analysis it has been found that vasundhara coal content 31% of carbon, 5% of moisture, 29% of volatile matter and 35% of ash.

Table 4.1: Proximate analysis of Vasundhara coal

Coal type	Proximate analysis (Wt%)			
	Moisture	Volatile matter	Ash	Fixed carbon
Vasundhara coal	5	29	35	31

4.2 Results of hardness test

In general heat treatment and carburization of low carbon steel AISI 1025 resulted in an increase in hardness. The tests results of hardness is shown in tables (4.2-4.4) and graphs (4.1-4.3).

Table 4.2- Hardness test values for 850^{o}C

Temperature	Time	Specimen No	Hardness (HV)
850^{o}C	1hr	A	252.34
850^{o}C	1hr	B	253.4
850^{o}C	1hr	C	254
850^{o}C	2hr	A	253.45
850^{o}C	2hr	B	255.35
850^{o}C	2hr	C	256
850^{o}C	3hr	A	253
850^{o}C	3hr	B	257.4
850^{o}C	3hr	C	258.6
850^{o}C	4hr	A	263.25
850^{o}C	4hr	B	264.76
850^{o}C	4hr	C	266

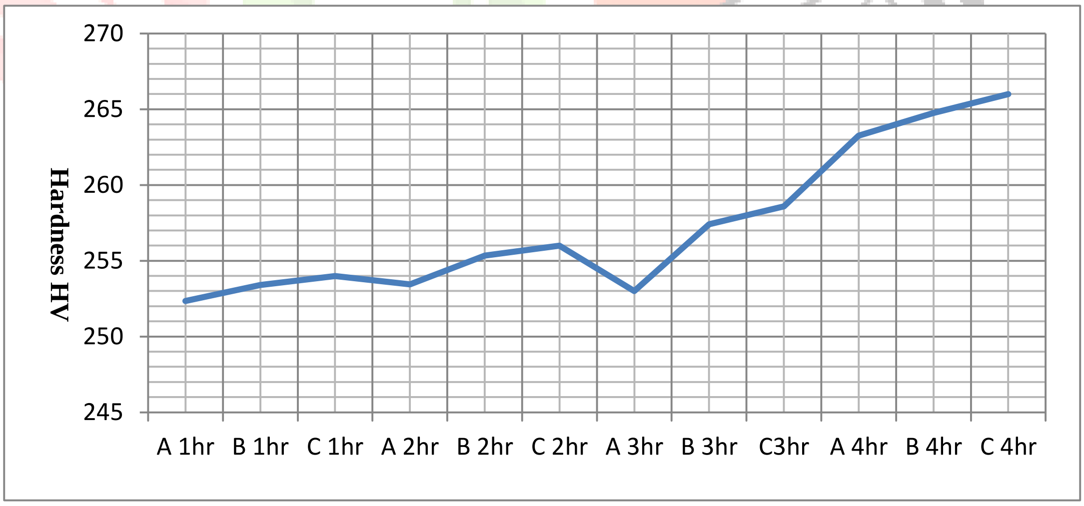

Figure 4.1: Hardness test values for 850^{o}C and times of 1,2,3 and 4 hours.

Table 4.2- Hardness test values for 900°C

Temperature	Time	Specimen	Hardness
900°C	1hr	A	277
900°C	1hr	B	279.3
900°C	1hr	C	280.6
900°C	2hr	A	282.4
900°C	2hr	B	283
900°C	2hr	C	285
900°C	3hr	A	284.2
900°C	3hr	B	286
900°C	3hr	C	288
900°C	4hr	A	288.6
900°C	4hr	B	289
900°C	4hr	C	290.6

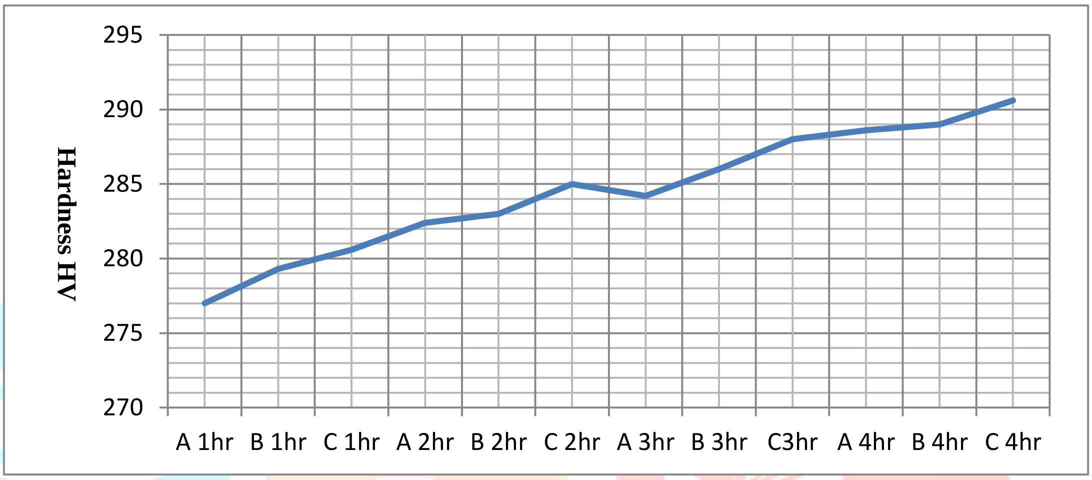

Figure 4.2 Hardness test values for 900°C and times of 1,2,3 and 4 hours.

Table 4.4 Hardness test values for 950°C

Temperature	Time	Specimen	Hardness
950°C	1hr	A	291
950°C	1hr	B	292.7
950°C	1hr	C	293.56
950°C	2hr	A	293.56
950°C	2hr	B	295
950°C	2hr	C	296.4
950°C	3hr	A	297
950°C	3hr	B	298.23
950°C	3hr	C	299
950°C	4hr	A	299.65
950°C	4hr	B	299.75
950°C	4hr	C	299.83

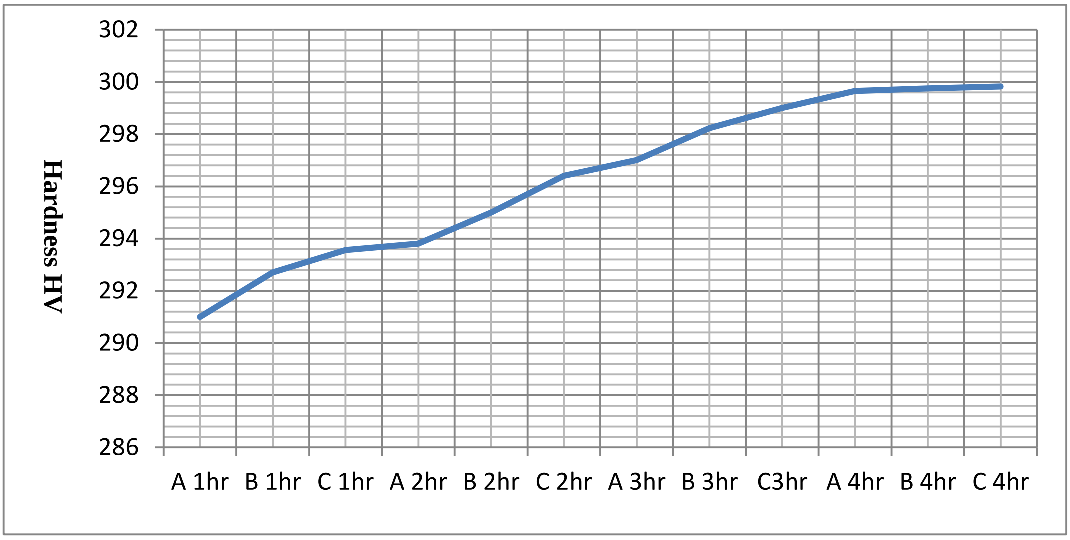

Figure 4.3- Hardness test values for 950°C and times of 1,2,3 and 4 hours.

The results as shown in tables (4.2 to 4.4) and figures (4.1 to 4.3) present the relationship between carburizing temperature and time, and hardness Vickers numbers for temperatures 850oC, 900oC, and 950oC, with time of 1,2,3 and 4 hours. As shown in figure 4.1 it can be seen that the highest hardness was obtained at 850oC was for 4 hours (266 HV). This has occurred due to the longer soaking time which gives the carbon an opportunity to penetrate into the surface. This can be applied on 900oC and 950oC temperatures as shown in figures 4.2 and 4.3.

The case depth increases with rise in carburization temperature and time. The best carburizing temperature was 950°C where the steel surface absorbs carbon at a faster rate and the rate at which it can diffuse inside producing super saturated case which may produce cracks during quenching. In pack carburization it is difficult to control exactly the case depth because of many factors affecting it, such as density of packing amount of air present inside the box.

Carburizing time is very long process, as carburizing boxes as well as bad heat conducting carburizing materials need to be heated. It is difficult to control the surface carbon and the carbon gradient; it is difficult to control the case depth exactly.

4.3 Results of impact test

From the results of the impact test as shown in tables (4.6-4.8) and figure (4.4) it can be seen that the impact values are varied between 35.7J and 88J.The highest value occurred at the soaking time of 1 hour at temperature of 850oC and lowest for the soaking time of 4 hours at temperature of 950oC. Therefore, it is concluded that the carburization process decreases the impact value of low carbon steel. This result is expected and it is also supported from the literature [18]. It is also obtained from the impact test results that as the soaking time increases from1 hour to 4 hours there is a large decrease in the impact values from 88J – 35.7J. This means that the longer soaking time the lower impact value.

Table 4.6- Impact test results for 850oC

Soaking	Impact (J)
1hr	88
2hr	76.3
3hr	68
4hr	63

Table 4.7- Impact test results for 900oC

Soaking	Impact (J)
1hr	60.7
2hr	57.7
3hr	54.3
4hr	52.2

Table 4.7- Impact test results for 950oC

Soaking	Impact (J)
1hr	49.3
2hr	45.5
3hr	42.5
4hr	35.7

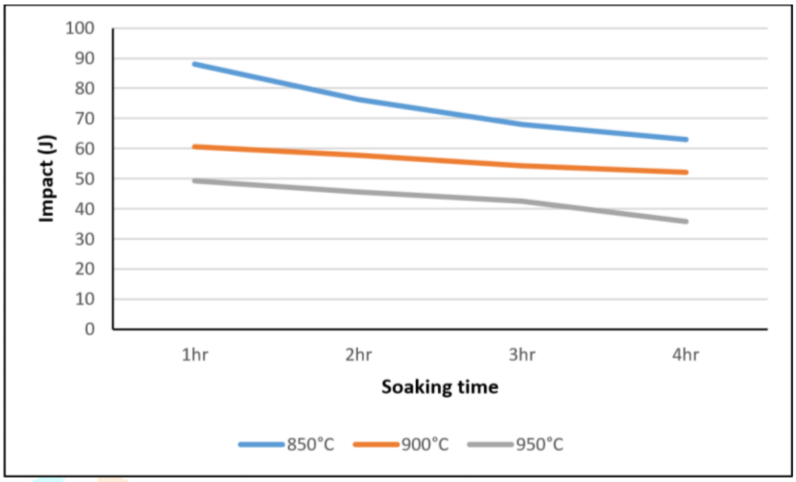

Figure 4.4- Impact test values for 850°C, 900°C and 950°C

5. Conclusions

The influence of case hardening on the mechanical properties of the low carbon steel (AISI 1025) was investigated. The main conclusions of this investigation can be summarized in the following points:

1. The mechanical properties of mild steels were found to be strongly influenced by the process of carburization, carburizing temperature and soaking time at carburizing temperature.
2. Some conversion of carbon-enriched skin austenite to martensite can be inferred from the increase in hardness in most of the samples;
3. The carburization process decreases the impact energy (toughness) of the mild steels. And the toughness is decreases with increase in the carburization temperature.
4. It found that the highest temperature was used achieved the highest surface hardness with remain a tough inside.
5. The increase in temperature of carburization lead to increases diffusivity of carbon into the surface.
6. Optimum combination of mechanical properties is achieved at the carburizing temperature of 900°C soaked for 4 followed by oil quenching and tempering at 500°C for 1 hour.

REFERENCES

[1] Parrish G., The Influence of Microstructure on the Properties of Case-Carburized Components, American Society for Metals, 1980.

[2] Oyetunji A. and Adeosun S.O., Effects of Carburizing Process Variables on Mechanical and Chemical Properties of Carburized Mild Steel, Journal of Basic and Applied Sciences, 2012.

[3] Aramide F O., Pack Carburization of Mild Steel, using Pulverized Bone as Carburizer: Optimizing Process Parameters, Leonardo Electronic Journal of Practices and Technologies, 2010.

[4] Lakhtin Y.M. Engineering Physical Metallurgy and Heat Treatment. Mir Publ, 1977.

[5] Oberg, E. Machinery’s Handbook, 25th ed., Industrial Press Inc.,1996.

[6] Metals handbook 9th ed., American society for metals, vol.9, 1985.

[7] Celik O., Ahlatci H. and Kayali E. S. , High temperature tensile and abrasive wear characteristics of As – cast ductile iron, ISIJ International, 43 (2013) : 1274 – 1279.

[8] John V. “Introduction to Engineering Materials” Macmillan Education LTD,1992.

[9] Thomas G. Digges, Samuel J. Rosenberg, and Glenn W. Geil .Heat Treatment and Properties of Iron and Steel.1966.

[10] Ipek R. and Selcuk B, The dry wear profile of cam shaft, Journal of material processing technology, 168 (2015): pp. 373–376.

[11] Yamada S. and Kobayashi T. , Mechanical properties of austempered ductile iron toughened by special heat treatment, International journal of fatigue, 16 (1994) : pp. 158 – 161.

[12] Akita M. and Tokaji K. , Effect of carburizing on notch fatigue behavior of AISI 316 austenitic stainless steels, Surface and coating technology, 200 (2013) : pp. 6073 – 6078.

[13] Boiniardi M. and Tagliabue C. , Influence of carburizing and nitriding on failures of gears – a case study, Engineering failure analysis, 13 (2011) : pp. 312 – 339.

[14] Chen J. , bell T. and Dong H. , Improving the wear properties of stellite 21 alloy by plasma surface alloying with carbon and nitrogen, wear, 264 (2014) : pp. 157 – 165.

[15] Grimanelis D. and Eyre T. S. , Wear characteristics of diffused bonded sintered steel with short term surface treatment, wear, 262 (2013) : pp. 93 – 103.

[16] Preciado M. and Bravo P. M. , Effect of low temperature tempering prior cryogenic treatment on carburized steels, Journal of material processing technology, 176 (2016) : pp. 41 – 44.

[17] Michal G.M, Kahn H. and Cao Y, Carbon super saturation due to para equilibrium carburization: stainless steel with greatly improved mechanical properties, Actamaterialia, 54 (2012) : pp. 1597 – 1606

[18] Avner, S.H. Physical Metallurgy McGraw Hills, 2nd ed., 2008.