‘I / We* confess that have been read this outstanding piece of works and at my / us * this piece of work is acceptable from the scope and the quality for the awarded Bachelor of Mechanical Engineering (Structure and Material)’

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GAS CARBURIZING EFFECTS ON IMPACT TOUGHNESS OF LOW CARBON STEEL

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This report is submitted as partial fulfillment of the requirements for the award of Bachelor of Mechanical Engineering (Structure & Material)

Faculty of Mechanical Engineering
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" I hereby declare that this project report is written by me and it is my own effort and that no part has been plagiarized without citations"

Signature :………………………………....
Name of Writer:…………………………….…
Date :………………………………….

To my lovely parents and sisters, my supervisors and all my friends

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ABSTRAK

Kaedah penyusukkarbon adalah satu proses pengerasan permukaan sesuatu bahan. Proses ini juga penting untuk meningkatkan haus dan lusuh bahan untuk mencapai tujuan. Dalam kajian ini, specimen-spesimen ini telah diuji dengan ujian impak untuk mengkaji kekerasan terhadapnya. Kajian penyusukkarbon ini telah menggunakan gas karbon monoksida sebagai agen penyebaran. Kaedah *hypothesis test* penyusukkarbon menggunakan gas terhadap keluli karbon rendah digunakan dan didapati bahawa proses penyusukkarbon memberi kesan terhadap keluri karbon rendah dengan meningkatkan kekerasan sifat bahan asal tersebut. Kajian lanjut juga telah dijalankan pada suhu 900°C dan keputusan menunjukkan penambahbaikkan dan ia juga telah terbukti melalui *Minitab Statistical Software*. Oleh itu, kajian ini telah membuktikan bahawa penyusukkarbon mampu memberi kesan yang baik terhadap sifat sesuatu bahan. Selain itu, dicadangkan agar memastikan keadaan tiub relau dalam keadaan baik supaya persekitaran makmal sentiasa terkawal. Daripada kajian ini, ia didapati bahawa purata kajian impak untuk tanpa penyusukkarbon ialah 232.4 J, penyusukkarbon pada 500°C at 1 hour is 219.5 J and at 900°C at ½ hour is 292.5 J. Walaubagaimanapun, diatas beberapa sebab seperti kemudahan yang sediada masih belum bersedia untuk kajian ini telah membataskan kajian lanjut dilakukan. Dicadangkan agar peralatan makmal yang hendak digunakan dilengkapkan dengan cirri-ciri keselamatan terutamanya untuk proses penyusukkarbonan denganDiharapkan agar pada masa akan datang kajian ini boleh dijalankan dengan lebih jayanya.

ABSTRACT

Carburizing is a process of surface hardening for material. This process is important to improve wear and tear of the material to meet certain proposes. In this study carburize and uncarburize specimen was test with the Charpy impact test in order to determine the strength of materials. The carburizing process was carried out in a tube furnace using carbon monoxide as a carburizing agent. Hypothesis test method was made and the results show that the strength of material is increased by carburizing at 900°C and the Minitab Statistical Software proved the same results. It can be concluded that the gas carburizing process can increase the strength of the material. On the other hand, the tube furnace should be under control environment for safety reason. Average impact energy for uncarburize specimen is 232.4 J, carburized specimen at 500°C at 1 hour is 219.5 J and at 900°C at ½ hour is 292.5 J. Although, further analysis cannot be done due to some technical aspects it is proven however that carburizing process increased the impact energy of low carbon steel investigated. This primary study shows the possibility of gas carburizing as a surface hardening process for low carbon steel. It is recommended to improve the safety aspect of experimental lab equipment for gas carburizing process to allow extensive study for better collection of data for carburized low carbon steel.

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CHAPTER 1

INTRODUCTION

This research is about gas carburizing effects on impact toughness of low carbon steel; using the impact test and the heat treatment include two processes which are carburized and uncarburized.

Low carbon steels can be treated to develop a hard surface or "case", while the interior of the steel or core is unaffected and retains its normal ductility and toughness. Surface hardening (or case hardening) processes may be divided into two classifications a) those in which the composition of the surface materials must be changed, and b) those in which the composition of the surface materials is not changed (Chapman.W.W, 2004).

Carburizing, nitriding, carbonitriding and cyaniding processes are used to satisfy the first classification, and flame hardening and induction hardening can be used to create the characteristics of the second classification (Chapman.W.W, 2004). The process of low carbon steel such as stampings, forgings and it applications in industrials are seamless tube, boiler, plate, chain, sprockets, bearing, roller, chain, rivets, nails, wire, pipe and others. The advantages of low carbon steel are process good formability, process good weld ability and best of all metals, easy to handle and low cost and rated at 55% until 60% machine ability (soft and drags which build up heat on the tool).

Heat treatment can be define as an operation or set of operations in a metal involving heating and controlled cooling. Transformation in the solid state can be obtained using heat treatment procedures, which cause changes in microstructure resulting in materials with a wide range of hardness and mechanical properties. Although an exact relationship between hardness and wear performance does not exist, hardness has traditionally been the properly used for quality control, selection of steel, and heat treatment and performance evaluation (Totten. G.E. and Liang. H, 2004).

Gas carburizing is a surface hardening process in which steel or an alloy of suitable alternative compositions is exposed at elevated temperature to a gaseous atmosphere with high carbon potential, hardening of the resulting carbon rich surface layer is accomplished by quenching the part from the carburizing temperature or by reheating and quenching (Tomsis. J.L and Hodder. R, 2000). Gas carburizing expose the steel parts to carburizing gases such as methane, propane, butane or from vaporized hydrocarbon liquids. The process can be performed in either batch of continuous furnaces and case depths, with depth being dependent on time and temperature.

Impact test meant to determine the behavior of materials when subjected to high rates of loading, usually in bending, tension or torsion. The quantity measured is the energy absorbed in breaking the specimen by a single blow (Tomsis. J.L and Hodder. R, 2000). These tests are used to indicate the toughness of materials and particularly its capacity of resisting mechanical shock. In impact test however the unsatisfactory material would prove to be extremely brittle as compared with the correctly treated one, which would be tough. The Charpy impact test is used to determine the amount of energy absorbed by a material during fracture. This absorbed energy is a measure of a given material's toughness and widely applied in industry because of easy to prepare and conduct; it fast and cheaply.

1.1 Objective

To study and discuss the effects of gas carburizing on impact toughness of carburized low carbon steel using statistical analysis. To compare the results of the heat treatment which is evaluated using the Charpy V-notch impact testing.

1.2 Scope

In this study, gas carburizing treatment and Charpy impact test had been done on low carbon steel materials. The carburization of impact specimens was done at two differences temperature of 500 ^{o}C for 1 hour and 900 ^{o}C for ½ hour and the result were compared and discussed statistically.

1.3 Problem statement

Low carbon steel are process good formability, process weld ability and best of all metals, easy to handle and low cost rated at 55% until 60% machine ability. Gas carburizing had been identified as one of the noble method to provide material with hard surface but at the same time keeping the ductility at material. Thus, carburized steel has high-carbon content on outer surface and maintaining low-carbon in the interior. In the process of carburizing, steel is heat treated, the case is hardened while the core remains soft and tough.

CHAPTER 2

LITERATURE REVIEW

2.0 Heat Treatment

Heat treatment is defined as a physical process which entails the controlled heating and cooling of material, such as metal or alloys to obtain desired properties. Heat treating is an energy intensive process that is carried out in difference furnace such as electric and gas. Shortening heat treated treatment cycles can provide great environment and financial benefits through energy saving. Many texture detail furnace equipment and its design but little to no literature review can be found on furnace method (Boyers et al. 1985) and (Cubbery et al. 1981).

The heat treatment processes described thus far involve microstructure alterations and properties changes in the bulk of the materials or component by means of through hardening. It is not desirable to through harden parts because a hard part lacks the necessary toughness for these applications, a small surface crack could propagate rapidly through such a part and cause total failure. In many cases, however, alteration of only the surface properties of a part is desirable. This method is useful particularly for improving resistance to surface indentation, fatigue, and wear. Typical applications for case hardening are gear teeth, cams, shafts, bearings, fasteners, pins, automotive clutch plates, tools and dies. Several surface hardening processes are carburizing (gas, liquid, and pack carburizing), carbonitriding, cyaniding, nitriding, boronizing, flame hardening, induction hardening, and laser hardening (Kalpakjian. S. and Schmid. S.R, 2006).

Basically, these are operations in which the component is heated in an atmosphere containing elements such as carbon, nitrogen or boron that alter the composition, microstructure and properties of surface. For steels with sufficiently high carbon content, surface hardening takes place without using any these additions elements. Only heat treatment processes described are needed to alter the microstructure, usually by either flame hardening or induction hardening. Because case hardening is a localized heat treatment, case hardened parts have a hardness gradient. Typically, the hardness is a maximum at the surface and decrease below the surface, with a rate of decrease that depends on the compositions of the metal and the process variables. Surface hardening techniques also can be used for tempering to modify the properties of surface that have been subjected to heat treatment. Various other processes and techniques for surface hardening, such as shot peening and surface rolling, improve wear resistance and various other characteristics (Kalpakjian. S & Schmid. S.R, 2006). Shot peening can be effective to decrease austenite content because the surface deformation causes the mechanical transformation from austenite to martensite, producing compressive residual stress in the surface as well as increase of fatigue life (Krauss. G, 1995).

Decarburization is the phenomenon in which alloys containing carbon lose carbon from their surface as a result of heat treatment or of hot working in a medium usually oxygen that reacts with the carbon. Decarburization is undesirable because it affects the hardenability of the surface of the par by lowering its carbon content. It also adversely affects the hardness, strength, and fatigue life of steels by significantly lowering their endurance limit. Decarburization is best avoided by processing the parts in an inert atmosphere or a vacuum or by using neutral salt baths during heating heat treatment (Kalpakjian. S. and Schmid. S.R, 2006).

2.1 Surface Hardening

In many industrial applications it is necessary to develop a high surface hardness on a steels part so that it can resist wear and abrasion. This can be achieved by increasing the hardness of high carbon steel, but high hardness is then accompanied by low ductility and toughness (Chapman. W.W, 2004). Surface hardening a process which includes a wide variety of techniques is used to improve the wear resistance of parts without affecting the softer, 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. In ordinary carbon steels, these two different sets of properties are found only in materials of different carbon content. Thus, steel with about 0.1 percent carbon will be tough; with 0.9 percent carbon will be very hard when suitably heat-treated (Higgins. R.A, 1997). Further, 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.

Table 2.1: The table show that the general classification of steels surface hardened by induction is as follows.
(Source: Totten. G.E, 2007)

Material description	**AISI**	**Typical Application**
High carbon steel	AISI 1050 – AISI 1080	Primary used for tools such drill bits and other cutting tools due to their ability to achieve high hardness.
Medium carbon steel	AISI 1035 – AISI 1050	Used in automotive industry, such as front wheel drive components and drive shaft.
Low carbon steel	AISI 1020 – AISI 1035	Used where toughness rather than high hardness is required such as in clutch plates or pins for farm equipment.

Table 2.2: The table had shown about the chemical composition of case hardening steels.
(Source: Higgins. R.A, 1997)

Composition %					
C	Mn	Ni	Cr	Mo	Characteristic and uses
0.15	0.7	-	-	-	Machine parts requiring a hard surface and a tough core, e.g. gears, shaft, cams.
0.15	1.3	-	-	-	A carbon manganese steel giving high surface hardness where severe shock is unlikely.
0.13	0.5	3.25	0.85	-	High surface hardness combined with core toughness - high duty gears, worm gears, crown wheels
0.17	0.5	1.75	-	0.25	High hardness and severe shock resistance – automobile parts(steering worms)
0.15	0.4	4	1.2	0.2	Best combination surface hardness, core strength and shock resistance - crown wheels, bevel pin.

2.2 Charpy Impact Test

This energy absorbed by the specimen, as it breaks, can qualitatively be related to it's fracture mode (ductile or brittle.) Ductile fracture, which involves substantial plastic deformation, would require much more energy than brittle fracture. Note that the fracture energy measured in a Charpy impact test is a relative energy and can only be used to compare dimensionally identical specimens; it cannot be easily used directly in engineering calculations (R.E. Reed-Hill, 1973).

By testing the fracture energy of a sample at many different temperatures, a curve such as Figure 3 can be developed. Because the transition from completely brittle (low impact energy) to completely ductile (high impact energy) occurs over a broad range of temperatures, several procedures exist for the determination of the actual "transition temperature." One way is to examine the fracture surface. A brittle failure, where the sample cleaved, will be shiny. A ductile failure, where the surface was plastically deformed, will be dull. Often, a sample will display both types of failure. In the middle of the sample, where a triaxial-type constraint on the stress is highest, the fracture will be brittle and the fracture surface shiny and highly faceted. At the edge of the sample, where the triaxial constraint is partially relieved, the failure may be ductile, leaving a dull surface. See Figure 2.2. The transition temperature is sometimes determined to be the temperature when the fracture surface is 50% ductile (R.E. Reed-Hill, 1973).

A second definition, and the one that will be used here, is that the transition temperature is the temperature where the fracture energy is half way between the pure brittle and pure ductile impact energies. This can be determined using a plot of the impact energies versus temperature similar to that shown in Figure 2.1.

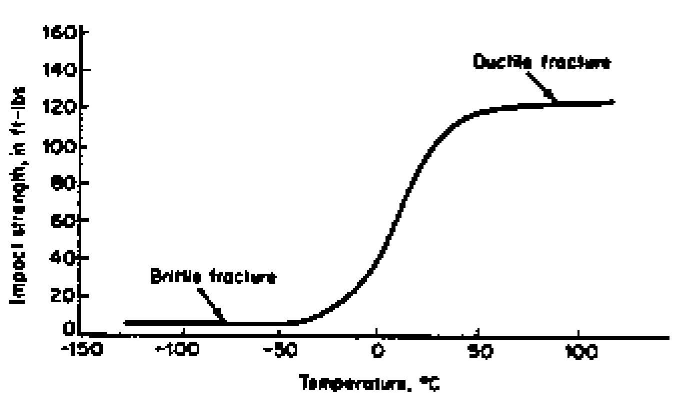

Figure 2.1: Representative Charpy impact test results

(Source: R.E. Reed-Hill, 1973)

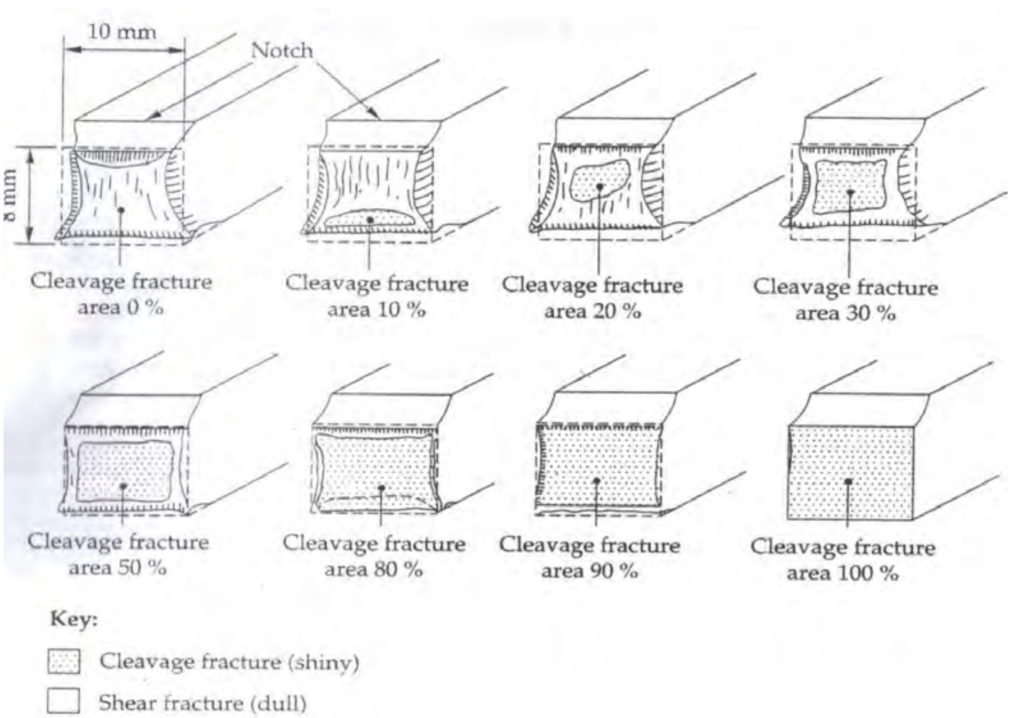

Figure 2.2: This figure show the fracture appearance charts and percent shear fracture comparator.

(Source: Nayak. A, 2005)

2.2.1 Quantitative Results

The quantitative result of the impact test the energy needed to fracture a material can be used to measure the toughness of the material and the yield strength. Also, the strain rate may be studied and analyzed for its affect on fracture.

The ductile-brittle transition temperature (DBTT) may be derived from the temperature where the energy needed to fracture the material drastically changes. However, in practice there is no sharp transition and so it is difficult to obtain a precise transition temperature. An exact DBTT may be empirically derived in many ways: a specific absorbed energy and change in aspect of fracture (Meyers. M.A and Chawla. K.K, 1999).

2.2.2 Qualitative Results

The qualitative results of the impact test can be used to determine the ductility of a material (Mathurt. K.K et al. 1994). If the material breaks on a flat plane, the fracture was brittle, and if the material breaks with jagged edges or shear lips, then the fracture was ductile. Usually a material does not break in just one way or the other, and thus comparing the jagged to flat surface areas of the fracture will give an estimate of the percentage of ductile and brittle fracture (Meyers. M.A and Chawla. K.K, 1999).

2.3 Carburizing

Carburizing is one of these treatment promoting high surface hardness, strength, fatigue resistance, and wear resistance. Therefore, it is used in highly stressed components such as shaft, bearings and gears. Carburizing process include pack carburizing, gas carburizing, and salt bath. It is applied to low carbon steels, about 0.2%C (Totten. G.E. and Liang.H, 2004). In most commercial carburizing, the surface may contain about 0.80% to 1.0% C, with the concentration tapering off until, at a depth determined by time, temperature and other carburizing practice variables, the carbon is that of the original low carbon steel (Henkel. D and Pense. A.W, 2001).

Carburizing increase the surface carbon content of low carbon steel (0.1 -1.2%C) by 0.7 -1% in a carbon medium. This medium can be solid, molten salt, a gaseous or plasma medium. At low temperatures carbon will not diffuse into steel. Both the steel and carburizing material must be heated during carburizing to an elevated temperature. In practice, carburizing is done at temperatures between 900^0C and 950^0C (Prabhuder. K.H, 2000). Gas carburizing is carried out in both continuous and batch type furnace. The gases naturally used are the hydrocarbons methane and propane (product of petroleum production). This should be of high purity otherwise oily soot may be deposited on the work pieces (Higgins. R.A, 1997).

Advantages of gas carburizing are time – temperature cycles can be determined accurately for close control of the case depth. Composition of the carburizing gas can be varied to provide a close control of the carbon content of the case, the whole charge is heated to a carburizing commences. It is hence possible to obtain a uniform degree of case depth that is not obtained by any other method, part handling is clean and relatively efficient, the process is readily adaptable for continuous operation, and requires minimum floor space, less time is required and direct quenching of the charge from the carburizing temperature reduces the heat treatment cost and also results in minimum distortion. The limitations of gas carburizing are high capital investment for the furnace, a generator is required and baskets and fixture are expensive (Prabhuder. K.H, 2000).

Totten. G.E. and Liang. H. (2004) indicates that the influence or retained austenite or wear resistance, in the case of carburized steel or hardened steel, has long been a controversial subject. This situation occurs because of the complexity of the mechanisms involved in the wear of the materials. In addition, there is the interaction of factors such as hardness, residual, stress, surface finish, microstructure grain size, globular and