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TIME AND TEMPERATURE EFFECTS ON FRACTURE PROPERTIES OF CARBURIZED LOW CARBON STEEL

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"I verify that this report is my own work except for the citation and quotation that the source has been clarify for each one of them"

Signature: ……………………………….

Name of writer: …………………………

Date: …………………………………….

To Alya Sofea, my beloved family and friends

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Firstly, thanks to Allah for giving a good health and mind which enable me to faced the entire problem and complete this research.

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ABSTRACT

Carburizing which have been widely used as one of surface treatment to a material can improve the mechanical properties of materials such as surface hardness and wear resistance. The carburization method that is used in this study was pack carburizing using Wilcarbo powder. The method was very effective in introducing carbon but the method was exceedingly slow. Material that was used in the study was Low Carbon Steel (AISI 1020).16 specimens were prepared according to the standard ASTM E399. Certain machining process need to be done in order to prepare the specimen to the required dimension such as cutting, facing and grinding. The carburizing was conducted with variation of time and temperature to study the effect to the fracture properties of the material used which is low carbon steel. 5 pieces of specimen was prepared as a reference to do the comparison between results of carburized and uncarburized specimen while the other specimen was carburized before proceeding to fracture toughness test by using three-point bending test. Specimen with higher carburizing temperature resulting in lower value of K_{IC} . The average fracture toughness value obtained for uncarburized specimen is 125.088±17.981 MPa/√m and for the carburized specimen is 126.607±14.929 MPa/√m. Highest fracture toughness value was obtained at 850°C carburizing for 3 hours and the lowest fracture toughness value was obtained at 900°C carburizing for 6 hours. However, the differences is so small and can be assumed that both temperature and time has no significant effects on the fracture properties of the carburize specimen.

ABSTRAK

Penyusukkarbonan merupakan salah satu kaedah rawatan permukaan kepada bahan yang telah digunakan secara meluas untuk meningkatkan ciri-ciri mekanikal untuk sesuatu bahan seperti kekerasan permukaan dan ketahanan bahan. Proses penyusukkarbonan yang digunakan di dalam kajian ini ialah menggunakan penyusukkarbonan menggunakan bungkusan. Cara ini sangat berkesan untuk menghasilkan karbon tetapi memakan masa yang lama. Bahan yang digunakan di dalam kajian ini ialah keluli karbon rendah (AISI 1020). 16 spesimen digunakan di dalam kajian ini disediakan mengikut standard ASTM E399. Beberapa proses perlu dilalui untuk mendapatkan dimensi yang diperlukan untuk ujian kerapuhan. Penyusukkarbonan dijalankan dengan kepelbagaian masa dan suhu untuk mengkaji kesan-kesan terhadap kepelbagaian masa dan suhu terhadap ciri-ciri kerapuhan bahan yang digunakan samada menggunakan process penyusukkarbonan atau tidak. Lima spesimen telah digunakan sebagai kawalan dengan hanya menjalani ujian kerapuhan tanpa menjalani rawatan permukaan ini. Nilai purata ujian kerapuhan untuk specimen tanpa rawatan ialah 125.088±17.981 MPa/√m dan specimen yang menjalani penyusuk karbonan ialah 126.607±14.929 MPa/√m. Nilai kerapuhan tertinggi diperolehi daripada spesimen yang menjalani proses penyusukkarbonan pada suhu 850°C selama 3 jam dan nilai kerapuhan terendah ialah daripada spesimen yang menjalani proses penyusukkarbonan pada suhu 900°C selama 6jam. Walau bagai manapun, perbezaan nilai kerapuhan sangat sedikit dan boleh di anggap bahawa masa dan suhu tidak memberikan kesan terhadap ciri-ciri patah spesimen yang menjalani rawatan penyusukkarbonan.

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SYMBOL	DEFINITION
AISI 1020	Low Carbon Steel
CO	Carbon Monoxide
CO_2	Carbon Diokside
Fe_3C	Cementite
°C	Degree Celcius
K_{IC}	Fracture Toughness
UTeM	University Technical Malaysia Melaka

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 General Introduction

Carburizing is a heat treatment process to increase the surface hardness and wear resistance of components which are required to perform good impact strength and resistance to wear in service. Basically, the process is based on the theory of thermal absorption and diffusion of carbon atoms into steel. The process is usually done at an elevated temperature with a chemical agent such as solid or molten salt that can provide adequate quantity of atomic carbon for the diffusion and absorption process. A broad range of metals can be carburized including steel, nickel and alloys. Typical components that are subjected to this treatment are gears, spindles, shafts, cams, levers, steering parts, distribution gears, etc.

Pack carburizing is one of the methods in the carburizing process. It is the earliest application in carburizing, where parts were simply placed in a suitable container and covered with a thick layer of carbon powder. The process is done by packing the component in a solid carburizing compound in a suitable container and heating it slowly in a furnace to attain a temperature of 900ºC and 950ºC(Prabhudev K.H., 2000).Although it is very effective in introducing carbon, this method was exceedingly slow, and as the demand for greater production grew, a development of new process were established include vacuum carburizing and plasma carburizing. Another recent development in carburizing is fluidized bed furnace which can provide much faster rate of carburizing compared to the conventional process (Prabhudev K.H., 2000).All of these processes perform better mechanical properties and higher hardness to components than conventional carburizing. Before this, many studies were found focuses on hardness, wear resistance and microstructural properties of carburizing low carbon steel (Tokaji *et. al*., 2003, Aminul I. *et. al*. 2002). In this research, the effect of time and temperature variation on fracture properties of carburized low carbon steel (AISI 1020) is studied.

Fracture mechanics is a subject for critical study that has barely been for around a century. It was invented during World War I by English aeronautical engineer A.A Griffith, and known as a method for predicting failure of the structure containing a crack*(Internet source:27/08/2007)*.Then, the fracture toughness is known as the resistance of a material to fracture. Basically, it depends on temperature, environment, loading rate, the composition of the material and its microstructure also the geometric effect*(Internet source: 06/08/2007)*.In this research, the fracture toughness of material which is low carbon steel is determined by using three-point bending experiment. In this experiment, V-notch is machined to the specimens which are loaded to failure. The fracture toughness is given by calculating the driving force for the failure condition.

1.2 Objective

To study and discuss the effects of carburizing time and temperature variation on fracture properties of carburized low carbon steel using statistical analysis

1.3 Scope of Research

a) To do literature study on carburizing process and fracture mechanics
b) To carry out carburizing treatment at different time and temperature setting on low carbon steel
c) To carry out fracture toughness test on the material using bend specimen, before and after treatments
d) Surface characterization of every specimen.
e) To compare the data using statistical analysis

1.4 Problem Statement

Cracks are difficult to avoid and occur more frequently than we might at first think. The present of crack in a component or machine, vehicle or structure may weaken it so that it fails by fracturing into two or more pieces. The study of fracture toughness and the mechanical properties of low carbon steel are very important to understand the behavior of the steel. With that, the analysis done can be used to avoid any accident in designing. Hence, in this research, the effect of time and temperature variation on fracture properties of carburized low carbon steel (AISI 1020) is studied.

1.5 Planning and execution for PSM Project

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FINAL YEAR PROJECT TITLE: **Time and Temperature Effects on Fracture Properties of Carburized Low Carbon Steel**
PLANNING AND EXECUTION FOR PSM

	PSM 1												PSM 2													
	J U L				A U G				S E P T				J A N				F E B				M A R				A P R	
RESEARCH ACTIVITY/TIME	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1.Literature review		■	■	■	■	■	■	■	■	■	■	■					■	■	■	■	■	■	■	■		
2.Experimental activities:-																										
A)cutting of specimens					■	■	■	■	■																	
B)Surface treatment process:-																										
I. Uncarburized specimens																										
ii. Carburizing at 850°C for 3 hrs															■	■	■									
iii. Carburizing at 850°C for 6 hrs															■	■	■									
iv. Carburizing at 900°C for 3 hrs																■	■	■								
v. Carburizing at 900°C for 6 hrs																■	■	■	■							
C) Mechanical testing via 3-point bending																										
i.Uncarburized specimens														■	■											
ii. Carburized specimens																■	■	■	■	■	■					
D) Surface Analysis																		■	■	■	■					
Results and analysis																					■	■	■			
Report writing for PSM								■	■	■	■	■											■	■	■	
Preparation for PSM Seminar																										■
Submission of report & log book												■													■	■

Figure 1.1 : Gant Chart for Planning and Execution for PSM 1 and 2

CHAPTER 2

LITERATURE REVIEW

2.1 Steel

Generally, steel is an alloy consisting mostly of iron, with carbon content between 0.02% and 2.04%, depending on grade. Carbon is the most cost-effective alloying material for iron, but various other alloying elements are used such as manganese and tungsten. Carbon and other elements act as a hardening agent, preventing dislocations in the iron atom crystal lattice from sliding past one another. The amount of alloying elements and form of their presence in the steel can control the quality in terms of hardness, ductility, and tensile strength of the resulting steel. Steel with increased carbon content can be made harder and stronger than iron, but is also more brittle. Though steel had been produced by various inefficient methods long before the Renaissance, its use became more common after more efficient production methods were devised in the 17th century. Further refinements in the process, such as basic oxygen steelmaking, further lowered the cost of production while increasing the quality of the metal. Today, steel is one of the most common materials in the world and is a major component in buildings, tools, automobiles, and appliances *(Internet source: 20/07/2007).*

Modern steel is generally identified by various grades of steel defined by various standards organizations. Other than that, it is also identified by the composition, such as carbon, low-alloy or stainless steel and the product forms, such as bar plate, sheet, strips, tubing or structural shape. The heat treatment such as annealing, quenching and tempering also can be used to identify the steel *(Internet source: 27/08/2007).*The classification of steel is shown in Figure 2.1.

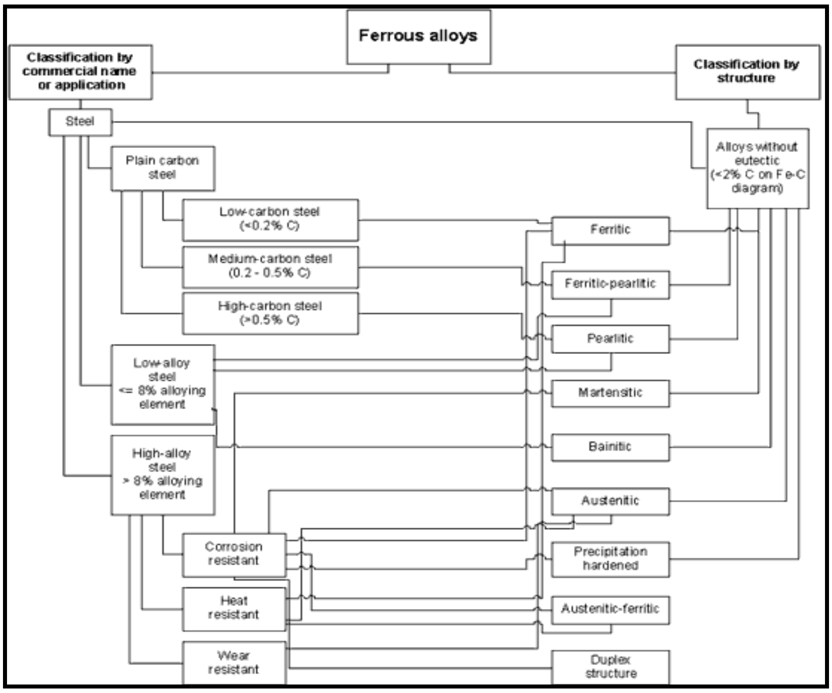

Figure 2.1: Classification of steel

(Internet source: 27/08/2007)

2.2 Low Carbon Steel

Carbon steel, the most widely used in engineering material, accounts for 85% of the annual steel production worldwide. Carbon steel is a metal alloy, combination of two elements whish is iron and carbon. The only other elements that exists in carbon steel are manganese, silicon, and copper with each of the element are present in a small quantities to affect the properties of this steel. The largest category of this class of steel is flat-rolled products (sheet or strip), usually in the cold-rolled and annealed condition. The carbon content for these high-formability steels is very low, less than 0.10% C, with up to 0.4% Mn *(Internet source,17/7/2007).*Steel with low carbon content has the same properties as iron, soft but easily formed. The metal becomes harder and stronger when the carbon content rises but less ductile and more difficult to weld. It is used in many applications such as in transportation, chemical processing, pipelines and construction.

Low carbon steel is the most common form of carbon steel that can provides material properties that are acceptable for many applications. The steel consist of less than 0.25% carbon usually approximately 0.05-0.29 carbon content. It has low tensile strength, but it is cheap, malleable and the hardness can be increased through carburizing process. Density of this metal is 7861.093 kg/m^3 , the tensile strength is a maximum of 500MPa and it has a Young's modulus of 210 GPa *(Internet source: 23/8/2007).*

2.3 History of Carburizing Steels

The carburizing process were discovered by early blacksmiths to increase the strength, surface hardness and enhanced wear resistance of agricultural tools such as scythes, axes and weapon such as swords. All these tools were found to have carburized layer. At that time, the process is done by leave hot forged in the hot coals followed by quenching in water and would harden the surface layers. Later processes involved putting such implements into cast iron boxes with charcoal and bone ash. These were heated to "red heat" (around 900 ºC) and left for several hours depending of the layer required. Then, they were quenched and tempered *(Internet source: 12/09/200).*

Cooling the forged tool in water (quenching) forms martensite. In order to make the tools useful, they have to be re-heated to a lower temperature than that used for the forging temperature. This tempers the steel and reducing the hardness, also improves its toughness. This causes a big increase in the surface hardness, enhanced wear and fatigue resistance. Basically, the carbon content of the case and its depth is controlled by the carburizing time and temperature.

2.4 **Carburizing**

Carburizing is a heat treatment process to increase the surface hardness and wear resistance of components which are posses a fairly good impact strength and resistance to wear in service. In the process, an austenitized ferrous material is brought into contact with a carbonaceous atmosphere or medium of sufficient carbon potential as to cause absorption of carbon at the surface and, by diffusion, create a concentration gradient (Chapman *et. al.*,2004).In fact, as early as the ninth century, the Benedictine monk, Theophilus Presbyter gave a precise method for hardening metallic files. A mixture of three parts of horn meal and one part of salt was used on the surface of heated files which was reheated and water quenched after the process (Prabhudev K.H., 2000).

The process can increased the hardness of steel with a carbon content between 0.1 and 0.3%. There is no technical limit to the depth of hardening with carburizing techniques, but it is not common to carburize to depths in excess of 0.050 in.*(Internet source, 17/8/2007)*.In this process, steel is introduced to a carbon rich environment and elevated temperatures for a certain amount of time. Because this is a diffusion controlled process, the longer the steel is held in this environment greater the carbon penetration will be and the higher the carbon content in these areas. Figure 2.2 shows the purpose of carburizing and carburization process.

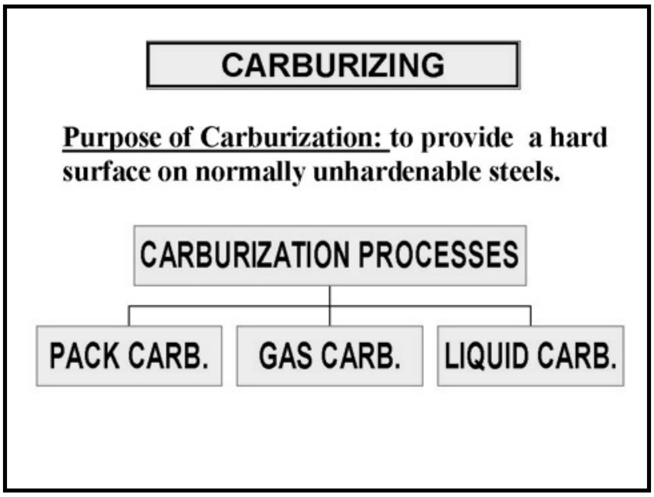

Figure 2.2: Carburizing process

(Internet source: 17/08/2007)

All of the carburizing processes (pack, gas, liquid) require quenching from the carburizing temperature or a lower temperature or reheating and quenching. The part is then quenched so that the carbon is locked in the structure and form martensite structure that have good wear and fatigue resistance*(Internet source,*