EFFECT OF COKE SIZE ON THE MECHANICAL AND WEAR PROPERTIES OF CARBURIZED MILD STEEL

By

Ashraf Talaat Hamed Kadous

A Thesis Submitted to the
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In Partial Fulfillment of the Requirements for the Degree of
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In
Mechanical Design and Production Engineering

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Title of Thesis:

EFFECT OF COKE SIZE ON THE MECHANICAL AND WEAR PROPERTIES OF CARBURIZING MILD STEEL

Key Words:

Mild Steel, Carburization, Coke Size, Mechanical Properties, Wear resistance.

Summary:

The aim of this research is to investigate the effect of various coke sizes on the properties of carburized mild steels, five sets of samples carburized at 850°C, 900 °C and 950°C for 120 min. and1000°C,1050 °C for 60 min. carburized using three different sizes of coke namely A (< 0.4 mm**)**, B (1:1.6 mm) and C (4:5 mm). After carburization samples are quenched in water and then tempered at 200°C for 15 min., Mechanical Properties and adhesive wear test. Results of sample carburized at 1050 °C , coke grain size B (1 ~ 1.6 mm) gives the optimum results for the mechanical and wear .

ACKNOWLEDMENTS

Praise is to Allah for without His will this work would not have even started.
I would like to thank Prof. Pro. Dr. Mahmmoud A. Adly, who never denied me his helping hand whenever needed and bore the responsibility of supervision and guidance with all care and tenderness. His kindness helped me a lot to overcome any encountered problems. Words can never express my gratitude to Dr. Emad Elkashif I wish to express my gratefulness for his continued help, fruitful discussions during the research and constructive criticism that contributed to the editing of this thesis. His continuous encouragement was the spur that helped me overcome frustration, and his valuable assistance enabled me to cross the critical stages of this work. I would also like to thank Dr. Ahmed Y. Shash, my profound gratitude to him for guidance and fruitful discussions throughout the work. His technical supports Encouragements helped me to finish this work.

I am greatly indebted to them for their constructive suggestions and criticism from time to time during the progress of my work I express my sincere thanks to Prof.Dr. Laila Salah, Head of the Department of Mechanical Engineering, Faculty of Engineering at Cairo University for providing me the necessary facilities in the department I am thankful to Prof. Dr. Morsy A. Morsy, and Dr. Mohamed K. ELfaoakhary (Research and Development Center of metals) for their co-operation in experimental work .and spirit of my father and my mother and my wife and children I am also thankful to Youssef Abdel Nabi and all the staff members of the Department of Mechanical Engineering & Materials Engineering for Faculty of Engineering at Cairo University.

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ABSTRACT

The aim of this research is to investigate the effect of various coke sizes on the carburizing process of mild steel, this effect is evaluated through measurement of the mechanical properties and wear resistance for different carburizing condition therefore five sets of samples were prepared and carburized at different temperatures and times. Three sets were carburized at 850^{o}C, 900 ^{o}C and 950^{o}C for 120 min. while two other sets are carburized at 1000^{o}C and 1050 ^{o}C for 60 min. All sets were carburized using three different sizes of coke namely A (< 0.4 mm**)**, B (1 : 1.6 mm) and C (4 : 5 mm).

After carburization all sets were quenched in water and then tempered at 200^{o}C for 15 min. After tempering, different mild steel samples were subjected for microstructure observation, hardness test, Charpy impact test, tensile testing and adhesive wear test. The experimental results were analyzed and shows that mild steels carburized at 1050^{o}C with intermediate coke grain size B (1 ~ 1.6 mm) gives the optimum results for the mechanical and wear properties which may be due to the microstructure obtained at this temperature (martensitic case and bainitic core).

This indicates that coke size B gives the optimum combination of surface area and porosity needed for the reaction kinetics.

Chapter 1 : Introduction

1.1 Introduction

Engineers usually require a material with a blend of high yield strength and good elongation, but these properties are often mutually exclusive. It has been shown that the yield strength of normalized low Carbon mild steel can be increased by inducing strain hardening effects in the steel until the yield stress attains values up to and beyond the ultimate tensile strength but unfortunately, the elongation is correspondingly reduced [1]. Steels are alloys of iron and Carbon together with any other alloying elements. The steel is classified as low carbon steel, high carbon steel and medium Carbon steel.

The controlled heating and cooling processes used to change the structure of a material and alter its physical and mechanical properties [2, 3]. Heat treatment is generally employed for the purpose such as to improve mechanical properties like tensile strength, hardness, ductility, yield strength and so on. The heat treatment and carburization increase the mechanical and wear resistance. The heating of a metal at a constant temperature for a suitable duration of time is called soaking time Mechanical properties of mild steels were found to be strongly influenced by the carburizing temperature and soaking time at carburizing temperature. The mechanical properties of mild steel were found to be strongly influenced by the process of carburization, carburizing temperature and soaking time at carburizing temperature [4-7].

Carburizing is a metal treatment process that adds Carbon to the surface of the metal that has a low Carbon content to increase the hardness of the metal. The metal is heated at an elevated temperature in an atmosphere rich with Carbon. Heat will cause carbon atoms to diffuse into the metal surface. The process is done below the melting point of the metal being carburized. There are five carburizing methods—pack, gas, liquid bath, vacuum, and plasma. Pack carburizing uses a furnace to heat the metal parts to be carburized that are packed inside a container with a sufficient amount of Carbon powder. The heating process will last for 12 to 72 hours at a high temperature.

This method is noted to be slow compared to the other methods and has heating inefficiencies because of the difficulty in maintaining an even temperature. Gas carburizing follows the same procedure applied in pack carburizing. It, however, feeds carbon monoxide (CO) to the furnace to improve diffusion, which is not done in the pack method. The process has safety issues because CO is a poisoning gas that is odorless and colorless and could be inhaled by persons working inside the plant. The gas method is preferred in carburizing large volumes of metal Hardening [8–14] is accomplished when the high-carbon surface layer is quenched to form martensite so that a high carbon martensitic case with good wear and fatigue resistance is superimposed on a tough, low-carbon steel core.

Carburizing steels for case hardening 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% C because too high carbon content can result in retained austenite and brittle martensite.

Carburizing steel is widely used as a material of automobiles, farm implements, machines, gears, springs and high strength wires etc. which are required to have the excellent strength, toughness, hardness and wear resistance, etc. because these parts are generally subjected to high load and impact. Such mechanical properties and wear resistance can be obtained from the carburization and quenching processes. This manufacturing process can be characterized by the key points such as it is applied to low carbon workpieces, workpieces are in contact with high carbon gas, liquid or solid, it produces hard workpiece surface, workpiece cores retain soft [15].

Hardness is the property of a material to resist permanent indentation. Because there are several methods of measuring hardness, the hardness of a material is always specified in terms of the particular test that was used to measure this property. Although hardness testing does not give a direct measurement of any performance properties, hardness correlates with strength, wear resistance, and other properties. Hardness testing is widely used for material evaluation due to its simplicity and low cost relative to the direct measurement of many properties .

Tensile strength, hardness, toughness, elasticity, plasticity, brittleness, and ductility and malleability are mechanical properties used as measurements of how metals behave under a load. These properties are described in terms of the types of force or stress that the metal must withstand and how these are resisted. The ability of a material to absorb energy and deform plastically before the fracture is called “toughness”. It is usually measured by the energy absorbed in a notched impact test like Charpy or Izod tests. In present work for each of the sample, a test was conducted for 3 times and the average of all the samples was taken as the observed values in each case [16].

Pack carburizing normally is performed at temperatures from 815 to 955 °C. In recent years, the upper limits have been steadily raised, and carburizing temperatures as high as 1095 °C have been used Steel making processes have improved to the extent that fine grain size is maintained at temperatures approaching or exceeding 1040 °C. Above this temperature, the coarsening effect occurs only after prolonged periods of time, allowing high-temperature treatment without excessive grain coarsening [17].

1.2 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 0.03 mm. This hardening process includes a wide variety of techniques is used to improve the mechanical properties and wear resistance of parts without affecting the softer, tough interior of the part. This combination of hard surface and resistance to 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. 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. 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.

1.3 Types of case hardening

The case hardening of steels is generally categorized into the two different types.

1.3.1 Low Carbon steel

For this kind of case hardening the chemistry of the surface needs to be changed by adding carbon or nitrogen to get hard martensite on the surface quenching. This category of treatment is known as chemical heat treatment technique and involves carburizing, nitriding, carbonitriding and cyaniding

1.3.2 Medium Carbon steel

For this kind of steel the surface can be hardened by flame, induction and laser hardening techniques.

1.4 Carburization

Carburization is simply defined as the addition of carbon to the surface of low carbon steel at temperature generally between 850-950℃. Carburization is the most widely used method of surface hardening. It consist of enrichment of surface layers of low Carbon / mild steel (C less than or equal to 0.30%) with Carbon up to 0.8 % to 1% C 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% C because too high a Carbon content can result in retained austenite and brittle martensite.
The carburizing process increases the grains size due to presence for a long time in the austenitic region of the phase diagram and makes necessary a posterior heat treatment to refine the grains. Classic quenching generates a martensitic hard but brittle material. On the other hand, intercritical quenching transforms the outward carbon-rich solid solution into martensite, while the internal microstructures present a mixture of martensite, producing a less-brittle material

1.5 Types of carburization

There are many types of carburization processes as follows:

1. Solid carburization
2. Gaseous carburization
3. Vacuum carburization
4. Plasma carburization
5. Salt bath carburization

1.5.1 Solid carburization

The solid or pack carburization involves heating the steel parts embedded in a powder mixture of 85% coal and 15% BaCO3 at a temperature in the 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 a reaction. Carbon medium such as Carbon powder or cast iron shavings and heated in a furnace for 12 to 72 hours at 900 ºC. CO gas is produced at this temperature which is a strong reducing agent. Due to high temperature, carbon is diffused into the surface as the reduction reaction occurs on the surface of the steel. can be subject to the normal hardening methods when enough Carbon is absorbed inside the part During the process the part which needed to be carburized is packed in a steel container and surrounded by granules of charcoal. The charcoal is treated with an activating chemical such as Barium Carbonate ($BaBO_3$) that promotes the formation of Carbon Dioxide (CO_2). CO_2 will then react with the excess Carbon in the charcoal to produce carbon monoxide (CO). Next, carbon monoxide will react with low Carbon steel surface to form atomic carbon which diffuses into the steel. Carbon gradient supplied by Carbon Monoxide is necessary for diffusion. It is to be noted that, carburizing process does not harden the steel but it just only increases the Carbon the part. The Carbon monoxide is then decomposed to free atomic Carbon plus Carbon content to some predetermined depth below the surface to a sufficient level to allow subsequent quench hardening. Fig. 1.1 below show schematic drawing for the pack carburizing process. In this figure one can see Carbon monoxide circulating around dioxide following reaction.

$$2CO \rightleftarrows C + CO_2$$

The atomic carbon enters the steel through the following reaction

$$Fe+2CO \rightleftarrows Fe(C) + CO_2$$

The addition of $BaCO_3$ enhances the carburizing effect. $BaCO_3$ decomposes and evolves. CO_2 which react with coal to form carbon monoxide

$$C+CO_2 \rightleftarrows 2CO$$

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.[18]