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Research Paper

Comparative of wear resistance of low carbon steel pack carburizing using different media

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Abstract

In this study, various carburizing compounds charcoal, cow bone, CaCO3 were added as energizer for the carburizing compounds in percentage of 10%. To produce another compound to pack carburized mild steel 1020 AISI for investigates the influence of these compounds on wear resistance.
Many Cylindrical specimens for the adhesion wear tests were prepared from the used metal with dimensions (10x20mm) according to ASTM (G99-04) specifications
Three Heat Treatment process namely pack Carburizing Quenching, and Tempering were done. Firstly the mild steels specimens are carburized at 925° C for 2hr as soaking time and slow cooling in furnace then carburizing specimens were re heating to 870 °C for half hr. and water Quenching .Tempering was done at 160°C for 1 hour and air cooled. the Carburized and Tempered mild steels are subjected for different kind of test such as Adhesive Wear Test with pin on desk method, Hardness Test were taken using Vickers micro-hardness tester and optical microscope is used for microstructure examination X-ray diffraction for phases observation.
The result showed that all carburizing compound were contributed in increasing wear resistance and the compound of cow bone with 10% CaCO3 as energizer had a carburizing case depth of 2.32 mm which gives the highest wear resistance while charcoal compound gives a case depth of 1.1 mm .The work shows that cow bone can be used as compounds and energizer in pack carburization of mild steel. The hardness profile plot of the 90 wt.% 10% caco3 cow bone carburized mild steel was also higher than the other compositions and this value contributed on improvements of wear resistance.

Keywords: *Adhesive Wear; Pack Carburizing; Heat Treatment; Energizer.*

1. Introduction

Owing to their high wear resistance, steels are widely used as wear-resistant bulk and hard facing materials in a range of industrial applications as valves, shafts, gears, etc. However, most engineering components are subject to wear, a considerable economic loss occur due to wear in the engineering components of machine and equipment during service strength and hardness which effect on wear resistance[1] that classified to many types such as, adhesive wear which occurs when two surfaces are moving relatively one over the other, and this relative movement is in one direction or a successive movement under the effect of the load so that the pressure on the adjacent projections is big enough to make plastic deformation and adhesion. This adhesion will be at a high grade of efficiency and capability in relative to the clean surfaces and the area will be increased during movement at the end there will be some relative wear in the superficial tissues in the weak points of the noticeable places [2].
The importance of surface treatments based on both classical and modern technologies has therefore increased Carburizing, also known as carburization, is a heat treatment process in which the surface composition of the low carbon steel changes by diffusion of carbon and results in a hard outer shell (case) with good wear resistance it has been shown that using surface treatment engineering materials increases the wear resistance, decreases friction coefficient, and improves corrosion resistance[3]. Mechanical properties of mild steels were found to be strongly influenced by the

carburizing temperature and soaking time. The set of properties exist only in steels of different carbon content. Low carbon steel containing approximately 0.1% carbon, will be tough but soft, while high carbon steel will be only hard. The desired set of properties can best be met by employing a low carbon steel with suitable core properties and surface hardening it with carbon or nitrogen to a regulated depth [4].

Rapid penetration of the surface of steel can only be effective if the solute element dissolves interstitially. Once dissolved, the elements increase the hardness of the surface by forming interstitial carbides, nitrides or borides depending on the diffusing atoms. Locally produced steel does not often meet the requirement for manufacturing spare parts due to their low carbon content. When there is need for high carbon steel case for special purposes, production of high carbon steel cases locally, using abundant local materials becomes imperative. This reduces the burden on foreign reserves and creates employment opportunities. When the steel is cooled rapidly by quenching, the higher carbon content on the outer surface becomes hard via the transformation from austenite to marten site, while the core remains soft and tough as a ferrite and/or pearlite structure The objective is to produce a hard, wear-resistant case which will be resistant to both bending and contact fatigue while still maintaining the toughness and ductility of the low carbon core [3] [5] Pack carburization or solid carburization uses solid carburizing material as the carbonaceous source Commercial pack carburization utilizes energizers in the case hardening of mild steel. Different types of energizers are used together with carbonaceous materials to increase the carbon potential of carburizing materials. The commonly used energizers are $BaCO_3$, Na_2CO_3, and $CaCO_3$ [3].

Many studies investigate the wear behavior of pack carburizing mild steel.

Swapnil R.[6] studied the effect of case hardening treatment on the structure and properties of automobile gears, pack and gas carburizing process was implemented for low carbon steel by infusing elements into the metal surface forming a hard case wheels. And Compared the results of the following gears viz. grade of EN353, SAE8620 and 20MNCR5, Microscopic examination relieved the fact that there exists the amount of retained austenite along with the marten site which had an effect on mechanical properties.

M. Alagbe [7] research the effects of graphite, charcoal, palm kernel shell and mixed carburizer on surface hardening of low carbon steel and he was conducted on the effect of these media on wear characteristics using pack carburizing, The results obtained indicate that all the carburizing media responded well to all surface hardening with palm kernel shell giving the highest hardness value because, it is more efficient than charcoal and graphite. The mixed carburizer gives the least hardness, because it has the lower diffusion/penetration. Due to the refinement of the case and the core of low carbon steel with various carburizers, it was observed that graphite has the highest energy value/resistance to fracture. It appears that surface hardening of low carbon steel using graphite, charcoal, palm kernel shell and mixed carburizer can be adopted as a heat treatment process for improving its wear resistance at less cost.

Emmanuel Jose Ohize [8] studied the effect of coal, bone charcoal and wood charcoal on the hardness, tensile and impact strengths of mild steel and he showed that Coal, bone charcoal and wood charcoal as carburizing materials each had considerable increasing effect on hardness and tensile strengths but a decreasing effect on impact strengths of mild steel. Then showing Wood charcoal had the greater effect while coal had the least effect on hardness and tensile strengths.

Ihom, A.P., Nyior [9] studied the potential of some organic waste materials for surface hardness improvement of mild steel. Waste organic materials like sugar cane, rice husks, egg shell, melon shell, are caeca flower droppings; plastics, polyethylene, and charcoal were used during the study. These materials were prepared in various shapes and sizes before mixing them with mild steel specimens The results have established the potentials of waste organic materials for surface hardness improvement of mild steel. The waste organic materials used in the casehardening media all showed improvement in the hardness values of the mild steel specimens over the 30 HRC hardness value of the untreated mild steel specimen.

The objective of this work is to case harden mild steel 1020 using cow bone and charcoal alone and then use of commercial carbonates of calcium as energizer at 10% for above media for pack carburizing and show their influence on wear resistance.

2. Experimental work

2.1. Metal selection

Low carbon steel 1020 AISI is chosen, its chemical analysis by using ARL Spectrometer.is shown in Table 1.

Table 1: The Chemical Composition of the Used Steel 1020 AISI.

Wt.% of element	C	Si	MN	Cr	Mo	Cu	Co	V	W	Ai	Ni	P	S
Actual value %	0.2	0.009	0.65	0.011	0.004	0.041	0.004	0.0009	0.003	0.001	0.012	0.09	0.05
Standard value %	0.18-0.23	0.01	0.3-0.6	-	-	-	-	-	-	-	-	0.04	0.05

Hardness (HB) =125

2.2. Preparation of specimens

Cylindrical specimens for the adhesion wear tests were prepared with dimensions (10x20mm) according to ASTM (G99-04) specifications from the used metal used as shown in Fig.(1).

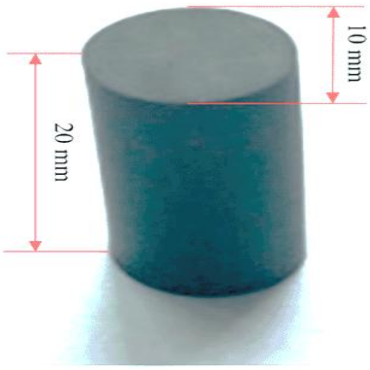


Fig. 1: Dimensions of Wear Specimen

2.3. Categorizations

After completing the specimen, they were categorized to groups as shown in Table (2).

Table 2: Categorization of Pack Carburization Test Specimens

Specimen sample	Condition of specimen
A	As received
B	100% charcoal
C	90 %charcoal +10% $CaCO_3$
D	100% cow bone
E	90 %cow bone +10% $CaCO_3$

2.4. Carburization of mild steel samples

The different test specimen samples made up of mild steel for wear properties testing were subjected to pack carburization treatment. In this process the mild steel 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 electrical furnace and then maintained at the required carburization temperature of 925°C with the soaking time of 2 hours, and furnace cooling

2.5. Heat treatment of carburized mild steel

5-aAfter the carburization process, the steel is often harder than needed and is too brittle for most practical this was investigated by Quenching process including heating the steel to 850 °C for half hour and suddenly dipped onto a cooling medium bath. In this experiment water are used. The hardness in steel depends essentially on its quenching rate.

5-bTempering of Carburized Mild Steel Samples
To relieve the internal stresses and reduce brittleness, we should temper the steel after it is hardened, So in this tempering process the carburized steel samples were heated at the temperature of 160°C for duration of 1 hour then cooled by air.

2.6. Microstructures test

For microstructure test the specimens were prepared as shown below:-

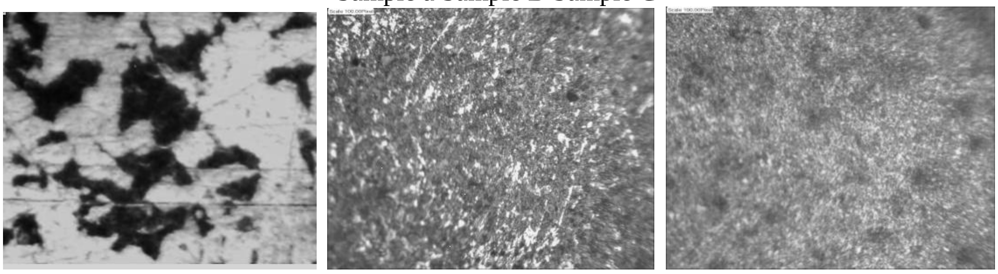
a) The specimens are treated with emery papers grad (220, 320, 500, 800, 1000, and 1200).

b) Polishing by gloss cloth with auxiliary glossing of Al_2O_3 solution of grain size of 5μm.

c) Etching process was done by immersing each specimen in etching solution (Nital solution) which consists of 98% Methyl alcohol and 2% Nitric acid for 30sec .Then the specimen was washed with water and alcohol and dried in oven.

d) Microstructures of specimens were examined with optical microscope provided with computer and digital camera, microstructure photos are shown in Fig. (2)

Sample a Sample B Sample C



Sample D Sample E

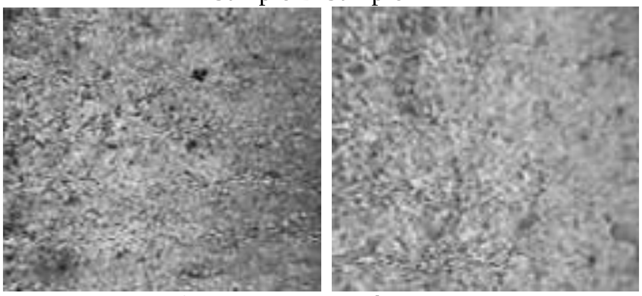


Fig. 2: Microstructure Photos at 40x

2.7. X-Ray diffraction

X-ray diffraction for specimens group (B, C D&E) results are shown in Table (3)

Table 3: X-Ray Diffraction Results

Specimen sample	phases
Sample B	FeC + Fe3C
Sample C	FeC + Fe3C
Sample D	Fe3C+Fe7C23
Sample E	Fe3C+Fe7C23

2.8. Micro hardness test

Vickers hardness test load of 500gf with a load holding time of 15 seconds. Indentations were made starting 0.25mm from the edge end at an interval of 0.25mm to a distance of 3mm towards the middle and were repeated when specimens were turned at right angles from the first measurement. From the hardness values obtained for each specimen, hardness value and effective case depths at various Medias were extracted as shown in Table (4). Hardness profiles were plotted as in Fig (3) and case hardening depth for specimens are shown in Fig (4).

Table 4: Average Carburizing Case Depth and Vickers Hardness Value

Specimen symbol	Carburizing case depth(mm)	Hardness value Kg/mm2
B	1.1	530
C	1.3	600
D	2.0	640
E	2.32	720

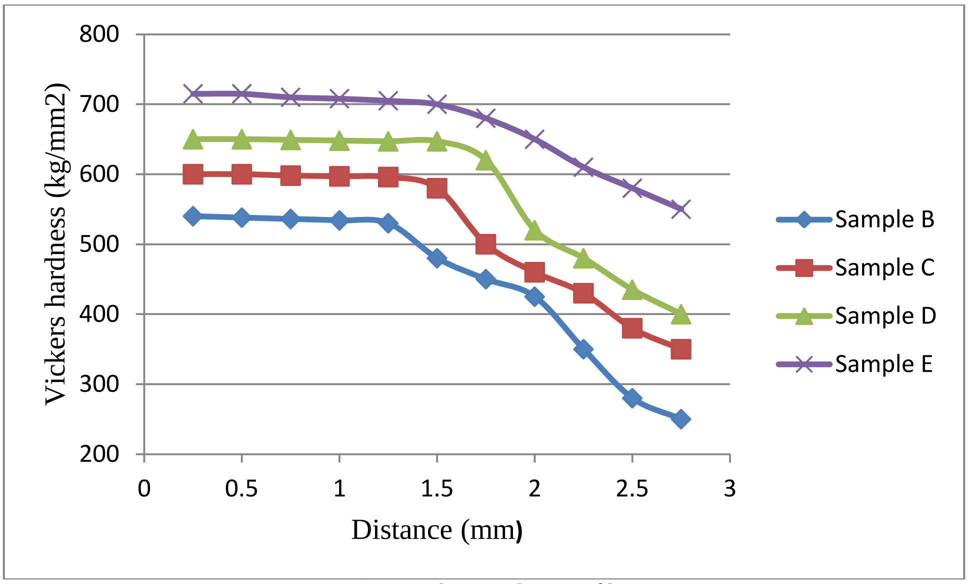


Fig. 3: Vickers Hardness Profile

Adhesive wear test

Adhesive wear test was implemented for all specimens in Table 2 using pin on disc method as shown in Fig.(4) including, fixing the specimen by the bearer in vertical position on steel disc having hardness of 58 HRC and rotated at940 r.p.m ,then Specify the variables which we want to know its effect on the wear rate like(time, load, depth),we weigh the specimen before and after test.

The wear rate is calculated from the following equation

$Wr=\Delta W/2\pi rnt$

Where

Wr is wear rate in gm/cm

$2\pi r$ is the sliding distance (cm)

t is the time in minute n is number of revolution

$\Delta w= w1-w2$ and n=940 (r.p.m)

Wear Resistance = 1 / Wear Rate

The obtained resultes are shown in fig.(5) and fig. (6)

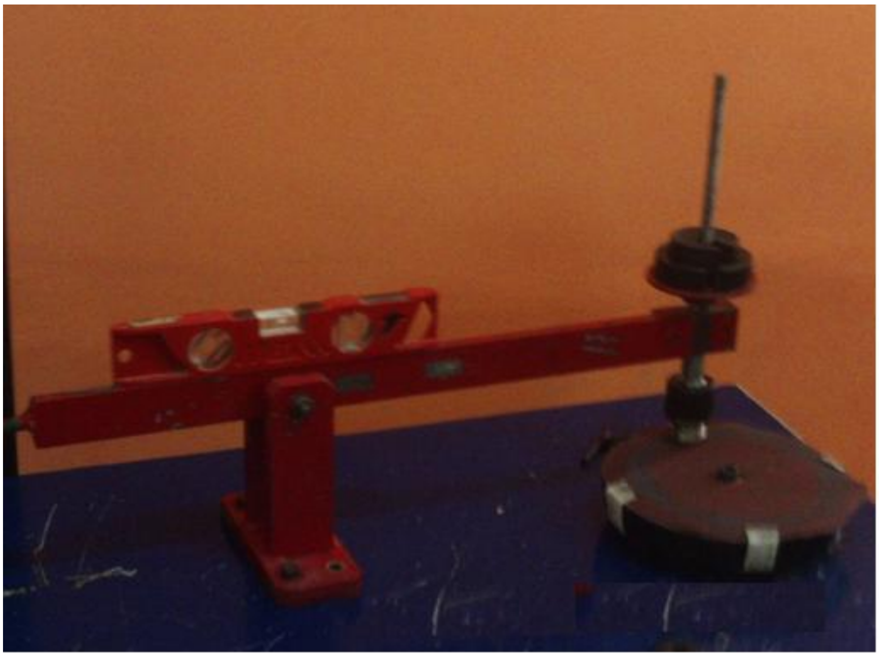


Fig. 4: Wear Equipment Photograph

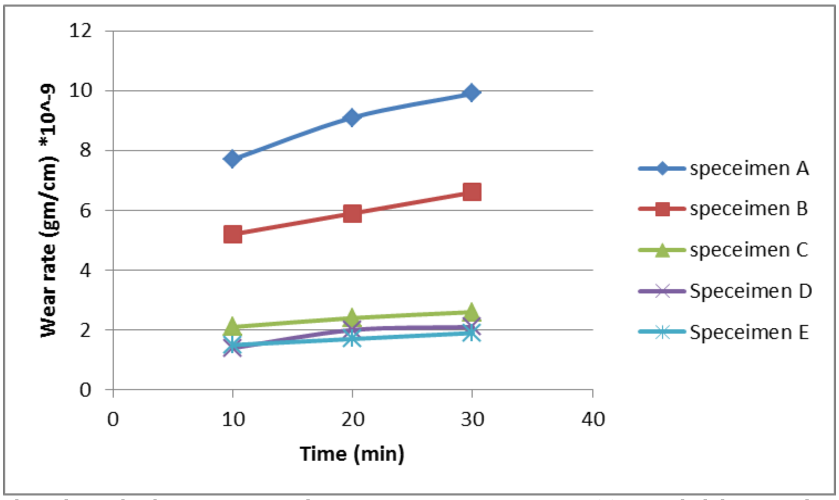


Fig. 5: The Relationship between Time and Wear Rate Constant Parameters (1) Kg and Sliding Speed 7.1m/Sec

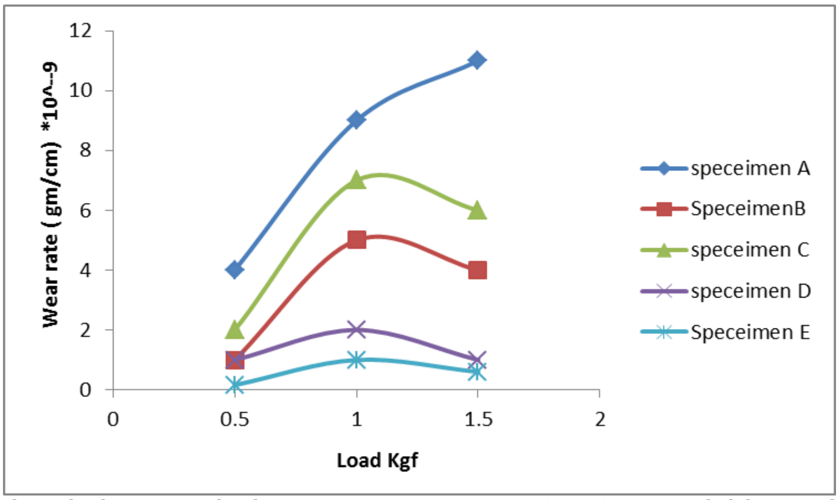


Fig. 6: The Relationship between Load and Wear Rate Constant Parameters (Time (15 Min) and Sliding Speed (7.1) M/Min

3. Discussion

Figure 2 shows Metallographic studies of cases produced by pack carburizing have shown that at the carburizing temperature of 925oC, austenite which is formed is unsaturated with respect to carbon. A carburizer such as charcoal, cow bone, or mixed carburizer comes in contact with the surface of the low carbon steel, it diffuses. As a result, a very thin layer of extremely fine carbon is deposited on the surface. This carbon is absorbed by the steel till saturation is attained. As the steel specimen is water quenched, marten site and retained austenite grains are produced and concentrated on the surface. The increase in hardness values are due to the increase in martens its occurs on case hardening .This phase was investigated by X- Ray diffraction Table (3).

Table(4) and fig (3) shows the average case depth obtained with various carburizing compounds .compositions90%cowbone 10% Ca CO3had the highest average case depth of(2.32) mm. 100% charcoal has an average case depth of(1.1)mm, in a previous work had explained the increase in the average case depth in specimen s(D,E) to be as a result of the cow bone ability to act as an energizer in the carburizing mixture and cow bones contain calcium carbonate which is a known energizer in pack carburization According to Ahom; these equations are responsible for the increase in the average case depth of the mild steel due to the role of the cow bone as energizers

$CaCO3 \rightarrow CaO + CO2$ (1)

$CO2 \rightarrow 2CO$ (2)

$2CO \rightarrow C\ Atomic + CO2$ (3)

$CaO + CO2 \rightarrow CaCO3$ (4)

$2CO + Fe \rightarrow Fe3\ C + CO2$ (5)

Which on dissociation at high temperature on the surface of the mild steel releases the nascent carbon which diffuses into the mild steel? The CaO in the presence of carbon dioxide still at high temperature combines to form calcium carbonate and the cycle continues.

Fig(5),(6) shows the relationship between wear rate and its parameters (Time, Load,) wear rate increased when time, load, increased and this was clear in all specimens group A, B,C ,D and E in all figs .and wear rate decrease at the same, Since wear resistance depend on hardness then when hardness as shown in Table (4) increase after carburizing heat treatment the wear resistance will increased. Fig.(5) which represent the relationship between time and wear rate show that specimen (A) gives the high wear rate while specimen (E) gives the lowest for the reason mentioned before. Fig.(6) shows the effect of second parameter (load) and wear rate it caused an increasing in the plastic deformation in surface tips peaks between two sliding surfaces, the adhesive process of the two tips surfaces depends on applied load, if the load is low the contact appears in upper bit and this was very thin during sliding process that causes a thin layer from oxide works as a protective surface film which limits the touching between the two sliding surfaces and prevent the direct metallic connection between the surfaces tips thus the required force to cut the occurred connection between the two surfaces tips less than the force between the metal atoms itself and that will cause a decrease in wear rate [10][11] On the other hand an increasing in applied load will break the oxide film because of its brittleness for its shoots out the friction sliding surfaces for both the discs and specimen during the sliding process which causes a strong metal contact between them make the required force to shear its contact tips more than the force between the metal atoms itself. Also because of the effect of pack carburizing contributed to increase hardness this is obvious in specimen (B) to (E) respectively.

4. Conclusions

From the study, the following conclusions were drawn:

1) Cow bone can be used as energizer supply of atomic carbon.

2) The carburizing compound with 90% charcoal / 10% cow bone gave the highest average case depth of 2.32 mm and therefore it gives better results than the other three compounds.

3) The average case depth was increasing as the cow bone in carburizing mixture was increased.

4) 4-carbonates of calcium as energizer at 10% for above media for pack carburizing and show small influence on obtaining result for cow bone

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