[Kumar, 5(12): December2018]
DOI- 10.5281/zenodo.2525776

ISSN 2348 – 8034
Impact Factor- 5.070

GLOBAL JOURNAL OF ENGINEERING SCIENCE AND RESEARCHES

IMPROVEMENT IN TENSILE STRENGTH OF MILD STEEL BY CARBURIZATION TECHNIQUE

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Abstract

This paper evaluates the effects of heat treatment through carburization acknowledged improving of various properties of mild steel. In the present process the wear behaviors of mild steels carburized at different temperature range of 860, 900 and 940oC have been studied and it is found that the heat treatments greatly improves wear resistance of the mild steels. The aim has been to examine the effects of these different carburization temperatures and conditions on the wear properties of the carburized mild steels. For above purpose firstly the mild steels are carburized under the different temperature range as stated above and then it is tempered at 180oC for half an hour after this the carburized and tempered mild steels are subjected for different kind of test such as abrasive wear test. The results of these experiment shows that the process of carburization greatly improves the wear properties like wear resistance and these properties increases with increase in the carburization temperature but apart from this if we increase temperature further then deformation in specimen dimension occurs. Therefore, experimental results show that the mild steels carburized under different temperature range as stated above, with in which the mild steels carburized at the temperature of 940oC gives the best results for the different kinds of wear properties because at this temperature it gives highest wear resistance, so it must be preferred for the required applications.

Keywords: *Carburization, Mild Steel, tensile strength.*

I. INTRODUCTION

The carburization provides a gradual change in carbon content and carbide volume from the surface to the bulk, resulting in a gradual alteration of mechanical and wear properties. The heat treatment and carburization increases the mechanical and wear resistance. Carburizing is the addition of carbon to the surface of low-carbon steels at temperatures generally between 860°C and 940°C at which austenite, with its high solubility for carbon, is the stable crystal structure. Hardening 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 [1]. 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 0.7 and 1% C. However, surface carbon is often limited to 0.9% because too high a carbon content can result in retained austenite and brittle martensite. Carburizing is one of the most widely used surface hardening processes. The process involves diffusing carbon into a low carbon steel alloy to form a high carbon steel surface. Carburizing steel is widely used as a material of automobiles, form 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 [2]. 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[3].

AI. LITERATURE REVIEW

Effect on tensile strength:- The investigation on the mechanical and wear properties of iron and steel component under different condition have been made by a number of workers. Most of these investigation had been made on analysis of wear properties a very few studies were made including both the mechanical and wear properties under the same parameters and conditions. Luo et al [4] studied the effects of microstructure on the abrasive wear behavior of spheroidal cast iron and reported that the wear resistance of spheroidal grey cast iron was inferior to that of steel with a similar matrix. Quenched structures were more resistant to abrasion than the austempered structures. In addition, the wear performance of quenched iron and steel samples were reported to be better than austenized at higher temperature.

Celik et al [5],[6] studied the high temperature abrasive wear behavior of an as-cast ductile iron and reported that the high temperature tensile properties were affected by dynamic strain aging. Serrated flow was observed in the temperature range between 100 and 300^{o}C. In this temperature regime, tensile strength values were almost invariable. Above 400^{o}C, increase of temperature decreased the tensile strength. Minimum ductility was observed at 500^{o}C. At 600^{o}C, higher ductility was observed than that of 500^{o}C. he also concluded that after the increase in wear resistance at 50–100^{o}C, abrasive wear resistance decreased with increasing temperature. Dynamic strain aging caused improvement of abrasion resistance. The highest resistance to abrasive wear is observed at temperature range between 50 and 100^{o}C. At this temperature range ductile iron exhibited more than 15% higher abrasion resistance than room temperature. Izciler and Tabur [7] on his study of abrasive wear behavior of different case depth gas carburized AISI 8620 gear steel concluded that in respect with microstructures, samples subjected to longer periods of gas carburizing exhibit greater case depth The samples having greater case depth and surface hardness are more wear resistant than that with low case depth and ductile reinforcement. Also absorbed energy of the composite decreases with decreasing test temperature since the steel wire in the composite loses its ductility and behaves as a brittle material as the test temperature was decreased. He also reported that Impact toughness of the gray cast iron was not improved with the increasing normalization temperature since there is no change in the morphology of graphite flakes in the gray cast iron with normalizing heat treatment. Normalizing heat treatment does not affect impact toughness of the cast composite significantly, because the partially dissolved region is very narrow due to insufficient volume fraction for the current work condition.

Carburization Temperature:- The authors found that the hardness and abrasion resistance of carburized mild steels increased considerably with increase of carburization temperature up to 940°C and soak time up to 2 hours; use of coal tar pitch and quenching oil on mild steel surface and its subsequent carburization in charcoal greatly Improved the wear resistance of carburized mild steel; the highest abrasion resistance was observed in the steel samples carburized in partially burnt charcoal and the hardness and wear resistance values of mild steels carburized by using coal tar pitch were comparable with those of heat treated high carbon low Cr steels. Bepari et al [8] studied the effects of Cr and Ni addition on the structure and properties of carburized low carbon steels and found that both Cr and Ni promote the formation of retained austenite in carburized and hardened steel, Cr being more effective. Both were found to refine the martensite platelets, with Ni being more effective the hardenability was found to increase with increase of austenite grain size and with extent of carbon penetration in carburized steel. Researchers have to improve the wear resistance of steel materials, but very little attention has been paid in reducing the wear of farm implements materials. Thus, there is an urgent need to substantially upgrade the mechanical properties and wear resistance of low carbon and mild steels in actual soil conditions.

BI. OBJECTIVES OF THE PRESENT WORK

The aim of present work is to improve the mechanical properties and wear resistance of the mild steels by using gaseous carburization less energy consuming carburization technique. In this connection the following studies were aimed to be carried out.

1. Carburization of mild steel samples at different temperatures and under various conditions using less energy consuming techniques.
2. Tempering of these carburized mild steel samples at a definite temperature for a particular period of time.

ISSN 2348 – 8034
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IV. METHODOLOGY

In our investigation we follow heat treatment process in which gaseous carburization process we choose for our experiment. During the process, austenite transforms into martensite the hard layer of carbon surfaced up to 0.03 to 0.09mm. The specimen of given dimension are put into the furnace and methane gas (in which CO carbon mono oxide gas is in unstable state in furnace) is pass in appropriate proportion into the furnace chamber where specimen soak carbon for 2 hours at fixed temp 860° C,900° C and 940° C respectively. Then quenched in water and after that tempered in the furnace for half an hour at 180°C.

Materials Selection:- Mild steels of the required dimensions were purchased from the local market and the test specimens were prepared from it. The chemical composition of mild steel by (wt %) is given as follows C-0.16, Si-0.03, Mn-0.32, S-0.05, P-0.2, Ni- 0.01, Cu-0.01, Cr-0.01 and Fe.

Preparation of test specimens:- The test specimen for analysis of different mechanical and wear properties like abrasive wear, toughness, tensile strength and hardness were prepared as per ASTM standard and its description is given below.

Specimen for abrasive wear and hardness test:- The abrasive wear and hardness is determined from the same specimen. A standard specimen of dimensions (4cm x 2.5cm x 0.5cm) of mild steel is prepared for the same purpose.

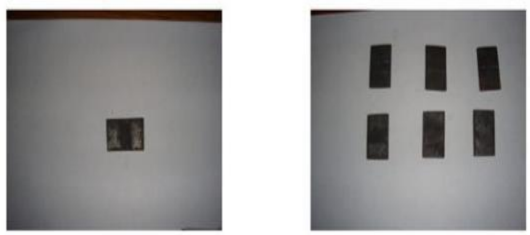

Fig 1:- specimen for abrasive wear test

Tempering of carburized mild steel samples:- After the carburization process, the steel is often harder than needed and is too brittle for most practical uses. Also, severe internal stresses are set up during the rapid cooling from the hardening temperature. 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 180^{o}C for duration of 0.5 hours and then cooling it usually in the still air. The carburized and tempered mild steel specimens are then subjected to various kind of mechanical and wear test.

Abrasive wear test:- The materials considered for this experiment is carburized mild steel samples which is carburized under different temperature range of 860, 900 and 940^{o}C with dimensions 4.0cm x 2.5 cm x 0.5 cm. The test was conducted on a machine called Pin on disc machine (make: SD scientific industries) as shown in fig. The sample was mounted perpendicularly on a stationary vice such that its one of the face is forced to press against the abrasive that is fixed on the revolving disc. Hence it is the abrasive paper that tends to wear the surface of the samples. When the disc rotates for a particular period of time, the sample can loaded at the top to press against the disc with the help of a lever mechanism. In this experiment the test can be conducted with the following parameters

a. Load
b. Speed
c. Time

In the present experimental work, speed and time wear kept constant while the load was varied from 14.7 N to 49 N. Parameters that remained constant throughout all the experiments are given in Table No. 1.

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Table No 1:- Parameters Taken constant in Abrasive Wear test

RPM	400
Time	4 minutes
Type of Abrasive paper	Emery, 80 grade size

For each of the sample, test was conducted for 5 times and the average of all the samples was taken as the observed values in each case. Once the parameter is set and work piece is mounted, the test is carried on for the desired time. The wear track so formed on the rotating disc is a circle. After each test only the mass loss of the specimen was considered as the wear. The wear rate of each sample was calculated from the weight loss, the amount of wear is determined by weighing the specimen before and after the test using precession electronic weighing machine. Since the mass loss is measured it is converted to volume loss using the density of the specimen. Hence wear volume, wear rate and wear resistance can be calculated as follows.

1. Wear Volume:-
   Wear Volume = Weight Loss/Density
   Density of the Specimen = 7.86 g/cm^3
2. Wear Rate:- It is defined as wear volume unit distance travelled
   Wear Rate = Wear Volume/Sliding Distance(s)
   Sliding distance(s) can be calculated as
   Sliding Distance(s) = V x time
   = (2* π*R*N/60)*time
   Where R = Radius of abrasive wheel (7.25 cm)
   N = RPM (400)
   π = 3.14(constant)

3. Wear Resistance: - Wear Resistance is the reciprocal of wear rate.
   Wear Resistance = 1/wear rate

Machine specification:- The specification of charpy machine used for the toughness test of present work is as follows.

Weight of hammer	18.75 kg
Striking of hammer	5 cm / s to 5.5 cm / s
Angle of hammer striking edge	30^0
Radius of curvature of striking edge	2 mm
Swing of hammer both ways	0

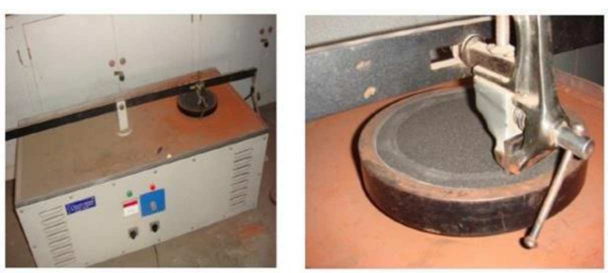

Fig 2:- pin on disc machine for abrasive wear testing

Tempered mild steel samples which are carburized under different temperature range of 860, 900 and 940^{o}C. For each of the sample, test was conducted for 5 times and the average of all the samples was taken as the observed values in each case.

V. EFFECT OF CARBURIZATION TEMPERATURE ON WEAR RESISTANCE OF CARBURIZED MILD STEEL

The effect of carburization temperature on wear resistance of carburized mild steels for the three different temperatures of 860, 900 and 940°C is shown in the Table No 2, it means with increase of carburization temperature the wear resistance also increases and the wear resistance is maximum for the mild steels carburized at temperature of 940°C and it is minimum for the mild steels carburized at temperature of 860°C. So the mild steels carburized at temperature of 940°C are giving the best results and it is preferred. Relationship with the hardness this means with increase in the hardness values of carburized mild steels the weight loss due to abrasion is decreases. That is because of the hard material having the greater abrasive wear resistance, so the less wear occurs in the carburized mild steels and the weight loss decrease [9].

Table No 2:- Abrasive Wear Resistance at Different Carburizing temperatures and conditions

Carburization Conditions		Tempering Conditions		Weight Loss (gms)	Wear Volume ($cm^3 x10^{-2}$)	Wear Rate ($cm^2 x10^{-7}$)	Wear resistance ($cm^{-2} x10^7$)
Temp (°C)	Soaking Time(Hrs)	Temp (°C)	Soaking Time(Hrs)				
Simple Mild Steel	-	-	-	0.220	2.77	4.02	0.265
860	2	200	0.5	0.123	1.79	2.58	0.413
900	2	200	0.5	0.118	1.5	2.20	0.455
940	2	200	0.5	0.99	1.28	1.92	0.485

VI. RESULT AND CONCLUSION

The results of abrasive wear test of carburized mild steels, carburized at different temperature of 860, 900 and 940°C is shown in Table No 2, roughly speaking, the weight loss during abrasion of all these carburized steels decreases linearly with the increase of hardness and carburization temperature. From the experimental results of abrasive wear test (Table No 2), the following regularities can be found.

1. The weight loss during abrasion is highest for uncarburized simple mild steel and is lowest for the mild steel carburized at temperature of 940°C.
2. The wear rate is highest for uncarburized simple mild steel and is lowest for the mild steel carburized at temperature of 940°C and this wear rate is gradually decreases with increase in carburization temperature, This is due to the fact that the weight loss during abrasion is directly proportional to the wear rate, so as the carburization temperature increases the weight loss during abrasion decreases and simultaneously there is the decrease in the wear rate.
3. The wear rate is also load dependent and the abrasion test results shown that the wear rate increases gradually while increasing the applied load, so the wear rate is highest for the load of 49 N and it is lowest for the load of 14.7 N.
4. The wear resistance is highest for the mild steel carburized at the temperature of 940°C and it is lowest for the uncarburized mild steel. For taking the case of only carburized mild steels also the wear resistance is highest for the mild steel carburized at the temperature of 940°C and is lowest for mild steels carburized at temperature of 860°C. Hence the abrasion results explain that the wear resistance is directly proportional to the carburization temperature, as the carburization temperature increases the wear resistance increases.
5. The net results is that the mild steel carburized at temperature of 940°C giving the best results, as it has having the highest wear resistance, lowest weight loss due to abrasion and lowest wear rate.

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