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"Effect of tempering temperature and applied load on various wear environment of carburized mild steel"

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Abstract: *This work presents the effect of various wear environments like 20% soil & 80% sand and 40% soil & 60% sand on as received and carburized mild steel sample at different load like 75N, 200N & 375N and at different tempering temperature like 200ºC, 250ºC & 300ºC. The mild steel sample was carburized at 950ºC. The heat treatment after carburization has been acknowledge that at some instant it improving the various properties of mild steel. The mechanical properties and wear behavior of mild steel samples carburized at temperature of 950ºC and tempered at different tempering temperature of 200ºC, 250ºC & 300ºC have been studied and it is observed that the sample with heat treatment improves the hardness, tensile strength and wear resistance of mild steel. For this experiment firstly the mild steel samples are carburized at temperature 950ºC than soaking for two hour and then it is tempered at different temperature range of 200ºC, 250ºC & 300ºC for 1h, 1.5h, 2h. After this the carburized and tempered mild steel samples are subjected for different kind of test such as abrasive wear test at different load like 75N, 200N & 375N, and tensile test. the result of these experiment shows that the carburized and tempered process greatly improve the mechanical and wear properties like hardness, tensile strength and wear resistance and these properties increases with increase in tempering temperature. The aim of these experiments is to examine the effects on mechanical and wear properties for mild steel samples which were carburized and tempered at different temperature and various wear environments.*

Keywords: *Mechanical properties, carburizing, tempering temperature, wear rate*

I. Introduction

The service conditions of many steel components such as gears, cams, valves, agricultural equipments etc, make it necessary for them to possess both hard and wear resistant surfaces but tough and shock resistant cores [1]. A low carbon steel of approximately 0.1% carbon will be tough while a high carbon steel of about 0.9% or more will possess adequate hardness (and inherently low toughness) when suitably heat-treated. The combination of hard, wear resistant surface and tough core required in the aforementioned components involves the treatment of a shock-resistant steel so as to alter the nature of the surface in order to increase the hardness while the core remains more or less unaltered.

There are two major processes through which such an alteration of the surface layers of steel components may be carried out, namely, (I) processes which impart surface hardness by changing the microstructure of the surface skin without changing the chemical composition of the surface. Such steel must not have a carbon content of less than 0.4% for them to be amenable to hardening (by any of flame, induction, laser, and electron beam hardening) (II) processes which impact surface hardness by changing the surface chemistry of the steel by diffusing carbon, nitrogen or both carbon and nitrogen into its surface. Steels for this process may have a carbon content of about 0.1%. Examples of this latter process include carburizing, nitriding, cyaniding, diffusion coating, and hard surfacing.

The method of carburizing was selected for this investigation because it has the advantages of ease of operation, adaptability and portability of the equipment required, ability to heat-treat component after this.

II. Literature Review

S. Tekeli and A. Güral [2] studied Dry sliding wear behavior of heat treated iron based powder metallurgy steels with 0.3% Graphite + 2% Ni additions. To determine the effect of various heat treatments on the microstructure and dry sliding wear behavior of iron based powder metallurgy (PM) steels, atomized iron powder was mixed with 0.3% graphite + 2% Ni . It was seen that hardness and wear strength in inter critically annealed specimens were higher than that of quenched + tempered specimen.

T.S. Eyre [3] studied that Wear characteristics of metals, the precise role of physical and mechanical properties of metals in wear is little understood. Halling has stated that the major growth area for the next decade lies in the role of surface treatments for improving tribological characteristics. These, however, are already becoming available faster than our rate of understanding of their precise tribological properties.

M. Scholl, R. Devanathan and P. Clayton [4] studied of Abrasive and dry sliding wear resistance of Fe-Mo-Ni-Si and Fe-Mo-Ni-Si-C weld hard facing alloys Although the overall trend is one of increasing abrasive wear resistance with increasing hardness, there is considerable scatter in the results. While the Fe-Mo-Ni-Si alloys have approximately only a third of the abrasive wear resistance of the more common white irons, the Fe-Mo-Ni-Si-C alloys came close to matching the white iron performance.

Kumar and Gupta [5, 6] carried out extensive studies on low stress abrasive wear characteristics of carburized low carbon steels, and heat tested medium carbon and alloy steels. The authors found that the hardness and abrasion resistance of carburized low carbon steels increased considerably with increase of carburization temperature and soak time; use of coal tar pitch and quenching oil on low carbon steel surface and its subsequent carburization in charcoal greatly Improved the wear resistance of carburized low carbon steel; the highest abrasion resistance was observed in the steel samples carburized in partially burnt charcoal and the hardness and wear resistance values of low carbon steels carburized by using coal tar pitch were comparable with those of heat treated high carbon low Cr steels.

M. Izciler and M. Tabur [7] studied Abrasive wear behavior of different case depth gas carburized AISI 8620 gear steel with different case depths were examined. It has been observed that gas carburizing time affects the case depth, and in turn, specimen with higher case depth has shown better wear resistance. In addition to this, as the case depth has increased, the hardness of the material has increased as well.

Shafaat Ahmed.S.M.A. Haseeb and A.S.W. Kurny [8] studied the wear behavior of Al–4.5% Cu–3.4% Fe in situ composite: Effect of thermal and mechanical processing .Al–Cu-based MMCs reinforced by Al–Fe intermetallics are investigated for their wear behavior. The extent of abrasive wear was largest in the as-cast MMC as evidenced by deep groves on the worn surface as well as by the highest wear rate. Dark patches of presumably transfer layer were found in some cases, particularly on the (rolled + solution treated + aged) samples.

Khusid et al [9] on his work studied the Wear of carburized high chromium steels and reported that Carburization raises the abrasive wear resistance and allows significant suppression of the adhesion phenomena under dry sliding. The results obtained determine the regime of surface resistance and bulk strength properties hardening of high chromium steels required to produce the desired combination of wear. The results of an experimental investigation carried out by resistance to nucleation and propagation of micro-cracks etc.

Y. Sahin and K. Özdin [10**]** studied A model for the abrasive wear behavior of aluminum based composites. It was demonstrated through established equations that the wear rate increased with increasing applied load, abrasive size and decreased with sliding distance.

J.J. Coronado and A. Sinatora [11] studied Abrasive wear study of white cast iron with different solidification rates. The abrasive wear resistance of white cast iron was studied. The iron was solidified using two solidification rates of 1.5 and 15 °C/s. The austenitic samples showed cracking and fracture of M_3C carbides. For the predominantly martensitic matrix, the wear rate was higher at the solidification.

A.P. Harsha [12] studied of low stress abrasive wear characteristics of high performance engineering thermoplastic polymers Wear studies have been carried out using angular silica sand particles of size ranging between 150 and 250 μm and used as dry and loose abrasives. Abrasive wear studies was carried out at a constant sliding velocity (v = 2.4 m/s) of rubber wheel and at different loads (5–20 N). The results showed that abrasive wear rates were strongly influenced by the applied load and type of polymeric material.

III. Methodology

3.1 Preparation of test specimens

The test specimens for analysis were prepared as per ASTM standard and their description is given below.

3.1.1 Specimen for abrasive wear and hardness test

Specimens of same dimensions are used for both the abrasive wear rate analysis and hardness testing. Dimensions of the specimen are 75mm × 25mm × 5mm.

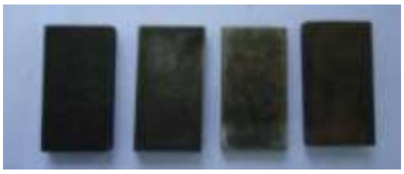


Fig. 3.1 Specimen for abrasive wear rate analysis and hardness testing

3.1.2 Specimen for tensile test

A tensile test specimen as per ASTM standard is prepared for this purpose is based on the following equation.

$L = 5.65\sqrt{A}$

Where, L = Gauge length

A = Cross sectional area

The dimensions of the specimen are:

Thickness - 6mm
Width - 25mm
Gauge length - 100mm

Fig. 3.2 Specimen tensile test

3.1.3 Carburization of mild steel samples

It is proposed to compare the behavior of low carbon steel for the as received specimen with heat treated specimen. The heat treatment process used in the current investigation is Carburization. The entire carburization process is explained below.

Firstly, samples are placed on the thick bed of carburizer kept in a stainless steel container. The container is fully covered from all sides and the top of the container is covered with a steel plate. The container was then introduced into the electrical box type furnace (Fig. 3.3.) maintained at the required carburization temperatures. The carburization temperatures used in present work are 950 °C. Specimens are subjected to different soak time of 2h. After carburization, the specimens are quenched in oil. This results in hardening of the specimen surface.

Fig. 3.3 Electrical furnace box type (single and double door)

3.1.4 Tempering of carburized samples

After the carburization process, the steel is often harder than needed and is too brittle for most practical use. 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. For this, the carburized steel samples are tempered at 200°C, 250°C, 300°C for 1hr, 1.5hr, 2hr and then allowed to cool in still air.
Now the specimens are ready for testing.

3.2 Abrasive wear test

The test was conducted on a machine called Dry Abrasion Test Rig TR-50 (Company: DUCOM) as shown in Fig. 4.4.

Fig.3.4 Dry Abrasion Test Rig TR-50 (door close and open)

Table 3.1 Machine Specification of Dry Abrasion Test Rig TR-50

TYPE NO. – TR-50
VOLTS – 30
VA – 4000
SL.NO – 140301S174
YEAR – 2003

The sample is mounted perpendicularly on a stationary vice such that its one of the face is forced to press against the abrasive (mixture of soil and sand). The size of sand grain is from 212-300μm. The abrasive is made to flow from a nozzle against a rotary disc. The rotary disc has a rubber covering. The disc forces the abrasive mixture against the specimen to cause abrasive wear. The size of sand grain is from 212-300μm. In this machine, the test can be conducted with the following parameters (i) Speed (ii) Time or (iii) Load.

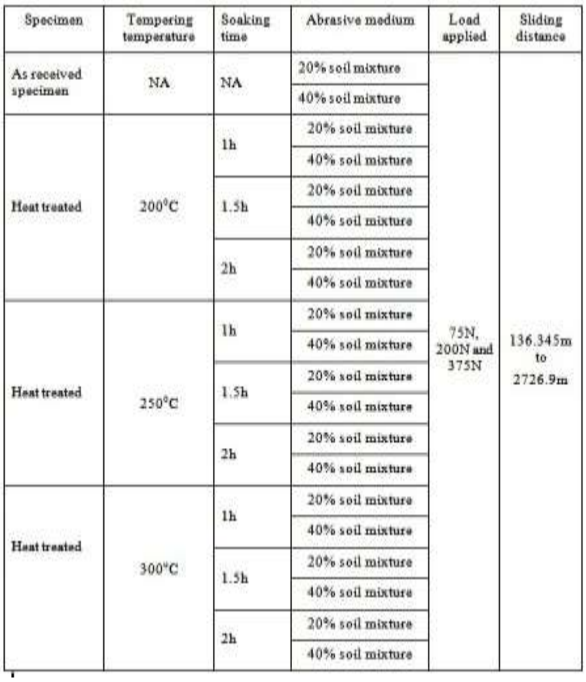
In the present work, speed and time are kept constant while the load is varied. The loads used are 75N, 200N and 375N. Parameters that remained constant throughout all the experiments are:

Table 3.2 Parameter taken constant in Dry Sand abrasive wear test

Speed	100 rpm
Time	2.25 min

For each sample, tests are conducted 20 times and the average value is taken as the observed value in each case. The machine has facility to fix the desired parameters, speed and time. The load is applied by placing the weights on a hook in cantilever. After each test, weight loss of the specimen is noted to determine the wear. The amount of wear is determined by weighing the specimen before and after the test using precession electronic weighing machine.

Table.3.3 Details procedure of abrasive wear test



Specimen	Tempering temperature	Soaking time	Abrasive medium	Load applied	Sliding distance
As received specimen	NA	NA	20% soil mixture	75N, 200N and 375N	136.345m to 2726.9m
			40% soil mixture		
Heat treated	200°C	1h	20% soil mixture		
			40% soil mixture		
		1.5h	20% soil mixture		
			40% soil mixture		
		2h	20% soil mixture		
			40% soil mixture		
Heat treated	250°C	1h	20% soil mixture		
			40% soil mixture		
		1.5h	20% soil mixture		
			40% soil mixture		
		2h	20% soil mixture		
			40% soil mixture		
Heat treated	300°C	1h	20% soil mixture		
			40% soil mixture		
		1.5h	20% soil mixture		
			40% soil mixture		
		2h	20% soil mixture		
			40% soil mixture		

3.3 Wear rate

It is defined as mass of wear per unit distance travelled.

Wear rate = mass wear / sliding distance(s)
Sliding distance (s) can be calculated as
Sliding distance (s) = V x time = (2 π R N / 60) x time
Where, R = radius of abrasive wheel (10.85cm)
N = R.P.M (100) π = 3.14 (constant) Time = 2.25 minute = 225 sec

3.4 Tensile test: The tensile strength of the specimen is determined by using Universal testing machine.

Specifications of Universal testing machine

Sample Type : ASTM
Model : AG-1/100kN

P. No : 346-5211-11(frame)
V : 3ϕ 200-230
Hz : 50-60
VA : 1.8k
Frame capacity : 100kN
Frame weight : 800kg

Fig. 3.5 Universal testing machine (AUTOGRAPH)

IV. Results & Discussion

4.1 Effect of sliding distance on the various wear environment of carburized mild steel at load 75N and different tempering temperature :-

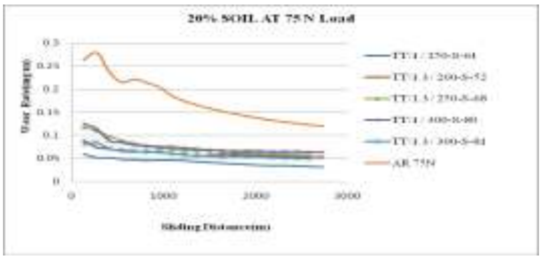


Fig.4.1 Wear Rate Vs sliding Distance for 20% soil mixture at 75N load

4.2 Effect of sliding distance on the various wear environment of carburized mild steel at load 200N and different tempering temperature :-

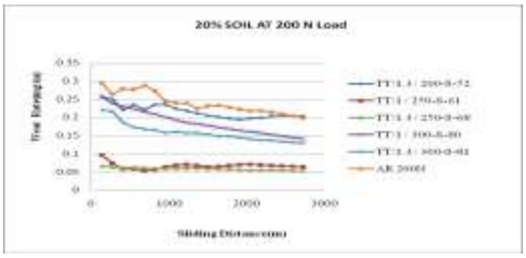


Fig.4.2 Wear Rate Vs sliding Distance for 20% soil mixture at 200N load

4.3 Effect of sliding distance on the various wear environment of carburized mild steel at load 375N and different tempering temperature :-

***Fig.4.3 Wear Rate Vs sliding Distance for 20% soil mixture at 375N load*.**

4.4 Effect of sliding distance on the various wear environment of carburized mild steel at load 75N and different tempering temperature :-

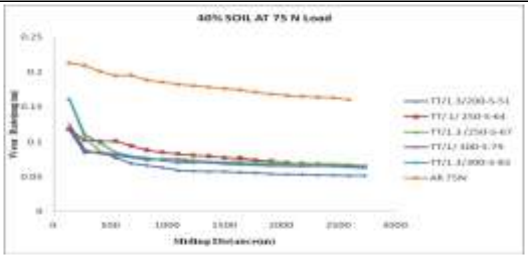


Fig.4.4 Wear Rate Vs sliding Distance for 40% soil mixture at 75N load.

4.5 Effect of sliding distance on the various wear environment of carburized mild steel at load 200N and different tempering temperature :-

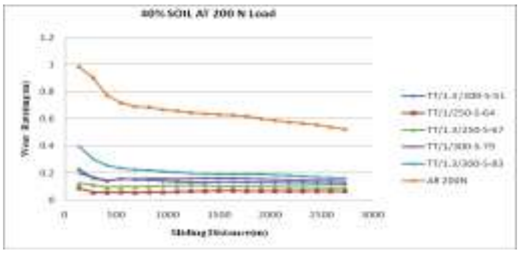


Fig.4.5 Wear Rate Vs sliding Distance for 40% soil mixture at 200N load.

4.6 Effect of sliding distance on the various wear environment of carburized mild steel at load 375N and different tempering temperature :-

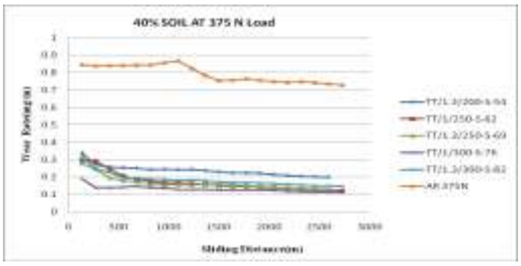


Fig.4.6 Wear Rate Vs sliding Distance for 40% soil mixture at 375N load

4.7 Effect of sliding distance on various wear environment like 20% soil & 80% sand of carburized mild steel at constant tempering temperature of 200ºC at different load:-

Fig. 4.7 Effect of different load on wear rate of mild steel carburized at 950ºC and tested at 200ºC

4.8 Effect of sliding distance on various wear environment like 20% soil & 80% sand of carburized mild steel at constant tempering temperature of 250ºC at different load:-

Fig 4.8 Effect of different load on wear rate of mild steel carburized at 950ºC and tested at 250ºC

4.9 Effect of sliding distance on various wear environment like 20% soil & 80% sand of carburized mild steel at constant tempering temperature of 300ºC at different load:-

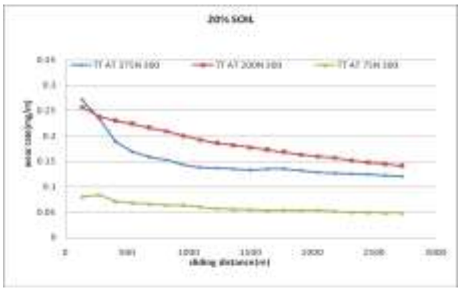


Fig 4.9 Effect of different load on wear rate of mild steel carburized at 950ºC and tested at 300ºC

4.10 Effect of sliding distance on various wear environment like 40% soil & 60% sand of carburized mild steel at constant tempering temperature of 250ºC at different load:-

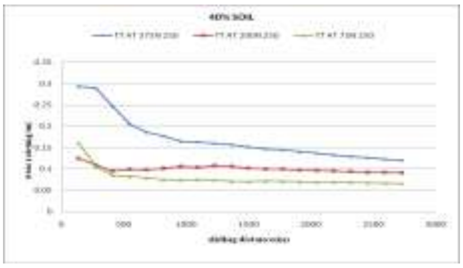


Fig. 4.10 Effect of different load on wear rate of mild steel carburized at 950ºC and tested at 250ºC

4.11 Effect of sliding distance on various wear environment like 40% soil & 60% sand of carburized mild steel at constant tempering temperature of 300ºC at different load:-

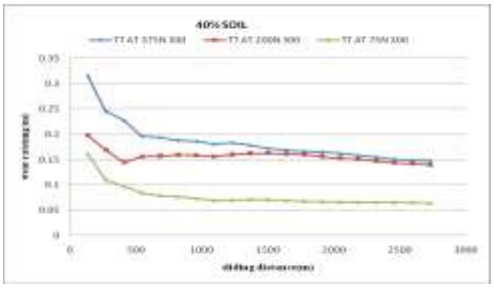


Fig. 4.11 Effect of different load on wear rate of mild steel carburized at 950ºC and tested at 300ºC

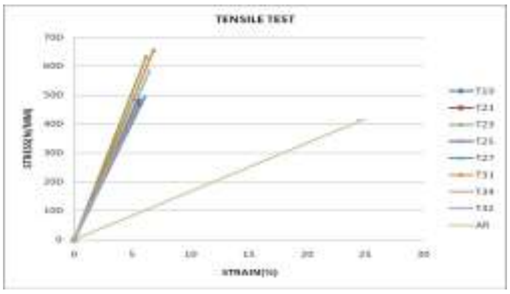


Fig.4.12 Stress Vs Strain% for different heat treated and as received sample

V. Conclusion

In this experimental work the different kind of mild steel samples were carburized at 950ºC and various wear environment such as mixture of 20% soil & 40% soil and tempered under the different tempering temperatures like 200ºC, 250ºC and 300ºC and then tested for various kind of test like abrasive wear test, tensile strength test. The result abrasive wear test for as received mild steel simple and the mild steel sample carburized at 950ºC and tempered at 200ºC, 250ºC &300ºC and various wear environment for different loads 75N, 200N & 375N.

The wear rate due to abrasion decreases with sliding distance. The wear rate due to abrasion is highest for the load of 375 N and it is lowest for the load of 75 N. The result show that with the increase in the applied load the wear rate due to abrasion is also increases from the graph (fig.4.1 to fig.4.6).

From these results we found that the wear rate due to abrasion is highest for the mild steel tempered at temperature of 200ºC for 20% soil and it is lowest at temperature of 300ºC for 40% soil. From the graph (fig. 4.7 to fig. 4.11) it is clear that the wear rate curve decreases gradually with increase in the tempering temperature. This result is expected because as the tempering temperature increases, the hardness of carburized mild steel also increases and therefore abrasive wear rate decreases.

Tensile strength of heat treated mild steel varies linearly with hardness and tempering temperature. The tensile strength is highest for the mild steel tempered at temperature of 300ºC and lowest for as received sample of mild steel. The results show that the tempering greatly improved the tensile strength of mild steel from the graph (fig. 4.12).

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