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Effect of High Temperature Tempering on Wear & Mechanical Properties of 0.2 and 0.45 % C Mild Steel

Prof L. N. Karadi, Prof. S. S. Chappar, Prof. A. D. Talikoti & Prof B. M. Angadi
Department of Mechanical Engineering
V.P Dr.P.G.Halakatti College of Engg. & Tech.,Bijapur

Abstract

The influence of tempering heat treatment on mechanical properties of 0.2 & 0.45% hardened Carbon steel was investigated in the present study. Observations showed that high temperature tempering reduces wear rate, decreases the hardness from 196 VHN to 180 VHN(8.16% reduction in hardness) for 0.2 % C & 224 VHN to 195 VHN(12.94 % reduction in hardness) for 0.45 % C.Tensile strength was increased from 0.4155 to 0.5747 KN/mm^2 and % of elongation increased by 40.58 For 0.2% C and 0.5040 To 0.8802 KN/mm^2 and % of elongation increased by 77.77 for 0.45 % C. Compression strength increased from 0.77 KN/mm^2 to 0.89 KN/mm^2 for 0.2% C and 0.69 KN/mm^2 to 0.79 KN/mm^2 for 0.45 % C.

Introduction

Steel subjected to hardening possess martensitic microstructure, which is the strongest structure than pearlite and austenite. Although martensite is very strong phase, it is normally very brittle. Even slight impacts may cause fracture of the hardened metal. Hence it is very necessary to modify the properties, which is usually done by tempering process.

Tempering is a heat treatment process that reduces the brittleness of steel without significantly lowering its hardness and strength. Tempering is an essential operation that has to be performed after hardening. The main purpose of tempering is to reduce brittleness of hardened steel, to improve toughness of steel, to relive internal stresses and to increase percentage of elongation at higher temperatures. Based on reheating temperature range of hardened steel, tempering may be classified as a) Low temperature tempering b) Medium temperature tempering a) High temperature tempering.

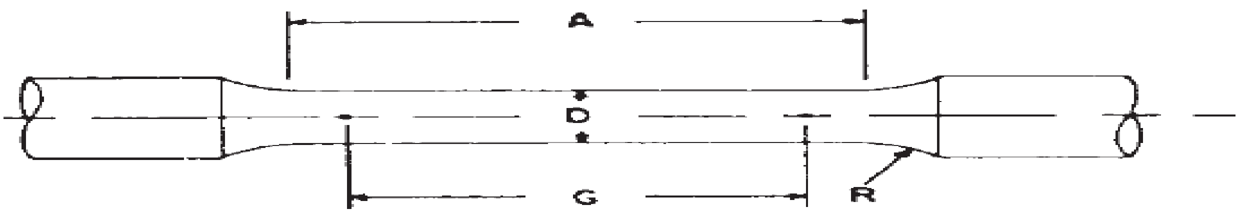
Experimental details

In the present study high temperature tempering was carried out after quench hardening. It is done by reheating the hardened steel to a temperature below A_1 (500-500 ^{o}C) line followed by slow cooling in still air. Once the steel is tempered the specimens are prepared to carry out the tensile (Tensile test specimens were prepared according to ASTM E 8M – 04 standards), compression, Hardness and wear tests.

Result and Discussions

Due to high temperature tempering specimen develops coarse spheroidal structure known as sorbite which is ductile as compared to martensitic microstructure. Due to high temperature tempering it eliminates the residual stresses completely and imparts high ductility, plasticity and hence improvement in tensile strength and compression strength is observed with adequate (slight reduction) hardness as shown in table 1, 2 and 3.

Tensile test



	Dimensions ,mm Standard specimen
G- Gauge length	62.5 ±0.1
D-Diameter	12.5 ±0.1
R-Radius of fillet,	10
A-length of reduced section	75

Fig 1 Tensile test specimen according to E 8M – 04 ASTM standards

Specimens	Tensile strength (KN/mm^2)	% of elongation	% reduction in area
Hardened 0.2% mild steel	**0.4155**	**13.23**	**43**
Tempered 0.2% mild steel	**0.5747**	**18.60**	**48.38**
Hardened 0.45% mild steel	**0.5040**	**8.1**	**49.6**
Tempered 0.45 % mild steel	**0.8802**	**14.4**	**53**

Table 1.Tensile strength of the specimen before and after heat treatment

Hardness

Specimens	Vickers Hardness No
Hardened 0.2% mild steel	**196**
Tempered 0.2% mild steel	**180**
Hardened 0.45% mild steel	**224**
Tempered 0.45 % mild steel	**195**

Table 2.Hardness of the specimen before and after heat treatment

Compression Test

Specimens	Compression strength KN/mm^2
Hardened 0.2% mild steel	**0.77**
Tempered 0.2% mild steel	**0.89**
Hardened 0.45% mild steel	**0.69**
Tempered 0.45 % mild steel	**0.79**

Table 3.Compression strength of the specimen before and after heat treatment

Wear test

Wear pins of 25 mm length and 8 mm diameter were machined from the cast specimen obtained from graphite split mould (12.5 mm diameter and 125 mm length). Wear tests were conducted using pin on disc wear testing machine (TR-20, DUCOM, PIN-ON-DISCMACHINE). The disc is made of low carbon alloy steel (EN-32 Steel, 160 mm diameter and 8 mm thickness) having hardness value of about 62RC. Wear losses were recorded. Wear losses were measured with a linear variable differential transformer (LVDT) and it was monitored by the loss of length due to wear of the specimen of the fixed diameter. The wear loss was measured in microns (µm). Weight loss method is followed to get the more accurate results. In this method weight of the wear pin before and after conducting the wear test is recorded using an electronic weighing machine. Difference between the initial and final weight gives the weight loss due to wear. Three sets of wear testing experiments are conducted to study the tribological wear behavior of all these alloys. Three sets of experiments are:

1. Normal pressure dependent experiments.
2. Sliding speed dependent experiments.
3. Sliding distance dependent experiments.

Normal pressure dependent experiments

These sets of experiments were conducted on each wear pin to study the effect of normal pressure (i.e., load) variation on tribological characteristics of 0.2 and 0.45% Carbon steel alloy before and after high temperature tempering heat treatment. Different normal pressures applied on the wear pins are: 0.1952 N/mm^2, 0.3903 N/mm^2, 0.5855 N/mm^2, 0.7806 N/mm^2, 0.9758 N/mm^2, and 1.1709 N/mm^2. The sliding distance and sliding speed were kept constant at 565.486 and 1.884 m/sec respectively for each test.

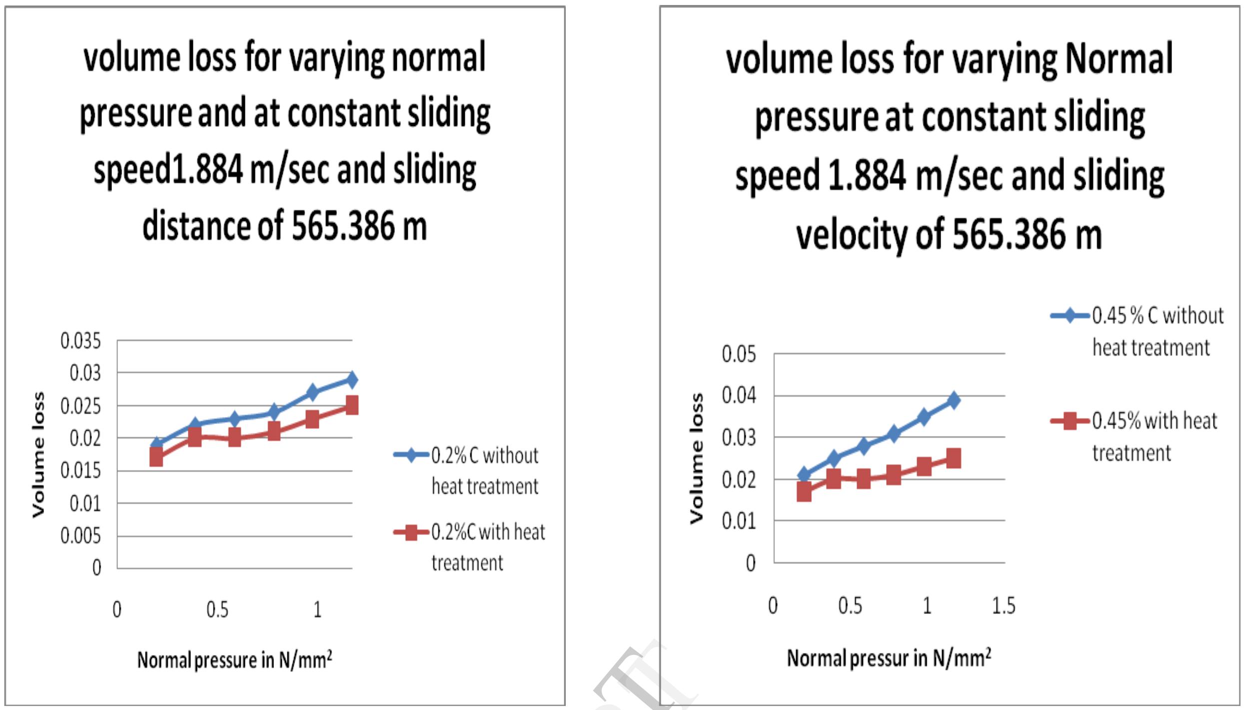
Sliding speed dependent experiments

These sets of experiments were conducted on each wear pin to study the effect of normal pressure (i.e., load) variation on tribological characteristics of 0.2 and 0.45% Carbon steel alloy before and after high temperature tempering heat treatment. Different Sliding Speed applied on the wear pins are: 0.942 m/sec, 1.884 m/sec, 2.827 m/sec and 3.7704 m/sec. The sliding distance and Normal Pressure were kept constant at 282.743 m and 0.9758 N/mm^2 respectively for each test.

Sliding distance dependent experiments

These sets of experiments were conducted on each wear pin to study the effect of normal pressure (i.e., load) variation on tribological characteristics of 0.2 and 0.45% Carbon steel alloy before and after high temperature tempering heat treatment. Different Sliding Distances selected for the wear pins are: 282.431 m, 565.486 m, 848.229 m, 1130.972m, 1413.716 m, and 1696.459 m. The Sliding Speed and Normal Pressure were kept constant at1.884 m/sec and 0.9758 N/mm^2 respectively for each test.

Effect of normal pressure



0.2% Carbon steel | 0.45 % Carbon steel

Fig 2.Volume loss Vs Normal pressure for 0.2 and 0.45% C with and without tempering heat treatment

Figure.3 shows the plot of volume loss and normal pressure for 0.2 and 0.45% C with and without tempering heat treatment. The normal pressure is obtained by varying the pressure from 0.2 N/mm2 to 0.98 N/mm2 at constant sliding velocity of 1.88 m/sec and for a constant sliding distance of 565.49 m. At each normal pressure, the weight loss from the specimens was determined, and it's converted into volume loss by using measured density of the material. The graph obtained shows the volume loss increases with increase in normal pressure. Contact normal pressure is important parameter which significantly affects the wear response of mild steel under dry sliding conditions. Normal pressure is main variable of dry sliding wear as it controls the degree of adhesion (metallic intimacy), sub-surface damage, thermo-mechanical effects on the sliding surface due to frictional heat and tendency to form and break the oxide film. Surface peaks are known to deform under external load. Increase in deformation increases actual area of contact which in turn increases the metallic intimacy. Wear rate increases with increase in carbon content of material. From figure it is very much clear that volume loss after tempering decreases for both 0.2 and 0.45% Carbon steel.

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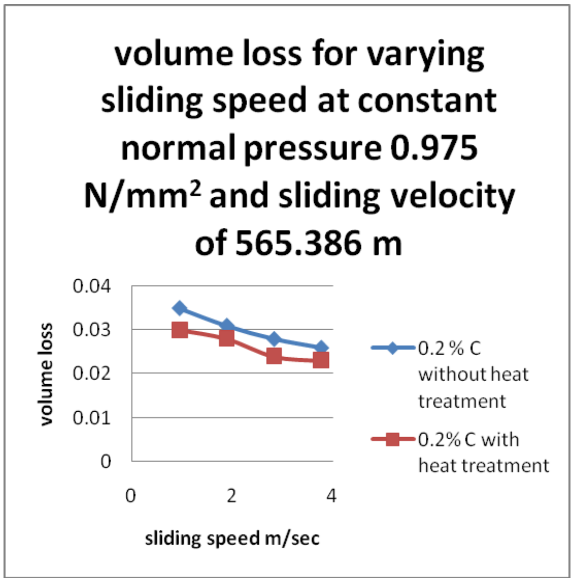
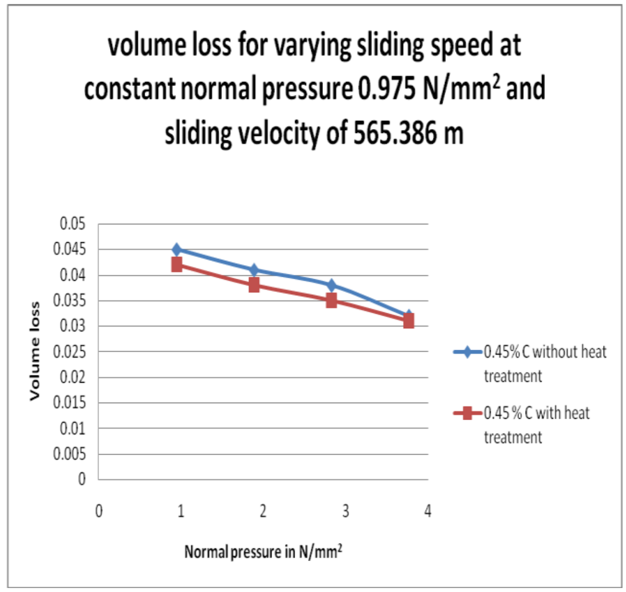
Effect of sliding speed



0.2 % Carbon steel

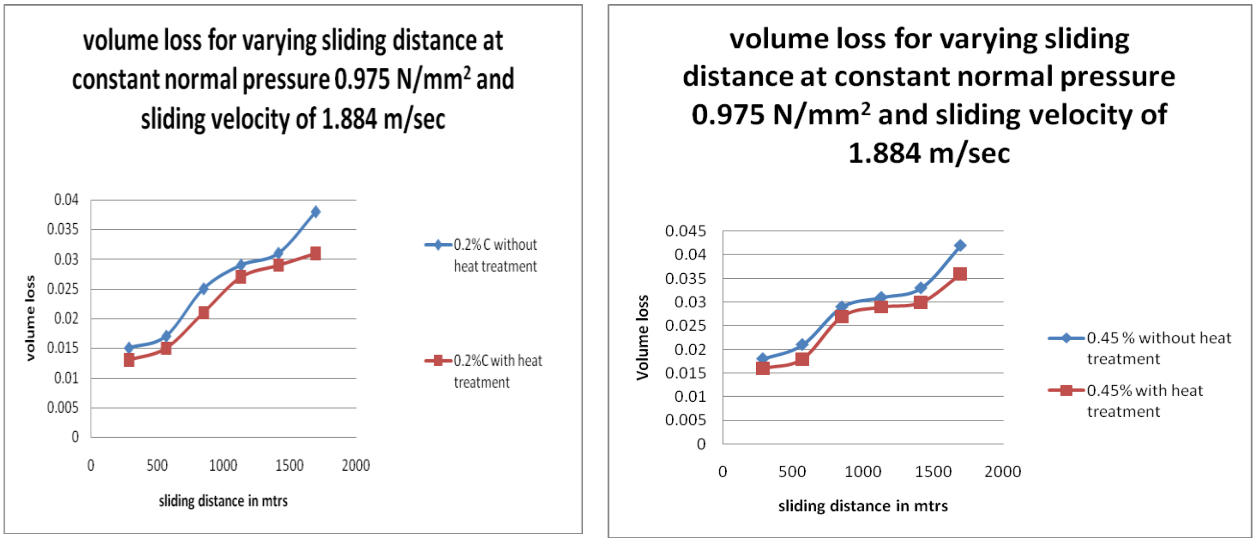


0.45% Carbon

Fig 3. Volume loss Vs sliding speed for 0.2 and 0.45% C with and without tempering heat treatment

Figure.4 shows the plot for volume loss and sliding velocity for 0.2 and 0.45% C with and without tempering heat treatment. The different sliding velocity is obtained by varying the speeds from 0.9425 m/sec to 3.7699 m/sec at a constant normal pressure of 0.9758 N/mm2 and at a constant sliding distance of 565.49m. At each sliding velocity, the weight loss from the specimens is determined, and the volume loss is obtained by using the density value.It is observed that the volume loss are maximum at low sliding velocity of 0.94 m/sec and minimum at high sliding velocity of 3.77 m/sec. Volume loss decreases with increase in sliding velocity from 0.94 m/sec to
3.77 m/sec. With increase in the sliding velocity there is an increase in the interface temperature. This may be lead to the formation of oxide layer at higher interface temperatures. The oxide layer reduces the chance of direct metallic contact due to which tiny contact points (asperities) interaction is decreased. Wear rate increases with increase in carbon content of material. From figure it is very much clear that volume loss after tempering decreases for both 0.2 and 0.45% Carbon steel.

Effect of sliding distance



0.2 % carbon steel

0.45 % carbon steel

Fig 4. Volume loss Vs sliding distance for 0.2 and 0.45% C with and without tempering heat treatment

Figure.5 shows the plot for volume loss and sliding velocity for 0.2 and 0.45% C with and without tempering heat treatment. The different sliding distance is obtained by varying the sliding distance from 282.74 m to 1696.46 m. At each sliding distance, the weight loss from the specimens is determined and converted into volume loss using the measured density of the material. It is observed that volume loss increases with increase in sliding distance. Sliding distance is important parameter which significantly affects the wear response of aluminium silicon alloys under dry sliding conditions. Sliding distance is main variable of dry sliding wear as it controls the degree of adhesion (metallic intimacy), sub-surface damage, thermo-mechanical effects on the sliding surface due to frictional heat and tendency to form and break the oxide film. Surface peaks are known to deform under external normal pressure. Increase in deformation increases real area of contact which in turn increases metallic intimacy. Wear rate increases with increase in carbon content of material. From figure it is very much clear that volume loss after tempering decreases for both 0.2 and 0.45% Carbon steel.

Conclusions

The experimental investigations have been carried out to study the "Effect of High temperature tempering on mechanical properties of 0.2 & 0.45 % C mild steel". Mechanical properties such as tensile strength, compression strength, hardness were studied. Wear tests were carried out with varying normal pressure, sliding velocity and sliding distance. The results are obtained from the series of tests by keeping two parameters out of the three (sliding distance, sliding speed and normal pressure) constant against wear.

The present investigation has led to the following conclusions.

1. Due to high temperature tempering, specimen develops coarse spheroidal structure known as sorbite which is ductile as compared to martensitic microstructure. It is observed that the high temperature tempering eliminates the residual stresses completely and imparts high ductility, plasticity and hence improvement in tensile strength for both specimens of 0.2 and 0.45 % carbon steel.

2. Due to increase in ductility, compression strength improved for both high temperatures tempered specimens of 0.2 and 0.45 % carbon steel as compared to specimens without tempering.

3. Due to high temperature tempering, specimen develops coarse spheroidal structure known as sorbite which is ductile as compared to martensitic microstructure so that hardness of tempered specimen decreases slightly as compared to specimens without tempering.
4. Volume loss or wear rate increases with increasing normal pressure (Contact load) and Sliding distance. Contact load and sliding distance are two very important parameters which significantly affect the wear response of aluminium silicon alloys under dry sliding conditions. Contact load and sliding distance are main variables of dry sliding wear as they control the degree of adhesion (metallic intimacy), sub-surface damage, thermo-mechanical effects on the sliding surface due to frictional heat and tendency to form and break the oxide film. Surface peaks are known to deform under external load. Increase in deformation increases real area of contact which in turn increases metallic intimacy. In general, an increase in normal load is known to increase the wear rate due to increased metal to metal contact between mating surfaces. Depending upon the sliding distance, composition of alloys, and counter surface and surface finish, increase in wear rate with normal load may be linear or nonlinear. Wear rate increases with increase in carbon content of material. Wear rate of tempered specimens decreases as compared to specimens without tempering.

5. Volume loss decreases with increase in sliding velocity from 2.8274m/s to 3.7699 m/s. With increase in the sliding velocity there is an increase in interface temperature. This may be lead to the formation of oxide layer at higher interface temperatures. Wear rate of tempered specimens decreases as compared to specimens without tempering.

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