Scientific Research and Essays Vol. 7(7), pp. 782-789, 23 February, 2012
Available online at http://www.academicjournals.org/SRE
DOI: 10.5897/SRE11.492
ISSN 1992-2248 ©2012 Academic Journals

Full Length Research Paper

Effect of longitudinal stress levels on sliding wear

H. Imrek*, V. Firat and M. Bagci

Department of Mechanical Engineering, Selcuk University, Alâeddin Campus, 42075 Konya, Turkey.

Accepted 22 August, 2011

In this study, sliding wear on specimen surfaces subjected to tensile loads was investigated. Specimens were loaded with four tensile loads that correspond to 0, 20, 40 and 60% of the specimens' yield strength value, and then the resulting variations of wear rate with respect to sliding distance were investigated. In addition, a constant dead load of 60 N was exerted on the specimens and two different values of sliding speed were adjusted at 0.628 and 1.256 m/s throughout the tests. In literature, a similar study was conducted by varying normal loads on specimen whereas in our study, besides the constant normal load on specimen, the effects of sliding speed changes on wear under tensile stresses were taken into consideration too. The results of the tests have shown that the maximum sliding wear occurs at a load that corresponds to 60% of the specimen's yield strength. Just as the wear increases with stresses, it was also found that an increase in sliding speed leads to increase in wear as well.

Key words: Sliding wear, tensile loads, yield strength, sliding speed, wear rate.

INTRODUCTION

Mechanical interaction, friction (relative motion), gradual and continuous movement (as opposed to sudden impact) are considered as necessary and enough conditions to cause deformations on material surfaces and a sliding wear even though the latter is never needed (Cocks, 1962; Blau, 1997; Hanlon et al., 1997). There are various factors affecting sliding wear. Some of them are the nature of the contact, geometric configuration of contact area, the state of operating, type of load, relative speed, temperature, material pair, material hardness and surface roughness (Zimba et al., 2004; Gunduz et al., 2008). The difficulty in measuring and understanding of wear behavior is caused by many factors involved in the process. Such factors hinder classifications, understanding and, consequently, modeling of wear mechanism. For this reason, experiments involving wear are generally conducted by dealing with just one parameter with respect to time. Under the light of this general view, this study concentrated on wear behavior under the effects of stresses only (Jiang et al., 2004).

A lot of researches on investigation of factors affecting wear have been and are still conducted; but only few studies exist on investigation of effects of stresses on wear as a result of applied external loads. In Finnie's (1972) experimental study, effects of striking angle, impact speed, surface properties and stress state of the surface, particle density and their shapes as well as particle strengths were investigated. The research found that the stress on the surface had still some effects on the wear regardless of how small the effects were. On top of that, the study also investigated the stress level in the surface where external bending moments were applied and found to have increased the wear slightly. Tilly and Sage (1970) found that mechanical properties like stress and hardness of materials such as metal, plastics and ceramics play important roles to their wear resistances. It was also found that erosive wear starts as pitting and fracture on the materials then the effects increases radially based on the initial striking intensity. That is, a difference between hardness and stress on the surface led to variation of the wear. In another study, Naga et al. (1991) investigated the effects of stresses on sliding wear by applying an axial tensile stress on test specimens.

However, apart from the axial tensile stress, other types

*Corresponding author. E-mail: imrekh@gmail.com.

Abbreviation: SEM, Standard error of mean.

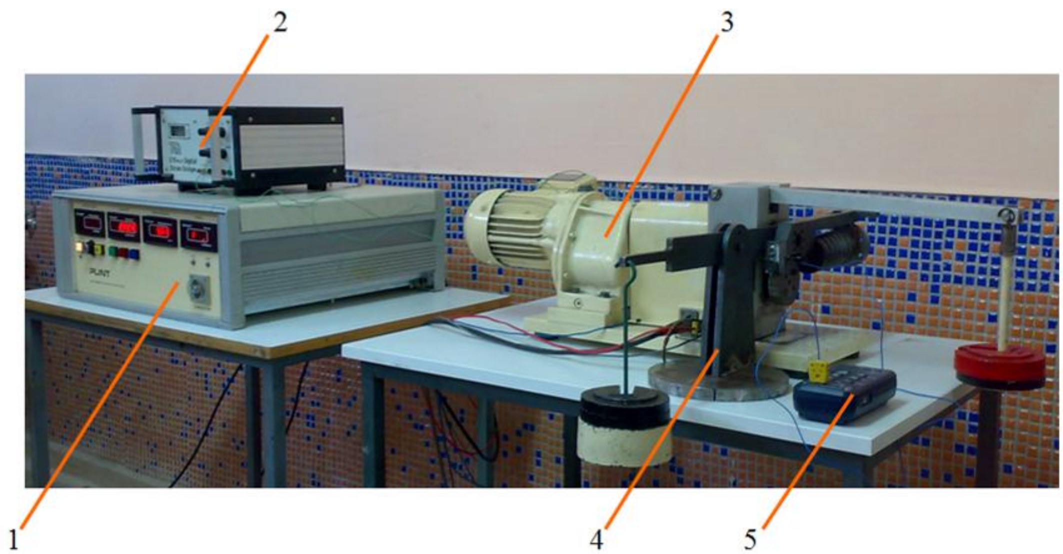


Figure 1. General view of test device.

of stresses were also encountered and therefore net effects of the tensile stress on sliding wear could not be precisely determined.

In this experimental study, a special specimen holder was designed to help with removing extra effects of stresses and therefore maintaining only the effects of tensile stresses so that the behavior of sliding wear could be investigated. Moreover; beside the effects of normal load, our study concentrated on effects of sliding speed on wear under external stress. The results showed that, generally, wear rate increases with stress and speed.

MATERIALS AND METHODS

Test device

As shown in Figure 1, the test device used in this experimental study which is based on a disc-on-a block contact geometry, consists of a control unit (1), which measures entities like number of revolutions, total cycles and friction force, digital strain meter (2), block-on-ring wear unit (3), a special specimen holder (4) and digital thermometer (5).

Loading of the specimens was achieved by mounting the specimen holder onto a clamp and tightening a nut along a screwed bolt. Then, this specimen holding apparatus was fixed into its place on the test device. Loading values were adjusted with the help of a strain gauge having a gauge factor of 2.15 placed on the screwed bolt and read through a digital strain meter (Figure 2). A half bridge circuit connection was used and the stability of the whole system was 1 $\mu\varepsilon$. Moreover, in order to prevent other types of stresses apart from the axial tensile stress, an adjustable supporting bolt was placed under the test specimen.

Stress rates and axial tensile loads exerted on the specimens for every cycle during the tests are given in Table 1.

A photograph and a schematic drawing of a special specimen holder apparatus and its balancing mechanism are given in Figure 3. This section of the system consists of a cylindrical helical spring (a), screwed rod (b), tightening nuts (c), specimen fixer (d), test specimen (e), adjustable supporting bolt (f), balancing arrangement (g), balancing handle (h) and a balancing dead weight (i).

Test specimen

In this experimental study, low carbon steel specimens prepared according to DIN EN 10025–94 (E295) standards were used, and their dimensions and chemical compositions are respectively given in Figure 4 and Table 2. The test specimens with a hardness of 144 HB had had their surfaces precisely ground with an average roughness of 0.9 μm.

Dimensions of the abrasive disc used, which was made of 100Cr6 steel are given in Figure 4, whereas its chemical compositions are given in Table 2. The disc used had hardness of 615 HB and its surface was scratched with emery before conducting every test in order to make sure that no debris of a previous specimen remains on the disc surface.

Test procedure

The test specimens were cut with a laser cutting machine, interested surfaces ground, cleaned with acetone and then dried with compressed air. Initial weights of the specimens were recorded after being weighed on a scale having an accuracy of 10^{-4} gr. Then the specimens were mounted into the specimen holder apparatus and the loads given in Table 1 were exerted under the control of a digital strain meter. In order to avoid sagging on specimens under application of loads, and to prevent formation of other type of stresses, the specimens were supported by an adjustable supporting bolt.

Balancing of the specimen holder was achieved by suspending a dead weight on the balancing handle and thereby the weight on the specimen could precisely be exerted. Then, for every test specimen, a constant load of 60 N was applied as a dead weight through the handle of the block-on-ring set; then the test set was run at constant speeds of 200 and 400 rpm over sliding distances of 377 and 1131 m. On top of that, a thermocouple under the contact

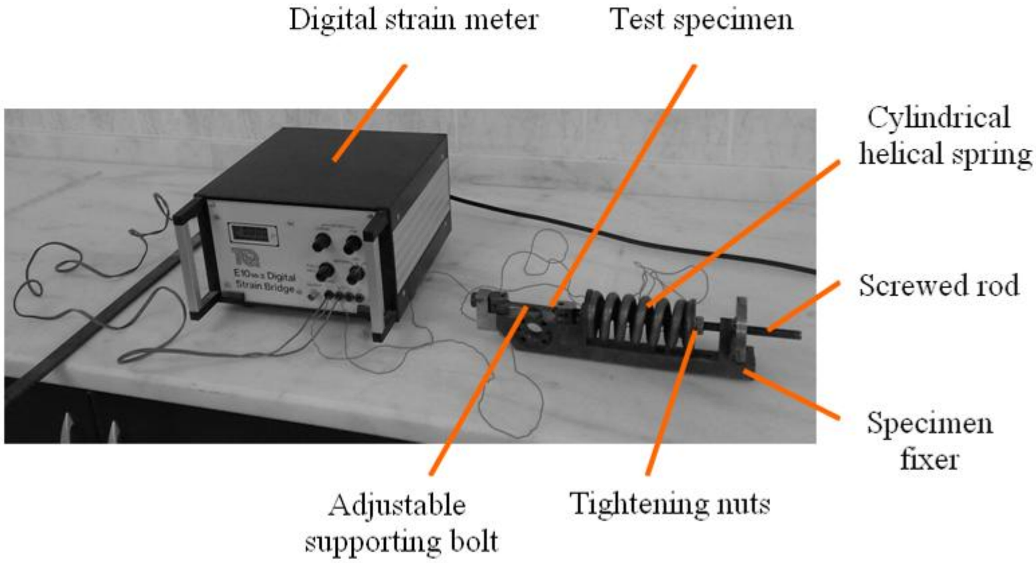


Figure 2. Adjusting required stress on a specimen with digital strain meter.

Table 1. Values of stress rates and axial tensile loads applied on test specimens.

Test number	Stress rate σ (N/mm^2)	Axial tensile load F (N)
1	0 * σ_{ys}	0
2	0.2 * σ_{ys}	216
3	0.4 * σ_{ys}	432
4	0.6 * σ_{ys}	648

* Yield strength of the test specimen, σ_{ys}, 180 N/mm^2; its cross section, 6 mm^2.

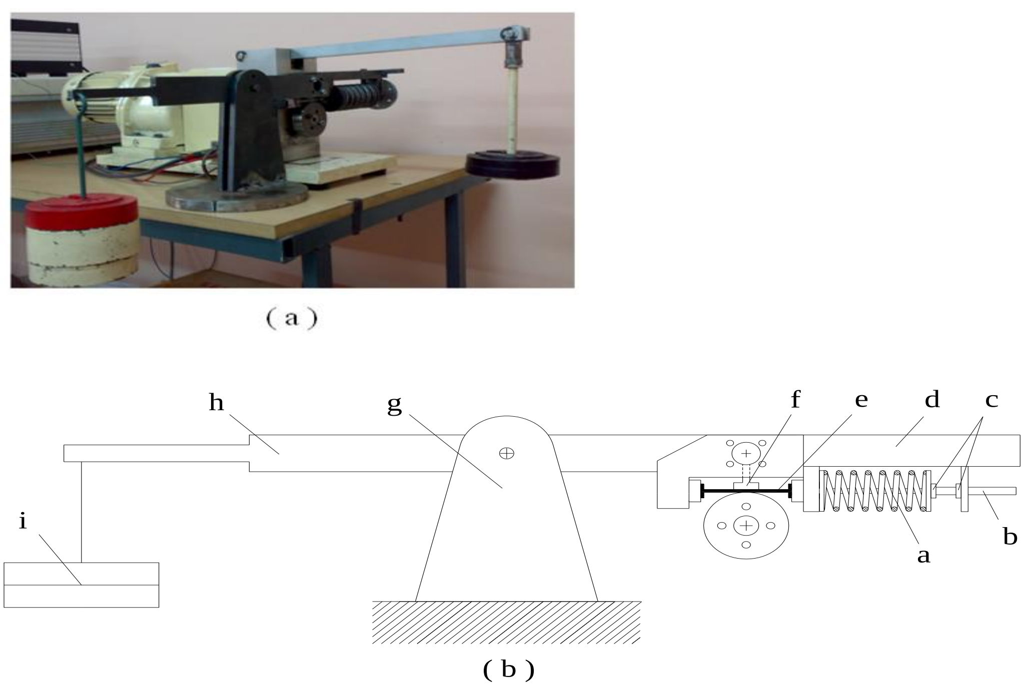


Figure 3. Specimen holder apparatus: (a), photograph; (b) schematic drawing.

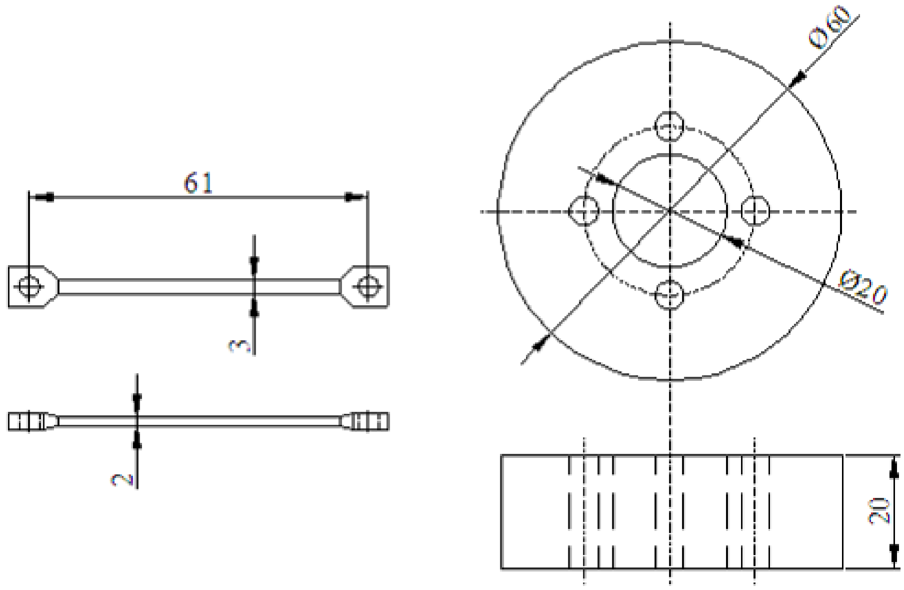


Figure 4. Dimensions of test specimen and abrasive disc.

Table 2. Chemical compositions of the test specimen and abrasive disc (% weight).

Element	Test specimen	Abrasive disc
C	0.2	0.97
Si	0.4	0.25
Mn	0.9	0.35
Cr	-	1.5
P	0.025	-
S	0.03	-
Ni	-	max. 0.3
Al	0.015	-
N	0.009	-

with specimen surface was used to record temperatures resulted from application of stresses and sliding speed on the test specimen. After every test, the specimens were cleaned again and their weight losses recorded. The wear rate values obtained were used to plot the graphs of axial tensile stress versus wear. The values seen on the graphs were obtained by taking an average of five different tests for a given test condition. In addition, the error bars were included in the graphs in order to show clearly maximum and minimum values of wear rates. Consequently, a clear distinction in experimental values as a result of the changes in the stresses could be observed.

RESULTS

In order to make clear comments on the tests results, the graphs of sliding speeds against wear rates for all stress values are grouped together in Figure 5 for sliding distances of 377 and 1131 m, respectively. When the plots are studied, it is seen that an increase in stress causes wear rate to increase too. Similarly, it was found that the wear rates increase with sliding speeds, probably due to friction heating (Bagci and Imrek, 2009). It was concluded that the increase in sliding speed deteriorate the ability of the specimen to resist wear and this leads to higher wear rates.

In Figure 5(a), the yield strength of 20% over a sliding speed of 0.628 m/s caused increase of wear rate of 29%, whereas at 40 and 60% yield strengths, the wear rates observed were 49 and 71%, respectively. Similarly, a sliding speed of 1.256 m/s at 20% yield strength caused an increase of 5% in wear rate; while this speed, respectively caused increases of 50 and 54% in wear rate over 40 and 60% yield strength. It is therefore, concluded that increasing stresses and sliding speeds generally lead to an increase in wear.

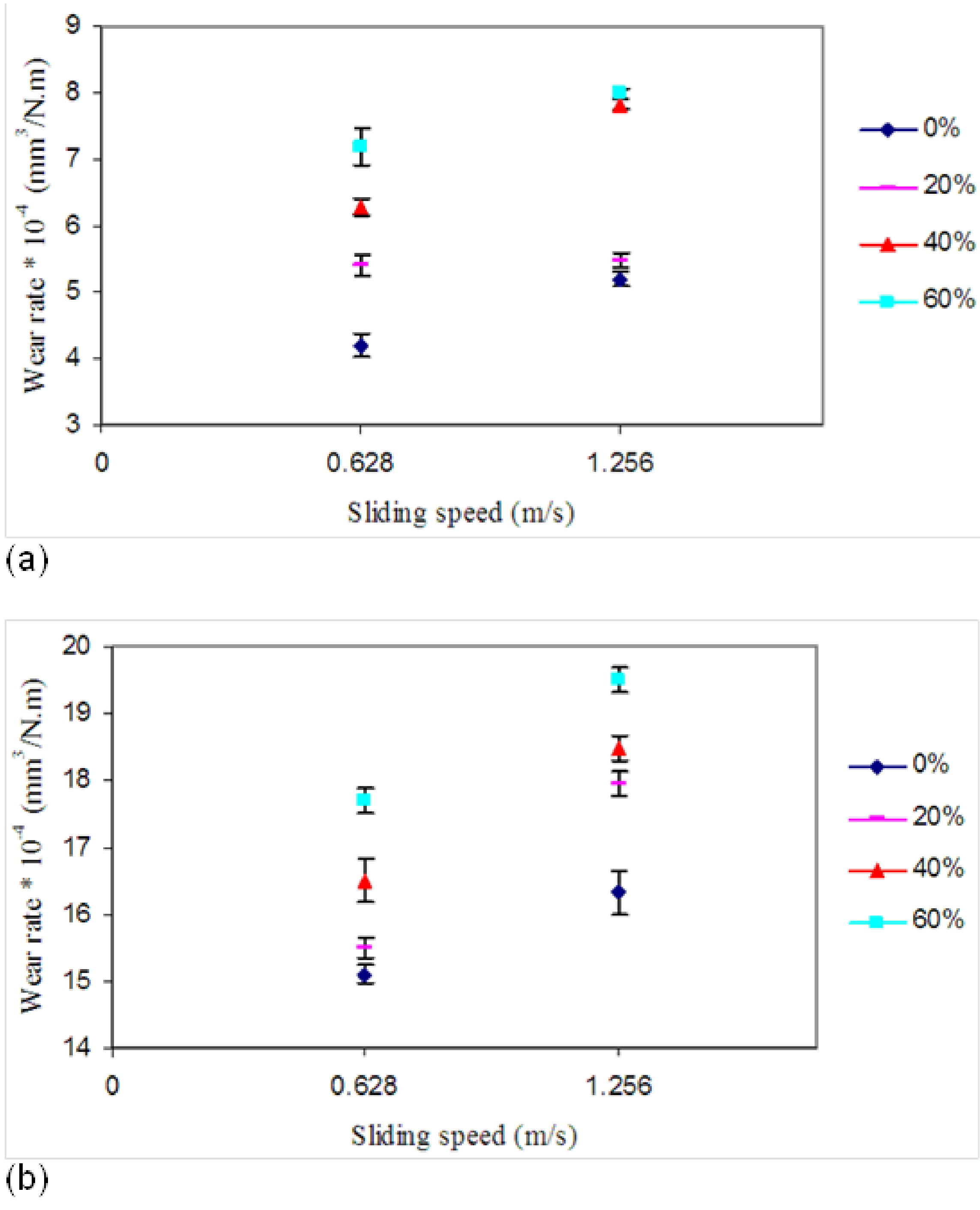


Figure 5. Graphs of wear rates against sliding speed at 0, 20, 40 and 60% yield strengths: (a), 377 m; (b), 1131 m.

As shown in Figure 5(b), an increase in the applied axial tensile loads causes an increase in wear rates regardless of the fact that the wear increases at different rates on both sliding speeds. Moreover, it is also found from the graph that the increase in sliding distance affects wear rates negatively.

The temperature of the specimen surface is determined against the sliding speed under a constant load of 60 N is shown in Figure 6. It was found that at the same sliding speed, the changes in axial tensile loads applied on the

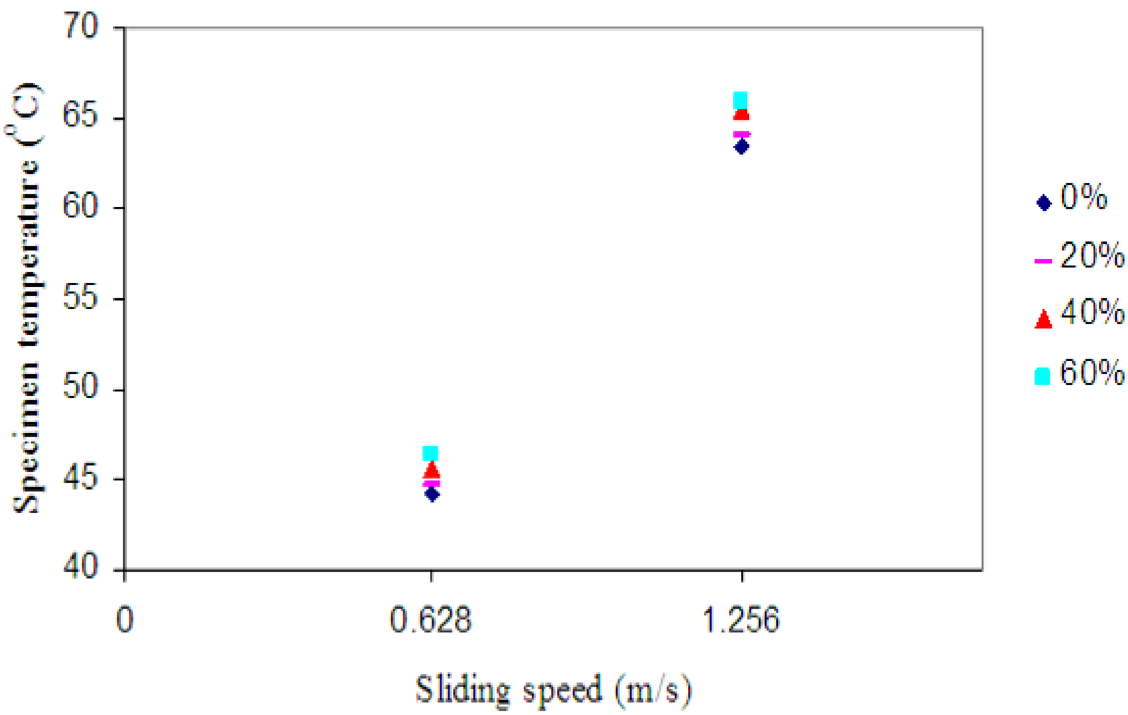


Figure 6. Graphs of steady-state temperature versus sliding speed at the constant load of 60 N.

specimen did not cause any remarkable effect on the temperature of the contact surface. At 0,628 m/s sliding speed, the temperature of about 45°C was determined on the contact surface of the specimen. However, as the sliding speed was increased to 1,256 m/s, the temperature was observed to 65°C.

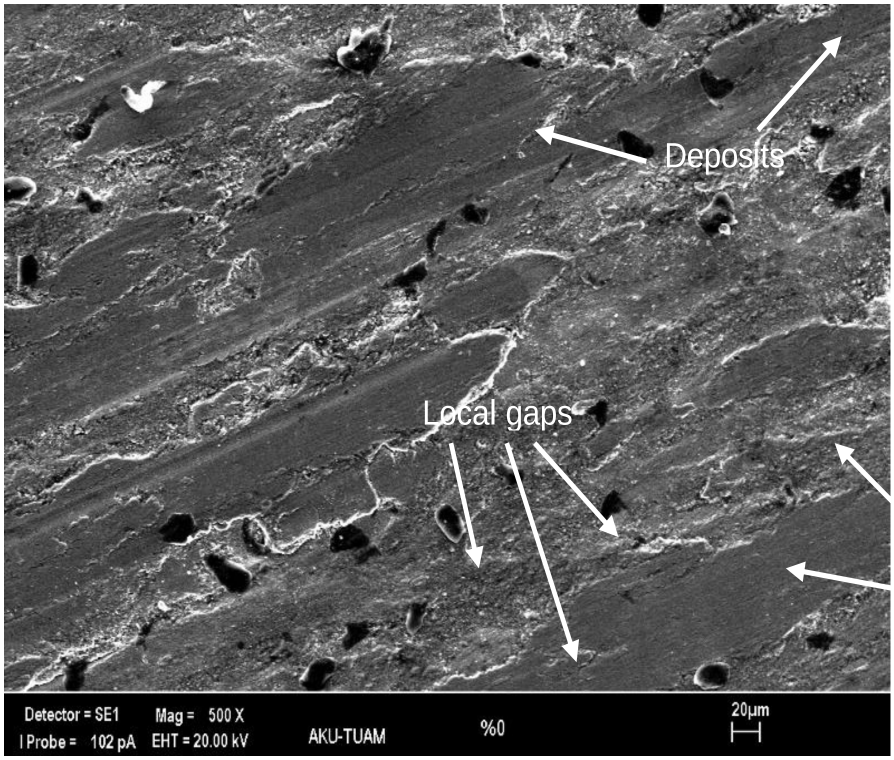
DISCUSSION

When the graphs are studied, similar results as those obtained by Naga et al. (1991) for sliding wear are found. However; in the experimental study conducted by Naga et al. (1991) apart from the axial tensile stresses, there were other types of stresses on the cross section of the test specimen, therefore, hindering the investigation of effects of only axial tensile stresses. In this study, the other types of stresses were eliminated leaving only axial tensile stresses and their effects on wear investigated accordingly.

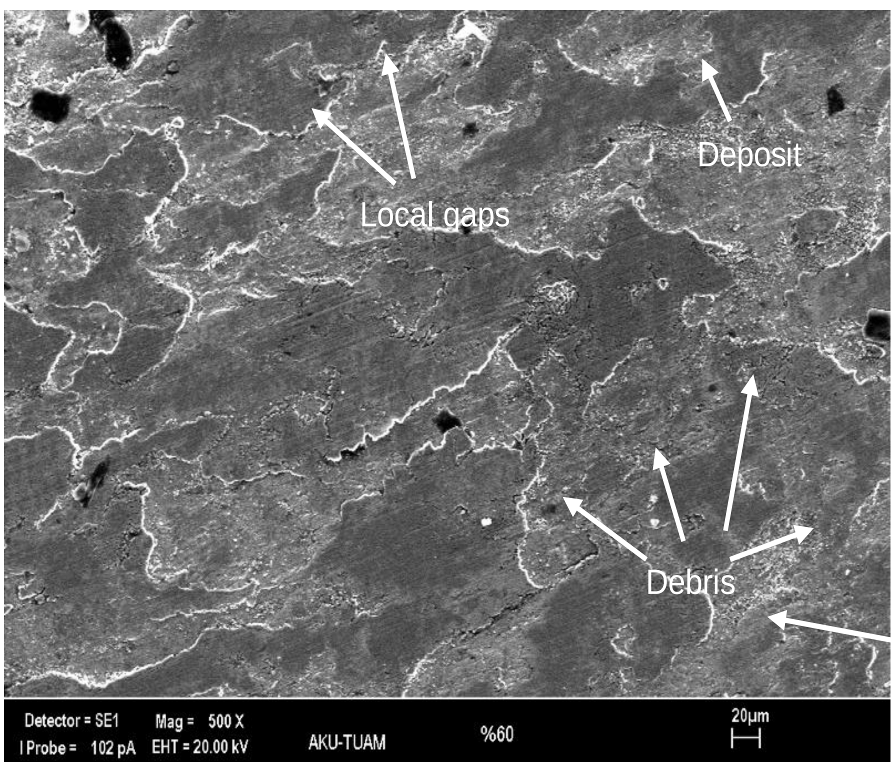
Behavior of metal materials towards sliding wear shows great dependence on mechanical properties of the material (that is, hardness, microstructure etc.) and the environment (temperature, stress etc.) the material is subjected to. This means that, apart from the many structural operating parameters, physical and chemical changes in a material have some effects on wearing of the material. If an external load is applied axially on a material that material tends to change physically as a result of that load. Physical changes on the outer surfaces of a material loaded in this way, subsequently, will affect wear rates of the material too. When an axial tensile load is applied on a specimen, an elastic shape change occurs in the structure as a result of the formed stress; and this condition is reflected by the changes in inter atomic distances between adjacent atoms. This distance increases along the stress direction and decreases across the stress direction (Rigney, 1997; Pıhtılı and Tosun, 2002).

Standard error of mean (SEM) views of the test specimens are given in Figure 7. These views show variations on the test specimens' surface during sliding wear. SEM view of the test specimen without any applied stress but subject to sliding wear at 1.256 m/s is given in Figure 7(a). Local gaps have occurred at some regions that removal of particles from the specimen surface. Moreover, deposits were seen at certain points of the surface.

In Figure 7(b), SEM view of test specimen's for a 60% yield strength value at 1.256 m/s is given. The local gaps on the surfaces of the specimens have decreased. However, layers have diverged and debris has increased. This situation has occurred due to the axial tensile stress because the layers on the surface of the specimen are weak. Thus, separations from the surface have increased. In addition, small temperature changes between stresses may have simplified delamination of surface layers. Moreover, deposits on certain points of



(a)



(b)

Figure 7. Standard error of mean (SEM) views of test specimens for 1.256 m/s sliding speed: (a), 0%; (b) 60%.

the surface have decreased considerably.

Conclusions

1. At the end of the experiments, it is concluded that increases in the magnitude of applied stresses on the cross section of a test specimen under a given loading interval increases sliding wear rate in the specimen. The lowest wear rate is observed at a load that corresponds to 0% of materials yield strength. Wear rates generally show an increase when tensile loads corresponding to 20, 40 and 60% of the yield strength are applied on specimens.
2. Wear rate increase is also observed when the sliding speed is varied from 0.628 to 1.256 m/s.
3. Increase in the interval at which abrasive disc remains in contact with a specimen leads to an increases in wear rate.
4. From SEM studies, it was found that the wear damage in the metals is characterized by local gaps, deposits and debris on the surface.

REFERENCES

Bagci M, Imrek H (2009). Effects of sliding speed in a CuZn10 brass material on wear. J. Balkan Trib. Assoc., 15(1): 35-44.

Blau PJ (1997). Fifty years of research on the wear of metals. Trib. Int., 30(5): 321-331.

Cocks M (1962). Interaction of sliding metal surfaces. J. Appl. Phys., 33: 2152-2161.

Finnie I (1972). Some observations on the erosion of ductile metals. Wear, 19: 81-90.

Gunduz S, Kacar R, Soykan HS (2008). Wear behaviour of forging steels with different microstructure during dry sliding. Trib. Int., 41: 348-355.

Hanlon DN, Rainforth WM, Sellars CM (1997). The effect of processing route, composition and hardness on the wear response of chromium bearing steels in a rolling-sliding configuration. Wear, 203-204: 220-229.

Jiang J, Stott FH, Stack MM (2004). A generic model for dry sliding wear of metals at elevated temperatures. Wear, 256: 973-985

Naga SAR, Riad SM, Mokhtar MOA, Gewfil EA (1991). Wear failure as influenced by external stressing. Wear. 145: 297-302.

Pıhtılı H, Tosun N (2001). Effect of load and speed on the wear behaviour of woven glass fabrics and aramid fibre-reinforced composites. Wear, 252: 979-984.

Rigney DA (1997). Comments on the sliding wear of metals. Trib. Int., 30(5): 361-367.

Tilly GP, Sagse W (1970). The interaction of particle and material behaviour in erosion processes. Wear, 16(6): 447-465.

Zimba J, Samandi M, Yu D, Chandra T, Navara E, Simbi DJ (2004). Un-lubricated sliding wear performance of unalloyed austempered ductile iron under high contact stresses. Mat. Des., 25: 431-438.