THE WEAR BEHAVIOR OF Z200 CD 12 STEEL

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ABSTRACT

The wear behavior of a tool steel type Z 200 CD 12 has been studied using a pin-on-disk tribometer.

The experimental study was conducted to determine the variation of friction coefficient in terms of sliding distance. The surface coefficient versus sliding distance shows two distinct behaviors : a linear induction behavior and a stable one. The friction coefficient remained constant after a number of revolution and was not affected with speed of disk. The surface topography was investigated using Scanning Electron Microscopy (SEM).

Damage mechanisms were investigated which show the following:

- The beginning of adhesion wear followed by the removal of roughness existing on the sample surface,
- An abrasion wear phenomenon (the generation of loose wear debris from disk).

1- INTRODUCTION

A variety of cutting materials has widely increased the diversity of cutting tools and consequently the necessity to evaluate tool materials. Thus, characteristics are necessary to estimate correctly wear during cold work.

The importance of wear behavior is widely acknowledged. It is frequently included in discussions of the role of friction coefficient and wear rate at surface contact between two materials /1,2/. Extensive studies have been carried out over the past few years using a pin-on-disk to aim at a better understanding of tribological characteristics of several steel materials /3-8/. The present work contributes to the study of tribological properties of the Z 200 CD 12 steel which belongs to a steel group and contains 12% chromium by weight %. This steel requires the control and the analysis of several physical and chemical parameters. Other studies have used similar tool materials and pointed out the importance of transfer for sliding wear phenomenon and for friction /9,10/. The effect of hardness on wear has been studied by Gore *et al.* /11/.

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In tribology of interface, every wear problem must be considered with respect to the mechanisms and parameters of contact. The "First Body" concept accommodates the displacement imposed by the mechanisms. This approach is proposed by Berthier /12/, who defined five sites of accommodation for displacement: S_1, S_5: first body; S_2, S_4: screen and S_3: third body. For each site four possible types of accommodation (elastic, breaking, cutting, bearing) were associated (Figure 1).

This study was conducted to investigate the effect of different sliding speeds on the friction coefficient and wear rate and to determinate the wear mechanism for interface between Z200 CD 12 and carbure of tungsten.

In the present paper the authors describe their observations on the variation of friction with sliding distance. Detailed structural, surface topography and damage mechanisms have been obtained by using optical microscopy and scanning electron microscopy (SEM). The results provide new information on the contact surface.

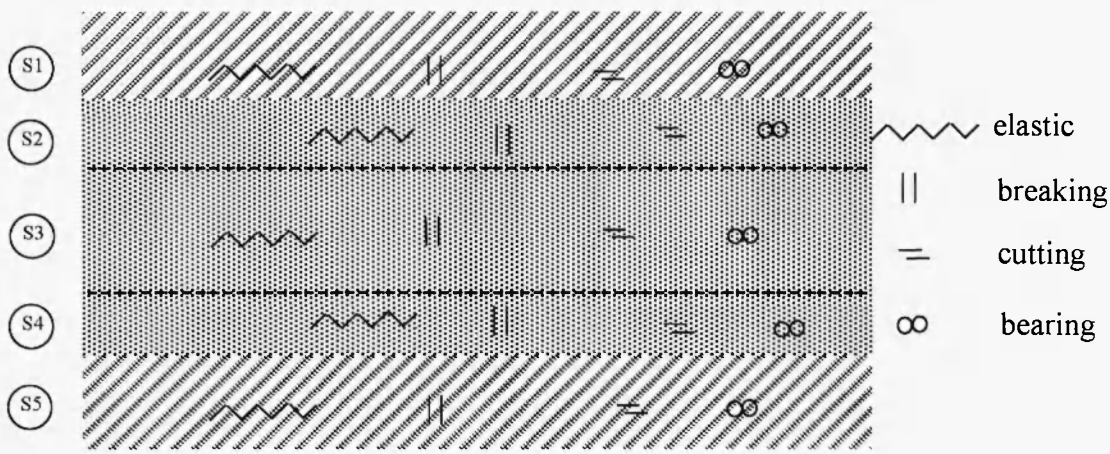


Fig. 1: Sites and modes of accommodation of displacement

MATERIALS AND METHODS

Thermal treatment

The cycle of thermal treatment chosen for Z 200 CD 12 consists of three steps:

**Heating*: A preheating at 750°C for 1 hour followed by a heating at 960°C for 1h 15 min

**Quenching*: This operaticn permits the decrease of temperature from 960°C to 230°C and the cooling of specimen at ambient condition .The measure of hardness after quenching gives 64 HRC.

**Heating*: After heating for three hours to 300°C, the hardness, was measured at 59 HRC.

Metallurgy:

This material is a 12 % chromium steel and its structure appears to be martensitic. This structure, however, cannot be modified by the heat treatment. This hypothesis is confirmed by observations made with an optical microscopy and by other studies /13/ (Figure 2).

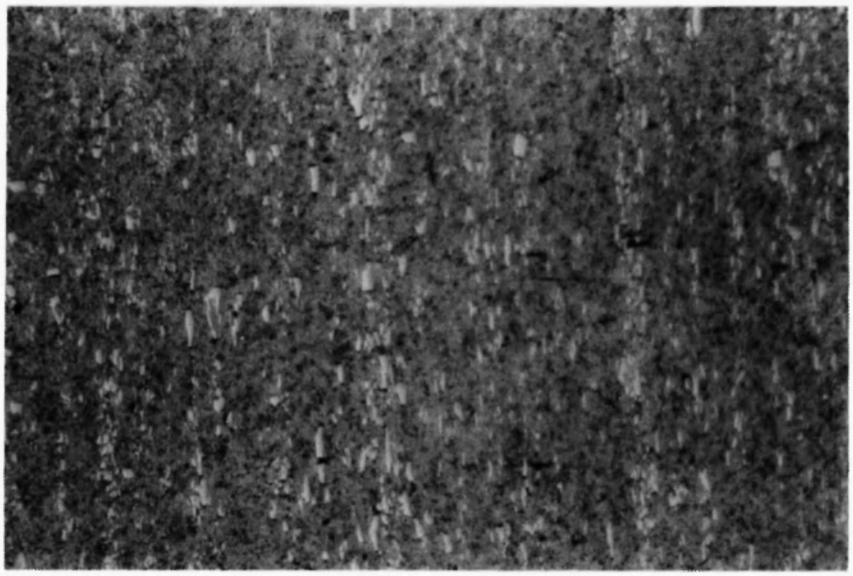


Fig. 2: Structure of tool steel Z 200 CD 12: martensitic with big linear and paralleled carbures Magnification * 12,5

Samples:

The wear tests were performed on a pin–on-disk using the Z 200CD 12 disks and a carbon - tungsten steel counter body.

The pin specimens were made of carbon-tungsten with elastic modulus of 700 GPa, Poisson ratio ν_1= 0,2 and elastic limit Y_1 =6 GPa. The pin has a hemispherical form with a diameter of 6 mm. The disks were made of a treated tool steel Z 200CD 12 with elastic modulus of 210 GPa, Poisson ratio ν_2= 0,3 and elastic limit Y_2 =1,6 GPa. The disks have a diameter of 45 mm and thickness of 10 mm. The disks were prepared with a surface roughness of 0.05 μm±0.01.

Experimental procedures

The mechanism of accommodation in tribological testing depends on the configuration and the experimental conditions. In our study, we have chosen a tribometer pin-on disk which seems be the most representative of application. The tribometer pin-on disk device has a horizontal contact surface.

It was composed of a device which maintained the pin with a force captor and disk support. The disk is connected to a constant speed D.C. motor that permits the control and the regulation of speed.

The horizontal load versus number of revolutions were continuously recorded by a plotter. The wear tests reported in this paper were carried out on a pin –on disk machine of the form shown in Figure 3.

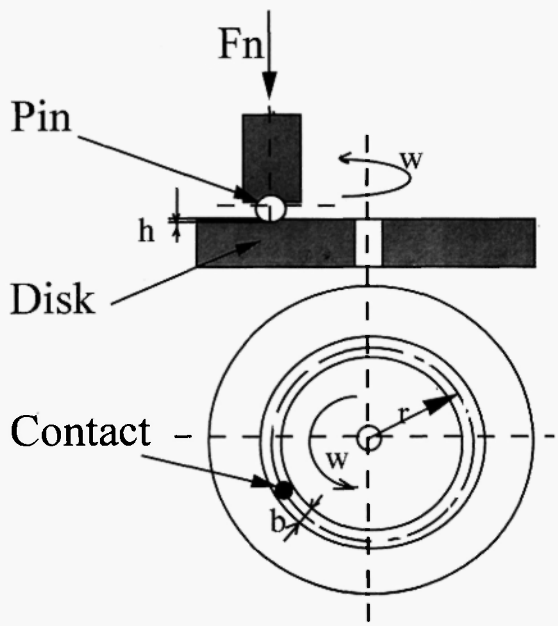


Fig. 3: Contact pin-on disk

Test parameters

Tests were carried out at ambient temperature 23°C±1°C and relative humidity 40±10%. Tests were performed with a normal force of 5N and at 15 rev/min, 28 rev/min, 50 rev/min, 74 rev/min and 125 rev/min. Each test duration lasted for 3600 s. The number of specimens used in this study was 5 for each test. No lubricant was used during the experiments .

RESULTS AND DISCUSSION

In the field of elasticity, the Hertz theory allow us to determine some solutions for this problem. The analysis of the contact geometry enables us to find the boundary conditions on the displacements within or outside the contact area /14-16/. In the case of the contact sphere/plan, the maximum pressure

P_0 at the contact interface can be calculated by Johnson's /17/ equation:

$$P_0 = \frac{3F_n}{2\pi a^2} \tag{1}$$

where F_n is the normal applied force, and the contact area (a) is

$$a = \left(\frac{3RP}{4E^*}\right)^{\frac{1}{3}} \quad \text{and} \quad \frac{1}{E^*} = \frac{1-\nu_1^2}{E_1} + \frac{1-\nu_2^2}{E_2} \tag{2}$$

R being the ray of sphere; E_1, E_2 the Young's Modulus; and ν_1, ν_2 the Poisson ratio of two materials.

The contact area (a= 40 μm^2) was calculated from eq (2) and the maximum pressure P_0 (1490 MPa) was determined from eq (1). This value of max pressure P_0 was lower than the beginning of plastification P_{01}= 1,6 Y=2560 MPa. We can affirm that the selected experimental conditions of the Z 200 CD 12 steel were loaded in the elastic zone.

Coefficient of friction

The variation of coefficient of friction defined by Coulomb as the ratio between tangential and normal forces in the contact of the two friction surfaces is often described by the change of the accommodation mechanism. The results of friction tests obtained at ambient temperature recorded evolution of coefficient of friction by the continuous measure of tangential force as a function of time (thus of number of revolutions). A typical friction coefficient – number of revolution curves is shown in Figure 4. The experimental results show the presence of two distinct behaviors: a linear induction behavior and a stable behavior after a number of revolutions.

Linear induction behavior: At the beginning of the test, we have destruction of the superficial screen S_2 of the pin and S_4 of the disk. This can be explained by the modification of adhesion forces and an increase in the friction coefficient. In fact, after friction of the pin on disk, the two surfaces S_2 and $S_4$are [[districted???]] and the contact will be transmitted directly between $S_1$and S_5.

We have a junction of surfaces which leads to an enlargement of real surfaces during the friction and so an increase of the real contact area through the increase of the number of turns by destruction of roughnesses [Figures 5 (a,b,c)]. In addition, the production of the third body S_3 which contributes to the change of the type of contact (from a contact of two bodies by the formation of debris) causes the variation of the friction coefficient.

Stable behavior: After a number of revolutions, the final value of friction remains constant ($\mu \cong 0.9$). Moreover, this value is not affected by the speed of the disk. When the sliding distance increases, the pin material fills the valleys between the peaks and will gradually smooth the surface. This will

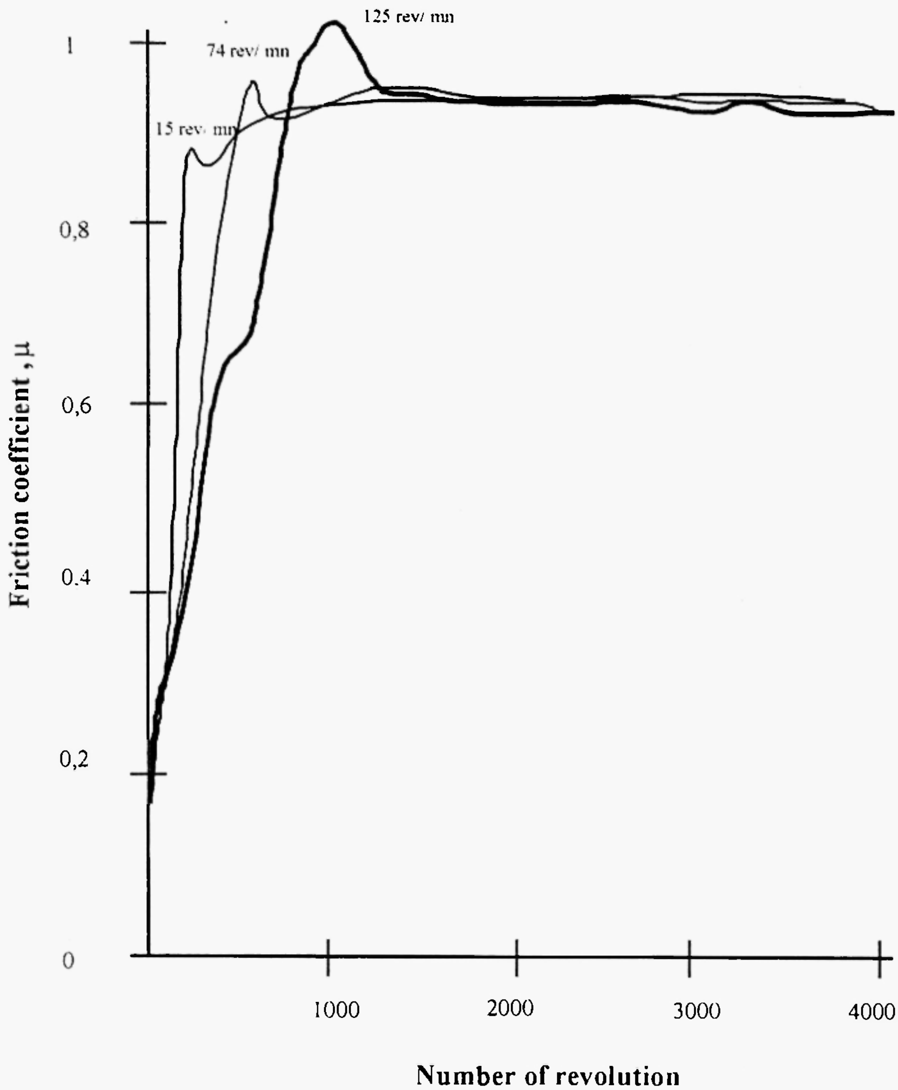


Fig. 4: Variation of coefficient of friction with round number at 15 rev/min, 74 rev/min and 125 rev/min

decrease the contact pressure between pin and disk and newly formed debris will get rubbed off more easily.

The roughness was measured before and after testing. The comparison is summarized in Table1. We noted that the roughness value increased after the tests and this can be principally explained by destruction of abrasions. Also, the surface roughness depends on the sliding distance. When the surface roughness is greater than 0.05 μm, a thin coating will closely edge the highly peaked surface profile and the overall roughness will not change very much. Smoothing of surface will take longer .In both cases the contact pressure drops sufficiently, within the duration of the test, to enhance the creation of loose particles.

a

b

c

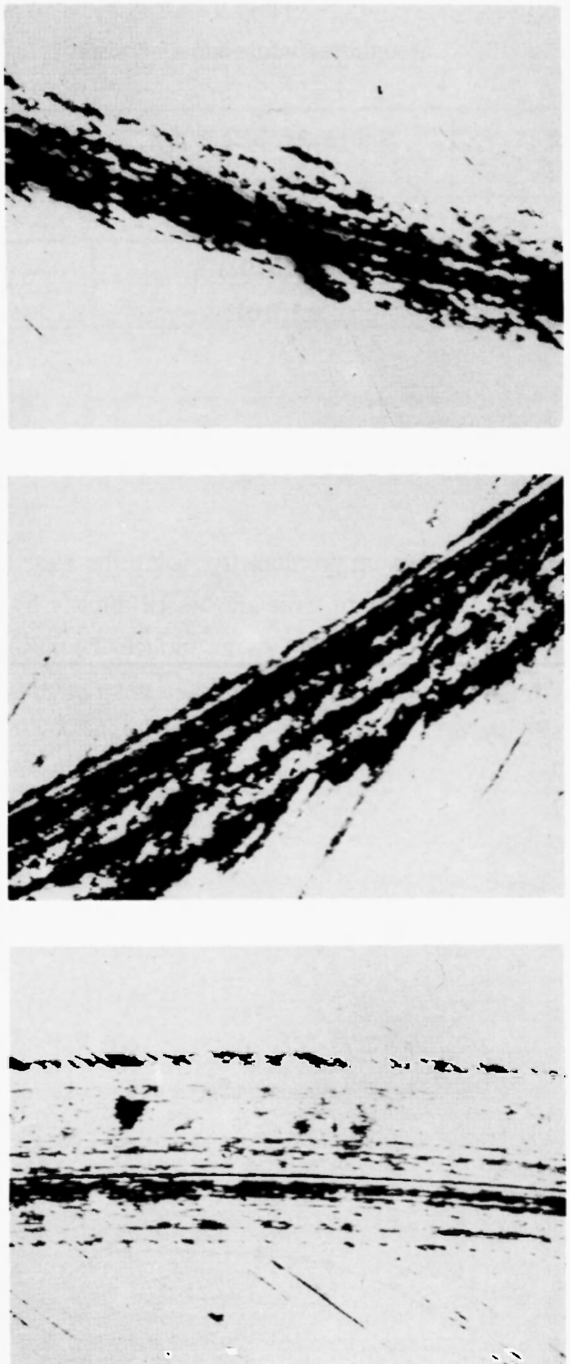


Fig. 5: Optical micrographof showing track - Magnification * 540

a: V= 15 rev/min

b: V= 74 rev/min

c: V= 125 rev/min

Table 1

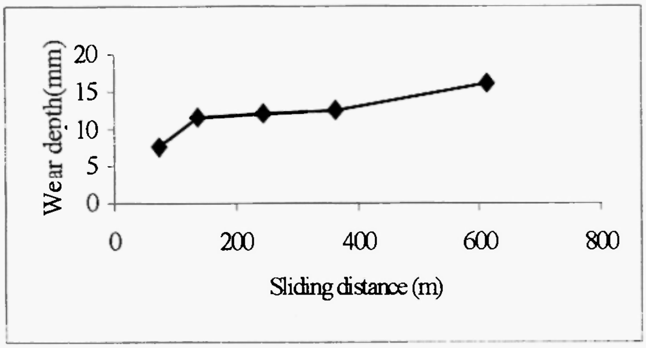
Roughness before and after tests

Sliding distance (m)	Roughness before test (μm)	Roughness after test (μm)
73.5	0.05(0.01)	0.09 (0.01)
613	0.05(0.01)	0.12(0.01)
73.5	0,1(0.01)	0,12(0.01)

Wear performance

We identified the wear depth by using profilometry, while the wear width was identified using optical microscopy. The depth and width of wear are caused directly by the sliding distance They demonstrated a non-linear variation (Figure 6a,b). At the surface, the plastic deformation of abrasions was caused by the surface wear, in this case, the wear mechanisms conducted by adhesion between two surfaces of materials (see Figure 7a).

a



b

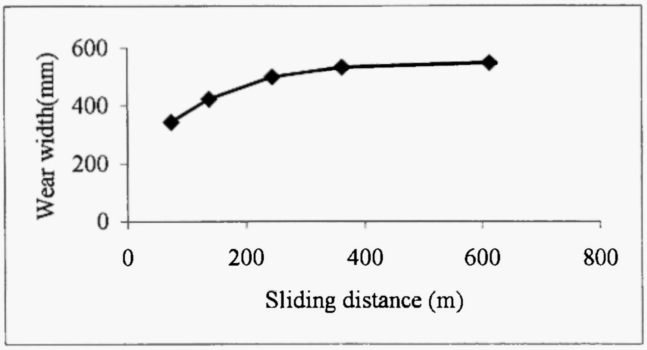


Fig. 6: **-a:** Wear depth versus sliding distance **–b:** Wear width versus sliding distance

The behavior of wear depth (Figure 6a) was characterized by three parameters which depend on sliding distance. Initially, wear depth was increased rapidly until 137 m sliding distance, and until 363 m, the wear depth almost remains constant achieved in the second regime and followed by an increase value of wear depth. Figure 6b shows that, after a sliding distance of 245 m, the wear width remains constant. The wear width varied non-linearly with sliding distance. Thus, due to surface oxidation, the hardness for different layers of the disk was different.

The wear performance was evaluated using Scanning Electron Microscopy (SEM) and surface profilometry, as well as by calculating the wear coefficient K. According to Gzichos *et al.* /18/, the wear volume Wv can be calculated from track dimensions, such as:

$$Wv = \frac{h}{6b}\left(3h^2 + 4s^2\right)2\Pi r \tag{3}$$

where b is the width, h the depth and r the radius of the wear track. Based on this, the wear coefficient K can be estimated as follows

$$K = \frac{Wv}{Fn \cdot s} \tag{4}$$

where Fn is the normal force and s is the sliding distance. The wear coefficient K is of fundamental importance, and provides a valuable means of comparing the severity of wear processes in different systems. For a sliding distance up to 137 m (see Table 2), the wear volume increases but the wear coefficient remains constant when oxidation is restricted. For advanced sliding distance the wear coefficient increases if the wear volume decreases. This observation was confirmed by the presence of oxide layers at the interface that were affected by a critical speed. To understand this mechanical behavior, the analysis of damage at the surface has been investigated.

Table 2

Wear coefficient, wear volume of Z 200CD 12 disk in the pin-on disk wear

Number of revolutions V (rev/min)	Sliding distance S (m)	Wear volume Wv (mm^3)	Wear coefficient K (mm^2/N)
15	73.5	0.140	$3.8\ 10^{-7}$
28	137	0.264	3.810^{-7}
50	245	0.326	2.6710^{-7}
74	363	0.362	$2\ 10^{-7}$
125	613	0.479	1.5610^{-7}

a

b

c

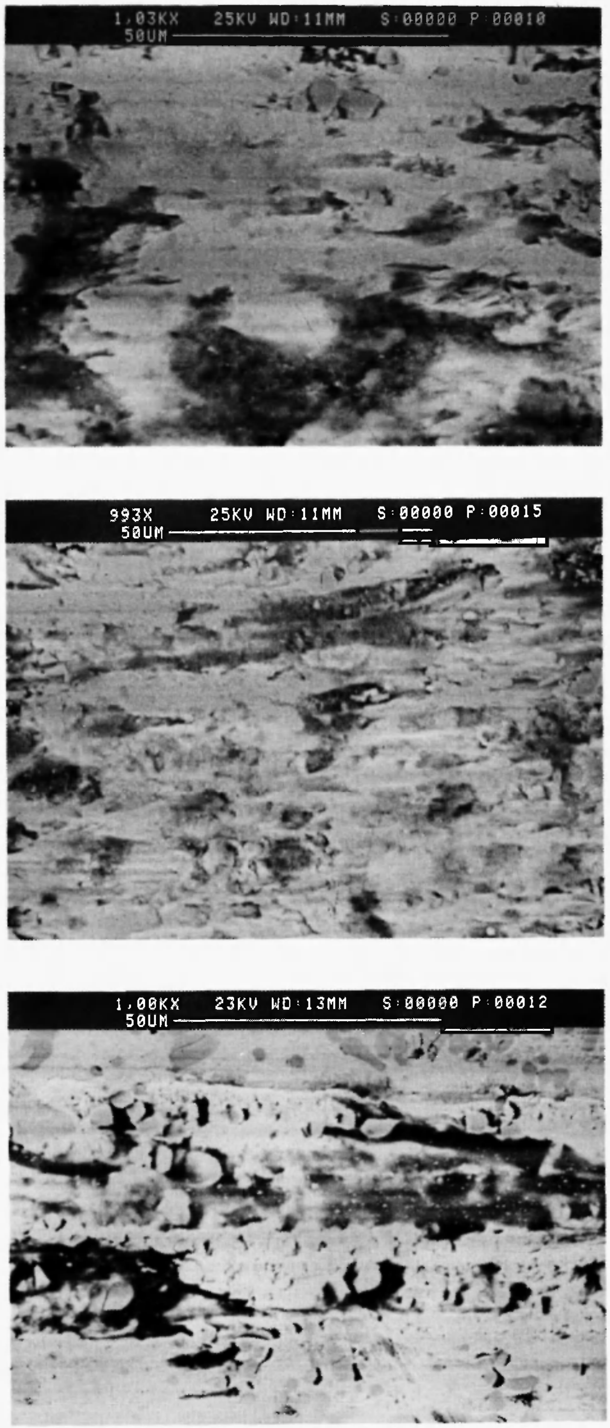


Fig. 7: SEM photographs - sections of wear scar

a: after 137m sliding distance

b: after 363m sliding distance

c: after 613m sliding distance

Analysis of wear damage

The initial contact between the two surfaces in each test is made by the roughness peaks of both surfaces. This means that, since the contacting surfaces are very small, the contact pressure between pin and disk is high. The high contact pressure causes a plastic deformation of tool steel Z 200CD 12. Tests were interrupted at various sliding distances to analyze the basic mechanisms responsible for wear, and tracks were observed by optical microscopy. Wear was characterized by a brown wear track on the disk and a small wear surface on the pin. The topography of the surfaces for different distance sliding and the debris were examined by Scanning Electron Microscopy (SEM) (Figures 7a,b,c). Adhesion mechanism of wear was observed when the sliding distance was not important (Figure 7a). The destruction of abrasions was noted at advanced sliding distance (Figure 7b). SEM observation showed that compact wear debris particles were developed in the track corresponding to the transition in friction coefficient with time. This track is formed by partially oxidized disk material adhering to pin. These particles will act as a third body in the wear process (three-body abrasive wear) (Figure 7c). Eventually, most of the particles are pushed aside by the pin motion to the outer regions of the track when they start to abrade the tool steel Z 200CD 12 (Figure 8).

Fig. 8: Debris were pushed aside by the pin - magnification * 12,5

CONCLUSION

The wear mechanisms of tool steel type Z 200CD12 has been investigated under pin on-disk testing tribometer. This study was undertaken to measure the friction variation versus number of revolution.

The wear mechanisms and damages behavior were analyzed by SEM optical microscope. The effect of a number of parameters such as number of revolutions, disk roughness, etc., was studied.

The variation of friction coefficient versus sliding distance shows two distinct behaviors: linear induction and stable one. Measured results indicated that the friction coefficient remains constant after a number of revolution and not affected by the speed of disk. Examination of the disk surface showed the beginning of adhesion at constant load followed by destruction of abrasions and the generation of debris which initiates the abrasion wear

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