ISSN 2176-5480

22nd International Congress of Mechanical Engineering (COBEM 2013)
November 3-7, 2013, Ribeirão Preto, SP, Brazil

EVOLUTION OF SLIDING WEAR OF BRONZE-ALUMINIUM 630 ALLOY IN CONTACT WITH AISI 4340 STEEL IN DIFFERENT MICRO-STRUCTURAL CONDITIONS

Renato Araujo Barros[1]
Humberto Lopes Rodrigues[1-2]
1.Unesp-Faculdade de Engenharia de Gauratinguetá, Av. Ariberto Pereira da Cunha, 333, 12.516-410 Guaratinguetá, SP, Brazil.
2. FATEC, Faculdade de Tecnologia de Pindamonhangaba, 12455-010, SP, Brazil
greensleeves@uol.com.br, humberto@feg.unesp.br

Antônio Jorge Abdalla[1-3]
3. IEAv/DCTA, Instituto de Estudos Avançados, 12.231-970, São José dos Campos, SP, Brazil
abdalla@ieav.cta.br

Abstract. *Sliding wear behavior in metals is characterized by the presence of three distinct stages. The first one, given by "smoothing" of the roughness of contact pairs, does not present a constant wear rate. The second one is configured with a constant wear rate, demonstrating a superficial stability due to existing tribolayers. The third one presents an increased rate of wear showing a severe condition of deterioration of surfaces. In this work were carried out tests of type pin-on-disc, with the pins made of the bronze-aluminium 630 alloy and the discs made of AISI 4340 steel in three different micro-structural conditions: ferritic-pearlitic, martensitic and bainitic. The pin-on-disc tests were performed with the bronze pins kept as static element placed in contact with the surfaces of the rotating steel disks, with the loss of volume of materials being measured by weighing the specimens. Based on the quantification of the wear of pins through their loss of volume related to the distance slid it was possible to identify and analyze, from the graphics, the three stages of wear.*

Keywords: *wear;pin-on-disc;sliding;AISI 4340 steel*

1. INTRODUCTION

The AISI 4340 steel is used commercially since 1955 as a high-strength steel. Currently, this material is used in critical structural applications in aerospace and nuclear power industries. Is a material that combines deep hardening (high hardenability) with high ductility, high resistance and good toughness, and good weldability. It has high fatigue resistance, and is often used in severe conditions, which are subject to high load. This ultra-rugged steel can reach values in the order of 1900 MPa, when properly hardened and tempered.

The resulting phase transformation microstructure has a key role in obtaining the mechanical properties of steels, especially those of high strength heat-treated, in most cases, by quenching and tempering (5.6). The constituents of the steels are known as ferrite, Pearlite, Bainite, martensite and austenite. In practice, the microstructure resulting from such processing may have one phase, for example, martensite and Bainite, or can be mixed, containing two or more phases. Combinations of these structures are responsible for assigning different characteristics to the material (7).

Wear by adesion is defined as the "transfer of wear material of a surface to another during the relative movement, due to the formation of junctions in solid phase ". These formed junctions are sheared and part of less resistant material is transferred or may remain between the surfaces (Crnkovic, 1993).

The mechanism of adhesion wear has normal force applied in the dependency of bodies in contact, the relative velocity between the sliding surfaces of the temperature, hardness and roughness of materials and chemical affinity between them (Jost, 1990). The mechanism also produces many fragments of hard materials in work, by deformation and rupture of adhesive junctions, which in their motion paths output, promote a micro-abrasion on the surfaces through which, therefore, responsible for a whole microgrooved surface (Farrel, 1970). Abrasion on the surfaces of materials, produced by particles generated in wear, leads to a similar interpretation of the abrasive wear mechanism (Moore, 1971).

Different wear mechanisms have been proposed for a severe wear of metals. All of them involve plastic deformation, but differ in details of each process of the materials involved. It is not difficult to find a mistaken conclusion between the probable mechanisms involved in a particular case, but an analysis criticism of both worn and surfaces of the fragments can provide information quite useful (Krushov, 1974).

The worn surfaces will assume the number of fragments worn in all life-cycle stages (Fig.1), in which the stages I and III are severe wear and the stage II a level of moderate wear or wear rate constant, determined by the angular coefficient of wear curve (Yust, 1985).

ISSN 2176-5480

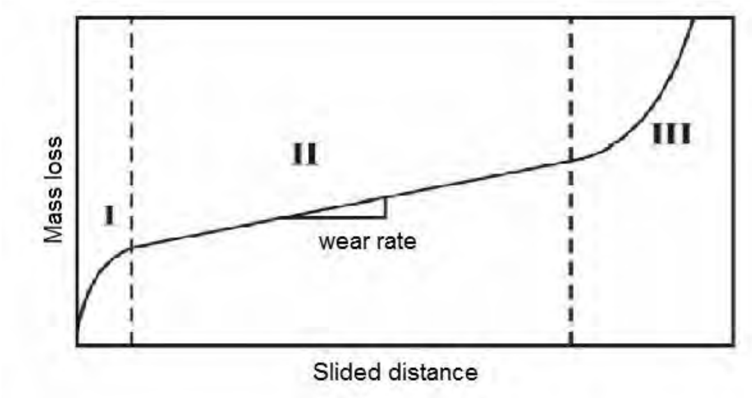


Figure 1. Mass loss variation with slided distance

2. MATERIALS AND METHODS

The materials used in this work were AISI 4340 steel (disc), and aluminum bronze alloy 630 (pin) 228HB hardness.

The tests were carried out on a test equipment pin-on-disc type.

Apart from steel discs with the materials as delivered, three discs were submitted to treatment of quenching and tempering, and other three discs were submitted to austempering treatment.

Wear tests were carried out for the pair of bronze-aluminium alloy 630 (pins) in contact with the Steel AISI/SAE 4340 (disks) in different heat treatment conditions (material as supplied, material subjected to bainitic treatment and the material submitted to tempering treatment), subject to the conditions of Tab. 1.

Table 1. Test Parameters (speed, load and slided distance)

Speed (m/s)	Load (N)	Sliding distance (m)
0,5	5	3300
1,0	5	3300
1,5	5	3300

The measurement of wear both in pin and disc can be made through rate and wear coefficient. The wear coefficient K * is defined by the volume of wear per unit and per unit distance, as illustrated by the Equation 1, with the usual units for K in [mm N-1 m-1], being the wear volume V in [mm3], W in [N] and the sliding distance X in [m].

$$K^* = \frac{V}{XW} \tag{1}$$

In the evaluation of wear considering the wear coefficient K *, it is assumed that wear is proportional to the normal load and the sliding distance, even though this is not always occurs. However, their use becomes acceptable, as long as it does not occur significant changes of wear mechanism involved during the sliding. The volume of this study is to wear the pin as it was determined according to the difference of mass before and after every test step, and its density average of tribological pair materials.

Given the volume of wear at each stage of the test, the behavior of volume of wear accumulated in the various steps in sliding distance accumulated, which in general stage of non-linear wear (running), followed by a linear wear or stationary wear rate. The wear rate K is set by the volume lost per unit of distance, and the values of the wear rate can be obtained through Equation 2, through the linearization of the curve in the State of stationary wear (see Fig.1).

$$K = tg\,\theta = \frac{V}{X} \tag{2}$$

The worn surfaces will assume the number of fragments worn in all life-cycle stages (Fig. 1), where the stages I and III are severe wear and the stage II a level of moderate wear or wear rate constant.

3. RESULTS

ISSN 2176-5480

Initially, for the determination of the rate of wear, it is necessary to identify the chart distance travelled x loss of volume, the region in which the curve displays a tendency to linearity, i.e., the region in which the characteristics of wear is moderate, in order that we can, by means of the coefficients of angular straight lines obtained through linear regression curves, get the values from rates of wear, as the Equation 2. Therefore, for the determination of the region in which this trend begins to appear, in first tests were performed at intervals of 25 meters of sliding, passing later to a range of 50 meters. From the distance total travelled about 500 feet, the tendency of linearization began to appear. In then went on to use a range of 100 meters and 300 meters, having this last shown appropriate to this study. Fig. 2 shows the curve which was built for this parameter was set, test developed at a speed of 0.5 m/s for 4340 steel disc a supplied against the brass PIN.

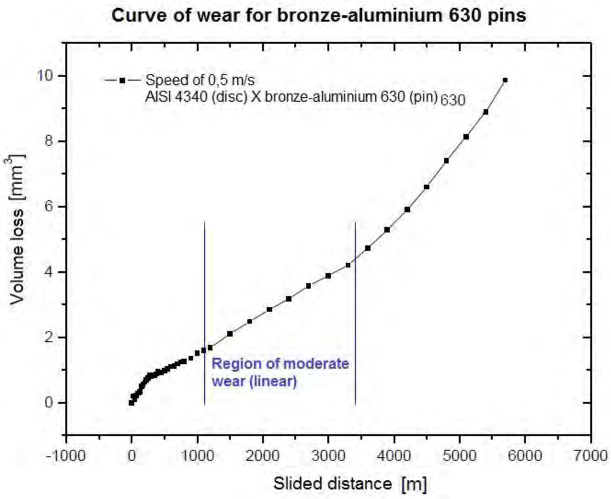


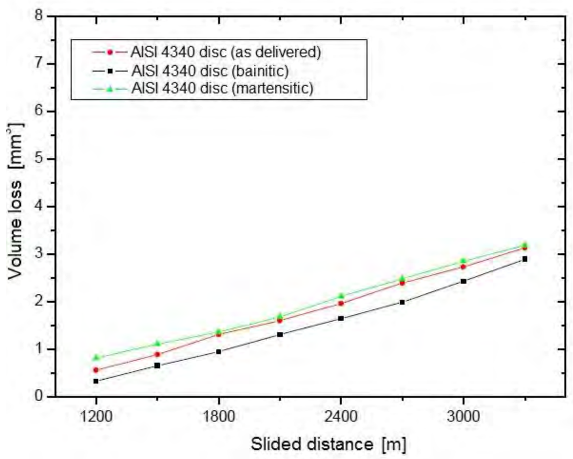
Figure 2. Chart to the definition adopted for the range of wear curve linearization.

It is possible to observe, from the graph in Fig.2, from a distance of approximately 500 metres, that the curve starts to resemble a straight. Within this the region of moderate wear, was adopted the region between 1200 and 3300 meters of sliding distance as reference to be applied in all trials of wear. For the calculation of the rate of wear was a formula one race held on linear regression of each curve and got the angular coefficient of straight and, consequently, the rate of wear of the pin to each of the situations.

Another important aspect to be considered in this work was the definition of analysis of wear rate of aluminium bronze 630 and not the steel discs. This gave the from the analysis of the curves obtained for the pins and disks, for the speed of 0.5 m/s (Figure 3.6). It is possible to see that the loss of material for wear on the part of the pins is sharp and growing to the three conditions. On the disks, it is noted that the loss volume shows a different trend, there is an alternation of gain and loss of mass, indicating that this material is deposited, accession and PIN loosening the bronze on the steel disk. In this way, the indications are that the pins, and not the discs steel, are critical components that must be analyzed in this study.

The chart presented in Fig.3 show that there is a great similarity in behavior in relation to wear the pin, regardless of the microstructural disc condition.

Figure 3. Wear development of pins with relation to microstructure of disk



4. CONCLUSIONS

The high values of hardness of steel, compared with the hardness of the material of the pin (HB 213) and their ductility favored so prevalent intense wear by accession; PIN wear tests-disc, the volume loss behavior of PIN, in Depending on the distance, much like occurred, for the three studied steel disk structures:

The wear rate calculations for the aluminum bronze pin 630, to be tested against the 4340 steel in three micro-structural conditions studied showed higher rate when the disc featured bainitic structure.

5. ACKNOWLEDGEMENTS

The authors thank the CNPq, the CTA/IEAv, FATEC Pindamonhangaba and the Department of Materials and Technology of the FEG/UNESP.

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