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Analysis of wear for a base Steel 5% Cr, applying 392 N of load and variable speed of 0.18 m/s, 0.36 m/s and 0.54 m/s, using the T05 Block-on-ring wear tester machine

Análisis de desgaste para un acero base 5% Cr, aplicando carga de 392 N y velocidad variable de 0.18 m/s, 0.36 m/s y 0.54 m/s, utilizando la máquina de prueba de desgaste T05 Block-on-ring

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Abstract

In the present study, an experimental analysis of the friction forces, speeds and friction coefficients that influence the size of the wear track in a steel exposed to mechanical contact was carried out, for this, steel blocks with an alloying element of. 5% Cr base and D2 steel standard ring, representing the Block-on-Disk method, according to the ASTM D2714 standard were used. The test parameters were: 392N load, for 800 seconds, with variable speeds of 0.18 m/sec, 0.36 m/sec and 0.54 m/sec; the test is performed in a dry environment using the T-05 Block-on-Ring wear tester machine. This analysis contributes to the technological development of a material that has a lower coefficient of friction and therefore improves its mechanical properties for systems exposed to this principle, such as the wheels of traveling cranes or railway trains, diesel machinery transport systems and various services, etc.

Friction, Wear, Block-on-Disk

Resumen

En el presente estudio se realiza un análisis experimental de las fuerzas de fricción, velocidades y coeficientes de fricción que influyen en el tamaño de la huella de desgaste en un acero expuesto a contacto mecánico, para ello se utilizaron bloques de acero con un elemento de aleación base de 5% de Cr y anillo patron de acero D2, representando el método Block-on-Disk, de acuerdo con la norma ASTM D2714. Los parámetros de prueba fueron: 392N de carga, durante 800 segundos, con velocidades variables de 0.18 m/seg, 0.36 m/seg y 0.54 m/seg; el ensayo se realiza en un ambiente seco utilizando la máquina de desgaste T-05 Block-on-Ring. Con este análisis se está contribuyendo a desarrollar tecnológicamente un material que tenga un coeficiente de fricción menor y por consiguiente mejore sus propiedades mecánicas para sistemas expuestos con este principió, tales como las ruedas de las grúas viajeras o trenes de ferrocarril, sistemas de transporte de maquinaria diesel y servicios diversos, etc.

Fricción, Desgaste, Block-on-Disk

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Introduction

Wear is an inevitable phenomenon that occurs whenever two surfaces interact. Normally, wear does not cause violent failures, but it generates functional consequences such as reduced efficiency, higher energy consumption, power losses and the generation of heat from the components, due to the increase in friction coefficients. In recent decades, there has been a growing interest in the subject of friction and wear, and considerable effort has been put into determining its causes and how to prevent its consequences.

Wirokanupatum S. (1999), performs wear tests, where he compares the abrasion phenomenon in dry and wet condition, in a medium carbon steel, confirming that the wear and friction coefficient changes when the operational parameters such as: load, size, shape and abrasive hardness are changed.

Deuis et Al (1998), performs a comparison between the behavior of the friction coefficient in a dry and wet environment for coatings on aluminum, noticing that the wear in a humid environment is less than in dry.

Hirpa G. Lemu (2013), also verified that in a humid environment the friction coefficient is lower than in the dry environment and affirms that the friction force increases as a function of time; Forlerer et al., (2000), performed friction wear tests on a block-on-ring machine with lubrication of mineral oil in a ZA27 alloy reinforced with Si, Cu precipitates and SiC particles of an average size of 5 microns. They verified that the most reinforced material is the most resistant to wear, and the non-reinforced friction coefficient is μ = 0,15, while for reinforced materials is μ =0,12.

The word friction comes from the Latin "Fricare" which means friction or rubbing. It manifests itself as a gradual loss of kinetic energy when two bodies are in contact and in relative motion.

Defined as: the resistance force to the movement of a body, when it moves over another, being this force tangential to the interface and in the opposite direction to the displacement; causing energy consumption, accordingly, this force can be defined, based on the first thermodynamic law, as: the work done due to the friction force is equal to the sum of the increase in internal energy and the energy dissipated in the form of heat or temperature rise (ASM, ASM Handbook,1992, Vol. 18).

The French physicist Guillaume Amontons in 1699 quantitatively established the laws of friction. Later in 1748, Euler tried to explain the difference between the static and dynamic coefficient, but it was not until 1785 that José Marie Coulomb established the third fundamental law of this phenomenon.

It should be noted that the coefficient of friction for metals, as indicated by the 3rd law of friction, is independent of the sliding speed, but only up to 10 m/s, since after this value the coefficient of friction decreases as the velocity increases. (Hutchings. Tribology, 1992). Stembalski et Al. (2013), verified this principle in his study. Determination of the friction coefficient as a function of sliding speed and normal pressure for steel C45 and steel 40HM.

Asaduzzaman Ch. et Al. (2013) and Chowdhury M.A. *et al*., (2013), determined that although the normal load and the slip speed were varied, the force and the friction coefficient are stabilized after thirteen minutes of contact with the materials.

The static friction coefficient μs is obtained by placing a body on an inclined plane, as shown in Figure 1.

By increasing the angle of inclination φ, up to where the object begins to move; in this position, the static friction coefficient is determined, using the following equation (Bayer R. G., 1944):

$$\mu s = \frac{W \sin\varphi}{W \cos \varphi} = \text{tg}\, \varphi \quad (1)$$

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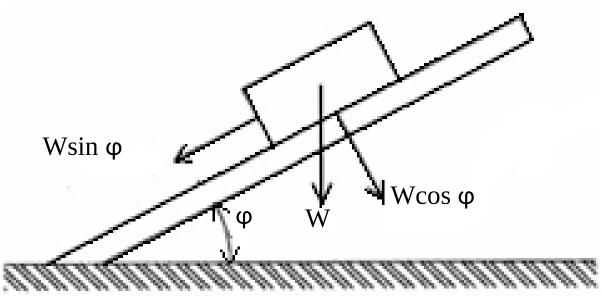

Figure 1 *Representation of friction angle*

Mechanical contact is one of the main phenomena that produce wear, generated by friction loads in systems that are exposed to high coefficients of friction; This principle is present in any system that is exposed to loads or dynamic movements, such as machinery and equipment used for construction, manufacturing processes, transportation, various services, and even our body is subjected to rotary movements that produce frictional forces. Frictional forces are an inevitable phenomenon that occurs whenever two surfaces interact, normally, controlled loads do not cause violent failures, but they generate functional consequences such as reduced efficiency, higher energy consumption, power losses and heat generation from the components, due to the increased coefficients of friction; this phenomenon becomes critical when there is no lubrication between the two surfaces in contact.

The measurement of frictional forces and the calculation of friction coefficients are frequently supported by the different tribometers. There are different types of tests to determine the coefficients of friction ranging from the inclined plane designed by Leonardo da Vinci; as well as the different standardized tests, such as those established by the American Standard Testing Materials (ASTM), or other organizations, such as the American National Standards Institute (ANSI) and the International Organization for Standardization (ISO) (Bayer RG, 1944).

To calculate the friction coefficient, the following equation is used:

$$\mu = \frac{f_r}{N} \qquad (2)$$

Where:

μ = Friction Coefficient

fr = Friction force
N = Applied normal force

Research methodology

The study consists of the preparation of three 5% Cr steel specimens, the machining conditions comply with the ASTM D2714 standard, the tribological system consists of the stationary block, made of the tested material (in our case 5% Cr steel), pressed at load P against the ring (in our case Steel D2), the equipment used for the test is the T-05 Block-on-Ring wear tester machine, which is shown graphically in Figure 2 a), and the illustration of the tribosystem in Figure 2 b). In this test, the ring is rotated with constant speed against the stationary block, and during the entire cycle is subjected to a constant load of 392N, and speeds of 0.18 m/sec for Sample 1, 0.36 m/sec for Sample 2 and 0.54 m/sec for Sample 3; taking contact force measurements by means of sensors connected to the CPU and measuring the wear track at the end of the test. The tests are performed in a tribometer to simulate wear in the absence of lubricant. The monitoring of the test lasts 800 seconds.

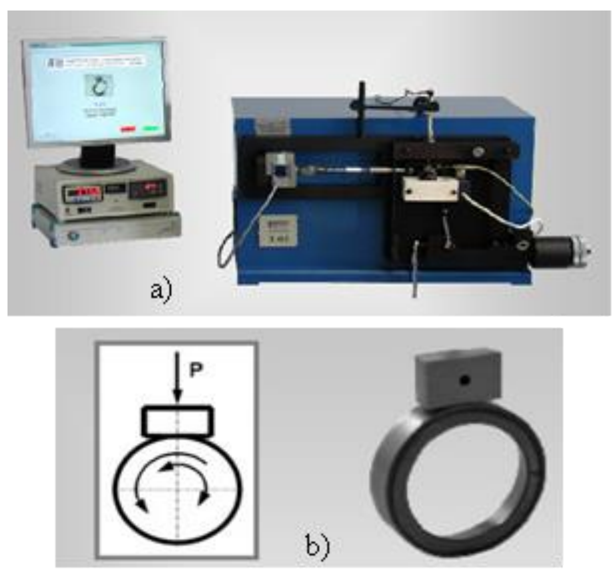

Figure 2 a) Machine T05 Block-on-ring b) Ilustration of tribosystem

Results

The 5% Cr steel samples have a hardness that varies in a range of 50-52 HRC; the chemical analysis of this material can be seen in Table 1, where it can be verified that, due to its low carbon content, it corresponds to a chromium-alloy steel.

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C	Si	Mn	Cr	Mo	V
0.55	0.15	0.60	5.00	0.80	0.15

Table 1 Chemistry composition of Steel 5%Cr

The wear in certain geometric contacts produces loss of material on one of the surfaces, initially the contact between the block and the disc is a line, but as it wears, the contact between both becomes an area where the track of wear in the block is observed as a rectangle, for our case of analysis we take the linear measurement of the width of the wear track considering four points to divide it, which are identified with the variables L1 to L4, we can see this distribution in Figure 3, and its dimensions are shown in Table 2, also indicating the average of each of the samples, which is 922,500 µm for Sample 1, 852,500 µm for Sample 2 and 772,500 µm for Sample 3.

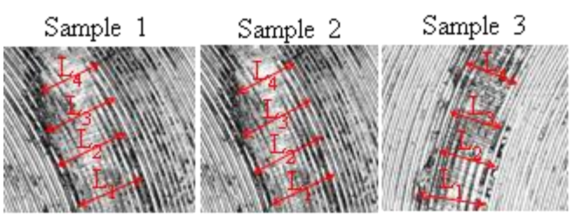


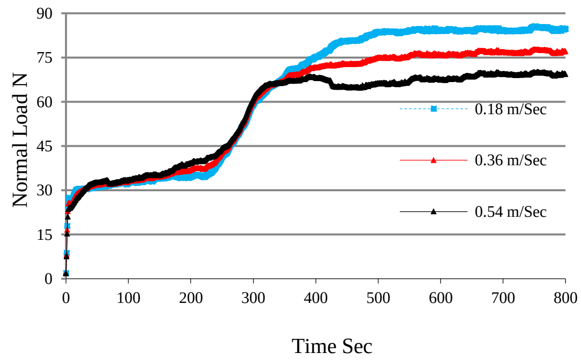
Figure 3 Identification of width on wear track for steel samples 5%Cr

Sample	L_1(µm)	L_2(µm)	L_3(µm)	L_4(µm)	L_{Prom} (µm)
1	970.000	1020.000	920.000	780.000	922.500
2	990.000	960.000	750.000	710.000	852.500
3	860.000	830.000	700.000	700.000	772.500

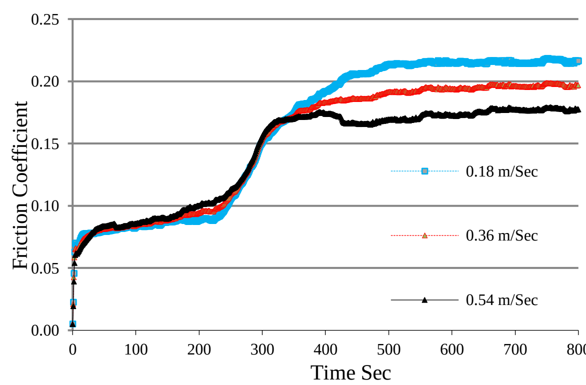
Table 2 Length of width on wear track for steel samples 5% Cr

The results obtained from the different tests are known as tribodata. In Graph 1, the behavior of the friction force as a function of time can be observed, indicating that the friction force is greater for Sample 1, which was tested with the lowest speed, these results coincide with the coefficient of friction, which is shown in Graph 2, which also shows that the coefficient of friction is greater for sample 1. For both cases of load and coefficient of friction, the test stabilizes and reaches its maximum values at approximately 350 sec.

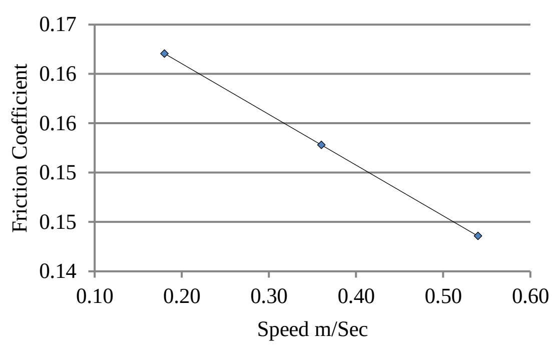
In Graphic 3, it can be observed how the coefficient of friction has a linear behavior that decreases as a function of speed; the lowest coefficient of friction is 0.144 and corresponds to a speed of 0.54 m/sec.



Graphic 1 Illustration of Friction load in function of time



Graphic 2 Illustration of Friction Coefficient in function of time



Graphic 3 Illustration of Friction Coefficient in function of speed

Conclusions

The width of the wear track is greater in Sample 1, which coincides with the greater friction force and the greater friction coefficient; thus, proving that wear is a function of speed; the higher the speed, the lower the friction coefficient and accordingly the lower the wear, as indicated by the 3rd law of friction for metals, according to Hutchings (1992).

This proves that the force and coefficient of friction stabilizes at approximately 13 minutes (800 seconds) according to the studies carried out by Asaduzzaman Ch. M. et al., (2013)

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It was shown that the friction coefficient values obtained in this study (μ=0.144), with speeds of 0.54 m/sec, are within the range of coefficients established by Forlerer et Al. (2000).

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