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ANALYSIS OF FRICTION COEFFICIENT FOR A BASE STEEL 5 % Cr, APPLYING VARIABLE LOADS OF 196 N, 294 N AND 392 N, AND SPEEDS OF 0,18 m/sec, 0,36 m/sec and 0,54 m/sec

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The present study consists in analyzing the friction coefficient as a variable of the normal load and slip speed for 5 % Cr steel, by applying the Block-on-Disk method according to ASTM D2714. The friction coefficient increases linearly 23,25 % from 0,214 to 0,266 when the load is increased from 196 N to 392 N; the same phenomenon is observed when the friction coefficient increases 47,82 % from 0,23 to 0,34 when the slip speed increases from 0,18 m/sec to 0,54 m/sec. The friction coefficient increased by 23,25 % for an increase in the load from 196 N to 392 N, which corresponds to 100 %, while an increase of the friction coefficient of 47,82 % occurred by increasing the speed from 0,18 m/sec to 0,54 m/sec which corresponds to 200 %.

Key words: Cr steel, friction coefficient, block-on-disk, normal load, slip speed

INTRODUCTION

Mechanical contact is one of the main phenomena that produces high friction coefficients. This principle is presented in any system that is exposed to loads or dynamic movements, such as machinery and equipment used for construction, manufacturing processes, transportation, miscellaneous services. The friction coefficient is an inevitable phenomenon, which occurs whenever two surfaces interact. The ASTM considers that the friction coefficient is due to hard particles or protuberances that are forced and moved along the surface of a soft solid, resulting in a loss of material or scratching of the same surface [1]. Hindu S. Wirokanupatum 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 [2]. Deuis et al, 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 [3].

Hirpa G. Lemu, 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 [4]; Asaduzzaman Ch. M. 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 [5-7]. E. Forlerer, 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 and μ = 0,08 [8]. In 1785, Jose Marie Coulomb established that third law of friction, is independent of the slip speed, but only up to 10 m / s, since after this value, the friction coefficient decreases as the speed increases [9]. Stembalski M. verified this principle in his study Determination of the friction coefficient as a function of slip speed and normal pressure for C45 and 40HM steel [10].

The coefficient of static friction or μs, is obtained by placing a body on an inclined plane, as the angle of inclination φ increases, the object begins to move; in this position the coefficient of static friction is determined, by the following equation [11]:

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

The measurement of the friction forces and the calculation of the friction coefficients are frequently supported by the different tribometers, applying standardized tests, such as those established by American Standard Testing materials (ASTMD2714), or other organizations such as American National Standars Institute (ANSI) [12].

The following equation is used to calculate the coefficient of friction:

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

Where:

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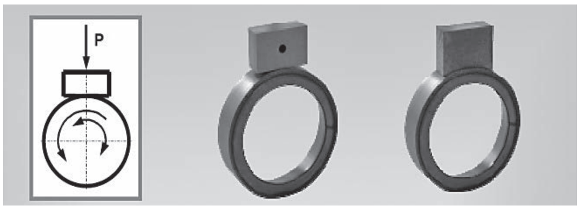

Figure 1 Ilustration of tribosystem

μ = coefficient of friction
fr = friction force
N = normal force applied

METHODOLOGY

Thirty test pieces were prepared, fifteen to be proved to a fixed slip speed of 0,18 m/sec with variable loads of 196 N, 294 N and 392 N, during a time of 800 seconds (13,33 minutes); and the other fifteen to be proved, to a fixed load of 294 N with variable speed of 0,18 m/sec, 0,36 m/sec and 0,54 m/sec.

The tribological system consists of the stationary block, made of the material tested (in our case base steel 5 % Cr), pressed in the load P against the ring (in our case steel D2), the equipment used for the test is the machine T-05 block-on-ring wear tester, illustration of the tribosystem is shown in the Figure 1. In such test the ring is made turn at constant speed against the stationary block, which during the whole cycle is submitted to a constant load. Measurements of contact force, material wear and temperature by sensors are then collected in the CPU. The tests are carried out in a tribometer in absence of lubricant. The parameters of test are accomplished with under ASTM D2714 standard.

RESULTS

Figures 2a), 2b) and 2c), show graphically the average value of the friction coefficient for the tests made with five test pieces to 196 N, five test pieces with 294 N and five test pieces with 392 N; for all the cases the time of the test was 800 seconds with fixed slip speed of 0,18 m/sec.

Comparing the three previous graphs as shown in the Figure 3, can see that the behavior is very similar in all the cases. During the first 450 seconds the time of stability is observed, later the friction coefficient tends to become stable and is kept stable, after 720 seconds approximately (12 minutes). Here it is possible to observe that for a greater load of 392 N major instability is generated in the test, reaching the critical point at 320 seconds; nevertheless it becomes stable by later following the pattern previously described. The values of the friction coefficient is shown in Table 1, which are of 0,214, 0,231 and 0,266 for the loads of 196 N, 294 N and 392 N respectively; The friction coefficient increases linearly 23,25 % from 0,214 to 0,266 when the load is increased from 196 N to 392 N. These same values

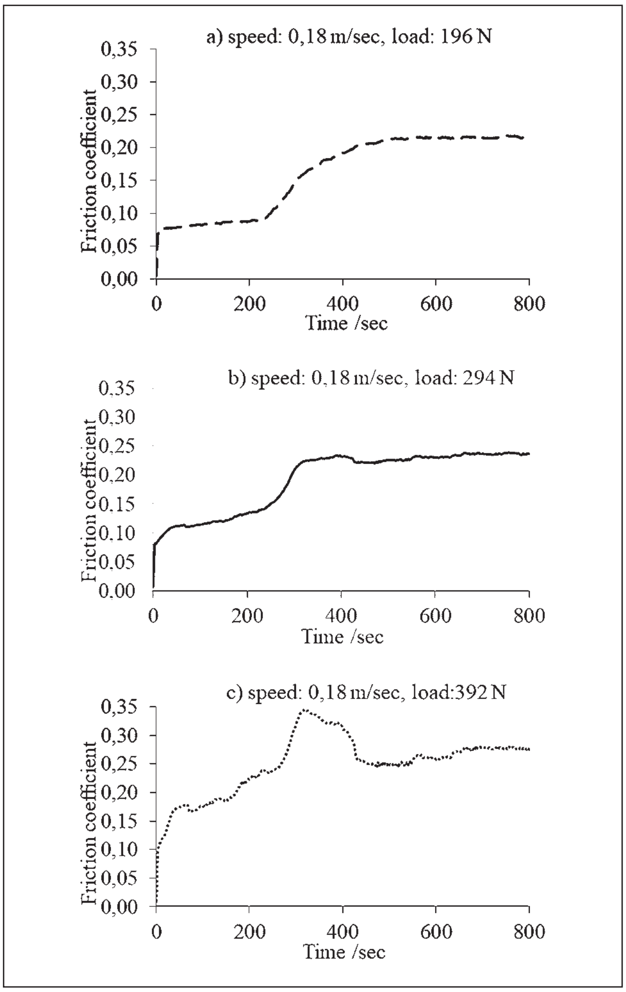

Figure 2 Friction coefficient as a function of normal variable load and a constant sliding velocity of 0,18 m/sec

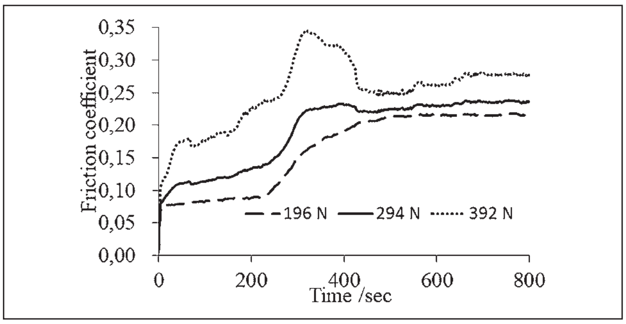

Figure 3 Friction coefficient as a function with the normal variable load

Table 1 **Values of friction coefficient for normal variables loads and constant slip speed of 0,18 m/sec**

Normal load / N	Friction coefficient
196	0,214
294	0,231
392	0,266

represent graphically in Figure 4, where we can see the line increase of the friction coefficient in 23,25 % for an increase of load of 100 %.

Figures 5a), 5b) and 5c), graphically show the average values of the friction coefficient for the tests performed with five test pieces at 0,18 m/sec, five test pieces with 0,36 m/sec and five test pieces with 0,54 m/

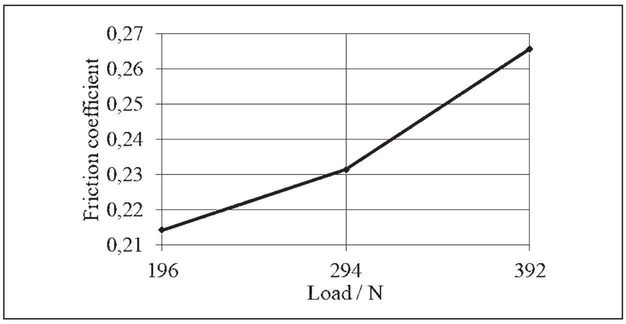

Figure 4 Increment of the friction coefficient as a function with the normal load

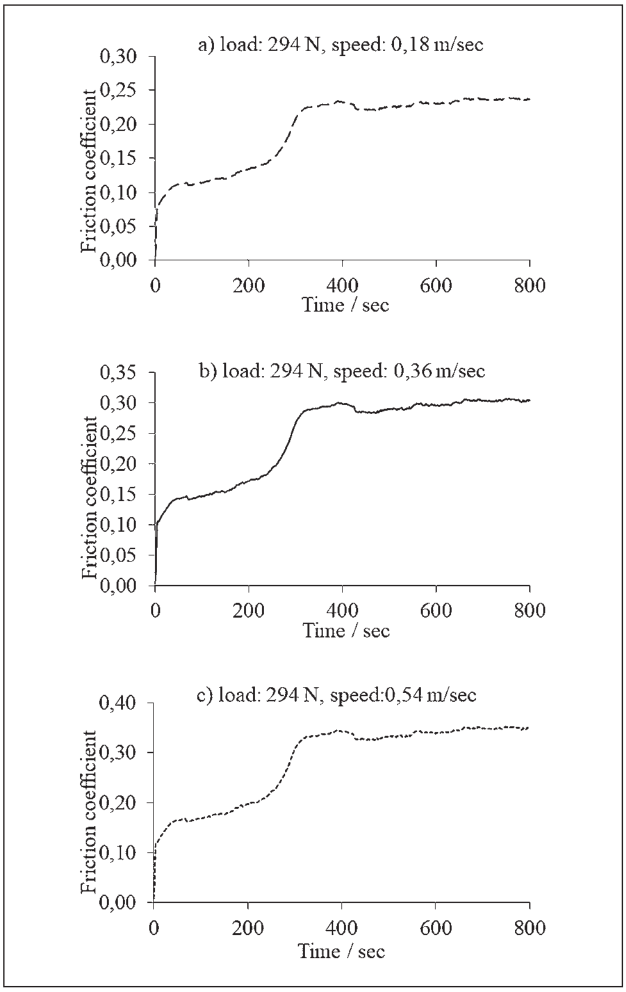

Figure 5 Friction coefficient as a function with slip speed and fixed load of 294 N

sec; for all the cases the time of the test was 800 seconds with fixed load of 294 N.

Comparing the three previous graphs as shown in the Figure 6, can may observe that the behavior is similar in all the cases, the time of stability is 450 seconds; later the friction coefficient tends to become stable and is kept stable after 720 seconds approximately (12 minutes). The values of the friction coefficient are shown in Table 2, which are of 0,231, 0,296 and 0,341 for the speeds of slid of 0,18 m/sec, 0,36 m/sec and 0,54 m/sec respectively. The friction coefficient increases linearly 47,82 % from 0,23 to 0,34 when the slip speed increases from 0,18 m/sec to 0,54 m/sec. These values are represented graphically in Figure 7, where it is possible to observe the graph line increase of the friction coefficient in 47,82 % for a speed increase of 200 %.

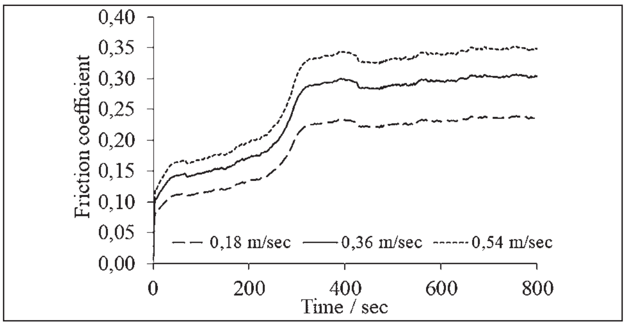

Figure 6 Friction coefficient as a function with variable slip speed

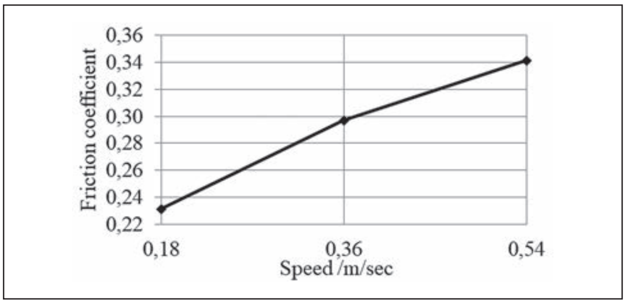

Figure 7 Increase of friction coefficient depending on slip speed

Table 2 **Values of friction coefficient for normal variable slip speed and normal constant load of 294 N**

Slip speed / m/sec	Friction coefficient
0,18	0,231
0,36	0,297
0,54	0,341

CONCLUSIONS

The values of the friction coefficient from 0,215 up to 0,231, are within the normal parameters as compared to those obtained by mechanical contact test of steel-on-steel published by Tabor D. In “Friction mechanisms, effect of lubricants, Tribology Handbook”, a value of 0,215 for a dry environment was obtained [12]; whereas the values of 0,265 up to 0,341 slightly above of the results obtained by Tabor D were due to the increase of the slip speed.

When materials come in contact small particles from peaks of the materials due to the roughness become detached. This characteristic appears until a polished area is produced between both surfaces of wear, and the phenomenon has been studied by R.D Arnell, who demonstrated the influence of the size of the abrasive, and establishes that the friction coefficient is directly proportional to the size of grain up to the point known as critical size of the abrasive. From this point, the coefficient of wear is kept constant [13]. Also it was confirmed by Shravan H. Gawande and Mohammad Azaduzzaman Chowdhury, that the friction coefficient increases depending on the load and after a certain time it will remain constant for the rest of the test, changing depending on the type of analyzed material [14-15]. This principle could be verified for both cases of analysis since the forces of friction after 720 seconds, were kept constant up to finishing the tests, as it is observed in the Figures 3 and 6; the stability of the test is reached to 12 minutes for both cases of speed and variable load.

The friction coefficient increases proportionally to the load and slip speed; but also it is observed that the greater the load and the slip speed, the larger instability of the test during the initial 450 seconds. This may be verified in the graph of Figure 3, for the load of 392 N, and peaks can be observed in the graph of the Figure 6, for the speed of 0,54 m/sec.

There is proportionality between the increase of load and slip speed, since the friction coefficient was increased by 23,25 % for an increase in load from 196 N to 392 N. This corresponds to 100 %, while the increase of the friction coefficient of 47,82 %, for an increase in speed from 0,18 m/sec to 0,54 m/sec corresponds to 200 %.

REFERENCES

[1] ASM: Vol. 18, Friction, Lubrication, and Wear Technology. ASM International Ohio USA 1992.

[2] Wirojanupatump S.: A direct comparision of wet and dry conditions with the rubber and steel. Wear 233-235(1999), 655-665. DOI:10.1016/S0043- 1648(99)00208-2

[3] Deuis R.L., Subramian C.: Three-body abrasive wear of composite coatings in dry and wet environments. Wear 214 (1998) 1, 112-130. DOI:10.1016/S0043-1648(97)00197-X

[4] Hirpa G.L, Trzepiecinski T.: Numerical and experimental study of Friction Behavior in Bending Under Tension Test. Journal of Mechanical Engineering 59 (2013) 1, 41-49. DOI:10.5545/sv-jme.2012.383

[5] Asaduzzaman Ch. M., Muhammad N.D.: Experimental investigation of friction coefficient and wear rate of stainless steel 202 sliding against smooth and rough stainless steel 304 couter-faces. Friction and wear research I (2013) 3, 34-41.

[6] Asaduzzaman Ch. M.: Experimental investigation of friction coefficient and wear rate of different sliding pairs. World Applied Sciences Journal 28 (2013)5,608-619. DOI:10.5829/idosi.wasj.2013.28.05.1168

[7] Chowdhury M.A,: Experimental investigation of friction coefficient and wear rate of composite materials sliding against smooth and rough mild steel counterfaces. Tribology in industry 35 (2013) 4, 286-296.

[8] Forlerer E.: Desgaste por fricción en la aleación de Zn-Al:ZA27 y en un compuesto de ZA27 reforzado con Si y CSi. Coloquio latinoamericano de fractura y fatiga, Argentina 2000.

[9] Hutchings.Tribology: Friction and wear of engineering materials, University of Cambridge UK 1992.

[10] Stembalski M., Determination of the friction coefficient as a function of sliding speed and normal pressure for C45 and steel 40HM. Archives of civil and mechanical engineering 13 (2013) 4, 444-448. DOI:10.1016/j.acme.2013.04.010

[11] Bayer R. G.: Mechanical wear prediction and prevention. Marcel Dekker, New York USA 1944.

[12] Tabor D.: Friction mechanisms, effect of lubricants: Tribology Handbook, Neale M. J.,Ed. Butterworth and Co. Publishers Sección F3, Oxford UK 1973.

[13] Arnell R.D.: Tribology Principles and Desing Applications: Macmillan Publishers London UK 1991.

[14] Rajesh S. Gopse: Tribological behavior of high fraction carbon steel alloys, J Bio Tribo. Corrosion 2 (2016) 3, 1-9. DOI: 10.1007/s40735-016-0034-3

[15] Dewan Muhammad Nuruzzaman: Experimental investigation on friction coefficient of composite materials sliding against SS201 and 301 counterfaces. Procedia Engineering 105(2015), 858-864. DOI:10.1016/j.proeng.2015.05.106

Note: English language translation: Juan Garcia Noguera, M.S University of Nebraska, USA.