EXPERIMENTAL INVESTIGATION ON THE EFFECT OF ELECTRICAL CURRENT FLOW ON THE COEFFICIENT OF FRICTION BETWEEN TWO DRY RUBBING SURFACES

بحث عملي لدراسة تأثير سريان التيار الكهربى على معامل الإحتكاك للسطوح الجافة

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الملخص العربى :

يهدف هذا البحث إلى تعيين تأثير سريان التيار الكهربى على معامل الإحتكاك بين السطوح الجافة عملياً مع الأخذ فى الإعتبار تأثير المعاملات الأخرى مثل السرعة والأحمال والمعادن المستخدمة.

وقد أجريت هذه التجارب باستخدام جهاز *"Pin-disc tribometer"* وهو عبارة عن مسمار قطره ٦مم وقرص له قطر ٢٠٠مم يمر بينهما تيار كهربى يتراوح بين صفر وثمانية أمبيرات وفرق جهده ثابت عند ١٢ فولت. وتمت قياسات معامل الإحتكاك عند عدة أحمال ثابتة وتيار كهربى متغير وذلك بقياس قوة الإحتكاك الناتجة باستخدام جهازى قياس الإنفعال و *"FFT Analyzer"* .

كما قدر تأثير تغير المواد المتلامسة والسرعة والأحمال على معامل الإحتكاك مع تغير التيار الكهربى بإجراء دراسة شملت ثلاثة مجموعات من المواد المختلفة وهى الحديد والنحاس والألومنيوم وذلك لسرعات إنزلاق تتراوح بين ١٠٠ إلى ٧٠٠ لفة/دقيقة وأحمال ثابتة تتراوح بين واحد وثمانية نيوتن.

ولقد وجد - كنتيجة لهذا البحث - أن معامل الاحتكاك يتوقف بدرجة كبيرة على شدة التيار الكهربى.

ABSTRACT

The main object of this paper is to determine experimentally the effect of electrical current flow on the coefficient of friction between two dry rubbing surfaces.

The tests were performed utilizing a pin-disc machine (Tribometer) with a pin having a diameter of 6 mm and 200 mm diameter disc. The current was be varied from 0 to 8 amperes with a constant potential difference of 12 volts.

The coefficient of friction was calculated, at different loading and electrical current, based on the measured friction force. The measurement was carried out via strain gauge and FFT analyzer.

A parametric study was carried out to highlight the effect of material, velocity and load on the coefficient of friction with the electrical current flow. Three sets of materials were used; steel-steel, copper-copper and aluminum-aluminum. Sliding velocity was increased up to 700 r.p.m., while the load changed from 1 to 8 Newton.

As a result of this investigation, it was found that the coefficient of friction is depending strongly on the electrical current flow at all operating conditions.

KEY WORDS:

Coefficient of friction, Electrical current, Constant weight and speed, Materials.

INTRODUCTION

The coefficient of friction between two rubbing materials is an important parameter for both design and tribological purpose. Therefore many investigations [1, 2, 3] determined the coefficient of friction at different materials and loading conditions.

In general, the determination of the coefficient of friction between two dry rubbing surfaces has been experimentally achieved by the measurement of friction forces existing between these surfaces. The friction force is defined, generally, as the resistance to motion which is experienced whenever the solid body slides over another.

Rabinowicz [4] studied the nature of the static and kinetic friction and, then, introduced what is denoted as the mean kinetic coefficient of friction. Also, Alesten et al. [5], Zhao et al. [6] and Wang et al. [7] have measured the friction force in stable smooth sliding material. The effect of material properties on the coefficient of friction in cold rolling has been studied by Lenard [8].

Bowden and Leben [9], studied the kinetic coefficient of friction between different materials. A typical experimental record of friction force versus time is given.

Boden and Tabor [10], summarized the results of their study concern contact properties of pure iron at dry friction. They used the "Pin-Disc" apparatus to perform their experimental work.

Kato et al. [11] and Bristow et al. [12] also measured the kinetic coefficient of friction in stable smooth sliding. They concluded that the coefficient of friction versus sliding velocity, drastically change with temperature. The effect of velocity and the surface roughness on the friction force was studied by Jeng [13] and Berther et al. [14].

Despite many attempts, there is a lack of understanding of the influence of the electrical current flow on the coefficient of friction.

The object of the present research is to determine experimentally the coefficient of friction with the electrical current flow through the contact point during rubbing at variable loads, variable speed and variable electrical current for different materials. Also, the coefficient of friction at the same conditions without the effect of electrical current has been determined.

EXPERIMENTAL TEST RIG AND INSTRUMENTATION

Figure 1, shows the test rig together with the utilizes instrumentation for the present investigation. The test rig consists mainly of the tribometer; which is a stationary pin sliding against a rotating disc, and a dead weight loading system.

The pin has 6 mm diameter and is firmly held in the specimen holder, which is fixed by free joints by means of two set screws. The pin was pressed against the disc by variable static load. This load is applied by means of a dead weight loading system via the pin holder. The disc is driven by a variable speed motor. The pin and its accessories were kept horizontal by using the counter weight shown in the figure.

The electrical current flow through the contact point was induced by using 12 volts battery. This current is changed from 0 to 8 amperes by using variable resistance.

Three combinations of materials were used; these are steel-steel, copper-copper and aluminum-aluminum.

The friction force was measured via a strain gauge apparatus. The strain gauge is fixed on the lever between the specimens holder and the frame, as shown in Fig.2. This gauge measures the friction resistance and changes it into a proportional electrical signal. This signal was read by a strain meter and FFT analyzer which determines the maximum and the average resistance force. The advantages of the strain meter are the high resolution, cheeper, high stiffness and small size.

RESULTS AND DISCUSSIONS

As mentioned above, the present investigation is concerned with the experimental determination of the effect of the electrical current on the coefficient of friction between two dry rubbing surfaces.

The experiments were carried out at different loading, speed and material conditions. These operating parameters as well as electrical current are varied as outlined in Table 1.

Table 1: Operating parameters variation

Material	Steel, Copper and Aluminum	
Load	1 - 8	Newton
Speed	100 - 700	r.p.m.
Current	0 - 8	Amperes

The results of these experiments would be summarized in the following sections:

STEEL AGAINST STEEL EXPERIMENTS

Figure 3, illustrates the relation between the coefficient of friction and electrical current at different loading conditions. It shows that the coefficient of friction increases with the increase of both current and applied loads.

Figure 4, shows the relation between the coefficient of friction and speed at different values of electrical current. It is obvious that the coefficient of friction decreases with the increase of speed up to a certain value and then increases with the increase of speed. The minimum value of the coefficient of friction in this figure could be defined as critical speed. It may be also noted from Fig.4, that the location and magnitude of this critical speed depends on the applied load.

However, it may be concluded from Fig.3 and 4, that the electrical current has a great effect on the coefficient of friction at all speed and loading conditions.

COPPER AGAINST COPPER EXPERIMENTS

Figure 5, illustrates the relation between the coefficient of friction and current at different loading conditions. It is clear that the coefficient of friction increases with the increase of current at different loads. Whereas, Fig.6, shows the relation between the coefficient of friction and speed at different loads. It is obvious that the coefficient of friction decreases with the increase of speed to a certain value and then it increases with the increase of speed. The speed at which the minimum coefficient of friction occurs is called critical speed and its location and magnitude depends on the applied load.

ALUMINUM AGAINST ALUMINUM EXPERIMENTS

Figure 7, illustrates the relation between the coefficient of friction and current at different constant loads. It is clear that the coefficient of friction increases with the increase of both current and load. While, Fig.8, shows the relation between the coefficient of friction and speed at different loads. It is obvious that the coefficient of friction decreases with the increase of speed up to a certain value, and then increases with the increase of the speed. The value at which the minimum coefficient of friction occurs is called the critical speed and its location and magnitude depends on the applied load.

The three dimensional representation of the coefficient of friction against current and speed as illustrated in Figs.9, 10 and 11, which give the advantage to estimate the magnitude of the coefficient of friction with a speed ranging from 100 to 700 r.p.m. and current ranging from 0 to 8 amperes. It is clear that the coefficient of friction increases with the increase of current and speed.

CONCLUSIONS

1- The electrical current is positively correlated to the coefficient of friction between two dry rubbing surfaces at all loading conditions.

2- The relative speed between the rubbing surfaces is concavely relates to the coefficient of friction and there is a critical speed where the coefficient is minimized. The critical speed varies with the material as well as electrical current.

3- Applying electrical current to the rubbing surfaces in clutches and brakes will increase the coefficient of friction and hence improve these devices performance.

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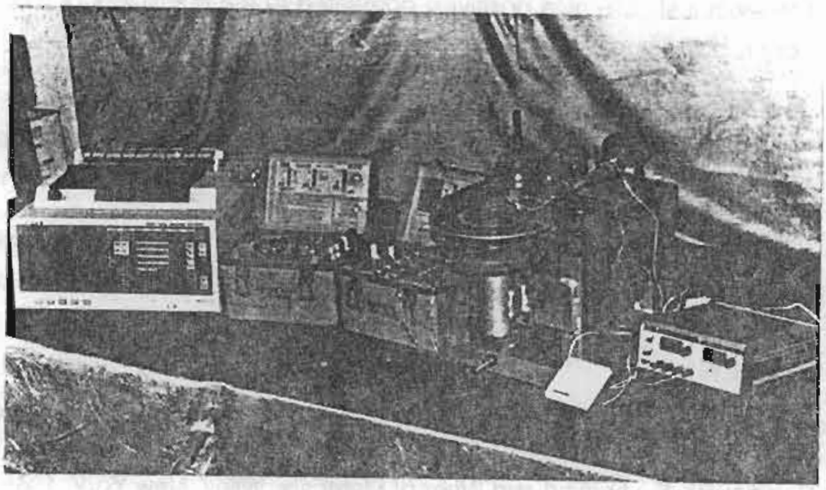


Fig. 1: The test-rig arrangement photograph.

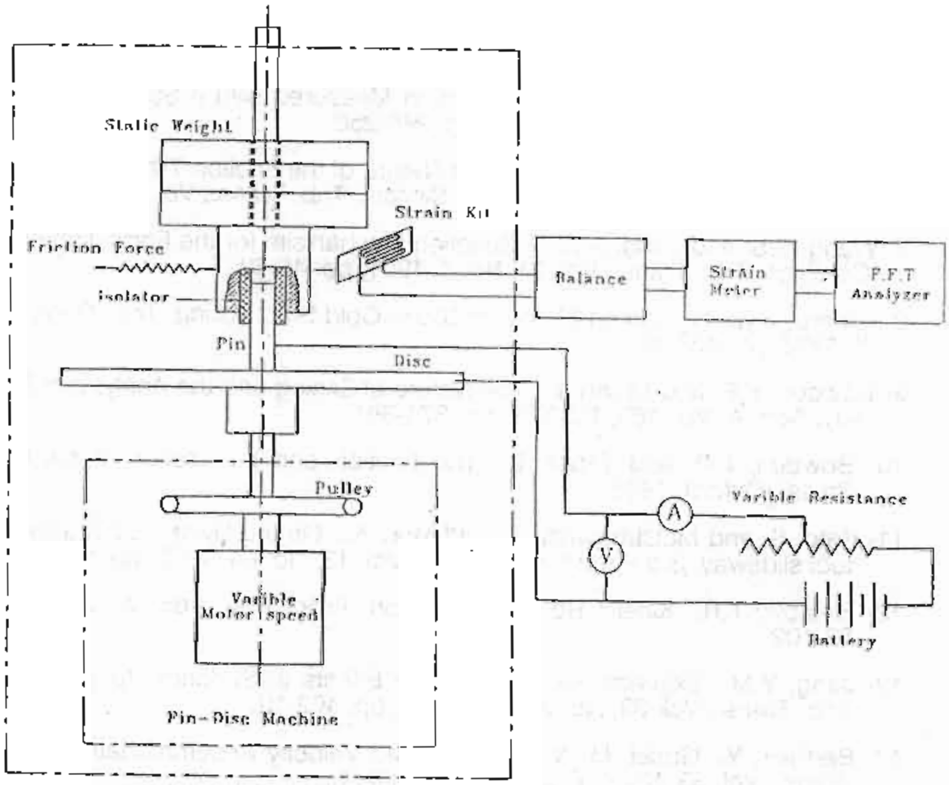
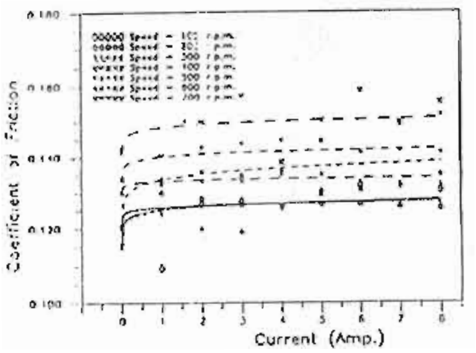
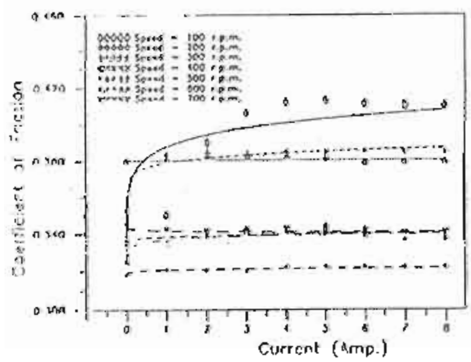


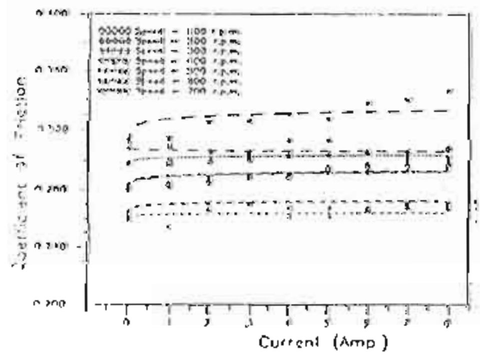
Fig. 2: Schematic diagram of the experimental apparatus.



(a) at load = 1.5 N.

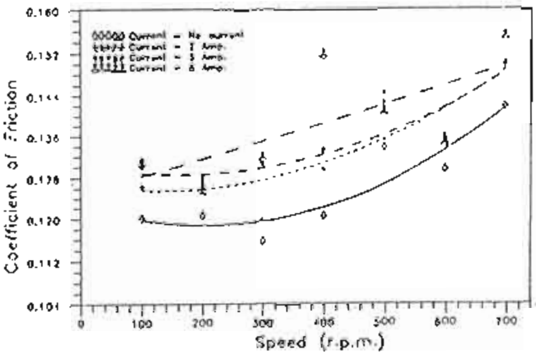


(b) at load = 4.2 N.

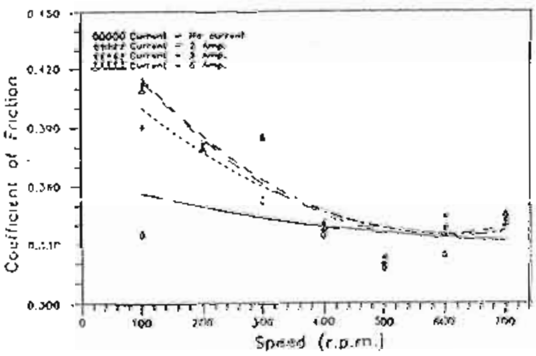


(c) at load = 8.0 N

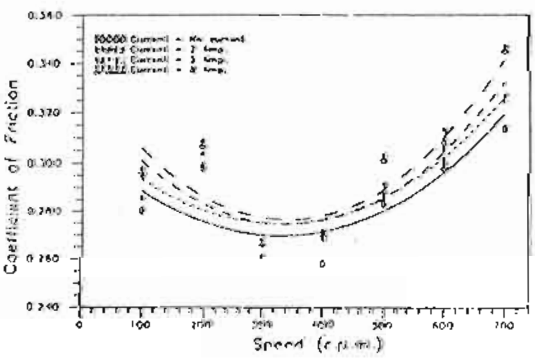
Fig. 3: The relation between steel on steel coefficient of friction and current with variable speed.



(a) at load = 1.5 N.

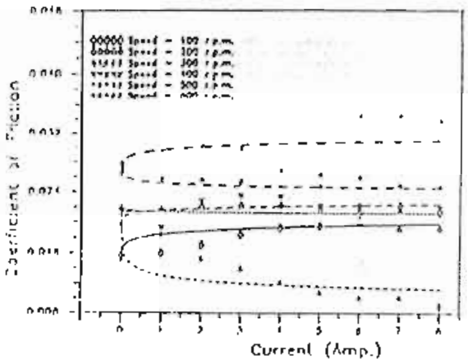


(b) at load = 4.2 N.

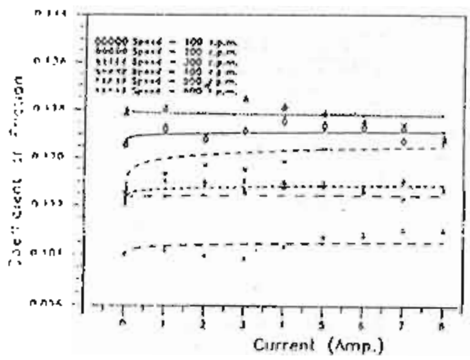


(c) at load = 8.0 N.

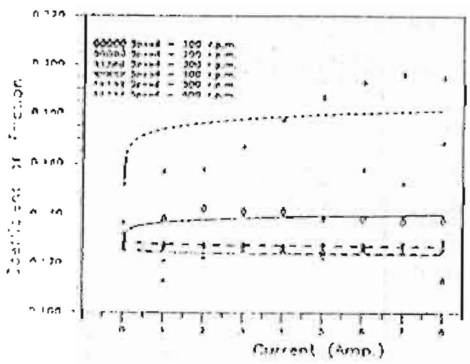
Fig. 4: The relation between steel on steel coefficient of friction and speed with variable current.



(a) at load = 1.5 N.

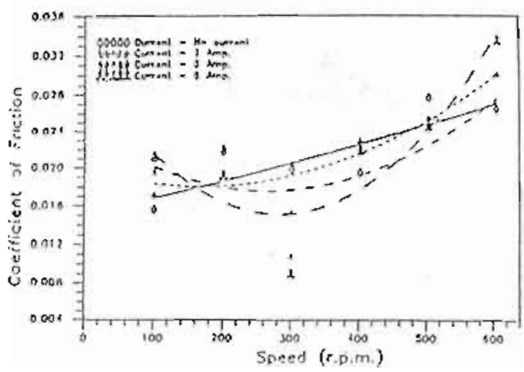


(b) at load = 5.0 N.

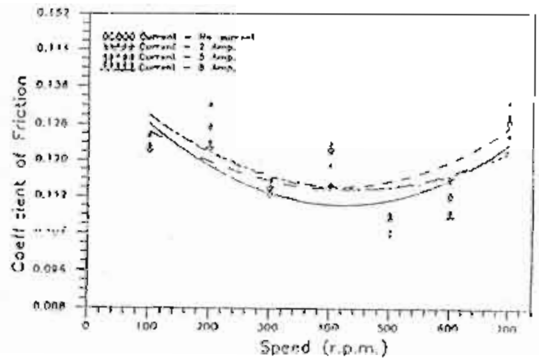


(c) at load = 6.5 N.

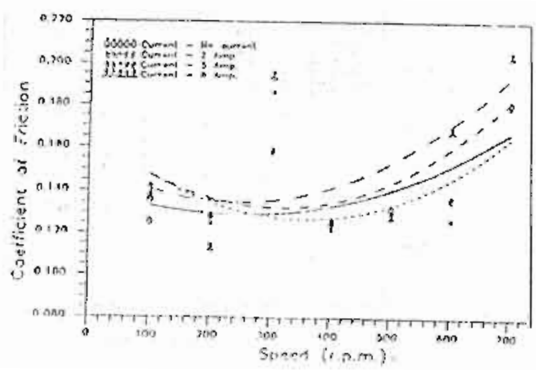
Fig. 5: The relation between copper on copper coefficient of friction and current with variable speed.



(a) at load = 1.5 N.

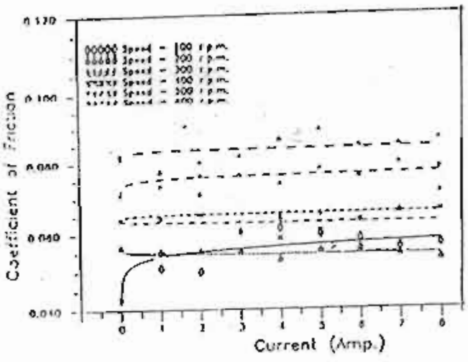


(b) at load = 5.0 N.

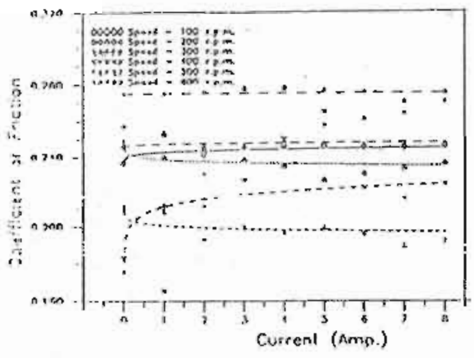


(c) at load = 6.5 N.

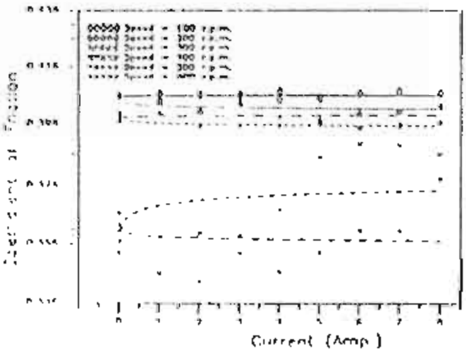
Fig. 6: The relation between copper on copper coefficient friction and speed with variable current.



(a) at load = 1.5 N.

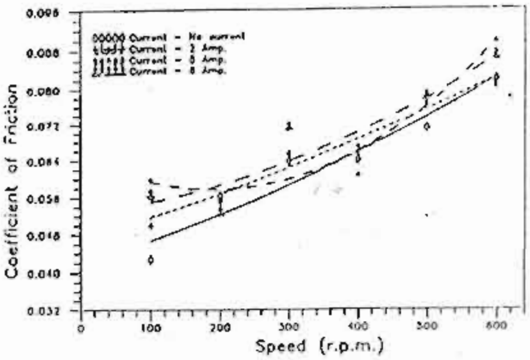


(b) at load = 3.0 N.

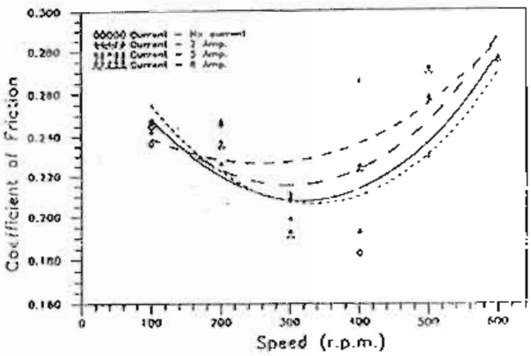


(c) at load = 8.0 N.

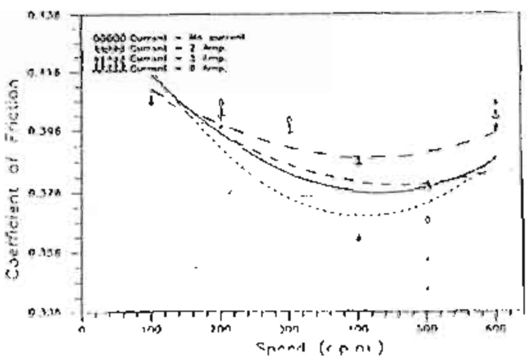
Fig. 7: The relation between aluminum on aluminum coefficient of friction and current with variable speed.



(a) at load = 1.5 N.



(b) at load = 3.0 N.



(c) at load = 8.0 N.

Fig. 8: The relation between aluminum on aluminum coefficient friction and speed with variable current.

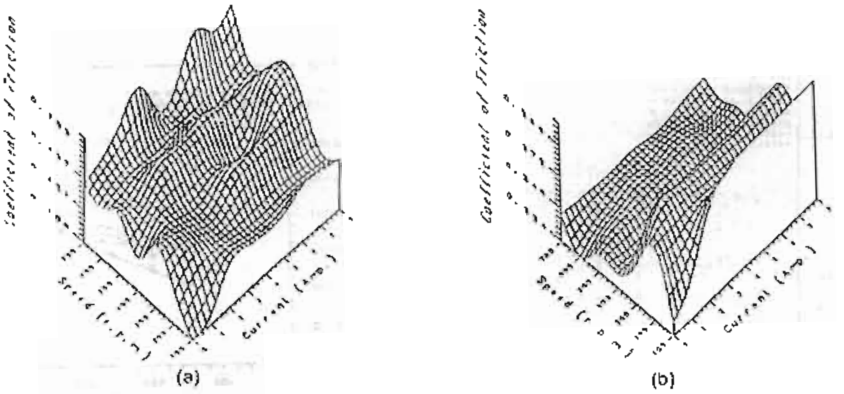


Fig. 9: Three dimensional representation of steel on steel coefficient of friction with current and speed at different load (a- at load = 1.5 N, b- at load = 4.2 N).

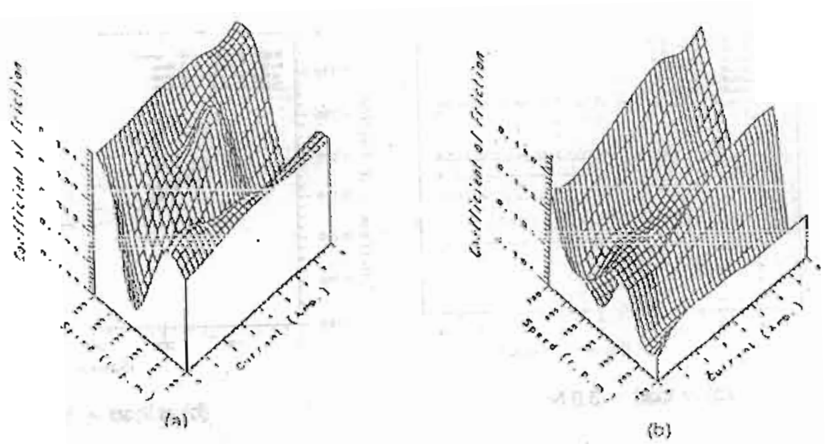


Fig. 10: Three dimensional representation of copper on copper coefficient of friction with current and speed at different load (a- at load = 5.0 N, b- at load = 6.5 N).

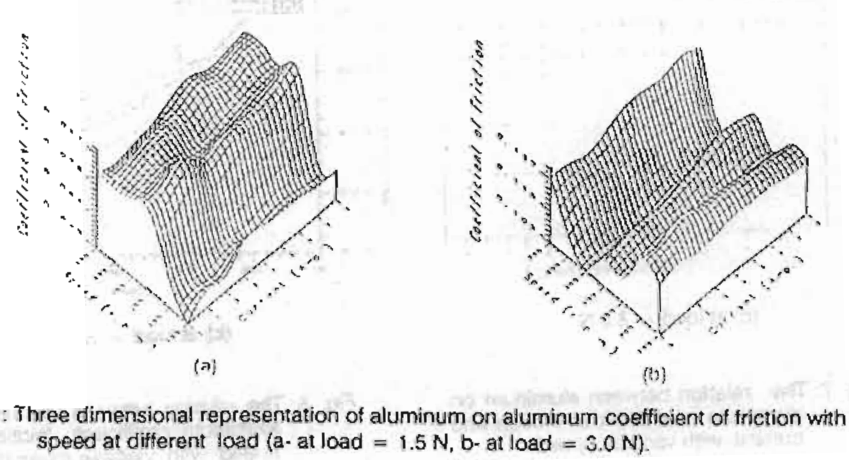


Fig. 11: Three dimensional representation of aluminum on aluminum coefficient of friction with current and speed at different load (a- at load = 1.5 N, b- at load = 3.0 N).