THE ASSESSMENT OF FRICTION PROCESS OF MODEL KINEMATIC PAIR WORKED UNDER DC VOLTAGE

OCENA PROCESU TARCIA W MODELOWYM WĘZLE KINEMATYCZNYM PRACUJĄCYM POD NAPIĘCIEM ELEKTRYCZNYM

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Abstract: *The subject of this paper is assessment of friction process of model kinetic pair worked under DC voltage. The friction under this conditions may take place in case of triboelectrical phenomena and in friction pairs of electrical motors. The significant influence of electric current flow on friction resistance and boundary film thickness was presented. Results of the research were compared to the results of research under load and without electric current applied.*

Keywords: *triboelectric phenomena, friction under voltage, resistance, boundary layer*

Streszczenie: *Tematem publikacji jest ocena procesu tarcia w węzle kinematycznym pracującym pod napięciem elektrycznym. Tarcie w takich warunkach może mieć miejsce w przypadku występowania zjawiska triboelektrycznego lub też w węzłach tarcia silników elektrycznych. W publikacji wskazuje się na istotny wpływ prądu elektrycznego przepływającego przez węzeł tarcia na opory ruchu oraz grubość warstwy granicznej. Wyniki badań węzła tarcia przez który przepływa prąd elektryczny porównano z efektami tarcia układu pracującego tylko pod obciążeniem.*

Słowa kluczowe: *zjawisko triboelektryczne, tarcie pod napięciem elektrycznym, rezystancja, warstwa graniczna*

1. Introduction

The friction process is the area of science, where decision of natural occurrence of some phenomena and accompanying mechanisms is still impossible, in spite of newer and more precise measurement techniques. The situation concerns also boundary layers, whose are formed on friction surfaces at special conditions called boundary friction.

The tribological research at boundary conditions is needed because of very different thesis concern properties of boundary layer and mechanisms of their creating in different conditions. The typical parameter that determine conditions of friction is coefficient of friction and temperature of kinematic pair. Besides the indexes, in tribological research is observed also electrons and charged particles emission, what is described in many articles [1-7,10-17] as the triboelectric phenomenon. This phenomenon has significant influence on forming and destroying of boundary layer [6,11,13,15,16]. It means that an energy emitted in kinetic pair (heat, electricity) can form but also devastate boundary films, what is depend on individual properties of the layers. A special feature of the layers is amount of energy, what can flow by kinetic pair without destroying the layer [11,15,16].

2. Experiment

Many articles [18,19,20,21] indicate that friction resistance can be reduced by DC voltage influence on friction zone. It should be also noticed that resistance of friction can rise under voltage influence. This difference depends on direction of current flow and also physical and chemical properties of materials taking part in friction. The thesis were checked on model kinetic pair, where specimen and counterspecimen were made from high quality steel called as 45. The scheme of the test rig is presented on figure 1.

Fig. 1 Scheme of electrical circuit joined with kinematic pair

The research was conducted on TR-2 tribometer, that is describe in international patents [8,9]. The tribometer contains separated channels to simultaneous and direct measurements as: friction force, oil film thickness, resistance and voltage in friction zone. Additional, the resistance circuit make possible of joining voltage to the friction surfaces. Then, the resistance measurement is impossible. Electrical resistance between pins and a disk was assessed when the electrical voltage was turned off.

The TR-2 tribometer makes possible the research under dry and liquid friction condition. The experiments with lubrication can be done owing to special chamber, where the lubricant in amount 100 – 150 ml is poured into.

The apparatus also give possibilities of speed, unit pressure and temperature changing. The range of adjustment of the parameters is wide: 0,01 – 5 m/s for speed; 0,1 – 150 MPa for unit pressure and 20 – 100 °C for temperature. During the research the temperature was stabilized at 20°C and the specimens worked in high purity paraffinic oil. The speed of disc was stabilized on 1 m/s. Obtained datum were written with frequency of 10Hz and saved in registration device. The acquisition system make measurements possible to 22kHz frequency for each canal. The highest frequencies were used to calibration and check of measuring canals. In the research, there was used 10 Hz measurement frequency.

The tribometer worked in two pins on a disk arrangement. The specimens are made from stainless steel (45) with roughness $R_a = 0,2$ after precise polishing. The samples are located in the oil chamber with controllable temperature. The diameter of disc amounted to 60 mm, and surface area of pins equal 1 mm².

The aim of the research was to indicate changes of measured parameters during voltage increasing, where voltage was changed step by step, every 0,1 V. The duration time of one value of voltage was 120 second and the break between voltage turning on was 150 second. The source of DC voltage was AC/DC adapter with the electrical breakdown indicator.

There was conducted two experiments, where load was changed. On the first time, load was stabilized on 32,5 N (pressure 32,5 MPa), and the second research was conducted at 65 N (65 MPa).

The results of the research was presented below.

3. Results

The conception of using of electrical current to boundary layer research is result of thesis that boundary layer destroying can be at the moment when an energetic treshold of friction process is exceeded. We can control it by a load, a pressure, a temperature and a velocity changing.

When an electric current is inserted into friction zone, the regulary boundary layer is destroyed. It is noticed that size of electrical voltage needed to the layer damage is similar to energetic level of particles adsorbed on friction surfaces. When the energetic treshold is exceeded, both the oil film and boundary layer change an electric conductivity. Then the polar particles of lubricant (also boundary layer) are oriented in conductance direction.

The figure 2 present the moment when a boundary layer is destroyed. The situation take place at 0,8 V what causes that friction force (red line) grow up. Further rising of voltage, changes the friction force but also oil film thickness.

Fig. 2 The voltage inflence on friction surfaces. Parameters of research $v=1[m/s]$, $T=40[^\circ C]$, $p=25[MPa]$, lubricant –paraffinic oil, voltage: 0-30 [V]

The strenght of boundary layer depends not only on a kind of lubricant, but also unit pressure on the surfeces. For pure paraffinic oil and higher than previous unit pressure (32,5 MPa), the puncture voltage was 1,1 [V], that is illustrated on figure 3

Fig. 3 Changes of oil film thickness h and friction force F_t during DC voltage influence for unit pressure $P = 32,5 MPa$; F_t – friction force, h – oil film thickness, R – electrical resistance,

During the same research but with 1% stearyl alcohol, the destroying of boundary layer is faster, when the level of voltage was 0,8V. It is presented on figure 4.

Fig.4 The voltage influence on friction surfaces lubricated with paraffinic oil and 1% steryl alcohol

The Fig. 3 and Fig.4 show that the strength of boundary layer also depends on additives. In this case, the alcohol additive to paraffinic oil has negative influence on the electrical resistivity.

Significant influence on the layer strength and thickness has a unit pressure what can improve or worsen boundary layer making process. It can be compared on fig. 3 and fig.5

Fig. 5 Changes of friction parameters during DC voltage influence for unit pressure $P = 65$ [MPa]

The Fig. 5 presents boundary layer evaluation in two times higher unit pressure than on Fig.3. In these conditions the boundary layer formed in friction process is destroyed when the 0,8 Volt was put on kinematic pair. The voltage does not cause disappearing of the layer but its structure changing. The changes bring about that friction force is rising and oil film thickness is growing.

The applied voltage causes boundary layer more conducted. The state when the current threshold not exist, causes a slow rising of boundary film thickness and a slow decreasing of friction force. The crossing of energetic threshold in kinematic pair bring about sudden grow of friction force. The rise is not connected with fully destroy of boundary layer because the film thickness is growing. It can be proof that ionized and polar particles of oil are composed according to direction of current flow (from specimen to counterspecimen). Then the oil film thickness is rising.

Applying of electric current to kinematic pair shows that the excess of energy in friction zone can destroy boundary layer. The second way to devastate the layer is excessing of unit pressure. The both examples are illustrated on Fig.6 and Fig.7.

Fig.6 Changes of friction parameters during unit pressure increasing; lubricant – paraffinic oil.

Fig.7 Changes of friction parameters during voltage applying; lubricant – paraffinic oil; voltage – 1 [V]

The two figures present similar effects of boundary layer changes caused by external forces and current applying. The rise of unit pressure (Fig.6) causes decrease of electrical resistance but stabilized load brings about rebuilding of the electrical parameter. The resistance changes are similar when the current is applied into friction zone (Fig.7).

When the voltage is switched on, a measurement of resistance is impossible, but when the voltage is switched off, the resistance rises from value close to zero.

The changes of energetic state in friction zone are very difficult to compare it but it is possible to notice differences. On the Fig.6, oil film thickness is rising at the result of continuous growth of energy in friction zone derived from high load. An energy comes from voltage (Fig.7) do not caused so significant increasing of boundary film thickness. On the other hand, the voltage switching off bring about slow decreasing of the thickness to beginning state.

4. Conclusions

Obtained results allow to formulate following conclusions:

- The steering of friction force in kinematic pairs is possible owing to DC voltage influence.
- Additional and simultaneous measurement of electrical resistance (voltage falls) and oil film thickness gives new possibility of friction assessment.
- The electrical breakdown between lubricated friction surfaces do not have to cause the boundary layer decay.
- The electrical breakdown between stainless steel surfaces causes a friction force increasing.

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