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Evaluation of Self Diagnosis of Materials in Sliding Friction

Hatsuhiko USAMI and Junji SUGISHITA
Meijo university, 1-501 Shiogamaguchi, Tempaku, Nagoya, 468-8502 JAPAN
Fax: +81-52-832-1235, e-mail: usami@meijo-u.ac.jp, sugisita@meijo-u.ac.jp

Abstracts

The present paper describes possibility of self diagnosis of materials in sliding contact by measurement of thermoelectric potential. Silicon carbide, sapphire and hardened carbon steel were used for the specimen. Three different friction tests were carried out for the evaluation: In-situ observation of contact conditions under boundary lubrication, temperature measurements by infrared detector and measurements of thermoelectric potential. The results of our experiments show that the sensitivity of the thermoelectric potential is greater than that of the infrared rays. Thus, the thermoelectric potential generated at the interface of contact surfaces can provide a reasonably accurate information to evaluate the contact conditions.

1.INTRODUCTION

Tribological characteristics is important factors in determining the severe damage of structural components known as seizure. Since seizure is caused by severe adhesion at the surface, temperature and contact conditions at the interface are necessary to evaluate the generation of the seizure. If the interface has electrical conductivity, measurement of thermoelectric potential is readily available for evaluation of the surface temperature without the need for special sensing devices [1]. In the case of the interface having transparency, not only the temperature measurements but also observation of the contact conditions in service has been demonstrated [2,3].

In order to prevent damage of the structural components, large number of sensors have been applied. However, this complicates the diagnosis of the damage analysis. Recently, fiber reinforced materials incorporating self-sensing systems have been developed [4]. Such kinds of systems are available and provide a simple diagnosis.

The present paper describes possibility of the thermoelectric potential measurement for detecting the contact condition during sliding friction. To evaluate the relationship between the surface temperature and contact condition, temperature measurement and in-situ observation of contact area were carried out when a sapphire pin slides on a steel surface. The results of the surface temperatures obtained by the measurement of thermoelectric potential are then compared with those obtained by infrared rays. The possibility of the thermoelectric potential upon comparison in various contact conditions is evaluated to exploit the optimum use of the self diagnosis of the materials.

2.EXPERIMENT

2.1.Apparatus

A pin on disc type testing apparatus was used for the experiments. A schematic of the apparatus was shown in Fig. 1. The pin specimen was fixed into the dynamometer consisted from 2 curved beams and 4 strain gages. The lens assembly including CCD camera was installed just behind the pin specimen. Infrared rays from the contacting area was observed with CCD camera through an optical fiber cable.

The normal load at the contacting area was applied by pulling the upper end of the arm with the dynamometer. The disc specimen was mounted on the drive shaft by 4 bolts. The diameter of the wear truck was 100 mm. The irregularity of thrust motion per unit revolution was minimized less than 5 μm by adjusting the bolts. The experiments were carried out in air. First the disc specimen rotates, and then a normal load was applied.

2.2. Materials

Sapphire and silicon carbide were used for pin specimens to carry out in-situ observation and to measure thermoelectric potential, respectively. The material of the disc specimen was hardened steel containing 0.45 wt. % carbon. Testing surface of the specimens were finished by polishing.

3.RESUTS AND DISCUSSION

3.1. Friction force and contacting condition

In order to evaluate relationship between friction force and contacting condition, friction behavior under boundary lubricated condition was evaluated. Commercial grade oil was used for the test. The oil was spread before the evaluation and did not supply during the evaluation. Therefore, it is estimated that contact area exceeds with oil consumption by friction. Dry friction was carried out before the evaluation for running in to avoid severe damage of the specimen surface by chipping. Coefficient of friction as a function of sliding distance was shown in Fig. 2. The value of the coefficient of friction was about 0.1 at initial stage. At a sliding distance of 4000 m, The value begins to increases with the sliding distance rapidly. The region of rapid increase of the coefficient of friction corresponds to the seizure generation.

Figure 3 shows a series of optical images during the seizure generation. Since the oil consumption near the contact area results in the seizure and the increase in the coefficient of friction, the images represents to the transition from boundary lubrication to dry condition. Bright area in the images corresponds to the high temperature region and expands with the increase in the coefficient of friction. The bright area moves inside the apparent contacting area during the expansion.

3.2. Temperature measurements

Infrared ray measurements

CCD camera assembly was replaced with the infrared ray detector to measure the surface temperature. The detector was made from germanium. The measuring area, response time and temperature range were 0.2 mm in diameter, 0.1 m sec. and 700 to 2000 °C, respectively. Figure 4 shows the results. The measured values had variations. The maximum value of the temperature increases with the increases in the applied load. As shown in Fig. 5, the coefficient of friction was almost constant during the test and against the applied loads. The area of infrared ray measurement is smaller than that of real contact region. Since the measured temperature corresponds to the flash temperature depends on the real contact area [5], considering the behavior of the coefficient of friction, it suggests that contacting area moves during the test and expands with the increase in the applied load.

Thermoelectric potential

Thermoelectric potential generated at the interface was measured using a pair of silicon carbide and hardened steel. The potential was measured and recorded by an oscilloscope during the friction test. Before the test, thermoelectric potential was measured on static contact of the silicon carbide and the steel to obtain the calibration curve of the temperature. The measured values were converted with the calibration curve and were shown in Figure 6. It was confirmed that the coefficient of friction in each sliding speed was almost constant against the sliding distance. At a low speed of 3 m/s, temperature was low and almost constant. Variations in the temperature become greater with the increase in the sliding speed.

Compare with the temperature in Fig. 3, the sensitivity of the temperature obtained by the thermoelectric potential is greater than those obtained by the infrared rays. Consequently, it is estimated that thermoelectric potential generated at the interface during the sliding contact is available for the evaluation of the contact condition

4.CONCLUSIONS

The possibility of the thermoelectric potential for self-diagnosis in sliding contact was evaluated by compare with in-situ observation. Following is the summary of the results.

1. The sensitivity of the thermoelectric potential is greater than that of the infrared rays.
2. Thermoelectric potential generated at the interface during the sliding contact can be used to evaluate the contact conditions.

References

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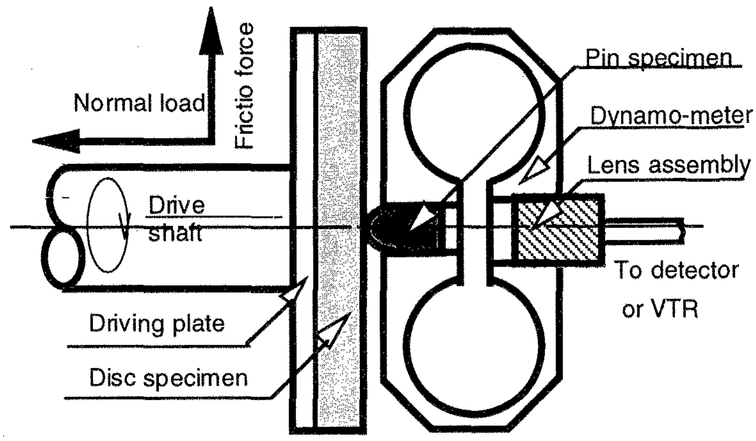

Fig. 1 Schematic of Testing Apparatus

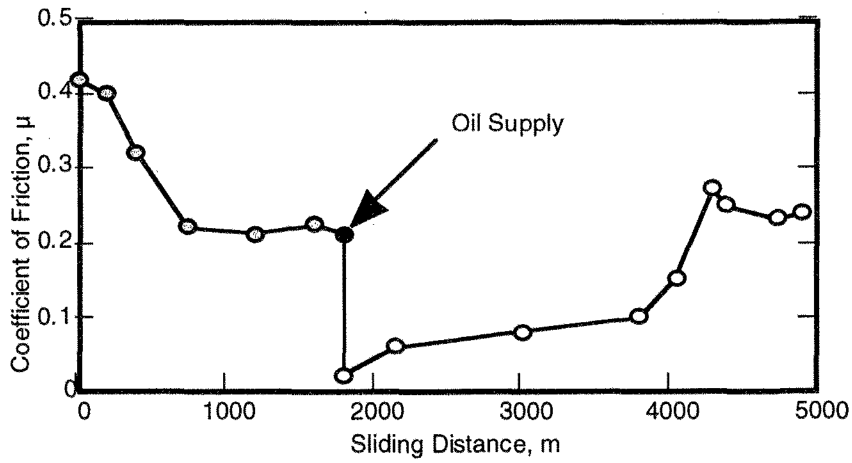

Fig. 2 Coefficient of Friction as a Function of Sliding Distance(19.6 N, 9m/s)

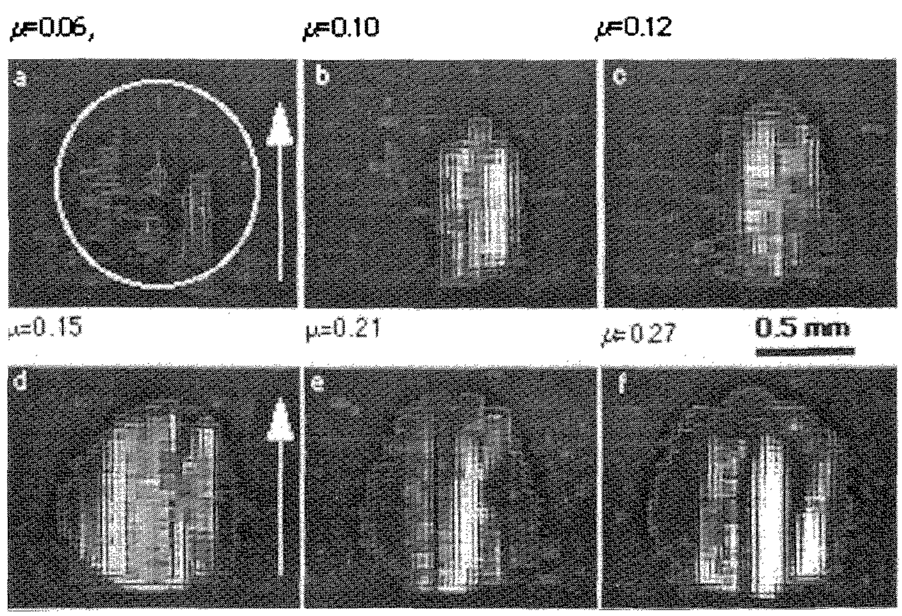

Fig. 3 In-situ Observation of Contact Conditions (19.6 N, 9 m/s)

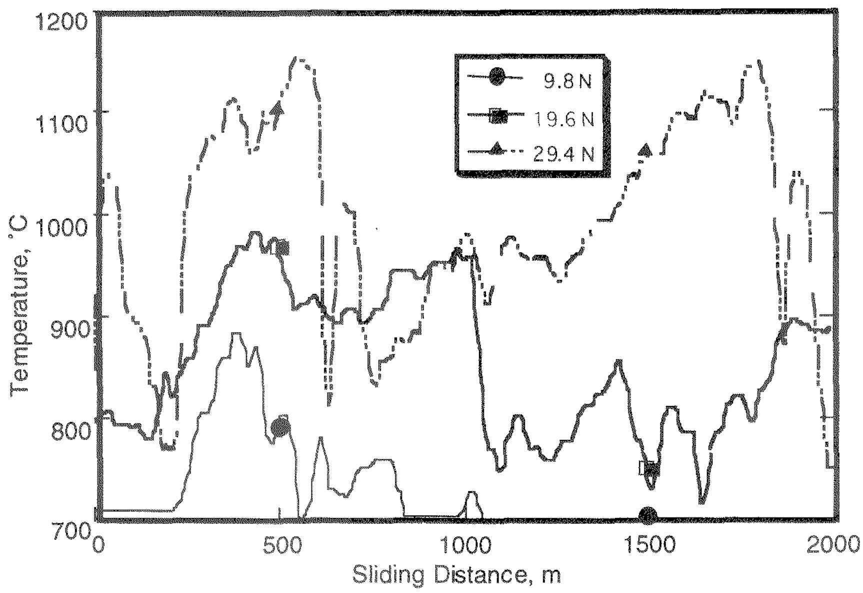

Fig. 4 Surface Temperature by Infrared Detector (14 m/s)

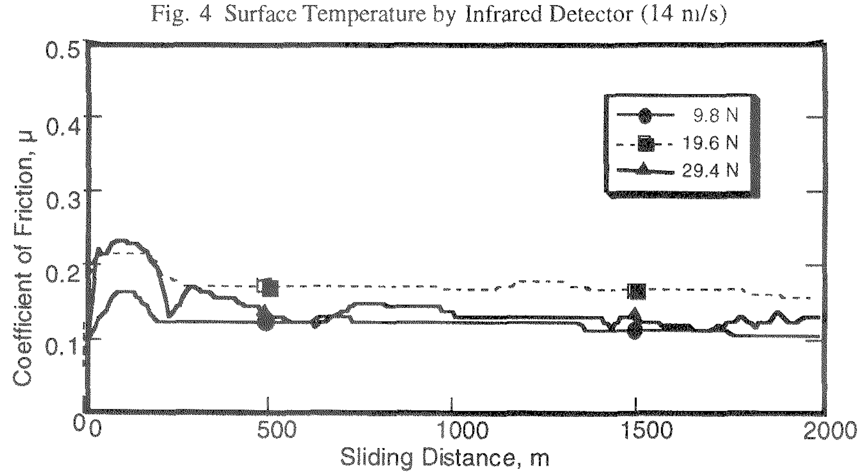

Fig. 5 Coefficinet of Friction in Dry Condition (14 m/s)

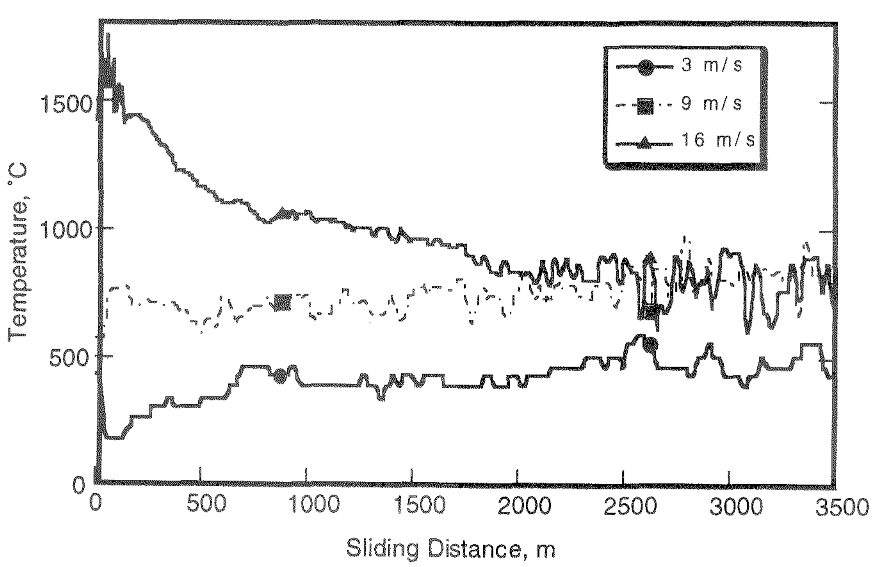

Fig. 6 Surface Tempreature by Thermoelectric Potential (49 N)