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Effect of trace moisture content on low friction mechanism of carbon fiber filled PTFE

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ABSTRACT – Effects of the moisture content in high purity gas on friction characteristics of carbon fiber filled PTFE was investigated by pin-on-disc tests. Results showed that the coefficient of friction responds sensitively to changes in the moisture content. Analyses of transfer films by Raman spectroscopy showed that carbon film became thin and homogeneous when the water content was small, and it was confirmed that the carbon film became thick and inhomogeneous when the moisture content is large. It is suggested that the carbon film on the surface was activated by moisture in the atmosphere.

1. INTRODUCTION

PTFE has self-lubricating property. Its composite materials are widely used as sealings. It was previously reported that the carbon film self-forms and exhibits low friction when friction test was carried out using PTFE filled with carbon fibers and metal [1]. Besides, Friction characteristics are affected by atmospheric gas and moisture content [2]. However, it is not clear the mechanism of self-forming carbon film. If we can clarify the process of carbon film formation, we will be able to obtain additional clues to lower friction. This study aimed to explore the process of PTFE filled with carbon fibers forming carbon film on the sliding surfaces. We evaluated the effect of moisture content using a pin on disk friction tester, Raman spectroscopic analysis.

2. MATERIAL AND METHOD

Experiments were conducted in high purity hydrogen gas using a pin-on-disk type tribometer installed in an environmental control chamber equipped with a scroll vacuum pump, a turbo molecular vacuum pump and gas filters. In this apparatus, it is possible to perform a sliding test while controlling the moisture content at the ppm level in a high purity gas atmosphere.

PTFE filled with 20 vol. % PAN-based carbon fiber was used for the pin specimen. The steel disk made of SUS440C(JIS). The disk surface was polished to a surface roughness Ra = 0.05μm.

Experimental conditions are shown in Table.1. In this study, experiments were conducted to change the water content during the friction test. After attaching the specimen, the inside of the chamber was evacuated to 5.0×10-4Pa, gas was introduced using a filter, and the moisture content of the hydrogen was set to about 0.7 ppm. After the friction test was started and the friction coefficient became stable, the gas flow path was switched from the gas filter to the humidifier, and the moisture content of the atmosphere was changed to about 60 ppm.

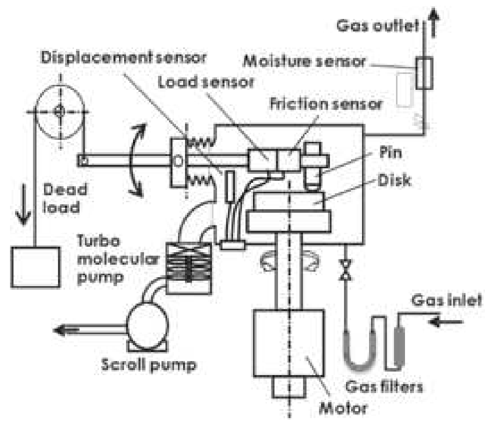


Figure 1 Experimental apparatus.

Table 1 Experimental conditions.

Atmosphere	H2
Contact pressure	1MPa
Sliding speed	2m/s
Sliding distance	40000m
Moisture content	0.7ppm-60ppm
Sliding distance	40000m

3. RESULTS AND DISCUSSION

Figure 2 shows the friction test results. After the start of the friction test, the coefficient of friction sharply decreased, showing stable low friction of about 0.043 after 3000m. After increasing the moisture content of the surrounding atmosphere, the coefficient of friction also increased sharply almost at the same time. After passing 1000 m, introduction of humidified hydrogen was stopped, but the friction coefficient remained high.

In order to consider the factors that show such friction behavior, the test under the same conditions was repeated. Comparison was made using a microscopic Raman spectroscopic analyser on a specimen at 10000 times point showing low friction and a specimen immediately after increasing moisture content. Fig.3

shows images of optical microscope. It was confirmed that a carbon film was formed on the pin and the disk surface. On the pin surface, it was confirmed that the carbon film was uniformly formed when the moisture content was small, whereas the formation of the carbon film was inhomogeneous by increasing the water content.

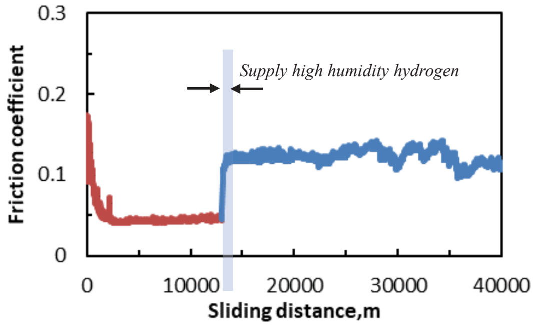
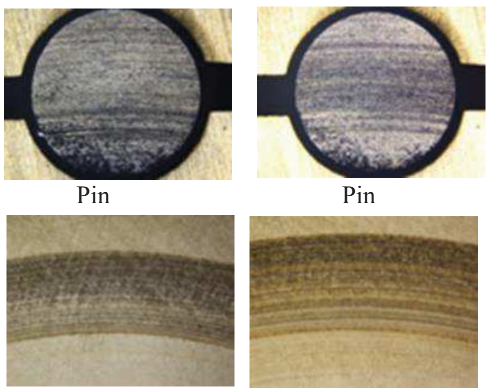


Figure 2 Friction coefficient with sliding distance.



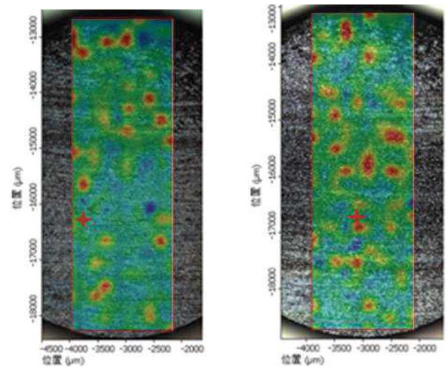
Pin Pin

Disk Disk

(a) (b)

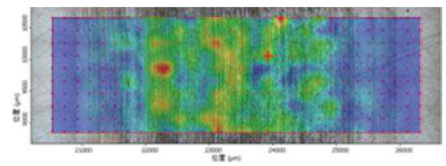
Figure 3 Pin and disk surface; (a) Low humidity (0.7ppm), (b) High humidity (60ppm).

Next, in order to investigate the formation of the carbon film on the pin and disk surface, mapping evaluation by Raman was carried out. Lattice points were set in arbitrary areas on both surfaces. From the Raman spectrum obtained from each point, the area intensity of the signal derived from carbon at 1800cm-1-900cm-1 was calculated and mapped as an index of carbon content. It was confirmed that in the pins, the total carbon content increased and the region showing a strong peak also increased in the high moisture content. From these facts, in the case where the amount of water is small, a more uniform carbon film was formed and stable low friction was shown. On the other hand, as the water content increased, the surface of the carbon film was activated, and more carbon films were formed, causing agglomeration of carbon. It is conceivable that the coefficient of friction increased due to cohesion between carbons. It is also thought that the behavior showed unstable behavior due to irregular detachment of agglomerated carbon. Moreover, no clear difference was confirmed on the disk. It is considered that it is because only a part of the transfer film of the disk was evaluated, so it is necessary to increase the number of measurement points more.

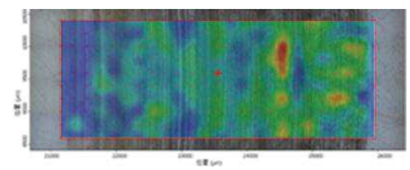


(a) (b)

Figure 4 Raman mapping of carbon in pin surface; (a) Low humidity (0.7ppm), (b) High humidity (60ppm).



(a)



(b)

Figure 5 Raman mapping of carbon in disk surface; (a) Low humidity (0.7ppm), (b) High humidity (60ppm).

4. SUMMARY

We investigated the influence of the change in the moisture content in the hydrogen atmosphere on the friction characteristics of carbon fiber filled PTFE. As a result, when the moisture content in the gas was small, it showed a low and stable coefficient of friction, and as the moisture content increased, the friction coefficient rapidly increased. There is a difference in the amount and shape of the carbon film formed on the surface depending on the amount of moisture, which suggests that this affects the difference in friction coefficient. In the future, in order to analyse the mechanism more in detail about the difference in the formation of carbon film due to the difference in moisture content, it is necessary to analyse using XPS or FT-IR.

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