Effects of Lubricant Oil on Sliding Contact Phenomena in Carbon Brush-Slip Ring System

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***Abstract*— Sliding contact systems are widely used as a method of exchanging electrical power and/or signal between static and moving components. Considerable challenges remain regarding the need for improving the service life and reliability of these systems. The sliding characteristics of C-brushes and Cu-rings have been thoroughly investigated; however, lubricated C-brush and Cu- sliding contact systems have received comparatively little attention. In this work lubricants are shown to influence contact resistance of slip ring-brush system.**

I. INTRODUCTION

Sliding contact systems are widely used to exchange electrical power between static and moving components. Slip ring system using C-brush is used for example transfer of power of collector ring in a thermal power plant and Nasser in wind power generation to ground segment. It remains necessary to improve the service life and reliability of these systems. We are interested in lubricant oil to reduced wear by adding to the C-brush and achieved improve service life and reliability. The sliding characteristics of C-brushes and Cu-rings have been thoroughly investigated; however, lubricated C-brush and Cu-ring sliding contact systems have received comparatively little attention. The present study examines the effects of lubricant oils on sliding contact phenomena in a carbon brush-slip ring system.

The study further examines the effect of lubricating oil on the contact state. The contact voltage drop at a constant current (0A to 10A) was studied.

A. Classification of brushes

Brushes used in common direct current machines and applications requiring large mechanical strength are produced mainly from coke-based materials. For low-voltage generators and motors, metalized graphite brushes or coke-based brushes are often used. For slip rings used in induction motors that carry alternate currents, highly metalized graphite brushes are used. Natural graphite brushes are the main type of brush used for collector rings such as those of synchronous generators that carry direct current

B. Lubricant

Lubricants, such as engine oil, machine oil, and insulating oil, are used to facilitate sliding between rings and brushes in electrical contact. Lubricants prevent seizure, wear, rust, and corrosion by reducing friction loss and improving cooling, stress dispersion, washing, and sealing [2].

In general, lubricants are combinations of base oil and additives, with an exact composition varying according to the intended use. Commonly used base oils are mineral oils purified from crude oil during the production of petrochemicals. For certain applications synthetic oils are used [3][4].

II. TEST EQUIPMENT

Fig. 1 shows the experimental circuit used in the present study, while Fig. 2 shows photographs of the Cu-slip ring and C-brush. The contact voltage drop between the ring and brush was measured by the measurement brush. Current is supplied from a stabilized DC power source. The contact voltage drop Vc was record by pen recorder and digital multimeters. Fig. 3 shows photograph of experimental contact.

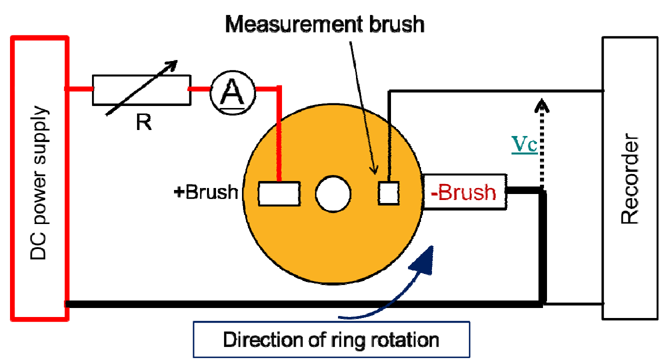

Fig. 1. Experimental circuit

Fig. 2. Cu-ring and C-brush

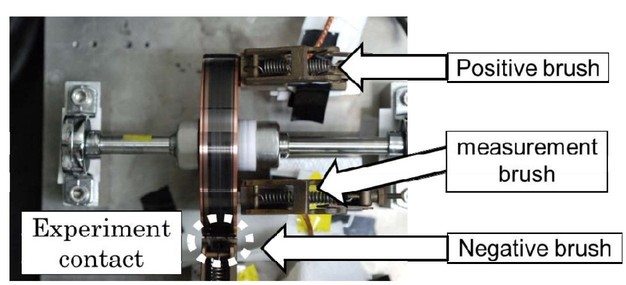

Fig. 3. Experiment contact

Table 1 gives the experimental conditions. In the experiment, we use 4 types of surface conditioning: 1) after polishing, 2) no-lubricant oil, 3) conductivity oil and 4) ester oil. Conductivity oil uses to recover conductivity in stationary contact. Ester oil is used for mechanical lubrication oil. In addition, experiments were carried out in stationary contact and sliding contact state [5].

TABLE I. EXPERIMENTAL CONDITIONS

Surface condition	After polishing, No-lubricant oil, Conductivity oil, Ester oil
Current	CC 0A ～10A
Brush	
Material	Natural graphite
Surface roughness	#600
Force	2.35N
Ring	
Material	Tough-Pitch Copper
Surface roughness	#600
Rotation speed	Static(0 min^{-1}), Sliding(500 min^{-1})
Temperature	Laboratory (22～24℃)
Humidity	Laboratory (60～75%)
Oil amount	0.3mg

Fig. 4 shows the experiment flow diagram. The V-I characteristic test was carried out at the following timing, just after polishing ring and brush, after pre-sliding (No-lubricant oil condition) and after 5-hour-sliding (conductivity oil or ester oil conditions).

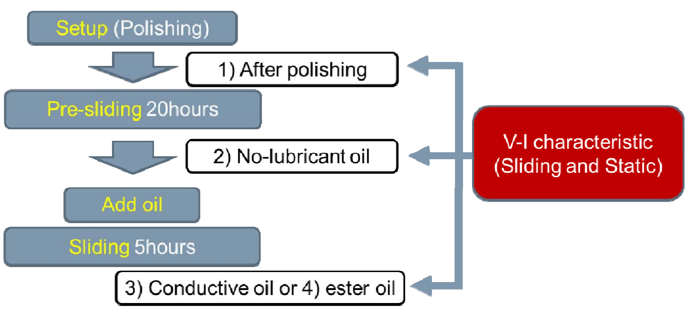

Fig. 4. Experiment flow diagram

Fig. 5 shows electric current timing chart in the experiment. The electric current value change→2 minute waiting →current value change is repeated. The current value is changed by the order of
0→0.1→0.5→2→4→6→8→10→8→6→4→2→0.5→0.1→0
and repeated 3 times.

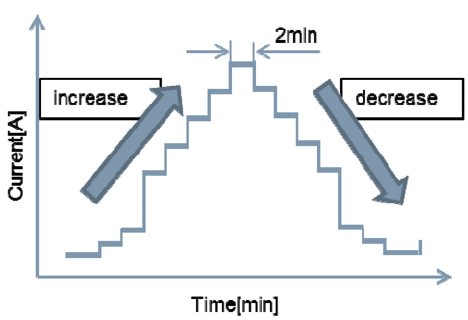

Fig. 5. Current timing chart

III. Experimental Results

The value of following chart is average of 3 times tests. Solid line and dotted line show the contact voltage drop when increasing current and decreasing current.

A. Surface of ring and brush

Fig. 6 shows the picture of ring and brush surface before experiment of V-I characteristic. Figure 7 to 9 show the picture of ring and brush surface after experiment. Brush surface pictures of conductivity oil and ester oil conditions removes oil and take picture. In the case of after polishing, film is not existed on the ring, and mild surface of the brush. In case of no-lubricant oil condition, it can be seen film of graphite and the brush surface became rough. In case of conductivity and ester oil condition, it can be seen the liquid that graphite and oil mixed is stacked in the surface of ring. There are no great differences compared with no-lubricant oil condition in the surface of brush.

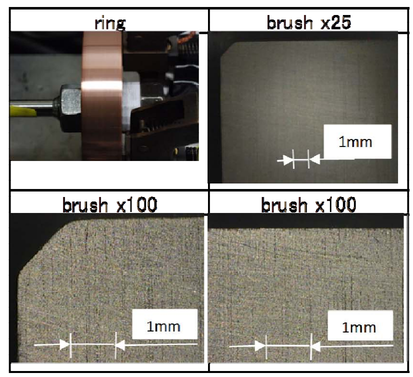

Fig. 6. Surface of ring and brush after polishing

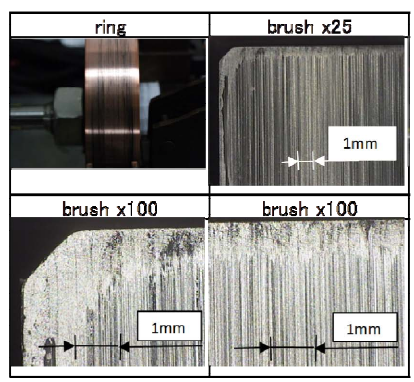

Fig. 7. Surface of ring and brush no-lubricant oi after testl

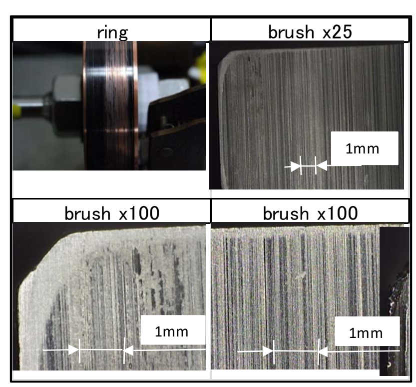

Fig. 8. Surface of ring and brush conductivity oil after test

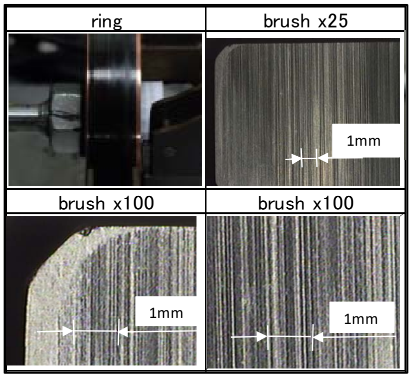

Fig. 9. Surface of ring and brush ester oil after test

B. Relationship between contact voltage drop and current under sliding state

Fig. 10 shows the relationship between contact voltage drop and current under a sliding state. The contact voltage drop was linear for the most part by the condition of after polishing. The condition of no-lubricant oil gave the result which indicates voltage-saturation characteristic and a hysteresis. In conductivity oil condition, hysteresis goes off and becomes linear (0.5A~10A). In ester oil condition, voltage-saturation characteristic becomes conspicuous and contact voltage decreases linearly in decreasing direction.

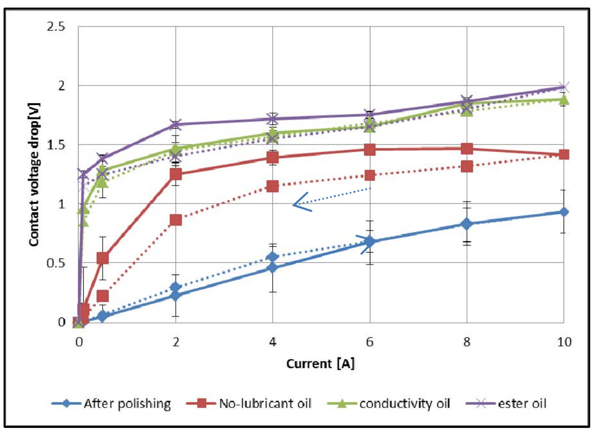

Fig. 10. Relationship between contact voltage drop and current under sliding state

C. Relationship between contact resistence and current under sliding state

Fig. 11 shows the relationship between contact resistance and current under sliding state. In case of the conductivity oil and ester oil conditions, the contact resistance is especially higher than no-lubricant oil condition at low electrical current (0.1A~2A). In case of the no-lubricant oil condition, the contact resistance in increasing current direction (0.1A to 10A) isn't linear, but in decreasing direction (10A to 0.1A) is linear. In case of after polishing condition, the contact resistance is linear in both direction.

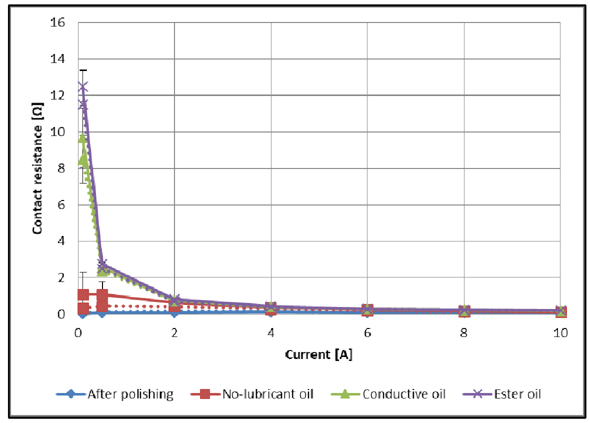

Fig. 11. Relationship between contact resistence and current under sliding state

D. Relationship between contact voltage drop and current under stationary state

Fig. 12 shows relationship between contact voltage drop and current under stationary state. In case of no-lubricant oil condition, indicated a hysteresis and the highest contact voltage drop. It assumes that oxide film was generated, because "No lubricant oil condition" characteristics is data of after sliding for 20 hours. In the case of conductivity oil condition, the contact resistance shows hysteresis that is linear and decreases at the time of electric current decrease. In case of ester oil condition, the contact resistance shows a hysteresis as well as voltage-saturation characteristic becomes conspicuous. Overall, contact resistance decreased linearly at the time of electric current decrease.

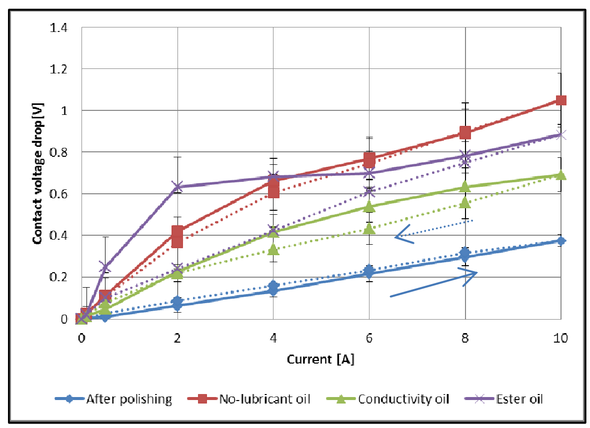

Fig. 12. Relationship between contact voltage drop and current under stationary state

E. Relationship between contact resistance and current under stationary state

Fig. 13 shows relationship between contact resistance and current under stationary state. In case of after polishing, the contact resistance is almost constant. In case of conductivity oil condition, the contact resistance becomes lower than no-lubricant oil condition. In case of ester oil condition, the contact resistance when decreasing current is low, compared with increase current.

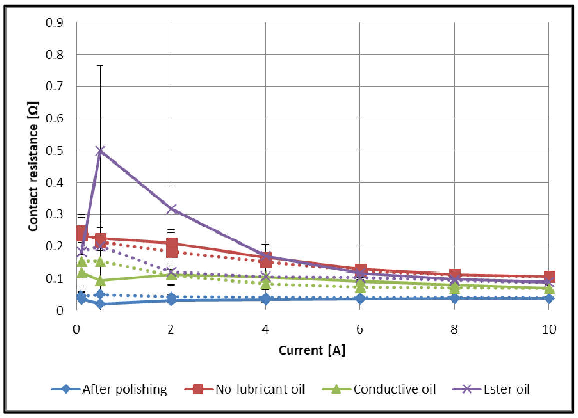

Fig. 13. Relationship between contact resistance and current under stationary state

IV. Discussion

A. Surface of ring and brush

The surface state doesn't change at before experiment and after experiment under no-lubricant oil, conductivity oil, ester oil conditions. In after polishing condition, thin carbon film remains stuck on the ring surface after experiment.

B. Voltage-saturation characteristic

Surface film generation (graphite, oil and graphite) and sliding action are regarded as the factor which brings voltage-saturation characteristic from a result.

1) Voltage-saturation characteristic by sliding

Comparing no-lubricant oil results between sliding and stationary conditions (Fig. 10, Fig. 12), it can be seen that voltage-saturation characteristic becomes stronger by sliding. It is assume that caused by moving a-spot or decrease of a-spot by surface oxide.

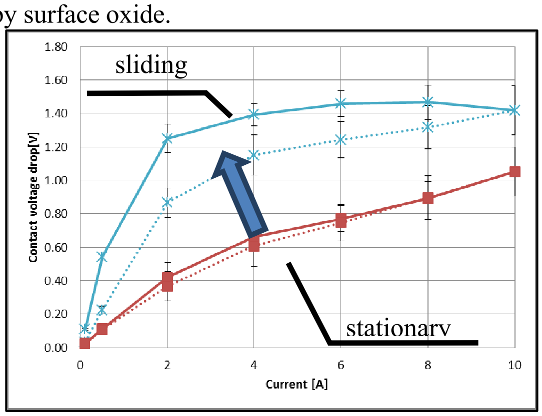

Fig. 14. Comparing no-lubricant oil under sliding and stationary states

2) Voltage-saturation characteristic by film

Comparison of after polishing and other 3 types of conditions at stationary state (Fig. 12). It can be seen, voltage-characteristic has been caused by a film of graphite or mixture of graphite and oil. It is assume that caused by semiconductivity with surface film or decrease of a-spot by surface oxide.

C. Hysteresis

1) In case of a stationary contact

Electric heat occurred by lacking of a-spot for current density by film (oil and graphite). Contact voltage drop increases immediately after electric current change. After that it's decreasing gradually. To become a constriction resistance [1] in decreasing direction (10A~0A) by a-spot formed in increasing direction (0A~10A), it becomes near an ohm.

2) In case of a sliding contact

It is assume that the hysteresis of contact voltage drop under sliding state caused by contact temperature that generated with current and friction.

D. Spike on ester oil condition at 0.5A under stationary state

Fig. 15 shows results of contact resistance under Ester oil condition. Peaks decreased according to the number of times, it assume that peak occurred by a thermal factor. The special quality is different from before 0.1A and after 0.5 A. The point of contact temperature, the friction coefficient and the wear amount need future's investigation because it's lacking in data by this stage.

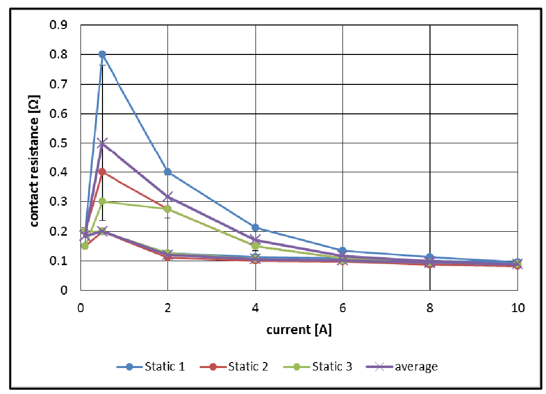

Fig. 15. Results of contact resistance under Ester oil condition

V. Conclusions

Lubricating oils influence contact resistance of slip ring-brush systems.

Consequently the followings can be made clear.

(1) Oil is making voltage-saturation characteristic occur as a film.

(2) Oil has an influence on the V-I characteristic and hysteresis.

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