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Lubrication of Space Systems by Tribo-coating

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It is a time to introduce a new concept of lubrication to space systems. Minimum amount of lubricant should be supplied to a contact interface instead of preparing too much lubricant on surfaces on the earth. In situ controllable lubrication method is wanted to overcome unexpected tribo-troubles in space.

Tribo-coating, which forms a thin solid film in nm-scale by vacuum deposition during friction, is a promising lubrication method for space.

Keywords : Solid lubrication, Tribo-coating, Vacuum, Space

1. INTRODUCTION

For the future of human being, space technology has an important role and lubrication technology of space systems is one of the most important key technologies for the reliability and long life of the systems.

Present major methods of lubrication in space systems are solid lubrication and grease lubrication. Especially for severe contact conditions of high temperature and high load, solid lubrication is generally used.

In the present solid lubrication, solid lubricants such as Pb, In, Ag, Au, and MoS_2 are pre-coated on the earth by a certain ammount thickness. Therefore, the life of a present space system is determined by the wear life of a coating of a lubricant.

In this state of lubrication technology for space systems, a new lubrication method shortly called "Tribo-coating" is introduced in this paper. It is a lubrication method which supplies a solid lubricant during friction from a heat source to the contact interface by short-time evaporation and deposition in vacuum.

This method was first proposed in 1990 [1] and has been developed in the past 12 years, and has been tested in the international space station in the past one year.

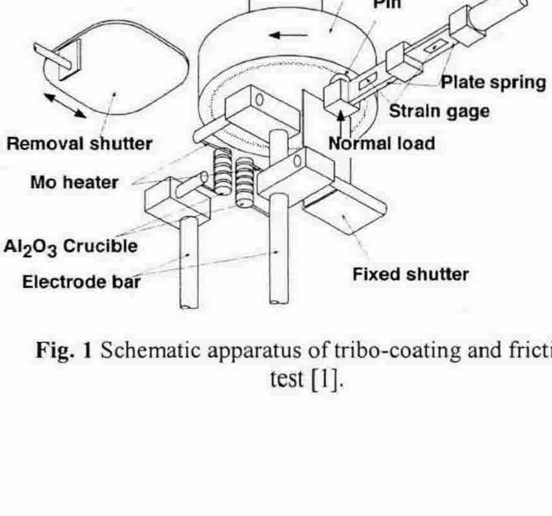

Fig. 1 Schematic apparatus of tribo-coating and friction test [1].

2. EXPERIMENTAL APPARATUS AND PROCEDURE

Fig. 1 shows the principle of this lubrication method, where a solid lubricant is evaporated from a crucible by heating in vacuum and is deposited on the friction surface of a rotary disk which is rubbed by a pin during deposition.

Deposition rate of a lubricant is varied within 200 nm/min and deposition time is varied within a few minutes.

Pin is made of Si3N4 (HIP) and disk of stainless steel (SUS 440C), which is selected as the best material combination. Indium (In) is selected as the best solid lubricant in this study. After cleaning specimens by acetone and ethanol, they are incorporated into the apparatus and the system is evacuated up to the vacuum of 10-6 Pa. Tribo-assisted coating is started together with the start of sliding friction.

3. EXPERIMENTAL RESULTS

3.1. Comparisons of different coatings

In Fig. 2 In-film of about 100 nm thickness by tribo-coating was formed in the starting period of friction cycle, which shows lowest friction and longest life among four kinds of coatings.

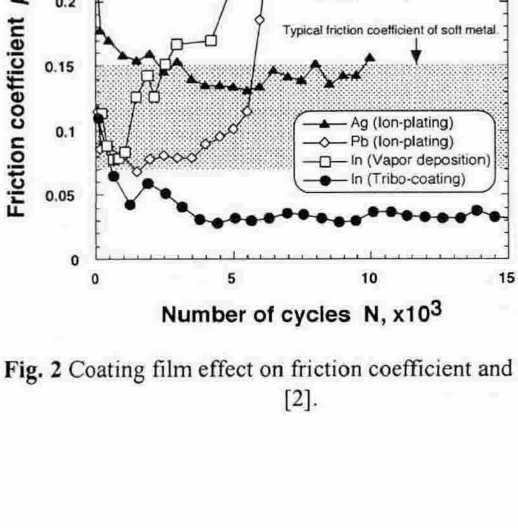

Fig. 2 Coating film effect on friction coefficient and film life [2].

3.2. Effect of repeated tribo-coating

In Fig. 3 friction coefficient is reduced from about 0.065 to about 0.04 by the second tribo-coating and to about 0.029 by the third tribo-coating. Film life per each cycle becomes longer by the repetition of tribo-coating.

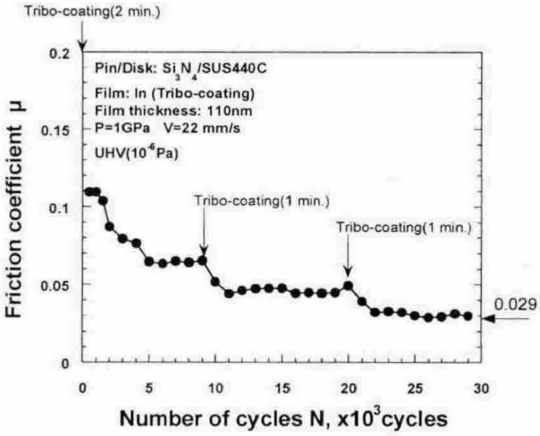

Fig. 3 Reduction of friction by repeated tribo-coating [3].

3.3. Effect of surface roughness on friction coefficient and film life

Fig. 4 shows that, at the initial surface roughness of Rmax = 0.02 μm, friction coefficient $\mu \approx 0.02$ and film life Nc $\approx 4x10^5$ ycles are generated.

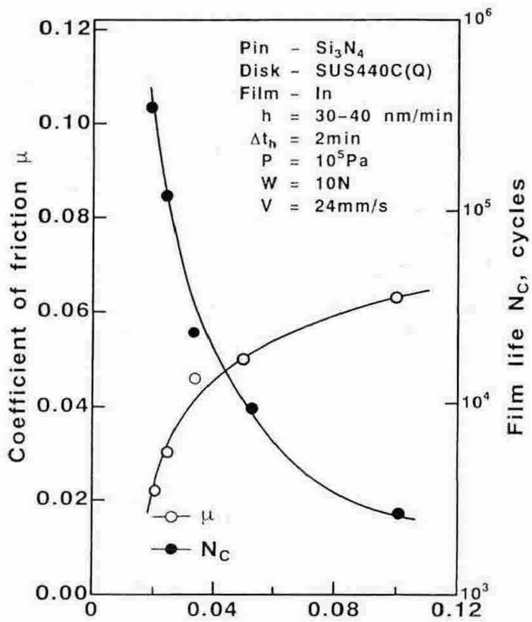

Fig. 4 Friction coefficient and film life by one-time tribo-coating in relation to initial surface roughness of disk [4].

3.4. Effect of tribo-coating on rolling friction of a ball bearing

In the apparatus shown in Fig. 1, pin-on-disk specimens were replaced by a ball bearing and tribo-coating of In was made on the bearing. Fig. 5 shows that repeated tribo-coating can reduce friction in the similar way as shown in Fig. 3, and the observed value of friction coefficient at around 0.002 is much less than that of conventional bearings of solid lubrication for space. Fig. 6 shows the life of In-film of 150 nm thickness formed by one time tribo-coating at the start of rolling in relation to rotational speed.

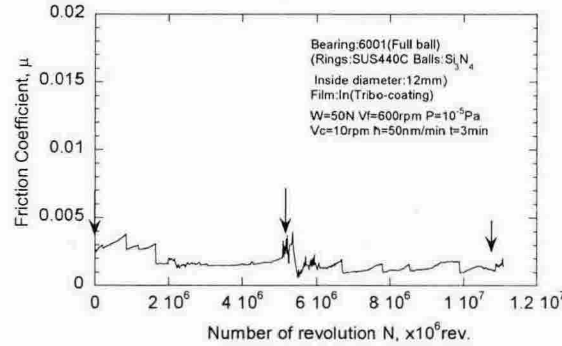

Fig. 5 Reduction of rolling friction of a ball bearing by repeated tribo-coating [5].

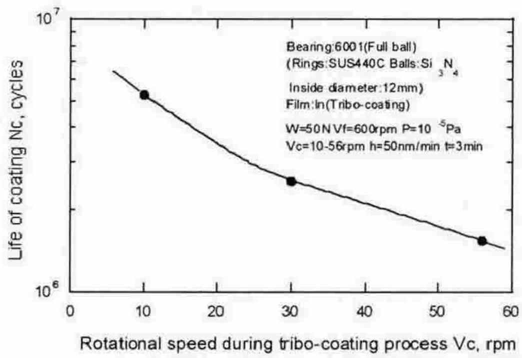

Fig. 6 Life of In-film on a ball bearing formed by one-time tribo-coating in relation to rotational speed [5].

4. CONCLUSION

Solid lubrication by tribo-coating, which deposits a solid lubricant film by evaporation to the contact interface during friction in vacuum, is practically useful for the space systems. Minimum amount of solid lubricant formed by tribo-assisted coating is enough to generate low friction and long life.

5. REFERENCES

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