

## PERFORMANCE OF THE ANTIWEAR ADDITIVES UNDER LUBRICANT IMMERSION CONDITION IN VACUUM

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### KEYWORDS

*Space tribology; Lubricant additives; Wear; Lunar surface exploration*

### ABSTRACT

In future space missions such as the Artemis Program, a manned lunar development, conventional lubrication methods of applying multi-alkylated cyclopentane (MAC) and perfluoro polyether (PFPE) are not enough antiwear performance. In this study, a new lubrication method which uses oil containing antiwear additives under oil immersion conditions will be realized. Since antiwear function of additives is reported to be involved by the oxygen or moisture in air<sup>1)</sup>, it is necessary to understand the function of them in vacuum, but there is little report about it and no report under immersion condition.

Therefore, to define the chemical design of lubricants for spacecraft, the function of antiwear additives was evaluated in vacuum such as the anti-evaporation and antiwear properties under oil immersion condition. Moreover, the tribochemical phenomenon in vacuum was revealed by the chemical surface analyses of the wear tracks.

Nine antiwear additives were prepared as P-type, S-type and SP-type additives having phosphorus, sulfur and both. Each additive was dissolved in poly- $\alpha$ -olefin (PAO) at 0.1 mass%P or 0.1 mass%S. For the outgas evaluation, a petri dish with about 1 g of additives was placed in a chamber and vacuumed to  $10^{-4}$  Pa for 4 hours at 80 °C. Then, reduction of mass after the test were measured. The ball-on-disk tests were carried out under oil immersion condition under air or vacuum as  $10^{-4}$  Pa and at 80 °C. Sliding speed and maximum contact pressure were 0.5 m/s and about 1.3 GPa. Specimen were made of stainless steel 440C. After the tests, the chemical composition on the wear tracks was analyzed by the electron probe micro analyzer (EPMA).

The results of antiwear and anti-evaporation properties are shown in Fig. 1. The antiwear performance reduced in the case of almost all additives regardless of additives evaporation. But some additives such as DEHP, OP and TASP were hardly evaporated and their antiwear performance were kept in vacuum, which means they are promising additives for space use.

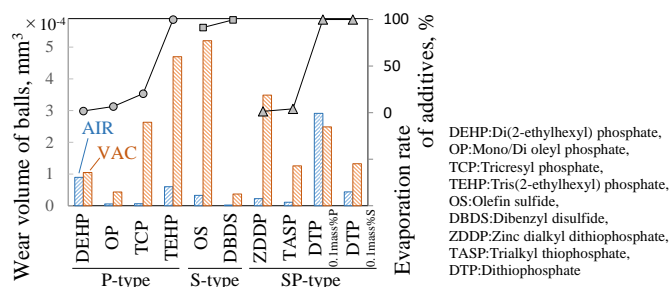


Fig. 1 Wear volume of balls and evaporation rate of additives.

On the other hand, some additives such as TCP and ZDDP were hardly evaporated but their antiwear performance reduced in vacuum. It caused by decrease of their tribofilm formation which were confirmed by the EPMA analyses. It seemed to be caused by the lack of atmospheric composition needed to form tribofilms.

Some additives such as DBDS and DTP were almost all evaporated but their antiwear performance were kept even in vacuum. Their reactivities presumably became higher in vacuum. Especially, S-type and SP-type additives seemed to be easily decomposed due to the lower binding energy when sulfur is included. In addition, increase of exposure of the fresh surface presumably contributed to the high reactivities in vacuum because it easily reacts with sulfur additives considered by the Hard and Soft Acid and Base principle.

Performance of antiwear additives having phosphorus and/or sulfur were evaluated in vacuum. Some additives were confirmed as promising candidates for space use. Antiwear performance and tribofilm formation in vacuum were considered to be affected by the evaporation characteristics and the reactivities of additives against steel surface.

### ACKNOWLEDGMENTS

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### REFERENCES

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