WED-T9-S7-R1

7th World Tribology Congress, WTC 2022
July 10-15, 2022, Lyon, France

Tribological Properties of Lubricants for Gearbox of Human Pressurized Lunar Rover

YOKOYAMA Takashi*[1)], MATSUMOTO Koji[1)], KENMOCHI Nobuo[1)], SHINYOSHI Takatoshi[2)], SANO Toshinari[2)]
TADA Akira[3)], TAKAHASHI Naoko[4)]

[1)]Japan Aerospace Exploration Agency, Japan [2)] Toyota Motor Corporation, Japan
[3)] ENEOS Corporation, Japan [4)] TOYOTA CENTRAL R&D LABS.,INC., Japan
*Corresponding author: yokoyama.takashi@jaxa.jp

In the development of a gearbox of the human pressurized lunar rover, lubrication technology in a vacuum environment is one of the important issues. In order to achieve long-life, new lubricants containing automotive lubricant additives to a low-vapor-pressure lubricant base oil used for space environment was evaluated. This paper will report the friction and wear properties in a vacuum at high temperature, and usefulness of the oil.

Keywords: space lubricants, lubricant additives, human lunar exploration

1. Introduction

Many countries are planning to explore the Moon. In Japan, feasibility study of a human pressurized rover, shown in figure 1, is underway. It is planned to have the capability to travel 10,000 km on the lunar surface.
Since the Lunar rover has a gearbox to reduce the rotation speed of the motor, the lubrication of the gearbox in the ultra-high vacuum environment on the lunar surface is one of important issues. The Lunar rover gearbox will be lubricated with large quantity of oil mixed with various additives, just like vehicles on the ground, which has never been applied in space.
In this study, the feasibility of lubricants containing automotive lubricant additives in a vacuum environment was validated if they could work effectively.
In this paper, the results of outgas evaluation and friction and wear properties in a vacuum condition with a lubricant base oil for space and automotive lubricant additives are reported.

Figure 1: Imaginary drawing of the human pressurized rover.

2. Sample oils

Three types of sample oils, as shown in table 1, were evaluated. Sample oil A is MAC, Multi-alkylated Cyclopentane, which is commonly used as a space lubricant because of its low vapor pressure. Sample oil B is MAC base oil with various additives used for automatic transmission lubricant, and sample oil C is a general automotive lubricant consisted of the same additives as oil B and PAO as the base oil.

3. Experiment

Outgassing and tribological properties of sample oils were evaluated. For the outgas evaluation, a container with about 10 g of sample oil was placed in a vacuum chamber and vacuumed to 10^{-4} Pa for 4 hours.

Table 1: Sample oils

Sample oil A	MAC only
Sample oil B	MAC + additives
Sample oil C	PAO + additives

Then, reduction of mass before and after the test and change of degree of vacuum were measured.
Sliding tests by ball-on-disk friction tester were carried out under oil-coated condition to obtain friction coefficient and wear volume under air, vacuum and under room temperature and high temperature. Sliding speed and contact pressure were 0.5 m/s and about 0.9 GPa. Ball specimen was made of bearing steel ASTM 52100 and disk were made of stainless steel 440C and chromium molybdenum steel AISI 4130.

4. Results and Discussion

4.1 Outgas evaluation

Reduction of mass measured before and after tests showed that oils B and C containing additives were ten times more volatile than oil A. It was inferred that the additives component was more volatilize than base oil.

4.2 Friction and wear properties
The friction coefficients were the same at 0.1 for all oil, for both atmosphere, and for both temperature conditions. Wear volume are shown in figure 2. Despite volatilization of additives, the anti-wear performance of additives was observed. Balls after tests under each condition are shown in figure 3. It seems difference in tribofilm formation depending on conditions.

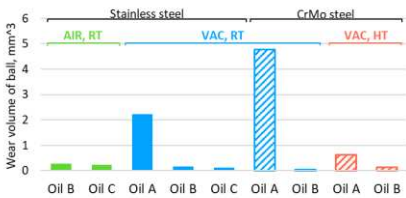

Figure 2: Wear volume of ball under each condition.

Figure 3: ASTM52100 balls after tests.