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The effects of solid lubricants for space vehicle under the 10^{-7} torr ultra-high vacuum

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ABSTRACT – In a space environment vehicle components as bearings, seals and gears use solid lubrication to have high wear resistance on their mission duration. Because conventional lubrication has not good performances in wide temperature range and can be evaporation at the rarely ambient condition like lunar surface. This work provides tribological discussion about the component and requirement of space tribology. Also Pin-on-disk test is described to determine the effect on the solid lubrication under the high vacuum condition (about 10^{-7} torr). This paper will discuss the following: space mechanism components, solid lubrication, and factors affecting wear phenomenon under the high vacuum.

1. INTRODUCTION

Space robots are indispensable tools for future space activities such as building and operation of the international space station, inspection and repair of orbiting satellites, and conducting lunar or planetary explorations [1,2]. The space robot will experience the complex space environment such as high vacuum, gravitational field, extreme temperature condition, solar radiation and dust [3]. The executive components of the robot often suffer from friction, wear. Therefore, the reliabilities of the executive components of the robot are very important for successful mission.

Moreover, the challenges for future space robot appear to be even greater because missions are being planned that will require mechanisms to more complex and for longer periods of time. In the early of the space program, the required life time and cycle of space machine was minimized. It was usually possible to achieve successful mission. As increasing the mission life time, the other components of space machine breaks down. Thus, in the last years, lots of research has been considerably improved.

This work aims to develop the space tribo-component which used include the dynamic mechanic part of the Korean Lunar Rover. The space tribo-component will be employed to dynamic factors during required mission time on the actual lunar surface. In this paper describe about spur gear train in the rover and that solid lubrication.

2. DESCRIPTION OF SPACE TRIBOLOGY

2.1 Lubrication of the space dynamics mechanism

Space mechanism lubricant choices were based on space heritage rather than on latest technology or best available materials. With the limited mission lives and minimal duty cycles of the early space program, this strategy was highly successful.

It represents a SEM results on the Figure 1. This SEM analysis shows that are not coated with any material as in ⓒ. It also shows the layers which are confirmed that the Ni and Cu coating layers (indicate to ⓑ) on the upper and lower layers and also observed Ag(silver) coating layer (indicate to ⓐ) is applied. As the element analysis results, the materials to be coated were well coated in the proper layer.

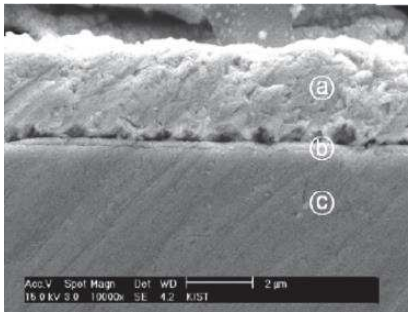

Figure 1 SEM analysis on the silver coating substrate.

2.2 Tribology and Dynamics of Gear

Space robot systems contain mechanisms requiring lubrication. As demanding operating conditions, each mechanics endure many challenges to success mission. Especially, all of dynamic mechanisms such as wheels, slip-ring assemblies, scanning devise, robotic arms, bearings and gear trains is component requiring lubrication.

While the space vehicle is doing mission, which problem makes a failure mission? Specially, in the gear train. It may be a lot of problem with detecting or not expectation. However, for some research already were be conducted, it can be predict of gear failure on typical problems.

Already as mentioned, one of important cautions, it easily changes friction character is a contact stress between friction materials. Therefore, it needs estimate of gear dynamics on the effect of solid lubrication while experiment in the vacuum chamber. Before experiment, calculate to gear contact stress each normal load on the pinion.

2.3 Gear train test under the ultra-high vacuum

This space tribo-component test rig can experiement dynamics of gear, bearing in the high vacuum chamber. It can measurement rotating speed of

pinion, torque and displacement between the gear train while real-time.

The width of both gear is 8 mm and the gears are standard module 1 gear train in this study. Actually, this test rig is preliminary one for proving measurement system in a real-time. The environment condition in the chamber has ultra-high vacuum as 10^{-7} torr. Therefore, in this chamber, it is possible to prove the effect of the solid lubrication in the high vacuum.

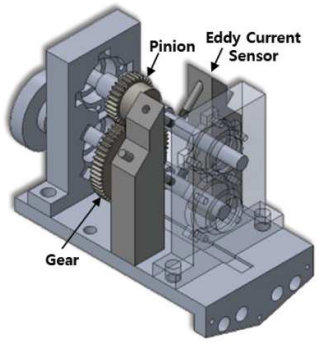

Figure 2 Space Tribo-component Test rig.

2.4 Gear test results

Compare with difference speeds, 80 and 180 rpm, Backlash variation is possible to ignore according to result of speed variation. However, for this experiment, measurement error compare with ideal backlash. Thus, this measurement system can get more specific prediction for gear power loss while space rover doing missions in a real-time.

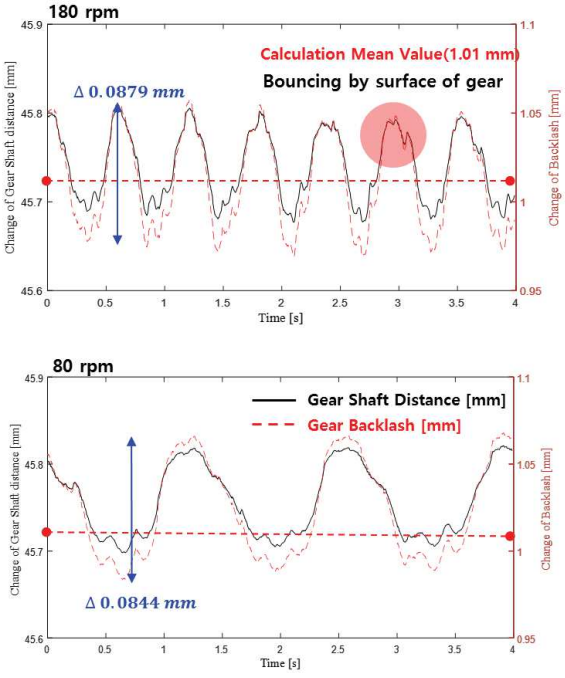

Figure 3 The test results of gear coated silver film.

2.5 Pin-on-disk test

A Pin-on-Disk test is defined for documents of ASTM standards, ASTM G99-95a. The guide is clearly mention, the guidelines of test method are typical recommendation, not required.

Why need a wear test like a pin-on-disk test is for importance of know what is the friction coefficient on the each materials of lubricants and various conditions. Of course, already a lots of research had conducted for a long years. However, the study to adopt on the space environment is not enough. Furthermore, the wear test is extremely sensitive experiment, can be easily change value by normal force and material of the surface. Therefore, for assemble the components on the lunar rover, it need experiment as exactly correspond condition of environment.

2.6 Test rig description

This study conducts to get a curve for wear phenomenon under the high vacuum condition.

In this test rig, it measurement rotating speed of disk material, torque while the pin makes a track on the disk, actually, this torque present friction coefficient of that material of disk and pin. Also, it detects whether the normal load properly hold on the disk from pin.

According to preliminary test, it can be find a friction coefficient on the raw material of disk and pin. This raw material means material of test gear without lubrication. And then, Test again to find on the silver coated disk and pin. The silver coating covers the raw material of disk and pin.

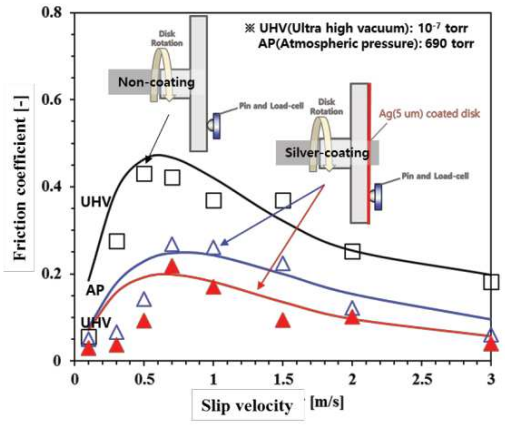

Figure 4 Friction results under the high vacuum.

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