VACUUM TRIBOLOGY TESTING OF ALLOYED MoS_2 FILMS AT VTM MODEL OF TRIBOLAB.

J.I. Oñate [§], M. Brizuela, M. Bausá, A. García – Luis and I. Braceras.
Fundacion INASMET. San Sebastian (SPAIN)

[§] Corresponding address: Fundación INASMET. Mikeletegi Pasealekua, 2. 20009 San Sebastian (SPAIN)
Tel.: + 34 943 003700. Fax: + 34 943 003800. e-mail: ionate@inasmet.es

ABSTRACT

TriboLAB is an experiment on space tribology that will be carried out at the EuTEF module of ESA Columbus Laboratory at the ISS. A Vacuum TriboLAB Model (VTM) has been designed and developed prior to the Flight Model (FM) to serve as a testing equipment and evaluate "on ground" tribological data of selected lubricants, comparing the results with those to be obtained at the environment of the ISS. The VTM of TriboLAB can perform ball bearing and pin-on-disc tests of lubricants. The characteristics and performance of this experimental equipment will be presented in this conference.

This work reports on the performance of these solid lubricant films in the pin-on-disc section of VTM model. Tribological tests have been carried out under vacuum with the VTM using previously developed and tested solid lubricants. Thin films of MoS_2 alloyed with WC and produced by magnetron sputtering PVD have been used for these tests. The wear conditions at the VTM, due to the variation of normal load (5 N +/- 1 N) produced as a consequence of the load application by a pivot flexure, are more severe than conditions previously applied on commercial tribo-testers and as a consequence the durability of these films has been lower.

The friction force measuring system at the VTM is highly sensitive and friction traces have reproduced this situation, however, the results still demonstrate the lubricating performance of the thin film with mean values of about 0.02.

INTRODUCTION

TriboLAB is a scientific instrument to perform space tribology tests at the ISS [1,2]. This instrument will be located at the EuTEF module of the ESA Columbus Laboratory. A vacuum tribological model, hereinafter called VTM, has been designed and developed to generate "on ground" tribological data of selected lubricants and compare these with results that will be obtained at the environment of the ISS. The VTM of TriboLAB can perform both ball bearing and pin-on-disc tests of lubricants. The characteristics and performance of this experimental equipment will be presented in more detail in this conference [3].

Thin films of MoS_2 alloyed with Ti and WC have been previously developed by the authors and have shown excellent vacuum tribology properties and a promising performance during atmospheric testing at various degrees of humidity [4,5]. The results obtained up to date by the authors in commercial tribo-testers compare very favorably with similar metal alloyed solid lubricant films under air tribology and also unalloyed standard sputtered MoS_2 films [6,7]. Specially, the WC modified MoS_2 presents - when tested under vacuum at 0,75 GPa contact pressure - the characteristic low friction under vacuum of these solid lubricants (μ of 0.01 to 0.03), an excellent endurance exceeding 1 Million wear cycles and also acceptable friction and wear properties during atmospheric testing up to 50 – 60 % RH. These results have been obtained using commercial tribo-testers with a contact geometry of "ball on disk" and a comparison with the results from VTM would provide an insight into the performance characteristics of the scientific instrument and how it compares with other available instruments designed for ground testing. Different tribometers can produce a wide variation of results when testing the same material and cautions should be followed when evaluating tribological properties of space lubricants [8]. This work reports on the tribological evaluation of these films using the VTM TriboLAB.

EXPERIMENTAL WORK

Tribology tests under vacuum have been carried out in the VTM Model of TriboLAB, that will be presented in this conference. This equipment has been designed to accommodate two types of tribological tests: pin on disk and ball bearing tests. A cross section of the VTM can be seen in Fig. 1 below, and Fig. 2 shows the pin on disk lay out and the components. In this instrument there is six experimental cells and therefore the possibility of performing six pin on disk and six ball bearing tests.

This paper only refers to the pin on disk experiments and as a consequence only this part of the full experiment will be explained in more detail. The test set up shown in Fig. 2 consists in a *coated disk* that rotates, attached to a main shaft that drives all experiments. The *arm*, that contains a ball or spherically ended pin at one extreme, is made with flexures and the ball at the end is set in contact with the disk by means of a *pivot flexure* (torsional spring) that applies the nominal contact force between ball and disk. The load that is applied by this method has been calibrated to 5 N +/- 10%.

A *cam* controls the angular position of the torsional spring and the applied force. Its function is to select the disk to be tested, since only one pin-on-disk test is carried out at a time from a total of 6 positions that are made available. This cam rotates attached to a shaft that is shared for all experiments; a ball at one end of the arm is in contact with the cam. Friction and normal forces are measured by means of *strain gauges* bonded on the flexures.

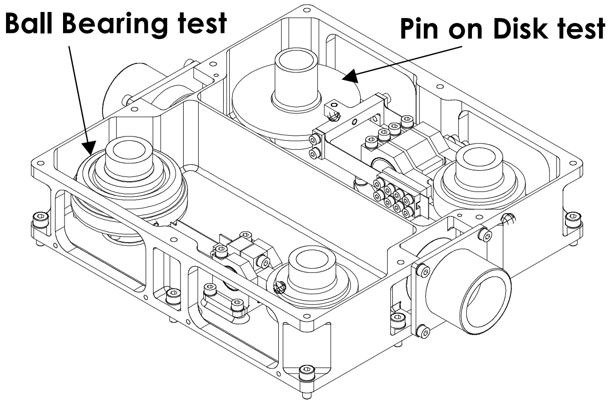

Fig. 1: VTM experiment cell view showing the pin on disk test (right) and the ball bearing test (left).

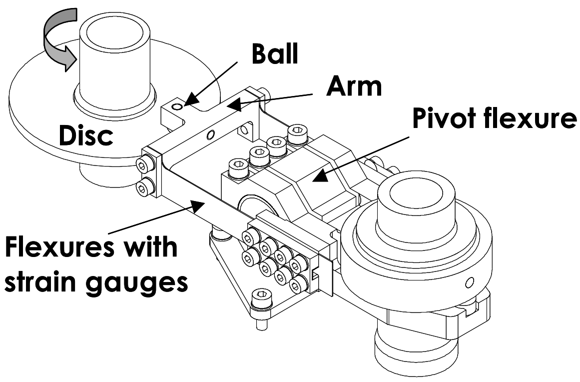

Fig. 2: Pin on disk test lay-out and components

All pin on disk tests were carried out with AISI 440C disks coated with the MoS_2 thin film alloyed with WC. Details of the experimental coating procedure and the composition of this lubricating film have been reported previously [4]. Once that the 6 coated disks and balls were positioned in the pin on disk cells of the VTM TriboLAB, the instrument was introduced in a vacuum chamber (see Fig. 3) and as soon as the vacuum level reached 10^{-6}mbar the tests could be started. The applied normal load with the present system is constant at 5 N, but during tests the variation observed in the normal load was +/-1 N. The rotational speed was 75 rpm and the 6 mm ball was placed at a fixed radius of 25 mm to perform the tests. The test criteria was to perform the test for each disk until reaching a mean friction coefficient higher than 0.2 for a time of 100 s. Monitorised parameters were the normal load, tangential force and friction coefficient, the data adquisition rate was 150 data/min.

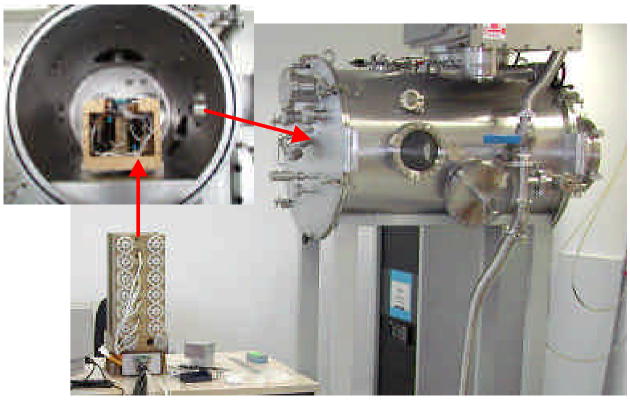

Fig. 3: Photograph showing the VTM TriboLAB and its position in vacuum chamber.

RESULTS AND DISCUSSION

A representative friction trace from the pin on disc tests is presented in Figure 4. Friction coefficients of MoS_2 thin films alloyed with WC measured under these testing conditions in the VTM TriboLAB were always, during initial stages of testing, very low with a mean value lower than 0.02. These results are in agreement with those obtained in these films using a commercial tribometer under vacuum [4]. Figure 5 reproduces as an example a friction trace obtained from this thin film in the commercial tribometer at a constant load of 5 N.

However, after a period of smooth running with a low friction coefficient, that is characteristic of MoS_2 solid lubricants, a higher friction variability was observed (Fig. 4). The main difference between both tribometers is that while in the commercial one, the load is applied by a dead weight and is constant at 5 N, in the VTM TriboLAB it is applied by a torsional spring. This causes during the test a measured variation in the normal load that ranges from 4 to 6 N (0.7 to 0.8 GPa). Figure 6 shows an example of how this normal load varies from 4 to 6 N during a representative test. It is known [9] that the durability of sputtered MoS_2 is strongly dependent of load and contact stress. Higher contact stresses and a cyclic loading behaviour conditions, such as those encountered in the VTM, would produce as a consequence a lower endurance life of the lubricating thin film.

Additionally, in the present tests the discs were ground at a surface roughness of 0.2 µm while in the tests represented in Fig. 5, the discs were surface polished to 0.01 prior to coating. The total thickness of the film in both cases was similar (about 1.2 µm). Since film life tends to decrease with increasing surface roughness of the substrate [9], it is reasonable to think that a higher surface roughness of the coated disk has also contributed to the reduced endurance of the film. This can be improved by using thicker sputtered films and further tests will be performed with a 2 µm thick coating, since a general rule is to deposit a film thickness of at least x 10 the value of Ra of surface roughness. Moreover, further tests will be carried out with disks with improved surface finish (about 0.1 µm Ra).

To account for the differences observed between the VTM and the commercial apparatus, it is also recognized [8] that different tribometers can yield variations in results and different data acquisition and management can produce significant differences in friction traces.

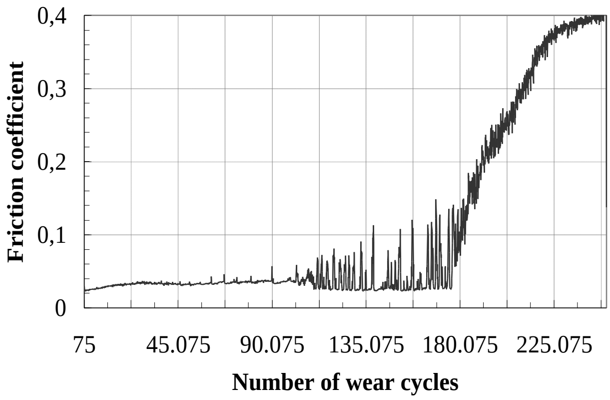

Fig. 4: Representative friction curve from MoS_2 alloyed thin film, tested in VTM TriboLAB.

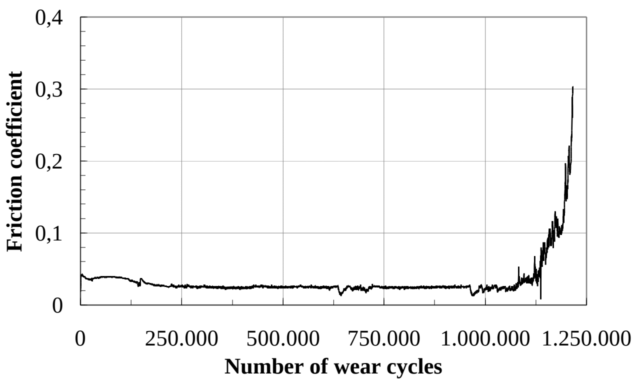

Fig. 5: Representative friction curve from MoS_2 alloyed thin film, tested in a commercial tribometer under vacuum (identical mating material, 5 N load, 0.75 GPa).

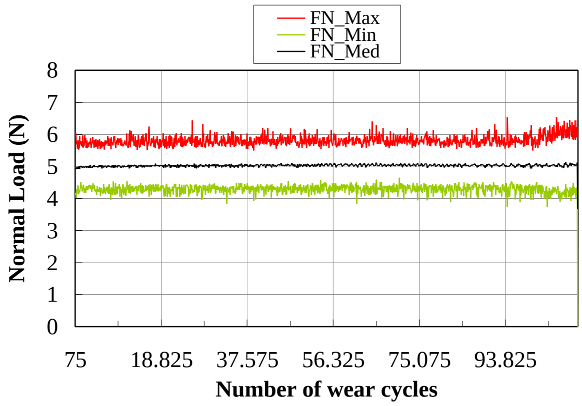

Fig. 6: Graph showing the variation of normal load during test. Line in the middle represents the averaged normal load between maximum (upper) and minimum (lower).

CONCLUSIONS

The following conclusions can be summarised:

- Pin on disk tests on MoS_2 thin films alloyed with WC have been carried out under vacuum using the VTM model of TriboLAB.
- Friction coefficient values of the films during initial stages of wear in this VTM tribometer are very low (about 0.02) and consistent with previous results obtained with a commercial tribometer under vacuum.
- The endurance life of these films, evaluated in the VTM TriboLAB, is significantly lower that the durability achieved in the commercial tribometer. Following a failure test criteria at reaching a mean friction coefficient of 0.2, the endurance life has been up to about 200.000 wear cycles.
- The reduced durability is explained in terms of a higher mean contact stress in the VTM TriboLAB, variability in the normal applied load (from 4 to 6 N) as a result of the pivot flexure and also increased surface roughness of the substrate.
- Further tests with thicker films and better surface finish are in progress to increase the endurance life of the lubricating film.

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