COMPARISON BETWEEN VARIOUS COMMERCIAL LUBRICANTS AT CRYOGENIC TEMPERATURE IN A VACUUM

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ABSTRACT

The coefficient of friction between two parts which are moved in a vacuum can increase dramatically right up to seizure. Some high technology coatings such as sputtered molybdenum disulfide have been found to offer an efficient solution to this problem. Such coatings however suffer the disadvantages of being expensive and of having a rather long delivery time. A series of tests has been carried out to evaluate the tribological properties of commercial dry lubricants and bearing materials at low temperature under vacuum. The study was completed by outgasing measurements to evaluate the suitability of these different materials for their application in a cryogenically cooled vacuum environment.

INTRODUCTION

Moving one part over another in a vacuum can lead to problems with friction due to the absence of the oxide film which, in conventional tribological practice, provides a safety net against seizure. If low pressure is accompanied by very low temperature fluid lubricants cannot be used any longer. One of the parts has either to be protected or to be made of a material which has good friction properties. Many companies offer various dry lubricants and bearing materials. Some of these materials were tested to compare their performance with that one of one of the most efficient coating: sputtered molybdenum disulfide.

FRICTION AND LIFE TEST

Friction is the resistance to sliding one solid over another. The frictional resistance is proportional to the normal load (L) across the sliding surface.

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Table 1. List of the various coatings which have been tested

Material of the plates	: stainless steel (AISI 440C); roughness: Ra 0,6μm; uncoated
Material of axle	: stainless steel (AISI 440C); roughness: Ra 0,6μm

Curve No.	Coating of the axle	Method of application	Manufacturer
1	MoS_2	Sputtering	ESTL, Risley, Warrington WA3 6AT, U.K.
2	321R	Spray	Dow Corning, Pel Kovenstr. 152, D-8000 München
3	3402C	Spray	Dow Corning
4	C200	Immersion	Cefilac, Rue de la roche du Glui, F 29 St. Etienne
5	C.A.	With brush	Klüber, Geisenhausenerstr 7, D-8000 München
6	240N	With brush	Klüber
7	10A	With brush	Klüber
8	Cardal	Spray	Molydal, 60 rue des Orteaux F-75020 Paris
9	Ramos 250	Spray	Molydal
10	Rofen SC	Spray	Molydal
11	Adermos	Spray	Molydal
12	180A	With brush	Klüber
13	MoS_2 powder	Burnish with leather	Dow Corning

Let us consider the experiment shown in Figure 4. A plate (P) is pressed onto a rotating axle (A) with a force (L). A frictional force (F) is exerted on the plate (P). The relationship is expressed mathematically as follows:

$$F = \mu * L$$

where F is the frictional force, L is the load acting normally to the surface and μ is a proportionality constant known as the coefficient of friction. If the frictional force is that necessary to keep the plate fixed while one initiates the movement, μ is the static coefficient of friction. If the force is that necessary to keep the plate in position while the axle rotates at a constant speed then μ is the kinetic coefficient of friction. The experiment shown in Figure 4 has been set up in a cryostat so that we can measure the coefficient of friction at low temperature. The axle is mounted in a kind of mandrel which is cooled to the temperature of liquid nitrogen. The two plates are also actively cooled via flexible thermal links.

Each plate is kept in position by a wire which is, at the other end, attached to a force measuring device. In order to avoid possible calibration problems the load cells are mounted on the warm wall of the cryostat and the wires are made of a material which has a very low thermal conductance. The coatings listed in Table 1 have been applied on axles made of stainless steel (AISI 440C) thermally hardened and chemically cleaned. In order to evaluate the reliability of the

Table 2. List of the bearing materials which have been tested

Material of axle : stainless steel (AISI 440C)
roughness: 0,6µm uncoated

Curve No.	Material of the plates	Company
2_1	FP15 Metafran	Helgerit, Langenfeldstr. 1 D-7434 Riederich
3_1	D.U.	The Glacier, Alperton Wembley, Middlesexs U.K. HA0 1HD
4_1	DQ1AN14	The Glacier
5_1	PTFE	Du Pont, Anton Spinoystraat 6 B-2800 Mechelen
6_1	Oilon	Nylacast Oilon Ltd., Brighton Road, Leicester, LE5 0HD, U.K.
7_1	Vespel	Du Pont
8_1	Cast Nylon	Nylacast Oilon Ltd.
9_1	Rulon J	Nylacast Oilon Ltd.

coatings, five samples of each coating have been run against uncoated plates of the same material until a seizure occured.

Figure 1 shows the kinetic coefficient of friction of the various coatings while Figure 3 shows the average of the evolution of the kinetic coefficient of friction against the number of revolutions. Figure 2 shows the kinetic coefficient of friction of the bearing materials listed in Table 2.

OUTGASING MEASUREMENTS

When a material is placed in a vacuum the gas which was previously add or absorbed begins to desorb. The desorption rate is mainly influenced by the pressure, the temperature, the shape of the material and by the nature of its surface. The generation of gas resulting from the desorption is known as outgasing. Two distinct methods have been used to measure the desorption rate of the various coatings and bearing materials.

The first method, known as constant volume method, consists of analysing the evolution of the pressure in a given volume during given time intervals.

The second method, called diaphragm method, has been described by Steckelmacher and is based on a measurement of the pressure difference across a given conductance. Figure 5 shows the disorption rates of some of the materials listed in Tables 1 and 2, compared with the outgasing rates of stainless steel and anodized aluminium alloy measured under the same conditions.

CONCLUSION

The curves displayed on the previous pages illustrate the relatively good performance of two coatings: the 3402C from Dow Corning (coating no. 3) and the C200 from Cefilac (coating no. 4).

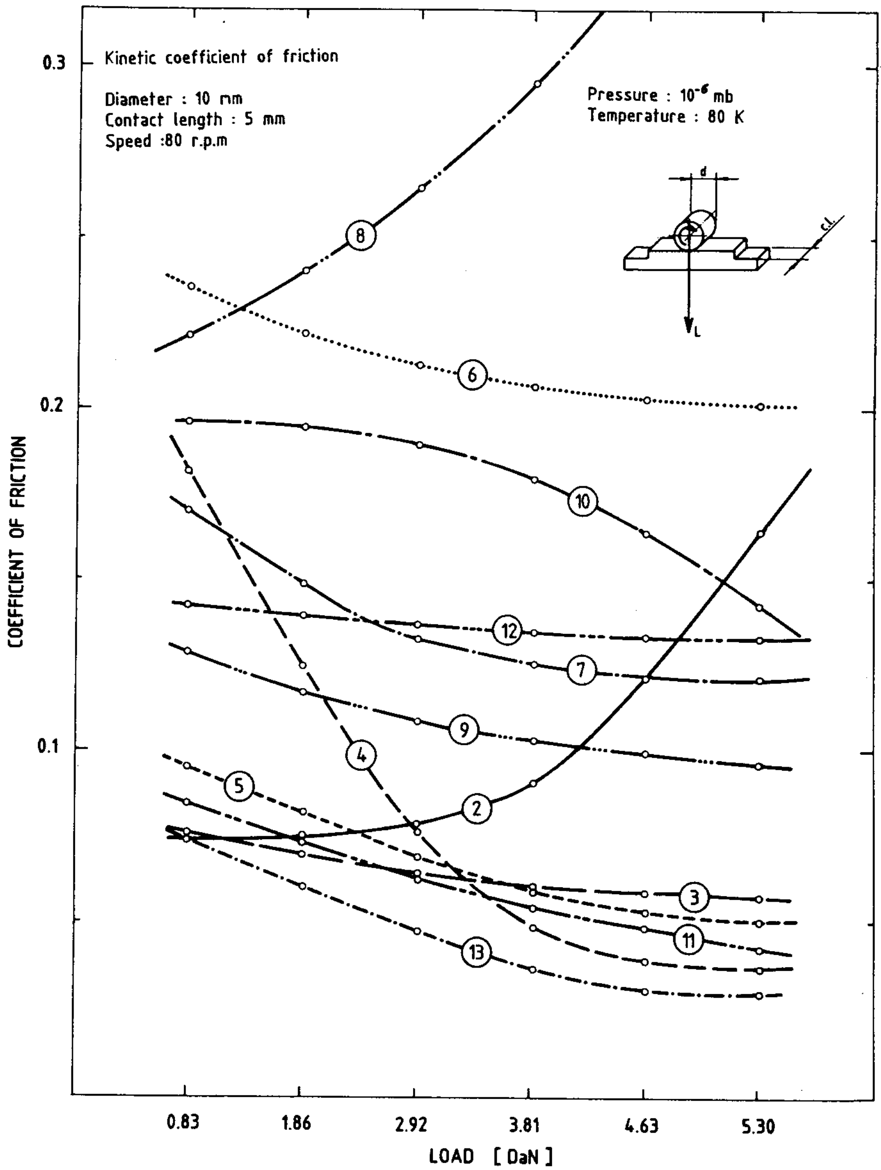

Fig. 1. Coefficient of friction of the coating listed in table 1.

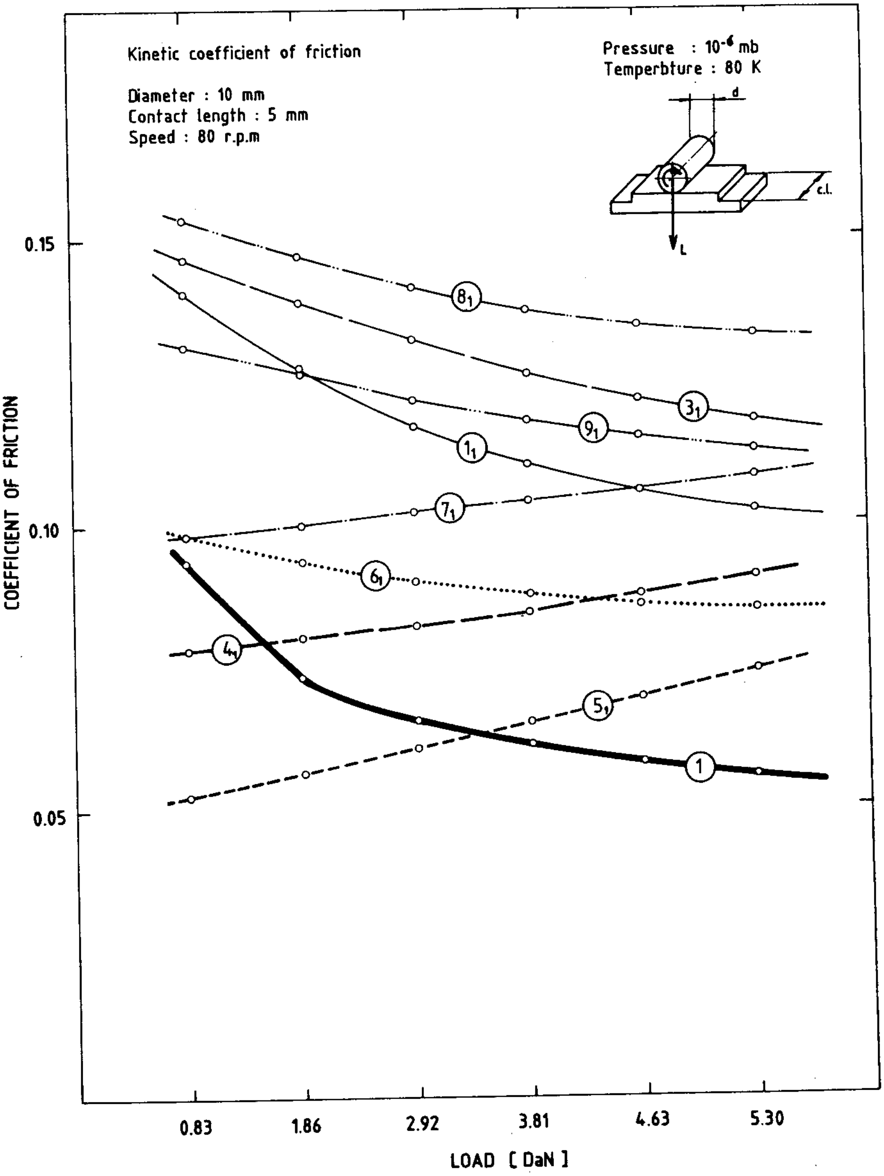

Fig. 2. Coefficient of friction of the bearing material listed in table 2.

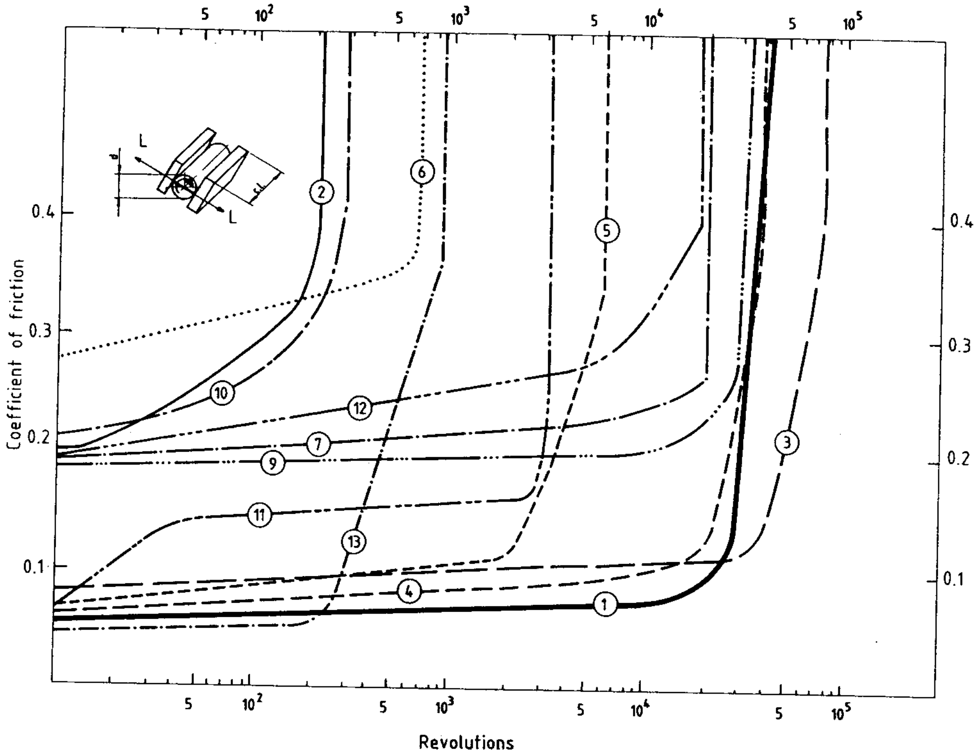

Fig. 3. Life time evaluation (evolution of the coefficient of friction against the revolutions number). Speed 80 r.p.mn; load: 10 daN; diameter: 10 mm; contact length: 15 mm.

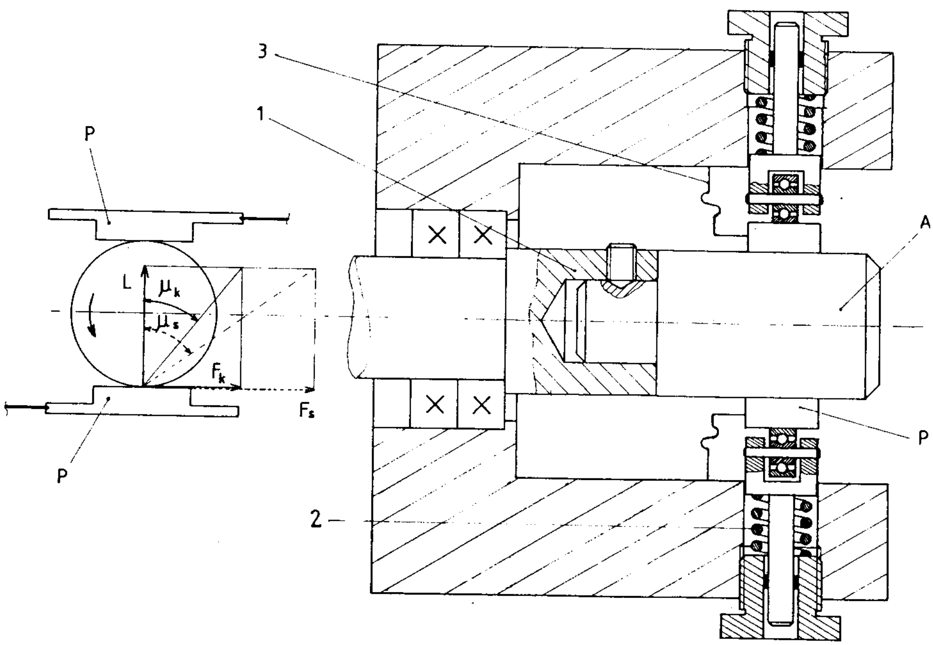

Fig. 4. Lubricant tester.
(A) Axle; (P) plates; (1) mandrel; (2) spring which define; (3) thermal links.

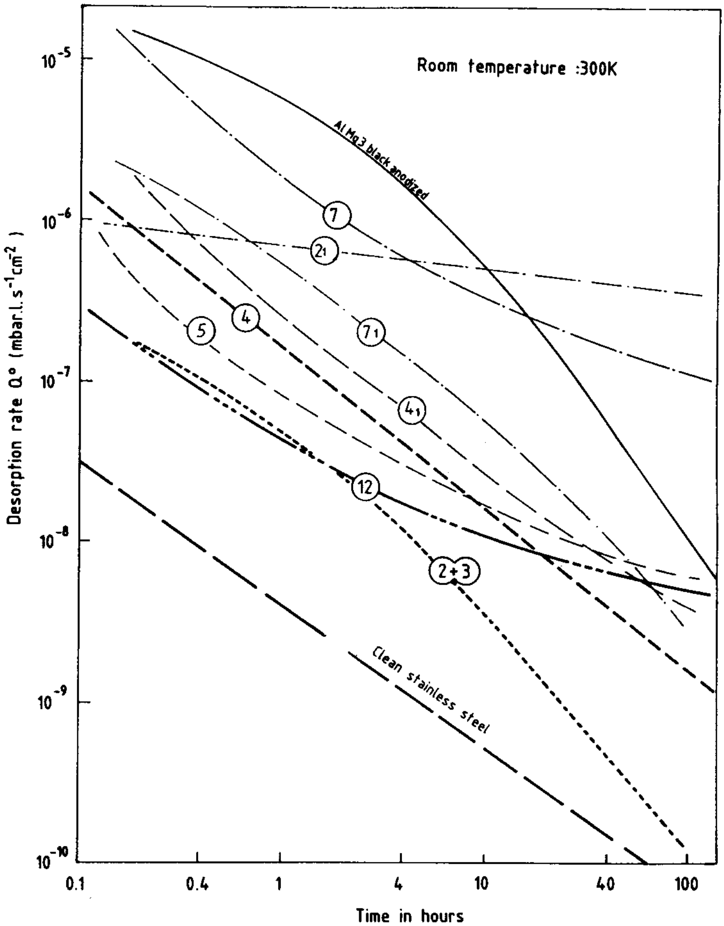

Fig. 5. Outgasing rate.
The AlMg3 sample is a cylinder (25 mm diameter and 2 mm thick). The stainless steel (AISI 440C) sample is a cylinder (25 mm diameater and 2 mm thick), electropolished and chemically cleaned. The coatings listed in table 1 are applied on the two faces of stainless steel cylinders (25 mm diameter and 2 mm thick) electropolished and cleaned.
The bearing materials samples are cylinders (25 mm diameter and 2 mm thick).

The method of application of these coatings generally does not guarantee the shape and form accuracy required for high precision parts. They nevertheless offer a very rapid and low cost solution to any laboratory and experiment work. From the bearing materials which has been tested, the ones which show the best tribological performances are the non-metallic materials. Therefore the use of such materials is restricted because of the poor mechanical hardness and because of the high thermal expansion coefficient.

REFERENCES

Clauss, F.J., 1972, Solid lubricant and self-lubricant solid Academic press, New York.

Roth, A., 1976, Vacuum technology, North-Holland Publishing Company.