TR 65219

OCTOBER 1965

ROYAL AIRCRAFT ESTABLISHMENT

TECHNICAL REPORT No. 65219

THE CORROSION OF STEEL IN CONTACT WITH MOLYBDENUM DISULPHIDE

by

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U.D.C. No. 620.193.4 : 669.14 : 546.774.2

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SUMMARY

The corrosion of steel surfaces in contact with molybdenum disulphide (MoS_2) has posed the question whether the process is induced by the lubricant. The present investigation shows that MoS_2 can accelerate the attack of steel at high humidity. The milled material is much more corrosive than the unmilled product. The addition of a suitable inhibitor is effective in suppressing corrosion.

Departmental Reference: CPM 44

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1 INTRODUCTION

Corrosion problems have arisen when MoS_2 has been used as a solid film lubricant for steel surfaces. Whether the corrosion was directly attributable to the MoS_2, or whether the material merely offered less protection than other types of lubricant, was not known. An attempt to clarify the situation was made by exposing to high humidity different types of steel in contact with MoS_2.

2 EXPERIMENTAL METHOD

Steel discs of 1 inch diameter were polished to a mirror-like finish by rubbing first on a series of successively finer grades of emery paper and then on Selvyt cloth impregnated with a 3 micron diamond, polishing compound. After degreasing and drying, the MoS_2 was applied and the specimens aged for 6 days at 90% r.h. and a temperature of 20°C.

3 EXPERIMENTAL RESULTS

3.1 Deposited and rubbed films of MoS_2

Films of MoS_2 were applied in various ways to three steels of differing corrosion resistance: (S 96 - 2½% nickel, chromium, molybdenum steel; En 40c - 3% chromium, molybdenum steel, and S 62 - high chromium, non-corroding, steel). After degreasing in trichloroethylene and drying, rubbed films were formed on the metal surfaces with (1) synthetic MoS_2 prepared in the laboratory, (2) unmilled MoS_2 to specification CS 2819, and (3) the latter material after (a) ball milling and (b) coating with a mixture of sodium stearate and stearic acid. The coated powder was included as it had proved to be the only effective lubricant in a bomb release mechanism[1].

Because of the fine finish on the metal surfaces and with the exception of the milled powder, the films obtained by rubbing were very thin. Thicker films were prepared by using a commercial aerosol suspension of MoS_2 and by brushing a suspension of the unmilled material in alcohol. Uncoated specimens were also included. On completion of the test the films were removed by ultrasonic cleaning and the surfaces examined under a microscope. Results are given in Table 1 and Fig.1 shows surface profiles after exposure to test and removal of the milled MoS_2 and sprayed films.

3.2 Powder deposits

In a second series of tests, experiments were confined to S 96 as being the least corrosion-resistant of the three steels. After polishing, the specimens were cathodically cleaned in sodium carbonate solution until they could be completely wetted by distilled water. Immediately after rinsing in distilled water and careful drying under an infra-red lamp, powder was piled on to the specimens so that the whole surface was covered to a depth of about 1mm. Corrosion tests were then made under the same conditions as before but the range was extended to include other types of lubricant and non-lubricant powders. Results are given in Table 2. These results indicate that MoS_2 can accelerate the corrosion of steel at high humidity. The marked corrosion produced by the coated powder is surprising considering its success as a lubricant for bomb release units. In this application, however, the lubricant is used in the form of a rubbed film and Table 1 shows that this produced no accelerated corrosion of steel 'Composite' tests were made to examine the above results more closely. In these, loose powder was applied over rubbed films instead of directly in contact with the metal but, during preparation, it was noticed that polishing had made the specimen surface convex and the rubbed film was significantly thicker at the centre. After 6 days at 90% r.h., isolated shallow pits were found at the centre of the specimen but, at the edges, much deeper pitting similar to that obtained using the loose powder alone. A similar experiment with unmilled MoS_2 powder showed that, in this case, the presence of a rubbed film resulted in slight improvement. The tendency of loose MoS_2 powders to promote the corrosion of steel can therefore be partially offset by the presence of a rubbed film, presumably having some ability to reduce the accessibility of oxygen and water vapour to the metal surface.

3.3 The effect of corrosion inhibitors

Attempts were made to reduce the corrosion produced by MoS_2 by incorporating buffers or corrosion inhibitors; those chosen were silver acetate , barium hydroxy stearate, calcium chromate and a commercial vapour contact inhibitor (VCI 280). MoS_2 was mixed with 5% by weight of each of these compounds and humidity tests made with piled powders as before. A test was also made with a mixture of 90% MoS_2/10% graphite, which had given superior results to MoS_2 alone in laboratory friction studies under conditions of high humidity. Results are given in Table 3.

Fig.2 shows surface profiles and the improvement in corrosion resistance given by the addition of 5% VCI 280 to the MoS_2 powder.

4 REMARKS

Tests using thin rubbed films of MoS_2 show that the milled powder is corrosive towards steel. S 96 and En 40c specimens were, in fact, found to be pitted after only 1 hour exposure under the conditions described. This result is attributed to the sulphuric acid which is known to be present after milling. It has also been shown[2] that, in the presence of air and water, MoS_2 undergoes slight oxidation according to the reaction:

$$2MoS_2 + 9O_2 + 2H_2O = 2MoO_2.SO_4 + 2H_2SO_4 .$$

The tests also show that, in the form of loose powder, unmilled MoS_2 can cause accelerated corrosion of steel. That this result was predominantly due to chemical rather than physical action is confirmed by the tests made on other powders of comparable particle size. With these, only WS_2 which has a similar structure and properties to MoS_2, showed comparable, though less extensive, corrosion and here, also, the micronated material was much more corrosive than the ordinary grade.

In practice MoS_2 is applied to metal surfaces usually as a bonded film but occasionally as a rubbed film. There are indications that a static rubbed film is less corrosive towards steel than loose powder but extensive further testing would be required to establish what classes of binder would be preferable from the point of view of suppressing corrosive tendencies. Even when using bonded films, however, MoS_2 particles will be generated between sliding bearing surfaces, and it is feasible that they will become oxidized with the formation of traces of sulphuric acid. Such an event could lead to corrosion, once the lubricant film had been penetrated.

The incorporation of buffers and corrosion inhibitors was beneficial to varying degrees, but VCI 280 was the only material tested which gave complete protection against corrosion. Whether any benefit would be derived in practical applications has not yet been determined.

5 CONCLUSIONS

(1) The corrosion of steel at high humidity is accelerated by contact with MoS_2.

(2) Milled MoS_2 and synthetic MoS_2 are much more corrosive than the unmilled natural product.

(3) Boron nitride, WS_2 and graphite also induce corrosion but to a less marked degree.

(4) Under the conditions of test, corrosion can be prevented by the addition of a small quantity of corrosion inhibitor.

Table 1

THE EFFECT OF MoS_2 FILMS ON THE CORROSION OF STEEL AT HIGH HUMIDITY

Coating	Condition of metal surface after ageing 6 days at 90% r.h. and 20°C		
	S 96	En 40c	S 62
None	A few small pits	A few small pits	A few small pits
Unmilled MoS_2	"	"	"
Coated MoS_2	"	"	"
Synthetic MoS_2	"	"	"
Milled MoS_2	Etched all over	Etched all over	Covered with small pits
Unmilled MoS_2 in alcohol suspension	Periphery etched; also other areas pitted and etched	Periphery and isolated small areas etched	One or two small areas etched. Periphery not attacked
Aerosol suspension	Pitted and etched all over	Mosaic of pits and cracks	Some etching

Table 2

EFFECT OF VARIOUS POWDERS ON THE CORROSION OF S 96 STEEL

Powder	Condition of metal surface after 6 days at 90% r.h. & 20°C
None	Slight pitting (Fig.3(a))
MoS_2 (CS 2819)	Etched in 'worm-like' pattern to depth of 0.7 microns (Fig.3(b))
MoS_2 (American) Ordinary grade	Groups of pinholes; isolated pits.
MoS_2 (American) Micronated	Covered by rough protruberences; also pitted to depth of 2 microns (Fig.3(d))
Coated MoS_2	Material adhesive; removed by rubbing; rusted and pitted to depth of 2 microns
Synthetic MoS_2	Etched and pitted to depth of 3 microns (Fig.3(c))
WS_2 Ordinary grade	Slight pitting; isolated pits 1 micron in depth
WS_2 Micronated	Covered with a greyish film; large diameter pits up to 1 micron deep
Pure graphite	A number of shallow pits
Boron nitride	Very adhesive; removed by rubbing; etched areas up to 0.2 microns deep
Metal free phthalocyanine	Slight pitting
P.T.F.E.	Slight pitting
Jeweller's rouge	Small areas etched
Talc	A few isolated pits

Table 3

THE EFFECT OF BUFFERS AND INHIBITORS ON THE CORROSION OF S 96 BY MoS_2

Composition of mixture	Condition of metal surface after 6 days at 90% r.h. and 20°C
None	Isolated pin holes
MoS_2 + 5% silver acetate	Considerable number of rust spots; isolated pits
MoS_2 + 5% barium hydroxy stearate	Similar to silver acetate but more pitting
MoS_2 + 5% calcium chromate	Isolated rust spots
MoS_2 + 5% V.C.I.280	Slightly better than using no powder
MoS_2 + 10% graphite	Similar to MoS_2 alone

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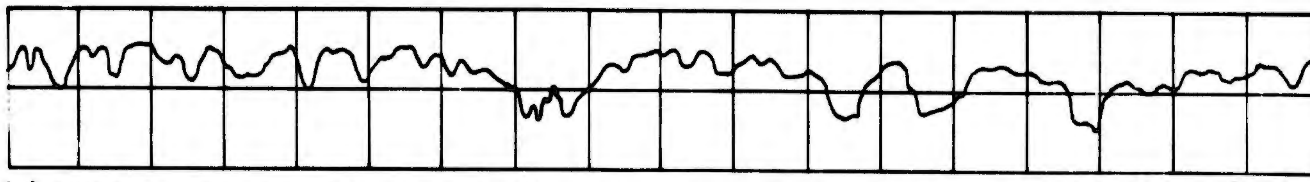
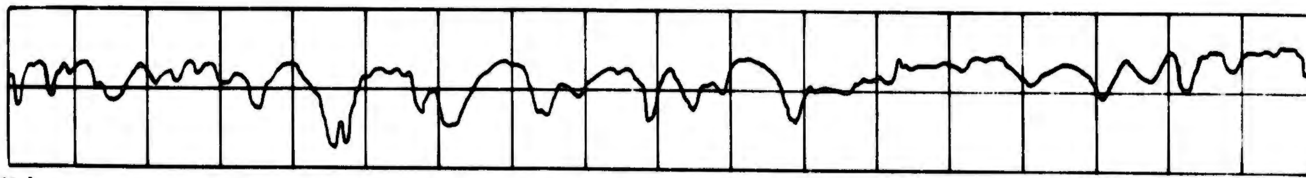
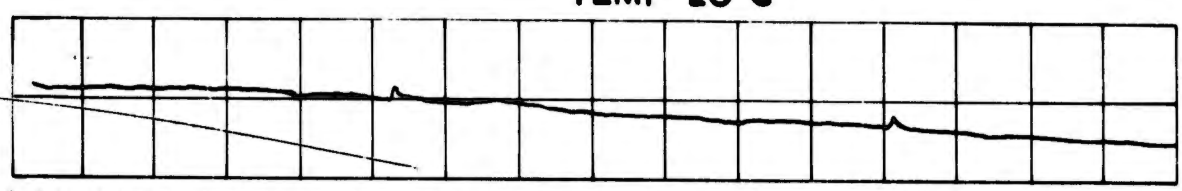
No.	Author	Title, etc.
1	E. Kay	Development of a lubricant for use with electromagnetic release units. R.A.E. Tech. Note Chem 1398, 1962
2	G.H. Khan I.A. Fed'kovskii V.V. Smirnov	On the problem of the oxidisability of molybdenite during flotation. Izvestya Vysshikh Uchebnykh Zavedenii Isvetraya Metallurgiya, No.4, 1962, pp 54-59, R.A.E. Translation 1036, 1963



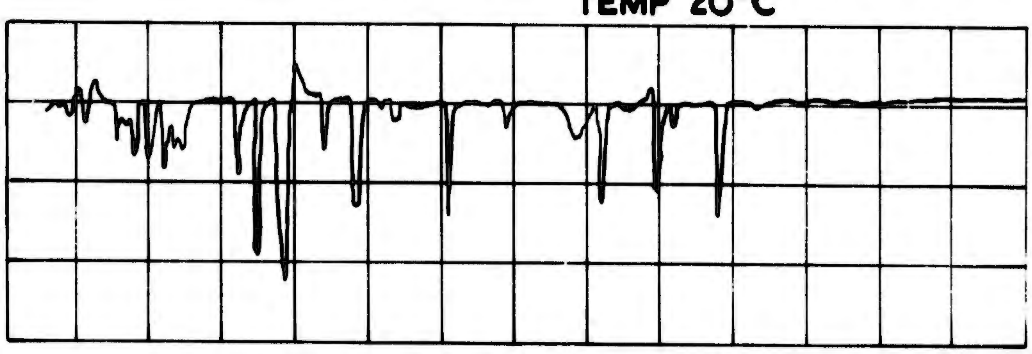
(a) MILLED MoS_2, RUBBED FILM ON S96 STEEL; AFTER 6 DAYS AT 90% rh, TEMP 20°C



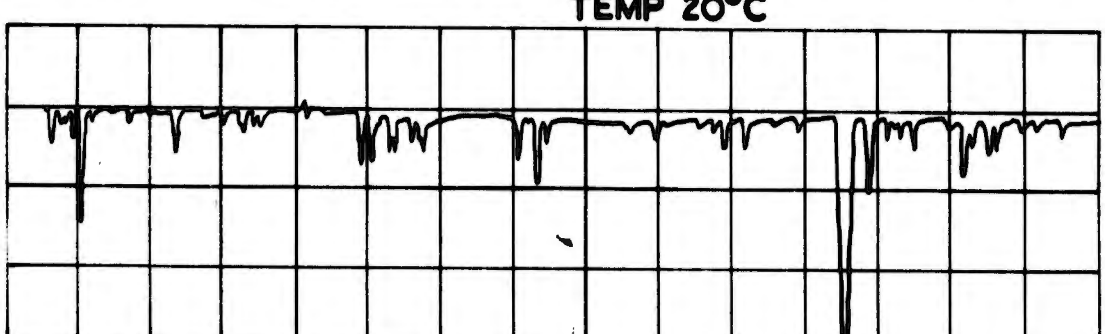
(b) MILLED MoS_2, RUBBED FILM ON En 40c STEEL; AFTER 6 DAYS AT 90% rh, TEMP 20°C



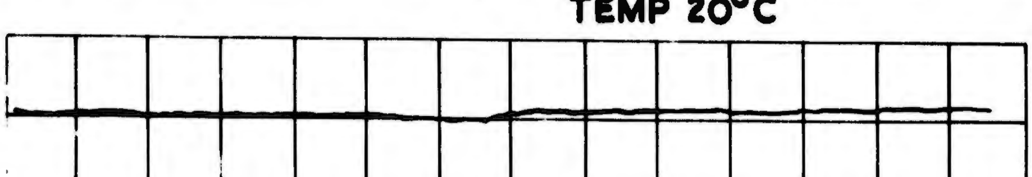
(c) MILLED MoS_2, RUBBED FILM ON S62 STEEL; AFTER 6 DAYS AT 90% rh, TEMP 20°C



(d) SPRAYED FILM OF MoS_2, ON S96 STEEL; AFTER 6 DAYS AT 90% rh, TEMP 20°C

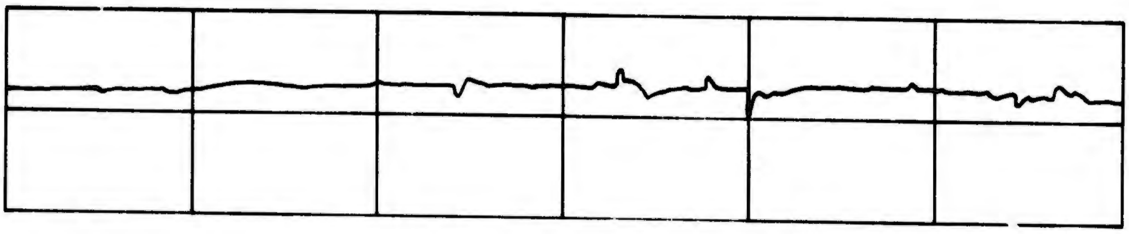


(e) SPRAYED FILM OF MoS_2, ON En 40c STEEL; AFTER 6 DAYS AT 90% rh, TEMP 20°C

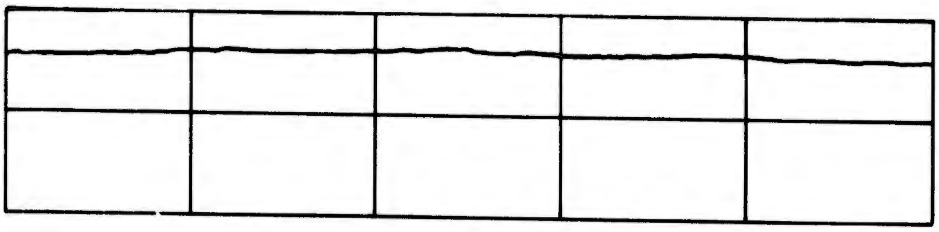


(f) SPRAYED FILM OF MoS_2, ON S62 STEEL; AFTER 6 DAYS AT 90% rh, TEMP 20°C ALL 5000 VERTICAL MAGNIFICATION, 100 HORIZONTAL MAGNIFICATION

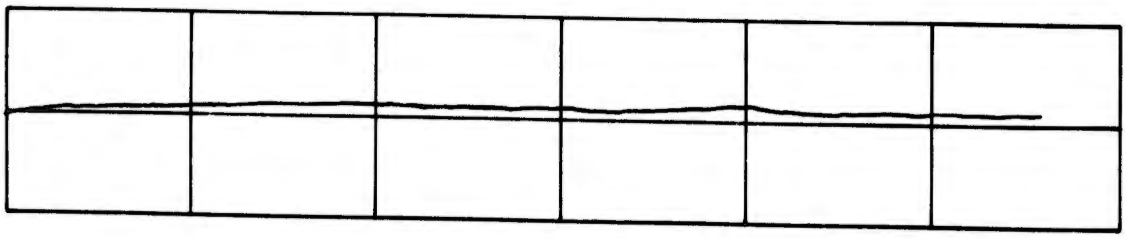
FIG.1 (a-f) SURFACE PROFILES OF VARIOUS STEELS AFTER AGEING IN CONTACT WITH FILMS OF MoS_2



(a) MoS_2 (CS2819) PILED ON S96 (6 DAYS AT 90% rh, TEMP 20°C)



(b) NQ POWDER (CONTROL)(6 DAYS AT 90% rh, TEMP 20°C)



(c) MoS_2 (CS2819) + 5% VCI 280 PILED ON SPECIMEN
(6 DAYS AT 90% rh, TEMP 20°C) VERTICAL MAGNIFICATION 5000;
HORIZONTAL MAGNIFICATION 100

FIG.2(a-c) EFFECT ON THE CORROSION OF STEEL OF THE ADDITION OF CORROSION INHIBITOR TO MoS_2

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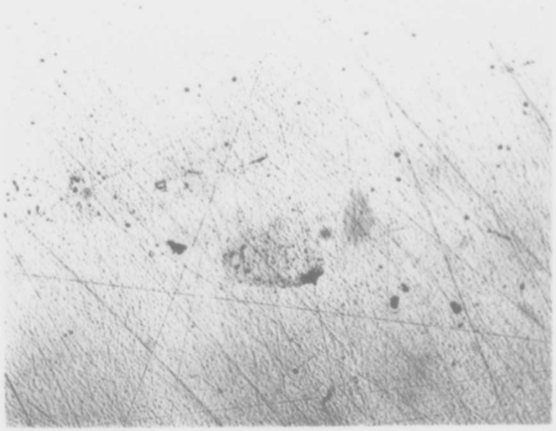
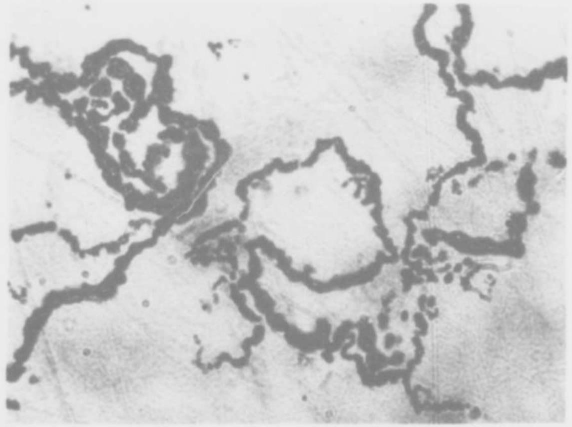
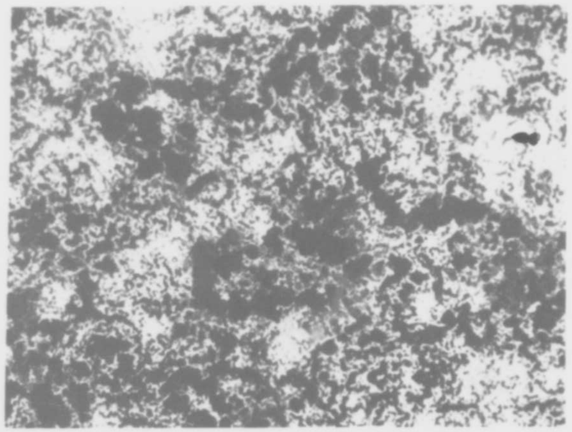
Fig.3



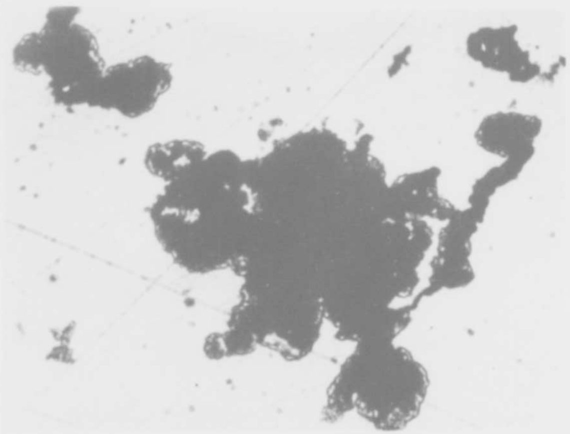
(a) Control; no MoS_2 present (6 days at 90% r.h., temp. 20°C) x 150



(b) MoS_2 (CS2819) (6 days at 90% r.h., temp. 20°C) x 150



(c) Synthetic MoS_2 (6 days at 90% r.h., temp. 20°C) x 150



(d) Micronated MoS_2 (American) (6 days at 90% r.h., temp. 20°C) x 150

FIG.3 APPEARANCE OF S96 STEEL SPECIMENS AFTER AGEING IN CONTACT WITH VARIOUS MoS_2 POWDERS

DETACHABLE ABSTRACT CARDS

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669.14 :
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