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Effect of Organic Compounds on Coefficient of Friction of Clean Molybdenum Disulfide

清浄な二硫化モリブデンの摩擦係数に及ぼす各種有機化合物の影響

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1. Introduction

Two of the authors (M. M and T. N.) investigated the effect of various vapours on the coefficient of friction of clean molybdenum disulfide (MoS_2) and came to conclusions that the clean MoS_2 exhibited a little higher coefficient of friction, that adsorbed vapours could reduce the friction and that some chemical compounds with MoS_2 might reduce the friction at extremely high vacuum[1].

The present experiments investigated the effect of organic compounds, especially long chain or chemically active ones, on the coefficient of friction of clean molybdenum disulfide in using the same technics as the previous report.

2. Method of Experiments

The MoS_2 used was the same one previously reported[1]. that is, powdered natural MoS_2 and the size of the flakes was of the order of 1 μm. The friction apparatus used was also the same one as reported previously[1], except some modifications in order to introduce vapour evaporated from organic compounds which are in solid state at room temperature. The equipment was used in a vacuum system at pressure down to 10^{-9} Torr. The MoS_2 power was deposited on copper substrate by electrophoretic coating as previously reported[1]. The reciprocating stroke was 15 mm and the reciprocating period was 3 seconds. The load on the slider was chosen as 200g

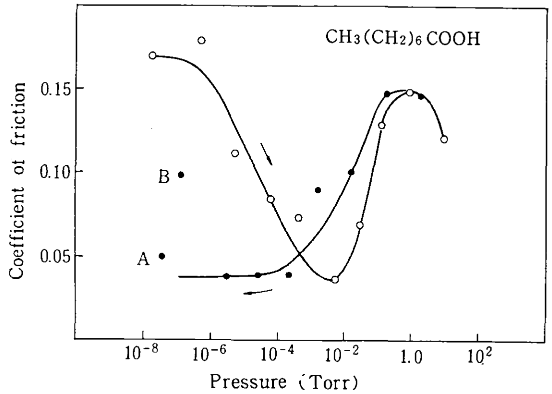

Fig. 1　Effect of propionic acid on coefficient of friction of clean MoS_2. 'A' indicates a value after 38 hours stop. 'B' a value after heating

3. Experimental Results

3.1 Effect of propionic acid

The properties of used compounds are shown in Table 1. The effect of propionic acid on friction of MoS_2 at each pressure is shown in Fig. 1, which is similar to that of 1-buthanol[1]. It seemed that length of carbon chain, rather than carboxyl radical had effects on friction. In Fig. 1, dots 'A' and 'B' indicates values after stopping for 38 hours and after baking, respectively.

3.2 Effect of n-caprylic acid

Effect of n-caprylic acid on friction is shown in Fig. 2. Since the compound is solid at room tem-

Table 1　Properties of used organic compounds

Name	Formula	M.W.	m.p. (C)	b.p. (C)	v.p. (20C)	Temp. at 1 Torr
Propionic acid	CH_3CH_2COOH	74.08	−20.8	140.8	2.5	
n-caprylic acid	$CH_3(CH_2)_6COOH$	144.22	16.5	239.3	10^{-3}	
n-amyl chloride	$CH_3(CH_2)_4Cl$	106.6	−99	108	−	
stearic acid	$C_{17}H_{35}COOH$	284.49	71	238	−	173.7 C

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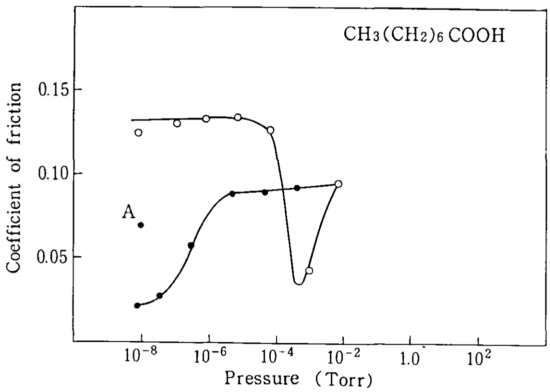

Fig. 2　Effect of n-caprylic acid. "A" indiates a value after 18 hours stop

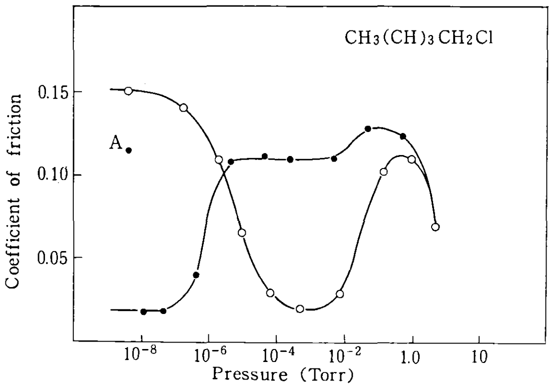

Fig. 3　Effect of n-amyl chloride. "A" indicates a value after heating

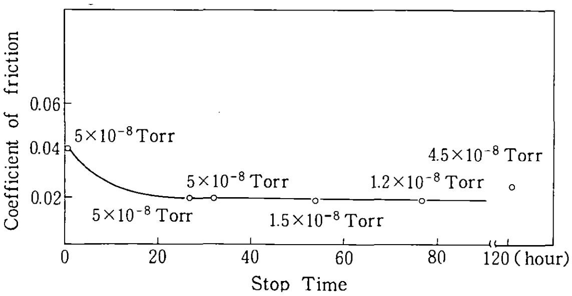

Fig. 4　Stop time effect of n-amyl chloride on MoS_2

perature, it was heated at 90 C and evaporated. The result might be affected by other vapours.

3.3　Effect of n-amyl chloride

Effect of n-amyl chloride was examined in order to investigate the effect of active element in organic compounds. A result is shown in Fig. 3, indicating that the compound was very hard to evaporate, and that MoS_2 adsorbed the compound could attain low coefficient of friction at room temperature. After heating, the friction recovered its high value as shown by a point "A" in Fig. 3.

Effects of stop time and temperature at high vacuum are shown in Figs. 4 and 5, respectively. The former shows that the friction was very stable even in high vacuum at room temperature, and the other shows increase of friction at high temperature.

3.4　Effect of stearic acid

Since stearic acid is also solid at room temperature, different experimental methods from that of vapors and liquids were taken. One was evaporation method, which is shown in Fig. 6. A heating boat with a hole was placed near the plate, and the compound in it was evaporated during friction tests. A result is shown in Fig. 7, indicating that film could reduce the friction and that excess film again increased the friction. When the evaporation was stopped and the

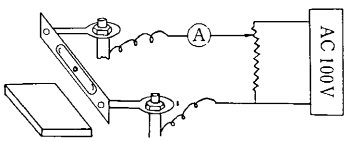

Fig. 6　Schematic diagram for evaporation of stearic acid

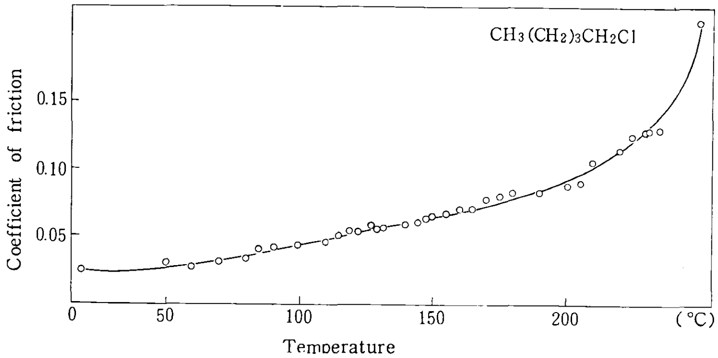

Fig. 5　Heating effect of n-amyl chloride on MoS_2

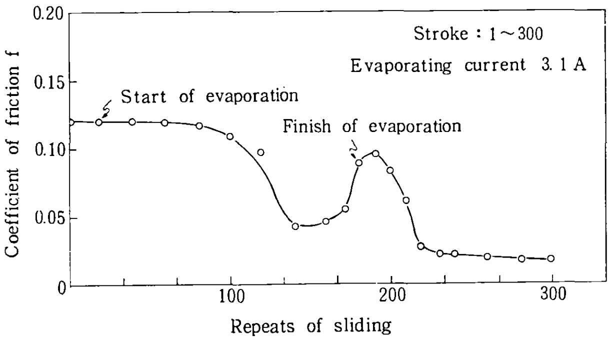

Fig. 7　Effect of stearic acid by evaporation

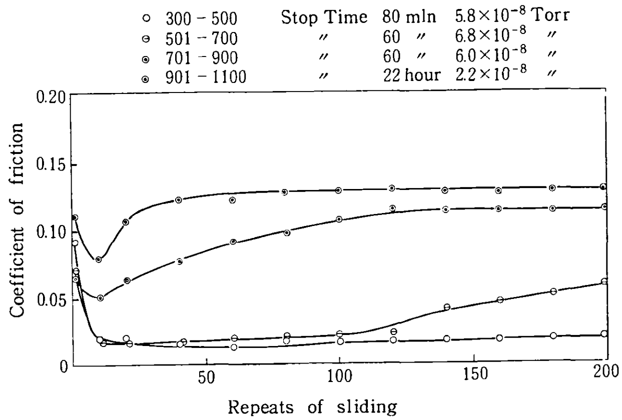

Fig. 8　Effect of sliding and stop time on low friction film of stearic acid on MoS_2

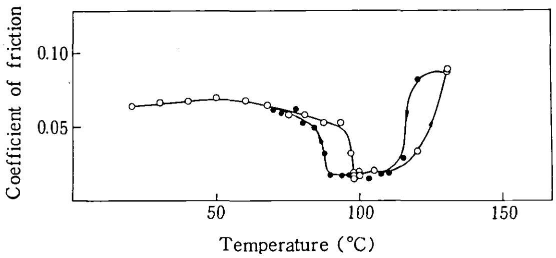

Fig. 9　Effect of heating on low friction film of stearic acid on MoS_2

friction test was continued, the friction was again reduced. After reduction of friction, the experiments were performed with accompanied by stop times. Result is shownin Fig. 8, indicating that friction was increased by desorption of the film. It was shown that a certain amount of adsorption could reduce the friction and excess amount again increased the friction. The result is nearly the same as other vapours in its qualilative nature.

The second experiment was performed by MoS_2 film with 1 mg stearic acid in ethanol. The coefficient of friction was high and about 0.06 even after 4200 strokes. Since the value was nearly the same as that of stearic acid in its boundary lubrication, it seemed that excess compound existed on the surface. In heating, reduction of friction occurred at about 100C. The causes are not clear now.

Conclusions

The organic compounds used in this experiment had effects on coefficient of friction of MoS_2 in that a certain amount of adsorption could reduce the friction. The result coincided with that of other vapours qualitatively. Of these compounds used, organic chloride is more difficult to evaporate from MoS_2 surface than other compounds. It was concluded that only introduction of vapours could not obtain low frictional material in high vacuum and at high temperature, but that some chemical reactions would be necessary to get a material of such natures.

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References

1) M. Matsunaga and T. Nakagawa, Effect of Various Vapors on Coefficient of Friction of Clean Molybdenum Disulfide, ASLE Trans. 19. 3, 216, 1976

正　誤　表（9月号）

頁	段	行	種　別	正	誤
467	右	↑3～4	本　文	……0.5%，5%とした.	混和水に対して0.5%，1%とした.