COMPARISON LUBRICITY BEHAVIOUR OF NANOLAMINATED Ti$_3$SiC$_2$
AND SOLID LUBRICANTS

M. B. Rahaei
Materials and Energy Research Center, Tehran, Iran

1. General

In this research, the lubricity behavior of Ti$_3$SiC$_2$ was investigated by using a pin-on-disc sliding wear test with a AISI 52100 steel. In the pin-on-disc test, samples show the low friction coefficient ($\mu$), especially in low loads. Microscopic observations show a lubricating layer on samples surfaces that the result of decreasing of $\mu$ due to the lubricating behavior. In a high load, samples show increase in $\mu$ ($\approx 200$ N) and wear rate in 80 N loads, approximately. The results showed that Ti$_3$SiC$_2$ has a lubricity behavior in low loads ($< 80$ N) and can be used as a solid lubricant. Then lubricity behavior of this compound was then evaluated in comparison with graphite and MoS$_2$ solid lubricant. Likewise lubricity mechanisms are layer structure in compounds, and constituted permanent and lubricant oxide layer on surface of samples.

2. Introduction

The ternary compound, nanolaminated Ti$_3$SiC$_2$ is known that has many of the best properties of both metals and ceramics, such This unique combination of properties makes Ti$_3$SiC$_2$ a likely candidate for structural applications at elevated temperatures [6, 7], such as turbine blades and stators, heavy duty electric contacts, bearings, etc [4].

A number of useful publications have been written on the use of solid lubricants for space applications. Realistically, the most likely candidates are in the following categories: - Soft metal films: especially Pb, but also Ag and Au, - Lamellar solids: e.g., MoS$_2$ and WS$_2$, and - Polymers: such as PTFE films and glass fiber reinforced composites. Many other candidates could also be considered, but these are the primary choices [3]. Solid lubricants are useful for conditions when conventional lubricants are inadequate [2]. The friction coefficients of solid lubricant materials are of about 0.06 to 0.15 depending upon humidity and sliding conditions [1]. However, currently, reports on the tribological behavior of Ti$_3$SiC$_2$ are limited, especially lubricity and wear rate in high load. In the present paper evaluate the tribology behavior (lubricity and wear) of Ti$_3$SiC$_2$ ternary compound against 52100 steel pin in low and high loads, then compared with graphite and MoS$_2$ solid lubricants. The unit cell of Ti$_3$SiC$_2$ that compose a nanolayered structure, and graphite and MoS$_2$ solid lubricants, as shown in Fig. 1.

3. Experimental procedure

The contracted phases of the Ti$_3$SiC$_2$ were characterized employing XRD-Philips X'pert-MPD and Microstructure observation by SEM-XL30. The macro-hardness was evaluated by a Vickers diamond indenter at load 50 N using the following formula in Eq. 1. The wear rate (wear coefficient in mm$^3$/Nm) was calculated under opposite frame: $\Delta m / (\rho . F . L)$. Then compared with graphite and MoS$_2$ slid lubricants.
4. Results and discussion

According to XRD analysis, (Fig. 1), As can be seen in the SEM represented at Fig. 3, the product was not uniform, some regions rich in the ternary Ti$_5$SiC$_2$ phase, and some being a two-phase mixture of TiC and few amount and Ti–Al binary phases was detected. The results of friction test are listed in Table 1 in various loads, likewise in sliding distance curves, in the pin-on-disc test (Fig 2). It was found that the material undergoes a critically transition stage where the friction coefficient ($\mu$), increases linearly of 0.06 to 0.35 in 200 N load. A change in wear mechanism is initial observed at high load, especially in load over 200 N, that increase (COF and wear rate). The final result show that a low wear rate in 80N load ($< 10^{-6}$ ) and low COF in low load ($< 200$N ) (Fig. 2). Therefore proposed this compound can use as solid lubricant in load lower than 80 N.

Table. (1). Friction coefficient and wear rate for Ti$_3$SiC$_2$ sample in various normal load.

<table>
<thead>
<tr>
<th>Load (N)</th>
<th>10</th>
<th>40</th>
<th>80</th>
<th>120</th>
<th>160</th>
<th>200</th>
<th>240</th>
<th>280</th>
</tr>
</thead>
<tbody>
<tr>
<td>COF ($\mu$)</td>
<td>0.06-0.08</td>
<td>0.06-0.1</td>
<td>0.06-0.1</td>
<td>0.06-0.12</td>
<td>0.06-0.12</td>
<td>0.06-0.12</td>
<td>0.3-0.4</td>
<td>0.35-0.39</td>
</tr>
<tr>
<td>WR$\times 10^5$ (mm$^2$/Nm)</td>
<td>2</td>
<td>6</td>
<td>12.2</td>
<td>20.3</td>
<td>21.3</td>
<td>25.6</td>
<td>198</td>
<td>182</td>
</tr>
</tbody>
</table>

In Table (2) had come friction coefficient of for Ti$_3$SiC$_2$ sample in comparison MoS$_2$ and graphite solid lubricant. The result shows that nanolayered Ti$_3$SiC$_2$ has lubricity behavior in higher loads without humid environment, also can use in higher temperature in comparison MoS$_2$ in low load, because of don’t decompose.

Table. (2). Friction coefficient and wear rate for Ti$_3$SiC$_2$ sample in various normal load.

<table>
<thead>
<tr>
<th>COF ($\mu$)</th>
<th>Load (N)</th>
<th>10</th>
<th>40</th>
<th>80</th>
<th>120</th>
<th>160</th>
<th>200</th>
<th>240</th>
<th>280</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ti$_3$SiC$_2$</td>
<td>0.06-0.12</td>
<td>Failure</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Graphite</td>
<td>0.24</td>
<td>0.16</td>
<td>0.05-0.12</td>
<td>Failure</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MoS$_2$</td>
<td>0.05-0.15</td>
<td>0.05-0.15</td>
<td>0.05-0.15</td>
<td>0.05-0.15</td>
<td>0.05-0.15</td>
<td>0.05-0.15</td>
<td>0.05-0.15</td>
<td>0.05-0.15</td>
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</tbody>
</table>

5. Conclusion

In this work, the tribology behavior of Ti$_3$SiC$_2$/steel friction pairs was investigated. This compound showed low COF $\approx 0.06-0.12$ in low load ($<200$N) and a critically behavior in 200 N load, which that change wear mechanism of tribochemical to abrasion. Likewise illustrated low wear rate $\approx < 10^{-6}$ in load lower than 80 N. Lubricity mechanisms in low load was composed permanent oxide layer (tribochemical mechanism) and layered structure, but in high load has abrasion mechanism and plastic deformation. Therefore nanolaminated Ti$_3$SiC$_2$ can be used as a solid lubricant in low load, and high temperature due to constituted a passive layer in high loads. In comparison if that MoS$_2$ has lubricity behaviour in high loads but in high temperature decomposed. Also in comparison graphite has lubricity behavior without a humid environment.

6. References