# Friction and Wear of Polyimide-PTFE-Diamond Composites

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Diamond composites hold promise as a tribological material because of low friction and high wear resistance. We studied friction and wear of polyimide-20vol% PTFE-diamond composites in open air at room temperature, focusing on the effects of diamond size, and diamond content, sliding conditions, and mating material. Friction coefficient and wear tend to increase with increasing diamond size and content. Composites of appropriate diamond size and content showed a friction coefficient below 0.1 and specific wear of $10^{-7}$ $mm^3/Nm$. Friction and wear of composites sliding against stainless steel were higher than those of $Al_2O_3$ an increase that became increasingly not able with increasing diamond size.

**Keywords:** diamond, polyimide, PTFE, friction, wear

## 1. INTRODUCTION

P o l y i m i d e -PTFE-cluster diamond composites show excellent friction and wear [1] but are extremely expensive and unstable in supply. We studied the development of tribological materials having the same and higher performance using inexpensive, widely used high-pressure diamonds and a polyimide-PTFE matrix.

## 2. SPECIMENS

We used high-pressure diamond powders with particle sized 0-1, 1-2, 3-6, and 6-12 μm. Mixed powders of polyimide, PTFE, and diamond were formed in spark plasma sintering at 50 MPa, and 220℃ for 5 min. The matrix was polyimide-20vol% PTFE. Diamond content was changed from 5 to 30 vol%. A specimen 20 mm diameter and 6 mm thick consisted of 2 layers; only the 1 mm thick surface layer was polyimide-20vol% PTFE-diamond composite (diamond layer).

## 3. FRICTION TESTS

Friction and wear tests were done using a ball-on-block reciprocating friction tester, at loads of 10 and 25 N; friction speeds of 10, 20, and 40 mm/s; and friction times of 60 and 240 min. Mating balls were $Al_2O_3$ and austenitic stainless steel (SUS304).

## 4. RESULTS AND DISCUSSION

### 4.1 Effects of diamond size and content

The friction coefficient generally was lowest at 5-10% diamond content, increasing with increasing diamond content (Fig. 1). Composites with fine diamond below 6 μm showed a very low friction coefficient of 0.05 to 0.08 at a content of 5 to 10%, although the effect of diamond size was unclear. This was nearly equal to that of the lowest value for cluster diamond composites. The friction coefficient of coarse diamond and high diamond content was higher than that of the matrix.

The specific wear of a diamond layer sliding against $Al_2O_3$ ball (Fig. 2) showed a tendency similar to the friction coefficient. Specific wear was lowest value at 5% content, increasing with increasing diamond size and content. The degree of change in wear with diamond content was moderate in a composite with fine diamond, but notable in a coarse diamond composite. The range of diamond size and content giving lower wear than the matrix was the nearly same as that of the friction coefficient. Specific wear in the proper region of size and content was a middle reading of $10^{-7}$ $mm^3/Nm$.

$Al_2O_3$ ball wear increased with increasing diamond size and content, but specific ball wear was about 1 order smaller than that of the diamond layer, suggesting that the diamond composite is a moderate material that damages mating materials only negligibly.

An increase in the friction coefficient and specific wear of coarse diamond and a high content diamond composite was considered as follows: as a typical abrasive material, the abrasive action of diamond increases with increasing diamond size and content, generating high friction and large wear on the mating material. Because the particle-holding pro perty of the matrix is not necessarily strong enough, diamond may easily exfoliate as the content increases. Exfoliated particles damage the friction surface and accelerate friction and wear.

Friction and wear in 5% diamond composites sliding against $Al_2O_3$ and SUS304 balls are compared in Figs. 3 and 4. With $Al_2O_3$, the difference in the friction coefficient and specific wear was negligible in a fine diamond (0-1μm) composite, but they increased notably against a SUS304 ball with increasing diamond size. In a coarse diamond (6-12 μm) composite, the friction coefficient against SUS304 was about 3 times higher than that against $Al_2O_3$, and wear was over 15 times greater. SUS304 ball wear notably increased with increasing diamond size, generating deep streaks on the surface.

### 4.2 Effects of load and speed

Figure 5 shows the friction coefficient against an $Al_2O_3$ ball with changing load (25 and 10 N) and friction speed (40 and 10 mm/s). The total sliding distance was 144 m. Generally, a lower friction coefficient was obtained at high load and high speed. At a load of 25 N, the friction coefficient decreased with increasing diamond size. At 10 N, however, the friction coefficient clearly increased for coarse diamond size; friction coefficient at low load and speed exceeded 0.1.

Specific wear was generally nearly $1 \times 10^{-6}$ $mm^3/Nm$ (Fig. 6), but the wear at high load appeared to be smaller to some extent than that at low load. The wear at low load was about the same at each diamond size, appeared to be smaller to some extent than that at low load. The wear at a low load was about the same at different diamond sizes, but that at a high load appeared to decrease at the coarsest diamond size.

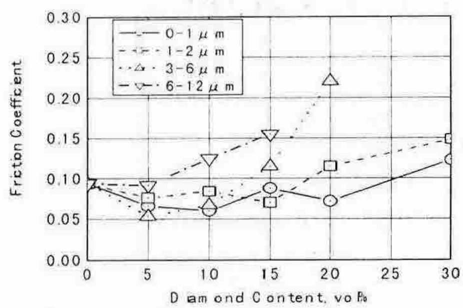


Fig. 1 Friction coefficient of polyimide-20% PTFE-diamond composites at different sliding conditions.

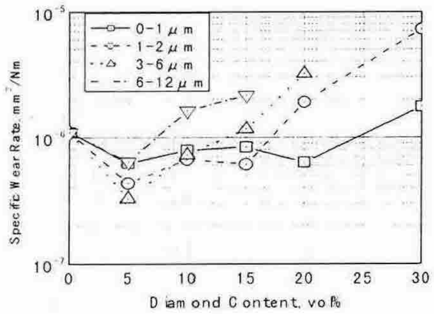


Fig. 2 Specific wear of polyimide-20% PTFE-diamo
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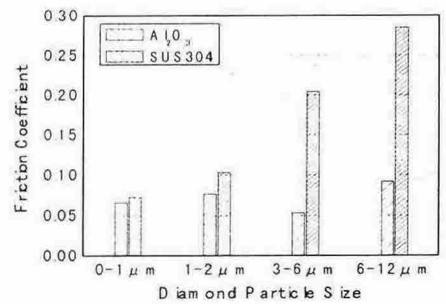


Fig. 3 Friction coefficient of polyimide-20% PTFE-5% diamond composites at different sliding conditions.

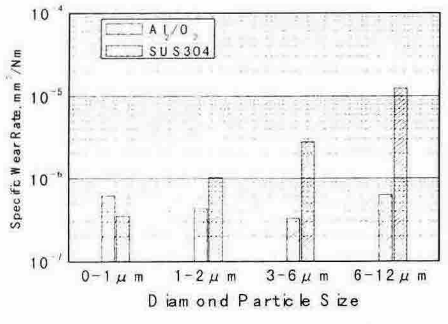


Fig. 4 Specific wear of polyimide-20% PTFE-5% diamond composites at different sliding conditions.

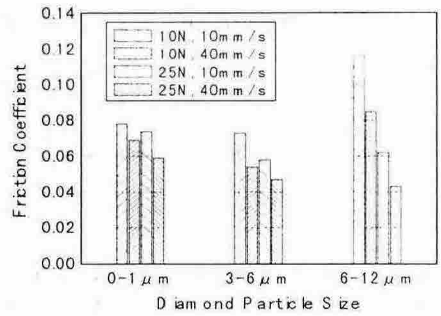


Fig. 5 Friction coefficient of polyimide-20% PTFE-5% diamond composites at different sliding conditions.

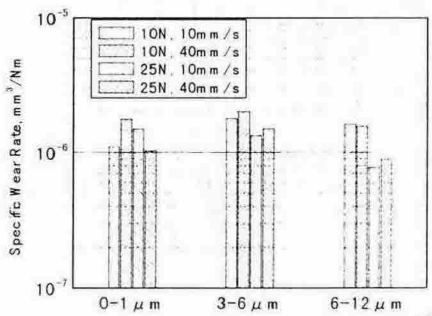


Fig. 6 Specific wear of polyimide-20% PTFE-5% diamond composites at different sliding conditions.

## 5. SUMMARY

Polyimide-PTFE-diamond composites had the following tribological properties:

(1) Friction coefficient and specific wear generally increased with increasing diamond content, an increase that became notable with increasing diamond size.
(2) At optimum diamond size and content, the friction coefficient was 0.05-0.06 and specific wear was a middle reading of $10^{-7}mm^3/Nm$.
(3) Composites damaged mating $Al_2O_3$ only negligibly.
(4) Tribological properties are equivalent to those of cluster diamond composites.

## 6. REFERENCES

[1] Umeda K., Takatsu S., Tanaka A. "Tribological Properties of Polyimide-PTFE-Cluster Diamond Composite Produced by Spark Plasma Sintering (SPS)." Proceedings of International Symposium on Spark Plasma Sintering (ISSPS). Singapore. 2001, to be published.