EFFECTS OF THE FRACTION OF PTFE AND FILM THICKNESS ON WEAR AND FRICTION IN AN ePTFE AND EPOXY COMPOSITE SOLID LUBRICANT COATING

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ABSTRACT
Wear tests were performed on various expanded PTFE / epoxy composite films, using a 304 stainless steel pin, in a pin on disk configuration. The density and thickness of the expanded PTFE films were varied, and the effects on friction and wear were examined. It was found that there are trends for increased wear resistance with increasing density, and increasing film thickness. Wear rates less than $10^{-8}$ mm$^3$/Nm were calculated on some of the composite films. The film thickness range from 75-510 µm and the density ranged from 0.304 to 0.904 g/cm$^3$. The tests were run at a 5N load and 1m/s sliding speed with varying sliding distances.

INTRODUCTION
Polytetrafluoroethylene (PTFE) is a well known solid lubricant that is chemically inert, and is often used as filler in composites to reduce friction coefficient. Durable coatings of PTFE are relatively difficult to create and bond due to the chemical inertness. In this paper a new composite structure made of expanded PTFE and epoxy will be described. Briefly, the major phase is PTFE, which in its expanded form is connected through fibrals. This structure is unique in that the major phase is compartmentalized by the minor phase, which is epoxy. This structure retains low friction coefficient and greatly increases the wear resistance while providing a pathway for strong bonding of the films though the epoxy.

MATERIALS
For this study several coatings made from ePTFE and epoxy were prepared at various thicknesses (75-510µm) and densities of PTFE (0.304-0.904 g/cm$^3$). The coatings are numbered 1 through 12 in ascending order based on the coating thickness prior to compression and bonding of the film. These coatings and the respective coating density and uncompressed thicknesses are shown in Figure 1.

<table>
<thead>
<tr>
<th>Sample</th>
<th>$t_i$(µm)</th>
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<tbody>
<tr>
<td>1</td>
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<td>7</td>
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<tr>
<td>6</td>
<td>180</td>
<td>12</td>
<td>510</td>
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Figure 1 Scanning electron micrographs of the top surface of the coatings. The coatings are number versus thickness. The PTFE regions are represented by light grey areas and the epoxy regions are represented by the dark grey areas. The density and uncompressed coating thickness are given in the table above.
The product of uncompressed film thickness and density of PTFE is essentially the cross-sectional area of PTFE available for solid lubrication.

**EXPERIMENTAL SETUP**

Each coating was bonded to a 2 inch diameter steel disk and all experiments were run on a rotating pin-on-disk tribometer. Both the materials and the tribometer are described in more detail in reference 1. The standard experimental conditions were: ¼” diameter stainless steel ball, 5 N dead weight normal load, and 1 m/s sliding speed. Each sample was run until the ball wore through the coating or reached in excess of 5 million cycles.

**RESULTS AND DISCUSSION**

The In general, the friction coefficient of the thinner coatings was lower than the thicker coatings, from $\mu=0.126$ increasing to $\mu=0.160$. This response was not very sensitive to the range of film thickness and PTFE loadings evaluated.

The wear rate for each coating was determined by assuming the wear track cross-section has a cross-sectional radius of curvature prescribed by the radius of the pin sample. This geometry was integrated along the wear track path to give the approximate volume of material. In the case of the coatings that ran over 5 million cycles, the volume removed was determined using a scanning white light interferometer that measured the worn profiles at several different locations along the wear track. The wear resistance tended to increase with increasing amounts of PTFE available to the contact. The highest wear rate was $k=2.79\times10^{-3}$ mm$^3$/Nm and the lowest wear rate was $k=1.75\times10^{-8}$ mm$^3$/Nm). These results are shown below in Figure 3.

**CONCLUSION**

These coatings showed order of magnitude changes in wear rate based on the film thickness and the available amount of PTFE. The friction coefficients were relatively insensitive to variations in thickness or PTFE volume. The composition with the lowest wear rate was a 510 µm uncompressed expanded PTFE film that had a density of 0.904 g/cm$^3$ prior to compression. This film lasted for over 50 million cycles of sliding having an average friction coefficient of $\mu=0.16$ and a single point wear rate of $k=1.75\times10^{-8}$ mm$^3$/Nm).

**REFERENCES**