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CARBON NANOTUBES AS ADVANCED LUBRICANT ADDITIVES

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Abstract. Single wall carbon nanotubes (SWNTs) present interesting tribological properties under boundary lubrication at ambient temperature. Used as additives to polyalphaolefin (PAO) base oil, they lead to a drastic decrease of both friction and wear of antagonist steel surfaces. These results are obtained with only 1 wt% of nanotubes dispersed in oil but with a minimal contact pressure of 0.83 GPa indicating that a structural modification is necessary for such improvements. Characterization of nanotubes by analytical TEM and Raman spectroscopy before and after friction is used to understand how nanotubes behave in the contact area.

Keywords: Single wall carbon nanotubes; tribology; friction; wear; additives

SWNTs were prepared by electric arc technique.¹ Nanotubes grow in long bundles. Their mean diameter is close to 10 nm. Effect of nanotube concentration in PAO was studied with a pin on flat tribometer (pin and flat made of steel). Tests were performed in ambient air, at room temperature, with a sliding velocity of 2.5 mm/s.

Figure 1a shows the influence of the nanotube concentration on the friction coefficient for a contact pressure of 0.83 GPa. With 1 wt% and 2 wt%, a drastic decrease of 70 % of the friction coefficient was observed. The influence of the contact pressure on the friction coefficient (test performed with a dispersion of 1 wt% of nanotubes in oil) reveals that a minimal contact pressure of 0.83 GPa must be applied to reach a very low and stable friction coefficient (Fig. 1b). This suggests that the efficiency of SWNTs is due to structural changes induced by the friction. Addition of nanotubes in oil induces also a strong reduction of the wear of the rubbing surfaces which is three times smaller than that observed without nanotubes.

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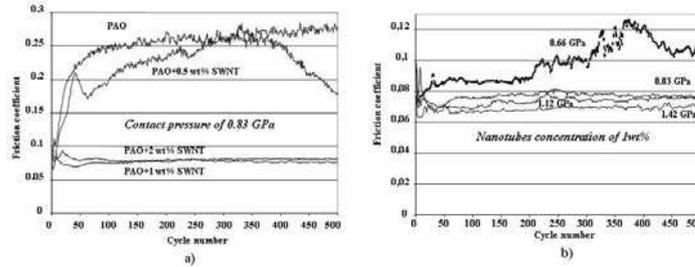


Figure 1. Influence of a) nanotubes concentration and b) contact pressure on the friction coefficient of the lubricant.

Wear particles collected from the pin and the flat were observed by TEM. Figure 2a shows the presence of amorphous carbon containing well-dispersed catalyst particles. The comparison of the Raman spectrum of the wear particles with that of the nanotubes (Fig. 2b) shows clearly the disappearance of the RBM modes at low frequencies and the growth of the D-band characteristic of disordered carbon.

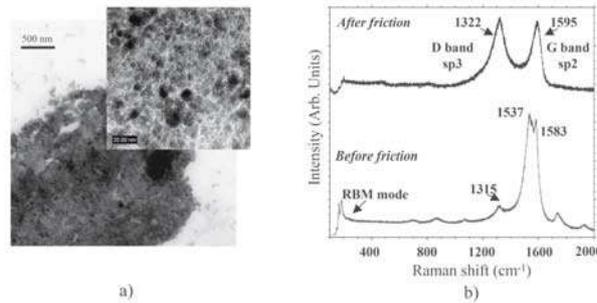


Figure 2. a) TEM images of carpet-like wear debris collected from the pin; b) Raman spectra ($\lambda = 632.8 \text{ nm}$) obtained before friction on the SWNTs and after friction from wear debris.

These analyses prove the strong alteration of the SWNTs structure during the friction. The mechanism of lubrication by the nanotubes can be explained by a crushing of the nanotubes followed by a sliding under shearing. The wear reduction can be due to the formation on the antagonist surfaces of a protective amorphous carbon layer containing metallic particles of catalyst, similar to a Ni-doped DLC like material, well known for its good tribological properties.

References

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