INFLUENCE OF A LIQUID ORGANIC COMPOUND ON TRIBOLOGIC PROPERTIES OF GRAPHITE PARTICLES

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Introduction

Friction and wear, principal causes of energy losses and surface damages when materials are in dynamic contact, can be efficiently reduced by the introduction of a lubricant between the sliding surfaces.
Graphite, used as solid lubricant, presents good friction properties attributed to its structure in which the basal planes, connected to each other by van der Waals forces, can be cleaved easily. Previous works showed that the tribologic properties of graphite are strongly influenced by the environmental conditions [1-3].
The aim of the present work is to study the tribologic properties of graphite in the presence of a liquid organic compound. Raman Spectroscopy, Transmission Electron Microscopy and nano-indentation investigations are carried out in order to characterize the structure, the crystallites size, the chemical composition and the mechanical properties of tribofilms formed by pure nanoparticles and in the presence of liquid.

Tribologic experiments

The tribologic properties of graphite are evaluated using an alternative ball-on-plane tribometer consisting of an AISI 52100 steel ball rubbing against an AISI 52 100 steel plane on which the tested material is deposited.
A normal load F_N of 5 N is applied leading to a contact diameter of 110 µm (according to Hertz’s theory) and a maximum contact pressure of 0.75 GPa. The sliding speed is 4 $mm.s^{-1}$.
The solid lubricant films are deposited on the steel plane from polycrystalline powder by a burnishing method. The thickness of the obtained films is about 2-3 µm. Two protocols are used to study the intrinsic tribologic properties of the particles and the influence of liquid organic compounds.
a) The friction test is carried out on the deposited film to evaluate the friction coefficient of pure particles.
b) The tribologic test starts on the film and then the liquid organic compound is added to the contact. In the case of volatile liquid, the determination of the friction coefficient after liquid evaporation allows us to compare the tribologic behaviour with that observed under air.

Results and discussion

Figure 1 presents the evolution of the friction coefficients as a function of cycles number for pure graphite and at the addition of dodecane. As it can be noticed, after an induction period (30 cycles) attributed to the rearrangement of the particles, the friction coefficient of pure graphite in air is µ=0.08. When liquid dodecane is added the friction coefficient decreases immediately down to µ=0.05 and remains stable up to the end of the tribologic test.

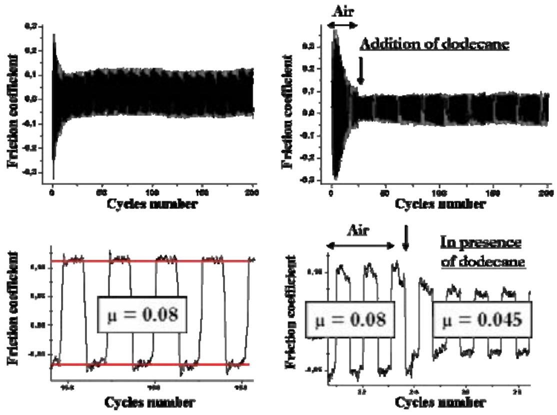

Figure 1: *Evolution, as a function of cycles number, of the friction coefficient of pure graphite and graphite in the presence of dodecane.*

Three hypotheses are first proposed to interpret these friction results:
- Intercalation of organic molecules in the van der Waals gap which can reduce the interlayers interactions,
- Adsorption of molecules on the crystallites, which can damp the interactions between particles,
- Hydrogen lubrication resulting from the degradation of hydrocarbon molecules.

X ray diffraction carried out on graphite powder in the presence of dodecane does not reveal any evolution of the interlayer spacing and then excludes the intercalation process.
The results of friction experiments in the presence of various organic molecules are presented in figure 2. The quite constant friction coefficient value equals to µ≈0.05 (except for cekanoïc acid µ=0.12) obtained for most of the molecules, whatever their surfactant properties are, strongly supports that the adsorption of molecules on the crystallites surface is not the main action mechanism implied in the friction improvement.
The use of carbon tetrachloride (CCl_4), which does not contain any hydrogen atoms, allows us to eliminate the hydrogen lubrication hypothesis.

The evolution of the friction coefficient of graphite as a function of the viscosity of the liquids introduced during the friction tests (figure 3) clearly shows that the increase of the viscosity results in an increase of the friction coefficient implying the presence of the liquid phase in the contact.

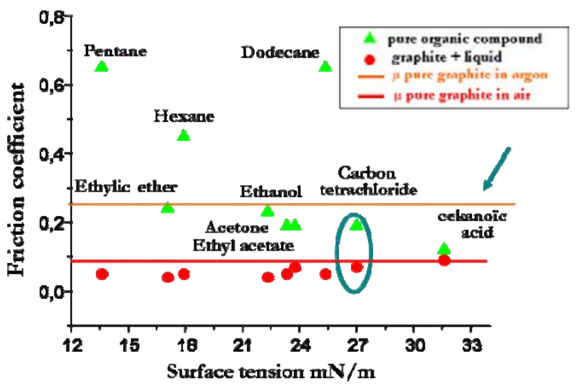

Figure 2: Evolution of the friction coefficient of graphite particles as a function of surface tension added organic liquid

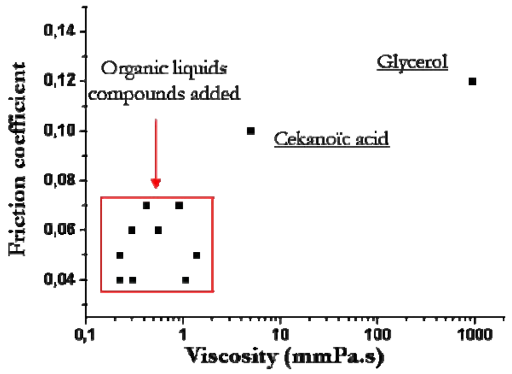

***Figure 3**: Evolution of friction coefficient of graphite particles as a function of the viscosity of the added liquids.*

Further tribologic tests confirm that the friction reduction process is mainly due to the simultaneous presence of organic liquid and particles in the sliding contact.

Raman spectroscopy is used to measure the crystallites size of the particles (La) [4]. Figure 4 presents the evolution of the crystallites sizes during the friction test of pure graphite and in the presence of ethanol. The crystallites size is greater for the films formed in the presence of organic liquid (La=30±10Å) than for the pure particles films (La=14±4Å).

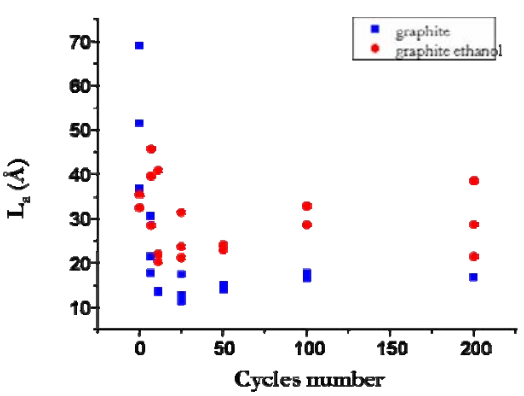

***Figure 4**: Evolution, as a function of the cycles number, of the crystallite size in tribofilms obtained with pure graphite and graphite in the presence of liquid ethanol*

These results point out that the fluid presence in the contact reduces the mechanical stresses undergone by the solid particles during shearing.

Figure 5 presents the evolution of the hardness measured on the two tribological films as a function of the displacement into the surface. Nano-indentation investigations show that the hardness measured in the ethanol/graphite film is lower than for film build with pure graphite particles.

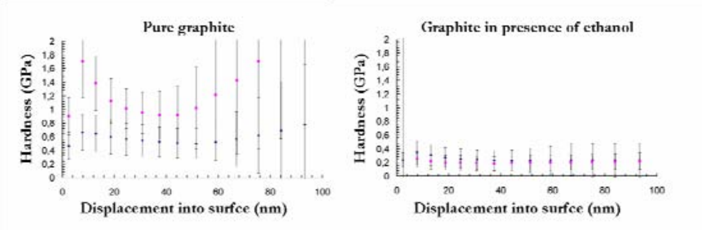

***Figure 5**: Evolution of the hardness as a function of indentation depth for pure graphite and ethanol/graphite films.*

A higher porosity of the ethanol/graphite film could explain the easier deformation of the film under pressure.

Conclusion:

The various tribologic experiments completed with initial materials and tribofilms characterizations allowed us to conclude that friction properties improvements of graphite in the presence of organic liquids mainly result from the simultaneous presence of solid particles and low viscosity organic liquid in the sliding contact. The presence of liquid between the nanoparticles reduces interaction between them and increases their mobility.

Acknowledgements

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References

[1] Landcaster, J.K., Tribology International, 23 (1990) 371

[2] Zaidi, H., Nery, H. and Paulmier, D., Appl. Surface Science, 70 (1993) 180

[3] Yen,B.K., Wear, 192 (1996) 208

[4] Tunistra, F. and Koenig, J.L., J. Chem. Phys., 53 (1970) 1126