TRIBOLOGICAL STUDY OF VARIOUS GRAPHITE POWDERS SLIDING AGAINST STEEL

M. Schmitt, S. Bistac

Institut de Chimie des Surfaces et Interfaces – CNRS
15, rue Jean Starcky BP 2488 68057 Mulhouse Cedex France

ABSTRACT

With its high resistance, good hardness and electrical conductivity in the basal plans, graphite is used for many years in various tribological fields such as seals, bearings or electrical motor brushes, and also for applications needing excellent lubrication and wear-reducing properties. But thanks to its low density, graphite is at the moment destined for technologies for which the combination of the possibility of reducing the weight of the components, and the ability of enhancing their efficiency is a fundamental asset. This is especially the case in the aeronautical industry where composites containing carbon, and more particularly graphite, are more and more widespread.

In this context, the friction and wear of industrially produced graphite powders were evaluated in order to identify promising tribomaterials for braking use. Six different powders (natural and synthetic) having various grains sizes, were tested when sliding against steel, under various applied normal loads. The morphological and structural modifications of the graphites were observed by Scanning Electron Microscopy and AFM, and analysed by Raman spectroscopy. A classification of the various graphite powders could thus be realised; the determining of the friction and wear mechanisms for the different materials, according to their own characteristics, as well as to the applied normal load, was also achieved.

1. INTRODUCTION

Graphite is a multipurpose material: it is used in fields as varied as metallurgic industry, transport and advanced technologies. Many studies have shown the influence of the environment on the graphite behaviour: its friction coefficient can be high in vacuum, whereas it is greatly reduced when working under oxygen or water vapour [1,2]; this decrease of the friction coefficient was attributed to the passivation of the dangling bonds created during the sliding [3]. But if the environment plays an important part in the tribological behaviour of graphite, the applied normal load is also of great importance, more particularly when this material is intended to be used for braking application. This study lies within the framework of the previous context as it focuses on the influence of the applied normal load, as well as of the grains size, on the tribological behaviour of graphite powders, having different origins, sliding against steel discs. The objective of this study is the elaboration of a classification of these six powders, as a function of their friction and wear performances, in order to determine the most adapted graphite for a given application.

2. EXPERIMENTAL DEVICE

Graphite pins

Six graphite powders, industrially produced, were tested; their characteristics and designation are detailed here:
- “A” and “B” families: these graphites are synthetic and present two different grains size, 15 µm (A15, B15) and 75 µm (A75, B75),
- “C” family: this is a natural graphite whom particles size is 10 µm (C10) and 75 µm (C75).

These powders are compacted with a press to get small graphite pins of 5 mm diameter and 3 mm height (Hv: 1.4 kg.mm⁻²).

Counterfaces

XC38 steel discs (44 mm diameter) are submitted to a polishing process in order to reduce their roughness to a value lower than 10 mm (Hv: 220 kg.mm⁻²).

Experimental conditions

The tests were carried out on a home-made pin on disc tribometer, at the ambient during 40 min. The sliding speed was set at the constant value of 0.015 m.s⁻¹ (10 rpm), and various normal loads were applied: 30.4, 40.4, 45.4 and 50.4 N.

3. RESULTS AND DISCUSSION

3.1. Characterization of the graphite pins before friction

SEM and AFM observations

Both SEM and AFM images indicate that the compaction of the powders leads to homogeneous pins, where the graphite particles are well organized: there is practically no empty place
and no stack. The surfaces of the natural graphites seem to be smoother than the ones of the synthetic graphites; the crystals of the powders having the biggest grains size, have a form of sheets with sometimes right angles, whereas the small grains size materials show crystals which are more rounded.

Raman spectroscopy
All Raman spectra, realised on the six different graphites, show a G peak around 1580 cm\(^{-1}\) coupled with a G' band centred in the neighbourhood of 2680 cm\(^{-1}\); these two bands are characteristic of the sp\(^2\) hybridisation of the carbon. The wavenumber of the G peak is clearly here shifted to the left (compared with the reference of 1580 cm\(^{-1}\)), indicating that the residual stresses in the pin are tensile ones [4]; this can be attributed to the partial expansion of the graphite sample after the compacting. There is moreover a D band (1360 cm\(^{-1}\)) on the Raman spectra of the graphites having the smaller grains size (A15, B15, C10); the existence of this peak is directly linked to the disorder of the structure.

3.2. Experimental results
The friction coefficients obtained at the end of the tests, are in the range of 0.10-0.16, which is in accordance with the literature [5]. All the graphite samples withstood the experimental conditions, except A75 and C10 pins which were totally destroyed during the sliding under 50.4 N.

a) Influence of the nature of the graphites
The role of this parameter is not easy to bring to the fore; however, some trends emerge: the friction coefficients of the C family (natural) seem to be the lowest, whereas the highest values are obtained during the sliding of graphite pins originating from the B family (synthetic). Friction tests were carried out under 30.4 N, for the six powders, during only one lap, to evaluate the very first steps of the friction, on fresh steel surface. Raman analyses realised on the pins highlighted particularities concerning the D peak:
- this band, which already existed for the small grains size graphites, becomes more important, indicating an increase of the disorder of the network,
- this peak appears for A75, B75 and C75 samples: a comparison of their three intensities shows that the A graphite is the less disorganized, whereas the structure of the C one is drastically modified (the D peak intensity becomes, in this case, higher than the one of the G band).
This more important structural modification for the C sample, could be linked to an increase of the amount of amorphous elements [6]. The structure disorganization in the graphite powders occurs then since the first lap of the sliding, and its consequences differ from the origin of the graphites.

b) Influence of the grains size
The friction coefficients of the graphites with the 75 µm grains size, are lower than the ones obtained with the 15 µm grains size powders; the only exception is noticed during the sliding of the B family at 40.4 N. SEM images indicate that even if the B15 and B75 samples seem to have smooth surfaces, “micro-steps” are visible on the contact area of the B75 graphite; these elements could constitute an obstacle to the sliding, that leads to a more important friction for the B75 powder.

c) Influence of the applied normal load
Different trends are noticed here:
- the friction coefficients of the A75, B15 and C75 graphites increase with an increase of the normal load,
- for the three other graphites, it seems that there is a maximum load (45.4 N) inducing an opposite variation of the friction coefficient.
The behaviour of the A75 graphite is examined here, as an example of a « linear » increase of the friction coefficient as a function of the normal load. This evolution can be explained as follows: the use of higher normal loads leads to more important local normal force on the contact asperities; these latest are then distorted, even flattened. The contact area becomes consequently greater, inducing thus higher friction coefficient.
The Raman spectra realised on the graphite pins, after sliding under various normal loads, indicate an increase of the D peak intensity, as well as the formation of a dissymmetry in the G band: the typical « graphite-sp\(^2\) » structure becomes clearly less important, and the structural disorder gains in importance as long as the applied normal load becomes higher.

4. CONCLUSIONS
This study dealing first with the characterization of various graphite powders industrially produced, and then with their tribological behaviour during sliding against XC38 steel discs (under various applied normal loads), has highlighted the following points:
- both SEM-AFM observations and Raman analyses realised on the pins, after compacting, show the structural differences (grains size, disorder) of the six powders,
- friction tests carried out during only one lap at 30.4 N, indicate that the disorganization of the surfaces, which occurs for the six graphites, is really important for the C75 sample,
- in the same experimental conditions, the friction coefficients of the graphites having the biggest grains size, are lower than those obtained with A15, B15 and C10 graphites, except for the B family at 40.4 N,
- an enlargement of the applied normal load leads to an increase of the friction coefficient for A75 and C75 graphites; for the four other graphites, it seems that a « limit » load could induce a complete change of the tribological behaviour.
This preliminary work on these graphites clearly indicates that complementary tests had to be performed in order to better understand their behaviour in friction and wear, and also to classify these powders in order to select the most appropriate for a specific application (braking, …).

REFERENCES