FRICTION CHARACTERISTICS OF SOME GRAPHITES AND CARBON COMPOSITES SLIDING AGAINST THEMSELVES

E. M. TATARZYCKI
The BFGoodrich Company Research and Development Center
Brecksville, Ohio 44141

Introduction

Researchers generally agree that the low coefficient of friction of graphite may be explained by its lamellar structure and the presence of a vapor film between these lamellar and other graphite debris. The concept of the lamellar theory is credited to Bragg[1] and later improvements to Holm[2]. Savage[3] showed that the low coefficient of friction of graphite depends upon adsorption films of water vapor. Later Rowl's[4] experiments showed that easily condensible gases(such as hydrogen, water vapor, oxygen and heptane) also resulted in low coefficients of friction. In more recent studies of carbons and graphites Lancaster[5] reported friction transients which he attributed to the desorption of water vapor. The purpose of this study is to describe the coefficient of friction-time-temperature relationships of some graphites and carbon composites and show that they are affected by the presence or absence of moisture.

Experimental Procedure

All the friction experiments were performed on a BFGoodrich developed machine called the Tribotester. This machine uses two identical disc type specimens rubbing against each other. One specimen rotates while the other remains stationary. Each specimen has an annular rubbing surface 6.35mm wide and a mean rubbing diameter of 5.08cm. Rubbing speed and load were maintained constant throughout each test at 0.69 m/s and 756 N respectively. Torque and interface temperature were recorded continuously as functions of time. Coefficient of friction was calculated. Duration of the test was limited to a rubbing distance of 2540m.

Three commercially purchased graphites, Pure Carbon PO-3, POCO AXF-5Q, and POCO AXF-90 were evaluated. In addition a BFG carbon/carbon composite(rayon based fiber in a pitch impregnated matrix) was studied.

All specimens were pre-conditioned in humid air,pre-heated in an oven or soaked in water. Test environment was ambient air, dry air, dry argon or moist air from a humidifier.

Results and Discussion

Because of the specimen geometry and design of the Tribotester a certain amount of heat buildup occurred in the specimens. At low speeds and light loads only a slight temperature increase was observed. For higher loads, higher temperatures occurred. At some point in the test an equilibrium condition was reached after which both the temperature and coefficient of friction remained constant.

Figures 1 and 2 show how the friction and temperature varied with time during the test. Figure 1 shows the behavior of carbon/carbon composite specimens which had been oven dried just prior to test. Thus, for all practical purposes the rubbing surfaces were void of moisture. Figure 1 shows a peaking of friction early in the test and before equilibrium was reached. Additional composite specimens were soaked overnight in water and then tested in the same manner. Results of these tests are shown in Figure 2. Peaking of the friction occurred just as it had with the dry specimens, but at the beginning of the test the friction was low. Other tests were run on specimens which had been pre-conditioned in humid air. Still others were tested with a moist air humidifier providing the ambient atmosphere. Results were identical to those of the water soaked specimens. Based on these results and the previous work of others it was hypothesized that the presence of water on the rubbing surface provided a lubricating effect as observed by the low friction. As rubbing proceeded, sufficient heat was eventually generated to evaporate the moisture from the surfaces and cause the sudden rise in friction which then caused the temperature to rise more quickly. Once the moisture evaporated the friction appeared to be temperature dependent as shown in Figure 3. Below a temperature of about 200°C the influence of moisture may be seen. At 200°C the friction peaks; beyond this temperature a single characteristic remains. Note that the friction decreases rapidly. At 400°C it has a value of 0.4. If rubbing is stopped at any time during the test(point A), the specimens permitted to cool down(point B) and the test restarted, the friction is determined by the surface temperatures at the initiation of rubbing(point C). Below 200°C(point D) the friction assumes the higher values if the surfaces are dry(point E). If, on the other hand, the surfaces are exposed to atmospheric air for a long period of time moisture is adsorbed and low friction results(point F). Many tests were performed to verify this reversibility of the friction-temperature relationship.

Being able to supply either a humid environment or wet surfaces was rather easy. To provide a dry surface was more difficult. Baking the specimens and cooling in a desicator was fine. After removal from the desicator but before startup there was sufficient time to permit the adsorption of moisture from the air. As long as specimen temperatures were maintained higher than 120°C adsorption would not occur, but below 120°C that possibility always existed.

Consequently, it was decided to not only pre-dry the specimens but to supply a dry atmosphere as well. Thus moisture-free air was purchased in bottle form and piped into a rather loosely enclosed chamber surrounding the test specimens when mounted on the Tribotester. A specimen which had been initially soaked was tested in the dry air chamber. As expected, it exhibited the wet friction characteristic. The test was continued until the temperature was well above 200°C. At this point the surfaces were moisture free and the Tribotest chamber was engulfed in dry air. The specimens were cooled to room temperature and retained in the dry air for four hours ensuring sufficient time for any possible adsorption to take place. Then the test was restarted and the observed friction behavior was that of a dry material. The same procedure was repeated several times with the same results. When a pre-dried specimen was used, the typically dry friction characteristic was also observed.

In order to fully resolve the possibilty that neither oxygen nor nitrogen was causing the low coefficient of friction the above tests were repeated but with dry argon gas instead of the dry air. Results were identical with those of the dry air tests. It was quite apparent that moisture was being adsorbed onto the friction surfaces and producing a lubricating effect. In the absence of moisture the magnitude of friction was determined by magnitude of temperature.

All of the above tests were performed on the BFG carbon/carbon composite. Other materials evaluated were commercially purchased graphites PO-3, POCO AXF-5Q and AXF-90. The frictional behavior of these materials is identical to that of the carbon/carbon composite.

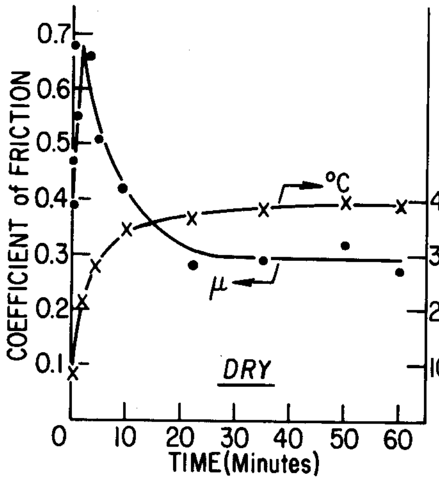

Fig. 1-Variation of friction and temperature with time for a dry carbon/carbon composite.

References

1. Bragg,W.L.,Introduction to Crystal Analysis, G. Bell & Son,Ltd.,London,1928,p.64.
2. Hohm,R.,Electrical Contacts,Hugo,Gerber, Forlog,Stockholm,1946,p.193.
3. Savage,R.H.,J. Appl. Physics,19,1 (1948).
4. Rowe,G.W., Wear 3, 274 (1960).
5. Lancaster,J.K., Wear 34,275 (1975).

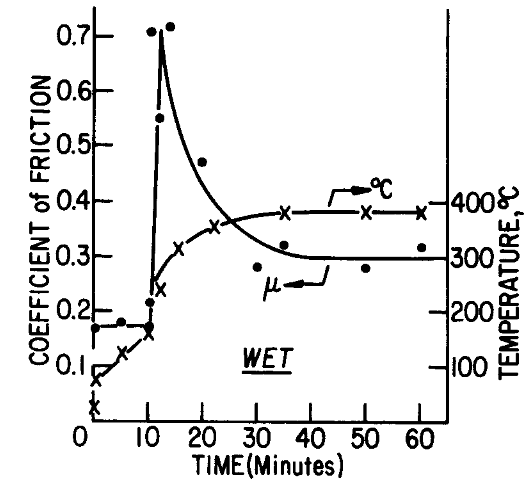

Fig. 2-Variation of friction and temperature with time for a wet carbon/carbon composite.

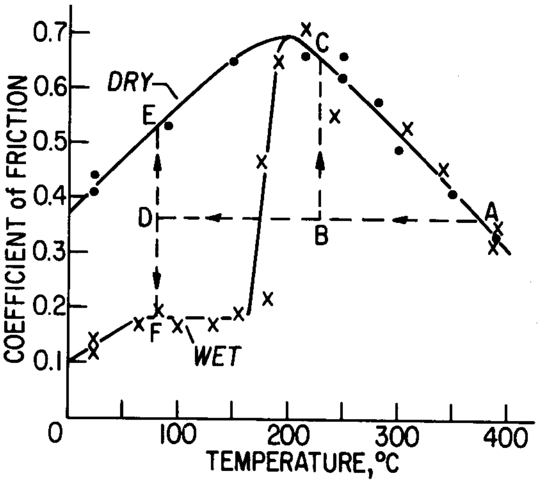

Fig.3-Friction-Temperature relationship showing reversibility of a carbon/carbon composite.