EFFECTS OF OXYGEN AND MOISTURE ON CARBON-COMPOSITE FRICTIONAL BEHAVIOR

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Introduction

Carbon-composite friction materials are state-of-the-art in aircraft brakes. They have demonstrated their ability to provide light weight, smoothly operating, long life systems which are capable of absorbing large quantities of energy while maintaining safe braking characteristics. Carbon materials also exhibit several unique properties which require specific consideration during the design of an integrated braking system. Among these are the tendency to show oxidation degradation at higher operating temperature, the susceptibility to friction reduction in the presence of moisture, and a slow speed (or static) friction coefficient which is sensitive to both temperature and the environment. These properties have been found to some degree in all of the carbon-composites evaluated at Bendix, including those fabricated by suppliers other than Bendix. The slow speed (static) behavior is of particular interest for aircraft with high residual thrust or those operating on aircraft carrier decks. This paper discusses the first phase of an investigation of such slow speed and static friction phenomena, and the role played by the environment in modifying such behavior.

Experimental

Testing was conducted on a small shaft dynamometer containing a specimen environmental chamber constructed so that a fixed flow rate of a chosen gas could be maintained around the friction specimens. The flowing also assisted in cooling the specimens between simulated braking engagements. The test specimens were carbon-composite rings 2-3/16 in. (5.56 cm) O.D. by 1-3/8 in. (3.49 cm) I.D. and 0.25 in. (0.64 cm) thick. For a given test, both rings were of the same composition. During this investigation the kinetic energy absorbed during a dynamic braking engagement (mass loading) was varied over the range of 130,000-1,000,000 ft.lb./lb. and the normal force was varied over the range of 30-540 psi. Initial sliding velocity of dynamic engagements was in the range of 20-60 ft./sec. A thermocouple for bulk temperature indications was imbedded in the stationary ring.

Increased moisture content in the atmospheres was obtained by blending dry gas with gas passed through a bed of distilled water. For each dynamic brake stop, records were made of generated torque, bulk temperature and time to complete the stop.

The test technique consisted of exposing the test rings to a series of identical simulated braking engagements in a chosen atmosphere, continuing until the dynamic friction coefficient was stable. At the completion of the stop, the normal force was allowed to remain applied, and as the cooling friction discs reached the desired temperature, sufficient force was exerted on a lever arm attached to the flywheel to initiate sliding and to continue relative motion through a circular arc of approximately 1 cm. Recordings of the generated torque were used to calculate the friction coefficients.

While results from the small dynamometer are qualitatively transferable to a full-scale brake system, the specific values for friction coefficient are not identical. Therefore, data on friction in this paper will be presented in relative terms to amply define the observed phenomena without inferring specific values to any brake system.

Results and Discussion

Carbon exhibits a dome shaped curve of static friction coefficient vs. temperature. Values for static friction at both high (+ 400°C) and low (< 150°C) temperatures are most frequently below the average dynamic friction generated during the immediately preceding stop. At all but the lowest temperatures there is no significant difference (independent of temperature) between the force required to initiate sliding and that required to sustain slow relative motion, and even near room temperature where an initial "spike" may occur in the torque measurement. The peak is almost always below the dynamic value. Further, the same temperature dependence of friction is observed if a continuous relative motion (~ 1 cm/sec.) is maintained during the complete cooling cycle. Repeated measurements taken at approximately 5 second intervals at 66°C gave no variation in friction, tending to rule out the effect of sliding distance.

The result of changing the atmosphere in the test chamber from air to nitrogen is shown in Figure 1. Little increase in friction at high temperatures is seen but the low temperature drop is completely eliminated. Figure 2 shows the effect on a different specimen of increasing the moisture content of a nitrogen atmosphere. A small but significant drop in friction at both high and low temperatures is seen. The effect of moist air is much greater as shown by the test presented in Figure 3. A moderately humid atmosphere results in the complete elimination of the dome effect. Also shown in Figure 3 is a static friction test on a specimen run in dry air but which followed the soaking of the specimen surfaces in liquid water for one minute prior to the dynamic stop. Sufficient water was contained in the specimens to reduce the maximum temperature obtained during the dynamic stop. It is possible that sufficient moisture was still present in the sample tested at wet bulb 20°C for it to act in a similar fashion. The strong effect that the degree of prior work at the surface has on static friction near room temperature is shown in Figure 4. Here, a good relationship is found between static friction at 66°C and the product of mass loading and surface loading (average horsepower per square inch).

The mechanism of static friction is essentially mechanical in character. The drop in friction is related to conditions which ease the shearing of carbon or graphite platelets at the sliding interface. Although the reason for the high temperature drop is not understood, the reduction at lower temperatures appears to be clearly related to moisture. It is most enhanced by the presence of oxygen, generally accepted to be a requirement for any significant adsorption of water. The reduction in the presence of moist nitrogen is thought to be related to small amounts of oxygen being desorbed from the substrate during the high temperature portion of the braking engagement, although the interaction of water with possible nitrogen complexes is not ruled out. The decreasing value of room temperature static friction with increasing energy loading suggests that higher temperatures and longer cooling times in air increases moisture pickup.

This work is continuing with particular interest in separating the surface condition effects from moisture adsorption effects, and with further definition of the conditions responsible for the high temperature drop in static friction.

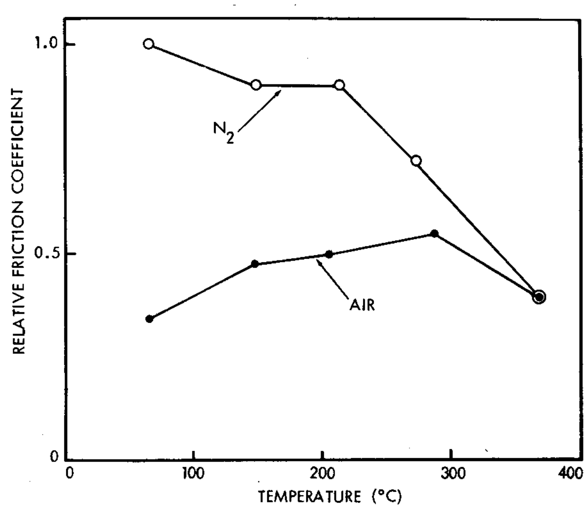

Fig. 1. Effect of Excluding O_2 on Static Friction. Prior Dynamic Mass Loading - 580,000 Ft. Lb. /Lb.

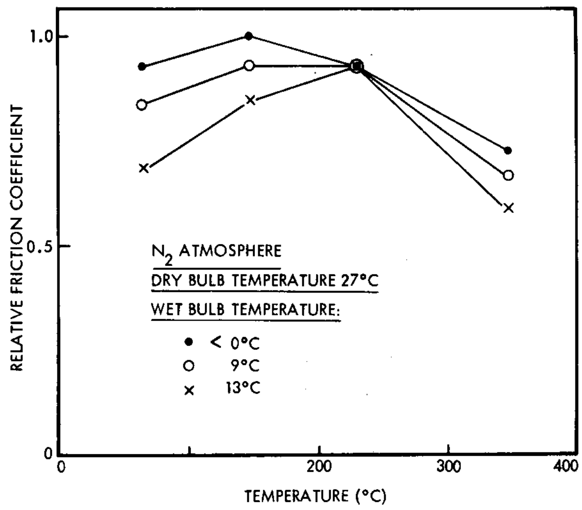

Fig. 2. Effect of Moist N_2 on Static Friction. Prior Dynamic Mass Loading - 580,000 Ft. Lb. /Lb.

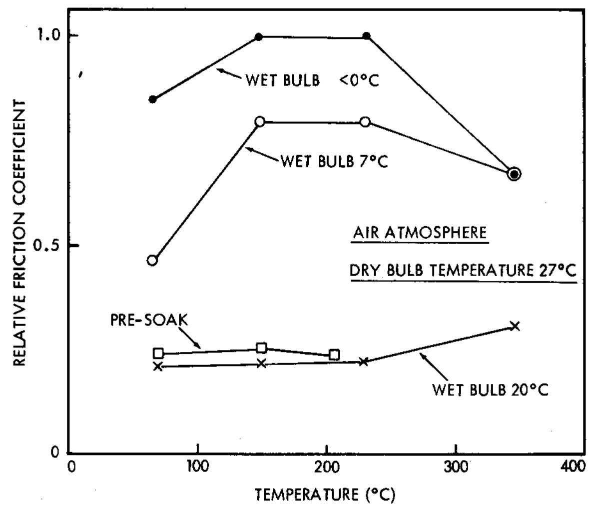

Fig. 3. Effect of Moist Air on Static Friction. Prior Dynamic Mass Loading - 580,000 Ft. Lb. /Lb.

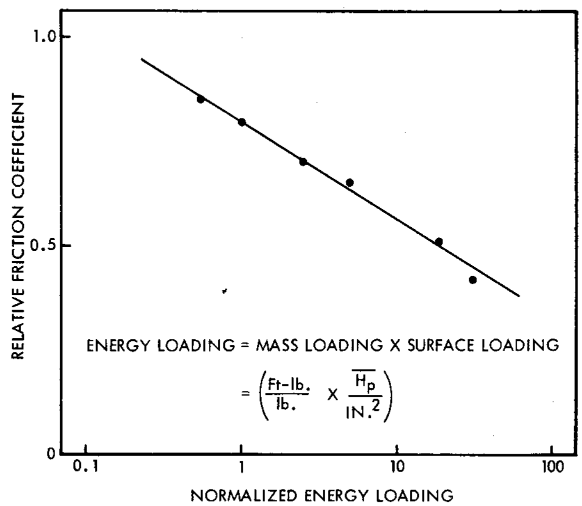

Fig. 4. Effect of Prior Energy Loading on Static Friction at 66°C.