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SEM and SPM studies of friction composite materials based on carbon graphitized fibers

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Carbon composites based on graphitized fiber and pitch matrix demonstrate high wear resistance and heat resistance, which makes them an ideal material for the manufacture of brake discs in the aircraft industry. The influence of the microstructure of graphitized fiber on the structure and wear resistance of friction composite materials was investigated and discussed.

Two samples of materials – type №1 (reference) and type №2 – were tested. The only difference in the production technology of these materials was the different composition of fiber impregnation (apret) before their graphitization. However, the samples showed a significant difference in wear resistance during friction testing. Samples were studied after tests carried out at the IM-58 friction machine. In order to estimate the effect of the microstructure of the fibers and the structure of the finished materials on their wear resistance, investigations were carried out using optical (OM), scanning electron (SEM) and scanning probe microscopy (SPM) methods. High resolution images of the friction surface of the samples were obtained using the SPM Smart SPM TM. AIST-NT cantilevers (fpN10), operated in taping mode with beam stiffness – 10-20 N/m and resonant frequency 200-300 kHz were used. The maximum scanning field was 100x100 µm.

The tribological tests showed that the wear resistance of samples of type №2 is much lower. This was explained by the SEM and AFM investigations. Figure 1 shows the SEM images of single fibers of composite materials (samples of type №1 and type №2).

a b

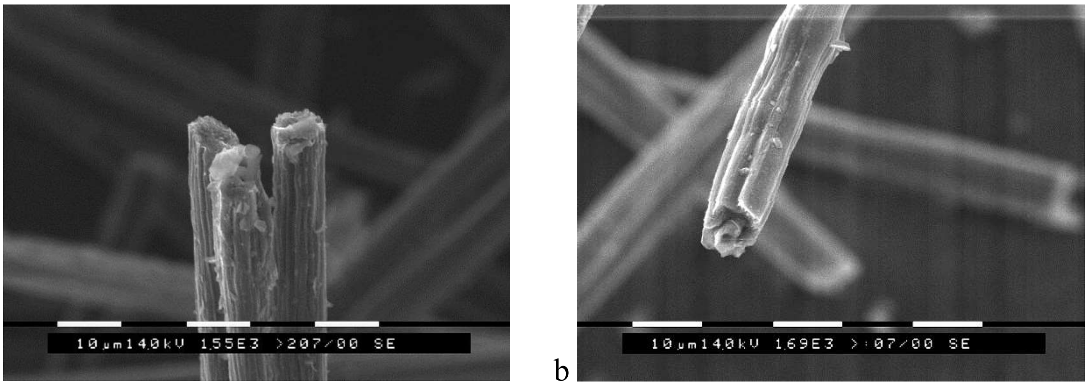

Figure 1. SEM-images of single fibers of composite materials: (a) sample of type №1 (reference), (b) type №2.

It is clearly seen that the structure of fiber (sample of type №1) consists of a large number of even plates, which are crystalline layers of graphite. The fiber sample of type №2 consists of a smaller number of thicker layers, which also have an uneven shape along the fiber axis. This leads to significant changes in the shape of the lateral surface of the fiber. The lateral surface of the fiber of reference sample type №1 has smooth fins of crystalline graphite layers, while the fiber of sample type №2 has an irregular shape with cracks and depressions. Changes in the surface structure of the fiber lead to changes in the layers of the matrix adjacent to the fibers. During the formation of the pitch matrix, carbon layers are formed around the fibers during the pyrolytic decomposition of the oil pitch. The structure of the layers of the matrix surrounding the fiber depends on the structure of the surface of the fiber. This leads to a change in the entire layered structure of the composite material.

SPM studies were carried out for a detailed study of the layers of the matrix surrounding carbon fibers. Figure 2 shows SPM images of the surface of composite materials of two samples after friction tests.

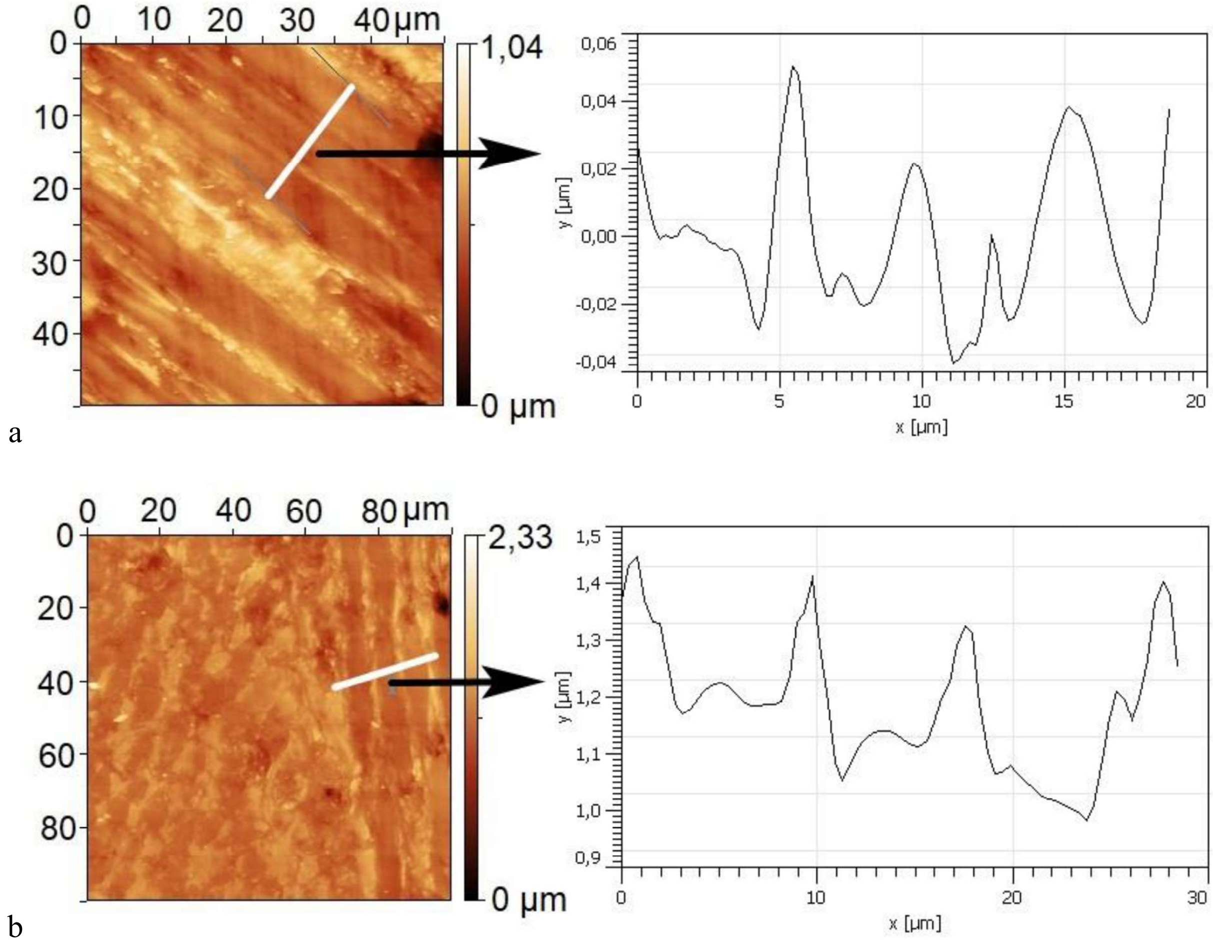

Figure 2. SPM-images of the surface of composite materials: (a) the morphology of material of samples of type №1 and the section profile; (b) the morphology of the material of samples of type №2 and the profile of the secant.

Analyzing profilograms of friction surfaces obtained using the SPM method, we can draw conclusions about the properties of the fiber and the matrix and their relative position. An important feature of the material of samples type №1 (Fig. 2 a) is that the difference of the levels of the surface around the underlying fiber are small – they are of the order of 0,01 µm, that is, the fibers are actually flush with the matrix. This means that the wear rates of the fiber and the matrix are almost identical, which ensures optimum wear resistance of the material as a whole. In materials of sample №2, the fibers lie noticeably below the level of the matrix – by 0,3–0,4 µm (Fig. 2 b). This means that, firstly, the wear resistance of the fibers of sample №2 is lower than the wear resistance of the matrix, and hence the wear resistance of the reference fibers. Secondly, the increased roughness causes an additional increase of wear by the abrasive mechanism.

The results obtained allow us to conclude that small changes in the production technology of fibers lead to significant changes in the structure and properties of the finished fibers. These changes effect on the wear resistance of the composite material as a whole.

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