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Effect of sapphire crystal structure peculiarities on attrition wear

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The attrition wear of sapphire has been shown to depend substantially on its crystal structure. The wear difference is of 1.1 to 2.1 times when the treating is performed using a free abrasive and of 1.1 to 2.9 times when the abrasive is fixed.

Показано, что износ сапфира истиранием существенно зависит от его кристалличес-кой структуры. При обработке свободным абразивом отличие в износе составляет 1,1–2,1, при обработке закрепленным абразивом — 1.1–2.9 раза.

The effect of sapphire crystal structure on its attrition wear is not studied today although the material is used widely in friction pairs of modern mechanisms. Sapphire is an anisotropic crystal with substantially different reticular density of crystallographic planes. So the atomic density in the (0001) plane is 0.2254 atoms per Angstrom unit while being almost two times lower (0.1199 atoms per Å) in the $\{11\bar{2}0\}$ plane [1]. Such a considerable density difference combined with even more considerable (2.5 times) one in interplane distances caused by specific morphologic and structural features of α-Al_2O_3 unit cells give rise to anisotropy of optical, chemical [2] and mechanical characteristics of the material.

This work is aimed at the attrition wear study of main crystallographic planes of sapphire under mechanical loading. The attrition wear rate was examined for 5 mm thick samples of 13 mm in diameter cut out of sapphire crystals grown by Stepanov technique. The planes being studied were parallel to the crystallographic ones used most often in engineering practice. The samples were treated by a free or fixed abrasive (80 to 28 μm grain size) using a 3ShP-350M machine, the spindle rotation speed was 100 revolutions per minute and loading was varied from $2.2\cdot10^{-2}$ to $1.1\cdot10^{-1}$ kg/mm^2.

The Table below presents the data obtained by averaging over four experiments. The wear rate was controlled by an indicator (the least division 1 μm). The spread in measured values was 6%.

It follows from the Table that the minimum wear rate is observed in the basis plane under treatment by both free and fixed abrasive. The maximum wear rate values are obtained in the plane parallel to $\{10\bar{1}0\}$ one under treatment by free abrasive and in that parallel to $\{10\bar{1}1\}$ one in the case of fixed abrasive. The observed substantial differences in the sample wear rate seem to be due to the effect of the grinding regime on the cleavage mechanism that, in turn, depends directly on the crystallographic orientation. So, when the wear is due to the free abrasive, its rate is in correlation with the quantity reciprocal to the reticular density of atoms in the planes under study and with that reciprocal to the number of free bindings per unit surface area.

The grinding mechanism by fixed abrasive differs somewhat from that using the free abrasive. When cutting into sapphire, a rapidly moving abrasive grain fixed in a