Boron nitride powder as lubricant additive

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1 Introduction

Boron nitride (BN) is a solid lubricant with a laminar crystalline hexagonal structure similar to that of graphite and MoS_2. It has been considered less effective than other solid lubricants, especially compared to the highly successful graphite and MoS_2. Its use has practically been limited to high temperature applications where graphite and MoS_2 fail due to decomposition or reaction. In recent years, however, it is re-evaluated as a clean lubricant for its white color and non-toxicity. The present work reexamines its possibility as a lubricating additive when used with lubricating oil.

2 Experiments

For the experiments a ring-roller tribometer was used. Three sliding rollers are placed on a ring to make an initial line contact. Ring and rollers are made of hardened bearing steel (SUJ2) with a hardness of 750 HV, Ra = 0.04 μm (rollers) and Ra = 0.09 μm (ring). Measured are the coefficient of friction and the wear rate under three sliding speeds (52.3, 157, and 785 mm/s) and two loads (392 and 784 N), all at an oil bath temperature of 40° C.

The oil used was JS15, grade VG15, a pure paraffinic oil (0.013 Pas), with addition of BN powder which was dispersed using continuous stirring. The lubrication regime was in most cases boundary or sometimes mixed lubrication.

3 Results

Addition of BN powder to the lubricating oil (no detergent used) gave for all tested powders a rise in friction coefficient compared to the situation without BN, from 0.08 (no BN) to 0.11-0.13 (with BN). However the fluctuations in the friction coefficient signal were much less; the friction coefficient seemed more stable. The most interesting effects occur in the change of BN content. Adding BN gives for all types a reduction in wear rate, dependent on the BN content. The best performance is at 4 weight%, where most powders realize a wear reduction of a factor 10 compared to the non BN case.

BN powder particle size, shape, crystallinity and purity proved of no significance, unlike expectation. Influence of the sliding speed and the average pressure were also investigated. In the case of the BN added case it was found that the higher load resulted in a higher wear rate, about two times higher, for the low and medium speed case. For the non BN case this was reversed; the high load gave a two times lower specific wear rate. Still, the effect of BN addition was clearly marked with a factor 10 less wear compared to the non-added case. For the highest speed, the differences between the high and low load and the BN and non BN case became almost zero. By varying the average contact pressure by using a modified test setting with instead of an initial line contact a plane/plane contact the influence of pressure was further investigated. The result for the lower contact pressures is not convincing for the application of BN additives, however in case of the higher pressures, i.e. above 100 MPa, the beneficial effect of BN shows.

The first successful tests were carried out without using a detergent to improve the suspension of the particles in the oil, only mechanical mixing was used. Later tests in which a detergent was used didn't give the good results obtained before without detergent. This means detergents have an big influence in this case on the lubricating mechanism.

4 Analysis

By using ESCA and EPMA tests it was found that the wear reducing effect was likely to be because of the presence of BN and not other reaction products like BO_xN_y, BO_x and BN_x, although those are present on the surface as well.

The mechanism behind the anti-wear behavior of BN additive is hardly investigated before. From the experiments done here it is possible to get some clues about the mechanism. Most likely the BN particles react under influence of high flash temperatures and mechanical shear with the metal surface, despite the fact that BN under static conditions is rather stable. In the concentrated contacts a lot of energy can be generated to fuel chemical reactions. The more severe the conditions, the more energy is available; from the experimental results it shows that high loads are needed for the anti-wear effect to occur. From an energy point of view the BO_xN_y, BO_x and BN_x are more favorable than BN, so once the energy barrier has overcome, by means of the load conditions, those form will be generated. It is known that these oxide have good attaching properties to a steel surface so a thin layer will be formed on the surface. What will happen next is not clear; either more of the same products will adhere to this layer, or BN itself will adhere to the intermediate layer. Because the particle size of the BN additive is of no influence of the mechanism, it is likely that the particles will be either crushed during sliding or will only react at the surface, giving off small BN parts, building thin layer over thin layer. The detergents form a surface active layer over the BN particles, thus preventing reactions of BN with the surface. This explains the poor performance of BN addition to oil with detergent added.

Also from ESCA analysis it shows that severer conditions cause more BO_xN_y, BO_x and BN_x to be generated. Besides that, less severe, mixed conditions don't show any benefits from BN.

5 Conclusions

The work done shows that there are opportunities to use BN powder as additive to oil. Still problems remain for successful applications: use of traditional, e.g. surface active or polar, detergents is not possible, and the coefficient of friction remains rather high. To avoid the first problem, that is how to make an effective suspension of the particles in the lubricant, the use in grease might be possible, as is done with MoS_2 when mixed with lithium soap based greases.

However, the advantages of non-toxicity and white appearance give incentives to continue the research. Also BN could be in some cases an alternative to MoS_2, thus widening the options of the tribologist.