ISSN 1063-4576

Journal of SUPERHARD MATERIALS

(Sverkhtverdye Materialy)

SHM

4

Vol. 20

1998

Allerton Press, Inc./NewYork

CONTENTS

VOLUME 20 **NUMBER 4** **1998**

Special issue

JOURNAL OF SUPERHARD MATERIALS

Proceedings

of the Seminar on nanometric diamond held at
V. Bakul Institute for Superhard Materials of the National Academy of Sciences
of Ukraine, Kiev, on February 24—25, 1998

	PAGES RUSSIAN	PAGES ENGLISH
Preface	3	1
Structure, substructure and phase composition of DSD and UDD ultradispersed diamond. G. P. Bogatyreva, Yu. I. Sozin, and N. A. Oleinik	5	3
Effect of desorbed gases on high-pressure sintering of diamond powders. A. A. Bochechka	10	8
Production facilities for synthesis of ultradispersed diamond. T. M. Gubarevich, A. P. Korzhenevskii, and D. N. Gamanovich	17	14
Structure features of explosion-synthesized nanodispersed diamond. A. V. Kurdyumov, N. F. Ostrovskaya, V. B. Zelyavskii, N. I. Borimchuk, and V. V. Yarosh	23	20
Physicochemical properties of fractions separated in ultradispersed diamond powders. S. I. Chukhayeva, P. Ya. Detkov, A. P. Tkachenko, and A. D. Toropov	29	26
Structure of polycrystals produced by sintering dynamically synthesized diamond powders. V. F. Britun and A. V. Kurdyumov	36	33
High pressure–high temperature compaction behavior of ultradispersed diamond powders. E. V. Zvonarev, V. T. Senyut, I. M. Starchenko, and V. M. Finskaya	41	38
Effect of gas desorption on the structure and properties of polycrystals sintered of nanometric diamond powders. A. A. Shulzhenko, A. A. Bochechka, V. G. Gargin, A. G. Gontar, L. A. Romanko, and V. N. Tkach	46	43

(continued)

© 1999 by Allerton Press, Inc.
Authorization to photocopy individual items for internal or personal use, or the internal or personal use of specific clients, is granted by Allerton Press, Inc. for libraries and other users registered with the Copyright Clearance Center (CCC) Transactional Reporting Service, provided that the base fee of $50.00 per copy is paid directly to CCC, 222 Rosewood Drive, Danvers, MA 01923.

	PAGES RUSSIAN	PAGES ENGLISH
Evolution of the compact structure during high-pressure sintering of nanodispersed diamond. V. V. Danilenko, I. A. Petrusha, G. S. Oleinik, and N. V. Danilenko.	53	49
Prospects for development and application of antifriction composites based on bronzes reinforced with detonation-synthesized diamond. V. M. Volkogon.	62	57
Structure of crystallites of ultradispersed diamonds. V. D. Andreyev and Yu. I. Sozin.	67	61
Preparation of wear-resistant antifriction composite coatings reinforced with ultradispersed diamond. V. S. Antonyuk.	72	66
Experience in and prospects for non-conventional use of detonation-synthesized ultradispersed diamond. V. Yu. Dolmatov.	77	70
Characterization and some properties of explosion-synthesized diamond powders. G. P. Bogatyreva and M. N. Voloshin.	82	74
Structure of suspensions of the explosion-synthesized ultradispersed diamond (nanodiamond). L. V. Agibalova, A. P. Voznyakovskii, V. Yu. Dolmatov, and V. V. Klyubin.	87	79

Journal of Superhard Materials
Vol. 20, No. 4, pp. 66–69, 1998

Sverkhtverdye Materialy
No. 4, pp. 72–76, 1998
UDC 621.891

PREPARATION OF WEAR-RESISTANT ANTIFRICTION COMPOSITE COATINGS REINFORCED WITH ULTRADISPERSED DIAMOND

V. S. Antonyuk

Kiev

This paper deals with the formation of wear-resistant antifriction coatings on components of friction couples. We suggest a new antifriction composite material containing nonferrous intermetallic compounds reinforced with explosion-synthesized ultradispersed diamond, to be used for coating friction surfaces. We report the experimental results and by the example of sleeves of internal combustion engines we show the efficiency of using this material as a functional coating for friction couples.

One of the modern engineering problems is to improve quality, reliability and service life of machinery, to reduce production and repair costs. Analysis of these problems shows that the service life of machinery can be prolonged by making its components of expensive high-alloy materials and nonferrous alloys in mass production. However, this way is not economically attractive. Therefore, the most promising method is to apply functional coatings on working surfaces of components made of structural steels.

There exist various methods of applying wear-resistant coatings and the preparation of heat-resistant antifriction coatings by a friction contact holds the greatest promise. Depending on the contact conditions of the friction couple (load, speed, environment, etc.), a wear process occurs such that the friction surfaces suffer no macroscopic damage, while their micro- and submicroreliefs are optimized.

There is a certain range of the loading and environment parameters of contact which permits the formation of a film on the surfaces in contact. The film is cellular in structure with an irregular arrangement of atoms.

The resultant secondary structures are metastable solid solutions or nonstoichiometric compounds. The best tribotechnical properties are achieved when both types of the secondary structures are present in the friction couple. In this case, the friction couple wear is a minimum. This can be attributed to the fact that the films of nonstoichiometric compounds exhibit a substantial adhesion to liquid and solid lubricants, while those of metastable solid solutions are wetted with the lubricants and the shear is localized at the lubricant–film interface.

As a result, when identical materials rub against each other, the films of the same type form on both surfaces. This increases the coefficient of friction and wear.

Structures similar to the metastable solid solutions form on the surface of ferrous materials (hardened steels, cast iron, etc.), while the structures like nonstoichiometric compounds form on nonferrous metals and alloys.

The antifriction property of couples in contact can be controlled by optimizing their surface condition and by using materials that are not prone to seizure when in operation, as well as by providing the necessary operating conditions because the processes of friction and wear occur in the field of dynamic fracture and regeneration of the secondary structures. The mechanism of these phenomena is not clearly understood. Therefore, the efforts aimed at studying the physical and chemical mechanisms of the processes proceeding in friction acquire a special importance.

© 1999 by Allerton Press, Inc.
Authorization to photocopy individual items for internal or personal use, or the internal or personal use of specific clients, is granted by Allerton Press, Inc. for libraries and other users registered with the Copyright Clearance Center (CCC) Transactional Reporting Service, provided that the base fee of $50.00 per copy is paid directly to CCC, 222 Rosewood Drive, Danvers, MA 01923.

The development of antifriction materials to operate under severe loads and high temperatures is based on adding various nonmetallic aids to composites that act as solid lubricants and protect the metallic surfaces against seizure. In operation, a so-called active layer can form on the working surfaces of the friction couple to prevent seizure. This layer is built up from the friction-couple wear products which are distributed on the working surfaces in the course of operation. Thus, we can consider the additives as both a reinforcing component of the composite, which increases the material's bearing capacity, and a solid lubricant whose functioning consists in separating the rubbing metallic surfaces to prevent their direct contact and localizing shear deformations in the lubricant layer thus reducing considerably friction and wear. When deciding on a solid lubricant, we must take into account its properties, and especially, its thermal conductivity to ensure an efficient heat removal from the friction surface.

Based on this reasoning, it seems promising to develop new antifriction composites based on nonferrous intermetallic compounds reinforced with ultradispersed diamond particles.

We carry out purposeful studies of processes of the formation of functional coatings on friction couples, using an antifriction composite material based on the copper–zinc–tin intermetallic compound reinforced with the explosion-synthesized ultradispersed diamond (UDD). The UDD particles synthesized by explosion in the form of clusters form a multilevel structure and have a large specific surface and thus an enormous surface energy. The UDD particles combine unique properties such as high hardness, thermal and chemical stability, good antifriction properties and are a unique reinforcing element for a metallic matrix of the composite material.

We applied the antifriction coatings onto the friction-couple surfaces, either dry or in the presence of various activating materials, by friction transfer of the antifriction material onto the working surfaces [1]. The preparation of the antifriction surface of the friction couple involves preconditioning to ensure a special microrelief on one of the surfaces and fill it with the antifriction material. The relief is prepared in the form of peaks and valleys to a depth corresponding to the total ratio of their areas. In doing so, we must preserve a special cross-hatching pattern (in terms of a relative depth and intersection angles of the grooves) and the formation of special surface roughness sections which increase the reference length of the surface microprofile. A positive result can be achieved by a proper choice of the depth of valleys and the respective peak-to-valley area ratio.

Let us illustrate the preparation of the antifriction coating containing the new composite material by means of the preferential transfer in the course of the friction contact by the example of the antifriction treatment of sleeves of internal combustion engines. For this purpose, we used the antifriction composite to make honing stones with the working surfaces of hardness 45–50 HRB. Then, we used these stones to machine specimens of a hardness HRC >40.5. The application of the antifriction coatings on the sleeve surface involves the following.

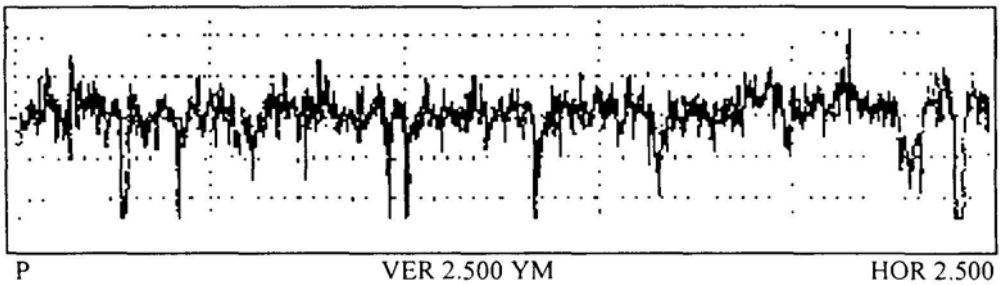
The as-washed and dried sleeve with a preconditioned relief was coated with the antifriction composite of the stone by honing. This was done on a Mod. Z3-400-160 (GEHRING) vertical honing machine with UMDA 15 MK3 honing stones at a spindle speed of 120 rpm and a stroke rate of 24.5 m/min. The gage pressure in the stone expanding system was 0.5 to 0.7 MPa.

Preliminary test runs aimed at optimizing the duration of the dry antifriction treatment which were carried out for 2 min have demonstrated that after 30 to 40 s the working surface was completely saturated with the antifriction material and its surface roughness changed from R_a = 0.76–0.95 μm (prior to coating) to R_a = 0.37–0.4 μm (after coating). The thickness of the resultant antifriction film was 0.4 to 0.5 μm.

To get a deeper insight into the formation of the antifriction coating and to estimate the efficiency of using the dry antifriction treatment under the production conditions, we treated a working surface of sleeves of a SMD-31 power-saturated internal combustion engine. In doing so we changed the honing sequence. In the conventional honing consisting of four operations (preliminary honing with AS 400/315 MP6-50 stones, course honing with AS65 250/200 MP6-50 stones, basic honing with ARK4 125/100 MP5.03-50 stones, and final honing with ASM 28/20 M5.01-50 stones) we eliminated the final operation and replaced the above-mentioned stones with AS50 400/315 MK2-100, AS50 250/200 MK1-100, and AS15 63/40 MK1-100 stones in the preliminary, coarse, and basic honing operations, respectively. These changes in the production

process were made in order to prepare an optimal microprofile of the work surface for the subsequent dry antifriction treatment with UMDA 15 MK3 stones.

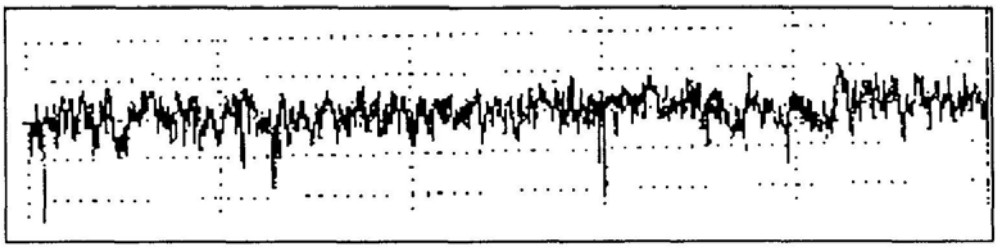
The profile charts of the work surfaces as measured with PERTHOMETR S8P device (FEINPRUFT, Germany) have shown that after the basic honing operation (Fig. 1) the surface had the following surface roughness parameters: R_{max} = 18.84 μm, R_z = 7.34 μm (according to DIN 4767, DB 31007) or R_{max} = 18.84 μm, R_z = 14.49 μm, R_a = 0.88 μm (according to GOST 2789-73), and after the dry antifriction treatment (Fig. 2) R_{max} = 8.76 μm, R_z = 3.66 μm (according to DIN 4767, DB 31007) or R_{max} = 8.76 μm, R_z = 6.79 μm, R_a = 0.62 μm (according to GOST 2789-73), the relative reference length of the profile t_p being 90%.



P VER 2.500 YM HOR 2.500

LC GS	0.800	MM	LC	GS	0.800	MM
>RMAX	18.84	YM	P	TP(3.43 5)	0	%
RZ	14.49	YM	P	TP(0.00 5)	5	%
RA	0.88	YM	P	TP(-1.00 5)	27	%
P SM	168.9	YM	P	TP(-2.00 5)	71	%
P TP (-0.50 5)	83%		P	TP(-3.00 5)	90	%
R3Z	7.54	YM	P	TP(-4.00 5)	95	%
			P	TP(-5.00 5)	97	%
			P	TP(-6.00 5)	97	%

Fig. 1. Profile chart of the surface of a sleeve of an SMD-31 engine. The final honing operation was carried out with AS15 63/40 MK1-100 stones.



P VER 2.500 YM HOR 2.500

LC GS	0.800	MM	LC	GS	0.800	MM
>RMAX	8.76	YM	P	TP(0.98 5)	0	%
RZ	6.79	YM	P	TP(0.00 5)	5	%
RA	0.62	YM	P	TP(-1.00 5)	34	%
P SM	121.4	YM	P	TP(-2.00 5)	77	%
P TP (-2.50 5)	90 %		P	TP(-3.00 5)	97	%
R3Z	3.66	YM	P	TP(-4.00 5)	99	%
			P	TP(-5.00 5)	100	%
			P	TP(-6.00 5)	100	%

Fig. 2. Profile chart of the surface of a sleeve of an SMD-31 engine. The dry antifriction treatment was performed with UMDA 15 MK3 stones.

Testing of thus treated sleeves of internal combustion engines has demonstrated the efficiency of the antifriction composite coatings in preventing burns, scores and seizures, with a significant reduction in internal friction losses. The running-in period of the ring–sleeve couple after the antifriction treatment was 6 to 8 hours. This efficiency of the coatings was achieved mainly due to the presence of UDD-based reinforcing additives in the composite. The structure of the film and the distribution of the UDD particles there call for a thorough investigation. Thus, the present study has shown that using the composite based on copper intermetallic compounds reinforced with explosion-synthesized ultradispersed diamond particles one can prepare highly efficient functional coatings that have considerable promise.

REFERENCES

1. I. V. Kragelskii, M. N. Dobychin, and V. S. Kombalov, Fundamentals of Friction and Wear Calculations [in Russian], Mashinostroenie, Moscow, 1977.

National Technical University of Ukraine
(former Kiev Polytechnical Institute), Kiev