Diamond jet-forming nozzles.

N.I. Polushin
State Technological University «Moscow Institute of Steel and Alloys» (MISIS),
Leninsky pr.4,Moscow, 117936, Russia
polushin@misis.ru

1 INTRODUCTION

This paper presents the results of the work on obtaining and studying the features of composite polycrystal material on the basis of nano-dispersed diamond powder and ceramic and metal bonds. TiN, TiCN, N and Ni-Cr alloy were used as the bonding agents. As the result, the polycrystals with the unique abrasive wear resistance were obtained by HPHT method. The following features are characteristic for the polycrystals obtained:

a) hardness – up to 80 GPa
b) abrasive capacity – up to 25 sm^3/mg
c) the polycrystal diameter ≤ 6 mm
d) the grain size no more than 10 mkm.

The developed diamond polycrystals (trade mark STM60P) possess a unique level of hardness and wear resistance.

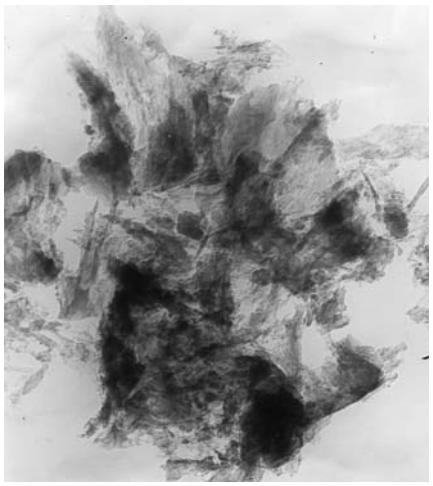
The technology was developed and manufacturing process started for the diamonds with stable wear resistance and qualitative characteristics 12-15 times exceeding sapphire nozzles of the best world manufacturers. Specifications on jet-forming nozzles (VTU 2-037-803) were developed. The product range is constantly extended both due to increase in quantity of standard sizes and the qualitative diversity (due to the progress in improving parameter of the nozzle channel roughness by means of application traditional and laser polishing methods). Designs are developed with direct and inclined channels, with the slot-hole channel and multi-channel.

2 STUDY ON THE PROPERTIES OF NANO-DISPERSED DIAMONDS

In order to obtain diamond polycrystals with increased wear resistance the composite consisting of synthetic nano-diamond and metal-ceramic binding material was developed and investigated. Nano-dispersed diamond powders obtained by explosive method were used.

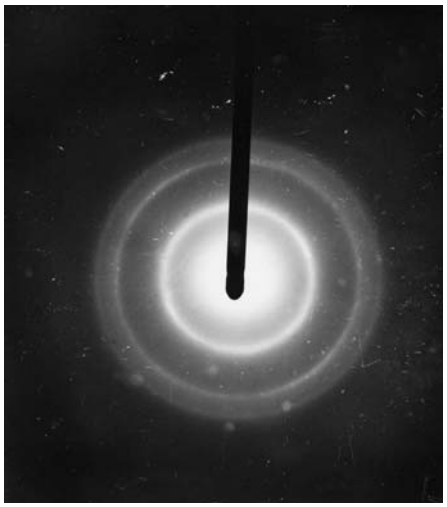
Fig.1. Enlarged ×30000

Fig.2. Enlarged ×40000



DOI 10.1051/names2007031

Fig.3. Diamond powder micro-diffraction



The pictures of the nano-dispersed powders have been got using the pass-through electronic microscope (Fig.1, Fig.2). To separate the particles, the powders were dispersed in the ultra-sonic disperser. The particles have a fiber-like appearance with a very developed surface. The edges of the mono-crystal quality are absent.

Displacement of the intra-surfaces distances calculated in accordance with the micro-diffraction pictures (Fig.3) proves the existence of the hexagonal modification of diamond along with the cubic one in the powder under examination. The results of the calculation are listed in Table 1.

Table 1. The results of the calculation of the diamond powder inter-surfaces distances in accordance with the micro-diffraction pictures

№ of line	2*r* (mm)	*d/n* (nm), calculation	*d/n* (nm), theoretical		*hkl*	
			cubic	hexagonal	cubic	hexagonal
1	16.5	20.7	20.6	21.8 20.6	111	100 002
2	26.8	12.6	12.6	12.6	220	110
3	28.9	11.8	–	11.6	–	103
4	31.8	10.8	10.7	10.7	311	112

3 OBTAINING DIAMOND POLYCRYSTALS

The sintering of diamond powder with various bonds was conducted by HPHT method. B-amorphous, nano-dispersed powders TiN, TiC, and Ni-Cr alloy were used as the bonding agents. The obtained diamond polycrystals had the small-size-grains structure (Fig.4), the bond was evenly spread in the structure of diamond polycrystal. These statements were proved by the pictures taken in the characteristic Ni spectrum (Fig.5).

4 THE COMPARISON OF ABRASIVE CAPACITIES OF THE MATERIALS WITH HIGH HARDNESS

Table 2. Abrasive capacity of various materials

№	The material type	Abrasive capacity (sm^3/mg)
1	STM60P	23.5
2	ASPK2	16.2
3	SVA15Bu	7.2
4	Corundum	1.2
5	Saphire	1.1
6	Hard alloy VK6	0.2

The obtained material (trade mark STM60P) has a unique abrasive wear resistance. Table 2 gives the data on the abrasive capacity of the newly developed material in comparison with 2 types of diamond polycrystals, ASPK2 and SVA15Bu,

DOI 10.1051/names2007031

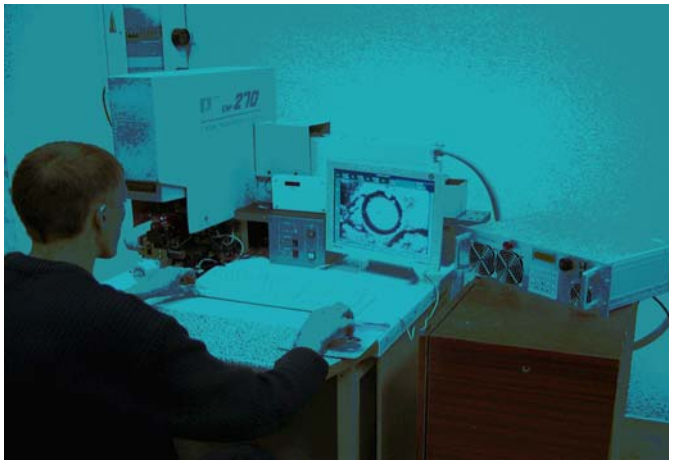
as well as with the traditional super-hard materials: sapphire, corundum and hard alloy containing 6% of cobalt.

5 APPLICATIONS OF THE DEVELOPED POLYCRYSTALS

The developed polycrystals are used for producing jet-forming nozzles.

Jet-forming nozzles are used for gas- and liquid-abrasive cutting, treatment and wet blasting processing of various materials (metals, ceramics, various rock kinds etc.). The treatment of articles is performed by impact of abrasive particles (high-silica sand as a rule). These particles are forced through the nozzle in a gas or liquid jet at a high speed. By means of this sort of equipment the following kinds of treatment are possible: blank cutting of various materials, especially in case when flame cutting is absolutely impossible (for example, for cutting of composite materials with organic ingredients, for disposal of obsolete worn equipment, etc.), or if heating of the material is undesirable due to possible structure destruction or changes in strength characteristics, or deposit removal from internal pipe surface in various heat exchanging systems, for application of flexible small-diameter long supply hoses (catheters) is possible, etc.

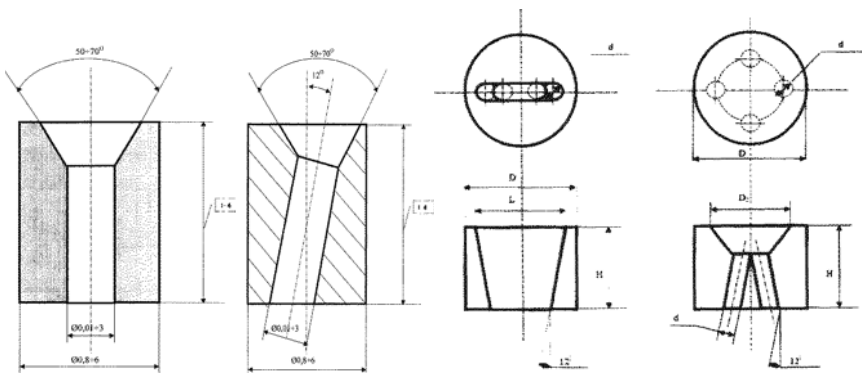
Fig.6. Laser equipment for producing diamond nozzles



Until recent time mineral ceramics, corundum, sapphire or hard metal alloys have been used as materials for nozzles and mouth-pieces. The working effectiveness of units with such accessories is not very high because the working life time of nozzles and mouth-pieces made of these materials is low. For example, durability of a corundum nozzle at liquid jet pressure of 25 atm and at abrasive (high-silica sand) consumption of 10 g/min is less than 4 minutes. Therefore, application fields for the equipment of this type were quite restricted until recently.

Nozzles and mouth-pieces are produced of the new type of diamond polycrystal with the unique abrasive wear resistance. The technology of laser treatment (Fig.6) is used allowing obtaining the articles of the necessary shape without decreasing the strength properties of the diamond. Quality of diamond polycrystals and their operational characteristics are defined mostly by the following parameters: hardness, abrasive capacity, polycrystal size, grain size in the polycrystal structure. Special procedure is used for diamond polycrystals quality total control. The

Fig.7. Various types of jet-forming diamond nozzles



DOI 10.1051/names2007031

procedure allows controlling the grade of graphite-diamond transition in polycrystals as well as the existence of pores, cracks and large metallic inclusions. Along with high quality of initial raw material, this method allows obtaining products with guaranteed operational parameters. The product range can be extended due to improving parameters of the nozzle channel roughness by means of application traditional and laser polishing methods. The most typical configurations of the nozzles are shown in Fig.7.

New features of laser technique applied for making nozzle and mouth-piece channels consist in computer programmable control of the beam parameters and of billet holding three-axis table traveling. This technique allows reducing machine time for the channel processing in 2-3 times, gives the opportunity to obtain nozzles with irregular opening shape, to improve the parameters of internal channel surface roughness after laser treatment down to R_z = 2.5–0.63, to reduce cut width down to 0.1 mm at the depth of 3 mm.

Specific parameters and properties of the developed object are the following.

a) the parameters of the nozzle laser treatment process:

- time for the nozzle channel manufacturing - not more than 7 min;
- roughness of the channel surface R_Z=2.5–0.63

b) operational characteristics of the nozzles:

- wear resistance at least 4 hours at liquid jet pressure of 25 atm and abrasive agent consumption 10 g/ min.

Jet-forming nozzles produced of the developed polycrystals (Fig.8) demonstrated the unique abrasive wear resistance.

6 CONCLUSIONS

- Composite polycrystal material on the basis of nano-dispersed diamond powder and ceramic and metal bonds was invented and polycrystals with the unique abrasive wear resistance were obtained by HPHT method.

Fig.8. The picture of the diamond jet-forming nozzles.

- The manufacturing technology was developed which allows obtaining diamonds with stable wear resistance and qualitative characteristics 12-15 times exceeding sapphire nozzles of the best world manufacturers. Thus, the developed material can successfully substitute the traditional ones in a number of applications.
- The developed polycrystals were used for producing jet-forming nozzles.
- Due to the durability of the nozzles of the developed material the working effectiveness of the equipment using these nozzles became much higher in comparison with traditional materials. That allows using the nozzles for various new applications: blank cutting various materials, cutting composite materials with organic ingredients, disposal of obsolete worn equipment, deposit removal from internal pipe surface, etc.
- The product range and, therefore, the number of applications are constantly extended: new sizes and configurations of nozzles are developed and the parameters of the channel roughness are improved.

DOI 10.1051/names2007031