Further Development of the New Thermally Stable Polycrystalline Diamond Compacts at High Pressure and High Temperature.

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Problem Description

One of the main directions of the development of new high-efficiency polycrystalline materials based on diamond is further improvement of sintering technology of two-layer polycrystalline diamond (PCD) compacts. At present the application of tools equipped with PCD inserts in oil and gas drilling increases intensively. The coal production using tools with PCD inserts has considerably increased as compared to drilling using traditional bits equipped with cemented carbide inserts. An increase of PCD-bits production becomes the basic line of the development of the world leading companies, which produce drilling bits. The quality of the PCD cutting elements is being constantly improved. Recently special attention has been given to the development of different technical solutions of the removal of residual stresses in HPHT-sintered PCD compacts.

PCD cutting elements widely used in drilling tools are two-layer plates produced by sintering at high pressure (6-8 GPa) and high temperature (1400-1600^{0}C). The diamond-containing layer forms as a result of the Co-WC-C liquid melt infiltration from the cemented carbide substrate. A high cobalt content (6-10 mass %) of the diamond-containing layer leads to a low thermostability of PCD inserts, which does not allow their efficient application at temperatures above 700^{0}C.

Quite often in machining different materials with tools equipped with diamond polycrystalline materials at high cutting speed, high temperatures (above 700°C) arise in the contact zone, which leads to a significant thermochemical wear of the PCD inserts. For solving this problem, it is necessary to develop new thermostable tool materials. Thus, the development of these two-layer composite materials with thermostable diamond-containing layer is very important as they provide an efficient machining at high cutting speeds and the use of various high-temperature methods of brazing tools. The modern technologies of drill bit production and high drilling speeds set technical task of the development of new PCD inserts having a high thermostability.

At the same time one of the actively developing directions of the production of superhard materials for drill bits is the manufacturing of single layer diamond-SiC two-phase thermostable composites widely used in various industries. In this case, during the sintering process a strong chemical bond forms at the diamond-silicon carbide interface and the structure of a two-phase composite forms with a basic diamond phase content of 75-85 vol.% on the average. Usually these are one-layer plates of cylindrical, square and triangular shapes with a volume of 0.1 to 0.05 cm^3. Thus, on the one hand, the use of drilling bits with PCD inserts expands rapidly but these PCD inserts have a substantial disadvantage (low thermostability), and on the other hand, drill bits equipped with thermostable polycrystalline diamond (TSPD) elements demonstrate high performance (e.g., those in shape a parallelepiped measuring 1.5x1.5x5.0 mm). Based on the analysis of different publications, which describe the properties of PCD inserts and TSPD elements, we can compare basic physical and mechanical properties of these superhard materials. The data show that the most important operating properties like hardness and wear resistance of the diamond-containing layer of PCD inserts and TSPD elements are close in value, but the PCD inserts exceed TSPD elements in strength. However, the latter retain their mechanical properties up to 1200^{o}C, while mechanical properties of PCD blanks are impaired on heating above 700^{o}C.

The technological conditions of fastening into drilling tools and operating conditions set the problem of the development of a two-layer diamond-containing–cemented carbide composite, which combines high wear resistance and high thermostability.

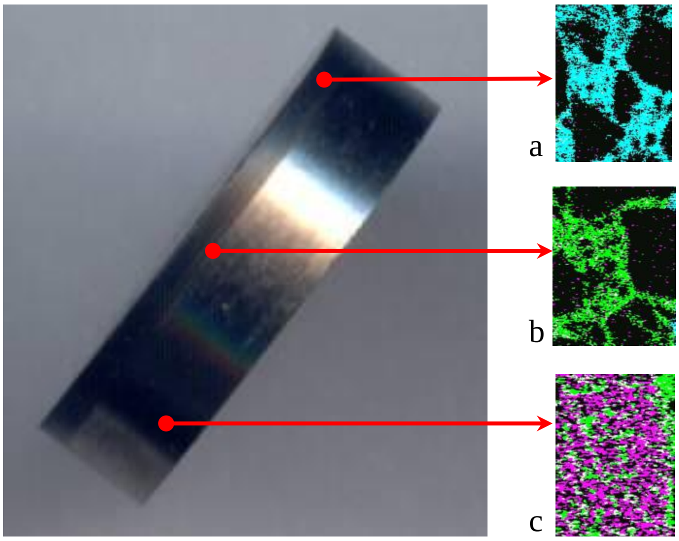
In work [1] it was shown possibility to form composite by method of oncoming infiltration of diamond layer from one side by liquid Si and from other side by Co melt. The process was conducted at a pressure of 5 GPa and at a relatively low temperature of about 1520 K and leaded to a diamond-containing layer fixed on the substrate, which in addition to diamond and SiC incorporates residual unreacted silicon. The layer density is 3.3 g/cm^3, which is essentially lower than that of composites employed in drilling tools (3.44-3.46 g/cm^3). The presence of free silicon may adversely affect the strength of the diamond-containing layer, which is impermissible as thus produced diamond-carbide two-layer blanks are designed for drilling tools.

In investigation [2] was shown HPHT-sinter PCD inserts with a thermostable layer of a diamond-SiC composite on a cemented carbide substrate, to define their wear resistance after the thermotreatment in air and then to test drill bits with these PCD inserts. To understand the HPHT-sintering of such thermostable PCD blanks, it is necessary to analyze the main stages of the structure formation of known commercially produced PCD inserts and TSPD elements. In both cases one of the main stages of the structure formation is the infiltration of the diamond micropowder by melts under high pressures and temperatures. At a pressure of 8 GPa, the Co-WC-C melt infiltrates a diamond micropowder at temperatures of 1500 to 1550^{o}C and molten silicon at a temperature of 950^{o}C. It was carry out HPHT-sintering with double-sided infiltration of diamond micropowder by molten silicon and Co-WC-C melt from a cemented carbide substrate.

Further development of the creation such thermally stable polycrystalline diamond compact can be in increase of the strength, wear resistance and thickness cutting diamond table like superhard materials.

The way of problem solving

Solution of the fabrication problem of the thermally stable polycrystalline diamond compact consists of creation new high pressure cells and new methods of sintering with use HPHT-equipments. Potential application such thermally stable polycrystalline diamond compacts will be not only into drilling bits industry and in field of the cutting tools productions.



Thermostable PCD insert: a) structure of a diamond-SiC composite; b) structure of the transition layer of the diamond-Co system; c) structure of the carbide substrate.

Basic publications

1. Nozhkina A.V., Shulzhenko A.A., Gargin V.G., Bochechka A.A. The formation of a diamond layer on carbide substrate during diamond interaction with Si, WC and Co// High Pressure Research.–2000.–Vol.18.–P.325–33.

2. OsipovA.S., Bondarenko N.A., Petrusha I.A., Mechnik V.A. Drill bits with thermostable PCD inserts// Diamond Tooling Journal.-2010.- N 3.- P. 31-34.

Innovative Aspects of the solution / development/ methodology, tool, prototype

Innovation aspects of this development involve creation of the HPHT-technology for making thermally stable polycrystalline diamond compact with better properties (strength, wear resistance and thickness cutting diamond table) in contrast to standard conventional PCD inserts.

Main advantages of the solution / development/ methodology, tool, prototype

Preliminary tests with drill bits equipped with the experimental produced thermally stable PCD inserts showed high performance at drilling of wells in geological formation of middle and high hardness in comparison to drill bits equipped with either cemented tungsten carbide blanks or conventional standard PCD inserts [2].

Financial and Economic Parameters

Costing of the drill bits equipped with the experimental produced thermally stable PCD inserts showed that it is not more cost of the drill bits equipped with either cemented tungsten carbide blanks or conventional standard PCD inserts.

Investment Offer *(is not obligatory)*

The goal of this section is to give a potential investor a notion of the required investment volume and proposed level of investor's involvement in implementation and exploitation of the project.

Current stage of development of the offered solution / development/ methodology, tool, prototype *(please, select)*

◌ Development phase – laboratory tested
◌Available for demonstration – field tested
◌Already on the market
Comments:

Intellectual Property Rights *(please, select)*

◌ patent applied for (name countries in which you have applied for patents in)
◌patents granted (enter the countries that have granted the patents; where the initial patent was granted and say a few words about the company)
◌copyright
◌exclusive rights
◌secret know-how
◌others (registered design, plant variety right, etc.)
Comments

Collaboration Details (Type of collaboration sought; *more than one option can be selected*)

◌ Technical co-operation
◌ Commercial agreement with technical assistance
◌ Joint Venture agreement
◌ License agreement
◌ Manufacturing agreement
◌ Financial resources
Comments:

Technology Key words

Diamond, high pressure and high temperature, thermally stable polycrystalline diamond compacts, infiltration, drill bit, wear resistance.