проходке и механической скорости с шарошечными долотами при бурении скважин (в том числе гидрогеологических) на небольшие глубины (до 200–300 м) в мягких и средней твёрдости породах, где более дорогие шарошечные долота не обеспечивают высоких механических скоростей вследствие невозможности создания необходимых осевых нагрузок.

У статті наведено опис конструктивних особливостей доліт ріжучого типу конструкцій СКБ НВО «Геотехника», ІНМ і АТ «Тульське НІГП», а також описані результати проведених випробувань вказаного інструменту.

Ключові слова: *долото, буріння, породи, твердосплавна пластина, свердловина.*

SHAFT CUTTERS FOR GEOLOGICAL EXPLORATION

The article describes the design features of the drill bits cutting type designs SKB NPO «Geotechnica», ISM, и AO «TulNIGP», and also placed the results of testing the drill.

Key words: *chisel, drilling, rocks, carbide insert, borehole.*

Литература

1. Породоразрушающий инструмент для геологоразведочных скважин: справочник / Н. И. Корнилов, В .С. Травкин, Л. К. Берестень, Д. И. Коган. – М.: Недра, 1979. – 359 с.
2. Будюков Ю. Е., Спирин В. И., Будюкова Т. Ю. Разрушение горной породы коронками режущего типа при бурении скважин на карьерах // Современ. пробл. экологии: тез. докл. VIII Междунар. науч.-техн. конф. под общ. ред. В.М. Панарина. – Тула: Инновационные технологии, 2015. – 89 с.
3. Технология бурения разведочных скважин / А. Г. Калинин, В. И. Власюк, О. В. Ошкардин, Р. М. Скрябин. – М.: Техника, 2004. – 526 с.
4. Отчёт по теме «Модернизация режущего породоразрушающего инструмента с целью повышения его стойкости и механической скорости бурения взрывных скважин в крепких породах на карьерах Тульской области» (за счёт гранта правительства Тульской области в сфере науки и техники 2014 г.) / В. И. Спирин, Ю. Е. Будюков, Н. Е. Борисов и др. – Тула, 2015. – 73 с.

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B. C. Liu[1,2], **C. Li**[2], **S. Q. Liu**[2], **X. Cao**[2]

[1]*State Key Laboratory of Superhard Materials, Jilin University, Changchun, Jilin, China*
[2]*College of Construction Engineering, Jilin University, Changchun Jilin, China*

IMPROVING HEAT RESISTANCE OF POLYCRYSTALLINE DIAMOND COMPACT CUTTERS WITH Co–Si–B BINDER FOR ROCK DRILLING

Polycrystalline diamond compact (PDC) cutters are widely utilized in oil and gas exploitation and geological drilling works, as their excellent comprehensive properties. The cobalt as binders exists in PDC is also the catalyst for diamond transforming into graphite under the high temperature, which will decrease the thermal stability of PDC seriously. So it is necessary to improving the heat resistance of PDC for drilling works. In this paper, PDC sintered with 10Co–3Si–1B binders had been prepared to decrease the content of cobalt in PDC and improve the heat resistance by forming SiC and B_4C. The thermo-gravimetric analysis (TG-DSC) results indicated that the beginning of oxidizing temperature of well-sintered PDC with 10Co–3Si–1B is up to 840 ℃, which improve the heat resistance significantly.

Key words: *polycrystalline diamond, cutters, heat resistance*

Introduction

As superhard compositematerial,polycrystalline diamond compact(PDC),which is usually composed of polycrystalline diamond and WC–Co substrate,and synthesized under the conditions of high pressure and high temperature (HPHT), are widely utilized as the tooth of drilling bits [1]. Compared with other wearresistant cutters, PDC cutters has better impact toughness and heat conductivity because WC–Co material is used as a substrate [2]. Now PDC has been widely used in processing cutting tools, mine, oil and gas drilling works, geological prospecting, deep drilling and so on [3].

Although it has excellent properties of high toughness,high hardness and wearresistance, which make it very suitable for drilling soft to medium hard formation with relatively low abrasiveness. But it is not fit for hard and compact rock formation with high abrasiveness [4]. The main reason is that during the drilling works, PDC cutters has a strong friction with the formation, which can produce lots of heat. Under the condition of high temperature environment, the cobalt in the polycrystalline diamond, which as a binder in synthesis process, becomes the catalyst for diamond transforming into graphite [5]. That will reduce the performance of PDC cutters. So it is very necessary to improve the heat resistance of PDC to maintain its performance stability at high temperature [6].

Many research works had been done to improve the properties of PDC. H. P. Bovenkerk and his team utilized the aqua regia to remove the portion of cobalt from PDC to keep its heat resistance, which had a good result in improving its thermal stability but has negative effects on wear-resistance and rupture strength [7]. Uedaa et al. tried to utilized $MgCO_3$ as a new binder to replace cobalt to synthesize PDC with belt-type press [8]. The synthesis condition was 7,7 GPa, 2300 °C and 30 min. Although the new style PDC had excellent thermal stability, which still had 60 GPa Vickers hardness after 1200 °C high temperature treatment without air, the toughness and hardness dropped out. Piotr Klimczyk et al used TiB2 to replace partial cobalt to improve its thermal stability, the results showed that the materials maintain the high hardness value up to 800 °C, but the hardness had a decline [9]. Despite the considerable studies on this type of materials, the high performance PDC for drilling industry with high heat resistance is still not prepared. In this work, high heat resistant PDC with Co–Si–B, which had a low cost and lower sintering conditions, had been successful prepared.

Experiments

The raw materials using in experiment were 30/40 µm size of diamond powder with purity of 99,9%, 5 µm silicon powder with purity of 99,99% purity, 1 µm cobalt with 99,9% purity, 1 µm boron powder with 99,9% purity and 0,2 mm Ni–Mn–Co alloy plate. The substrate material was WC–16%Co. The high pressure and high temperature experiment were performed in a 6×1200MN cubic press. As shown in Fig. 1, the alloy plate was put on the top, which would provide driving force during the infiltration process to make the diamond powder and substrate combine to polycrystalline diamond compact.

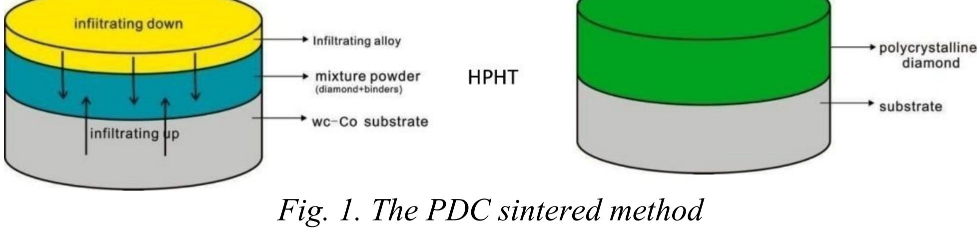


Fig. 1. The PDC sintered method

The Co–Si–B addition in diamond powders would also be binders to help the sintering process, which will improve the heat resistance of PDC byforming heat resistant compounds in polycrystalline diamond layer as well as decreased the content of cobalt. The sintered condition were lower by way of alloy plate infiltrating. The cell assembly used in high pressure and high temperature experiments is shown in Fig. 2.

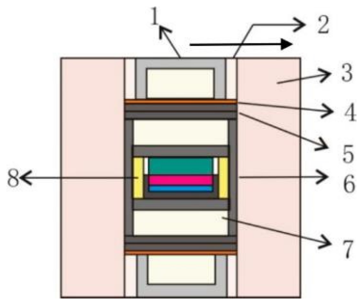


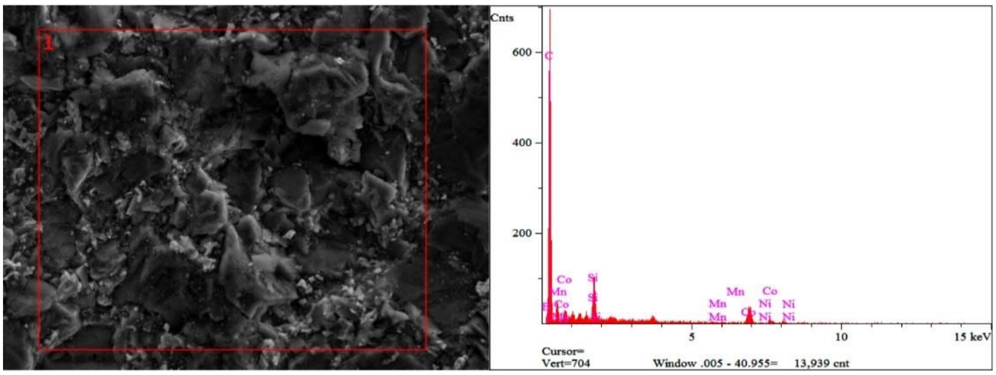
Fig. 2. The cell assembly used in HPHT: 1 – Steel cap; 2 – Dolomite tube; 3 – Pyrophyllite block; 4 – Copper sheep; 5 – Graphite disc; 6 – Graphithe tube; 7 – MgO–ZrO_2 disc; 8 – Insulating tube

During the sintering experiments, the pressures in the cell ranged from 5,0 to 6,5GPa and the temperature varied from 1350 to 1650℃ with theduration time about 5 to 7 min. Co–Si–B binders for improving the heat resistance of PDC had been utilized in experiments. Scanning electron microscope (SEM) and energy disperse spectroscopy (EDS) were used to analyze the microstructure and elements of sintered PDC. The X-ray diffraction (XRD)analyzer was applied to analyze the phase composition in polycrystalline diamond layers. The thermo-gravimetric analyzer (TG-DSC) was used to measure the thermal stability.

Results and discussion

SEM and EDS analysis

The results of SEM and EDS of sintered PDC samples with Co-Si-B binders were shown in Fig. 3.



а *б*

Fig. 3. The SEM of PDC with Co–Si–B (a) and the EDS of PDC with Co–Si–B(b)

It was shown that the diamond powder had recombined to form the large-grained polycrystalline diamond and there are some compounds formed in the diamond layer, which means that the alloy plate had infiltrated into the diamond powders. The content of the existent elements in diamond layer were shown in Tab. 1, the results showed that the diamond content account for 85% and the binders content were about 14%, in which the content of cobalt was about 6%. The higher content of diamond ensured the hardness and wear resistance of the PDC cutter, while the lower content of cobalt in the binder will be beneficial to the improvement of heat resistance of the cutter.

Table 1.**The contents of elements in PDC with Co–Si–B**

Elements	C*K*α	Co*K*α	Si*K*α	B*K*α	Ni*K*α	Mn*K*α
Wt.%	85.11	6.32	2.84	5.63	0.05	0.04

The results of SEM and EDS of sintered PDC samples with Co–Si–B binders were shown in Fig. 3. It was shown that the diamond powder had recombined to form the large-grained polycrystalline diamond and there are some compounds formed in the diamond layer, which means that the alloy plate had infiltrated into the diamond powders. The content of the existent elements in diamond layer were shown in Tab.1, the results showed that the diamond content account for 85% and the binders content were about 14%, in which the content of cobalt was about 6%. The higher content of diamond ensured the hardness and wear resistance of the PDC cutter, while the lower content of cobalt in the binder will be beneficial to the improvement of heat resistance of the cutter.

XRD analysis

The phase compositionsof polycrystalline diamond layer were further analyzed by X-Ray diffraction method, the results were shown in Fig. 4.

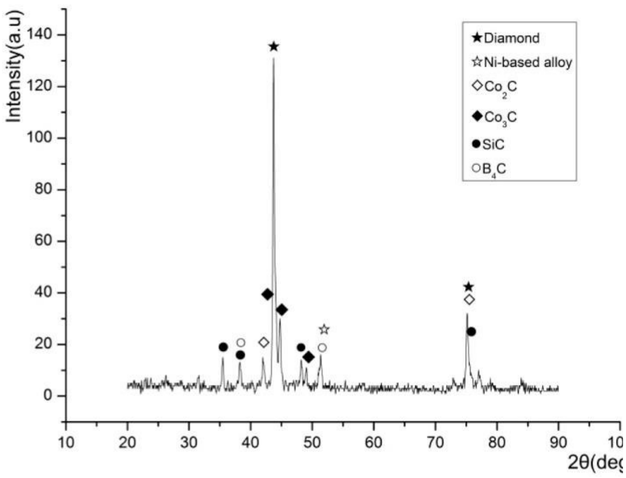


Fig. 4. The XRD of PDC with Co-Si-B binder

As shown in Fig. 4, SiC and B_4C were formed in thediamond layer of PDC.These heat resistant compound will significantly improvethe thermal stability of PDC.

Heat resistance analysis

The heat resistance of wellsintered PDC samples were measured in the air by utilizing the thermo-gravimetric analysis (TG–DSC) method. This is an oxidation resistance tests, in which the beginning of oxidation temperature of PDC in the air was utilized as the oxidation resistance property evaluation criterion. Heating temperatures were increased from room temperature at the heating rate of 20 °C/min.

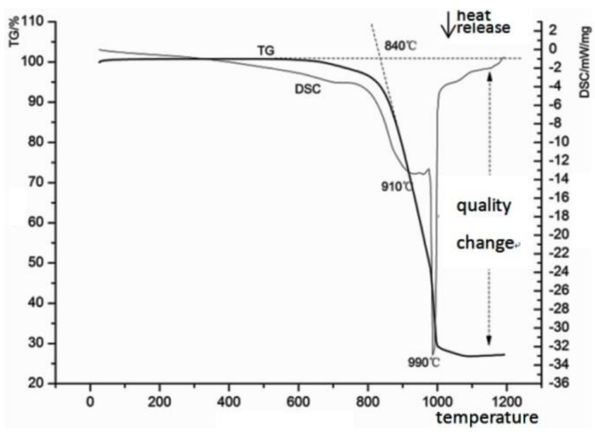


Fig. 5. The TG–DSC results of PDC with Co–Si–B binder

TG results of PDC with Co–Si–B binders were shown in Fig.5. As shown in Fig. 5, the beginning of oxidizing temperature of the PDC with Co–Si–B binder is up to 840°C. Compared with the conventional PDC(~760°C), the heat resistance has been improved.

Conclusions

The polycrystalline diamond compact (PDC) with improved heat resistance were fabricated by a new method, which was combined with the infiltration and powder mixing approaches, at the condition of P = 5,0~6,5 GPa, T = 1350~1650 °C, t = 5 ~ 7 min.

Co–Si–B binders system for improving heat resistance of PDC was identified, in which heat-resistant compound B_4C and SiC were formed in thediamond layers. the heat resistant PDC samples can maintain hardness value up to 840 °C.

Різці з алмазних полікристалічних композитних матеріалів (АПКМ) широко використовуються в нафтогазовидобувних і геологічних бурових роботах, через їх відмінні комплексні властивості. Кобальт в якості зв'язки в АПКМ є каталізатором для перетворення алмазу в графіт при високій температурі, що серйозно погіршує термостабільність АПКМ. У цій роботі АПКМ, спікається із зв'язкою 10Co–3Si–1B, щоб зменшити вміст кобальту в АПКМ і поліпшити термостійкість шляхом утворення SiC і B_4C. Результати термогравіметричного аналізу (TG-DSC) показали, що початок температури окислення спеченого АПКМ з 10Co–3Si–1B становить близько 840 ℃, що значно підвищує термостабільність.

Ключові слова: *полікристалічний алмаз, різці, термостабільність*

Резцы из алмазных поликристаллических композитных материалов (АПКМ) широко используются в нефтегазодобывающих и геологических буровых работах, из-за их отличных комплексных свойств. Кобальт в качестве связующего в АПКМ является катализатором для превращения алмаза в графит при высокой температуре, что серьезно ухудшает термостабильность АПКМ. В этой работе АПКМ, спекали со связующим 10Co–3Si–1B, чтобы уменьшить содержание кобальта в АПКМ и улучшить термостабильность путем образования SiC и B_4C. Результаты термогравиметрического анализа (TG-DSC) показали, что начало температуры окисления хорошо спеченного АПКМ с 10Co-3Si-1B составляет около 840 ℃, что значительно повышает термостабильгость.

Ключевые слова: *поликристаллический алмаз, резцы,* термостабильность

References:

1. The current state of PDC bit technology / Federico B., Alfazazi D., William K. et al. // World oil. – 2010. – 9. – P. 41–46.
2. The current state of PDC bit technology / Federic O. B., Alfazazi D., William K. et al. // World oil. – 2010. – 10. – P. 53–58.
3. The current state of PDC bit technology / Federico B., Alfazazi D., William K. et al. // World oil. – 2010. – 11. – P. 67–71.
4. PDC Bit technology for the 21st Century / Greg B., Ron C., Malcolm T. et al. // Oilfield review. – 2011. – 2. – P. 4–17.
5. Jain J. R., Ricks. G., Baxter B. et al. A Step Change in Drill-Bit Technology With Self-Adjusting Polycrystalline-Diamond-Compact Bits. – Texas: Society of Petroleum Engineers, 2016.
6. Simulation and Experimental Research of PDC Bit Cutting Rock / Kuang Y., Zhang M., Feng M. et al. // Journal of Failure Analysis & Prevention. – 2016. – P. 1–7.
7. Bex P. A., Shafto G. R. The influence of temperature and heating time on PDC performance. // Industrial Diamond Review. –1989. – 3. – P. 128–131.
8. Gu J., Huang K., Role of cobalt of polycrystalline diamond compact (PDC) in drilling process // Diamond & Related Materials. – 2016. – 66. – P. 98–101.
9. Polycrystalline Diamond Compact with Enhanced Thermal Stability / S.L, B.L, et al. // Journal of materials science and technology. – 2017. – 3.
10. Fumihiro U., Tadakazu O., Minoru A., Shinobu Y. Cutting performance of sintered diamond with MgCO3 as a sintering agent // Material research. – 2002. – 17(8). – P. 2153–2160.
11. Cobalt substitution in PCD cutting tool materials / Piotr Klimczyk, et al. –Burgos: International Days in Critical Raw Materials. – 2015.

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