doi: 10.18323/2782-4039-2025-1-71-1

Development of a laboratory tribotechnical facility for testing PDC cutters for wear

Vladimir A. Kolibasov*[1], postgraduate student,
assistant of Chair "Machinery and Equipment of Petroleum and Chemical Production"
Ildar D. Ibatullin, Doctor of Sciences (Engineering), Professor,
Head "Chair of Machinery and Equipment of Petroleum and Chemical Production"
Vladislav A. Novikov[2], PhD (Engineering),
assistant professor of Chair "Metal Science, Powder Metallurgy, Nanomaterials",
senior researcher of the Laboratory of X-ray Diffractometry, Electron and Probe Microscopy
Samara State Technical University, Samara (Russia)

***E-mail:** mahp@samgtu.ru,
csstea@yandex.ru

[1]ORCID: https://orcid.org/0000-0002-0503-2533
[2]ORCID: https://orcid.org/0000-0002-8052-305X

Received 10.02.2025 *Revised 25.02.2025* *Accepted 11.03.2025*

Abstract: In the practice of drilling oil and gas wells with diamond bits equipped with PDC cutters, cutter quality non-compliance with the declared class occurs. At the same time, the currently used methods of full-scale testing, when granite stone is used as a counterbody, are time-consuming and expensive, which complicates their use for prompt incoming inspection of new batches of PDC cutters arriving for assembly of diamond bits. This necessitated the development of a laboratory tribotechnical facility for quantitative assessment of the ability of PDC cutters to resist abrasion against abrasive materials. The study covers the development of a specialized tribotechnical facility that allows testing PDC cutters of various sizes for wear during friction against a diamond-containing metal work face, for which it is proposed to use diamond cutting wheels. The developed laboratory tribotechnical facility includes: an electromechanical rotary drive (a drilling-and-milling machine); a measuring unit with sensors for normal loads, friction force and temperature of cutter self-heating during testing; a lever loading mechanism; a set of mandrels for the possibility of installing PDC cutters of various sizes; a data collection system and licensed software. The results of practical evaluation of the developed laboratory tribotechnical facility on PDC cutters of various batches showed that testing on the new equipment allows for quick collection of data on the wear rate of the working edges of PDC cutters. The developed methods, equipment and criteria can be used to certify the wear resistance of PDC cutters.

Keywords: diamond bit; PDC cutter; tribotechnical facility; diamond-containing metal work face.

For citation: Kolibasov V.A., Ibatullin I.D., Novikov V.A. Development of a laboratory tribotechnical facility for testing PDC cutters for wear. *Frontier Materials & Technologies*, 2025, no. 1, pp. 9–19. DOI: 10.18323/2782-4039-2025-1-71-1.

INTRODUCTION

Currently, the most popular drilling tools for drilling oil and gas wells in soft rocks with interlayers of hard rocks and medium-hard rocks are bits with PDC (Polycrystalline Diamond Compact) cutters [1]. It is known that rock-destructing PDC cutters are the most loaded and least reliable elements of the design of diamond drill bits [2; 3]. When used at the work face, they have a chipping, crushing and abrasive effect on the rock being drilled. In turn, the rock has a destructive effect on the cutters: their working edge wears out when dragging against the rock, which leads to a gradual decrease in the aggressiveness of the cutters and, accordingly, a decrease in the drilling speed. In most cases, the durability of the PDC cutters limits the repair-to-repair period of the diamond bit, and therefore the efficiency of drilling wells [4; 5].

When drilling prospecting, exploratory and producing wells, the drilling tool passes through shale, limestone, sandstones, quartzites and other rocks of different strength and abrasiveness. To determine the degree of wear of the bits (crowns), it is necessary to bring the tool to the surface. The duration of the process of pulling and running operations significantly increases the cost of well construction [6].

PDC cutters are a superhard monolithic composite material produced by sintering a hard-alloy tungsten carbide base on a cobalt bond and a polycrystalline diamond insert [7]. The sintering process is carried out in cubic presses at ultra-high pressures (6...8 GPa) and temperatures (1400...1500 °C) in a liquid medium of a metal catalyst (cobalt) [8]. Despite the existing multi-stage control system in the production of PDC cutters, including control of raw materials, sintering pressure, visual inspection, defect analysis and laboratory impact and wear tests, studies have shown that changes in the wear resistance of PDC cutters occur from batch to batch [9]. Therefore, the introduction of incoming quality control of cutters arriving for assembly of diamond bits should be an integral part of the implementation of a quality system in bit production. The problem is complicated by the fact that, currently, there are no international norms and standards for assessing the quality of PDC cutters. Until recently, each company with diamond production developed its own testing methods and criteria for analyzing their reliability. Now, one can see a trend towards conducting seminatural tests, when the tested PDC cutters (in real design) are worn out on a rotating natural stone (Fig. 1) simulating a work face [10].

For example, the general technical requirements of the Institute of Oil and Gas Technology Initiatives for cutting action blade bits equipped with cutters with a diamond polycrystalline insert[1] propose to test PDC cutters for abrasive resistance on the basis of a turning-and-boring lathe, including a mandrel for installing the test cutter in the cutter holder installed at a given angle to the cylindrical granite stone surface. The lathe ensures cutting of the rock with a constant angular velocity (40...80 rpm) and axial load. The tensile strength of granite is set in the range of 150...250 MPa. A standard system for supplying lubricating and cooling liquid is used to cool the cutter. The cutting depth during tests is 0.25...1.0 mm. The cutting stroke is from the centre to the periphery. The return stroke is carried out without contact with the surface of the stone. After each cycle, the friction surface of the cutter is photographed to assess the volumetric wear, and then the cycles are repeated.

A similar method for assessing the wear resistance of PDC cutters was described in the Laboratory of Ultrahard Materials at MISiS. It involves drilling granite on a vertical turret lathe under high load. The wear rate is defined as the change in the weight of the cutter before the start of the experiment and after a certain number of passes in the granite [10]. Similar equipment for testing PDC cutters was used by LANDS Superabrasives, Element Six (E6), Drilling Industrial Systems (LLC), Volgaburmash (OJSC), and others. For example, Element Six (E6) tests cutters for wear resistance by turning a granite sample of fine-grained or medium-grained structure with a strength of at least 220 MPa at a rotation speed of 54 rpm (40–160 m/min), a cutting depth of 0.25 mm, and a feed rate of 4.5 mm/rev with water-cooling [4]. The Ufa State Petroleum Technological University has proposed a technique for testing cutters for wear during friction against granite, taking into account the work face profile [11]. Test modes: six levels of penetration per one cutter revolution δ=0.28, 0.4, 0.56, 0.8, 1.12, 1.6 mm at a rotation frequency of 90 min^{-1}. Flushing is carried out with technical water.

The considered tests are attractive because they create conditions that are as similar as possible to operational ones. However, some unaccounted factors, such as the flow of abrasive-containing drill fluid acting on the cutter, can lead to hydroerosive wear of the carbide base under the polycrystalline diamond insert, depriving it of support (Fig. 2). Moreover, during the drilling process, a specified axial load is maintained on the bit and on the cutters in particular [12; 13]. If the tests are carried out at a constant penetration depth, this leads to constant changes in axial loads, which creates uncertainty in the modes of loading the cutters during tests. The choice of granite or marble as the work face material is caused by the fact that these materials, due to their high abrasiveness and hardness, allow assessing the wear of the cutters in a relatively short time. However, natural materials have a heterogeneous (layered) structure in depth, which, taking into account the long duration of the tests, can lead to an error in the measurements depending on the location of the abraded layer of the work face [14; 15]. To solve this problem, it was proposed to use artificial abrasive materials – 64C (silicon carbide) grinding wheels, as a counterbody during testing, which due to their increased hardness, accelerate the wear process [10].

Despite the general test scheme, one can state that currently, there is no generally accepted technique for wear tests of cutters, which does not allow comparing the results of different researchers and confirming the declared quality of products. To move to the possibility of certifying the quality of cutters according to the wear resistance criterion, it is necessary to determine the list of confirmed indicators and their ranges or limit values, observing the unity of the conditions for conducting tests and measurements. At the same time, it is advisable to supplement the arsenal of full-scale methods for testing cutters with simpler and more efficient methods of laboratory testing. Their purpose is not to determine the wear rate of cutters during operation, but only to give a comparative assessment of the wear resistance of polycrystalline diamond inserts on the edges of cutters while maintaining the test scheme, acceptable forcing of mechanical stresses and increasing the aggressiveness of the counterbody for the quickest possible comparative analysis. All other factors – the value of the load on the cutter, the cutter angle to the counterbody, the speed of rotation of the work face, etc. – are chosen constant so that the wear rate of the PDC insert depends only on the properties of the insert on the tested cutter.

The purpose of the study is to develop a laboratory tribotechnical facility and a method for testing PDC cutters for wear.

METHODS

Development of a methodology for wear test of PDC cutters

When developing equipment for laboratory wear tests of cutters, the following assumptions were made. The design of the bit provides for an angular (usually at angles from 5 to 30°) position of the cutters relative to the work face, in which not the entire cutter surface contacts the rock, but only the protruding edge of the diamond polycrystalline insert (working edge). In this respect, it was decided to set an angle close to the average in the specified range equal to 15°, due to the geometry of the equipment.

To accelerate wear tests, the authors proposed using a metal-diamond "work face" in the form of a diamond-

[1] *Cutting action blade bits equipped with cutters with a diamond polycrystalline insert. General technical requirements. St. Petersburg, Institute of Oil and Gas Technology Initiatives, 2022. 81 p.*

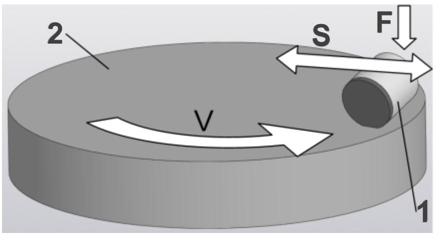


Fig. 1. *Scheme of PDC cutter wear tests:*
1 – tested cutter; 2 – counterbody (granite stone);
F – normal load; S – transverse feed; V – rotation speed of the movable counterbody
Рис. 1. *Схема испытаний PDC-резцов на изнашивание:*
1 – испытуемый резец; 2 – контртело (гранитный камень);
F – нормальная нагрузка; S – поперечная подача;
V – скорость вращения подвижного контртела

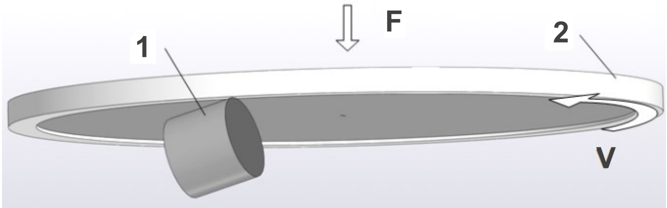


Fig. 2. *The proposed scheme for wear tests of the PDC cutters:*
1 – tested cutter; 2 – counterbody (diamond cutting wheel);
F – fixed normal load; V – wheel rotation speed
Рис. 2. *Предлагаемая схема испытаний PDC-резцов на изнашивание:*
1 – испытуемый резец; 2 – контртело (алмазный отрезной диск);
F – фиксированная нормальная нагрузка;
V – скорость вращения диска

containing rim of a diamond cutoff disk as a counterbody. Unlike the use of natural rocks (granite stone), which can have significant differences in hardness (6.5–7 units on the Mohs scale) and tensile strength (from 40 to 80 MPa), artificially created diamond tools are manufactured according to accepted technical specifications and have a regulated range of properties. To test PDC cutters, it is recommended to take wheels with a hard bond (6600 MPa on the Vickers scale). This will reduce the wear rate of the diamond rim and allow using one disk twice: first from one end, then from the other. In this case, there is no disk clogging. The tested edge of the PDC cutter effectively removes the metal layer and reveals new diamond grains. Moreover, with an increase in the hardness of the counterbody, the pressure at the point of contact of the cutter with the metal-diamond work face during friction increases. This creates conditions for a significant acceleration of wear tests.

The recommended load on the friction contact is 20 kgf (196.2 N). Higher loads lead to the appearance of areas of adhesion of the PDC cutter with the diamond rim, strong heating of the contact (over 300 °C), and rapid failure of the diamond wheel without the possibility of its secondary use. For the same reasons, the speed of rotation of the wheel was limited to 200 rpm. Lower loads lead to the necessity of increasing the test duration to form noticeable wear. Studies have shown that the characteristic values of the force of friction between the cutter and the diamond rim at the selected normal load are about 60...70 N, which with a cutting wheel diameter of 115 mm corresponds to a friction torque of 3.6...4.2 N·m. To implement such an effort, it is recommended to use a drive with a power of at least 400 W. Modernized vertical drilling machines equipped with a lever loading system can be used as such a drive.

The PDC cutters were tested for abrasive wear resistance under the following test conditions:

– friction pattern: "tooth edge – diamond wheel";
– rotation frequency of the metal "work face" – 200 rpm;
– counter sample ("work face") – diamond cutting wheel (125 mm);
– samples – two PDC cutters with the same service life;
– sample mounting angle relative to the "work face" – 15°;
– test time – 30 min;
– friction without lubrication (dry);
– continuous collection of data on the normal load applied to the contact and the friction force, and periodic temperature monitoring.

Development of equipment for laboratory wear tests of PDC cutters

Taking into account the above, a laboratory software and hardware complex (Fig. 2, 3) was developed at the Chair of Machinery and Equipment of Petroleum and Chemical Production of Samara State Technical University. The scheme of the friction unit (Fig. 2) of this facility is generally similar to the scheme of full-scale tests shown in Fig. 1. The model work face is also rotating relative to the fixed cutter inclined relative to the work face at an operating angle and cutting into it with the edge of the polycrystalline diamond insert. The difference is that the work face is inverted relative to the cutter, which creates conditions for the spontaneous removal (shedding) of wear particles from the friction zone. Moreover, such a mutual arrangement allows free loading of the cutter from above with a fixed load and rotation of the work face using standard and relatively inexpensive equipment – desktop drilling or drilling-and-milling machines as a drive. The edge of the cutter is pressed into the diamond rim for an amount determined by a fixed normal load and relatively stable strength properties of the rim. This creates identical friction conditions when testing various cutters and more closely matches the loading pattern of cutters during drilling.

The design of the device for testing PDC cutters for abrasive wear is shown in Fig. 3. The main components of the test facility are:

1) a drive consisting of an electric motor, a spindle unit, a rack, a base and a console table. Drilling or drilling-and-milling machines can be used as a drive. The modification of the machine includes the installation of a lever loading system allowing the creation of an axial load of up to 200 N. It is preferable to use machines with the ability to move axially the console table along the toothed rack;

2) a system for monitoring experimental data consisting of a measuring unit (Fig. 4), an E14-140 data collection system and PowerGraph software. The measuring unit is equipped with sensors for the average self-heating temperature of the PDC cutter, normal load and tangential load. In the lower part of the monoblock, there is a shank end for fixing in a vice on the console table. In the upper part, there is a vertical hole with a clamp allowing the fixation of the mandrel with the tested cutter. The range of measured values of the sensors: temperature T – up to 600 °C, normal load F_n – up to 1000 N, friction force F_{fr} – up to 500 N. The software allows calibrating the sensors and building diagrams of the measured values in real time with the adopted data collection frequency of 100 Hz. Since the PDC cutter materials (polycrystalline diamond insert and hard alloy) have good thermal conductivity, the process hole for measuring its average temperature is located directly under the PDC cutter;

3) a mandrel for the PDC cutter. The mandrel provides its reliable fixation on the monoblock and a specified angle

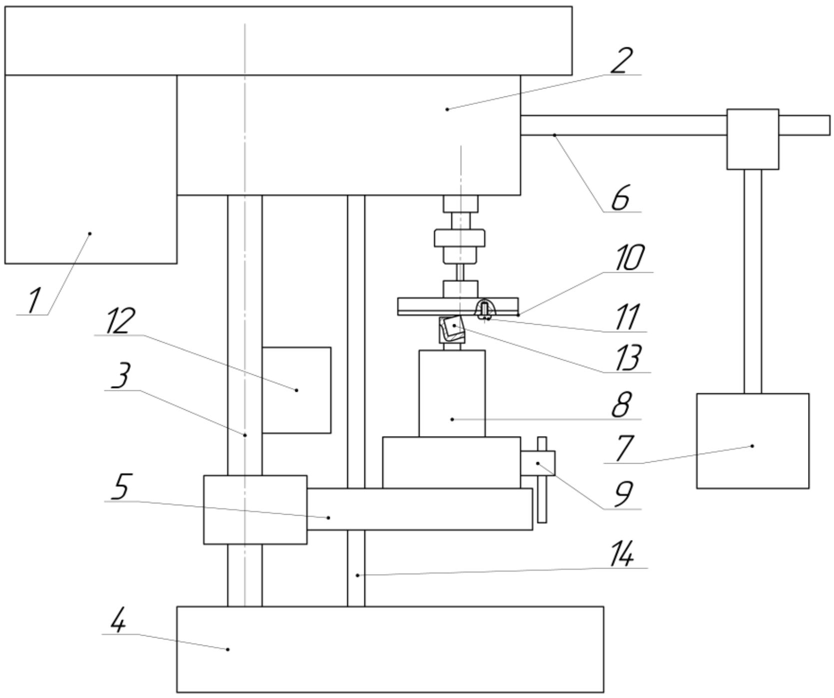


Fig. 3. *Device for abrasive wear tests of the PDC cutters:*
1 – electric motor; 2 – spindle unit; 3 – rack; 4 – base; 5 – console table; 6 – lever; 7 – load;
8 – data collection system; 9 – vise;
10 – diamond cutting wheel; 11 – lock; 12 – cooler; 13 – PDC cutter; 14 – screw coupling
Рис. 3. *Устройство для испытания PDC-резцов на абразивное изнашивание:*
1 – электродвигатель; 2 – шпиндельный узел; 3 – стойка; 4 – основание;
5 – консольный стол; 6 – рычаг; 7 – груз; 8 – система сбора данных; 9 – тиски;
10 – алмазный отрезной диск; 11 – фиксатор; 12 – охладитель; 13 – резец PDC; 14 – стяжка

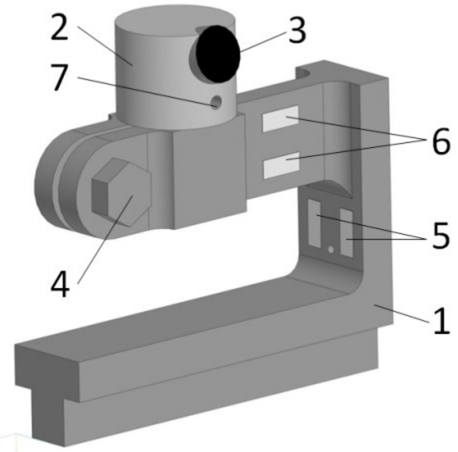


__Fig. 4.__ Measuring unit without housing:
1 – monoblock; 2 – mandrel; 3 – PDC cutter; 4 – clamp bolt; 5 – axial load sensors;
6 – friction force sensors (tangential load); 7 – process hole for thermocouple
__Рис. 4.__ Измерительный блок без корпуса:
1 – моноблок; 2 – оправка; 3 – PDC-резец; 4 – болт хомута; 5 – датчики осевой нагрузки;
6 – датчики силы трения (тангенциальной нагрузки); 7 – технологическое отверстие для термопары

of the cutter location. To unify the tests, a single angle of 15° was accepted for all cutters;

4) a mandrel for a counter-sample (Fig. 5). It allows fixing the diamond cutting wheel in the drive chuck and eliminates the possibility of bending the diamond cutting wheel under the action of axial load. Moreover, the diamond cutting wheel mandrel is additionally equipped with a lock that prevents the diamond cutting wheel from rotating around the rotation axis at high friction torques during tests, thus ensuring the same friction path when testing different PDC cutters and, accordingly, increasing the reliability of the results obtained.

RESULTS

The typical diagram of wear tests according to the "tooth edge – diamond wheel" scheme given in Fig. 6 shows that as the cutter wears, the friction torque increases. In this case, axial and torsional vibrations occur. Axial vibrations lead to the formation of a wave-like profile on the surface of the counter sample. Upon completion of the tests, a flat similar in shape to the worn surface is formed on the working edge of the cutter (Fig. 7).

Fractographic analysis of the surfaces of PDC cutters worn during operation (Fig. 8) and during laboratory tests showed a similar damage pattern in the form of a stepped

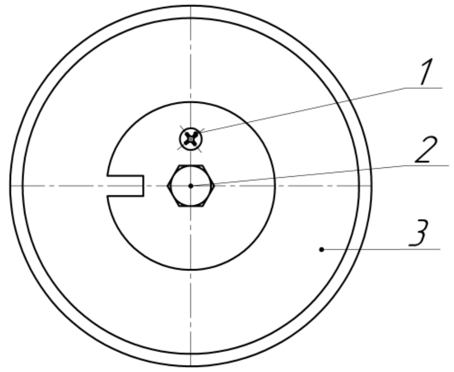


__Fig. 5.__ Mandrel for counter sample.
Diamond cutting wheel mandrel:
1 – hole for the lock; 2 – installed lock; 3 – diamond cutting wheel
__Рис. 5.__ Оправка для контробразца.
Оправка алмазного отрезного диска:
1 – отверстие под фиксатор; 2 – установленный фиксатор; 3 – алмазный отрезной диск

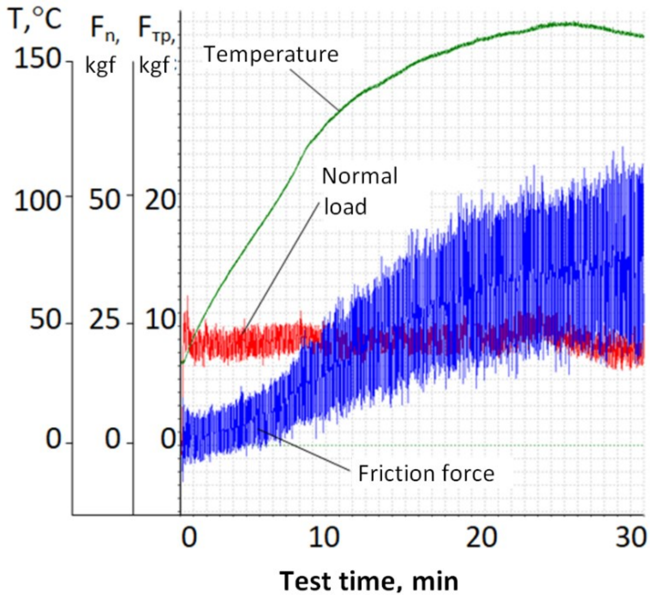
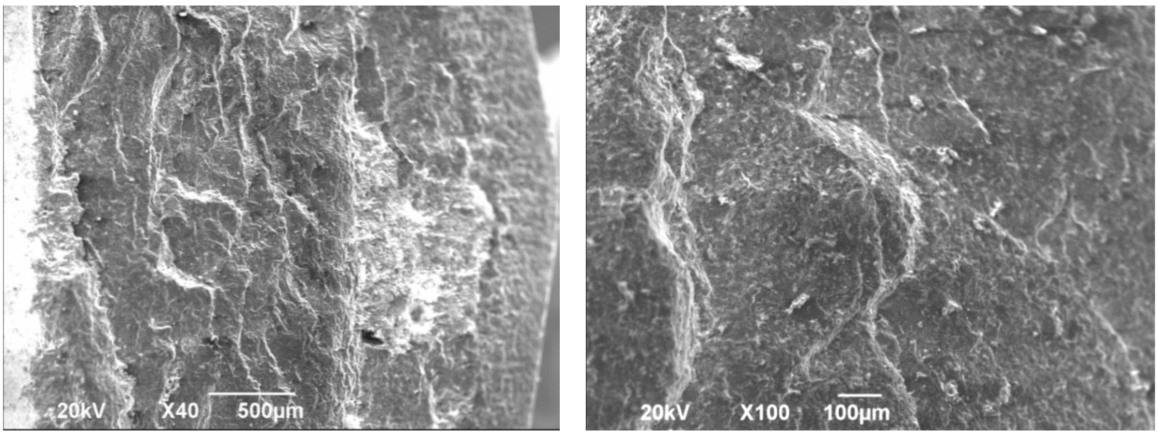


Fig. 6. *Typical view of the PDC cutter test diagram*
Рис. 6. *Характерный вид эпюры испытаний PDC-резцов*

Fig. 7. *View of the worn surface of a polycrystalline diamond insert*
Рис. 7. *Вид изношенной поверхности поликристаллической алмазной пластины*



a ***b***

Fig. 8. *Stepped structure of the wear surface of the polycrystalline diamond insert of PDC cutters: at magnification ×40 (**a**) and ×100 (**b**)*
Рис. 8. *Ступенчатая структура поверхности изнашивания поликристаллической алмазной пластины PDC-резцов: при увеличении ×40 (**a**) и ×100 (**b**)*

structure characteristic of fatigue wear. The studies of PDC cutters of different batches and quality classes for wear showed that the range of wear rates is from 1 to 11 mg/h, and the wear rate of the work face is from 0.8 to 8 g/h.

The wear rate of the counterbody characterizes the degree of aggressiveness of the cutter in relation to the work face. Cutters with a lower content of plastic cobalt binder turned out to be more aggressive to the metal work face.

A complex parameter characterizing the efficiency of the cutter during friction – the amount of removed work face (in mg) per 1 mg of weight wear of the cutting edge of the cutter is also of interest.

Based on the conducted studies, the authors proposed a criterion that allows classifying cutters into one of four groups of operational properties by wear resistance, which is given in Table 1.

DISCUSSION

The results of testing the developed laboratory tribotechnical facility on PDC cutters of different batches showed that tests on the new equipment allow obtaining data on the wear rate of the working edges of PDC cutters quite quickly. At the same time, the fact that grinding wheels are manufactured using a specific technology regulated by technical requirements creates prerequisites for improving the reproducibility of test results. Since diamond inserts are superhard materials, artificial diamond-containing materials manufactured using a specific technology can have the greatest abrasive effect on them. Such metal-diamond composites are used as a working layer in diamond grinding wheels and diamond cutting wheels, the use of the latter has a significant advantage in terms of economy.

The experimental equipment developed for conducting abrasive tests has a wide potential for application both in the field of well drilling and in other areas where it is necessary to assess the wear resistance of materials when exposed to abrasive media.

Studying the processing of materials using diamond cutting wheels often requires the development of specialized devices for optimal tool operation. One of the key elements of such a device is a mandrel that ensures reliable fixation of the diamond cutting wheel and PDC cutter. It is important to take into account that the mandrel design should prevent the wheel from bending under the influence of axial load and ensure the correct angle of the cutter.

The obtained results show that the developed methods for testing PDC cutters for wear and equipment can be used to differentiate cutters by wear resistance.

The quality management system for diamond and matrix bits requires improving the methods of incoming inspection of PDC cutter resistance to operational destructive factors. For effective incoming inspection of PDC cutter wear resistance, it is necessary to ensure both the adequacy of test results and the efficiency of testing without unnecessary costs. For this purpose, special laboratory equipment was developed at Samara State Technical University. To accelerate wear tests, it was proposed to use a metal-diamond work face in the form of a diamond-containing rim of a diamond cutting wheel as a counterbody. Unlike the use of natural rocks (granite stone), which can have significant differences in hardness (6.5–7 units on the Mohs scale) and tensile strength (from 40 to 80 MPa), artificially created diamond tools are manufactured according to accepted technical requirements and have a regulated range of properties. To test PDC cutters, it is recommended to take wheels with a hard bond (6600 MPa on the Vickers scale). This will reduce the wear rate of the diamond rim and allow using one disk twice: first from one end, then from the other. In this case, there is no disk clogging. The tested edge of the PDC cutter effectively removes the metal layer and reveals new diamond grains. Moreover, with an increase in the hardness of the counterbody, the pressure at the point of contact of the cutter with the metal-diamond face during friction increases. This creates conditions for forcing wear tests.

The recommended load on the friction contact is 20 kgf (196.2 N). Higher loads lead to the appearance of areas of adhesion of the PDC cutter with the diamond rim, strong heating of the contact (over 300 °C), and rapid failure of the diamond wheel without the possibility of its secondary use. For the same reasons, the rotation speed of the wheel was limited to 200 rpm. Lower loads lead to the necessity of increasing the test duration to form noticeable wear. The studies have shown that the characteristic values of the force of friction between the cutter and the diamond rim under the selected normal load are about 60...70 N, which, with a cutting wheel diameter of 115 mm, corresponds to a friction torque of 3.6...4.2 N·m. To implement such

Table 1. *Classification of PDC cutters by abrasion resistance*
Таблица 1. *Классификация PDC-резцов по стойкости к абразивному истиранию*

Group of cutter operational properties according to wear resistance	Cutter wear rate, mg/h
1	<2
2	2…4
3	4…6
4	>6

an effort, it is recommended to use a drive with a power of at least 400 W. For testing, the drive can be implemented on the basis of vertical drilling machines equipping them additionally with a lever loading system.

Similarly, OAO Volgaburmash (OJSC) practiced methods for assessing the abrasion resistance of teeth, in which a granite blank was installed on a turning lathe and turned with a special cutter, where instead of a replaceable cutting plate, the test tooth was installed so that its cutting edge was located at the place of the cutting edge of the cutter. Thus, the operation of the tooth at the work face was simulated. The disadvantages of this method are the duration and high cost of tests. One test requires time from several hours to several days. The use of granite stone both leads to economic expenditures and creates certain difficulties in terms of standardizing its characteristics: natural stone is heterogeneous, has strength that varies several times and may contain an unregulated number of defects. Moreover, during these tests, a large amount of stone dust is created, and since this has a negative impact on human health and safety, a separate room is required. In addition, dust can settle on production lines, equipment and finished products, which leads to defects, quality deterioration, and the need for additional cleaning and, as a result, to increased costs.

The manual developed by OOO PetroEngineering (LLC) proposes a technology for determining the feasibility of further operation of a PDC bit in field conditions. The technology is based on observations of the wear of hundreds of bits in Western Siberian fields and an analysis of maintenance documentation (flaw detection reports, bit run cards, repair cost estimates), as well as expert opinions from specialized professionals from various companies[2]. This technology is quite comprehensive and suggests assessing both the bit suitability for further work as intended and, based on economic calculations, the profitability of its repair (if the repair expenses do not exceed 20...30 % of the new bit cost) or the need for disposal (if the repair expenses reach 70...80 % ofthe new bit cost). The analysis of the bit condition is based on a visual inspection and wear assessment of five main elements that have the greatest impact on the bit condition: PDC cutters, cavities, flushing elements, bit diameter and thread condition. When counting the cutters that require replacement, all cutting elements with noticeable damage, regardless of their size and nature, are considered as such. It is believed that if the share of damaged cutters on a bit is more than 60 % of all rock-destructing cutters, then the bit operation should be finished before a decision is made on the advisability of its restoration or disposal. One should note that this guide is practical and economically feasible, but not every cutter damage should be considered a reason for its replacement, taking into account that this is the most expensive repair item. At the same time, the features of the geological section are not always taken into account.

The methodology adopted by the Burintekh Scientific and Production Enterprise considers bits unsuitable and subjected to rejection in the following cases: the diameter of the bit has decreased by 2...3 mm (depending on the size); wear of the cutters has caused a noticeable decrease in the mechanical drilling speed; overheating of the cutters is observed over the entire surface; with significant destruction of one or several cutters[3]. These recommendations are also not unambiguously clear for an operator using them with insufficient experience.

The considered approaches to the analysis of tool wear are based on the study of existing damage, but how to approach the prediction of the performance of the drill bit tool? To answer this question, there are various prediction models [16; 17], including methods based on the use of artificial intelligence. Thus, in the work [18] a two-stage neural network model is proposed, which at the first stage estimates the drilling speed, and at the second – predicts the percentage of PDC cutter breakdowns.

CONCLUSIONS

Conducting tests on a laboratory tribotechnical facility for PDC cutters of different batches allowed obtaining important data on the wear rate of working edges. Testing results showed that the range of wear rates varies from 1 to 11 mg/h. It is important to note that the wear rate of the work face fluctuates from 0.8 to 8 g/h. These results indicate the effectiveness of the new equipment for quick and accurate measurement of PDC cutter wear during operation.

The authors have developed methods and equipment for laboratory testing of PDC cutters for wear during friction against a diamond-containing metal work face, which can be used for incoming quality control of a batch of PDC cutters arriving for assembly of diamond drill bits. Research conducted based on the obtained data allowed developing a criterion for classifying cutters by their wear resistance. The proposed criterion allows determining more accurately the wear resistance category of cutters, which, in turn, helps to increase the efficiency of production processes. Except for the wear of PDC cutters, it is recommended to evaluate also the wear of the counterbody, which characterizes the performance of the cutter.

REFERENCES

1. Neskoromnykh V.V., Popova M.S., Parakhonko E.V. Development of rock cutting tool with PDC cutters. *Bulletin of the Tomsk Polytechnic University. Geo Assets Engineering*, 2020, vol. 331, no. 2, pp. 131–138. DOI: 10.18799/24131830/2020/2/2499.

[2] *Myasnikov Ya.V., Ionenko A.V., Gadzhiev S.G., Lipatnikov A.A., Leonov E.G. How to assess properly the wear of PDC bits in the field? Sphere. Oil and Gas: official website. URL: https://сферанефтьигаз.рф/iscpetro-2014-5/.*

[3] *Recommendations for assessing wear of PDC bits. Burintekh Scientific and Production Enterprise: official website. URL: https://burintekh.ru/upload/iblock/871/r817xkl9kjc04qjl3qtt25rfp3pmf8lh.pdf.*

2. Nenashev M.V., Ibatullin I.D., Zhuravlev A.N., Kosulin S.I. Engineering tools and methods of PDC bits entrance quality control. *Izvestiya Samarskogo nauchnogo tsentra Rossiyskoy akademii nauk*, 2011, vol. 13, no. 4-3, pp. 835–838. EDN: PCLSTT.
3. Konyashin I., Zaitsev A.A., Sidorenko D. et al. On the mechanism of obtaining functionally graded hardmetals. *Materials Letters*, 2017, vol. 186, pp. 142–145. DOI: 10.1016/j.matlet.2016.09.130.
4. Bogomolov R.M., Serikov D.Yu. Improvement of the cutting structures of the rolling cutter drill bits. *Oborudovanie i tekhnologii dlya neftegazovogo kompleksa*, 2018, no. 5, pp. 24–28. DOI: 10.30713/1999-6934-2018-5-24-28.
5. Vasilev A.A., Serikov D.Yu., Bliznyukov V.Yu. Improvement of drill bits of different types. *Stroitelstvo neftyanykh i gazovykh skvazhin na sushe i na more*, 2019, no. 6, pp. 28–31. DOI: 10.30713/0130-3872-2019-6-28-31.
6. Neskoromnykh V.V., Popova M.S., Komarovskiy I.A., Baochang L. Concave PDC cutter. *Bulletin of the Tomsk Polytechnic University. Geo Assets Engineering*, 2022, vol. 333, no. 4, pp. 181–192. DOI: 10.18799/24131830/2022/4/3488.
7. Tretyak A.A., Krivosheev K.V. Winning combination of PDC cutter arrangement on a rock-destructing tool. *Delovoy zhurnal Neftegaz.RU*, 2025, no. 3, pp. 36–40. EDN: NCPITK.
8. Bellin F., Dourfaye A., King W., Thigpen M. The current state of PDC bit technology. Part 1 of 3: Development and application of polycrystalline diamond compact bits have overcome complex challenges from the difficulty of reliably mounting PDC cutters in bit bodies to accelerated thermal wear. *World Oil*, 2010, pp. 41–46.
9. Kolibasov V.A., Ibatullin I.D., Parfenov K.V., Gordeeva E.S. Development of procedure and device for abrasion test of PDC cutters. *Neftegazovoe delo*, 2024, vol. 22, no. 6, pp. 53–62. DOI: 10.17122/ngdelo-2024-6-53-62.
10. Kuftyrev R.Y., Polushin N.I., Kotel’nikova O.S., Laptev A.I., Sorokin M.N. Wear resistance of polycrystalline diamond cutters for drill bits. *Steel in Translation*, 2017, vol. 47, no. 9, pp. 594–598. DOI: 10.3103/S096709121709008X.
11. Trushkin O.B., Akchurin Kh.I. PDC cutter pressure on plastic-brittle rock in the process of its destruction. *Journal of Mining institute*, 2020, vol. 244, pp. 448–453. DOI: 10.31897/PMI.2020.4.7.
12. Kanyanta V., Ozbayraktar S., Maweja K. Effect of manufacturing parameters on polycrystalline diamond compact cutting tool stress-state. *International Journal of Refractory Metals and Hard Materials*, 2014, vol. 45, pp. 147–152. DOI: 10.1016/j.ijrmhm.2014.03.009.
13. Moseley S.G., Bohn K.P., Goedickemeier M. Core drilling in reinforced concrete using polycrystalline diamond (PDC) cutters: wear and fracture mechanisms. *International Journal of Refractory Metals and Hard Materials*, 2009, vol. 27, no. 2, pp. 394–402. DOI: 10.1016/j.ijrmhm.2008.11.014.
14. Borisov K.I., Rubtsov V.L. Analytical investigation of rock temporal strength property at PDC cutting. *Izvestiya Tomskogo politekhnicheskogo universiteta*, 2014, vol. 325, no. 1, pp. 172–178. EDN: SITAEP.
15. Yahiaoui M., Gerbaud L., Paris J.-Y., Denape J., Dourfaye A. A study on PDC drill bits quality. *Wear*, 2013, vol. 298-299, pp. 32–41. DOI: 10.1016/j.wear.2012.12.026.
16. Ahmed O.S., Adeniran A.A., Samsuri A. Computational intelligence based prediction of drilling rate of penetration: a comparative study. *Journal of Petroleum Science and Engineering*, 2019, vol. 172, pp. 1–12. DOI: 10.1016/j.petrol.2018.09.027.
17. Zhao Y., Noorbakhsh A., Koopialipoor M., Azizi A., Tahir M.M. A new methodology for optimization and prediction of rate of penetration during drilling operations. *Engineering with Computers*, 2019, vol. 3, pp. 587–595. DOI: 10.1007/s00366-019-00715-2.
18. Tretyak A.Ya., Kuznetsova A.V., Borisov K.A. Determination of PDC cutter breakdowns using regression and neural network modeling. *Bulletin of the Tomsk Polytechnic University. Geo Assets Engineering*, 2019, vol. 330, no. 5, pp. 169–177. DOI: 10.18799/24131830/2019/5/275.

СПИСОК ЛИТЕРАТУРЫ

1. Нескоромных В.В., Попова М.С., Парахонько Е.В. Разработка породоразрушающего инструмента с резцами PDC // Известия Томского политехнического университета. Инжиниринг георесурсов. 2020. Т. 331. № 2. С. 131–138. DOI: 10.18799/24131830/2020/2/2499.
2. Ненашев М.В., Ибатуллин И.Д., Журавлев А.Н., Косулин С.И. Технические средства и методики входного контроля качества PDC зубков алмазных буровых долот // Известия Самарского научного центра Российской академии наук. 2011. Т. 13. № 4-3. С. 835–838. EDN: PCLSTT.
3. Konyashin I., Zaitsev A.A., Sidorenko D. et al. On the mechanism of obtaining functionally graded hardmetals // Materials Letters. 2017. Vol. 186. P. 142–145. DOI: 10.1016/j.matlet.2016.09.130.
4. Богомолов Р.М., Сериков Д.Ю. Совершенствование вооружения шарошечного бурового долота // Оборудование и технологии для нефтегазового комплекса. 2018. № 5. С. 24–28. DOI: 10.30713/1999-6934-2018-5-24-28.
5. Васильев А.А., Сериков Д.Ю., Близнюков В.Ю. Совершенствование буровых долот различных типов // Строительство нефтяных и газовых скважин на суше и на море. 2019. № 6. С. 28–31. DOI: 10.30713/0130-3872-2019-6-28-31.
6. Нескоромных В.В., Попова М.С., Комаровский И.А., Баочанг Л. Резцы PDC с вогнутой поверхностью режущей грани // Известия Томского политехнического университета. Инжиниринг георесурсов. 2022. Т. 333. № 4. С. 181–192. DOI: 10.18799/24131830/2022/4/3488.
7. Третьяк А.А., Кривошеев К.В. Выигрышная комбинация расположения резцов PDC на породоразрушающем инструменте // Деловой журнал Neftegaz.RU. 2025. № 3. С. 36–40. EDN: NCPITK.
8. Bellin F., Dourfaye A., King W., Thigpen M. The current state of PDC bit technology. Part 1 of 3: Develop-

ment and application of polycrystalline diamond compact bits have overcome complex challenges from the difficulty of reliably mounting PDC cutters in bit bodies to accelerated thermal wear // World Oil. 2010. P. 41–46.
9. Колибасов В.А., Ибатуллин И.Д., Парфенов К.В., Гордеева Е.С. Разработка методики и устройства для испытания PDC резцов на абразивное изнашивание // Нефтегазовое дело. 2024. Т. 22. № 6. С. 53–62. DOI: 10.17122/ngdelo-2024-6-53-62.
10. Куфтырев Р.Ю., Полушин Н.И., Котельникова О.С., Лаптев А.И., Сорокин М.Н. Износостойкость PDC режущих элементов, применяемых для комплектации PDC буровых долот // Известия высших учебных заведений. Черная металлургия. 2017. Т. 60. № 9. С. 745–751. DOI: 10.17073/0368-0797-2017-9-745-751.
11. Трушкин О.Б., Акчурин Х.И. Давление резцов PDC на пластично-хрупкую горную породу в процессе ее разрушения // Записки Горного института. 2020. Т. 244. С. 448–453. DOI: 10.31897/PMI.2020.4.7.
12. Kanyanta V., Ozbayraktar S., Maweja K. Effect of manufacturing parameters on polycrystalline diamond compact cutting tool stress-state // International Journal of Refractory Metals and Hard Materials. 2014. Vol. 45. P. 147–152. DOI: 10.1016/j.ijrmhm.2014.03.009.
13. Moseley S.G., Bohn K.P., Goedickemeier M. Core drilling in reinforced concrete using polycrystalline diamond (PDC) cutters: wear and fracture mechanisms // International Journal of Refractory Metals and Hard Materials. 2009. Vol. 27. № 2. P. 394–402. DOI: 10.1016/j.ijrmhm.2008.11.014.
14. Борисов К.И., Рубцов В.Л. Аналитическое исследование временной прочностной характеристики горной породы при резании-скалывании резцами PDC // Известия Томского политехнического университета. 2014. Т. 325. № 1. С. 172–178. EDN: SITAEP.
15. Yahiaoui M., Gerbaud L., Paris J.-Y., Denape J., Dourfaye A. A study on PDC drill bits quality // Wear. 2013. Vol. 298-299. P. 32–41. DOI: 10.1016/j.wear.2012.12.026.
16. Ahmed O.S., Adeniran A.A., Samsuri A. Computational intelligence based prediction of drilling rate of penetration: a comparative study // Journal of Petroleum Science and Engineering. 2019. Vol. 172. P. 1–12. DOI: 10.1016/j.petrol.2018.09.027.
17. Zhao Y., Noorbakhsh A., Koopialipoor M., Azizi A., Tahir M.M. A new methodology for optimization and prediction of rate of penetration during drilling operations // Engineering with Computers. 2019. Vol. 3. P. 587–595. DOI: 10.1007/s00366-019-00715-2.
18. Третьяк А.Я., Кузнецова А.В., Борисов К.А. Определение поломок резцов PDC с помощью регрессионного и нейросетевого моделирования // Известия Томского политехнического университета. Инжиниринг георесурсов. 2019. Т. 330. № 5. С. 169–177. DOI: 10.18799/24131830/2019/5/275.

Разработка лабораторного триботехнического комплекса для испытаний PDC-резцов на изнашивание

Колибасов Владимир Александрович*[1], аспирант,
ассистент кафедры «Машины и оборудование нефтегазовых и химических производств»
Ибатуллин Ильдар Дугласович, доктор технических наук, профессор,
заведующий кафедрой «Машины и оборудование нефтегазовых и химических производств»
Новиков Владислав Александрович[2], кандидат технических наук,
доцент кафедры «Металловедение, порошковая металлургия, наноматериалы»,
старший научный сотрудник лаборатории рентгеновской дифрактометрии, электронной и зондовой микроскопии
Самарский государственный технический университет, Самара (Россия)

***E-mail:** mahp@samgtu.ru,
csstea@yandex.ru

[1]ORCID: https://orcid.org/0000-0002-0503-2533
[2]ORCID: https://orcid.org/0000-0002-8052-305X

Поступила в редакцию 10.02.2025 *Пересмотрена 25.02.2025* *Принята к публикации 11.03.2025*

Аннотация: В практике бурения нефтегазовых скважин алмазными долотами, вооруженными PDC-резцами, имеют место случаи несоответствия качества резцов заявленному классу. При этом применяемые в настоящее время методы натурных испытаний, когда в качестве контртела используют гранитный камень, являются длительными и дорогостоящими, что затрудняет их применение для оперативного входного контроля новых партий PDC-резцов, поступающих на сборку алмазных долот. Это обусловило необходимость разработки лабораторного триботехнического комплекса для количественной оценки способности PDC-резцов противостоять истиранию об абразивные материалы. Исследование посвящено разработке специализированного триботехнического комплекса, позволяющего проводить испытания на изнашивание PDC-резцов различных типоразмеров при трении об алмазосодержащий металлический забой, в качестве которого предложено использовать алмазные отрезные диски. В состав разработанного лабораторного триботехнического комплекса входят: электромеханический привод вращения (станок сверлильно-фрезерной группы); измерительный блок с датчиками нормальных нагрузок, силы трения и температуры саморазогрева резца при испытаниях; рычажный механизм нагружения; набор оправок для возможности установки PDC-резцов различных типоразмеров; система сбора данных и лицензионное программное обеспечение. Результаты апробации разработанного лабораторного триботехнического комплекса на PDC-резцах различных партий показали, что испытания на новом оборудовании позволяют достаточно быстро получать данные о скорости изнашивания рабочих кромок PDC-резцов. Разработанные методики, оборудование и критерии можно использовать для возможности сертификации износостойкости PDC-резцов.

Ключевые слова: алмазное долото; PDC-резец; триботехнический комплекс; алмазосодержащий металлический забой.

Для цитирования: Колибасов В.А., Ибатуллин И.Д., Новиков В.А. Разработка лабораторного триботехнического комплекса для испытаний PDC-резцов на изнашивание // Frontier Materials & Technologies. 2025. № 1. С. 9–19. DOI: 10.18323/2782-4039-2025-1-71-1.