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PECULIARITIES OF REPAIR OF WORN OPERATING ELEMENTS OF DRILL BITS

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The peculiarities of wear of operating elements of the bodies of steel, matrix drill bits and heads were considered and studied, and repairability criteria were determined. Performed analysis of worn areas of operating elements of used drill bit bodies showed that at drilling wear of cutters and sockets is the most common, and wear of flushing channel components of the drill bit bodies occurs less often. Metallographic examination showed that the deposited layer and the base metal are connected by a thin transition layer of diffusion origin, which shows that base metal melting and filler metal dissolution did not occur in it. It is established that the drill bit repair is cost-effective in those cases, when the cost of such repair does not exceed one third of the cost of the bit proper. Multiple repeated reconditioning of operating elements of worn areas reduces the cost of manufacturing new drill bits several times. Conducted production trials of reconditioned drill bits showed that repair of worn areas of the operating elements allows considerable extension of the service life and saving 30−50 % of the initial cost of a specific drill bit type. 12 Ref., 2 Tables, 8 Figures.

Keywords: wear, surfacing, tungsten carbides, area, bridge, diamond-carbide cutter, polycrystalline diamond cutter, carbide coating, microstructure, wear resistance

Development of the technological processes of drill tools repair does not stand still, and now the enterprises and firms in Ukraine and abroad propose different methods of repair of worn areas of drill bit bodies. Drill tools that are used in the gas and oil industry wear during service that leads to shortening of operating life and often requires replacement or repair.

The main characteristics of wear of the operating elements of drill bits (both own and foreign production bits) in the fields of Ukraine are as follows: cutter wear — 17 %, cutter breaking — 30 %; cutter chipping — 31 %; loss of cutters — 3 %; wear of protective coating — 5 % and 19 % — absence of wear. For instance, abroad the headway of drill bits of PDC type (Polycrystalline Diamond Cutter) that are used for oil and gas drilling (by the data of Smith Inc.), is equal to 1067.5 m on average [1]. In Ukraine, the headway of domestic drill bits (usually, produced by Bakul ISM) is equal to 300–400 m on average.

At present, the new methods of repair and reconditioning of the worn areas by wear-resistant coating allow effectively resisting a number of problems of wear of the blades and bodies of drill bits under the conditions of alternating and shock loads, hydroabrasive wear, corrosion, etc., due to high adhesive strength of the protective surface layer, reduction of friction coefficient, improvement of corrosion resistance in an aggressive environment at increased value of hydrogen index ($pH = 7 – 12$).

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Leading developer-companies Baker Hughes INTEQ, Bit-Tech, Dowdco, Halliburton Security DBS, Hughes Christensen, Ulterra Drilling, Reed Hycalog, Smith Tool, Varel, Tri-Max (all US), TIX (Japan), United Diamond (Canada), Kingdrelm (China) and oth. have used coatings of different functional purposes for a long time, at manufacture and repair of operating elements of drill bits. Development of technological processes of manufacture and repair of drill bits is continuously improved due to application of new composite materials and technologies of protective coating deposition.

There exist the main surfacing methods, depending on the kind of the used energy: oxyacetylene surfacing, arc surfacing (open arc, gas-shielded, vibroarc, plasma), electroslag, induction, laser, and electron beam. When selecting the surfacing method, first the possibilities of its application in a specific case are assessed, then the possibility is determined of ensuring the technical requirements that are made to deposition of the base materials and, finally, the cost-effectiveness of surfacing is assessed. At assessment of cost-effectiveness of the surfacing process, the total cost of manual arc surfacing is taken to be 100 %, that of oxyacetylene surfacing — 74 % and of vibroarc surfacing — 82 %.

At deposition of the composite material on the worn areas of operating elements of the drill bits the advantage was given to arc surfacing. The essence of the surfacing process consists in the use of the heat for filler material melting and its joining with the base metal of the drill bit body. Using the possibilities of arc surfacing, a deposited layer of the required thickness and chemical composition with the required properties can be obtained in the part surface.

In view of the above-said, the objective of the work consisted in investigation and development of the technology of repair of the worn areas of operating elements of drill bit bodies.

Materials and methods. The object of study are the worn areas of operating elements of the bodies of used steel and matrix drill bits. Microstructural investigations were conducted by a standard procedure in electron microscope Tescan Mira 3 LMU and optical microscope Neophot 32. PRS-3M welding unit, Casto Fuse gas torch, and TeroCote 7888T composite material were used.

Investigation results. In order to protect the operating elements of drill tools from different kinds of wear, composite materials based on Ni, Fe, NiCr, NiCrBSi, copper alloys, etc., strengthened by tungsten carbides, are widely used [2–5]. This is, first of all, related to unique properties of the reinforcing phase of such alloys — tungsten carbides. Tungsten carbide is one of the hardest and most shock-resistant carbides, and deposition of hard alloy coating (HC) is a fast and simple method of application of tungsten-carbide coating on the worn areas of the operating elements, that are exposed to the impact of intensive abrasive loads, and it preserves its mechanical properties in a wide range of temperatures, is resistant to friction corrosion and is capable of forming a strong bond with metals [6, 7].

Proceeding from the results of the performed work [8, 9] on reconditioning of the operating elements of drill bit bodies, TeroCote 7888 T composite material was selected. It readily wets the base metal of both the steel, and matrix drill bits, and has no defects at deposition of the coating layer on the worn areas of the sockets of the openings of diamond-carbide cutters (DCC) and this bridges between the sockets that, in its turn, promotes machining of the openings of the sockets after surfacing and preserves the geometry for DCC fastening.

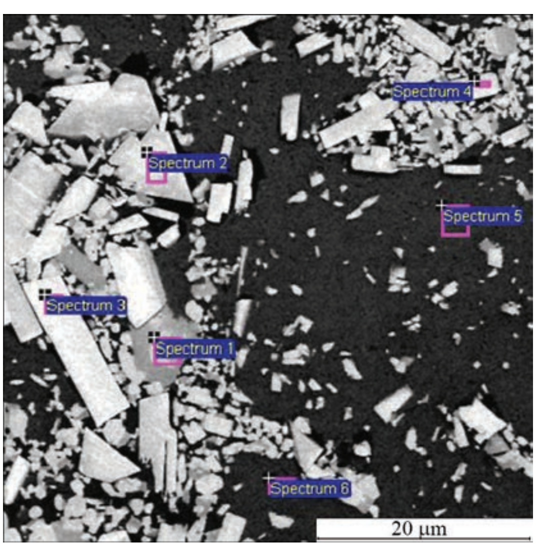

Figure 1. Microstructure of TeroCote 7888 T alloy

Conducted investigations of the composite material wear resistance under the conditions of hydroabrasive wear [10] showed that the wear resistance of protective coating from TeroCote 7888T, based on nickel with crushed particles of tungsten carbide is higher than that of «LZ-11-7» relite (spherical granules of tungsten carbide) and Diamax M (ground particles of tungsten carbide) based on iron by 1.7 and 2.9 times, respectively. Proceeding from the results of wear resistance studies, the TeroCote 7888T alloy was selected, on the base of which corrosion resistance studies of this material were conducted. Results of the performed corrosion resistance studies showed [11] that application of the protective coating deposited using TeroCote 7888T flexible cord, allows lowering the corrosion rate of operating elements of drill tools from 30Kh steel almost 53 times that will promote extension of its service life. Proceeding from the results of investigations of hydroabrasive and corrosive wear of composite materials, the main attention was given to this alloy, which belongs to the category of corrosion-resistant protective materials.

TeroCote 7888T composite material was used to restore the worn coating areas of drill bit body. This material of 5 mm diameter has a core from nickel wire of 1.2 mm diameter and a sheath from nickel-based matrix alloy (Ni–Cr–B–Si system), reinforced by tungsten-carbide particles of irregular shape. Tungsten carbides are characterized by different dimensions from 0.7 to several microns, and their quantity in the volume is < 65 %. The working temperature of melting is equal to 1170 °C (± 50 °C). The main structural phase of the alloy is γ-oversaturated solid solution based on nickel, reinforced by tungsten carbides, with the following depressant content in wt.%: silicon up to 1.36 and boron up to 0.6 (Figure 1, Table 1).

Figure 2 gives the distribution of elements in TeroCote 7888 T composite material, which provides convincing proof of the fact that the base of matrix alloy is the nickel-based solid solution (74.31 wt.%), coated by an alloy of Ni–Cr–Fe–Si–B system. This is confirmed by quantitative microanalysis in the studied areas (see Table 1).

Deposition of the coating layer on the worn areas of operating elements of the matrix and steel drill bits was performed by nonconsumable tungsten electrode TIG-process in the shielding gas – commercial argon (Table 2). Surfacing of worn areas of operating elements was performed in the horizontal position of

Table 1. Composition of the studied areas, wt.%

Spectrum number	B	C	Si	Cr	Fe	Ni	W	Total
1	0.56	4.84	1.08	8.77	0.00	18.83	65.91	100.00
2	0.63	8.19	0.00	0.25	0.71	1.70	88.52	100.00
3	0.65	8.19	0.00	0.00	0.00	2.42	88.73	100.00
4	0.62	9.10	0.00	0.30	0.00	0.00	89.98	100.00
5	0.52	3.60	1.36	6.08	2.50	74.04	11.89	100.00
6	0.00	3.32	1.25	6.27	2.54	74.31	12.32	100.00
Average	0.50	6.21	0.62	3.61	0.96	28.55	59.56	100.00
Deviation	0.25	2.58	0.68	3.88	1.24	35.99	37.84	–
Max	0.65	9.10	1.36	8.77	2.54	74.31	89.98	–
Min	0.00	3.32	0.00	0.00	0.00	0.00	11.89	–

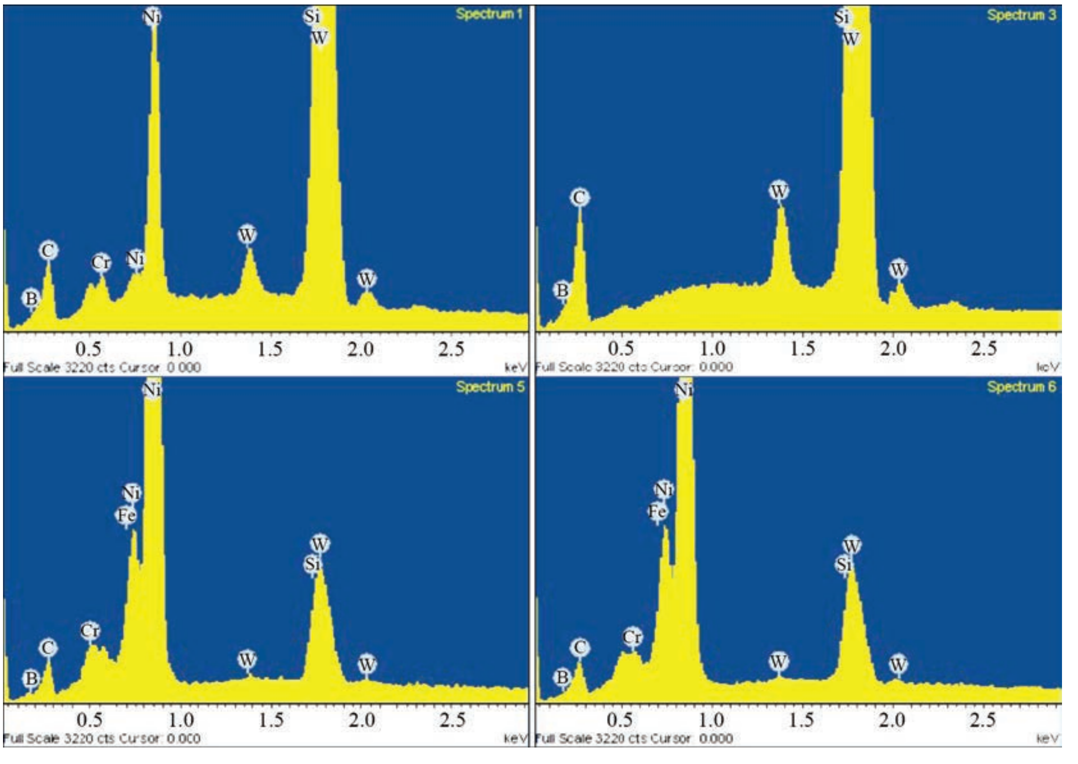

Figure 2. Qualitative distribution of elements in TeroCote 7888 T matrix alloy

the drill bit body. Average thickness of the deposited layer was equal to 2–4 mm, depending on worn area thickness.

The main method of repair of the worn areas of operating elements of matrix (Figure 3, *a*) and steel drill bits (Figure 3, *b*) consists in step-by-step performance of the technological operations: diagnostics of the worn areas, dismantling the worn diamond-carbide cutters and carbide inserts, machining of the worn areas of the body blades; machining of the sockets of blade operating elements; close fitting of graphite plugs into these sockets; flame or induction heating of the body operating elements up to the temperature of 400–500 °C; surfacing the areas between the plugs from the upstream and downstream sides of the mounting sockets of the operating elements by a wear-resistant alloy; body cooling to room temperature; removal of graphite plugs; machining the openings after surfacing; mounting the diamond-carbide cutters and carbide inserts into the socket openings; preheating the sockets up to the temperature in the range of 450–500 °C; brazing the diamond-carbide cutters and carbide inserts up to the temperature of 650–680 °C, as higher temperature starts affecting the strength properties of polycrystalline diamonds; and cooling the drill bit body to room temperature.

In order to determine the microstructure of the protective coating, microsections were cut out of the steel

Table 2. Arc surfacing mode

Voltage, V	Kind of current	Current, A	Argon flow rate, dm³/min	Deposition rate, m/h	Power source
10–12	Direct, straight polarity	80–100	2.5–3.0	2–4	PRS-3M

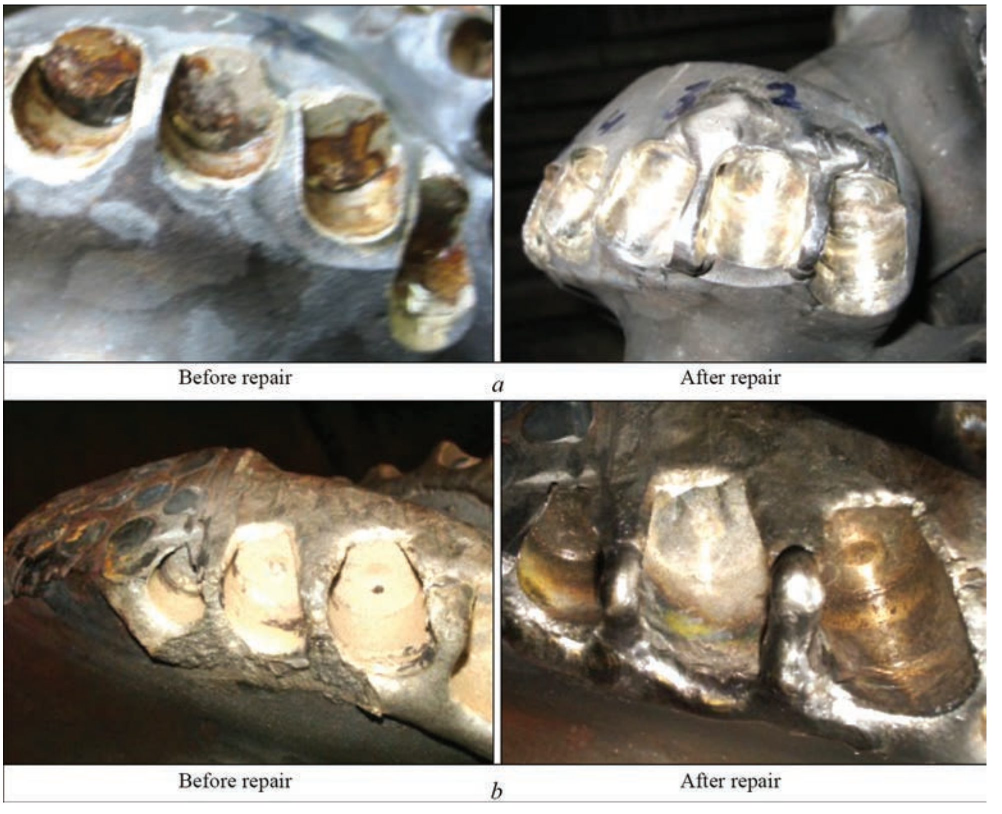

Figure 3. Appearance of worn areas of operating elements: *a* — matrix drill bit; *b* — steel drill bit

(Figure 4) and matrix drill bits (Figure 5) with the deposited layer. Metallographic investigations showed that the deposited layer and base metal are connected by a thin transition layer of diffusion origin, which indicates than no surface melting of the base metal or dissolution of filler metal in it occurred.

The microstructure of the deposited layer of the steel drill bit contains solid solution, based on nickel-chromium strengthened by tungsten carbides, and a certain amount of silicon and boron depressants. Presence of boron and silicon in the composition of filler wires gives them self-fluxing properties at deposition on steel. Tungsten carbides of an irregular shape (of different dimensions) are distributed over the entire microsection field. It is known from publications that sound wear-resistant coating should have a uniform distribution of the hard phases with the distance between these phases smaller than the size of the abrasive particles [12]. Work was also performed on deposition of a protective coating on the worn areas of the matrix drill bit. The microstructure of the deposited layer of the matrix drill bit (Figure 5) is similar to that of the steel drill bit deposited layer (Figure 4).

The obtained structure of the deposited coating of steel and matrix drill bits allows effectively protecting the surface of operating elements from erosion and

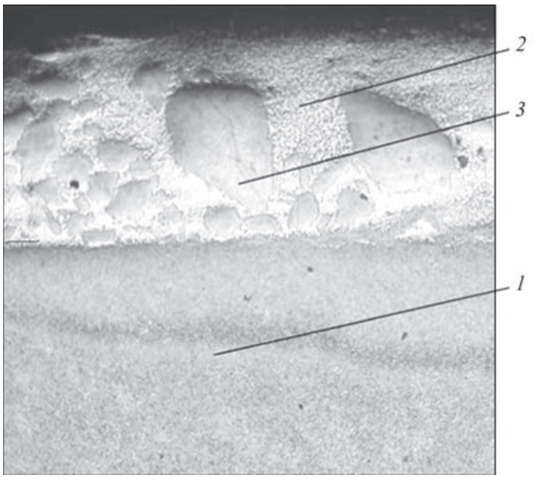

Figure 4. Microstructure (×50) of steel drill bit coating: *1* — 30Kh steel; *2* — matrix based on NiCrBSi alloy; *3* — tungsten carbides

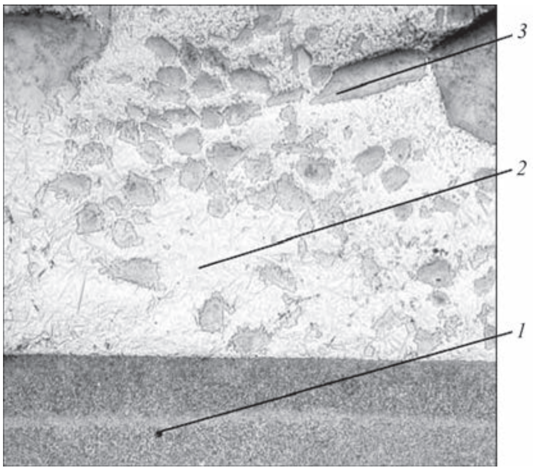

Figure 5. Microstructure (×50) of matrix drill bit coating: *1* — tungsten carbide matrix; *2* — matrix based on NiCrBSi alloy; *3* — tungsten carbides

Figure 6. Matrix drill bit of 215.9 mm diameter: *a* — before repair; *b* — after repair

Figure 7. Integral steel drill bit of 295.3 mm diameter of «Volgaburmash» (Russia): before (*a*) and after repair (*b*)

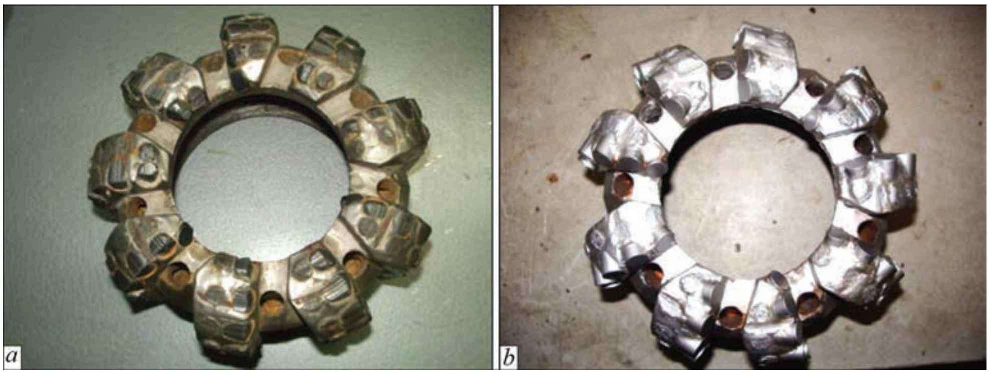

Figure 8. Integral drill head of 212.7 mm diameter of «Burinteks» (Russia): before (*a*) and after repair (*b*)

abrasive wear, caused by impact of such materials as sand, gravel, soil, minerals, etc. The viscous matrix of the alloy absorbs the shock loads and improves the corrosion resistance, whereas the special form of tungsten carbides makes it impossible to pull them out of the matrix.

The features of restoration of the worn areas of operating elements are demonstrated in the case of repair of drill bits of various sizes: restoration of operating elements of the blades of matrix body of 215.9 mm diameter drill bit of Smith Bits Company (USA), restoration of the worn area of the coating of operating elements of blades of the steel body of 295.3 mm diameter drill bit, manufactured by «Volgaburmash», Russia (Figure 7) and restoration of worn operating elements of blades of a drilling head of 212.7 mm diameter, manufactured by «Burinteks», Russia (Figure 8).

The steel and matrix drill bits, restored by PWI, have been successfully tested in the oil-gas-condensate fields of the Poltava region. Based on the testing results, Acts of industrial application of these drill bits have been obtained.

In keeping with the results of investigations and the conducted work, a compulsory repair procedures for the worn areas of the operating elements were drawn up for all the standard sizes of matrix and steel drill bits.

Conclusions

1. The current method of repair of the worn areas allows a significant (2 to 3 times) extension of the service life of the operating elements of bodies of

drill bits, operating under harsh conditions of corrosion-abrasive wear.

2. Proceeding from the results of industrial tests of the restored steel and matrix drill bits, it was established that application of this repair technology when drilling gas and oil wells allows extension of the service life and saving approximately up to 100% of the initial cost of this drill bit.

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