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INCREASING THE WEAR RESISTANCE OF ADAPTERS AND DRILL PIPES BY ELECRTROMECHANICAL PROCESSING

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The directions of the research on increasing the wear resistance of drill pipe locks, threaded joints and casing drill string have been defined: application of drill pipes from the nose-resistant surfacing to the lock with Russian and foreign materials (hardbanding); hardening of the surface layer of drill pipe locks by electromechanical processing; hardaning of the external and internal locking thread of drill pipes by electromechanical processing. Comparative tests of the wear resistance of various hardening materials (hardbanding) of Russian and foreign production and the drill pipe lock without surfacing have been made. The recommendations for increasing the wear resistance of threaded joints by the method of electromechanical processing are developed, which determine the ways of increasing the resource and reliability of drill pipes and sub-assemblies, the formation of unique properties of parts, reducing the labor-capacity of manufacturing and restoring parts, increasing the efficiency of enterprises and organizations, protecting the environment and creation of competitive products.

The materials of the article are of practical value for specialists of various fields engaged in the issues of increasing the reliability of technological equipment.

The production success of using wear resistant surfacing technology on the body of a drill pipe joint is due to the possibility of using relatively simple and mobile welding equipment, carrying out work in the places of use of a drilling tool or temporary (permanent) production bases with a small transport arm from the field, re-depositing surfacing materials restoration of drill pipe locks; a wide and growing list of companies that receive accreditation for the production of these works.

***Key words*:** hardbanding; adapters; drill pipes; wear resistance; thread; surface layer; electromechanical processing; hardness

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Introduction. Increasing the wear resistance of drill pipes (DP) and adapters is an urgent task, the solution of which will increase the efficiency of the oil companies. The most characteristic defects of DP and adapters are the wear of the outer diameter of the locks and thread damage. The low wear resistance of these parts of parts is due to the low hardness of the surface layer – no more than 32-36 HRC. In addition, the insufficient wear resistance of the threads of the listed parts is related to the design features, technological difficulties in its manufacture and recovery, the load circuit of the turns, the operating conditions of threaded joints during drilling, and also the assembly and disassembly of DP and adapters.

One of the problems of low wear resistance of drill pipes is abrasive wear and friction due to friction against internal walls of casing pipes [1]. More than 60 % of pipes are rejected because of wear of the outer diameter of the lock, while the remaining parameters of the pipe correspond to the permissible norms. The main reason for wear of drill pipe locks in an open trunk is the presence of a hard layer in aggressive geological formations. Existing studies prove that when designing technical and technological parameters of fracture of rocks during drilling, it is necessary to take into account not only their physical, mechanical and deformation characteristics, but also the nature of technical and technological interactions between the rock-cutting tool and the rock [2].

When drilling oil and gas wells, the bottom of the drill string consists of drill collars (DC), thick-walled drill pipes (TWDP) and steel drill pipes (SDP). DC and TWDP are made from a single billet of constructional alloyed steels of 40HGMA, 40HN2MA grades. SPD are compound, with locks welded to the body of the pipe by friction welding. Each of the listed parts of the SPD (Fig.1)

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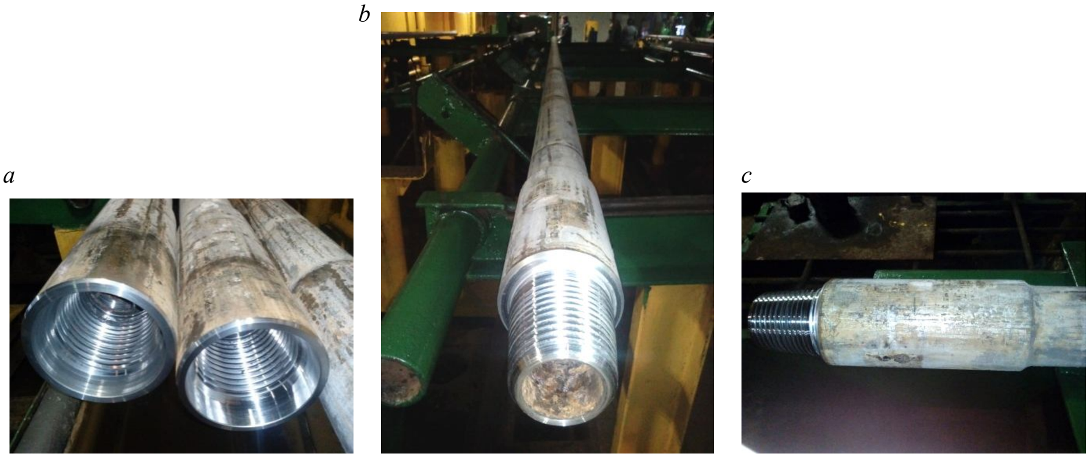

Fig.1. The steel drill pipe (*a*), the fragments of its clutch (*b*) and nipple (*c*) parts

is made of high-quality structural low-alloy steels and subjected to thermal treatment. The length of the DP is 8.5-12.5 m.

Formulation of the problem. Formulation of the problem. In order to improve the wear resistance of the DP on the outer diameter of the locks, surfacing is applied to belts with wear-resistant materials. Mostly, there are three belts, each of which has a width of 25.4 mm with a total width of 76.2 ± 6.35 mm. Surfacing of the belts is performed in an argon medium. The weld metal rises above the body of the lock to 2.5 mm. This method of increasing the wear resistance of DP is widely used by foreign companies [3, 11]. Thus, one of the priority directions in the manufacture and overhaul of drill pipes was hardening surfacing with wear-resistant materials (hardbanding) of the outer surface of locks. Hardbanding is a durable protective metal coating applied by welding on the outer surface of the drill pipe lock to increase the life of the lock and reduce casing wear [6, 10].

An equally important problem is the increase of the DP thread wear resistance. The solution of this problem is impossible without increasing the surface hardness of the threads, while maintaining high physical and mechanical properties of the middle of the turns [8]. The necessary physical and mechanical properties of the DP thread can be achieved by using combined treatment methods based on the use of concentrated energy flows.

One of these methods is electromechanical processing (EMP), based on the simultaneous thermomechanical action of a highly concentrated flow of electrical energy on the surface layer of blanks from steel and forming a high hardness and a finely dispersed structure. The results of research and experimental work indicate the possibility of increasing the wear resistance of DP and adapters by means of purposefully increasing the hardness of the most loaded parts to the optimum value [4, 5, 7, 9, 12-14].

Research method. Further application of wear-resistant surfacing in the drill string is impossible without determining the degree of their effectiveness. To this end, it is necessary to carry out a comparative analysis of the wear resistance of various surfacing materials and DP locks without surfacing.

The results of comparative tests of wear-resistant surfacing of Russian and foreign companies are presented as well as the technology of electromechanical processing in comparison with the initial state of SDP89 drill locks in the strength group G105 by two tests in accordance with the ASTM G65i and Casing Wear Test standard.

Accredited service companies that provide services for the application of wear-resistant surfacing provided samples of the following parameters for testing:

Nipple (or clutch) of the drill pipe lock SDP89 in the strength group G105	Lock outer diameter 127 mm
Surfacing height, mm	2.38 (+0.8)
Surfacing width, mm	76.2±6.35
Welding application	Standart

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The following samples were submitted for testing (Fig.2):

– Initial (nipple part of drill pipe without surfacing);
– Duraband NC (Postle Industries);
– OTW-12Ti (Castolin Eutectic);
– ARNCO 350XT (Arnco Technology Trust);
– NP 57 (Interpro, Russia);
– NP 58 (Interpro, Russia);
– ASM NGN-GS (ASM – special surfacing materials, Russia);
– OTW-13 CF (Castolin Eutectic);
– electromechanical processing (EMP).

Fig. 2. Research samples

For the samples production, the locks SDP 89 were machined: turning by the outer diameter until the unevenness of the surfacing was removed; boring inner diameter up to 105 mm; Cutting of a ring with a height of 20 ± 0.1 mm. The ring was cut into segments of 35 mm length. Four segments were cut from each ring, three of which were used for wear testing, and one sample for metallographic studies. Parameters of the submitted samples:

Clutch of drill pipe lock	SDP 89 in strength group G105
External diameter of the lock, mm	127
Surfacing height, mm	2.38 (+0.8)
Surfacing width, mm	76.2±6.35
Welding application	Standart

A schematic diagram of wear tests is shown in Fig.3.The sample is fixed to the base of the pendulum arm, from the end of which the lever is screwed. A load is hung on the right edge of the lever,

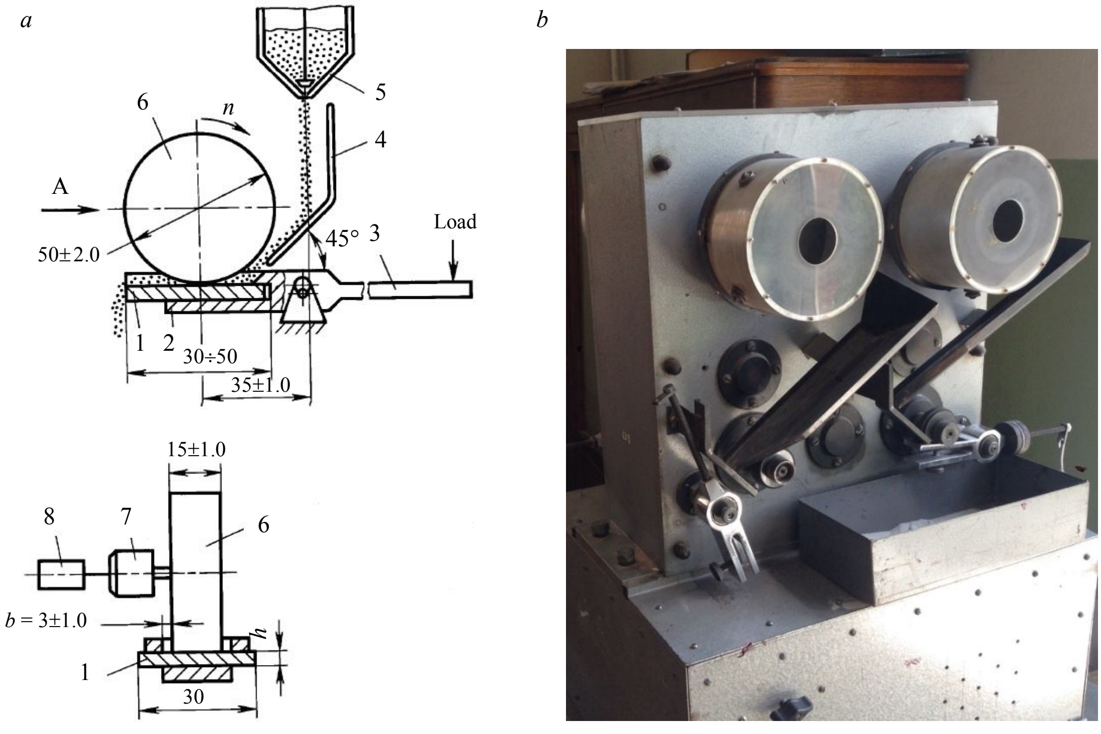

Fig.3. Schematic diagram of tests (*a*) and photograph of the stand (*b*)
1 – sample; 2 – the pendulum lever; 3 – the lever; 4 – the guide tray;
5 – dispenser feeding the abrasive particles; 6 – the rubber roller; 7 – drive;
8 – the counter of the control of total amount of turns of a roller

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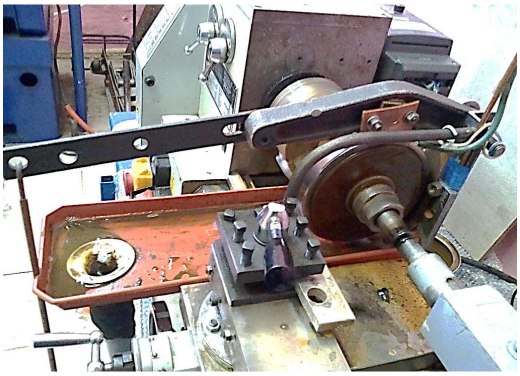

Fig.4. Stand for testing (Casing Wear Test)

which provides a constant load in the contact area of the sample and the rotating rubber roller. A 16 micron abrasive is fed through the rotating dispenser along the guide tray into the contact area of the sample and the rubber roller. The test duration, established by the standards ASTM G65 and GOST 23.208-79, was 30 minutes for each sample.

The stand (Fig.4.) for wear testing of DP lock and casing (Casing Wear Test) is equipped with:

• frequency control system for observing the exact and necessary speed parameters (155 r/min);

• lever mechanism, providing the necessary parameters of pressing the sample on-melting to the casing;

• a device for feeding a liquid mud with a density of 1050-1080 kg/m^3 to the contact zone «casing-surfacing» and the presence of abrasive particles in it at a rate of 20 g per 1 liter of drilling mud.

The chemical analysis of the samples was carried out using a laser atomic emission spectrometer «LAES». The grits were prepared according to a standard procedure on the «Stuers» sample preparation equipment. The etching of the samples was carried out in a 4 % solution of nitric acid in ethyl alcohol. The etching of the weld metal on the samples was carried out in a Marble reagent (20 g CuSO4, 100 ml HCl, 100 ml ethyl alcohol).

Metallographic studies were carried out on an optical microscope Carl Zeiss AxioObserver.D1m at magnifications from 200 to 1000 times. The microhardness was measured on a DuraScan 70 hardness tester at a load of 100 g.

The results of the study and their interpretation. In the process of drilling wells, the bottom of the drill string is in direct contact with the abrasive particles of the rock-fracturing formations. The intensity of destruction of the surface layers of DP during abrasive wear is practically independent of the initial strength properties of the material of the locks. The chemical composition of the material of the locks [5, 6] of the drill pipes indicates a considerable dispersion of the steels in terms of the carbon content (0.22-0.37), which, in combination with other alloying elements, corresponds to the grades of steel 20HGNM-38HGNM. The hardness of the material of the lock part of the DP is 28-36 HRC and is provided by induction volumetric heat treatment.

Alloying elements – chrome, manganese, molybdenum, nickel, are significantly increase the hardenability of steel. The effect of hardenability is enhanced by alloying the steel with several elements.

All alloying elements reduce the critical quenching rate.

Consequently, in alloyed steels the hardness can be increased with cooling at lower rates than in carbon steels. In addition, quenching of alloyed steels can be carried out in less abrupt chillers, which will reduce the probability of occurrence of hardening defects, primarily quenching cracks. This is especially important for the DP and the lock, which are connected together by contact welding by friction.

The results of wear testing of specimens according to ASTM G65 are as follows:

Number	0	1	2	3	4	5	6	7	8
Sample	Initial	Duraband NC	OTW-12Ti	ARNCO 350 XT	NP 57	NP 58	ASM NGN-GS	13 CF	EMP
Wear, g	0.2869	0.0534	0.1185	0.0944	0.0615	0.0644	0.1220	0.0628	0.1213

Tests of the welded materials in comparison with the materials of locks of serial production testify to the effectiveness of all the test samples. In general, the dependence of wear resistance on the hardness of the surfacing material is maintained.

Tests (Casing Wear Test) showed high wear resistance of DP locks of all surfacing materials (Table 1). The regularity is confirmed that materials with a relatively low hardness of surfacing

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wear the casing sample to a lesser degree (Table 2), and the wear resistance of the welded surface of the lock is more than 5 times higher than the wear resistance of the initial samples.

It should be noted that locks of DP hardened by EMP (Fig. 5) showed an increase in wear resistance of more than 3 times in comparison with the original pipes without cladding. Wear resistance of casing pipes in contact with samples of locks of DP after EMP increased 2.8 times (Table 2).

Table 1

Results of wear of the control samples (surfacing)

Sample	Weight of drill pipe sample, g					Lock sample wear, g
	Initial	2 hours	4 hours	6 hours	8 hours	
Initial	592.80	591.20	591.00	590.80	590.70	2.10
Duraband NC	765.50	765.20	765.00	765.95	764.90	0.60
OTW-12Ti	692.30	692.25	692.20	692.15	692.10	0.20
ARNCO 350XT	722.25	722.10	722.00	721.95	721.90	0.35
NP 57	721.80	721.60	721.40	721.20	721.05	0.75
NP 58	720.80	720.70	720.65	720.60	720.55	0.25
ASM NGN-GS	718.10	718.00	717.95	717.90	717.80	0.30
13 CF	614.80	614.50	614.45	614.40	614.35	0.45
EMP	646.30	646.10	645.90	645.80	645.70	0.60

Table 2

Results of wear of casing samples

Sample	Weight of drill pipe sample, g					Lock sample wear, g
	Initial	2 hours	4 hours	6 hours	8 hours	
Initial	65.2	60.9	59.5	58.6	57.2	8
Duraband NC	65.9	64.9	64.3	63.9	63.4	2.5
OTW-12Ti	64.6	64.2	63.8	63.3	63	1.6
ARNCO 350XT	63.5	62.3	61.7	61.3	60.8	2.7
NP 57	65.1	64.3	63.8	63.1	62.6	2.5
NP 58	64.9	64.3	63.8	63.1	62.6	2.3
ASM NGN-GS	64.1	63.2	62.5	62	61.7	2.4
13 CF	65.2	64.2	63.5	62.9	62.6	2.6
EMP	63.3	62.2	61.7	61	60.2	3.1

To determine the effectiveness of wear-resistant surfacing for changing the outer diameter of the SDP 86 locks in the conditions of the Ltd. «BIS-Service» pipe base (Nizhnevartovsk), metrological measurements were used. SDP 86 came for repairs in connection with the culling of them by external and internal locking thread. Measurements of the outer diameter of the locks were carried out with a sliding caliper SHZ 250 with an accuracy of 0.05 mm. It was revealed that, as a part of one drill string, both SDP 86 with welded-on welded belts (surfacing BoTn 3000) and pipes with locks without surfacing (Fig.6) were used.

The outer diameter of the SDP 86 locks without cladding was 103.5-104.8 mm, while with welded bands –

a *b*

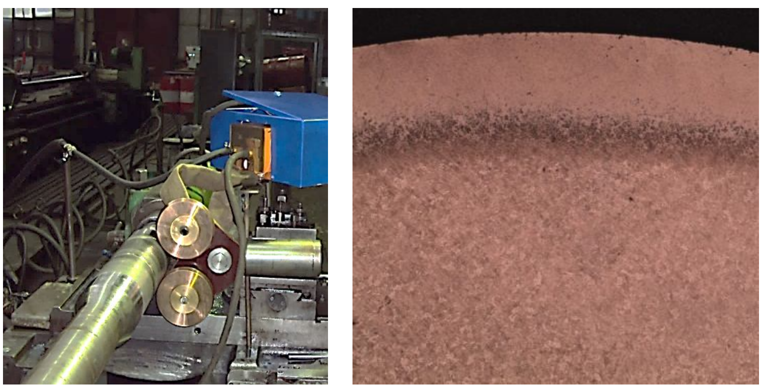

Fig.5. Fragment EMP of an external diameter of the lock of the drill pipe (*a*) and the microstructure of the quenched surface layer (*b*)

Fig.6. Fragments of the SDP locks without surfacing (in the middle) and with hardbanding

108±0.1 mm. Measurement of the outer diameter of the welded sections SDP 86 indicates an insignificant wear of the cladding (diameter 110.8-112.0 mm) and no wear of DP locks. The dyeing and delamination of the weld metal was not observed.

According to the results of metrological studies of the SDP 86, which came in for repair, we can draw the following conclusion:

– surfacing increases the durability of parts, contributing to the increase of wear resistance of locks of DP in the conditions of abrasive action of aggressive geological formations;

– the use of DP without wear-resistant surfacing is unacceptable, since their further operation as part of the drill string can lead to emergency consequences;

– the use in the drill string of pipes with overlaying and without surfacing of belts with different degree of wear of locks is also unacceptable;

– in the drill string it is necessary to use pipes with the same overlapping of locks.

No less important is the problem of low wear resistance of the lock thread of DP and transducers. A significant spread of steels (20XGHM-38XGHM) used for the manufacture of drill pipe locks adversely affects the wear resistance of not only the body of the drill lock, but also on the weakest place of the pipes – threaded connections. In combination with a low hardness of 210-260 HV and the strength of the threads, this results in low wear resistance of the threaded joints and their restoration to the pipe bases. The question of the durability of threaded joints is the «bottleneck» of the life cycle of a drill pipe with cast-in-place locks.

a *b*

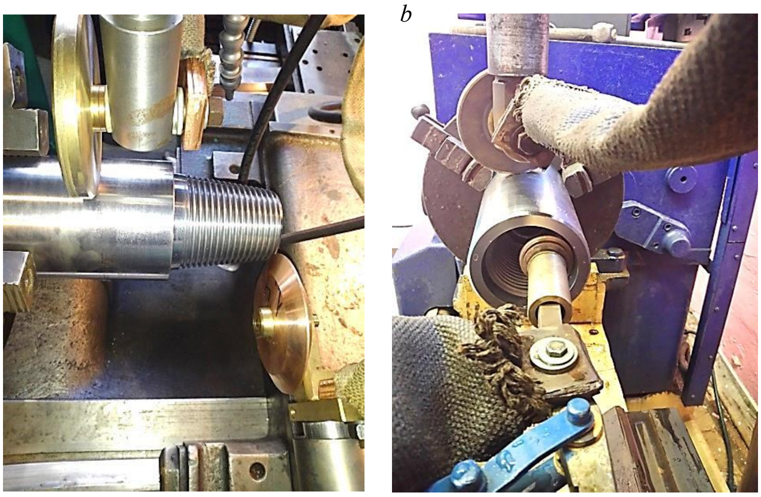

Fig.7. Fragments of electromechanical machining of the thread of the nipple (*a*) and the coupling (*b*) of the sub

a *б*

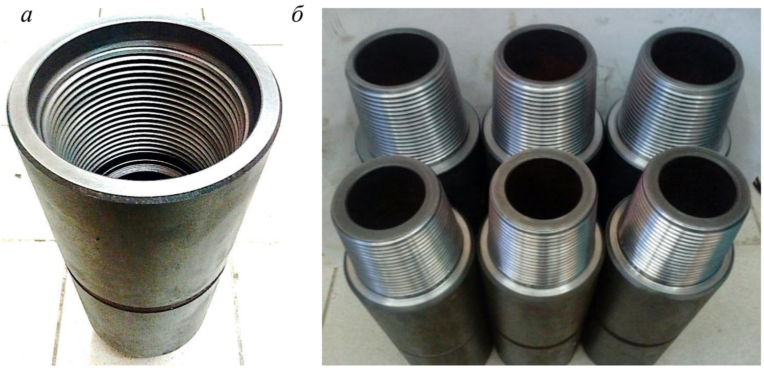

Fig.8. Fragment of the coupling (*a*) and nipple (*b*) parts of the transducers produced by Ltd. «PTF NIGMASH» P-133/133 – 3 pcs., -147/147 – 3 pcs. after electromechanical threading

Metallographic and metrological studies of the adapter made under the conditions of the «Alexandravskiy» Drilling Equipment Plant (Figures 7 and 8), bench tests conducted on the basis of the Kovrov Drilling Equipment Plant, confirmed the effectiveness of the EMP technology for screwing-screwing of threaded joints.

In the conditions of Ltd. «UK» Tatburneft «operational tests of translators P-133/133, P-147/147 manufactured by OOO» PTF NIGMASH «made of steel 40XH2MA with threaded EMO, are carried out. Intermediate test results

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indicate that when drilling wells after 978 cycles (500 standard) screwing-screwing of P-147/147 sublimers, wear of the thread is not fixed.

Conclusion

1. In work directions of carrying out of researches on increase of wear resistance of drill pipe locks, threaded connections and a casing drill collar have been defined:

– application of drill-resistant surfacing to Russian drill pipes with Russian and foreign materials (hardbanding);

– hardening of the surface layer of drill pipe locks by electromechanical processing;

– hardening of the external and internal locking threads of drill pipes by electromechanical processing.

2. The production success of using the technology of applying wear-resistant surfacing on the body of a drilling lock is caused by:

– using simple and mobile welding equipment;

– work in places where the drilling tool is used or temporary (permanent) production bases with a small transport shoulder from the field;

– repeated application of surfacing materials during restoration of drill pipe locks;

– a broad and growing list of companies that receive accreditation for the production of these works.

3. The chemical composition of the surfacing materials indicates the presence of carbide-forming elements (Cr, Ti, Al, V, Nb, Mn), unevenly distributed over the deposited coating, increasing hardness and forming with carbon simple or complex carbides, which have high hardness while maintaining sufficient viscosity .

4. The results of wear testing of welded materials in comparison with the materials of locks of serial production (ASTM G65 test for the degree of resistance to abrasion) testify to the effectiveness of all samples of Russian and foreign production. In general, the dependence of the wear resistance on the hardness of the surfacing material is directly dependent.

5. Wear resistance of surfacing materials NP 57, NP 58 (Interpro, Russia) is at the level of the best studied world samples Duraband NC, 13 CF (Castolin Eutectic). However, for NP 57, NP 58, it is necessary to refine the technology of deposition of surfacing and improve the quality of the coatings.

6. Tribological tests (Casing Wear Test) also confirm the effectiveness of Russian and foreign surfacing materials. At the same time, materials with a relatively low hardness of surfacing wear the casing sample to a lesser degree, and the wear resistance of the welded surface of the lock is more than 5 times higher than the.

7. Tests on two types of tests have shown that it is difficult to achieve the universality of the surfacing materials, but the use of drill string assemblies with different surfacing by drilling contractors is even more difficult, so it is recommended to choose the surfacing materials to be applied to locks that would give better average results. According to the test results for such materials, we could include: Duraband NC, 13 CF (Castolin Eutectic) and with the proper quality of the deposition technology, Russian materials NP 57 and 58.

8. The chemical composition of the material of the locks of Russian and foreign manufacturers of drill pipes indicates a considerable dispersion of steels in terms of carbon content (0.22-0.37), which, in combination with other alloying elements, corresponds to 20HGNM-38HGNM steel grades.

9. A significant dispersion of steels used to make drill pipe locks adversely affects the wear resistance of not only the body of the drill lock, but also the threading connections at the weakest point of the pipes. In combination with a low hardness of 210-260 HV and the strength of the threads, this results in low wear resistance of the threaded joints and the need for their recovery at the pipe bases. The question of the durability of threaded joints is the «bottleneck» of the life cycle of a drill pipe with cast-in-place locks.

10. EMP technology indicates the possibility of increasing the wear resistance of locks and threaded drill pipes and sub-assemblies, securing the casing by hardening the surface layer of drill locks as an alternative to hardbanding.

The commercial success of EMP technology can be dictated by the following:

– the cost of equipment for carrying out EMP technology is insignificant and commensurate with the cost of a mobile complex for applying wear-resistant surfacing;

– consumable surfacing materials and protective gases are not required;

– EMP is performed on a metal-cutting machine by a turner tapping;

– the productivity of the EMP operation is equal to the time of application of wear-resistant surfacing in the same dimensions of the products;

– the energy component of costs is next lower order than when surfacing;

– with EMP there are no harmful and dangerous factors;

– increasing the wear resistance of the external and internal locking thread of drill pipes, sub-contractors and adapters is performed on pipe-cutting machines.

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