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Increase of Wear Resistance of the Drill Pipe Thread Connection by Electromechanical Surface Hardening

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Abstract

The application of the electromechanical surface hardening (ESH) of a bx and external tool-joint thread Z-117 of drill pipes is substantiated. The results of the experimental researches of comparative wear resistance of the threaded connections of nipple and coupling, made of 1040 (40X) steel with threads only after improvement and improvement and ESH has been given. The most typical defects of nipple and coupling drilling pipes is the threads wear, a coupling end wear, the nipple thrust collar wear and the wear of the outer diameter of the locks. Products withstood set 500 cycles of screwing - unscrewing, without disturbing the geometry of the threads and the setting of the threaded joint, the make-up torque is 17-18 kN m. The effectiveness of hardening thread by the electromechanical surface hardened has been proved.

The purpose of the test: to determine the wear resistance of the threaded joint pin and a box of drill pipe with tool-joint thread Z-117, reinforced by various technologies.

Keywords: Drill pipes, subcouplings, tool-joint thread, hardening, wear hardness, electromechanical surface hardening (ESH), hardness.

INTRODUCTION

The reliability of the operation of machines and process equipment largely depends on the durability of the most stressed parts surfaces. In this case, the quality of manufacturing parts at the parent plant or the restoration of worn surfaces of products on the repair base should not depend on the organizational and technological characteristics of the enterprises that carry them out. At the same time, there is a significant range of parts, the manufacture and restoration of which is produced with a low quality that does not meet the reliability criteria. These products include drill pipes (DP) with external and bx threads. From the quality, first of all the threaded connections, the effective work of drilling companies in the oil and gas industries largely depends.

When drilling oil and gas wells, the drill string consists of: heavy drill pipes (HDP), thick-walled drill pipes (TDP), steel drill pipes (SDP), tool-joint thread, subcouplings and etc. All these parts, in the drill string, are connected together by thread. Each of the above parts is made of quality structural and alloyed steels and subjected to heat treatment. The length of the DP is 8.5 ... 12.5 meters, and the depth of the well is up to 11,200 meters.

For geological prospecting drilling in accordance with Russian State Standard 51510-99 (ГОСТ Р 51510-99) «Universal steel drilling pipes. General specifications» developed pipes with welded locks of 4 types of hardening (TU 41-01-676-95): N - normalized (correspond to strength groups D and K); I - improved (correspond to strength group M); NH - normalized with surface hardening; IH - improved with surface hardening.

The long-term operating experience of BT has that the pipe body on durability and reliability meets almost all, including complex, geological and technical conditions of drilling. At present, Russian and foreign companies have almost completely solved the issue of increasing the wear-resistance of DP due to surfacing materials on the tool-joint part of drill pipes [2, 3].

Considering that operation of the DP is under severe conditions, the problem of increasing the wear resistance of threaded joints remains unsolved [4]. Existing methods of heat treatment cannot be used to improve the wear resistance of threaded joints. Normalized or improved workpieces allow tapping of the outer and inner threads, but the hardness of 28 ... 36HRC does not provide wear resistance and strength of the threaded connection. In the process of operation, frequent sticking of the threaded coupling, as a result of which it is not possible to disassemble the DP without scoring on the thread. Methods of surface hardening increase some indicators of DP thread quality, but reduce the fatigue life of threaded parts [7, 8].

Under conditions of the alternating cyclic loads of the DP operation, cases of fatigue failure of pipes by thread are observed. Both in the first, and in the second case, drilling stops, and the company bears losses from cutting the thread of worn out pipes, eliminating the consequences of the accident and replacing the expensive DP. Considering that modern high-strength drill pipes have a high cost, the losses of companies from rejection are tens of millions of rubles. The most effective ways to increase the wear resistance of threaded drill pipes are structural and technological directions. In a constructive direction, the issue of reducing the load on the thread, its redistribution in turns and other areas, including the creation of double-resistant DPs, is being solved. Results of skilled pilot studies of comparative wear resistance of threaded connections of the nipple and coupling from steel 40X steel with threaded Z-117 carving after improvement, improvements and ESH are given in the presented work [10, 11].

METHODOLOGICAL FRAMEWORK

1. Four sets of nipple and clutch samples (fig. 1) with Z-117 locking thread reinforced by different technologies were tested.

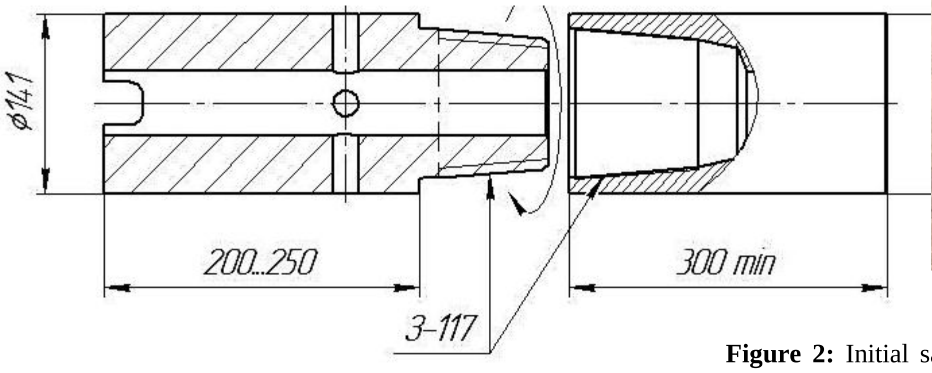

Figure 1: Samples of the nipple and the drill pipe coupler with locking thread Z-117

2. All blanks made of 1040 (40X) steel underwent volumetric heat treatment for a hardness of 28-36 HRC.
3. All samples were threaded on CNC machines.
4. Two sets of samples after the improvement and two with additional electromechanical surface hardening of the lateral surfaces of the threads.
   - Samples with locking thread Z-117 and with a standard hardness of 28-36 HRC (fig. 2);

(a)

(b)

Figure 2: Initial samples of the coupling (a) and nipple (b) from the locking thread Z-117 after improvement

- Samples from the locking thread Z-117 after electromechanical surface hardening (fig. 3);

(a)

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(b)

(c)

Figure 3: Samples of the coupling (a), nipple (b) and the results of measuring the hardness (c) of the locking thread of the pin Z-117 after electromechanical surface hardening

5. Control of geometrical parameters of an external and internal thread of samples was made in limit calibers. Measurement of the hardness of the lateral surfaces of the threads was carried out by the ultrasonic hardness tester MET Y1.
6. The thread sealant RUSMA R-14 TU 0254-068-46977243-2009 was applied to the screw connections prior to testing.
7. Samples of nipple and clutch were screwed by hand using a 0.5 meter long tap wrench.
8. The threaded joint being tested was installed on the machine MC-4 (fig. 4.) with fixing the position of the flywheel relative to the stationary frame (point "O").
9. We performed screwing operations until the stop and unscrewing to the point "O".
10. After every 5 "make-and-break" operations, the sample heating temperature was fixed, the thread state of the pin and the coupling were monitored. In the case of heating the samples to a temperature of 50 ° C or more, the "screwing-unscrewing" operations were stopped and switched to tests with other samples.
11. Frequency of rotation during the test - 6 rpm.
12. The number of "screwing-unscrewing" operations is 500 cycles.
13. The make-up torques - no more than 18 kN m, nominal for locking thread Z-117 according to TU 3663-001-86528288-2010.

Accordingly, following make-up torques are installed on the machine:

The first make-up torque is 5-6 kN m (500-600 kgf m)

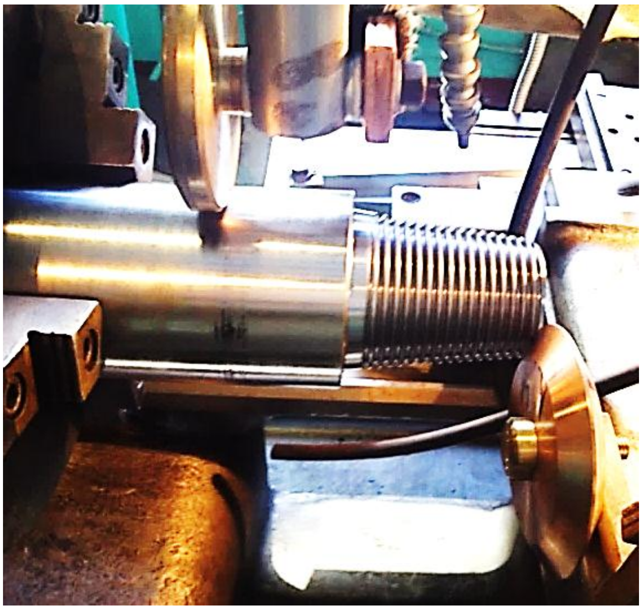
The second make-up torque 10-12 kN m (1000-1200 kgf m)

The remaining make-up torque is 17-18 kN m (1700-1800 kgf m).

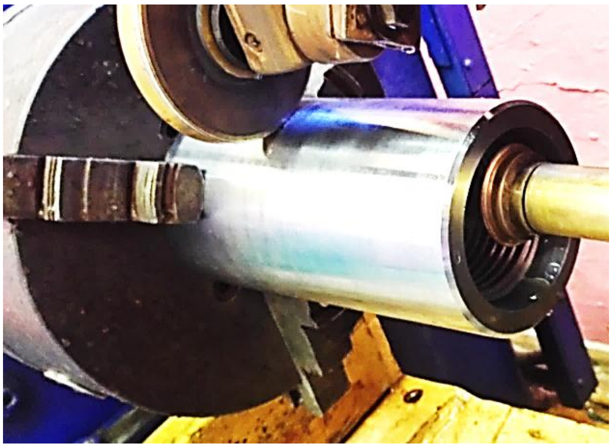
THE RESULTS OF THE STUDY AND THEIR INTERPRETATION

The electromechanical surface hardening of the lateral surfaces of the external thread of the nipple (fig.4, a) and the internal thread of the couplings (fig.4, b) is performed on the "Etalon" model installation in the conditions of

CJSC "Alexandrovsky Drilling Equipment Plant".



(a)



(b)

Figure 4: Fragments of electromechanical surface hardening of external (a) and internal (b) threads of samples with locking thread Z-117

Tests using the standard method (fig. 5) were performed on the coupling makeup machine MC-4 in the conditions of LLC «Kovrov Drilling Equipment Plant». Nipples are made with external locking thread Z-117, on the one hand, and a rectangular groove, on the other hand. The groove is necessary for transferring the torque during the "screw-on-screwing" operations.

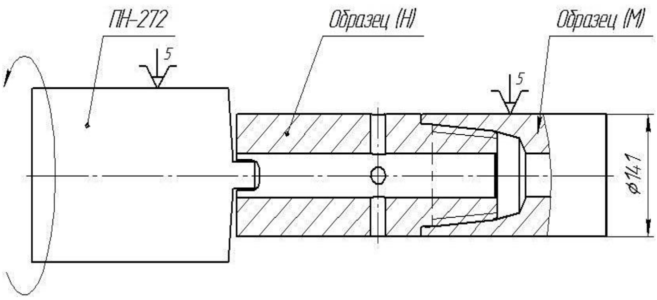


Figure 5: Test scheme

To increase the wear resistance of threaded joints, it is necessary [4-6]:

– increase the hardness of the lateral surfaces of the threads up to 52-56 HRC;

– eliminate during thermal treatment, and during operation, oxidation and decarburization of the surface layer;

– to form a gradient structure of the surface layer;

– provide a finely dispersed structure of martensitic and austenite residual on the surfaces of threads, while maintaining the plasticity of the middle of the turns;

– to exclude diffusion setting of threaded connections during operation;

– increase the strength of the threads.

The attainment of the above thread indexes by electromechanical processing is achieved by combining in a single technological scheme of thermal and mechanical influence of the concentrated flow of electrical energy of industrial frequency in a zone of the tool's force contact and lateral surfaces of the turns [1, 3].

It is necessary to emphasize that the ESH of the thread changes the structure and properties only the surface layer of the metal, and the hardening process itself is the final operation, on which high physical and mechanical properties are formed that increase the life of the threaded joints.

Table 1: Test results

The name of indicators	Improvement		Improvement and ESH	
	№ 1	№ 2	№ 1	№ 2
Hardness, HRC	32…36		52…56 – on the surface 32…36 – in the middle of a thread	
Number of test cycles	66	47	500	
Thread condition	Scorings		Thread without damage	
Other defects	Strong wear of the end face of the coupling and the thrust collar of the nipple		Average wear of the end face of the coupling and the thrust collar of the nipple	
Market value of hardening of one sample, rub.	350		600	

Analysis of the test results (table 1) indicates that the technology of volumetric heat treatment (improvement) and the subsequent cutting of the thread by the cutter does not guarantee the wear resistance of threaded joints in the manufacture and restoration of drill pipes. Large static and dynamic loads from the torque in the threaded connection, strong wear of the end face of the coupling and the thrust collar of the pin, the grasping of the contact surfaces of the parts and the scoring during screwing lead to the need for culling parts.

GENERAL CONCLUSIONS AND RECOMMENDATIONS

1. The results of the operation of the drill pipes indicate that the most characteristic defects of the nipple and coupling are the wear of the thread, the end of the coupling, the thrust collar of the nipple and the outer diameter of the locks.
2. Volumetric heat treatment of the nipple blanks and 40X

steel couplings with a hardness of 32-36 HRC and subsequent tapping do not provide durability and strength of the threaded joints of the Z-117 locking thread when tested on the coupling makeup machine MC-4.

3. Wearproof tests of threaded joints of a nipple and a clutch with a Z-117 locking thread made of 40X steel with a hardness of 32-36 HRC, showed the efficiency of thread hardening using electromechanical surface hardening technology. The products withstand the established 500 screwing-unscrewing cycles, without disturbing the geometry of the thread turns and setting the threaded joint at the make-up torque 17-18 kN m.
4. The test results testify to the efficiency of electromechanical surface hardening of the lateral surfaces of the external threads of the nipple and the internal threads of the couplings, which allows us to recommend technologies for hardening newly manufactured and recoverable DPs.

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