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FEATURES OF WEAR-RESISTANT TOOL JOINT THREADS FOR DRILL PIPES AND THEIR THREADING TECHNOLOGY

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A B S T R A C T

To connect the stands in a drilling column, tool joints of various designs are used. During lifting and lowering operations, numerous operations involving tightening, loosening, and breaking-out operations of tapered tool joint threads are performed. During tightening and loosening, friction and wear of the tool joint threads occur both along the flat edges of the thread tops and along the side surfaces. Wear occurs both along the height and along the flank surfaces of the threads. The probability of contact and friction along the flat edges of the thread tops is 40%, and friction conditions are quite severe due to the small contact area. During tightening and breaking-out, friction and wear occur only along the side surfaces of the tapered threads. The performance of tool joint threads is limited primarily by a reduction in their effective height due to wear. Wear resistance is one of their primary operational requirements. The wear-resistant locking thread design, developed based on identified wear patterns during lowering and lifting operations and studies conducted on full-scale samples using a dedicated rig, eliminates friction and wear along the conical flat edges of the thread tops, increasing their wear resistance by approximately 1.7 times. It is applicable to all types of conical locking threads, is easy to manufacture and control, and requires only modification to the profile of the thread-forming tool. Its use in conical locking thread designs requires no additional resources or expenses, and increases the length of thread contact along the lateral faces of the profiles.

Keywords: wear resistance; tool joint thread; tool; thread cutting; improvement.

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Introduction

The global demand for hydrocarbons continues to rise steadily, driving the accelerated development of exploratory, oil, and gas-condensate wells. In parallel, well depths are progressively increasing due to evolving geological and reservoir conditions. Under these circumstances, enhancing the efficiency of drilling operations remains a critical challenge for drilling contractors and a key determinant of their operational competitiveness within the energy sector.

The reliability of drilling equipment, together with the functional performance of its constituent elements, plays a decisive role in overall drilling efficiency. The drill string represents the primary load-bearing and torque-transmitting subsystem of drilling equipment and is typically assembled from multiple drill pipe stands and associated downhole components. During drilling operations, repeated make-up and break-out cycles of tool joint threaded connections are performed as an inherent part of tripping operations. These operations are realized through the engagement of external threads (pin ends) and internal threads (box ends) located at opposite extremities of the drill pipe stands [1–5].

Tool joint threaded connections are required to satisfy stringent mechanical, geometrical, and operational performance criteria, including high axial load-carrying capacity, efficient torque transmission, reliable pressure-tight sealing under high internal pressures, rapid assembly and disassembly, serviceability, and, critically, enhanced wear resistance under cyclic loading conditions [6–10].

To improve the operational performance of drilling system components—particularly the wear resistance of tribologically active surfaces—various design-oriented and process-based engineering strategies are implemented [11–15]. Among these, one of the most effective approaches involves the purposeful regulation and optimization of manufacturing quality parameters to achieve improved functional performance and extended service life of critical components [16–20].

To improve the performance characteristics of threads and threaded joints, the manufacturing quality parameters that determine them are controlled by various technological methods and measures [21–25].

Many years of drilling experience, as well as visual analysis of thread wear characteristics, show that the service life of tool joint components is mainly limited by the wear of tool joint threads during repeated make-up and break-out operations in the course of tripping operations [1, 26–29]. To ensure the wear resistance of tool joint threads, their surfaces are subjected to electromechanical hardening, phosphating, lubrication with solid graphite-based lubricants, and other

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treatments [29–33]. At the same time, special attention is paid to the development of thread designs with high wear resistance [34–36].

Problem statement

The tool joint threads of the pin and box are made up and tightened during running-in operations and are loosened and broken out during the tripping out of the drill string and the drill bit. During these transitions, the contacting surfaces of the tool joint threads undergo relative motion while being subjected to normal contact forces generated by axial loads, such as the weight of the added drill pipe stand (Q), the axial force resulting from the make-up torque, and other loads. The work performed by the resulting friction forces leads to wear of the contacting and sliding surfaces.

The friction regimes of the contacting thread surfaces differ at two stages [1, 4, 26]:

– make-up and break-out;

– tightening and loosening.

Studies on the wear resistance of threads 3-76 have established that the friction conditions and regime occurring along the flat crests of the thread turns at the initial stage of make-up are many times more severe than the friction regime along the flank surfaces of the thread turns. As a result, the wear intensity of tool joint threads is high, while their service life is relatively short [4, 27].

At Azerbaijan Technical University (AzTU), a wear-resistant tool joint thread design has been proposed (fig. 1), which eliminates friction and wear on the flat portion of the thread crest during make-up [34].

The distinctive feature of the proposed wear-resistant tool joint thread consists solely in forming the flat portion of the crest of the tapered thread profile parallel to its axis instead of following the generatrix of the conical surface. All other parameters of the wear-resistant tool joint thread are identical to those specified in the regulatory documents of ANI and GOST standards

However, for the practical application of the above-described wear-resistant tool joint thread, it is necessary to develop a detailed standard design of such threads, to analyze methods for improving their wear resistance, and subsequently to present, using a specific size as an example, an effective technology for their machining.

The objective of this study is to develop a standard design of a wear-resistant tool joint thread, to analyze the principles that ensure increased wear resistance, and to present the specific features of its threading process.

Research methodology

Using the example of tool joint threads 3-76, a wear-resistant tool joint thread design has been developed that differs from the corresponding threads specified by ANI and GOST standards only in the orientation of the flat crest sections of the tapered thread profile, which are formed parallel to its axis instead of following the generatrix of the conical surface (fig. 1). To ensure reliable achievement of the intended objective, a negative deviation in the orientation of the flat crest sections is recommended. The design of the wear-resistant tool joint thread, illustrated by the example of the 3-76 thread, is shown in figure 1 in accordance with GOST 28487-2018.

For the formation of tool joint threads by the multi-pass thread-cutting method, a cutting tool design ensuring the required accuracy was developed as a primary step. During the tool design, it was taken into account that the cutting process is performed by profiling (copying), the tolerances of the tool's form-generating dimensions were set to 0.25 of the tolerances of the corresponding thread design dimensions, and the tool wear life was considered.

During the development of the technological process for cutting external tool joint threads, the possible and inherent design and technological relationships associated with thread formation were taken into account [37, 38]. The proposed technology provides for the operation to be executed using five roughing passes, followed by one semi-finishing pass and one finishing pass. (It is also possible to adopt conventional factory thread machining technologies, with the distinction that the shoulders of the cutting tool are oriented parallel to the thread axis.) To ensure similarity of cutting conditions across all passes, the product of the cross-sectional area of the material removed per pass and the length of contact with the cutting edge of the tool was assumed to be constant. A simulation of the external tool joint thread cutting process was carried out.

Discussion of the obtained results

As a result, cutting the flat crest sections of tool joint threads parallel to their axis using the developed multi-pass method ensures an increase in their wear resistance, which is supported by both theoretical and practical considerations.

It is known that, for the connection of the pin and box with a tool joint thread, their initial static relative position must be established. In this configuration, the mutual orientation of the box and pin can assume any relative position within a single turn. Under ideal manufacturing and operational conditions, tool joint threads may contact according to two schemes: along the flat crest sections of the thread turns (fig. 2a) and along the flank surfaces (fig. 2b). Investigation of these contact scenarios and the design features of tool joint threads has shown that contact along the flat crest sections occurs over 2/5 of the 360° rotation (fig. 2a). Thus, the probability of contact and friction along the flat crests during make-up is 40%.

In the schematic diagrams, N_c, N_f, and N_r denote the normal forces acting on the contact profiles along the flat crest sections, the flank surfaces, and the rounded thread crests, respectively. In this case, the nominal contact area of the flat crest sections of the thread turns, Aa, initially increases, reaches its maximum value when the contact width becomes

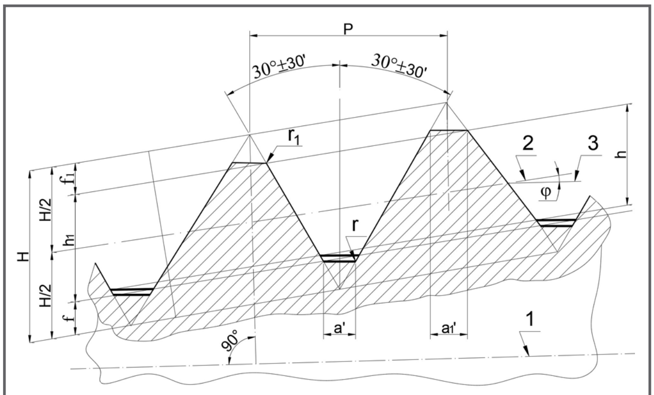

Fig. 1. Main elements of the wear-resistant tool joint thread

equal to the width of the flat crest of the thread turns, and then decreases (fig. 3a, curves). Theoretically, when this area becomes zero, contact between the thread turns shifts to their flank surfaces.

The probability of contact and friction along the flank surfaces (fig. 2b) prior to the start of make-up occurs over 3/5 of a full rotation. During the lowering of the drill pipe joint for the make-up of tool joint threads, the extreme circumferential points B of the external thread turns pass through the extreme internal circumferential points A of the internal thread turns (fig. 2b).

Following the wear of the thread crests, the rubbing profiles become rounded, and contact and wear occur along the rounded profiles (fig. 2c).

In practice, wear and the wear process are often characterized, respectively, by the total work performed and the specific work of friction. For the indicated contact and friction schemes, the nominal contact areas Ai, the total work, and the specific work of friction Wi were determined as functions of the number of revolutions *n* during make-up, assuming, as a first approximation, a linear relationship between them. The obtained results were then compared (fig. 3) [3].

As shown in figure 3, changes in the nominal contact area A_i and the specific work of friction W_i occur according to the dependencies $A_i = f(n)$ and $W_i = F(n)$. Comparison of the curves $A_i = f(n)$ and $W_i = F(n)$ (fig. 3a and 3b) indicates that the elimination of friction along the flat crest sections of the thread turns would result in a significant reduction in the specific work of friction.

When the flat crest sections of tool joint threads are cut parallel to their axis during the lowering of drill pipe joints, the probability of contact between the pin and box threads along the flat crest surfaces becomes zero. In other words, the likelihood of contact along the flat surfaces of the external and internal thread crests is eliminated, since in this relative orientation the thread profiles cannot engage, and the pin with the external thread continues to move axially. The axial movement of the pin continues until the flank of the external thread comes into contact with the flank of the internal thread (fig. 2b). Thereafter, during the make-up of the threads, contact occurs along the flank surfaces of the threads.

The sequence of wear of tool joint threads, taking into account wear during both make-up and release operations, is illustrated in figure 4c. As evident from this scheme, wear during make-up and break-out is the primary factor leading to a reduction in the effective working height of the connection, thereby decreasing the operational performance of tool joint threads.

The profiles of worn thread turns obtained from bench tests during make-up, as well as under field drilling conditions, were identical. Due to wear, thread profiles mainly undergo two types of modification: rounding of the thread crests (fig. 4a) and sharpening of the thread turns (fig. 4b). The first type of wear occurs on threads located at the beginning of the thread, while the second type occurs on threads located at the end. Threads at the beginning wear during make-up and break-out, whereas threads at the end wear during tightening and release.

Both theoretical and experimental studies conducted on full-scale samples have shown that eliminating friction on the flat crest surfaces significantly reduces the specific work of friction. The proposed design allows for the elimination of friction and wear on the flat conical portion of the thread crests, resulting in an increase in the wear resistance of tool joint threads by approximately 1.7 times [4].

The study of wear of tool joint threads, both in actual drilling operations and in laboratory investigations on full-scale samples using specialized test rigs, revealed two characteristic forms of wear (fig. 4a and b). Threads at the beginning of the pin and box threads are predominantly worn during make-up and break-out (fig. 4a), whereas threads near the exit of the thread are mainly worn during tightening and release (fig. 4b). In the latter case, wear occurs only along the flank surfaces of the thread profiles.

Thus, in the first case, thread wear primarily occurs due to rounding of the crests and reduction in thread height, while in the second case, wear occurs along the flank surfaces of the thread profiles, resulting in a reduction in their thickness. Consequently, tool joint components typically fail due to the decrease in the height of their working contact surfaces. Therefore, wear during make-up and break-out is the main factor limiting their service life.

The proposed design of tool joint threads and the associated machining technology provide a foundation for increasing their service life.

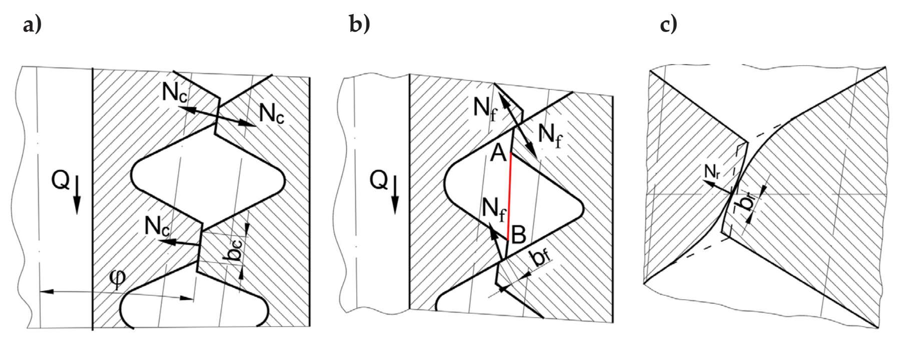

Fig. 2. Schemes of contact between tool joint thread turns during make-up: along the flat sections of the thread crests (a), along the flank surfaces of the profiles (b), and along the rounded crests of the thread turns (c)

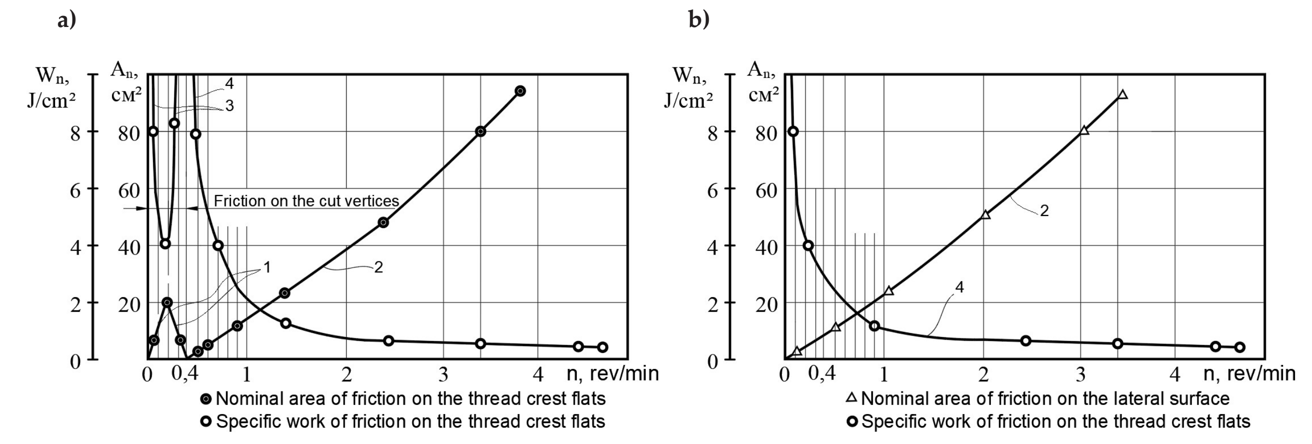

Fig. 3. Schemes of contact between tool joint thread turns during make-up: along the flat sections of the thread crests (a), along the flank surfaces of the profiles (b), and along the rounded crests of the thread turns (c)

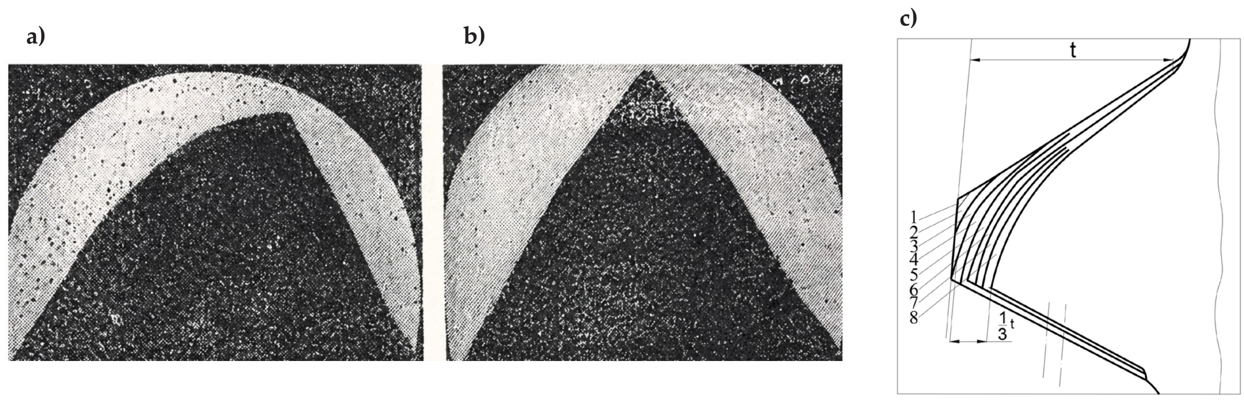

Fig. 4. Worn thread turns (a and b) of tool joint threads during repeated make-up, tightening, release from tightening, and break-out, and the wear scheme (c) of the tool joint thread

Conclusions

1. Under ideal manufacturing and operational conditions, tool joint threads may contact according to two schemes: along the flat crest sections of the thread turns and along the flank surfaces during make-up. The probability of contact and friction along the flat crest sections is approximately 40%.

2. Due to wear, thread profiles undergo two characteristic types of modification: rounding of the crests and sharpening of the thread turns. The first type primarily affects threads at the beginning of the thread, which are worn during make-up and break-out, while the second type affects threads at the end of the thread, which are worn during tightening and release.

3. Elimination of friction on the flat crest surfaces results in a significant reduction in the specific work of friction. The proposed design allows for the elimination of friction and wear on the flat conical portion of the thread crests, leading to an approximately 1.7-fold increase in the wear resistance of tool joint threads.

References

1. Baryshnikov, A. I. (1998). Improving the strength and durability of tool joint threaded connections of the drill string. Doctoral Thesis. *Moscow: Russian State Library.*

2. Khalturin, O. A. (2023). Improving the durability of threaded connections of drill pipes based on modeling and selection of the rational tightening torque during assembly. *Advanced Materials Research*, 690-693, 2831-2839.

3. Kuzminykh, D. V. (2011). Improvement of methods for increasing the durability of tool joint connections of the drill string under repeated make-up operations. PhD Thesis. *Ukhta.*

4. Rasulov, N. M. (2000). Improving the efficiency of machining parts with complex surfaces of revolution. Doctoral Thesis. *Baku.*

5. Rekin, S. A. (2005). Research and development of methods for predicting wear of drill string and casing string elements during well construction. Doctoral Thesis. *Ufa.*

6. (2008). API Spec 7-2: Requirements for threading, gauging, and testing of rotary shouldered thread connections. *American Petroleum Institute.*

7. (2018). GOST 28487-2018. Rotary shouldered threaded connections with tool joint threads for drill string elements. general technical requirements. *Moscow.*

8. (2015). GOST R 56349-2015 (ISO 10424-2:2007). Drill pipes and other drill string elements for the oil and gas

industry. Part 2. Basic parameters and inspection of rotary shouldered threaded connections. general technical requirements. *Moscow.*

9. (2007). ISO 10424-2:2007. Petroleum and natural gas industries. rotary drilling equipment. part 2. threading and gauging of rotary shouldered threaded connections. *Moscow*.

10. Pesin, M. V. (2018). Technological support and improvement of the durability of drill pipes based on modeling and control of thread strengthening treatment parameters. Doctoral Thesis. *Moscow*.

11. Dong, L., Zhu, X., Yang, D. (2018). Study on mechanical be haviors of double shoulder drill pipe joint thread. *Petroleum*, 5(1), 102-112.

12. Fedorov, S., Fedorova, L., Zaripov, V., et al. (2020). Increasing the wear resistance of the executive surfaces of machine parts by concentrated energy flows. Materials Today: *Proceedings*, 30(3), 388-392.

13. Rasulov, N. M., Nadirov, U. M., Abbasova, I. A., et al. (2020). Advanced technology for machining tapered threads of pipe coupling. *American Journal of Engineering and Technology Management*, 5(2), 35-40.

14. Rasulov, N. M., Damirova, G. V., Abbasova, I. A., Huseynov, Y. E. (2022). Improving the efficiency of thread rolling with management of technological connections. *SOCAR Proceedings*, SI1, 11–15.

15. Rasulov, N. M., Nadirov, U. M., Huseynov, G. R. (2013). On the quality of manufacturing of products and their durability. In book: Modern methods and technologies for the creation and processing of materials: collection of scientific papers. Book 2. Technology and equipment of mechanical and physical-technical processing. *Minsk: Institute of Physics of the National Academy of Sciences of Belarus.*

16. DeGarmo's, E. P., Black, J. T., Kohser, R. A. (2019). Materials and processes in manufacturing. 13th Ed. *USA: Macmillan.*

17. Rasulov, N. M. (2003). Management of technological dimensional relationships and efficiency of machining of machine parts. *Engineering Technology*, 3, 18–22.

18. Rasulov, N. M., Nadirov, U. M., Huseynov, G. R. (2014). Relationships Between Production and Operational Quality Indicators of Products. *Vestnik Mashinostroeniya*, 11, 85–88.

19. Suslov, A. G., Dalsky, A. M. (2002). Scientific foundations of mechanical engineering technology. *Moscow: Mashinostroenie.*

20. Yusubov, N., Abbasova, H. (2020). Models for machining accuracy in multi-tool adjustment. *International Journal of Automotive and Mechanical Engineering*, 17(3), 8067–8085.

21. Rasulov, N., Nadirov, U., Abbasova, I. (2025). Improving the efficiency of machining oppositely directed conical surfaces by managing dynamic technological relationships. *Reliability: Theory & Applications*, 20(SI7(83)), 252-258.

22. Rasulov, N. M., Nadirov, U. M., Abbasova, I. A. (2024). Improving of machining efficiency of threads and conical surfaces of diverse directions by managing static technological relationships. *Advances in Science and Technology*, 148, 97-102.

23. Rasulov, N., Shabiyev, E., Damirova, G., et al. (2024). Increasing the efficiency of forming complex rotating surfaces with the controlling of technological connections. *Key Engineering Material*s, 979, 55–62.

24. Rasulov, N. M., Nadirov, U. M. (2024). Ensuring the quality of taper pipe threads rolled in pipes with the control of kinematic technological connections. *Russian Engineering Research*, 44, 20–22.

25. Yusubov, N. D., Abbasova, H. M. (2020). Models for machining accuracy in multi-tool adjustment. *International Journal of Automotive and Mechanical Engineering*, 17(3), 8067–8085.

26. Fedorova, L. V., Ivanova, Yu. S., Voronina, M. V. (2017). Improving the wear resistance of threaded connections of drill pipes by electromechanical surface hardening. *Journal of Mining Institute*, 226, 456–461.

27. Pesin, M. V. (2015). Ways to solve the problem of failure of threaded connections of oilfield and drilling equipment. *Exposition Oil & Gas*, 4(43), 18–20.

28. Yakhimovich, V. A., Breki, A. D., Alkhimenko, A. A., et al. (2020). Methodology for investigating thread wear of drill pipes under repeated make-up and load holding conditions. *Proceedings of the Southwest State University*, 24(3), 8–20.

29. Zaripov, V. N., Khusnetdinov, T. R., Fedorov, S. K. (2018). Improving the durability of drill string subs by electromechanical treatment. In book: The future of mechanical engineering in Russia. *Moscow: Bauman Moscow State Technical University Publishing House.*

30. Fedorov, S. K., Fedorova, L. V., Ivanova, Y., Voronina, M. (2017). Increase of wear resistance of the drill pipe thread connection by electromechanical surface hardening. I*nternational Journal of Applied Engineering Research*, 12(18), 7485-7489.

31. Mindiarova, N. I. (2009). Reduction of friction work in threaded connections of tubing (NKT) by directed acoustic action. PhD Thesis. *Almetyevsk*.

32. Pesin, M. V., Makarov, V. F., Khalturin, O. A. (2022). Calculation and modeling of rational tightening torque during assembly of drill pipes. *Exposition Oil & Gas*, 7(92), 50–54.

33. Zaripov, V. N. (2018). Improving the wear resistance of threaded parts. RITM of Mechanical Engineering, 7, 38–40.

34. Dzhus, A. P., Faflei, O. Y., Deineha, R. O., et al. (2023). Design of double-shoulder threaded joints of drilling string elements. *Naukovyi Visnyk Natsionalnoho Hirnychoho Universytetu*, 3, 60-65.

35. Korabelnikov, M. I., Aksenova, N. A., Korabelnikov, A. M. (2021). Threaded tool joint conical connection of drill pipes. *RU Patent 2747498.*

36. Rasulov, N. M., Yaroshevsky, F. M. (1977). Tool joint connection for drill pipes. *SU Patent 563479.*

37. Rasulov, N. M., Nadirov, U. M. Alekberov, M. Z. (2020). Generalized assessment of machined surfaces quality. *Russian Engineering Research*, 40, 822–825.

38. Handbook of the mechanical engineering technologist. In 2 Volumes. Eds. A. M. Dalsky, A. G. Kosilova, R. K. Meshcheryakov, et al. *Moscow: Mashinostroenie.*