Threaded lock conic connection of drill pipes and method to increase its carrying ability and resource of work

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Abstract. This article presents the rationale and relevance of the use of an improved threaded keyhole conical connection of drill pipes for the oil and gas industry. The proposed threaded joint for drill pipes is characterized by an increased service life and a high rate of bearing capacity of the threaded joint in the conditions of drilling wells with complex spatial parameters, including when drilling sidetracks, horizontal and branched trunks of deep oil and gas wells.

1. Introduction
Threaded locking conical joints of drill pipes must fulfill a number of important functions, which are aimed at quick and reliable connection (screwing) of pipes together, the ability at high values of axial tensile and compressive loads to transmit the calculated torque to the drill pipe and rock cutting tool, provision of reliable sealing of pipes at high pressure flushing fluid. However, the practical use of drill pipes in well construction has shown that threaded tool joints, which accept complex alternating bending and tensile loads, remain the most vulnerable unit in the drill string assembly. During repeated screwing and unscrewing operations, the thread profile wears out and deforms, tightness and mechanical strength are lost, and the risk of thread breakage and an accident increases. In this regard, the task of increasing the bearing capacity indicators, reducing the accident rate and the service life of a threaded locking joint under complex cyclic loads is urgent and should be considered, taking into account the developed innovative technical and technological solutions.

The increase in drilling depths, the complication of the well profile and the length of the wellbore, including those with a horizontal end, has led to an increase in requirements and the need for continuous improvement of threaded pipe joints. Along with changes in the drilling technology, Russian State standards that regulate the requirements for threaded joints of drill pipes have changed: GOST 5286- (53) 75 [1]; GOST 28487-90 [2]; GOST R 50864-96 [3]. GOST 34438.2-18 [4]. Since 2020, GOST 28487-2018 [5] “Threaded joints with a locking thread of drill string elements has been enacted.” General technical requirements”.

At present, according to GOST 28487-90 [2] “Tapered keyhole thread for drill string elements” and according to GOST R 50864-96 [3], most of the domestic drill pipes are equipped with locking threaded joints, the outer diameter of which extends to locks with a diameter from 35 to 279 mm. The main technical requirements of GOST R 50864-96 standard coincide with the requirements of API 7 standard (American Petroleum Institute, USA). According to the above GOSTs, the tapers of threaded locking joints are regulated with a ratio of 1: 4 and 1: 6; and also the pitch of the threads of the triangular profile: - 5 or 6 threads over a length of 25.4 mm (inch).
When developing an improved type of threaded connection of drill pipes, the authors of the article carried out a patent analysis of the solutions closest in design, analyzed their advantages and disadvantages. Thus, to increase the strength of the threaded connection, the thread is made with run, ending near the resistant ends of the elements for drill pipes [6]. In the threaded connection of drill pipes according to patent RU No. 2354799 [7], two ratchet half-couplings are made for transmitting axial force at the ends of the nipple lock and the coupling, which complicates the threaded connection and does not increase its service life.

The threaded connection [8] is characterized in that the threads of the nipple and the coupling are made with a taper of 1: 8 and a pitch of 8.467 ± 0.05 mm, and the profile of the thread of the threads of the nipple and the coupling has an angle of inclination of the reference face of 20-30 ° to the normal to the axial line of the thread and the angle of inclination of the embedded face 35-44 ° to the normal of the axial line of the thread, while the hollow of the thread profile of the thread of the nipple and the coupling is made in the form of an ellipse arc showed an increase in torque resistance in relation to the standard connection of drill pipes by 81%.

The threaded TMK UP EXD drill joint, although it has several advantages over the first-generation double-joint, and can withstand higher torques than the TMK UP TDS, does not fully contribute to the longer service life of the joints due to the weakening and relaxation of stresses on the supporting surfaces during operation, and also complicates the repair of threaded parts in case of critical wear [9].

2. Results and discussion
Drilling of directional wells, including those with horizontal completion, often tack and tighten the drill string in the wellbore. As a result, drill pipes experience additional torque compared to the moment that occurs when screwing up the drill during assembly of the string on the surface of the well. The additional make-up torque has an increased effect on the threaded joint and can lead to exceeding the yield strength of the coupling material or nipple and their destruction. To prevent such accidents with a drilling tool, it is necessary to have a margin of safety of the threaded joint by the value of the expected increase in torque when the drill string is stuck in the well.

The increase in the bearing capacity of a threaded joint is achieved by the fact that the full-sized threaded part of the nipple of a typical locking joint in accordance with GOST 28487-2018 [5] and [8] is increased by a threadless conical extension. The linear size of the extension cord is in the range from 0.55 to 0.65 of the length of its threaded part, and in the coupling part of the locking joint, after the end of the threaded type cutting, an internal conical bore (surface) is provided congruent with the conical extension of the nipple part.

The abutting supporting surfaces of the nipple and coupling parts are structurally made with the possibility of their phased interaction when making up. So, at the stage of screwing the threaded connection, 30 ° -45 ° to the stop position (limiting fixed position of the nipple and coupling elements at a regulated torque) and the conical surface of the extension of the nipple part is introduced into the tensile radial contact with the conical surface of the coupling part. Then, in the next step, with further rotation of the nipple part relative to the coupling part, a tight grip (interference fit) of the threaded parts of the nipple and coupling is created.

And at the final stage of the screwing-up screw driving cycle, with the creation of a torque calculated for each size of the screwed threaded connection, the end surfaces of the nipple and coupling are closed, providing an interference fit (tension) at their ends. Figure 1 (on the left) shows the threaded tool conical connection of drill pipes in the screwed-up state, (on the right) shows fragment II of the parameters of the conical threaded connection, where: S - the thread pitch; hpr - thread profile height; σ - the width of the protrusion of the thread; r1 - the radius of conjugation of the vertices of the thread profile; r2 - the radius of curvature of the thread depression.
In the developed threaded connection, the end parts on the nipple and the coupling are made with negative taper. The value of the closing angle parameter (A) is 2-3 times higher than the angle of friction of steel on steel. This complex technical solution is aimed at balancing the axial load along the threads in the direction of its normalization and eliminating the effect of uneven loading, proved by Professor N.E. Zhukovsky in 1902. At the same time, the influence of the concentration of internal stresses arising under bending loads in the threaded grooves of the nipple part used in known solutions, as well as the technical requirements of the standard version, is minimized. To increase the sealing ability of a threaded conical connection, an option is provided for equipping a conical extension with a groove, with a ring placed in it.

Figure 2 visualizes the forces (force reactions) acting in the elements of a threaded conical connection after screwing up with a regulated torque, where: R is the reaction of the forces of the threaded connection section; F1 - reaction of the forces of the end face of the coupling part; F2 - reaction of forces on the conical section of the coupling part; P1; P2; T2; K1 - components of the reaction of forces, laid out along the axes.

The diagrams of the torques arising from the friction forces of the nipple part of the lock in the coupling part at the final stage of screwing the threaded connection are shown in Figure 3. Where: ϕ - the central angle of the beginning of the radial contact of the nipple cone is extended with the conical bore of the coupling part; ϕ1 - the central angle of the beginning of the radial contact of the threaded nipple with the internal conical thread of the coupling; ϕ2 - the central angle of the beginning of the end contact of the nipple with the end face of the coupling; M (F2) - the maximum value of the braking (torque) moment from the reaction of the coupling part from the contact of the conical extension; M (R) - the maximum value of the braking (torque) moment from the reaction of the threaded section of the coupling part from the contact with the thread of the nipple; M (cr) - the maximum value of the torque from the reaction of the coupling part, at the moment of termination of the relative rotation of the nipple and the coupling (position "stop").
Figure 2. Scheme of a threaded connection, with visualization of forces (reaction of forces) acting in the elements of a threaded conical connection after screwing up with a regulated torque.

Figure 3. Diagrams of torques from the friction forces of the nipple part of the lock in the coupling part at the final stage of screwing the threaded connection.
Figure 4 shows (for visualization) the diagrams of the axial load distribution for the threaded part of the coupling after screwing with the nipple, where: 4 - load distribution curve in the threaded connection of the coupling from reaction P2; 5 - load distribution curve in the threaded connection of the coupling from the reaction P1; 6 - the final curve of the load distribution in the threaded connection of the coupling from the reaction of forces P1 and P2.

**Figure 4.** Diagrams of axial load distribution diagrams for the threaded part of the coupling after screwing with a nipple

When using the proposed threaded connection, preliminary, in preparation for screwing, it is necessary to clean the foreign and internal particles of the inner and outer surfaces of the nipple and coupling parts from the particles of water and steam and apply a grease. Screwing is done with a mechanical key after combining the movable element of the nipple part of the pipe with the fixed-mounted coupling part of the pipe at the wellhead. The angular speed (ω) for make-up is taken to be ω = (3-6) s⁻¹, with the creation of a regulated torque (Mω) set for each size of the lock connection.

Moreover, in sector β (the angular parameter of the generatrix of the conical surface of the nipple threaded part) - 30° - 45° (0.5 ... 0.8 mm before the thrust ends of the nipple and the coupling close) to the stop position - (maximum fixed position the elements of the nipple and the coupling with a regulated torque) are first sequentially introduced into the tense (radial) contact conical surfaces of the extension of the nipple and coupling parts.

This solution is aimed, first of all, at counteracting the influence of negative alternating bending moments during the operation of threaded joints in the wellbore with intense curvature; as well as to equalize the axial load on the turns of the threaded joint assembly. With further rotation of the nipple part relative to the coupling part, a tight grip (tightness) of the threaded parts of the nipple and the coupling is created, and at the final stage of the screwing cycle of the threaded connection, providing the rated torque for each size of the threaded connection, the end surfaces of the nipple and coupling with an end interference are closed (voltage).
3. Conclusion
The use of the proposed threaded connection of drill pipes allows transmitting increased torque to the drill pipe and the layout of the bottom of the drill tool (BHA) in conditions of alternating bending loads in deviated wells. In addition, this threaded connection is characterized by increased tightness and increased resource of trouble-free operation.

References
[1] 1975 GOST 5286-(53) 75 Locks for drill pipes (Publishing house of standards)
[2] GOST 28487-90 Conical locking thread for drill string elements. Profile, dimensions. Profile.
[3] GOST R 50864-96 Conical locking thread for drill string elements. Profile, dimensions, technical requirement
[4] GOST 34438.2-2018 Drill pipes and other elements of drill strings in the oil and gas industry. Key parameters and control of threaded connections. Basic technical requirements
[5] GOST 28487-2018 Threaded connections with a locking thread of the elements of the drill string. General technical requirements
[6] 1984 Description to patent SU No. 1131481 F 16L 15/00 (France)
[7] Patent RU No. 2354799 Device for connecting drill pipes (18 April 2008)
[8] Patent RU 2508491 Threaded connection of drill pipes Bulletin of inventions No. 6 (2014)
[9] 2017 Operation manual for drill pipes with welded locks TMK UP EXD. REP From 02-015-2015, 2nd edition (LLC TMK Premium Service)
[10] GOST 27834-95 Welded tool joints for drill pipes. Technical conditions