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CALCULATION OF RATIONAL BENDING MOMENTS OF LOCKING THREADED CONNECTIONS BT AND WDP FOR DRILLING DEEP WELLS

Chernova M.Ye.
d.t.s., prof. / д.т.н., проф.
ORCID: 0000-0001-6014-3087
Ivano-Frankivsk National Technical University of Oil and Gas,
Ivano-Frankivsk, Karpatska Street,15, 76019

Abstract. *The paper considers one of the problems of safe construction of deep wells, which is related to the reliability of threaded connections of drill string elements. The reliability of locking threaded connections, for the most part, depends on the value of the screwing torque, which must be optimal. The optimal screwing torque was studied on full-scale samples of threaded connections, which were subjected to cyclic loads on special laboratory equipment.*

During the research, strain gauges were used that recorded the load values not only on the threaded connection itself, but also on the nearest parts of the pipe body. Thus, the static strength characteristics of the pipe body, which have mostly always been neglected by scientists, were taken into account.

Based on laboratory studies that require industrial confirmation, the limits of the maximum permissible values of the screwing torque for different sizes of lock threaded connections have been established in order to increase their durability in the conditions of operation of deep wells. In addition to the calculation ratios that make it possible to calculate the stress value in the most dangerous cross-section of the structure, the results of the studies specified in the corresponding tables 1 and 2 are also given for pipes of different strength types under conditions of different values of the Poisson's ratio. All information, in particular, the value of the screwing torque in the tables is given in values corresponding to SI.

Key words: *drill pipe, screwing torque, threaded connection***.**

Introduction.

During the military aggression against Ukraine, unfortunately, work related to the construction of oil and gas wells was sharply reduced. There are many reasons. Therefore, the post-war revival of oil and gas drilling in Ukraine is one of the priority tasks. The deadlines will be quite short, and the requirements for trouble-free drilling will be quite high. One of the reasons that cause the emergency state of the drill string (DS), in general, is the destruction of their threaded connections. And, given the fact that the wells will be drilled not only obliquely, but also deep and ultra-deep, special attention needs to be paid to the reliability of the locking threaded connections (LTC), which make up the lion's share in the layout of the DS.

The problem of strength and reliability of the drilling rig has been studied by many scientists to date, but the task has not been 100% solved. Due to the significant introduction of high-strength pipes, which is directly related to the increase in drilling depths, the requirements for the operability of the lock joints of the drill string in general are also increasing. The static and dynamic strength of the locks is largely determined by the amount of tightening of its threaded connection.

Main text.

The calculations of the screwing torque of a lock joint known today, assuming its maximum load resistance, almost do not take into account the static strength of the drill pipe body with which it works. The main condition for such calculations is to ensure the tightness of the joint, and this can be achieved under the condition of contact loads on the abutting ends of the locks of about 5 MN×m^2.

According to bench-top laboratory studies, the endurance limit of such locking threaded connections is more than 2 times lower than connections with contact loads at the ends, which are almost 400 kN×m^2 and more.

The optimal value of the contact forces at the end was determined by fatigue strength studies under cyclic alternating bending loads of locking connections of arbitrary diameter, in particular from 80 to 203 mm. The fatigue resistance of those locking threaded connections located in the upper part of the drill string is determined by using bench equipment, on which, in addition to cyclic alternating bending loads, the effect of a constant axial load is applied, simulating the weight of the drill string as a whole. The highest fatigue resistance was observed under contact pressures on the supporting ends of the threaded connection, which amounted to, in practice, a value of 400 kN×m^2.

These values are in very good agreement with the recommendations of such well-known companies as the British oil and gas company Shell and the French oil service company Schlumberger Limited [1].

For the calculation of the screwing torque of the lock threaded connections of drill pipes, we take the following conditions as a basis:

1. The static strength of the lock must be achieved taking into account the tensile-

compressive strength of the pipe body as such;

2. The contact pressure allowances on the abutting ends must be maximum;

Calculations for rational tightening of drill pipe lock joints are as follows [2;3]:

The maximum allowable static load on the drill pipe is determined from the ratio [4]:

$$P_{all} = \frac{P_{\max}}{k}; \tag{1}$$

here is $P_{\max}$ - the maximum tensile load at which the stress of the pipe body reaches the yield point;

k - the safety factor, lies within 1.35÷1.45.

3. The torque for screwing in locking connections is determined by the ratio:

$$M_{torq.} = a \cdot S_n \cdot \sigma_t; \tag{2}$$

here a - is a coefficient characterizing the design of the locking connection and the properties of the lubricant corresponding to it;

S_n - the area of the dangerous cross-section of the nipple, which is at a distance of 24 mm from the supporting protrusion;

σ_t - tensile stress in the dangerous section from tightening.

This maximum tightening stress is determined from the condition:

$$\sigma_t = \frac{\sigma_{y.st.}}{1.5} - \sigma_p; \tag{3}$$

here $\sigma_{y\,st}$ = 736 MPa – yield strength of the material from which the lock is made;

1.5 – safety factor;

σ_p - tensile stress in the dangerous section of the nipple from external load P_{per}.

$$\sigma_p = \frac{P_{all} \cdot K_n}{S_н}; \tag{4}$$

here K_n - is the coefficient of external load of the nipple during tension [2].

The screwing torques calculated from the relation (3) contribute to ensuring the maximum contact stress on the butts of the thread for the corresponding type of drill pipes. However, their value cannot exceed the permissible loads on the butts, which satisfy the inequality:

$$\sigma_{butt}^{all} \le \frac{\sigma_{y\,st}}{1.2} = \frac{736 \cdot 10^{6}}{1.2} = 613 M\Pi a;$$

here 1.2 - is the safety factor at the butts.

The permissible screwing torque is calculated from the following condition:

$$M_{torq}^{p.s.t.} = a \cdot \sigma_{butt}^{all} \cdot S_{butt}; \quad (5)$$

here S_{butt} - is the area of the supporting butts.

As a rational screwing torque, which is capable of providing static and dynamic strength, we use the smallest of the two values calculated by relations (2) and (5).

Benchtop fatigue studies conducted on full-scale lock joints of stabilized weighted drill pipes (SWDP) have shown that their fatigue resistance is fundamentally determined by the screwing torque (Ms.t.), and at a rational value, the ultimate strength is maximum.

For most connections, the optimal screwing torque is achieved at stresses in the dangerous section of the nipple corresponding to the ratio $\sigma_P = (0{,}3...0{,}4)\sigma_{\text{y st}}$, then at the supporting ends the contact stress will be within *342…441 MPa*, provided $\sigma_{\text{y st}} = 636...736 MPa$.

As is clear, according to the results of the research, if the value σ_P in the nipple is increased to a value of $0{,}7\sigma_{\text{y st}}$, the endurance limit of the locking threaded connections significantly decreases to a value of 10% of its maximum value.

It is a well-known fact that correctly selected values of the screwing torque ($M_{s.t.}$) for threaded connections of SWDP increase the reliability of their operation, including by preventing the phenomenon of overtightening during drilling.

The maximum value of the screwing torque of the SWDP is determined by the ratio:

$$M_{scr.t.}^{\max} = a \cdot \sigma_{t.}^{\max} \cdot S_n;$$

here

$$\sigma_{t.}^{\max} = \frac{\sigma_{\text{y.st.}}}{1.5};$$

1.5 – safety factor.

Depending on the operating conditions of the WDP, the recommended screwing torque value should be determined by the ratio:

$$M_{scr\,t} = a \cdot S_n \cdot \sigma_t = a \cdot S_n \cdot (0,4...0,6)\sigma_{\text{y st}};$$

It is recommended to determine the maximum permissible loads on the butts according to the condition: $\sigma_{butts}^{per} \leq \frac{\sigma_{\text{y.st.}}}{1.2}$;

here 1.2 - is the safety factor at the butts.

For SWDP - $\sigma_{butt}^{per} \leq \frac{637MPa}{1.2} \approx 530\ MPa$;

for WDP - $\sigma_{butt}^{per} \leq \frac{441MPa}{1.2} \approx 367{,}5\ MPa$;

The permissible value of the screwing torque, given the possibilities at the butt, must be determined by the ratio:

$$M_{scr.torq}^{\text{per}} = a \cdot \sigma_{butt}^{per} \cdot S_{butt}.$$

The recommended tightening torque for the main sizes of SWDP and WDP is given in Table 1 below.

Table 1 - Research data on recommended screwing torques for threaded connections of WDP

Type and diameter of WDP ***×10⁻³ (m)***	Tightening torque ***(N×m)***	
	μ=0.1	*μ=0.13*
σper=637 MPa		
SWDP2-108	5785,5÷7746.7	7256,4÷10198.2
SWDP2-120	8040.9÷11963.3	10198.2÷15297.4
SWDP2-133	12453.6÷18729.5	15885.7÷23828.6
SWDP2-146	17454.7÷23534.4	22259.6÷30006.4
SWDP2-178	30790.8÷46088.2	39420.1÷58836.0
SWDP2-203	46578.5÷62758.4	59620.5÷80409.2
SWDP2-223	64131.2÷86587.0	82174.3÷110807.8
SWDP2-254	76486.8÷114730.2	98060.0÷147090.0
SWDP2-273	76486.8÷115220.5	98060.0÷148070.6
SWDP2-299	77173.2÷115808.9	99432.8÷100217.3
σper=441 MPa		
WDP-146	13630.3÷17258.6	17552.7÷22161.6
WDP178	27652.9÷30987.0	35301.6÷39224.0

WDP-203	46774.6÷47068.8	58836.0÷60306.9

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The minimum tightening value is calculated under the condition $\sigma_t = 0{,}4\sigma_{\text{per}}$; and the maximum under the condition $\sigma_t = 0{,}6\sigma_{\text{per}}$; taking into account the permissible contact pressures on the supporting butts [5].

Summary and conclusions

Based on bench-top studies on the fatigue resistance of the lock threaded connections (LTK) by alternating cyclic loads, which amounted to 10^6 cycles, regularities were obtained for calculating the optimal values of the LTK screwing torque, in particular, it was established that

1. the largest value of the screwing torque corresponds to the smallest wall thickness of the drill pipe;

2. during the operation of lock joints of the type ZN-80, ZN-95, ZSh-108, ZU-108, ZUK-108, ZU-120, ZUK-120 (σ_{per}*=735.75 MPa*) with drill pipes of the *L* and *M* brands, we recommend limiting the permissible tensile-compressive loads on the pipe body to 50%;

3. the above studies require industrial confirmation, which can be carried out in peaceful, stable times.

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Scientific consultant: *Doctor of Technical Sciences, prof. Boris Chernov*

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