

Drill pipe threaded nipple connection design development

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Abstract. The paper presents the analysis of the behavior of the drill pipe nipple connection under the additional load generated by power pulses. The strain wave propagation through the nipple thread connection of drill pipes to the bottomhole is studied in this paper. The improved design of the nipple thread connection is suggested using the obtained experimental and theoretical data. The suggested connection design allows not only the efficient transmission of strain wave energy to a drill bit but also the automation of making-up and breaking-out drill pipes.

1. Introduction

The analysis of the behavior of the up-to-date thread connections used in drill pipes shows that the total loads applied to them are represented by the coupling torque, axial load, and impacts produced by percussive mechanism with the definite frequency.

A combination of these factors has a significant effect on the drilling rate which is proportional to the strain wave energy [2]. Moreover, the impact loads produced with the definite percussion frequency, generate the additional energy which allows increasing the drilling rate and has a wave-like behavior. The aim of this study is to analyze the operation of threaded nipple connection while passing of a strain wave through it and improve its design.

2. Experimental part

During the power pulse propagation over the drill string from the percussive mechanism to a drill bit, the energy losses are observed in drill pipe connections that lead to the decrease in the strain wave energy over the drill string.

The drilling tool presented in figure 1, operates in the following way. The percussive mechanism induces and maintains the in-and-out movement of the hammer. The hammer produces impacts on the steel shank in which the strain wave is formed at each impact. The strain wave is characterized by the shape (elevation), amplitude, length, and energy. These properties depend on the geometry of colliding elements, material properties, and speed of collision. A common operating mode of the percussive mechanism is such that the collision can be regarded as elastic, and the effect from the strain wave can be neglected.

While the strain wave propagates along the drill pipe and through thread connections, its shape is changed, and the energy dissipation is observed. The intensity of these processes depends upon the design and the size of the drilling tool members, their material properties, contact stiffness, etc.



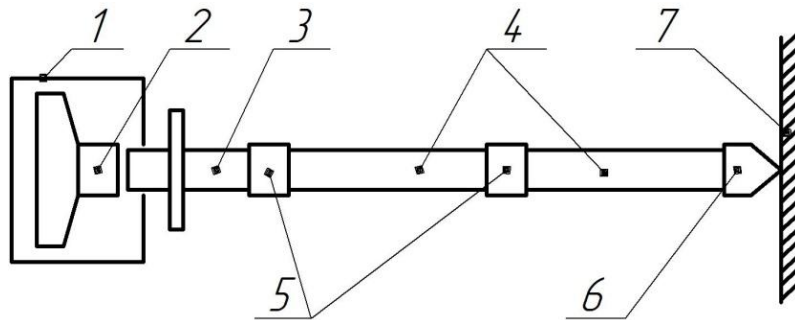


Figure 1. Schematic view of the drilling tool: 1 – percussive mechanism; 2 – hammer; 3 – steel shank; 4 – drilling pipe; 5 – thread connections; 6 – drill bit; 7 – rock.

While propagating along the drill pipe and affecting the drill bit, the strain wave makes the drilling tool to penetrate in the rock that leads to its subsequent failure. In order to maintain the drilling tool near the rock, the feed thrust should be applied to it. Usually, the value of the feed thrust is several tens less than that of the strain wave.

Except for impact loads, in many types of percussion drilling machines the coupling torque is applied to the drilling tool. Depending on the feed thrust value, the coupling torque provides merely either an angular rotation of the drilling tool between two subsequent impacts or the additional rock failure with a drill bit.

The section of the drilling tool covered with the strain wave, the stress state is generally considered to be spatial. Axial, flexural, radial, and shear stresses occur in this tool section.

Having achieved the running end of the drill string, the power pulse is reflected. Its waveform depends on conditions of the running end of the drill string and can be of three types:

- compression pulse at a total absence of the drilling tool penetration;
- tensile pulse at a total absence of resistance to the drilling tool penetration;
- tension-compression pulse at drilling tool penetration in the rock possessing a certain resistance.

Figure 2 presents the schematic movement of the running end of the drill string at different interactions between the drilling tool and the rock.

The reflected pulse propagation is accompanied by phenomena similar to that of the direct pulse. The difference is that tensile pulse causes the loss of contact between the drill string joints, and the further energy transmission through the nipple body increases the loss of the reflected strain wave energy. While propagating over the drill string, the reflected strain waves interfere with each other. Stresses within the interference area are determined by the vector summation of stresses produced by individual strain waves. Therefore, the stress peak in the connection can exceed the direct pulse stress by not over than two times.

Experimental studies carried out by Fisher [4], show approx. 50% increase of the surface stress that occurs due to the flexural pulse. These additional stresses turn to be the strongest at the beginning of the drill string, and then completely vanish. This is because the flexural pulse propagates more slowly than the compression pulse.

The strain wave energy is changed while propagating along the drill string and can be obtained from [3]

$$W = W_0 \cdot e^{-2 \alpha_1 L + \alpha_2 n}, \quad (1)$$

where W is the strain wave energy with distance L from the end of the drill string; W_0 is the strain wave energy at the end of the drill string; α_1 is the damping decrement of elastic vibrations in the drill

string material per unit length; \dot{W}_c is the energy loss rate in one connection of the drill string; n is the number of connections over length L .

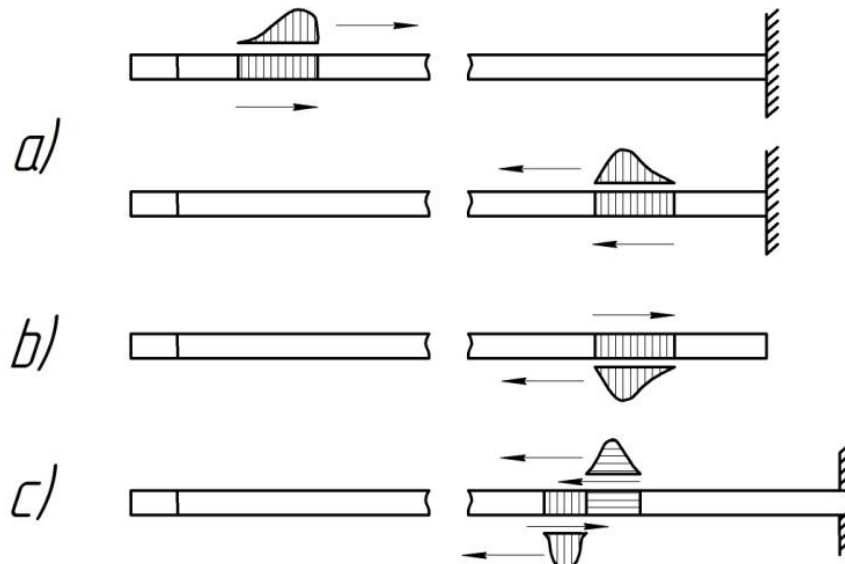


Figure 2. Schematic view of pulse propagation and the drill string section movement: a) no drilling tool penetration; b) no resistance to drilling tool; c) partial drilling tool penetration.

Research results obtained by Shadrina *et al.* in [5] show that the damping decrement is $\alpha_1 = 4 \cdot 10^{-3}$ (0.4 %), while the energy loss rate ranges between 0.8 - 18% depending on the design and the quality of the pipe connection.

The strain wave energy loss in one connection of the drill string is mostly caused by two factors, namely: reflection of strain waves in places of cross-sectional differences and joints of the drill string; frictions in the drill string or connecting element at pulse propagation over the connection.

During the strain wave propagation over the places of cross-sectional differences, the reflected pulse is observed, amplitude of which is defined by the direct pulse amplitude [2]:

$$F_r = \frac{S_2 - S_1}{S_2 + S_1} \cdot F_a \quad (2)$$

The strain wave energy is proportional to the squared peak value; the rate of impact energy loss due to reflection can be obtained from the ratio between the strain wave energy approaching to the connection and the reflected strain wave energy

$$a_r = \frac{W_r}{W_a} = \frac{F_r^2}{F_a^2} = \left(\frac{S_2 - S_1}{S_2 + S_1} \right)^2 \quad (3)$$

The strain waves reflection from the drill string joint depends on the coupling torque affecting the connection. The higher coupling torque, the tighter joint and the lesser the movement of drill string and connecting element at strain wave propagation. Hence, the lower are its energy losses. The increase in the coupling torque decreases the drill string relative displacement in the connection owing to which the inelastic resistance force is reduced during the loading cycle in the connection (figure 3). This behavior is explained by the transverse strain occurred in thread loading which is directed away from the nipple. At the certain value of the coupling torque, both the pressure in thread

contacts and inelastic resistance forces in thread connection decrease. The increase of the coupling torque results in the increase of the contact stiffness between threads and the nipple.

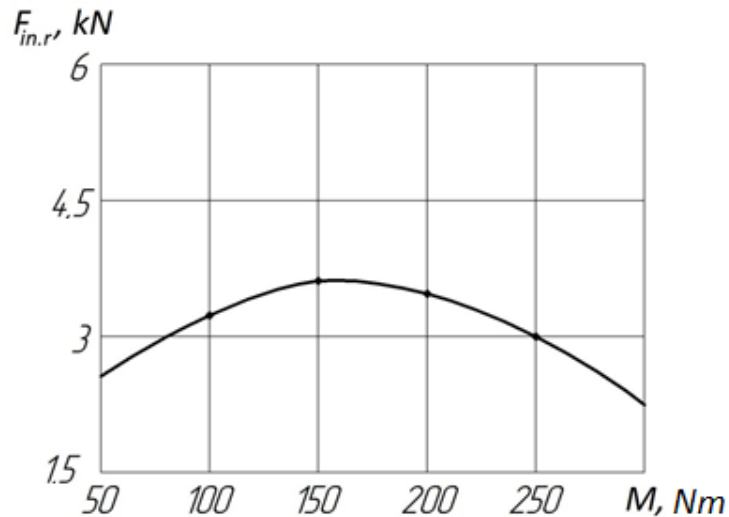


Figure 3. The dependence between inelastic resistance force and coupling torque.

Strain wave energy losses are mainly caused by the inelastic resistance forces occurred at the pulse loading and displacement of the nipple relative to the connected drill strings. Thus, it is advisable to design the thread connection that will reduce energy losses and increase the drill string operating capacity and the efficiency of well drilling [1].

The suggested design of the nipple thread connection allows the improvement of the drill string reliability, cutting transport and the automation of making-up and breaking-out drill pipes. The nipple connection shown in Figure 4, comprises two drill pipes having the female straight thread and the nipple having the continuous male thread. The nipple has a collar with two annular grooves on its both sides. Collar grooves are cut on the internal side of the drill pipe ends. Non-threaded segment of one of the nipple ends is rigidly fixed in the drill pipe and has longitudinal cuts that divide the non-threaded segment into elastic plates. Elastic plates have collars with a bevel front face which are fixed in the annular groove after the achievement of strain tolerance in the tapered groove. Wrench flats are cut on another non-threaded segment of the nipple end.

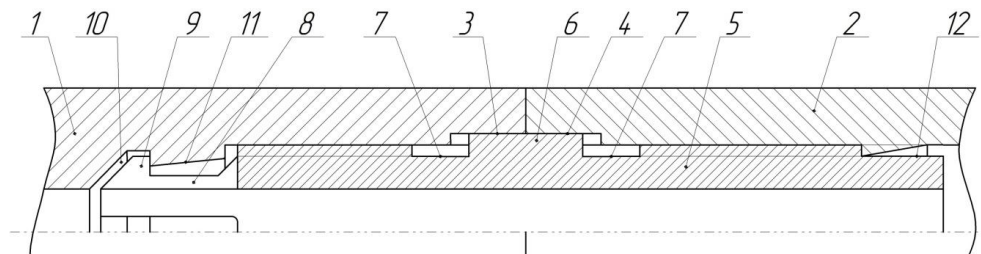


Figure 4. Cross-sectional view of nipple thread connection: 1, 2 – drill pipes; 3, 4 – grooves; 5 – nipple thread; 6 – collar; 7, 10 – annular groove; 8 – elastic plates; 9 – collar with bevel front face; 11 – tapered groove; 12 – wrench flat.

In percussion drilling, the drill string and connecting elements experience tensile, compressive and flexural loads and the coupling torque effect.

The suggested design of the nipple connection has the following advantages:

- Nipple locates inside two butt-coupling pipes providing the minimum energy loss at strain wave transmission.
- In strain wave propagating through the connection, pipe sections are compressed, while the nipple is unloaded from normal tensile and deformation stresses produced by the pre-tightening force.
- The collar and annular grooves cut in the nipple improve the connection durability at bending strain.
- The automation of making-up and breaking-out drill pipes is possible due to the nipple fixation in one of the drill pipes.
- The nipple connection hidden inside the drill pipe provides the consistency of the outer diameter of the drill string that improves the cutting transport and eliminates the possible drill string jamming in the well.

3. Conclusion

The suggested nipple thread connection can be used in percussion drilling of medium-hard and harder rocks ($f = 6 \dots 14$). The transmission rate of strain wave energy over the drill string increases due to the increase of the contact stiffness between thread connections.

References

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