Improved rotary union in top-drive hydraulic power packs used on drilling rigs

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Abstract. The paper is concerned with a top-drive hydraulic power pack used on a drilling rig. The efficiency of hydraulic power packs can be ensured through a rotary union in a hose reel. An effective circulation of working fluid in the hose reel requires an improved rotary union, which allows the flow of working fluid to be redistributed with minimal energy and additional costs. As a result, the lifetime of the system is increased and the downtime of the rig is reduced.

1. Introduction
The top-drive drilling rig is recognized as one of the most significant advances in drilling technology since the advent of the rotary table. Unlike conventional drilling rigs, top-drive rigs are steadily demonstrating a higher drilling speed and safety level. Such drilling rigs are much less likely to be prone to drill pipe stickings. In addition, top-drive drilling allows the operator to drill to such horizons and formations that would be inaccessible with conventional rotary drilling [1, 2].

A top drive method, originally developed by American experts, dramatically changed the life of a drilling crew, greatly facilitating its work. The top drive provides torque to the drill string in the desired direction, in whatever position it is. In addition, the top drive drilling eliminates the need for additional manipulations and additional tools during drilling [3-5].

2. Materials and methods
Recently, the top drive has become the most popular method for drilling oil and gas wells, designed for quick and trouble-free drilling of vertical, directional and horizontal wells. Combining the functions of a swivel and a rotor, it is equipped with a set of devices for performing hoisting operations. The top drive is exploited in the oil industry in line with new safety rules, provided that a horizontal section is more than several hundred meters long [6, 7].

The paper discusses a fluid circulation system in the top-drive hydraulic power pack (Fig. 1). A technical challenge is to improve the reliability and durability of a hose reel, and simplify its maintenance.
Figure 1. Top-drive hydraulic power pack: 1 – drive; 2 – hose reel; 3 – hydraulic oil reservoir; 4 – flow control

3. Results and discussion

The hose reel (Fig. 2) fixed in the top-drive hydraulic power pack is improved through quick disconnects removed from the assembly. They are located around three lines of the hydraulic system: the first line is circulation (supply) of hydraulic fluid to the hydraulic pump, the second line is circulation (return), the third line is drainage enabled by a triple-flow rotary union. The triple-flow rotary union is a mechanical device – a coupling through which hydraulic fluid is drawn from the fixed part of the hose reel to the rotating part of the hose reel. The triple-flow rotary union has three independent channels.

This technical solution can significantly increase its reliability, thereby reducing the cost of its maintenance and increase personnel safety.

Quick disconnects have a number of valve drawbacks, like cripplings of a shut-off valve spring, splinters getting into other items of the hydraulic system, freezing, leaks, deformation of the valve stem itself, foreign particles (dirt, sand, water, ice, etc.), and contaminated threaded matings [8].

These malfunctions can be eliminated either by replacing quick disconnects or repairing other equipment that has failed due to some destructed internal parts of quick disconnects, which leads to additional equipment downtimes and, consequently, financial losses for the entire enterprise.

The rotary union (Fig. 3) has a steel housing. The stem is made of 40X stainless steel. The metallized seal can withstand high working pressures in the system (P=3500 kPa). The bearing is mounted in the housing of the rotary union with an embedded part. It is possible to mount the rotary union on the equipment using a K-flange. The seal is made of teflon. A sliding bearing is made of graphite, has an embedded element that stops the bearing from the torque in the housing. There is an annular groove on the rotor that indicates the wear of the seal – as soon as it appears from the housing, the seal must be changed [9].

The outer part of the triple-flow rotary union is attached to the adapter – the shaft (Fig. 4). The shaft is held by a flange-shaped cap that contains the bearing. The inner part of the triple-flow rotary union is mounted in the center of the hose reel, using four fastening bolts with a diameter of 10 mm, on a pentactinal inner base. Three ends of high-pressure hoses (HPH) are drawn to the pentactinal inner base, which, passing through the base, are sectionwise wound onto the hose reel [10].

The ends of the high-pressure hoses are crimped by special fittings screwed into threaded adapters at 45° and self-locking angle at 90° located at the base of the triple-flow rotary union.

The length of the HPH lines wound around the hose reel is 40-60 m, the inner diameter of which,
except for the drainage line, should be at least 32 mm. Finally, the diameter of the drainage circuit is at least 25 mm.

**Figure 2.** Hose reel: 1 – stand; 2 – frame; 3 – shaft bearing; 4 – rotary union; 5 – reel

**Figure 3.** Triple-flow rotary union
The heart of the rotary union is the mechanical seal (Fig. 5) that ensures its tightness. It is crucial to choose a proper mechanical seal to ensure the efficiency of the rotary joint, since in the event of a failure and leakage of the medium, the efficiency of the cooling or heating process as such is significantly reduced. The design of rotary unions provides a quick and easy replacement of mechanical seals, which is very important to reduce downtime and repair costs [11, 12].

Being an integral part of a swivel joint, mechanical seals should be selected based on the characteristics of the medium.

The load onto the mating surfaces of the seals is minimized and almost independent of the pressure of the medium, which significantly prolongs the lifetime of the seals and the union as a whole.

The optimum balance of the seals allows a thin lubricating film between the mating surfaces of the seals.

**Figure 4.** Pentactinal inner base assembled with triple-flow rotary union: 1 – retaining clip for a high-pressure hose (HPH); 2 – 90° self-locking circulation-line angle; 3 – circulation-line HPH; 4 – 45° circulation-line adaptive coupling; 5 – triple-flow rotary union; 6 – 45° drainage-line adaptive coupling; 7 – drainage-line HPH; 8 – retaining clip for HPH; 9 – fittings; 10 – 45° circulation-line adaptive coupling; 11 – pentactinal inner base.
Figure 5. Triple-flow rotary union: 1 – cap; 2 – cylinder; 3 – rod; 4 – plug; 5 – retaining teflon ring; 6 – rubber seal; 7 – rubber ring; 8 – graphite ring

4. Conclusion
The technical effect implies that replacing an item of the top drive system extends the lifetime of the equipment, both of the item itself, the hose reel, and other elements located in the same line of the hydraulic system. The economic effect is achieved by reducing the cost of purchasing spare parts (quick disconnects), thereby eliminating equipment downtime during the operations performed by drilling crews. The advantages of the presented technical solution are that the load on the mating surfaces of the seals is minimized and almost independent of the pressure of the medium, which significantly prolongs the lifetime of the seals and the union as a whole.

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