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Use of materials with shape memory effect to improve the performance properties of parts of drill string

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Abstract. The use of materials with shape memory in the manufacture of parts of the drill string such as the nipple and the coupling of the boring lock and the bit of the drill bit can improve performance, as many of the drawbacks exhibited during operation are associated with design features, and the use of alloys with shape memory allows changing the design parts, taking into account the features of the equipment due to their functional characteristics.

1. Introduction

In various areas of the industry for the extraction of natural resources there are various kinds of problems associated with equipment with working conditions, not qualified personnel. But such a problem as an accident of drilling equipment will always pursue such major areas of industrial resource extraction as the oil and gas and mining industries. One of the most energy-consuming and resource-intensive accidents are considered to be accidents associated with a roller bit (Fig. 1) and a drill lock.

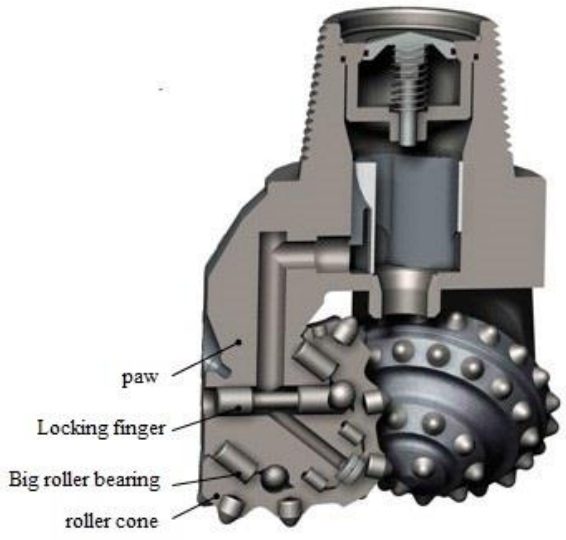

Figure 1. Roller bit in the cut

There are many problems with wear of roller bits, for example: a) loss of a cone, b) chipped cones, c) ero-sion of cones, d) departure or scrapping of teeth (ar-mament). All these problems lead to poor-quality op-eration of the drilling rig and to an accident during which it would be impractical and dangerous to drill in that well, for example, the loss of the cone will nega-tively affect the operation of the entire bit, because the material from which the cones are made is often identical (i.e. the interaction of the lost cone and the remaining will occur failure of the entire bit as a whole, and possibly the entire drill string). With this type of accident will have to drill an additional wellbore, which leads to an increase in production time, the costs of drilling the well and the total expended energy and resources.

During operation, the drill lock is simultaneously sub-jected to twisting, bending, stretching, compression, shock and vibration loads, as well as to the influence of an aggressive working environment. In conse-quence of this, such problems arise as: a) scrapping parts of the drill lock, b) self-unscrewing, threaded connections, c) breaking the turns of the threaded connections, d) accumulation of damage, leading to further destruction of the drill lock nipple, d) low cor-rosion resistance. These problems often lead to emer-gency situations. For example, the elimination of the accident at the breakdown of the drill lock, and in the subsequent break of the drill string due to the wear of the drill lock, according to preliminary estimates is more than 10 million. rubles.

In view of the analysis of such problems, a decision was made to introduce material with shape memory effect into the manufacture of the considered ele-ments of the drill string.

2. Design features of the proposed development

2.1 Material with shape memory effect

The property of a material with an SME is based on a thermoelastic phase transformation, which is inherent in a few alloys. For the first time a material with this property was discovered in 1932 by the Swedish re-searcher Andre Olander, and the gold-cadmium alloy played the role of the material under study. Further in the USA 1962 - 1963 in the naval laboratory, a shape memory effect was found in the alloy Ti and Ni, which was called Nitinol.

Nitinol has high physicomechanical characteristics, as well as such properties as thermoelastic phase trans-formation or shape memory and superelasticity. These properties make this material incomparable in terms of performance with the materials from which cones are made today.

Nickel titanium is able to restore plastic deformation to a certain value. Therefore, this material shows itself from the best side in the fight against abrasive wear, due to its superelasticity. Depending on the percentage of added impurities, it is possible to regulate the temperature of thermoelastic phase transformations.

2.2 Shredder from material with shape memory effect

As it is known, roller cone bits experience heavy loads during operation, such as skewing, compressing loads, which leads to the fact that the material from which the cones are made quickly becomes unusable due to large abrasive wear.

Figure 2. Comparison of TiNi and AISI 4815H.

When comparing the material with the shape memory effect (TiNi) and the material from which the cones are made (AISI 4815H), a number of advantages of the material with the shape memory effect were observed, is presented in diagram (figure 2). The material was chosen in accordance with OST 26-02-1315-84

This article proposes to make cones of material with shape memory effect and remove the locking fingers in the paws of the roller bit. Figure 1 shows the classic construction of a three-round chisel, and Figure 3 shows the bit design without a locking pin. Removing the finger from the design of the bit is accompanied by the ease of installation and disassembly of the cone from a material with shape memory effect on the shaft of the bit.

Due to the fact that the track along which the balls (bearing) are moving is composite, this negatively affects the operation of the balls, subsequently leading to their premature wear. But with the use of the pro-posed material, the inner bearing track (trunnion) will be integral, which will ensure a longer bearing life. A lightweight assembly and disassembly of the cones is provided by thermoplastic phase transformation. Before the installation of a roller cutter from a material with a shape memory effect, it is necessary to cool it to the phase transition temperature and stretch it a little, and then put it on the trunnion, then during heating the reverse phase transition will occur, that is, the material will go into its solid (austenitic) state due to ensure guaranteed tightness and self-fixing of the pressed teeth and roller cutters on the trunnion. After that the roller cutter will be ready for operation.

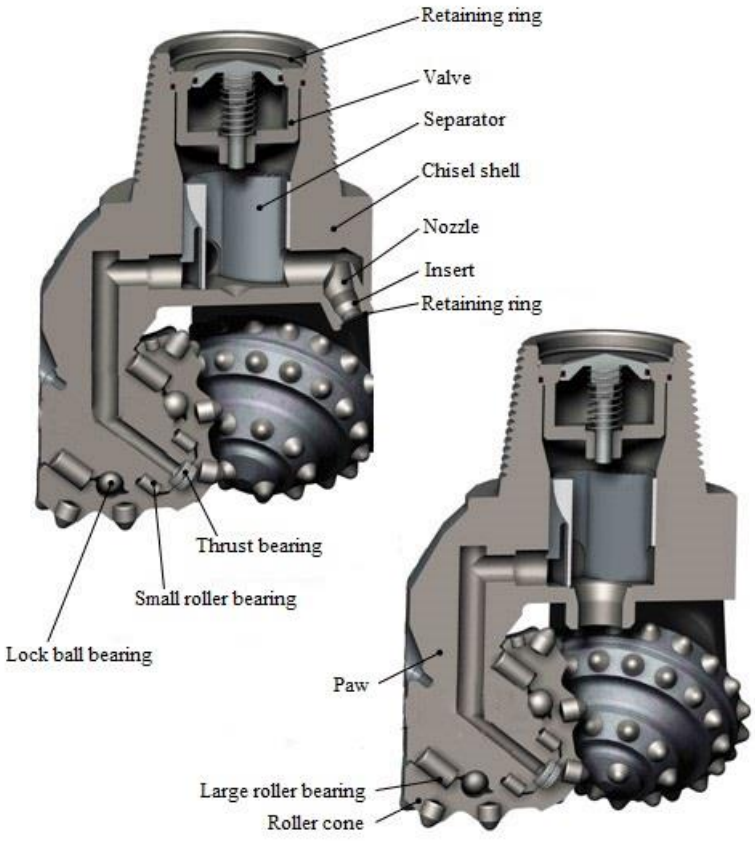

Figure 3. Proposed design tricone chisel

2.3. Drilling lock of material with shape memory effect.

Boring lock is one of the most important elements of the drill string, acting as a link between pipes, drilling and ground tools, it is subjected to temporary overloads, alternating and shock loads and besides the working environment often has a corrosive effect. Therefore, the goal is to develop a

boring lock from a material with a shape memory effect, with enhanced performance characteristics and a level of friction reliability, which allows avoiding many problems arising during drilling, including such as thread failure, residual deformation, corrosion-fatigue ulcers, which originate microcracks, which further lead to large-scale breakage of drill locks.

Comparing the material with the shape memory effect (TiNi) and the material used in modern oil and gas industry (steel 40XH), we found that Titannickel has significantly higher strength characteristics, which can be clearly seen from diagram (figure 4).

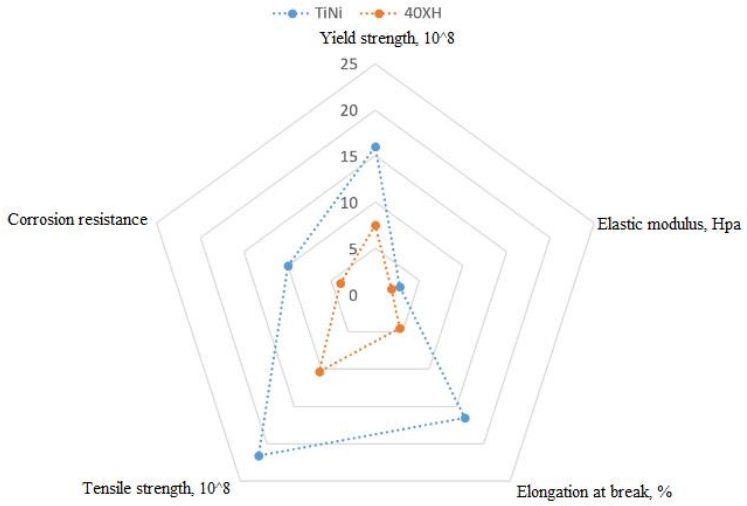

Figure 4. Comparison of TiNi and 40XH.

In addition to the manufacture of the nipple and the coupling of the drill lock from a material with a shape memory effect, it is proposed to introduce into its design a blocking element located on the edge of the threaded connection. Thus, the material with the shape memory effect will provide the necessary guar-anteed tension, and the blocking element will prevent self-unscrewing under shock loads and overloads that occur.

The proposed drill lock consists of nipple (figure 5) and coupling (figure 6). When this nipple contains a cylindrical tubular body, bounded by the end surfaces, on the side of one end surface, having an external tapered thread, at the end of which is cylindrical transitional stage with circumferential depressions, made in the form of spherical segments, and the sides of the other end surface, having an internal tapered thread, between which and the end surface there is a cylindrical transitional stage with protrusions arranged circumferentially, complements in the form of spherical segments. The clutch contains a cylindrical tubular body bounded by end surfaces, on the side of each end surface of the clutch an internal conical thread is cut, between which and the end surface there is a cylindrical transitional stage with circumferentially spaced projections. The nipple and the coupling of the drill lock are made of a material with a shape memory effect.

The principle of the installation of a castle joint is based on thermoplastic phase transformations of a material with a shape memory effect. As a result of cooling with liquid nitrogen vapors, the material enters a martensitic state, leading to a change in the geometry of the conical outer part of the threaded element, namely in the case of a nipple reducing its diametrical size at the coupling nipple and increasing its diametric size at the pipe-nipple connection, and the case with a coupling of increasing diametral dimensions, both in the nipple-coupling connection, and in the coupling-pipe connection. They together allow easily twisting / untwisting locking connection of drill pipes. When heated, the nipple and coupling acquire the geo-metrical parameters of the connecting elements, providing a guaranteed fit with a tightness along the entire length of the conical threaded connections of the part.

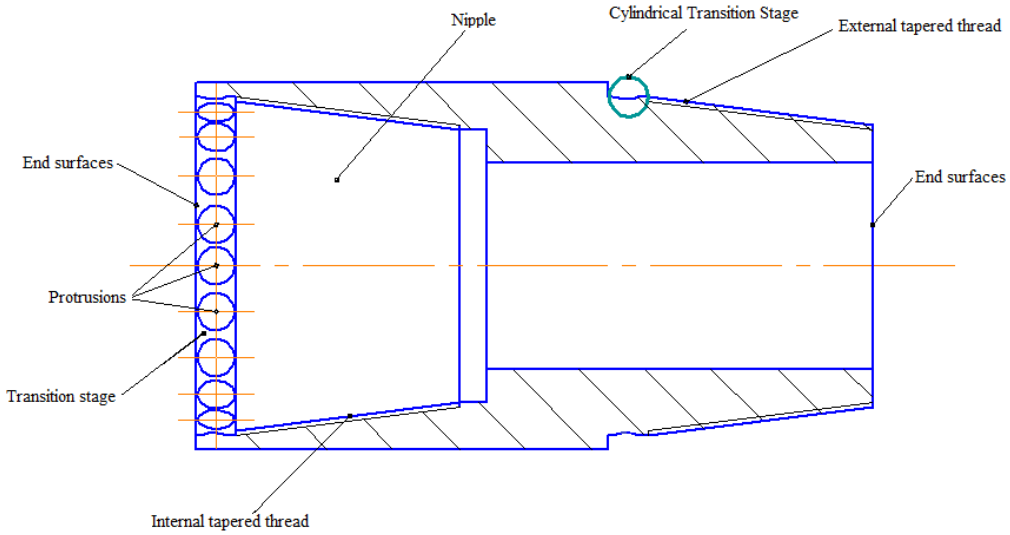

Figure 5. Proposed construction of the nipple drill lock

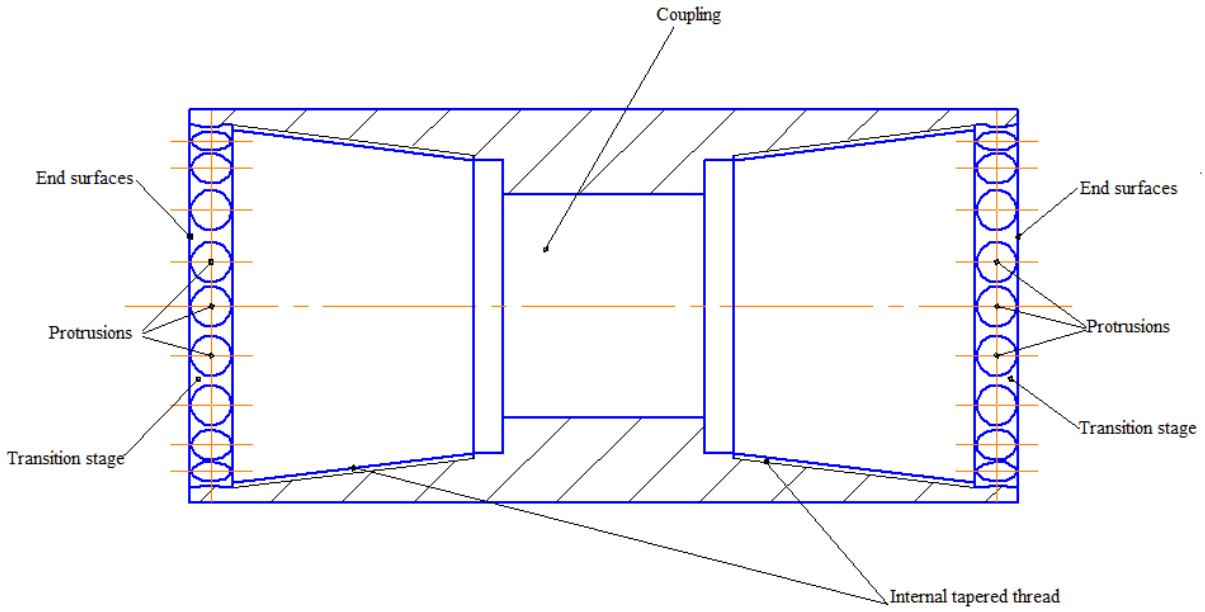

Figure 6. Proposed design of the coupling drill lock

3. Conclusion

As a result of research of drilling equipment, problems were identified and proposed for solving a number of problems, making a cone from a shape memory material with a simplified bit design due to the removal of the locking pin as the weakest element in the structure affecting the duration and performance characteristics of the bit. also the execution of the drilling lock from the material with the shape memory effect with the addition of blocking elements that prevent the drilling lock from self-unscrewing during operation, the most ensuring the fulfilment of all requirements for the drill lock during operation, regardless of the number of assembly / disassembly works.

The introduction of such developments in the industry will significantly increase the economic effect by reducing the cost of equipment repair. In the case of a roller bit, then using a material with a memory effect, it will become maintainable, which will allow it being reused after maintenance.

The material with the memory effect in the future will more than once find its application in the resource-extracting industry due to its unique intellectual and physicomechanical properties.

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