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Development of Rotary Steerable System of Small Diameter

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ABSTRACT

Using the existing worldwide experience as well as experimental results of Russian rotary steerable system for drilling wells with the diameter of 220 mm (RSS220), this article compares various concepts of implementation of push-the-bit principle upon geostationary arrangement of bias unit. On the basis of the obtained results, design solutions of a new RSS design of small diameter are proposed.

Key words: Directional drilling, rotary steerable system, push-the-bit, research, drilling mode, design solutions.

1. INTRODUCTION

Development of steerable bottomhole bias unit dominates in the field of innovative drilling technologies, especially those concerning segments of complicated profile and small diameters (148-155 mm) [1-3]. Numerous disadvantages of directional drilling with screw bottomhole motor can be eliminated or minimized by means of RSS when drill bit moves along preset path with continuous drillstring rotation, thus enabling better hole cleaning and reducing the risk of sticking [4, 5]. However, implementation of RSS of small diameter requires for thorough conceptualization due to limited free space for location of main components of bias unit (BU)**.**

2. PROPOSED METHODOLOGY

2.1 General description

In previous works [6, 7], operational principle for RSS of small diameter was similar to that of RSS220: geostationary BU operating in push-the-bit mode, which provided high technological efficiency, however, in the case of RSS220, this principle was based on linear drives. This was related with the fact that the most bottle-neck elements upon scaling were power supply elements and actuators.

2.2 Algorithm

Conceptualization and analysis of components of linear drive of small diameter demonstrated that the minimum attainable diameter was 23 mm [6]. Minimum possible diameter of lithium–thionyl chloride power source is 25 mm. During strength analysis of BU body and shaft it was discovered that the RSS220 layout arrangement could not be directly implemented in RSS of small diameter. Solutions to this problem by major manufacturers include refusal of installation of actuators and power supply sources in geostationary unit, however, mounting of biasing elements on rotary element of RSS contradicts with the considered concept and is not considered further. In the frames of the selected approach several mounting variants of control electronics, power sources, actuators and biasing units were analyzed. All of them were based on advantages of geostationary concept, however, they required for development of transmission mechanism of hydraulic or mechanic power between kinematic decoupled components of RSS.

3. RESULT AND DISCUSSION

Hydraulic power transmission requires for application of highly reliable radial seals capable to withstand high temperature and peripheral drilling bit speed with respect to geostationary unit, which can be as high as 1.5 m/s, this fact in highly abrasive environment reduces significantly lifetime of seals made of any material. Schematic view of such design is illustrated in Fig. 1.

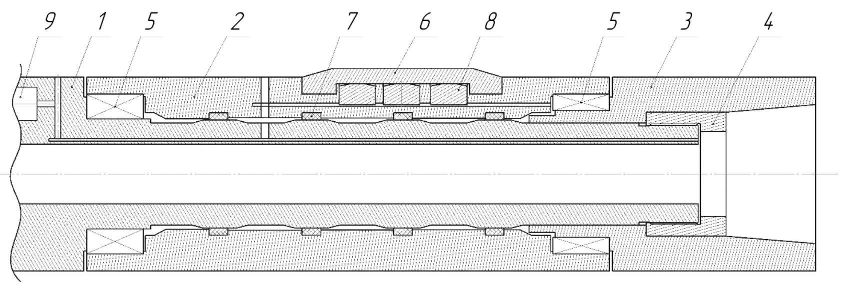

Figure 1: Hydraulic power transmission to geostationary BU: 1 –Rotary element of RSS; 2 – Geostationary element of RSS; 3 – Adaptor coupling; 4 – Lock nut; 5 – Radial and thrust bearings; 6 – Bias element; 7 – Radial seals; 8 – Pistons; 9 – Actuator

The bottleneck of this design is that at present cup and ring packings capable to operate under such conditions are unavailable in Russia. Foreign seals can be applied only in limited ranges of peripheral drilling bit speed (up to 0.4 m/s). Certain attention can be paid to the concept of mechanic power transmission due to axial motion of bearing blocks which control positions of all three bias elements [7]. Bearing blocks for axial motion can be presented by thrust bearings with PCD inserts. Schematic view of this approach is illustrated in Fig. 2.

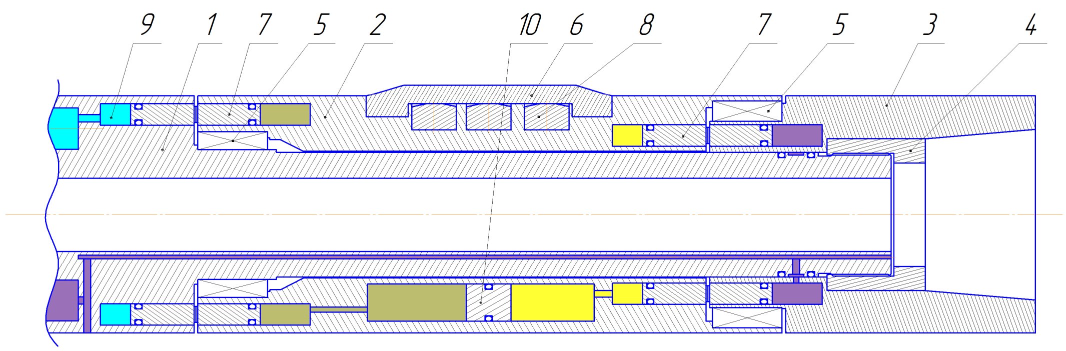

Figure 2: Mechanic power transmission to geostationary BU: 1 – Rotary element of RSS; 2 – Geostationary element of RSS; 3 – Adaptor coupling; 4 – Lock nut; 5 – Radial and thrust bearings; 6 – Bias element; 7 – Thrust bearings; 8 – Pistons; 9 – Actuator; 10 – Distributor piston.

Practical implementation of this concept requires for high amount of researching and experimental activities, since at present there are no analogs. Moreover, operation with mechanic power transmission will be complicated by drilling conditions due to necessity of linear movements of bearing rings in abrasive medium upon continuous vibrational impacts.

At the same time, field tests of RSS220V revealed certain drawbacks of its design which should be considered upon development of RSS of small diameter. One of the most important requirements resulting from the tests is the necessity to replenish the amount of hydraulic fluid after excessive external impact when a portion of fluid bypasses the circuit.

The applied at present flowchart with linear drives does not provide for replenishment of working fluid without RSS removal from the well. On the basis of performed analysis, it was concluded that the best solution to this problem was application of conventional hydraulic drive with closed circuit to control casing shoes. Such design in RSS of small diameter, in addition to replenishment of hydraulic fluid increasing the system reliability, is characterized by other advantages:

1. Compactness of the design, instead of three electric motors (as in the case of RSS220) only one motor of smaller sizes is applied: to drive hydraulic pump.

2. All hydraulic and mechanic elements can be mounted in geostationary BU of small diameter, enabling to transmit energy between rotary and geostationary elements by means of the simplest and reliable method, especially in well environment: by means of electromagnetic induction.

3. Control of shoe pressing to wellbore wall by pressure instead of distance of its movement (as on designs with linear drives as actuators), which results in better results of well curvature at segments with caverns.

4. Possibility of free expansion of actuators (shoes) aiming at increase in contact area with wellbore wall in order to decrease the rate of residual rotation of BU (this allows to obtain better energy efficiency and accuracy of well path control) as well as to reduce risk of failures upon rearrangement of shoe configuration.

This concept is illustrated in Figure 3.

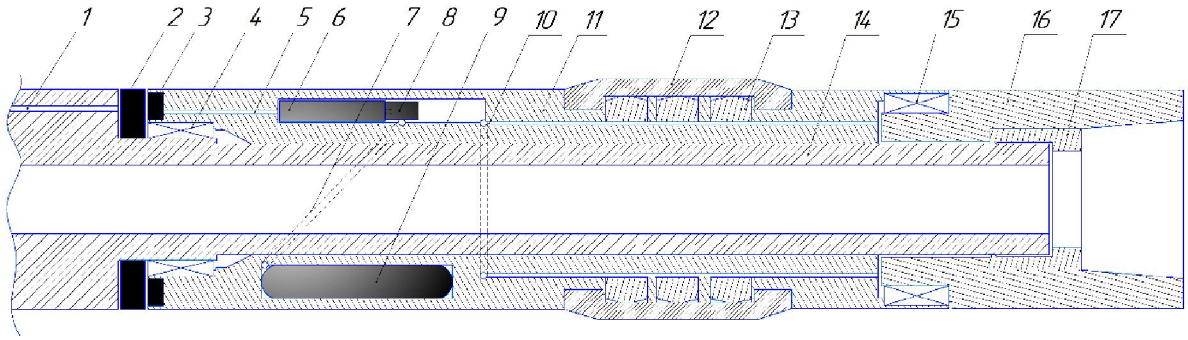

Figure 3: Induction power transmission to geostationary BU: 1 – Channel for supply cable of induction coil; 2 – Transmitting induction coil; 3 – Receiving induction coil; 4 – Radial and thrust bearings; 5 – Channel for supply cable of consumers in BU; 6 – Electric motor; 7 – Hydraulic channel; 8 – Hydraulic pump; 9 – Hydraulic tank; 10 – Hydraulic channel; 11 – Geostationary element of RSS; 12 – Bias element; 13 – Pistons; 14 – Rotary element RSS; 15 – Thrust bearings; 16 – Adaptor coupling; 17 – Lock nut.

5. CONCLUSION

Various concepts of RSS of small diameters implementing push-the-bit mode upon geostationary BU arrangement have been considered. It has been concluded that in terms of reliability, simplicity of embodiment, provision of best operational properties with required dimensions, the most promising concept is the RSS with induction power transmission to geostationary BU and hydraulic drive with close circulation. Further activities devoted to design and production of RSS models with small diameter will be based on this concept.

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