Methods of study in the characteristics of elastomers' samples of mud motors at modeling the conditions of their operation

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Abstract. The paper describes the development of the methods of experimental research on rubber elastomers parameters of mud motors at modeling the conditions of their operation. The specific features of mud motors operation as well as main aggressive agents affecting the state and parameters of elastomers, such as drilling mud type, ambient temperature, and mechanical action of the rotor on the plate of the stator are shown in the paper. Due to described agents, new methods of investigations and new units of experimental bed are developed.
The experiments confirmed the relevance of the proposed methodology, with its main advantages - ease of implementation and speed of research.

1. Introduction

One of the conditions of drilling with modern bits is the use of high-torque mud motors capable of ensuring the rotation of the tool in the frequency range of 100-400 rpm to achieve high rate of penetration. This condition is satisfied by the construction and power parameters of mud motor. Mud motor takes up one of leading positions among drilling bit gears in the construction of oil and gas wells, as well as their workover. Approximately 50-70% of drilling is provided with mud motors in various regions of Russia [1, 3].

Despite a wide range of advantages, mud motors still have some disadvantages, which limit their application. One of them is small operating time of the motor under field conditions, particularly in horizontal wells. In this case, the operating time is equal to 130 – 250 hours relative to the estimates of 300 – 400 hours. The reason for mud motor failure is a wear of rubber cover of stator that leads to power decrease of mud motor or its complete failure. As a consequence, the numbers of additional round-trip operations increase as well as the cost price of 1 meter of a well, while run speed decreases. A key factor influencing the wear rate of elastomer is an active interaction between its material and drilling mud under high temperatures. According to field research, elastomer of stator in aggressive environments changes its geometrical parameters (bloats or shrinks), and strength characteristics significantly decrease (crumb formation or cracking). As practically proved, in mud motors elastomer wears more often in hydrocarbon drilling mud [2-3].

Talking about the influence of high temperature on mud motors one should bear in mind not only the change of rheological characteristics of drilling mud as a working agent that rotates mud motor rotor. According to field research, the higher temperature and the more aggressive and more abrasive drilling mud, the higher wear rate and elastomer wear that depends on solids and contains [5]. It is connected with low thermoconductivity of rubber, and, if the motor has not special cooling channels, rubber components wear and fail [4, 6].

Improving the efficiency and durability of mud motor from their design to operation is considered by a number of researchers in the following areas: optimization of working agent shapes; application of new materials and covers for stator and rotor, modification of stator; development of advanced manufacturing technologies [1-2, 7-9].

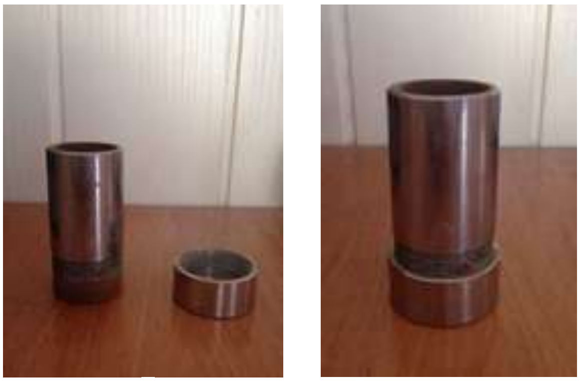
Firstly, some ways to decrease negative influence of high temperatures on mud motors are determined. Searching for and testing new rubber compounds that are wear-resistant under high temperature and are not prone to plastic deformation [4, 10].

Secondly, new operating rate of drilling equipment under high temperature conditions is developed. Then, it is important to make a model of temperature profile along wellbore at all stages of drilling [5] and to design effective drilling equipment. In addition, technological solutions for artificial decreasing the temperature of the drilling equipment and mud (cooling) are developed.

Another relevant area of the research is the development of alternative drilling mud formulation, which preserves its key parameters under minimum negative influence on mud motors, required to ensure the effective drilling, such as maintenance of suspension state and cutting transport; drill through tools cooling, preservation of bottom-hole zone permeability; effective transmission of hydraulic energy to bottomhole and feedback to surface; as well as prevention of complications during drilling. Therefore, the purpose of the paper has been chosen to design the research method of technical of elastomers' samples of mud motors at modeling the conditions of their operation.

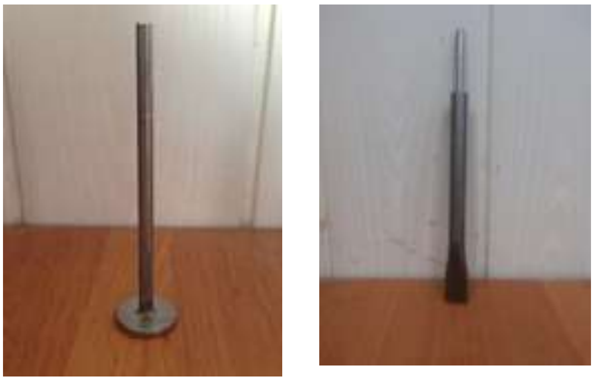
2. Designing the research method of technical characteristics of the elastomers' samples

An experimental bed has been designed to conduct research on the mechanical loads on elastomer in various drilling muds. It is a loading unit where a vertical drill press is used to supply a load. The loading unit consists of a metal cartridge with a removable bottom endcap allowing to place and firmly fix rubber samples (Figure 1) and a loading element which is made in two variations (Figure 2). Loading elements are used to simulate the load on the elastomer that is similar to interaction between rotor and stator of the motor in kinematic relationship. The tool with a flat profile of loading (Figure 2a) which has circular perimeter in cross-section with clearance of 1 mm relative to cartridge's sides is used to study the effect of long-term cylindrical loads on the sample, as well as to evaluate the influence of solids mud on sample parameters. The tool with a pointed profile (Figure 2b) is used to produce increased load, and simulate abrasive effect on sample. The design of the cartridge and the loading element, if they are fixed on a vertical drill press, provides a cyclical rotational mechanical action with a sample of elastomer. With the right terms, it allows us to simulate the interaction of "rotor-stator" pair in mud motor.



a b

Figure 1. A metal cartridge for elastomer's samples testing: a – in the disassembled condition; b– in the assembled condition.



a b

Figure 2. A loading element: a – a tool with a flat profile; b – a tool with a pointed profile.

Experimental samples are made of rubber IRP-1226 with geometrical sizes suitable for fixing them in a cartridge-clip. The technology of their production includes the process of cutting the cylindrical samples with 10-12 mm in thickness by special milling cutter of drill press. The diameter of the sample is determined by the experimental conditions. After cutting the sample, a notch, by which change in the sample diameter is controlled during the experiment, is made on it. Also, a point of thickness is marked on the sample.

The load on the sample of elastomer ranges from 2 to 14 kilos at a pitch of 2 kilos and is provided by adding load to a system of the axial load of the drill machine. The second changing parameter is the time of the experiment: 1, 5, 10 and 15 minutes. In the course of experiments tool sticking (its sticking to the loading tool with a flat profile) is observed with the time of more than 5 minutes and with the load of more than 6 kilos. In this regard, the time of the experiment for the load with more than 6 kilos is corrected and equaled to 1, 2, 3 and 5 minutes. At the first stage of the experiment the spindle's rate of rotation remains unchanged.

The following parameters are recorded in the experiment: the sample mass before and after the experiment, the sample deformation at the end of the experiment and 24 hours later. In addition, visual verification of samples is provided. According to the experimental results, the changes in mass of the sample during the experiments are insignificant and data on this indicator can be ignored.

The second research method is a static experiment in which samples in the form of plates sized 30x100 mm with rectangular cross-section (Figure 3) are kept in geometrical containers filled with drilling mud for different periods of time.

Two opposing holes are perforated in each sample to allow the loading unit. After completion of the specified time interval, samples are removed and installed in the system of loading where their upper end is fixed with static hook, while the lower end of the sample is inserted into the hook with loads hung on it. Such parameters as level of deformation under load (in different time intervals) as well as permanent deformation in 24 hours are measured. Special cylindrical valves are used to decrease heighten load on perforated holes. The use of temporary deformation loads qualitatively illustrates the working "rotor – stator" pair in mud motors because they can be remotely compared with cyclic loads of long duration.

3. Designing the method of elastomer testing under the influence of temperatures

To study the effect of temperature on the characteristics of the elastomers in various mud types, special experiment has been developed, in which the dimensions and durability of the rubber samples IRP-1226 have been observed in different mud types in the temperature range from 25 to 100 degrees. In addition, it is planned to research the influence of subfreezing temperature on elastomers that characterizes the operating conditions of mud motors in Western Siberia in the winter. The main problems in this case are the freezing elastomer or its cover with ice that, in any case, lead to a decrease in mud motors performance.


a


b

Figure 3. Elastomer's sample after the experiment: a – deformation under cyclic deformation load; b – abrasive wear.

Figure 4. Darkening of diesel fuel under temperature influences (100^{o} C) on elastomer's samples

When the static experiment has been finished, research on the effect of temperature on engineering specifications of rubber IRP-1226 is conducted in several ways: the direct mechanical action at high temperatures, (for this purpose it is planned to develop a separate pilot unit), while postponed mechanical action (after experiments on static exposure medium samples of drilling mud). This defines the mentioned above method of samples preparation for experimental research.

5. Conclusion

The developed method of experimentation has been tested in a series with application of service water as the drilling mud. The research method to study the effect of temperature is used for the base of drilling mud environments (diesel fuel, saturated salt solution, alkaline solution and biodegradable drilling mud). Each of described techniques allows us to observe visually the impact of the drilling mud environment on the parameters and characteristics of the samples. This was expressed in the sample deformation under cyclic deformation load (Figure 3), darkening of the mud (Figure 4), and splitting of samples in experiments evaluating the effect of temperature.

To sum up, in the course of the experiment:

– the problems of mud motors and technological factors limiting their application have been revealed;

– experimental units have been designed, and a method of experimental study of cyclic loading, abrasive and deformational effects on samples of elastomer has been developed;

– the technique of the experiment on the effect of temperature on the characteristics of the rubber of elastomer has been developed.

References

[1] Baldenko D, Baldenko F and Dvoynikov M Design solution to improve the working of downhole PDM *Journal "Burenie i neft"* URL: http://burneft.ru/archive/issues/2013-02/10

[2] Simonyants S L 2007 *Know-how to drill wells by hydraulic down-hole motors* (Moscow: the I.M. Gubkin oil & gas Russian State University) 160

[3] Baldenko D and Korotaev Yu The current status and Russian PDM perspectives of development *Burenie i neft* URL: http://burneft.ru/archive/issues/2012-03/1
Adamson K, Birch G, Hand S, Macdonald C, Mack D and Quadri A 1999 High-pressure, high-temperature well construction *Oilfield Review* URL: http://www.slb.ru/userfiles/file/Oilfield%20Review/1999/autumn/3%20pressure.pdf

[4] Esman B I, Dedusenko G Ya and Yaishnikova E A 1962 *Vliyanie temperatura na process bureniya glubokih skvazhin* 152 [in Russian]

[5] Gidravlicheskie poteri v zabojnyh dvigatelyah vliyanie temperatury na ih rabotu *Techology of wells drilling* URL: http://teplozond.ru/termogidravlika-pri-burenii-skvazhin/gidravlicheskie-poteri-v-zabojnyx-dvigatelyax-i-vliyanie-temperatury-na-ix-rabotu.html [in Russian]

[6] Fufachev O, Goldobin D, Plotnikov V and Traprznikov S New design of startors of screwy wownhole engines made by VNIBT-drill instrument CO. LTD *Journal "Burenie i neft"* URL: http://burneft.ru/archive/issues/2010-06/16 [in Russian]

[7] Anyanwu O N, Klotz C, Labrecque D and Ulrich C 2012 Optimized downhole mud motor delivers outstanding performance improvement in Alaska coiled tubing drilling *Society of Petroleum Engineers – Coiled Tubing and Well Intervention Conference and Exhibition* 88–100

[8] Ross M, Anyanwu O N, Klotz C and Ulrich C 2012 Rib-steered motor technology: The revolutionary approach extends the coiled tubing drilling application scope *Society of Petroleum Engineers – Coiled Tubing and Well Intervention Conference and Exhibition* 101–15

[9] Thompson J and Rossing M 2011 High-temperature downhole motor facilitates cleanout of obstructed thermal well, saving production downtime *SPE Automotive and Composites Divisions – Coiled Tubing and Well Intervention Conference and Exhibition* 455–61