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Experimental research of drilling mud influence on mud motor mechanical rubber components

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Abstract. The paper describes the experimental research of drilling mud influence on engineering parameters of mud motor mechanical rubber components. It is believed to be urgent due to increase in using mud motors in oil and gas well construction now, and, consequently, the issue of increasing their exploitation is becoming current. The development test results of elastomer IRP-1226 dependent on the mud type (alkaline, hydrocarbon or salt-saturated ones) and the temperature are shown in the paper. It is proved that the type of drilling mud and the temperature in bottom-hole zone have an influence on wear of mud motors elastomers.

1. Introduction

In modern mechanical engineering the quality of products, especially their durability, is one of the major parameters. It is important for mud motors used for drilling of oil and gas wells [1]. The main difference of a mud motor from other downhole drilling motors is using a multithread screw rotor gear as an operative part which presents internal cylindrical epicyclic gear including stator and rotor with teeth number equal 1 [1].

However, now well drilling technology is characterized by the problems connected with unstable mud motors operation, their failures, low durability of operative components, and accidents, such as backed off and drilling string failures. According to the data of drilling companies' reports, 5-12 accident happened per year caused by mud motors failure that lead to long workover or abandonment of wells. The using of mud motors shows that reasons for approximately 50% failures involves wear of operative components because of rubber-metal friction (steel rotor – rubber-metal stator). Engine operational life can vary from 90 to 235 hours depending on dimension type and operating conditions [2].

The issue of elastomer wear and destruction has been urgent by now. For example, D.F. Baldenko, F.D. Baldenko, M.V. Dvoinikov and V.P. Ovchinnikov have confirmed that wear of operative component per 100 hours is equal to 45%, and 33% among them (more intensive wear of stator rubber elastomer) is for the first 60 – 80 hours of engine operation in a well. The causes lie in strength capacity of interacted surfaces of operative components (rubber – steel), increased initial tension and

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growth of hydraulic and mechanical resistance in operative components in the process of running-in under radial forces [3–7].

In most cases, to evaluate the high wear problem of operative components (rotor-stator), researchers pay attention to mud motors constructional irregularity which is clearly revealed in operation under extreme conditions of cyclic load, high bottom hole pressures and temperatures, as well as aggressive drilling mud. So, the main methods to increase durability of mud motors components are thought to be connected with improvement of engine design and its kinematic scheme by size and component exchange, as well as rigidity and stator armoring [6 – 12]. It allows increasing engine operational life significantly, for example, operating time of some modernized models in development testing is up to 585 hours [10-12], and also, decreasing negative thermal and mechanical influence on elastomers. It cannot be denied that elastomer durability is significantly impacted by drilling mud in which an engine works. Therefore, one of the urgent issues to increase mud motor operation life is to improve drilling mud composition or special additives development.

2. Methods and materials

The influence of different mud types on rubber samples IRP-1226, which is oil-resistant rubber with improved wear-resistance and range of temperature from - 20 to $+100^0$ C. has been studied. Its nominal strength is equal to 9.8 MPa, failure elongation is 125% and Shore hardness number is 65 – 95.

At the first stage of the experiments the influence of mud type (saturated salt solution, alkaline solution (pH=14), oil, diesel fuel) on sample size in long interaction was analyzed. The decision of mud type for analysis is determined by the necessity to reveal aggressiveness of drilling mud to rubber IRP-1226. It will allow the researchers to evaluate additives efficiency for drilling mud. The evaluation was made according to one parameter: geometric sample size, because in research works elastomers instability in regard to aggressive ambient as swelling or decrease of a size [11-12] is often mentioned.

At the second stage of the experiments the influence of temperature on sample parameters in different types of drilling mud was studied. According to the given data, the most intensive wear of mud motor occurred using hydrocarbon drilling mud. Therefore, the following types of drilling mud were taken for the experiment: oil, diesel fuel, biodegradable drilling mud. The evaluation results were made according to geometric sample size too. While processing the experimental results, the change of sample relative size per time in mud was analyzed.

The samples were put into plastic containers during the experiment and completely plunged into mud under atmospheric pressure. To verify the experimental results, 3-5 samples were analyzed for each type of drilling mud. At the first stage of the experiment, one batch of samples was studied under normal temperature, while at the second stage two batches of samples were used: the first one was studied at room temperature, and the second one was analyzed under temperature 50^0C reached in cabinet dryer. The time of experiment was 15 days for each stage. This was because mud motors operation time equals to 200 – 600 hours with an average values of 240-300 hours [12, 14].

3. Results and Discussion

The results of the first stage of the experiments are shown in figure 1. The sample size was taken as a standard of comparison because it helps to evaluate the sample changes (swelling or decrease of a size). During the analysis it was revealed that all types of drilling mud had an influence on samples with the similar dynamics of size change: at the first stage (50-100 hours) it was noticed that the stable swelling (saturated salt solution) or decrease of a size (oil, diesel fuel, or alkaline solution). After it, the size dynamics changes oppositely and the next 100-150 hours of the experiment the sample size becomes stable. Besides, the final sample size change was fixed for all types of drilling mud reaching 0.5 – 1 cm^3 (increase of size in saturated salt solution, diesel fuel and or alkaline solution and decrease of size in oil). The largest change of the sample size between the initial and the final measurements was registered in alkaline solution. The experiment was carried out without additional conditions, such as mechanical load, high temperature and pressure. Therefore, it was concluded that in bottom hole the changes of parameters (shape, size) and elastomer wear would be faster.

The results of the second experimental stage are given in figure 2. In all cases, like in the first stage, the active changes of geometric sample size were observed. The following dependences were noted:

- at room temperature decrease of a size in diesel fuel and oil is more intensive than under temperature equal 50^{o}C that is caused by high evaporation degree of their volatile compound;
- significant increasing sample size is registered for biodegradable drilling mud under higher temperature that is proved by the predictions and stipulated by its low volatility;
- the most intensive changes of geometric sample size occurs in the period of 0 – 50 hours;
- in the period of 50 – 300 hours the intensity of sample changes tends to subside, and the trend line tends to a horizontal line;
- in general terms, the obtained dependences for different temperatures show the similar dynamics;
- the geometric sample size change is insignificant that is determined by static nature of the experiment.

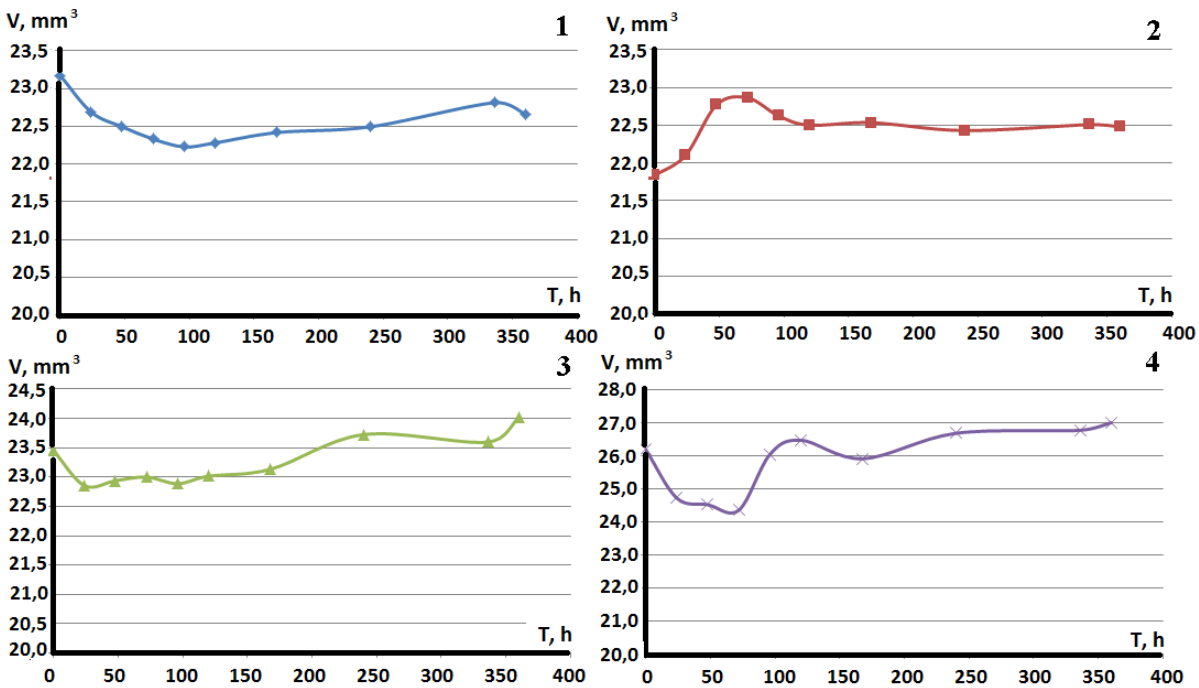
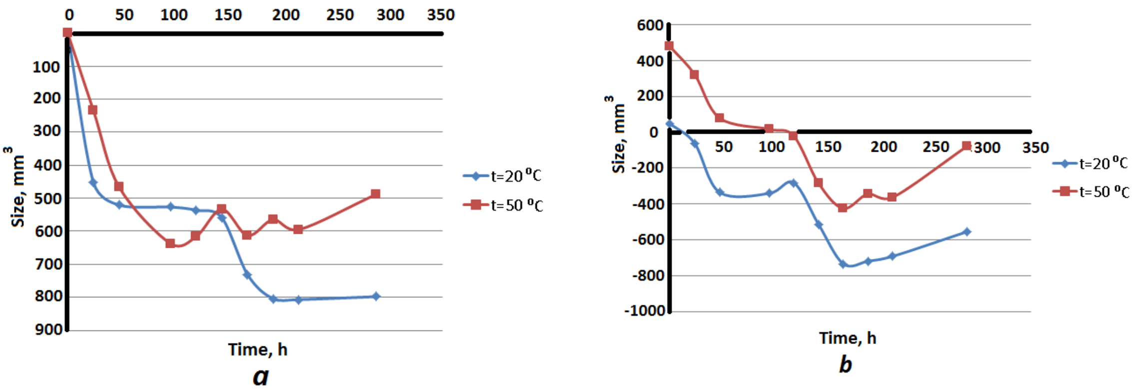


Figure 1. The dependence of size of sample IRP-1226 on the period of its putting in mud: 1-oil, 2 – saturated salt solution, 3 – diesel fuel, 4 - alkaline solution**.**



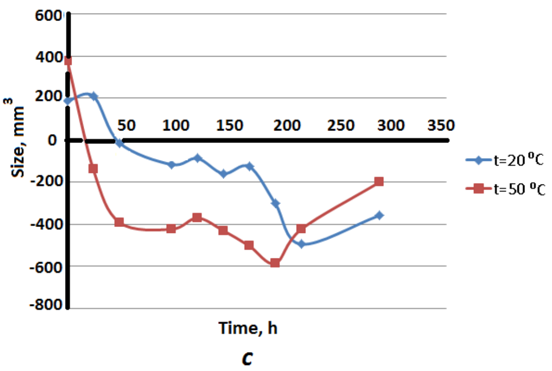
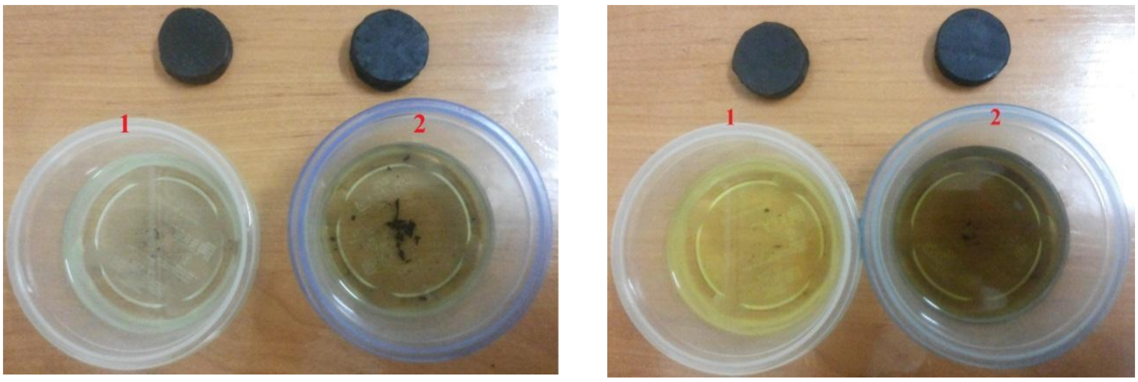


Figure 2. Relative change of sample size IRP-1226 in different types of drilling mud: a – oil, b – diesel fuel, c - biodegradable drilling mud.

During the experiment (to 50 hours) intensive splitting of samples was observed to be plunged into biodegradable drilling mud and diesel fuel at temperature 50°C (figure 3). As can be observed in the photos, the mud became dark and at the end of the experiment the detached pieces of samples could be found in it. It also confirms the high intensity of elastomer wear in hydrocarbon drilling mud even if the experiment is static.



a b

Figure 3. View of sample and types of drilling mud: a – diesel fuel, b – biodegradable drilling mud, 1 – t = 20° C; 2 – t = 50° C.

4. Conclusion

During the experiment the influence of different types of drilling mud on size of rubber samples IRP-1226 used as elastomer of mud motors has been analyzed. It has been proved that under long-term exposure, intensive change of rubber sample size takes place that is gradually stabilized for 200 – 250 hours. Total change of the sample size amounts 2 – 3% relative to the initial size.

Besides, the influence of temperature on sample size IRP-1226, which was put in hydrocarbon drilling mud has been analyzed. It has been noticed, that the most intensive wear occurs in such types of drilling mud as diesel fuel and biodegradable drilling mud that was revealed due to intensive splitting of samples. The dependence of the temperature on the degree of sample size change is more typical for biodegradable drilling mud, while it was not observed for oil and diesel fuel. As a conclusion, it can be said that the reason for this is high evaporation degree of hydrocarbon volatile compounds and decrease in mud aggressiveness to the samples. The following issues have been defined as possible research problems:

- to analyze the temperature influence from -30^{o}C to +90^{o}C;
- to evaluate the mass of a sample and its durability;
- to study abrasive wear of drilling mud to elastomer;
- to assess abrasive influence of mud motor on samples IRP-1226 in different types of mud and at different exposure.

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