Studies on operation and types of drilling pump valves

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Abstract. The current issue of the machine building industry is improvement of oil and gas production equipment performance. However, despite the improved design and technological parameters, its reliability is still low. The time between failures depends on both severe operating conditions and quality characteristics of parts. With an increase in drilling depths, complexity of operating conditions and abrasiveness of the drilling mud, the life time of the hydraulic part of the pump decreases. Operation of drilling pumps largely depends on the design features of the valves. According to the results of theoretical studies, wear of the valve pair occurs on the bearing surface. The design of valves with different seating surfaces and shapes of the sealing element was studied. Based on the research on the improvement of the drilling pump valves, the conclusions were drawn and the tasks for further research were formulated.

1. Introduction

Causes of failures of drilling pumps are dealt with in a significant number of works which were the basis for technical improvement of the hydraulic parts. However, despite the improved design and technological parameters, reliability of drilling pump valves is still low and the issue of improvement still remains relevant.

2. Method and materials

Causes of failures of drilling pumps are dealt with in a significant number of works which were the basis for technical improvement of the hydraulic parts. The time between failures depends on both severe operating conditions and quality characteristics of parts [1]. With an increase in drilling depths, complexity of operating conditions and abrasiveness of the drilling mud, the life time of the hydraulic part of the pump decreases. Replacement parts and assemblies of the hydraulic part of drilling pumps include a rod, a cylinder bushing, a piston, a stem seal, a valve block, and working elements of the compensator.

Table 1 shows the results of statistical processing of information on the production time of parts of the hydraulic part of drilling pumps.

As can be seen from Table 1, pistons and valves have a low operating time $t^*_{\text{m}}$ before failure. The revealed exponential law of distribution of their performance (variation coefficient $\upsilon^*$ is 0.83 and 0.77, respectively) indicates the sudden failure of these parts. The obtained values of the standard deviation $\sigma^*$ show that the life time of these parts varies considerably which is due to the influence of a large number of factors. This coincides with the data of other researchers. For example, according to the data obtained by Tolstoy in the article “Analysis of the performance of the main wearing parts of drilling pumps”, with an increase in the drilling interval from 1000–2000 m to 4000–5000 m, the life time of the hydraulic parts reduces two-fold.
The movement of the valve is controlled by the fluid flow. In drilling pumps, spring-loaded disk-type valves with elastic sealers are used. Valves used in drilling pumps differ in the design of the sealing element, its installation location, fastening methods and the design of the supports and guides [8]. To study the operation and wear of the valve pair, theoretical and practical studies were carried out.

The theoretical studies examined designs of foreign and domestic valves which are shown in Figures 1 and 2.

Practical studies aimed to analyze the nature of valve wear. Wearing begins during the first hours of pump operation. The first stage is mechanical wear of the rubber sealing element regardless of its

| Part       | Distribution law | Statistical distribution parameter |
|------------|------------------|-----------------------------------|
| Piston     | Exponential      | t^* m (h) 97.6  σ*(h) 80.8  υ*= σ*/t^* m 0.83 |
| Mud pump liner | Weibull       | 204.1  106.1  0.52 |
| Rods       | Log-normal      | 106.3  51.0  0.48 |
| Valves     | Exponential      | 72.5  55.8  0.77 |

Table 1. The results of statistical processing of information on the production of parts of the hydraulic part of drilling pumps.
location, namely, in places with the highest stress concentration [9–13]. One of these areas is the part of the cuff that is directly adjacent to the interface between the plate and the valve seat. When the cuff is set on the saddle or the plate is set on the cuff, the tapered part of the cuff is squeezed into the sealing gap and clamped. With further closure of the plate with the saddle, with an increase in pressure, the pinched volume comes off which causes the loss of tightness of the valve pair.

![Image of valve designs](image)

**Figure 1.** Foreign valve design

Pump valve

Pump valve

Disc valve produced by VNIINEFREMASH

SFD produced by VNIINEFREMASH

CS valve produced by VNIINEFREMASH

U8-MA pump valve produced by Uralmashzavod

There are also cracks in the bearing surfaces of the plate and the valve seat which leads to fatigue failure in stress concentration areas. The cuff is also destroyed by the cyclical effect of pressure, as well as by the flow rate of the fluid. Supporting surfaces are subject only to hydroabrasive wear. Contact pressure on the supporting surfaces can be changed by changing the load from the pressure exerted by the piston on the plate, and by reducing the area of the conical surfaces of the valve seat and the plate.

The operation of mud pumps largely depends on the design features of the valves: location of the sealing element; shape of the supporting surface of the plate and seat; tilt angle of supporting surfaces.

In addition, the operation of the valves depends on the material of their parts, a hardening method used for working surfaces of the plate and seat, etc. We analyzed wear of the valves sent for overhaul to the Aznakaev DD. The analysis results are presented in Table 2. The valve guiding surfaces wear out
as a result of the seat pad collision during pump operations. Moving the plate up and down in the environment of abrasive-containing drilling mud decreases the diameters of the guiding sleeves and the saddle. On the inner surface, one can observe saddle rectilinear indentations, dents directed along the generator.

Table 2. Analysis results for mud pump valve wear

| Type of the pump | Brand of the valve | Diameter of the valve | Wear                                      | Type of wear | Area of operation |
|------------------|--------------------|-----------------------|-------------------------------------------|--------------|-------------------|
| NBT-600          | NBT600             | 160,9                 | Scratches and risks on friction surfaces  | Abrasive     | Aznakaev DD       |
| NB-375           | NB375              | 163                   | Holes, dents, cracks on the working surfaces, brittle fracture | Impact abrasive | Aznakaev DD |
| BrN-1            | NB125              | 163                   | Traces of corrosion on the working surfaces | Corrosive mechanical | Tuymazy DD |
| 9T               | NB125              | 111                   | Spalls and potholes on working surfaces  | Impact abrasive | Tuymazy DD |
| 9MGr             | NB125              | 111                   | Changes in the size and the of the elastic element | Impact abrasive | Tuymazy DD |
| UNB600           | K10Ts              | 198,5                 | Development of cracks on the working surfaces, changes in the shape of the cuff | Impact abrasive | Tuymazy DD |

The gap on the seating surface between the plate and the seat is due to the inaccurate fit when closing the valve and the contact with abrasive particles. Sealing elements wear is due to the squeezing of rubber into the gap between the plate and the seat and other types of interaction of the rubber with mating parts in the abrasive-containing washing solution. Rubber failure is also due to abrasive grains.

Considering the working conditions and analyzing mud pump valve wear types, it can be concluded that wear is inherent in the following areas:
- guide surfaces;
- supporting and seating surfaces;
- sealing elements.

3. Conclusion

Based on the research on the improvement of the drilling pump valves, the conclusions were drawn and the tasks for further research were formulated:

1) analysis of previously performed works showed that under the operating conditions of mud pumps one of the causes of their low life time is the failure of valves. The mechanism of operation and types of destruction of individual valve elements are understudied;

2) the state of the support surfaces of valve elements can influence the stress-strain state of the elastic element and durability of the valve assembly.

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