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Improvement of mud pump valve

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Abstract. The valve assembly is the weak point of the drilling pump. The analysis of the reasons for the failure of the hydraulic part of the drilling pump was carried out, it was shown that the valve assembly of the drilling pump accounts for a significant part of the failures. A three-dimensional geometric model of the valve assembly and a finite-element model of the valve assembly on its basis are developed. According to the results of the calculation, the effect of changing the inclination angle of the axis of the guide tray to the axis of the landing hole in the valve seat on the stress-strain state of the valve assembly was determined. To exclude axial deviations, an improvement in the valve is suggested by changing the design of the upper guide bushing body, which will increase the durability and reliability of the mud pump assembly by self-centering the pylon and the polyurethane seal.

1. Introduction

The considerable number of works [1-11] is devoted to a research of causes of failures of boring pumps by results of which various technical improvements of details of a hydraulic part are made. Despite improvement of design-technology parameters, their reliability still remains low [12-15]. Exert impact both severe conditions of operation, and qualitative characteristics of details on a time between failures of pumps. With growth of depths of drilling, complication of service conditions and increase of abrasiveness of the applied flushing solutions, the resource of details of a hydraulic part considerably decreases.

The rod, the cylinder plug, the piston, consolidation of a rod, valvate knot and working elements of the compensator belong to number of replaceable details and knots of a hydraulic part of boring pumps.

Reliability of details of a hydraulic part in many respects depends on a resource of sealing devices and substantially is defined by service life of valves which durability with pressure of 16-18 MPa doesn't exceed 100 hours. Such durability of valves doesn't meet requirements of drilling that leads to frequent stops of the pump for the purpose of replacement of these knots. Replacement of knots and details of the pump demands considerable material and labor inputs with application of hard manual skills in very adverse climatic and ecological conditions [16]. Therefore now the problem of increase in service life on average remains till 200-300 o'clock not solved.

2. Improvement of valvate knot

The valvate devices used in boring pumps differ from each other in a design of a sealing element, the place of his installation, way of fixing and also a design of support and guides.

Studying the characteristic of working conditions and analyzing process of wear of valves of boring pumps it should be noted that the wear is found on the following sites:

- on the directing surfaces;
- on basic and landing surfaces;
- in sealing devices.

When studying the main problems connected with wear of valves it is offered to upgrade the valve, that is to change the valve guide plug allowing to provide self-centering of a tray in a valve saddle.

Performance of the case of the top guide of the plug with a spherical emphasis which center of the sphere is located in the middle of the plug of the lower guide allows to provide self-centering of a tray in a saddle, as a result of him the safety in operation of valvate knot is provided. In the figure 1 the offered valvate knot is represented.

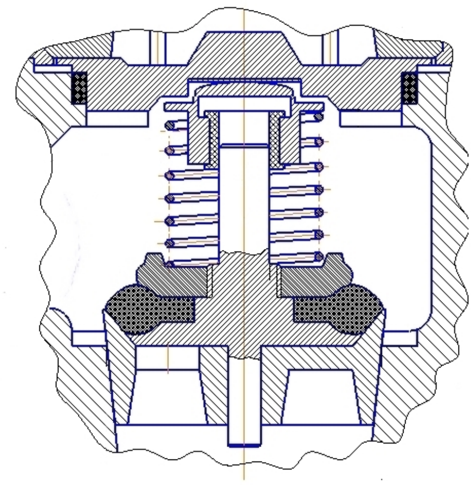

Figure 1. Advanced model of the valve.

The valve assembly comprises a tray with rods that are located in the housings of the upper and lower guide sleeves, and a seat. The body of the upper guide bushing is made with a spherical stop, the center of the sphere of which is located in the middle of the bushing of the lower guide.

Under the pressure of the pumped liquid, the valve tray rises, moving along the guide bushings. After removing the pressure under the action of the spring, the tray drops.

The possible angular displacements of the upper guide bushing relative to the lower are compensated for by performing the surface of the abutment in the form of a sphere.

By observations it is established that the mechanical wear of a rubber element of the valve irrespective of his arrangement and in places of the highest concentration of tension begins with the first business hours. One of such sites – the part of a cuff directly adjacent to the place of interface of a tray to a saddle. At the time of closing of the valve the distance between a tray and a saddle of the valve quickly decreases so sometimes landing of a tray happens to blow. It is possible in cases when owing to inertia of a tray before the valve manages to be closed, the liquid contraflow which is carrying away the condensing detail in the decreasing gap begins. At the same time perhaps rubbers snacking between metal surfaces, and at a further closing of a tray with a saddle with growth of pressure the jammed volume comes off that leads to a fast exit of consolidation out of operation. Knocks and blows also lead to failure of the basic and condensed metal details of valvate knot.

As the objective is solved by signs which are in total not revealed in other technical solutions, it is possible to draw a conclusion that the proposed solution corresponds to increase in reliability of operation of the valve by ensuring self-centering of a tray.

3. Assessment of the intense deformed condition of valvate knot of the boring pump a finite element method

Increase in their reliability and durability, being the major factor determining growth of competitiveness of products it is connected with reliable definition of "dangerous" places of a design. The most effective widely used modern remedy of achievement of a goal is use of a finite element method [17]. Now there is a large number of complexes of a finite element method, including ANSYS. Feature of ANSYS is extremely wide range of tasks which it is able to solve. Here problems of calculations on durability (both linear, and nonlinear), heat exchange, the hydrodynamics engineers mixed and even acoustics enter [18,19].

Mathematical modeling is widely applied at assessment change of the bearing ability of designs, durability and stability of vessels and devices of the oil processing and petrochemical productions which are operated long time. However, when performing strength calculations of vessels and devices by the techniques stated in the specifications and technical documentation it isn't considered that in the course of their long operation there is a change of mechanical characteristics of metal, including embrittlement, change of structure and phase structure [20].

As an object of a research the valvate knot of the boring pump UNB-600 made of the alloyed steel 45X has been chosen.

The following tasks have been considered:

- creation of three-dimensional (3D) geometrical and final element model of valvate knot;
- the analysis of influence of design features on the intense deformed condition of the device. For definition of influence of change of a tilt angle of an axis of the directing plate about a saddle of the valve of the intense deformed condition of valvate knot, the comparative analysis of results of calculations of models of valvate knot is carried out:
- the coaxial provision of the directing plate and saddle in perfect tune (without a deviation corner);
- the coaxial provision of the directing plate and saddle with a deviation on 0.5°.

4. Source data

Calculation with a finite element method has been carried out for conditions of hydraulic test of valvate knot as the most intense. As basic data the geometrical sizes of the valve according to the passport and the drawing of manufacturer have been accepted. Creation of geometrical model has been made when using the program SolidWorks complex (figure 2). Further the geometrical model has been broken into a grid of final elements.

For definition of influence of design features on the intense deformed condition of the valve the following basic data have been accepted (elastic properties of material):

- Material "Polyurethane": Young's modulus - 12 MPa; Poisson's ratio - 0.496; density - 1210 kg/m3.
- Material «Steel 41Cr4»: Young's modulus - 2×10^5 MPa; Poisson's ratio – 0.27; density - 7850 kg/m3.

  Creation of three-dimensional geometrical model in the program SolidWorks complex.

To construct three-dimensional model of a detail, the exact geometrical sizes are necessary. We take them from drawings and the passport of the valve of the boring pump.

The geometry of valvate couple has been broken into a grid of final elements in the ANSYS Meshing module. Sites with difficult geometry are automatically broken into tetrahedral elements.

One of ways of reduction of an error of the calculations connected with a settlement grid is consecutive increase in quantity of elements and tracking of changes of required size.

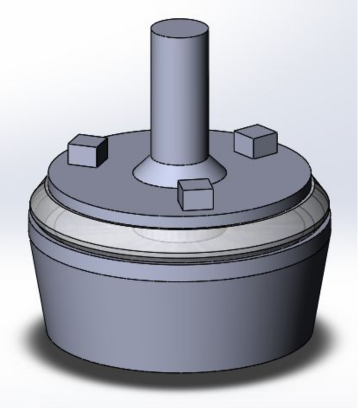

Figure 2. Geometrical model in the SolidWorks personal computer "SolidWorks".

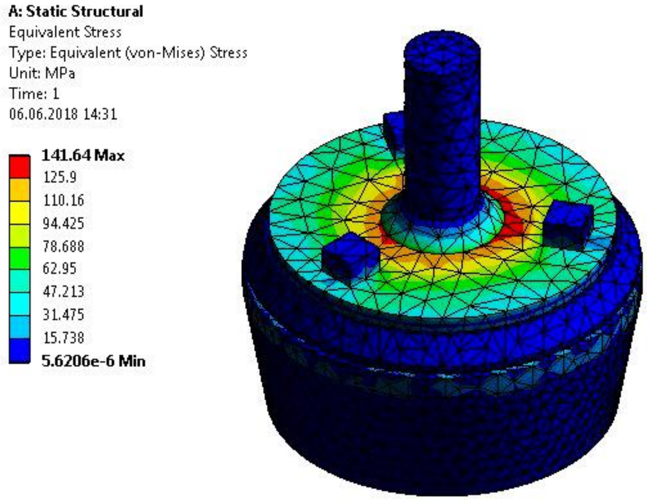

Figure 3. Without guide axis deviation (isometry).

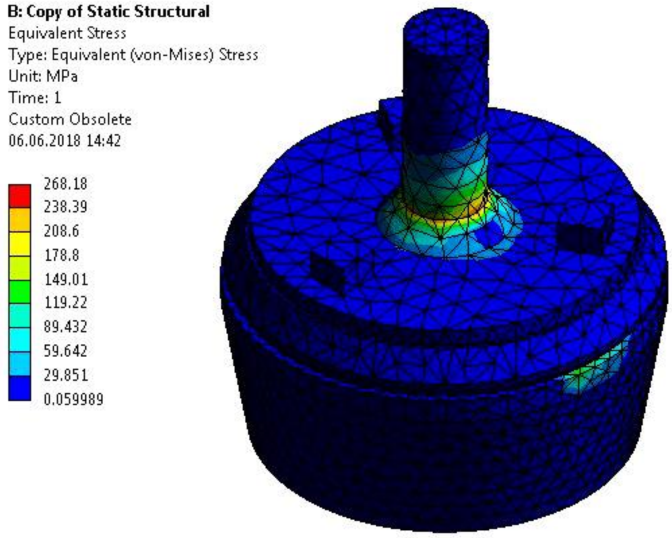

Figure 4. With a guide axis deviation (isometry).

It is expedient to increase quantity of elements until when change of required size can be neglected. When studying influence of quality of a settlement grid on results of calculation the following boundary conditions have been accepted:

- hydraulic pressure upon the valve from above – 30 MPa;
- hydraulic pressure upon the valve from below – 3 MPa;

During mathematical modeling distributions of hydraulic pressure for each set of boundary conditions received during the experiments are received:

- distribution of stresses with an ideal fit of the tray on the saddle (Figure 3)
- distribution of stresses when the guide axis deviates by 0.5 (Figure 4)

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5. Conclusion

On the basis of the created three-dimensional geometrical model of valvate knot and the constructed final and element model of valvate knot, influence of change of a tilt angle of the axis directing tarel to an axis of a landing opening in a valve saddle to the intense deformed condition of valvate knot has been defined. It is established that at ideal situation the maximum tension was within 140 MPa, and at a deviation of 268 MPa, what is almost twice more. For an exception of axial deviations improvement of the valve by change of a design of the case of the top guide of the plug is offered.

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