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PERFORMANCE SIMULATION OF MUD PUMP VALVE WITH A DAMPER CHAMBER BY FINITE ELEMENT METHOD

The valve and seat in modern mud pumps for oil and gas well drilling are expendable pump parts. New types of valve with a damper chamber without rubber or polyurethane seal and with metal-to-metal contact area and heavy-duty load bearing capacity have been elaborated [1]. Lighter weight body of plate characterizes this design. In comparison with the valve of ordinary construction a valve with a damper chamber contains additional structural elements, which in the moment of setting on of the plate forms the chamber of the promoted pressure between a seat and plate. It is considered that application of damper chamber will decrease the shock loadings or "hammer-effect" at the setting of plate.

However, for development of reliable working construction it is necessary to resolve next basic problems:

– to calculate the optimum size of clearances in damper chamber,
– to define speed of landing of plate at the entrance in a damper chamber,
– to overcome hydroabrasive wear in the clearances of damper chamber as a result of high speeds of mud flow.

It is possible to resolve first two problems by the mathematical model of work of mud pump valve with a damper chamber. For possibility of resolving of mathematical model it is necessary to define the coefficient of discharge in valve by the computer design of fluid flow, as a nonlinear function depending on the height of getting up of plate above a seat.

The computer three-dimensional parametric model of valve with a damper chamber has been developed for the valve assembly No. 7 of triplex single action pump. A parametric model gives a possibility to change the height of getting up of plate H and the geometrical parameters of seat and plate and clearances in damper chamber.

By a programmatic complex CosmosFlowWorks®, which will realize the finite element method for the tasks of hydrogasdynamics the value of speeds of stream and pressure was calculated in the area of landing of plate (Fig. 1). It gave possibility to calculate the co-

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efficient of discharge in valve. It is necessary to notice, that the resolving of such spatial finite-element task with the use of modern computers occupies long time. Taking into account it, the axisymmetric finite-element model of that valve in a programmatic complex ANSYS® was developed. Comparison of results for spatial and axisymmetric tasks allows to assert, that the cross bars of seat have not a substantial influence on the change of coefficient of discharge, therefore a working model is accepted for more quick axisymmetric model calculations (Fig. 2).

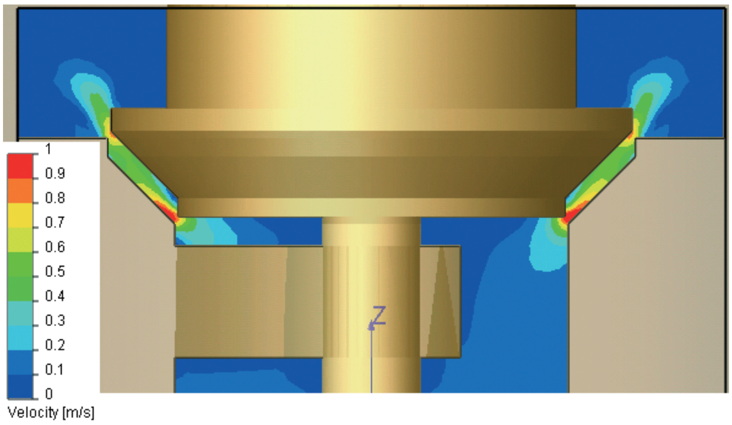

Fig. 1. Distribution of speeds of stream in the three-dimensional model of valve (discharge $Q = 0.001$ m^3/s, $h = 8$ mm, pressure on the output $P_1 = 101$ kPa)

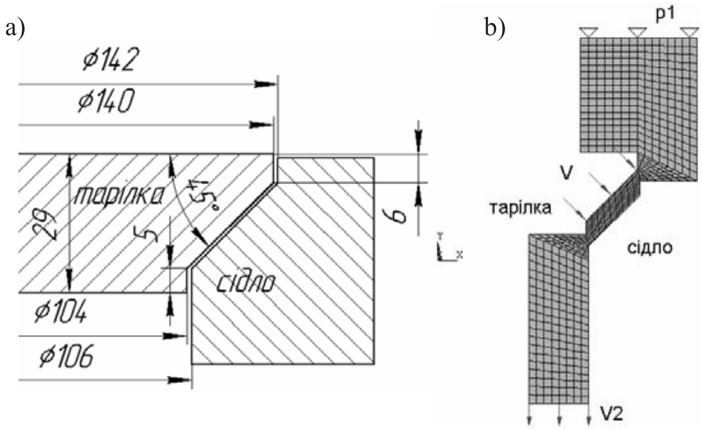

Fig. 2. Construction of landing area of valve No. 7 with a damper chamber (a) and FEM model (b)

Setting up of the plate was simulated by next boundary condition: V – speed of effluence from the surface of landing which answers to the speed of landing of plate. The discharge of pump was simulated by speed V_2, pressure on the output of the pump $p_1 = 0$ MPa.

This model consists of a few submodels which correspond to the certain height of getting up of plate H. In every submodels the coefficient of discharge of overhead and lower clearances of damper chamber was chosen at the height of getting up of plate to 6 mm

$$\mu = \frac{V}{\sqrt{\frac{2\Delta P}{\rho}}},$$

where:

V – average speed in the clearance [m/s],
ΔP – differential pressure in the chamber [MPa],
ρ – density of liquid [kg/m^3].

At the height of getting up of plate more than 8 mm coefficient of discharge almost does not differ from the coefficient of discharge of standard valve (Fig. 3c). The expected coefficients were used in a mathematical model, which describes work of valve with a damper chamber.

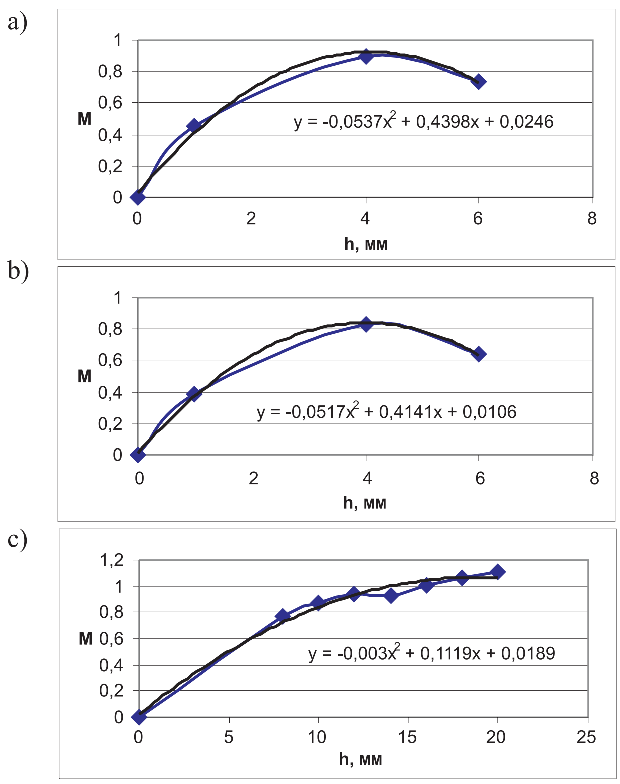

Fig. 3. Dependences of coefficient of discharge m from the size of getting up of plate above the seat *h*: a) upper clearance; b) lower clearance; c) valve on the whole.

At the opening of valve it is possible an intensive hydroabrasive wear of valve surfaces in the area of lower clearance (Fig. 4), and at closing – in the area of upper and lower clearance (Fig. 5). It is therefore necessary to protect these surfaces from the wear, for example, by application on them of hard alloy or by use of specially hardened impact and wear areas. At the opening of valve there is the substantial increase of turbulence of stream in the area of damper chamber (Fig. 4b).

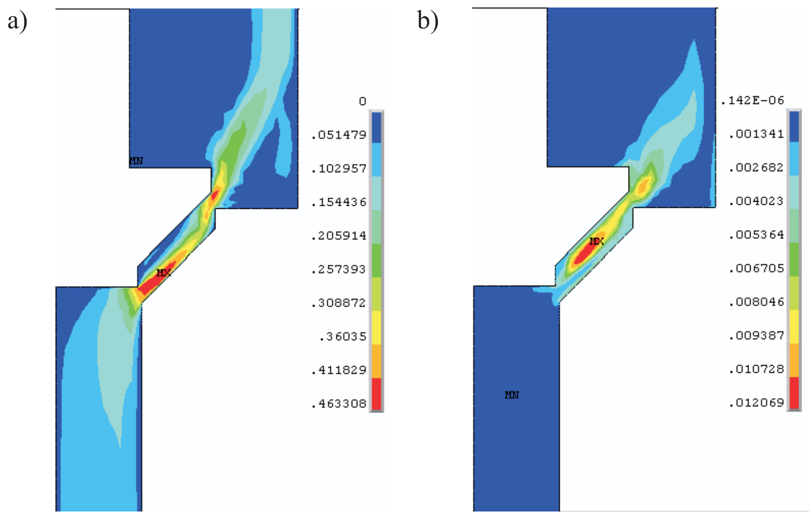

Fig. 4. Distribution of speeds of stream (a) and kinetic energy of turbulence (b) at the discharge (V_{y2} = 0.1 m/s, V = 0 m/s, h = 10 mm)

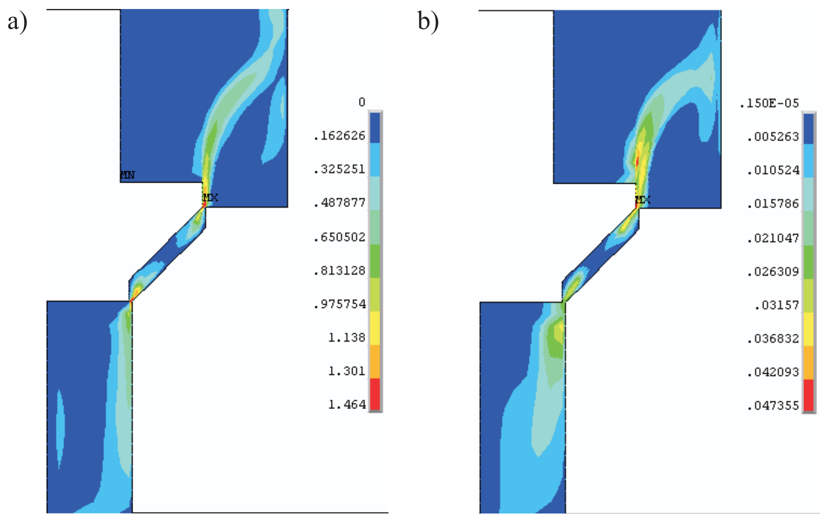

Fig. 5. Distribution of speeds of stream (a) and kinetic energy of turbulence (b) at the suction (V_{y2} = 0.1 m/s, V = 0,14 m/s, h = 6 mm)

The obtained results in general show the picture of speeds distribution in stream. The resolving of mathematical model of work of valve with a damper chamber and conducting of full-scale experiment will allow to set more exact boundary conditions of finite-element model and to represent more detailed processes which take place during the work of valve with a damper chamber.

REFERENCES

[1] Chaplinskiy S.S., Kopey B.V., Livak I.D., Kopey V.B.: *Modelling of mud pump valve without rubber seal*. Ivano-Frankivsk, Scientific Review of the National Technical University of Oil and Gas, No. 3(12), 2005, 46–49