Rationale for choosing the geometric dimensions of well hydraulic jet pump

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Barlow's equation written for a thick-walled cylindrical shell a relationship was found between the stress that occurs in the material of the above-bit unit body and the flow of flush fluid for different designs of the borehole pump-circulation system and the jet pump flowing section. The study made it possible to determine the minimum allowable wall thickness for the above-bit ejection system, which facilitates its fault-free operation.

Key words: well pump, above-bit device, ejector technologies, Barlow's equation, formation fluid, hudro-elevator, washing fluid.

The high efficiency of ejection technology has led to a wide range of their application in the drilling, development and operation of wells during the implementation of intensification methods of oil and gas production in collection systems and preparation of reservoir fluid. Complications of reservoir fluid extraction conditions require the creation of new methods of development of hydrocarbon deposits, and therefore improving of ejection technologies of oil and gas production is an urgent task.

Despite considerable experience in designing, design engineering of well hydraulic jet pumps is limited by justification of geometrical dimensions [1-4] and production material [5] of the elements of the flow part.

At present, there is no methodology for determining of the required well hydraulic jet pump. The special feature of the downhole equipment is a significant difference in the pressure of the column of pipes and channels of annulars space due to hydrostatic pressure and hydraulic losses in the pump cell - circulating system. The situation is complicated by the possibility of occurrence of cavitation in certain areas of the circulation system, when the magnitude of the hydrostatic and hydrodynamic pressure drops to zero. After a difficult operating conditions of ejection systems for case details of a jet pump is used thick membrane, thereby increasing the metal equipment and limited possibilities for its use.

The aim of research, the results of which are presented in this work is a theoretical justification of the selection method of the wall thickness of ejection system with external placement of the jet pump.

Asubject of research shown in Fig. 1 *a*, implements a combined washing of near withdrawing area [6] and can be classified as a jet gun of bit version with parallel connection of hydraulically linked to at-bit area of the jet pump and center inlet of workflow.

Determination of wall thickness of at-bit jet pump provides pressure calculation and analysis of the nature of the flow distribution in the pump cell-circulating system of wells.

The flow of drilling fluid flow $Q_н$ moving the central channel of the drill string and enters the cavity formed by the cylindrical shell of the case 1 of at-bit device (Fig. 1b). At point "в" occurs a distribution of main stream, one part of the flow Q_p is aimed at working nozzle 2 of the jet pump and the other with a flow $Q_д$ continued downward movement passes through the jetting bit nozzle 3 and after cleaning of the withdrawing goes to at-bit area and hydraulic annular channel space. Pressure difference acting on the cylindrical portion of the housing 1, determine the level of the horizontal dotted line a- a (see Fig. 1, *б*) carried out through the output section of the working nozzle jet pump 2. At point "к" we determine the pressure $P_к$ that matches the internal pressure in the cavity of the housing 1 of the jet pump, and at point "з" - the pressure $P_з$ that for cylindrical shell casing is external. Pressure difference $\Delta P = P_к - P_з$ create tension in the material cylindrical shell and is the main factor that determines the wall thickness of the housing of the at-bit unit.

The output pressure of the working nozzle jet pump changes from hydrostatic (in case of zero productivity of jet pump $Q_н$ and labor losses $Q_р$) to the value of saturated vapor pressure $P_{нп}$ of flushing solution when ejection system operates in cavitation mode [7]. In this case, at point "з" (Fig. 1 *б*) formed cavitation area that directly borders the outer cylindrical surface of the case of at-bit device, and the value of pressure in the annulus area takes the value of $P_з = P_{нп}$.. The pressure value of vapor compared with the value of the hydrostatic pressure $P_г$ is small : $P_{нп}$= (0,0005 - 0,001) $P_г$, so when determining pressures in case of at-bit device can take as $P_к$= 0 and $\Delta P = P_к$. The most difficult conditions of jet pump using - during its exploitation in cavitation mode, so that particular case is necessary to take into account when elaborating the methodology of calculation of wall thickness of the device.

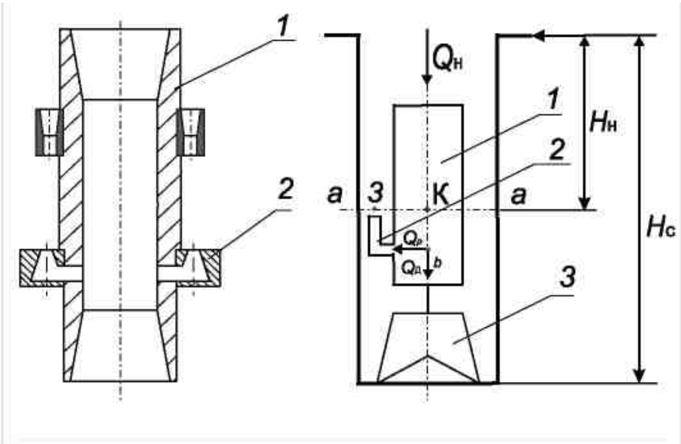

Fig. 1. Design (a) and hydraulic circuit (*б*) of ejection system for drilling: *1* – case of unit; *2* – operating nozzle of jet pump; *3* – bit

Modern methods of pressure calculating in a cylindrical shell include [8] the using of formula Lame and Barlow. Note that the recommendations for the use of the formula Barlow well represented in the standard American Society of Mechanical Engineers (ASME) [9]. Given that the calculations for the Lame theory allow 5% greater of pressure values than formula Barlow, just the last will use to determine the wall thickness δ of at-bit hydraulic elevator:

$$\delta = \frac{P_к d}{2[\sigma]}, \qquad (1)$$

where d - inner diameter of the casing hydraulic elevator; [σ] - allowable normal pressure.

For elevator as part of the drill string that works during drilling, was obtained a similar formula for determining the wall thickness of its case using momentless shell theory [10], neglecting the influence of axial pressure from the weight of the drill string and shear ressures from its torsion, compared with influence of ring pressure caused by pressure $P_к$.. It is clear that, in this case, is necessary to take adequate assumptions for safety factor value.

Thus, the strength design of the at-bit unit case reduced to determining the hydraulic resistance pump-circulation system elements of the well and pressure $P_к$. In the simulation process of the drilling fluid movement we suppose that the diameter of the drill string and the well throughout its length does not change, and the hydraulic losses in socket joint are minor.

Given the peculiarities of determining hydraulic losses in cell-circulating pump systems [11], the formula of pressure *P* determination is:

$$P_к = \rho g H_в + \frac{8}{\pi^2}\frac{\lambda_к \rho (H_с - H_н) Q_д^2}{d_в^5} + \frac{8}{\pi^2}\frac{\rho Q_д^2}{\mu_д^2 N^2 d_д^4} + \frac{8}{\pi^2}\frac{\lambda_з \rho H_н Q_д^2}{(D-d_з)^3 (D+d_з)^2}, \qquad (2)$$

where ρ-is density of drilling fluid; g - acceleration of gravity, $H_н$ and $H_с$ - the depth of the jet pump placement and the well, $\lambda_к$, $\lambda_з$ - the coefficients of the linear hydraulic resistance according to the channel of the drill string and annulus; $\mu_д$ - nozzle flow coefficient of the bit; *N* - number of bit nozzles, $d_д$ - the diameter of the bit nozzles; *D* - diameter of the hole (bit) $d_в$, $d_з$, - the inner and outer diameters of the drill string.

The first component of formula (2) determines the amount of hydraulic pressure at the level of jet pump $H_н$ placement. The second component , which determines the linear hydraulic losses in the drill string at the site of jet pump placement to bits, calculated under the formula Darcy - Veysbah [12] after replacing the velocity of the stream flow rate $V_к$ on $Q_д$. etc. The third component of the formula (2) defines the hydraulic losses in local stands formed by flushing system of the bit. The final component of the formula (2) defines the hydraulic losses in the annulus space above the location of the jet pump.

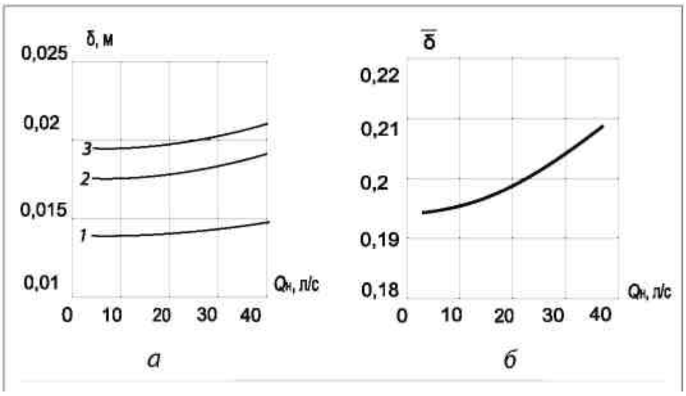

Fig. 2. Absolute (a) and relative (*б*) value of the wall thickness of the at-bit unit depending on its internal diameter and productivity of mud pump: *1* – *d*=0,0714 m; *2* – *d*=0,0904 m; *3* – *d*=0,1 m

Determination of the coefficients of the linear hydraulic resistance $\lambda_к$ and $\lambda_з$ provides a standard procedure of calculating the velocity of the drilling fluid, actual and transition Reynolds numbers. After setting the fluid mode movement and determination of the area of the hydraulic friction the coefficients of the linear hydraulic resistance $\lambda_з$, $\lambda_к$ are calculated by formulas of Stokes Blasius and Altshul. [12].

The solution of equation (2) requires a prior calculation of flow rate losses of drilling fluid in the circulation system of the well. Pump- circulating systems of withdrawing area forms a closed path in the form of two parallel hydraulic channels. The first channel consists of a hydraulic nozzle of jet pump is and the other - from the area of the drill string between the jet pump and bit, the rinsing bit system and annulus area below the location of the working nozzle. From the calculation theory of complex pipelines is known that the combination of two parallel hydraulic channels ending by nodes: input (point "в") and output (point "з"). Between nodal points are two simple pipelines with relevant local factors and linear resistance. By branching (node "в") through the central hydraulic channel moves a drilling fluid with the flow $Q_н$ and pressure $H_з$, and from node " з" moves the same amount of liquid, but with less pressure. Thus, the pressure losses in each of the hydraulic channels will be identical and are determined as the difference between pressure (or pressures) at the nodal points. Alignment of resistance losses in hydraulic channels of the withdrawing area is due to the redistribution of corresponding losses $Q_р$ and $Q_д$ in separate parts of the closed circuit.

Given the Darcy-Weisbach to determine linear and local hydraulic losses note equation of equal pressure in a closed circuit of parallel links:

$$\frac{8}{\pi^2}\frac{\rho Q_р^2}{\mu_р^2 n^2 d_р^4} = \frac{8}{\pi^2}\frac{\lambda_к \rho (H_с - H_в) Q_д^2}{d_в^5} + \frac{8}{\pi^2}\frac{\rho Q_д^2}{\mu_д^2 N^2 d_д^4} + \frac{8}{\pi^2}\frac{\lambda_з \rho (H_с - H_н) Q_д^2}{(D - d_з)^3 (D + d_з)^2}, \qquad (3)$$

where $\mu_р$ – discharge coefficient of working jet pump nozzle; n – number of jet pumps in the ejection system; $d_р$ – diameters of the jet pump nozzle.

The components of formula (3) are determined discharge coefficient of working jet pump nozzle, drill string, drilling bit system and annulus.

After substitution the last expression can be reduced to the quadratic equation

$$AQ_д^2 + BQ_д + C = 0, \qquad (4)$$

coefficients of which is determined by the formula

$$A = \frac{1}{\mu_р^2 n^2 d_р^4} - \frac{\lambda_к (H_с - H_в)}{d_в^5} - \\ - \frac{1}{\mu_д^2 N^2 d_л^4} - \frac{\lambda_з (H_с - H_н)}{(D - d_з)^3 (D + d_з)^2}, \quad (5)$$

$$B = -\frac{2Q_н}{\mu_р^2 n^2 d_р^4}, \quad (6)$$

$$C = \frac{Q_н^2}{\mu_р^2 n^2 d_р^4}. \quad (7)$$

If used the at-bit device *($H_c = H_н$)* the equation (4) is much-simplified.

Distribution of losses in the ejection system is defined by the component equations (4) - (7). In particular, if the number of jet pumps in at-bit ejection system is n = 4 [6], and the number of nozzles jetting bits N = 3, then if the conditions $H_c = H_н$; **Ц**$_р$ = \$x_∂$; $d_р = d_∂$ the flows losses in withdrawing area of the wells are $Q_∂ = 0{,}43Q_н$;$Q_р = 0{,}57Q_н$.

Taking into account the equality of pressure losses in the parallel links of closed circuit, the second and third term in equation (2) can be replaced by a component that determines the hydraulic losses in the working nozzle jet pump. However, simplification estimated equation reduces its information content regarding the design of drilling bits, as in this case does not contain the component that determines the flow resistance.

Using equation (1), (2), (4) - (7) will determine the wall thickness of the hydraulic elevator at-bit for such conditions : ρ = 1000 kg/m3 ; $H_с$ = 4000m, $\mu_д$ = 0.95 , $d_∂$ = 0, 01m ; $d_з$ = 0,216m; = 0.127m, [a] = 100 MPa (Fig. 2). The value of the inner diameter of the unit housing are taken (Fig. 2a) based on weighted geometric sizes of drill pipes wich usually used in manufacturing bases of service support UBR for manufacturing of drilling equipment. Analysis of the dependence indicates that the considered conditions prevailing effect on the value of pressures that occur in basic parts of hydraulic elevator under internal pressure. It should also be noted that the relative wall thickness of the case δ = δ/d does not depend on its internal diameter (Fig. 2b). For any values of the internal diameter of the unit case the value of its relative thickness is described by a single graphical dependence. In view of these results, basic parts of hydraulic elevator, given the generally accepted classification can be attributed to thick shells.

Conclusion

A developed pressure designe technology arising in cylindrical shell of the at-bit hydraulic elevator as a result of internal pressure makes it possible to determine allowable ratio under these conditions of wall thickness and internal diameter of the casing. The studies can be used at the design stage and exploitation eof jection systems, they help to increase the effectiveness of well construction in difficult geological conditions. The aim of further research is experimental verification of the proposed methodology for determining the wall thickness of the at-bit hydraulic elevator with external placement of the jet pump.

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NEWS

Branch Line of South Stream

Russian company "Gazprom" and the Bulgarian company «Plinacro» held talks on the construction of 100 km of the branch line from the future gas pipeline "South Stream" to feed gas to Croatia. This section of the pipeline will have an annual output of 2.7 billion $м^3$, the cost is estimated at 79.9 million USD. It is expected that the pipeline will be commissioned in December 2016..

Deputy Chairman of Gazprom O. Medvedev and the President of the Republic of Srpska M. Dodik signed implementation roadmap of energy projects in Serbia under the project "South Stream". Roadmap foresees the necessity to sign an intergovernmental agreement on cooperation between, Russia and Bosnia and Herzegovina, when implemented projects for the construction of the above branch pipeline and power plants that use natural gas as a fuel.

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