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THEORETICAL JUSTIFICATION OF AN AUTOMATIC DEVICE FOR DRILLING MUD FUNNEL VISCOSITY MEASUREMENT

Abstract. It is considered an installation for automatic measuring drilling mud funnel viscosity (a patent of the Republic of Kazakhstan), involving a rotating table, carrying a funnel with a nipple at the end. At each rotary movement the funnel passes through four positions: filling up with the measured liquid, measuring its funnel viscosity, washing up and removing the traces of the liquid, evacuation of remaining water out of the funnel. Stopping the table for carrying the measurement through and starting the time counter is affected by means of a located on the table cam, opening a live electrical contact at the moment of the funnel running clean from under the liquid delivering pipe. At completion of draining the liquid's measured volume, a float inside the funnel, while sinking, stops the time counter and restarts the table's rotation. The movement of the table is controlled by time relay and starting relay. The electrical signal of funnel viscosity is converted into digital form and conveyed to a control panel of the drilling operator. Computer program representing a model of the funnel viscosity measurement process is worked out. The funnel viscosity of a liquid is found as a sum of draining times of volumes of virtual cylinders, formed as a result of dividing the liquid's measured volume height into a certain number of equal parts, the virtual cylinder's diameter being taken as equal to the average diameter of the corresponding truncated cone. For each virtual cylinder the related to the height of its position in the funnel hydrostatic pressure is represented as an equation, involving a sum of two pressure drops: the first one, resulting from the flow contraction while moving down the funnel; the second one, required for the flow's passage along the nipple. On the second occasion, the accurate value of the hydraulic resistance factor being unknown, it was determined by method of iteration, providing a stepwise approximation to it. For each virtual cylinder the above mentioned equation made it possible to determine the liquid's flow rate, and by it – the velocity of its passing along the nipple and the velocity and the time of its level dropping in the funnel. The sum of those times represents the liquid's funnel viscosity. The model's adequacy was successfully corroborated by way of calculating the water index (15 s) of the standard flow meter ВБР-2, basing on its geometrical dimensions. The model was used for working out optimum values of the most important structural parameters of the installation for automatic measurement of drilling mod funnel viscosity, including dimensions of the funnel – considerably reduced as compared to the standard funnels, but with preservation or even raising the accuracy of measurements. It also helped to find the minimum possible interval between the successive measurements, basing on establishing the required time of each of the principal operations, performed at one full revolution of the table.

Keywords: drilling wells technology, drilling muds' funnel viscosity measuring instruments, automatic measurements, theoretic justification, computational mathematics, programming.

Introduction. Employees of the Drilling Technology and Machinery department have worked out a concept of drilling mud [1.2] parameters measurement automatization, basing on use of a rotating table [4]. As applied to the funnel viscosity, the automatic installation [3,5] is presented at the figure 1.

Driven by the synchronous motor 2, the rotating table 1 and the funnel 3 perform one measurement at each revolution. To do that, the rotation is interrupted and a halt made. A second halt is made for washing up the device. Intermittent nature of the table's motion is effected by a group of relays 9 (time relay and starting relay). The same as at the traditional appliance, the measurement is based on the time of draining an appointed volume of liquid 4 out of the funnel 3 with a nipple 8. Before the measurement the funnel is passing under the liquid supplying channel 13 and filled up with it to overflow. The "measurement"

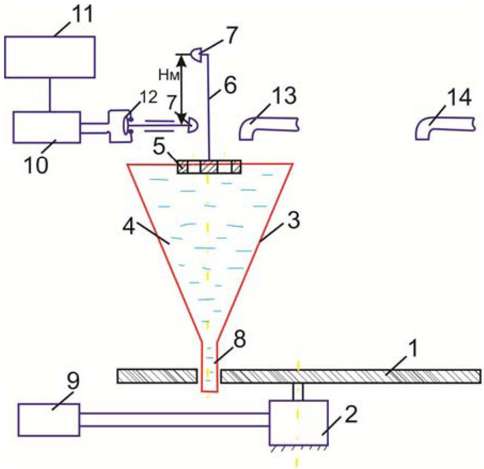

Figure 1 – An installation for the funnel viscosity automatic measurement

position corresponds to the moment, of the funnel getting clean from under the pipe 13, when the incoming flow stops and remains only the outcoming one. At that moment a cam on the rotating table acts upon the relay, which cuts the power supply of the electromotor, and at the same time starts a time counter. During the measurement, together with sinking level of the liquid, sinks the installed in the funnel float 5. At the moment, when the appointed volume V_M of the liquid has left the funnel, the linked with the float by the stem 6 cam 7 breaks the contact 12 and by doing that stops the time counter and resumes rotation of the table. The signal of the funnel viscosity is supplied to analog-to-digital converter 10 and after processing, appears on the display 11 in seconds. In a similar manner is the table's halt effected, when the funnel comes to the channel 14, supplying water in the "cleaning" position. The only difference consists in the fact, that the time of that second halt is a constant one.

For the purpose of obtaining maximal technological and economic effect from the above described device, theoretical and experimental research has been carried out. The liquid outflow time dependency on the funnel's geometry has been examined. Drilling muds have wide interval of funnel viscosities [1,2]– from 16 up to 100 s and more. For reference viscosity, the viscosity of distilled water at the temperature $20 \pm 5^0 C$ has been taken. It is constant for any given funnel and for the standard measuring funnels equals 15 s – it is named the "water index". The "water index" characterizes applicability of the funnel for viscosity measuring. The task of the presented research involved studying influence of a funnel geometry on its water index

In the process of liquid draining out of a funnel, under the hydrostatic pressure p of its column, two kinds of resistance are overcome with two corresponding pressure drops [6,7]:

$$p = \Delta_{P1} + \Delta_{P2} \ , \tag{1}$$

where Δ_{P1} – is the pressure drop on the flow, traveling through the funnel's nipple; Δ_{P2} – the pressure drop, caused by flow's contraction, while moving along the narrowing funnel.

$$\Delta_{P1} = \lambda \rho L \frac{8Q^2}{\pi^2 d^5} , \tag{2}$$

where Q – is the flow rate; ρ – the liquid's density (1000 kg/м^3 for water); λ – the hydraulic resistance factor, depending on the Reinolds criterion and the channel walls asperity; d – the pipe inner diameter; L – its length.

An important circumstance in this context is the fact, that pressure drop Δ_{P1} is inversely proportional to the fifth degree of d, and that diameter of the nipple 8 is very small as compared to the diameters of the funnel itself. Therefore at the further consideration the part of Δ_{P1}, related to the funnel, has been neglected; and only that of the nipple taken into account.

$$\Delta_{P2} = \rho \frac{8Q^2}{\pi^2 d^4 a^2}, \qquad (3)$$

where a is the factor of resistance to the flow contraction, which according to V. Simonov [7] in case of a tapered junction to the nozzle is varying from 0.95 to 0.99. So the funnel was considered as a tapered junction to the nipple.

The hydrostatic pressure of a column with the height H equals

$$p = 9.81\rho H, \qquad (4)$$

Using formulae (2), (3) and (4); the equation (1) can be converted to

$$9.81\rho H = \lambda\rho L \frac{8Q^2}{\pi^2 d^5} + \rho \frac{8Q^2}{\pi^2 d^4 a^2} \qquad (5)$$

From that the flow rate Q can be found:

$$Q = \sqrt{\frac{9.81 H\pi^2}{8(\frac{\lambda L}{d^5} + \frac{1}{a^2 d^4})}} \qquad (6)$$

In the process of funnel viscosity measurement, the column height H is continuously decreasing, which affects Q. The same is true with relation to the measured volume V_M of draining liquid, depending both on H and on the continuously narrowing diameter of the funnel.

The problem was solved by means of computational mathematics methods [8]. A program was compiled, whose algorithm is basing on parameters and considerations as follows:

– The initial volume of the liquid in the conic funnel:

$$V = F * H / 3, \qquad (7)$$

where F – is the area of the cone's base:

$$F = \pi D^2 / 4, \qquad (8)$$

where D – is diameter of the base

– The volume ratio (relative value of the measured volume):

$$K_V = V_M / V, \qquad (9)$$

– The geometrical similarity principle stipulates, that the linear dimensions of similar figures are related as cubic roots of their volumes. Conic shape of the liquid, filling the funnel, is similar to that, which remains there after the measured volume has drained out. Relative value of the remaining volume:

$$K_R = 1 - K_V, \qquad (10)$$

In view of the aforesaid the drop of the liquid's level H_M in the process of measurement (see figures 1 and 2):

$$H_M = H - H\sqrt[3]{K_R}), \qquad (11)$$

– H_M (see the figure 2) was divided by virtual horizontal planes into n equal sections. Thus, liquid in the funnel was divided into n conic elements numbed i, beginning with the uppermost element, numbered $i = 0$. The height of each element ("the step"):

$$S = H_M / n \qquad (12)$$

– Hereafter each conic element was considered as a cylindrical one, whose diameter equals mean (as related to the element's height S) diameter of the cross section of corresponding conic element:

$$D(i) = D(1 - S/(2H) - i * S/H), \qquad (13)$$

The cross section area:

$$F(i) = \pi D(i)^2 / 4, \qquad (14)$$

The volume of the virtual cylindrical element:

$$V(i) = F(i) * S \tag{15}$$

– It was assumed, that volumes of the cylindrical elements and corresponding conic elements are equal. Obviously the approximation error is decreasing with the quantity n of the elements.

– For each element the corresponding height of liquid column

$$H(i) = H - S/2 - S*i\,, \tag{16}$$

– The flow rate $Q(i)$ in the process of draining each liquid element is found by the formula (6)

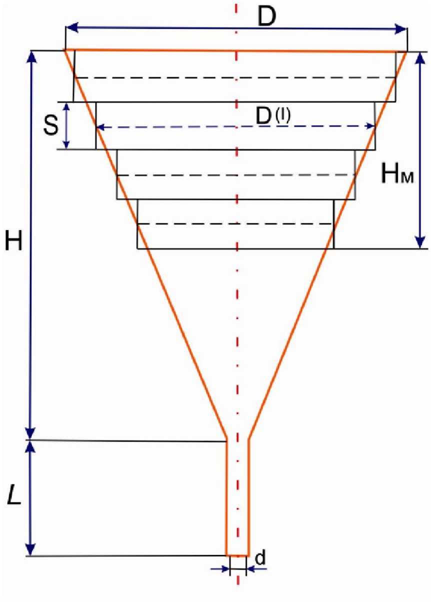

Figure 2 – Division of the funnel's measuring volume V_M into n virtual cylinders

– The corresponding speed of the liquid's level dropping:

$$\vartheta_H(i) = 4Q(i)/(\pi D^2(i)) \tag{17}$$

– The corresponding time of level dropping within the limits of the element:

$$T(i) = S / \vartheta_{H(i)} \tag{18}$$

– The funnel viscosity of the liquid is the result of the summing up the values, related to all of the n elements

$$T = \sum_n T(i) \tag{19}$$

– Initially factor λ in formula (2) was chosen, basing on general considerations. However in the program it is amended by iteration method. For that purpose, for each element the velocity of the liquid traveling through the nipple 8 was found:

$$\vartheta(i) = 4Q(i)/(\pi d^2) \tag{20}$$

The corresponding Reinolds criterion:

$$\mathrm{Re}(i) = \vartheta(i)\rho d / \nu\ , \tag{21}$$

where ν – is dynamic viscosity of the liquid

The amended value λ_C of hydraulic resistance factor was found by the formula of F.Shevelev [7], relating to water, passing through smooth pipes with $\mathrm{Re} < 10^6$:

$$\lambda_C = 0.25 / \mathrm{Re}^{0.226} \tag{22}$$

In a program loop the amended value of λ_C was put into formula (6) instead of a preceding one. At each cycle of the loop difference between their values becomes smaller and the loop ends, when it becomes negligibly small.

For verification of the algorithm and the program, calculation of water index of the standard funnel viscosity meter ВБР-2 [2] was performed

Table 1 – Description of the funnel of the ВБР-2 viscosimeter

#	Name	Value.	#	Name	Value.
1	Height H , m	0.232	7	Measured volume V_M , m^3	0.0005
2	Level drop H_M , m	0.079	8	Volume ratio K_V	0.714
3	Top diameter D, m	0.106	9	Hydraulic resistance factor λ	0.021
4	Nipple length L, m	0.100	10	Flow contraction factor a	0.99
5	Nipple diameter d, m	0.005	11	Virtual cylinders* number n	6**
6	General volume V, m^3	0.0007	12	Cylinder height, m	0.013

* According to fig. 2.

** When the quantity n of the virtual cylinders in the program was brought up from 6 to 50, the final result did not change. So from precision standpoint the $n = 6$ is satisfactory.

The data of table 1 were entered into the program, and the sum of level dropping times for all the 6 cylinders (formula 19) was found equal 15 s, – the same as in the ВБР-2 certificate

As compared to the traditional manual measurement the automatic measurement device involves a number of additional elements, increasing its size, mass, and cost. So the possibility of their reduction was examined

Precision of measurement is expressed by its relative error [9-17]

$$\delta = \Delta / A, \tag{23}$$

where Δ – is an absolute error, and A – measured value.

On the occasion under consideration A is the water index, which traditionally equals 15 s. At manual measurement the absolute error Δ is basically connected with subjective factors, such as timeliness of starting and stopping the stop watch, overfilling or underfilling the measuring cylinder, correctness of choosing the mud withdrawing place etc. In an automatic device all subjective errors are ruled out, which sharply reduces both Δ and δ. It follows from the formula (23), that the same precision can be achieved for smaller A if is reduced proportionally to reduction of Δ. So, eliminating subjective errors , makes it possible to reduce the water index of the funnel and consequently the funnel's dimensions, as well as dimensions of the whole automatic installation.

In table 2 descriptions of a funnel, with water index 10 s are given

Table 2 – Parameters of a funnel with water index 10

H, m	H_M, m	D, m	L, m	d, m	V, m^3	V_M, m^3	K_V	λ	a	T, s
0.1	0.034	0.106	0.04	0.005	0.00029	0.0002	0.714	0.021	0.96	10.0
43*	43	100	40	100	41	41	100	110	98	67

* Per cent of the corresponding data in table 1.

The table demonstrates essential reduction in dimensions of the funnel, as compared to those of ВБР-2. However the internal diameter d of the nipple and the volume ratio λ are left intact.

It should be observed, that while using this funnel, it does not present a problem for the results of measurements to be demonstrated on the display with coefficient 1.5 – that is according to the conventional scale of funnel viscosity measurement.

Table 3 – Modification of water flow parameters, while performing measurement by the funnel with water index 10 s (6 virtual cylinders)

I	H(i), cm	D(i), cm	F(i), cm^2	V(i), cm^3	P(i), Па	Q(i), cm^3/мин	$\vartheta(i)$ m/s	$\vartheta_H(i)$, m/s	T(i), s	Re(i)	$\lambda_C(i)$
0	9.7	10.3	83.3	47,3	953	1350	1.15	0.0027	2.10	57000	0.021
1	9.1	9.6	73.9	42,0	897	1310	1.12	0.0030	1.92	55300	0.021
2	8.6	9.0	65.1	36,9	841	1270	1.08	0.0033	1.74	53600	0.021
3	8.0	8.4	56.8	32,2	785	1220	1.04	0.0036	1.57	51800	0.021
4	7.4	7,8	49.1	27,8	730	1180	1.00	0.0040	1.41	50000	0.022
5	6.9	7.2	42.0	23,3	674	1130	0.97	0.0045	1.26	48000	0.022

The table illustrates performance of the algorithm, used for finding a funnel's water index:

– In the course of the measurement the height $H(i)$ of water column decreases from virtual cylinder number i to that of number $i+1$ according to formula (16) by the step S – formula (12). Proportionally to $H(i)$ decreases cylinder's diameter D(i) – formula (13) and hydrostatic pressure $p(i)$– formula (4). Cross section areas of the cylinders – formula (14), and their volumes– formula (15) are decreasing proportionally to $H(i)^2$

– The flow rate $Q(i)$ – formula (6), and the velocity $\vartheta(i)$ of the flow in the nipple – formula (20), are decreasing in proportion to $\sqrt{H(i)}$

– The speed $\vartheta_H(i)$ of water level dropping is found by formula (17), which is similar to formula (20). However if in formula (20) the diameter d of the nipple is constant, while in formula (17) decreasing are both: denominator D(i) and numerator $Q(i)$. As the rate of denominator decreasing is smaller, than that of numerator, the value of $\vartheta_H(i)$ (contrary to $\vartheta(i)$) is growing.

– After $\vartheta_H(i)$ is found, the time T(i), of the level dropping within the limits of each cylinder is determined by formula (18).

– The water index T is found by summing up the T(i) – formula (19),

– The Reynolds criterion $R(i)$ formula (21), related to the traveling through the nipple of the funnel water flow, is decreasing in proportion to $\vartheta(i)$, but that did not substantially affect the values of corrected hydraulic resistance factors $\lambda_C(i)$ – formula (22)

Basing on data of tables 2 and 3, the optimal parameters of the rotating table were determined:

Its radius

$$R \geq 2R_F, \quad (24)$$

where R_F – is the outer radius of the funnel top

The time of the table's revolution consists of 5 components (see the fig.3):

$$T_R = T_{HM} + T_{CL} + T_{HCL} + T_{DR} + T_{FL}, \quad (25)$$

where T_{HM} – is the time of halt for performing measurement; T_{CL} – the time of cleaning the funnel, while the table is moving; T_{HCL} – the time of the special halt for cleaning; T_{DR} – the time for draining cleaning water out of the funnel; T_{FL} – the time for filling the funnel with measured mud

T_{HM} conventionally varies from water index 15 s to 100 s (the scale of ВБР-2 viscosimeter). For the considered funnel it corresponds to actual interval from 10 to 70 s;

$T_{CL} + T_{HCL}$ mast guarantee elimination of measured mud traces in the funnel and its nipple. Meeting that requirement depends mostly on the cleaning water stream intensity. As for time, it is reasonable to make it equal to funnel viscosity of muds of high but not extremely high thickness With relation to the conventional funnels it can be taken for 60 s, ergo for the funnel under consideration it makes 40 s

T_{DR} is time, needed for full evacuation of the cleaning water out of the funnel – after the cleaning has terminated but before the filling with mud has started. The program for determining the funnel's water index makes it possible to find precise value of that time too. For that K_V =1 is entered in the program (formulae (9), (10), (11))

T_{FL} depends on diameter of the mud delivering pipe.

The minimal table's rotation period (with deduction of the time of its halts for measurement and cleaning) was found, basing on T_{DR} time and the diagram on the figure 3.

The table 1 is turning clockwise (see the arrow on the top).The diagram demonstrates mud 3 and water 4 delivery pipes positions with relation to the rotating table and the funnel 2. At the diagram the funnel is situated at the position HM - that of measuring halt. In that position the funnel has just left the interval FL. Directly, after the measurement is terminated and the table's motion resumed, it will enter the cleaning interval CL. In the middle of that interval the table makes a special halt for cleaning. After resumption of rotation, the funnel passes the second half of the cleaning interval CL, draining DR and filling FL intervals, and finally accomplishes the revolution making a halt for performing a next in turn measurement.

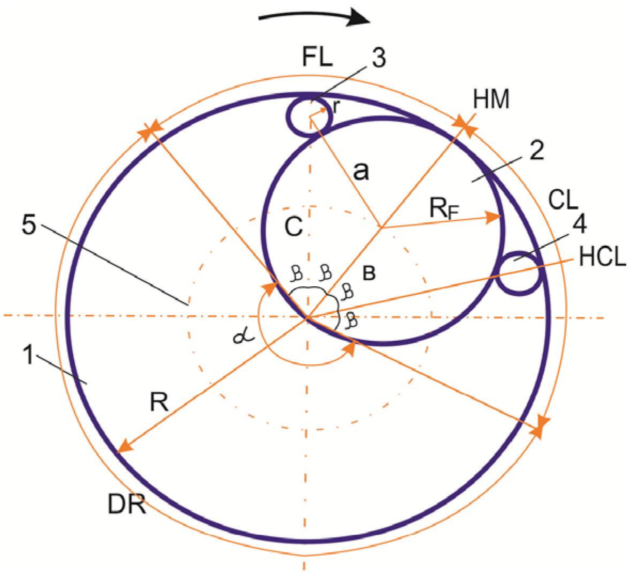

Figure 3 – Positions of the funnel on the rotating table

The table's rotation period (disregarding the halts)

$$T_{RP} = \frac{T_{Dr}}{\alpha} 360 , \quad (26)$$

where α is the angle corresponding to DR interval on the fig 3

As it follows from the diagram, that angle

$$\alpha = 360 - 4\beta , \quad (27)$$

where angle β is found by considering the abc triangle on the figure. Al the legs of the triangle are found directly from the diagram

$$a = R_F + r , \quad (28)$$

where r is radius of the mud and water delivery pipe (both pipes are alike).

$$b = R_F \quad (29)$$

$$c = 2R_F - r, \tag{30}$$

Hence according to geometrical rules

$$\beta = \arccos(\frac{c^2 + b^2 - a^2}{2cb}) \tag{31}$$

The maximal rotation frequency (rpm)

$$m = 60 / T_{RP} \tag{32}$$

Now to find the full time of the table's revolution the formula (25) can be written as

$$T_R = T_{RP} + T_{HM} + T_{HCL}, \tag{33}$$

Funnel mud filling (as well as cleaning while moving T_{CL}) time

$$T_{FL} = \frac{T_{DR}}{360} 2\beta \tag{34}$$

Table 4 – Descriptions of the rotating table for the funnel with water index 10 s

#	Name	Value	Formula
1	Funnel's top outer diameter D_F, m	0.108	
2	Funnel's top outer radius R_F, m ,	0.054	
3	Table's diameter D_T, m	0.216	24
4	Outer radius of mud and water delivery pipes r, m	0.010	
5	Measurement time T_M, s, from – to	10 – 70	
6	Cleaning time ($T_{CL} + T_{HCL}$), s	40	
7	Water draining time after cleaning T_{DW}, s	16	6,9,17,18,19
8	Mud filling time, T_{FM}, s	3	34
9	Angle β between vertical symmetry axis and HM	37^0	28,29,30,31
10	Angle α of DR interval	212^0	27
11	Table rotation period (regardless the halts), T_{RP}, s	27	26
12	Table's rotation frequency m, rpm	2.2	32
13	Actual table's revolution time T_R, s : from – to	74 – 134	25

Conclusion. At the drilling technology department of Satpajev Technology Research University a method of drilling mud parameters measurement automatization, basing on application of a rotating table has been proposed; worked out principal details of the installation for automatic measuring the drilling mud funnel viscosity; according to the laws of hydraulics, and by means of the computation mathematics, a computer model of the funnel viscosity measuring process has been created; successfully performed verification of the model's adequacy, by calculating the water index of a standard instrument for measurement funnel viscosity, basing on its geometrical dimensions; basing on the worked out computer model, for the purpose of reducing dimensions and costs of the installation for drilling muds funnel viscosity automatic measurement, optimal values of its principal parameters are established.

REFERENCES

[1] Georg R.Gray, H.C.H. Darly. Composition and properties of oil well drilling fluids. Gulf publishing company// Huston, London, Paris, Tokyo, Moscow 1985

[2] A drilling contractor's reference book. Moscow: "Infra ingeneria" 2006

[3] Biletskiy M., Kasenov A, Sushko & Begun A. The Kazakhstan Republic's Patent E21B 45/00 # 25680 of 16.06.2014

[4] Biletskiy M., Ratov B, Kasenov A. Method of automatic measurements of drilling mud quality parameters: Int. J.Chem.Sci.:11(4), 2013, 1705– 7012 ISSN 0972–768X . www.sadgurpablications.com

[5] Biletskiy M, Darmenov E. Automatization of drilling muds parameters control: Collected works of the conference "Geology and oil & gas in XXI sentuty". Almaty 2016

[6] Rabinovich. E. Hydraulics: Moscow “Nedra” 1980
[7] Mittelman B. Reference book on hydraulic calculations in drilling: Moscow, Gostoptekhizdat 1963
[8] Guter R. Ovchinskiy. B. Elements of digital analysis: Moscow “Nauka” 1970
[9] Vasiljev A. Foundations of metrology and technological measuremrnts: Moscow “Mashinostroenije” 1988
[10] Biletskiy M. Measuring equipment in drilling: Almaty KazNTU 2013
[11] Kassenov A.K, Ratov B.T, Moldabekov M.S, Faizulin A.Z & Bukenova M.S. (2016) The reasons of formation of oil seals when drilling geotechnological wells for underground leaching of uranium ores // 16t[h] International Multidisciplinary Scientific GeoConference, Albena, Bulgary, 2016, ISBN 978-619-7105-55-1 / ISSN 1314-2704, Book 1 Vol.1,633–639pp.
[12] Ratov B.T., Igembayev I.B., Omirzakova E.Zh. & Zhanabayev T.A. (2016) New generation of polymer drilling fluids with low content of clay for drilling of wells in difficult conditions // 16t[h] International Multidisciplinary Scientific GeoConference, Albena, Bulgary, 2016, ISBN 978-619-7105-57-5 / ISSN 1314–2704, Book 1 Vol. III, 865–874 pp.
[13] Biletski M. T., Ratov B. T., Kasenov A. K. & Ibyldaev M. H. (2015) Caving control while drilling through highly dispersible clays at uranium deposits of Kazakhstan // 15[th] International Multidisciplinary Scientific GeoConference, Albena, Bulgary, 2015, Vol. 2, pp. 157–164 DOI: 10.5593 / B12 / S2.021. ISBN 978–619–7105–32–2 / ISSN 1314–2704, Book1 Vol.2, 157–164pp.
[14] Kassenov A. K., Biletskiy M. T., Ratov B.T. & Korotchenko T.V. (2015) Problem analysis of geotechnical well drilling in complex environment // IOP Conf. Series: Earth and Environmental Science 24 012026 DOI: 10.1088 / 1755–1315 / 24/1 / 012,026.
[15] Kozhevnykov A. A., Ratov B. T., & Filimonenko N. T. (2014) Classification of fluids fed by displacement pumps // Int. J. Chem. Sci .: 12 (4), 1161–1168, ISSN 0972 – 768X
[16] Shipulin A.V., Nifontov Y.A., Ratov B.T., Fedorov B.V. & Zhanabayev T.A. (2014) To the issue of searching an alternative heating method for bottom hole zone of the oil formation // Life Sci J; 11 (10s): 457–460] (ISSN 1097–8135).
[17] Biletski M. T., Ratov B. T., Kassenov A. K. & Sushko S. M. (2013) Method of automatic measurements of drilling mud quality parameters // Int. J. Chem. Sci.: 11 (4), 1705–1712 (ISSN 0972–768X).

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БҰРҒЫЛАУ ЕРІТІНДІСІНІҢ ТҰТҚЫРЛЫҒЫНЫҢ ШАРТТЫ ЖАҒДАЙДА АВТОМАТТЫ ТҮРДЕ ӨЛШЕУДІҢ ҒЫЛЫМИ ДӘЛЕЛДЕНУІ

Аннотация. Айналмалы үстелге орнатылған түтікшесі бар құйғыш арқылы бұрғы ерітіндісінің шартты тұтқырлығы өлшенетін автоматты қондырғы қарастырылады (Қазақстан Республикасының патенті). Әр бір айналыста құйғыш төрт жақты өтеді: толтырылған өлшенетін ерітіндімен, оның тұтқырлығын өлшеу, ерітіндінің қалдықтарын жою, құйғышқа толтырылған суды жою. Өлшеуді жүргізу үшін үстелді қою және уақыт өлшегішті қосу құйғыштың ерітінді келетін түтікшеден шыққан кезде үстелде орналасқан тетікті әрекетке келтіру нәтижесінде қалыпты тұйық байланыстырғыш арқылы орындалады. Ерітіндінің өлшенетін көлемі аяқталғанда, құйғыштағы қалқыма төмен түседі уақыт есептегішті өшіреді және үстел айналымын жаңадан орындайды. Үстел қозғалысын уақыт релесі және қосқыш реле басқарады. Электірлік өлшегіш сигналдар сандық түрге ауысады және бұрғышының табло пультына жіберіледі. Құйғыш құрал көмегімен шартты тұтқырлықты өлшеу процессінің математикалық моделі жасалған, компьютерлік бағдарлама құрастырылған. Сұйықтықтың шартты тұтқырлығы виртуалдық цилиндірдің ағу уақытының жиынтығымен анықталады. Анықталған теңдей бөлшектердің саны сұйқтықтың өлшенетін көлемінің қысымы арқылы пайда болған, вертуалдық цилиндірдің диаметрі кесілген конустың сәйкестендірілген ораша диаметріне тең. Әрбір виртуалды цилиндірдің оның гидростатистикалық қысымының сәйкес биіктігі сұйықтықтың қысымын екі рет жоғалтқан теңдік түрінде көрсетілген: біріншіден құйғыш бойымен қозғалыс кезіндегі оның қысылған ағымның нәтижесінде және екіншіден оның ұшындағы түтікше арқылы өтуінде. Ең соңғы жағдайда гидравликалық кедергінің нақты коэффициенті оның шынайы белгісін қамтамасыз ететін инерция әдісімен анықталады. Әрбір виртуалды цилиндырға алынған басқару сұйықтықтың шығымын және сонымен бірге оның ұшы бойынша жылдамдығын, құйғыштағы деңгейінің түсуін және түсу уақытын анықтауға мүмкіндік берді. Бұл уақыттардың жиынтығы сұйықтықтың шартты тұтқырлығын береді. Үлгінің дұрыстығы ВБР-2 шығын өлшегішінің геометриалық өлшемдер негізінде жаслған құйғыштың су санын (15 с) өлшеу арқылы дәлелденген. Үлгі бұрғы ерітінділерінің шартты тұтқырлығын автоматты түрде өлшейтін қодырғының оңтайлы конструктивті параметрлерін жасауға қолданған, өлшейтін құйғыштың өлшемін оның өлшеу дәлдігін сақтап қалу арқылы кішірейту қарастырылған, сонымен бірге үстелдің толық бір айналымы кезінде өлшемдердің минималды мүмкіндігі қарастырылған.

Түйін сөздер: ұңғыны бұрғылау технологиясы, бұрғы ерітінділердің шартты тұтқырылығы, өлшеу құралдары, өлшеуді автоматтандыру, теориялық негіздеу, сандық математика, бағдарламалау.

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НАУЧНОЕ ОБОСНОВАНИЕ РАБОТЫ АВТОМАТИЧЕСКОГО ИЗМЕРИТЕЛЯ УСЛОВНОЙ ВЯЗКОСТИ БУРОВОГО РАСТВОРА

Аннотация. Рассматривается устройство для автоматического измерения условной вязкости бурового раствора (патент Республики Казахстан), включающее поворотный стол с установленной на нем воронкой с трубчатым наконечником. При каждом повороте воронка проходит четыре положения: наполнение измеряемым раствором, измерение его вязкости, промывка с удалением следов раствора, удаление заполняющей воронку воды. Остановка стола для производства измерения и запуск счетчика времени происходит под воздействием на нормально замкнутый контакт расположенного на столе кулачка в момент выхода воронки из-под подающей раствор трубки. При завершении истечения мерного объема раствора, находящийся в воронке поплавок, опускаясь, отключает счетчик времени и возобновляет вращение стола. Движением стола управляют реле времени и пусковые реле. Электрический измерительный сигнал преобразуется в цифровую форму и подается на табло пульта бурильщика. Составлена компьютерная программа, представляющая собой математическую модель процесса измерения условной вязкости с помощью мерной воронки. Условная вязкость жидкости определяется как сумма времен вытекания объемов виртуальных цилиндров, образованных в результате деления высоты мерного объема жидкости на определенное число равных частей, причем диаметр виртуальных цилиндров принимается равным среднему диаметру соответствующего усеченного конуса. Для каждого виртуального цилиндра соответствующее высоте его положения гидростатическое давление представлено в виде уравнения, как сумма двух потерь давления жидкости: во-первых, в результате сжатия ее потока при движении вниз по воронке и, во-вторых, при ее прохождении через трубчатый наконечник. В последнем случае точное значение коэффициента гидравлических сопротивлений определяется методом итераций, обеспечивающим последовательное приближение к его истинному значению. Для каждого виртуального цилиндра упомянутое уравнение позволило определить расход жидкости, и по нему – скорость ее движения по наконечнику, скорость опускания ее уровня в воронке и время опускания. Сумма этих времен и дает условную вязкость жидкости. Адекватность модели подтверждена путем вычисления водного числа (15 с) воронки серийно выпускаемого расходомера ВБР-2 на основании ее геометрических размеров. Модель использована для разработки оптимальных значений важнейших конструктивных параметров установки для автоматического измерения условной вязкости бурового раствора, включая размеры мерной воронки – существенно уменьшенные, по сравнению с серийно выпускаемыми воронками, при сохранении и увеличении точности измерений, – а также минимально возможный интервал между последовательными измерениями – на основе установления необходимого времени каждой из основных операций, осуществляемых при одном полном обороте стола.

Ключевые слова: технология бурения скважин, условная вязкость буровых растворов, измерительные средства, автоматизация измерений, теоретическое обоснование, вычислительная математика, программирование.