Means and Method for Measurement of Drilling Fluid Properties

You may also be interested in:

Means and Method for Measurement of Drilling Fluid Properties

A Lysyannikov[1], P Kondrashov[1] and P Pavlova[2]

[1]Associate Professor, Siberian Federal University, Krasnoyarsk, Russia
[2]Assistant, Siberian Federal University, Krasnoyarsk, Russia

E-mail: lysyannikov.alek@mail.ru

Abstract. The paper addresses the problem on creation of a new design of the device for determining rheological parameters of drilling fluids and the basic requirements which it must meet. The key quantitative parameters that define the developed device are provided. The algorithm of determining the coefficient of the yield point from the rheological Shvedov-Bingam model at a relative speed of rotation of glasses from the investigated drilling fluid of 300 and 600 rpm is presented.

1. Introduction

The main rheological parameters of drilling fluids are plastic viscosity, static and the yield point.

The change in the plastic viscosity upward the flow of the drilling fluid affects the ability to remove cuttings and hydraulic losses, which in turn determines the actual hydrostatic pressure in the well.

The yield point shift affects the fluidity of the solution, as the minimum level of tension should be ensured before solution deformation.

The change in the static shear stress affects the ability of the gel formed in the drilling fluid to keep the drill cuttings particles in suspension (after the cessation of the circulation) that prevents their deposition on the bottom hole and "jamming" as a possible variant and loss of drilling tools.

If the value of the static shear stress grows, the strength of the structure of the washing liquid increases resulting in difficult starting of the pumps, creates considerable pressure on the walls of the well, which in certain rocks can lead to hydraulic fracturing when restoring circulation and worsens the conditions of cleaning of drill cuttings particles and degassing of the cleaning agent.

Optimally balanced formula will prevent the possibility of oil and gas flowing from the wellbore resulting in release of the wash solution from the well and creating an emergency situation.

Continuous monitoring of drilling fluid properties allows setting an optimum mode of drilling and correcting it to reflect changes in the geological section reducing the consumption of chemicals in the drilling fluid (the cost of 1 m^3 of drilling fluid will decline and the long term savings will follow in the progressive mode).

On the market of the devices to control the rheological parameters of drilling fluids in Russia the situation is currently as follows:

• In early 1990s, on the Russian market, there were instruments monitoring the rheological parameters of drilling fluid, and foreign products found their niche. Therefore, the Russian

manufacturers of similar products had lower sales volumes and suspended their modernization, and the production almost stopped;

- in 2014, the cost of foreign devices caused by rise in the dollar significantly increased;
- import to Russia of industrial equipment from the countries of the EU and the USA was banned

and unless the sanctions imposed against Russia are be extended, Russian companies will be forced to resume work on product improvement, which would be virtually impossible to undertake in the short term.

2. Results and Discussion

Therefore today to measure, e.g. the static shear stress, yield point and plastic viscosity of drilling fluid it is necessary to use one foreign apparatus or two Russian apparatus such as: SNS and rotational viscometer VSN-3 (figure 1).

a   b   c

Figure 1. Apparatus for measuring the static shear stress, yield point and plastic viscosity of the drilling fluid: SNS-3 (a); VSN-3 (b); Brookfield rotational viscometer (c).

If anti-Russian sanctions are extended, the Russian companies will start production improvement. Define the key advantages and disadvantages of the existing foreign devices.
Advantages:
- high accuracy of measurements;
- the process is fully automated;
- measure the plastic viscosity (centipoise or MPa·s);
- measures the static shear stress (Pa);
- measures temperature (°C or °F);
- measure shear rate/shear stress;
- possible to set the speed of rotation of the spindle (up to 8 speeds);
- provided data visualization and display comparison;

- provided with automatic recording of results;
- automatic calibration of the device;
- ensured compliance with international standards API.

Disadvantages:
- high cost of 3 000 \$;
- the complexity of the design; • in case of breakage, the inability to self-repair.
- Define key advantages and disadvantages of existing devices of the Russian production.
- Advantages:
- simplicity of design;
- easy operation;
- ability to self-calibrate;

Disadvantages:
- SNS totally mechanical device requiring considerable attention during the measurement of drilling fluid properties;
- as a series of the SNS and VSN – 3 allows to determine only one parameter of the drilling fluid;
- a large mass of VSN – 3 (22 kg).

Based on the analysis of the existing designs of devices a conclusion was made. Due to the fact that the mass of the BCH-3 is several times greater than that of the instrument for determining the static shear stress, the best technical solutions used in devices: SNS 2, SNS-2 SNS-3 and foreign devices are recommended for the development of the prototype as a base for improvement. The principle of operation for both Russian and foreign instruments is to measure the torque in the circular shear flow of the investigated solution with constant speed in a thin annular layer (in the gap between coaxially placed cylinders). The device records the moment of the resistance to the rotation of the inner cylinder of the measuring device with the test drilling fluid at different gradients of the shear rate and the calculation of the dynamic tension of the shift and plastic viscosity.

To assist Russian manufacturers, we need to develop a device with the following quality parameters:
- the ability to provide simultaneous measurement of at least three parameters of quality drilling fluids;
- high precision measurements of rheological parameters of drilling fluids;
- low cost in comparison with foreign analogues;
- a simple design that enables in case of failure of self repair;
- a fully automated device with the ability to connect to a PC that earlier in Russia was not possible;
- mass at the level of the imported samples [1].

Quantitative parameters:
- measurement of static shear stress, from 0 to 20 Pa.
- measurement of the maximum yield point in the range from 0 to 100 Pa.
- measurement of plastic viscosity in the range from 0.5 to $10 \cdot 10\text{-}6$ Pa·s
- stepless regulation of speed of rotation from 0.2 to 600 rpm;
- temperature measurement from 0 to +35 °C;
- temperature measurement accuracy ±0.1 °C;
- the limits of permissible reduced error of the viscometer is ± 1,5 %.

In spite of the intense use of stepping motors in high precision applications in robotics and industrial automation, they have been scarcely used to drive rotational viscometers. Instead, to drive these instruments, researchers and manufacturers have been employing dc motors (either conventional or Brushless types) or ac motors (either induction or synchronous types) [2-5]. The main advantage of

stepping motors is the - precision (if applying potentials on windings stepping motors will rotate strictly at a certain angle), the cost of stepper drives, on average 1.5-2 times cheaper servos.

The new device required development of an algorithm for calculation of the parameters of the drilling fluid. Determining the limit shear stress and plastic viscosity is based on rheological models. All models have at least two parameters in one equation. Thus, the measurement task consists in solving a single equation with two unknowns. For example, the most common Shvedov-Bingham model has the form [6]:

$$\tau = \tau_0 + \mu_p \frac{dU}{dy};$$ (1)

where τ_0 – yield point; μ_p – plastic viscosity; $\frac{dU}{dy}$ – the derivative of the velocity in the direction perpendicular to the direction of fluid motion.

The apparatus must find a yield point – τ_0 and plastic viscosity – μ_p. To determine two unknowns, you need two equations. In that way measurements are performed at a relative speed of rotation of the cylinders, 300 and 600 revolutions per minute. After test operation, the coefficient of the equation system obtained [7] are:

$$\begin{cases} \tau_{300} = \tau_0 + \mu_p \left. \dfrac{dU}{dy} \right|_{300} \\ \tau_{600} = \tau_0 + \mu_p \left. \dfrac{dU}{dy} \right|_{600} \end{cases};$$ (2)

where τ_{300} и $\left. \dfrac{dU}{dy} \right|_{300}$, τ_{600} и $\left. \dfrac{dU}{dy} \right|_{600}$ is the yield point on the outer surface of the inner cylinder and the derivative of the velocity in the radial direction when the inner cylinder rotates at a speed of 300 and 600 rpm, respectively.

The yield points are associated with the angles of the ratios [3]:

$$\tau_{300} = \frac{\phi_{300} \cdot d^4 \cdot G}{64 \cdot R^2 \cdot h \cdot L};$$ (3)

$$\tau_{600} = \frac{\phi_{300} \cdot d^4 \cdot G}{64 \cdot R^2 \cdot h \cdot L};$$ (4)

where φ_{300} and φ_{600} – angles twisting steel filaments with a diameter d when the rotation speeds of the external cylinder 300 and 600 rpm, respectively; G – the shear modulus (G=79.3·10^9 Pa); R – the radius of the outer surface of the inner cylinder; h – the height of the inner cylinder; L – the length of the thread which is suspended inner cylinder.

The presented method is applicable to a linear dependence between the tangential stress on the outer surface of the inner cylinder and the derivatives of the velocity in the radial direction. To identify the parameters of other rheological models shown in figure 2, modern devices have more than two speeds that allow obtaining more data.

In order to precisely determine the coefficients of the rheological models, it is assumed that the next-generation device must have at least 8 speeds.

3. Conclusion

The main technical requirements to be met by the developed device are determined. The proposed algorithm based on the rheological model Shvedov-Bingama allows determining the yield point stress at speeds of 300 and 600 rpm.

The development of the new design of the instrument to control the rheological parameters will prevent the risk of possible deficit in this equipment in the Russian Federation. The instrument will provide determination of the three parameters of the drilling fluid (yield point and static shear stress, and plastic viscosity) resulting in no need to purchase additional hardware.

In further work, it is planned to develop the algorithm for determining the coefficients of dynamic shear stress and plastic viscosity based on different rheological models of the drilling fluid.
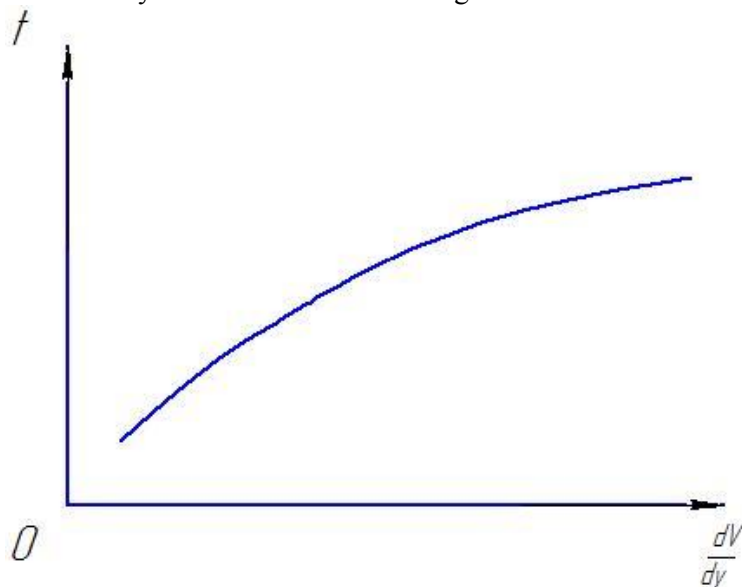

Figure 2. The dependence of the yield point.

References
[1]   Lysyannikov A V *and* Kondrashov P M 2015 *Proc. of Conf. Dedicated to the 70th Anniversary of the Great Victory "Prospekt Svobodnyj – 2015" (Krasnoyarsk)* URL http://conf.sfu-kras.ru/sites/mn2015/index.html
[2]   Tonmukayakul N *and* Nguyen Q D 2002 *Fuel* **81 (4)** 397–404
[3]   Van Den Brule B H A A *and* Kadijk S E 1992 *J. Non-Newton. Fluid Mech.* **43 (1)** 127–139
[4]   Stein D J *and* Spera F J 1998 *Rev. Sci. Instrum.* **69 (9)** 3398–3402
[5]   De Lucena S E *and* Kaiser W. 2008 *IEEE Transactionson Instrumentation and Measurement* **57 (7)** 1338 DOI: 10.1109/TIM.2008.917170
[6]   Tetelmin V V *and* Yazev V A 2009 *Reologiya Nefti* (Moscow: Granica)
[7]   Rabia H 1985 *Oilwell Drilling Engineering: Principles and Practice* (Graham & Trotman)