Automatic machine for feeding liquid equal to the frequency of the pulsator-vibrator

L M Zaripova and M S Gabdrakhimov

Ufa State Petroleum Technological University, Branch of the University in the City of Oktyabrsky, 54a, Devonskaya St., Oktyabrsky, Republic of Bashkortostan, 452607, Russian Federation

E-mail: Lilyabert31@mail.ru, info@of.ugntu.ru

Abstract. The main task of the drilling fluid circulation during drilling is to remove the remnants of the drilled rocks to avoid additional wear of the rock-cutting equipment. Bottom hole cleaning efficiency depends on both the rate of flow of the drilling fluid and its performance. During backwashing, the jet enters the well and, having passed under the end of the drill string, comes out to the surface along the string of rods.

1. Introduction
In the process of field development, while drilling wells, it is necessary to clean the bottom of the hole from cuttings and cuttings.

Wells flushing is one of the main tasks performed during drilling.

The primary purposes of flushing are the following:

- cleaning the bottom of the well from drilled rock and bringing it to the surface;
- cooling of rock cutting tools;
- strengthening of the borehole walls from collapse;
- removal of cuttings particles from the well; power transmission to a turbodrill or screw engine;
- prevention of oil, gas, and water entering the well;
- keeping drilled rock particles in suspension when circulation stops;
- cooling and lubrication of rubbing parts of the bit;
- reduction of friction of drill pipes against the borehole walls;
- prevention of rock falls from the borehole walls;
- a decrease in the permeability of the borehole walls due to crust formation.

The rate of separation of rock particles in the process of destruction of the borehole walls depends on the pressure of the column of drilling fluid and the hydromechanical effect of the fluid in the process of circulation. However, a significant positive effect of the pressure of the column of drilling fluid on the collapsing rocks will be only with a minimal flow of filtrate into the formation or its physicochemical strengthening effect on the rock. In plastic (creeping) rocks, the growth of the backpressure of the drilling fluid significantly complicates the development of narrowing of the wellbore. The reason is the physicochemical interaction of the drilling fluid with the rocks that make up the walls of the wells.
There are the following types of violations of the integrity of the walls of wells due to the interaction of the drilling fluid with rocks: rockfalls (talus); swelling; plastic flow (creep); chemical dissolution; erosion.

The stability of rocks is associated with the provision of continuous circulation of the drilling fluid during drilling in the presence of permeable rocks in the geological section. Most often, in the practice of exploration core drilling, such permeable zones are represented by aquifers. Depending on the reservoir pressure and the flushing agent used, the absorption of flushing fluid, water infiltration, and unstable circulation may occur. The absorption of drilling fluid increases the cost and sometimes makes it impossible to drill a well. Water infiltration deteriorates the quality of the flushing fluid during the circulation process and leads to additional environmental pollution. Unstable circulation complicates the drilling technology, maintenance of fluid quality, and its regulation [1-12].

Direct flushing is usually used and has the following advantages: first, the upward flow resists the collapse of the wellbore walls; secondly, sealing the inlet of the flushing stream does not encounter any particular difficulties and is structurally simpler than in the case of backflushing.

The advantage of backflushing is the better cleaning the bottom of the wells due to the high-speed drop of the jet at the bottom hole when passing from the annular gap between the tool and the borehole walls to the drill. Therefore, backwashing is sometimes used when drilling rocks that generate large amounts of cuttings and sand.

For wells operations, a pulsator was created – a vibrator for backwash. This goal is accomplished as follows:
- the body of the device has a through the channel, an upper and lower sub,
- a rocker valve is installed in the through the channel using an axis, consisting of a crank and a valve, connected by a finger,
- the body is provided with a flange on the outside, which has radial and longitudinal holes, which are equipped with attachments [13-14].

2. Methods and Materials

A pulsator-vibrator with a reversible valve creates oscillations of the flushing fluid with amplitude $\Delta P$ and frequency $\omega$. The frequency of the pulsator-vibrator depends on the flow rate of the flushing fluid $Q$ and the cross-sectional area of the vibrator $S$. The valve and the crank (striker) move inside the housing, strike it in a direction perpendicular to the axis of the device.

However, the casing absorbed these shocks and transmitted them to the borehole walls over a large area. The reason is the large body mass. As a result, the specific impulse transmitted to the walls decreases at a low speed, which entails a decrease in the energy of the shock impulse.

From the law of conservation of momentum, it follows that when the valve collides with the body, the following relationship is fulfilled:

$$M_{kor}V_{kor} = (M_{ud} + M_{kl})V_{cen},$$

(1)

where $M_{kor}$, $M_{ud}$, $M_{kl}$ are the mass of the body, striker, rocker valve, respectively; $V_{kor}$, $V_{cen}$ are the body, center of mass of the striker system, respectively.

From relation (1), the speed of the body after collision is determined:

$$V_{kor} = \frac{(M_{ud} + M_{kl})}{M_{kor}}V_{cen}.$$  

(2)

It is proposed to equip the device with a striker, which transmits an impulse from the striker directly to the borehole wall, bypassing the body of the pulsator-vibrator. The energy of the impulse transmitted to the borehole walls decreases by 20 times. The reason is that the body's mass is approximately 20 times greater than the mass of the striker with the overflow valve. The goal is to increase the energy of shocks transmitted to the wall.
The phases of movement of the rocker valve and the striker are displaced relative to each other. Therefore, it is advisable to link either with the rocker valve or with the striker. Since the mass and speed of the rocker valve is higher than that of the hammer, it is better to use a rocker hammer with a rocker valve.

The striker makes a rotational movement. The amplitude of displacement ($\Delta S_{ud}$) of the upper end for half a period is equal to the difference between the width of the flow section of the vibrato pulsator and the thickness of the striker. The average velocity of the upper end of the striker. The average speed of the upper end of the striker is

$$V_{ud} = \frac{2\Delta S}{T_{vib}}$$

where $T_{vib}$ is the oscillation period of the vibrator;

$$T = \frac{2\pi}{\omega}$$

where $\pi = 3.14$.

In turn, $\omega = 2\pi f$, where $f$ is the frequency of oscillations per second.

Since the speed of the striker changes from zero to the maximum at the moment of impact, it can be assumed that the speed of the striker at the moment of impact is approximately two times higher than the average speed of the striker:

$$V_{ud} = 2V_{ud,med.}$$

From where

$$V_{ud} = \frac{\omega \Delta S_{ud}}{p}$$

Impact impulse is determined by the mass and velocity at the center of mass of the striker:

$$K = \frac{M_{ud}V_{ud}}{2}$$

The maximum energy transferred to the striker will be equal to the energy of the striker itself:

$$T_{bk max} = \frac{J\omega^2}{2} = \frac{1}{3} M L^2 \left(\frac{V}{L}\right)^2 = \frac{1}{6} M_{ud} V_{ud}^2$$

Where $J$ is the moment of inertia about the axis of symmetry.

Of course, this is only possible under certain conditions. In order for the energy of the striker to be equal to the energy of the striker, the striker must stop after the impact, and this can be done only under the following conditions (laws of conservation of energy and momentum):

$$T_{ud} = \frac{M_{bk} V_{bk}^2}{2} = \frac{1}{6} M_{ud} V_{ud}^2$$

$$K_{ud} = M_{bk} V_{bk} = \frac{1}{2} M_{ud} V_{ud}$$

Having squared the second equation and dividing by the first, we determine the necessary mass of the striker:

$$M_{bk} = \frac{3}{4} M_{ud}$$

Thus, the optimal mass of the striker and the energy and momentum of a single blow has been determined.

The impacts can be strengthened by transferring the striker from the striker to the toggle valve because the valve moves with greater amplitude and, therefore, at a higher speed. The mass of the rocker valve is also greater than the mass of the striker. The valve makes a flat motion, which is like rotation around the instantaneous center of velocities. At the moment of striking the striker, the instantaneous center of velocities of the valve is at the very bottom of the valve. It can be assumed that
the instantaneous center of velocities is located at a point coinciding with the axis of the rocker valve.

The movement of the striker at the moment of impact coincides with the movement of the valve to use the same relationships. Only the speed during impact should be clarified. In one cycle, the valve makes four turns, instead of two turns of the striker; therefore, with the same dimensions, its speed is two times higher:

\[ V_{kl} = \frac{2\omega}{p} \Delta S_{kl} \]  

The kinetic energy and momentum are, respectively:

\[ T_{kl} = \frac{M_{bk}V_{bk}^2}{2} = \frac{1}{6}M_{kl}V_{kl}^2 \]  

\[ K_{ud} = M_{bk}V_{bk} = \frac{1}{2}M_{kl}V_{kl} \]  

With the mass of the striker equal to

\[ M_{bk} = \frac{3}{4}M_{kl} \]  

The pressure of the flushing fluid can carry out further amplification of the shocks.

3. **Results and Discussion**

The created pulsator refers to oil and gas wells designed for vibration impact on backwash during wells drilling. This vibrator improves drilling efficiency by generating vibrational backwash.

Figure 1 shows the structural diagram of the backwash pulsator.

The pulsator body 1 consists of channel 2, an upper sub 3, a lower sub 4. Through axis 5, a rocker valve is installed in the channel, consisting of a crank six and a valve 8, interconnected by a pin 7. 10, and 11 longitudinal holes; the latter is equipped with nozzles 12.

The pulsator-vibrator works as follows, with partial and backwashing. The device is installed in the arrangement according to the direction of the liquid flow of the circulation system. In this case, the liquid flow overshoots valve 8, which alternately opens and closes the channels 10. This algorithm is how the alternate pulsation of the liquid passes through the nozzles, the alternate washing of the sludge.
Figure 1. Structural diagram of the pulsator: a – diagram of the pulsator for backwashing; b – view A-A; в – section B-B; 1 – building; 2 – pass channel; 3 – upper sub; 4 – lower sub; 5 – axis; 6 – crank; 7 – finger; 8 – valve; 9 – flange; 10 – radial holes; 11 – longitudinal holes; 12 – nozzles

4. Conclusion
In the course of this work, a scheme of a pulsator designed for vibration action on backwash during well drilling was developed. Using mathematical calculations, it is shown that the use of the pulsator-vibrator operating mode allows more efficient washing. In addition, the developed vibrator increases the drilling efficiency by creating a vibrating backwash.

Thus, the pulsator-vibrator can be well controlled by the flushing liquid. The force is proportional to the area. Therefore, to obtain a significant impulse, it is necessary to achieve a significant internal area of the striker.

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