Well bottomhole cleaning device

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Abstract. Deterioration of bottomhole formation zone permeability is caused by mechanical pollution of porous medium, swelling of cement at its contact with water and accumulation of paraffin in low formation temperature deposits. In the process of oil production all extracted formation fluid: oil, water and gas pass through bottomhole zones of production wells and all water injected into formations – through the wellbore zone of injection wells. These processes occur at temperatures and pressures other than those at which these fluids (or gases) were originally on the surface or in the formation. As a result, different hydrocarbon components (asphalt-resin deposits) and different salts that fall out of the solutions as a result of thermodynamic equilibrium disorder can deposit in the wellbore zone, as in the filter. The choice of the impact method is based on the careful study of thermodynamic conditions and state of the wellbore zone, composition of rocks and fluids, as well as systematic study of accumulated production experience in this field.

1. Introduction
A productive formation containing gas, oil and formation fluid represents a complex hydrodynamic system in which physical and chemical processes are in a relatively equilibrium state prior to formation drilling.

During the operation of injection and production wells the permeability of rocks in the bottomhole zone decreases. Oil and gas formation was continually exposed to washing fluid impact at the stage of exploration works, as well as during drilling and throughout the whole period of operation up to formation development [1-5].

The main causes of pollution are as follows: penetration of killing or washing fluids into formations, swelling of clay particles in contact with fresh water, formation of water-oil emulsions, precipitation and deposition of asphalt-resin-paraffin components of oil or salts of produced water at the change of thermobaric conditions, accumulation of mechanical impurities and metal corrosion products in the wellbore zone, rock compaction as a result of hydrodynamic action on the wellbore zone during construction and operation of wells, fracture closing with the reduction of formation pressure. As a result of the above processes, the value of the colmataged net thickness can vary from 30 to 80% of the total penetrated thickness [6-11].

The choice of intensification method used in each case depends on many factors, in particular:
- type of collector;
- reservoir properties of the bottomhole formation zone;
- formation pressure;
2. Materials and Methods

In order to influence the wellbore zone, a device is developed, the vibration exciter of which represents a ball.

The proposed device consists of a housing, a central washing channel and side washing channels arranged radially at a certain angle. The ball is arranged on the central channel to interact with the seat. The bottom of ball vibration excitation unit is made as ribs. The upper part of the device ends with an adapter. In the process of fluid circulation due to formation of vortices around the ball, the latter oscillates, which includes periodic separation of the ball from the seat formed by ribs. The ball is lifted due to irregularities 3-5 mm high under it, through which the fluid flows. The flow rate under the ball is higher than above and around it, resulting in a load-carrying capacity.

The periodic opening and closing of the central flushing channel results in double circulation of the fluid. When the central channel is closed, the entire flushing fluid flow is supplied by the wellbore zone. A batch jet blow occurs. When the ball is separated from the seat, the fluid is directed through the central channel into the annular space of a well.

The diameter of the valve chamber shall be 2-3 times higher the diameter of the central channel. In this case, in the lower position of the ball valve, the fluid flows freely to radial holes.

3. Results and Discussion

The amplitude of the fluid differential pressure oscillation within the device is determined by the Bernoulli equation.

The fluid entering the device flows out through three holes (exit area S1, S2, S3) and the central hole of area S4, which can be considered as a hole in a thin wall.

Let us write the Bernoulli equation for jets flowing out of the radial channels and the central opening:

\[
\frac{aV^2}{2g} + \frac{P_0}{\rho g} = \frac{a_1V_1^2}{2g} + \frac{P}{\rho g} + \xi_1 \frac{V_1^2}{2g},
\]

\[
\frac{aV^2}{2g} + \frac{P_0}{\rho g} = \frac{a_2V_2^2}{2g} + \frac{P}{\rho g} + \xi_2 \frac{V_2^2}{2g},
\]

\[
\frac{aV^2}{2g} + \frac{P_0}{\rho g} = \frac{a_3V_3^2}{2g} + \frac{P}{\rho g} + \xi_3 \frac{V_3^2}{2g},
\]

\[
\frac{aV^2}{2g} + \frac{P_0}{\rho g} = \frac{a_4V_4^2}{2g} + \frac{P}{\rho g} + \xi_4 \frac{V_4^2}{2g},
\]

where \(a_1, a_2, a_3, a_4\) – Coriolis coefficients for fluid flow in the device, the first, second and third channels, in the central opening, respectively; \(V\) – flow rate inside the device; \(g\) – gravity acceleration; \(P_0\) – pressure inside the device; \(\rho\) – density of the washing fluid; \(V_1, V_2, V_3, V_4\) – jet velocity; \(p\) – fluid pressure in the bottomhole zone; \(\xi_1, \xi_2, \xi_3, \xi_4\) – coefficients of overall resistance of channels and the opening.

The Coriolis coefficient for steady state flow is determined by the flow mode, which in turn depends on the Reynolds number:

\[
Re = \frac{Ud}{v},
\]

where \(U\) – fluid flow rate; \(d\) – pipe diameter; \(v\) – kinematic viscosity of the fluid.

The fluid motion can be considered to be established in view of the small size of the device and the high propagation velocity in the fluid. Considering that the velocity \(U\) depends on the volumetric flow rate \(Q\) and the internal diameter of the device \(d\) from the formula we obtain:

\[
Re = \frac{4Qd}{\pi d^2 v} - \frac{Q}{d v}.
\]
The calculations show that the fluid motion in the device is turbulent and the $a_1, a_2, a_3, a_4$ coefficients can be taken as one.

The resistances when flowing through the radial channels are mainly determined by local resistances. The resistance factor for the conical nozzle at an optimal angle $\beta = 13.24$ is 0.06 – the same as for the hole in the thin wall, so $\xi_1, \xi_2, \xi_3, \xi_4$ can be taken equal.

The fluid velocity in a bit is defined as follows:

$$U = \frac{Q}{\pi d^2/4} = \frac{4Q}{\pi a^2}. \quad (7)$$

The fluid flow rate through the central holes and channels will also make $Q$.

$$S_1V_1 + S_2V_2 + S_3V_3 + S_4V_4 = Q, \quad (8)$$

where $\varepsilon_4$ – jet compression ratio when flowing through the holes ($\varepsilon_4 = 0.64$).

Considering the channels to be the same, we get the following equation system:

$$\frac{V^2}{2g} = \frac{v^2}{2g} \left(1 - \varepsilon\right) + \frac{p - p_0}{\rho g}, \quad (9)$$

$$3S_1V_1 + 4\varepsilon_4S_4V_4 = Q,$$

$$V = \frac{4Q}{\pi d^2}.$$

From which we get

$$V_1 = V_4 = \frac{Q}{3S_1 + 4\varepsilon_4S_4}, \quad (10)$$

$$p - p_0 = \rho Q^2 \left(\frac{4}{\pi d^2}\right)^2 \left(\frac{1}{3S_1 + 4\varepsilon_4S_4}\right)^2 / 2. \quad (11)$$

Thus, we determined the pressure drops in the device when the ball is raised. In the case where the ball closes the opening, the pressure drop can be determined by the same formula, considering $\varepsilon_4 = 0$:

$$(p - p_0)_{\text{ball}} = \rho Q^2 \left(\frac{4}{\pi d^2}\right)^2 \left(\frac{1}{3S_1 + 4\varepsilon_4S_4}\right)^2 / 2. \quad (12)$$

The pressure pulsation can be determined from the formulas:

$$\Delta p = \frac{\rho Q^2 \left(\frac{4}{\pi d^2}\right)^2 \left(\frac{1}{3S_1 + 4\varepsilon_4S_4}\right)^2}{18S_1^2(3S_1 + 4\varepsilon_4S_4)^2}. \quad (13)$$

The jet pressure on the well wall generated by the channel is determined as follows. The enlargement in the jet section can be neglected. The pressure force on the well walls depends on the fluid density, the flow rate, the cross-sectional area and the angle $Q$ formed by the incident jet with normal to the surface:

$$N = \rho S_1V_1^2(1 - \sin Q) = \rho S_1 \frac{Q}{3S_1 + 4\varepsilon_4S_4}(1 - \sin Q).$$

4. Conclusion

The laboratory and field studies showed high performance of this device.

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