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A method for reverse cementing of casing pipes

(57) Abstract

The invention relates to oil well drilling and can be used in gas and oil producing industry. The object of the invention is the improvement of the reliability of the determination of the time of the inflow of cement slurry in a casing pipe. A labeled aerated spacer fluid is pumped into the annular space ahead of the path of the cement slurry. For this, the gas volume content in the spacer fluid is maintained at not less than 0.5% under the well-bottom conditions. At the borehole bottom in the casing pipe, acoustic waves are generated and recorded. The time for the circulation of the kick of spacer fluid is determined by the acoustic wave amplitude having a value of zero. The use of the offered method makes it possible to realize the process of the reverse cementing and to stop it exactly at the desired moment, and it allows expenditures of time and money to be reduced significantly. 1 table.

The present invention relates to the drilling of oil and gas wells and can be used in the gas and oil producing industry.

The object of the invention is an improvement in the reliability of the determination of the time for the inflow of cement slurry in a casing pipe.

As follows from the experimental data (Table), at a gas volume content of 0.5% or more, acoustic waves generated in the casing pipe using an acoustic cement bond logging apparatus (ACBL) are completely attenuated. Therefore, the intentional aeration of a spacer fluid makes it possible to determine the time for the inflow of the cement slurry into the casing pipe from the acoustic wave amplitude damping, which gives the exact time to stop the cementing process.

The method is realized in the following manner.

The downhole device of the ACBL-apparatus is lowered with the help of a hoist cable into the casing pipe prepared for cementing and equipped with a lubricator. The device is installed in the lower part of the casing pipe at a distance of 15 – 20 from its shoe, and a kick of 1.0 -1.5 m^3 of the aerated spacer fluid is pumped into the annular space. The level of the aeration should be such that there will be not less than 0.5 vol% of gas in the spacer fluid normalized for the conditions at the bottomhole of the given oil well. Then the cement slurry is pumped in. At the same time, the ACBL-apparatus is switched on and adjusted in accordance with its operating manual; then, acoustic waves with an amplitude A_x are continuously generated and recorded by a log camera. The control over the cementing process is implemented visually by observing the A_x amplitude values.

In the process of cementing, a flushing liquid that is forced out from the annular space goes into the casing pipe and passes by the downhole device of the ACBL-apparatus. The A_x amplitude values remain close to its maximal values. When the aerated spacer fluid inflows into the casing pipe, the value of the A_x amplitude sharply drops to zero, which is the indication that the spacer fluid inflows into the casing pipe. The following increase of this amplitude indicates that the mixture of the spacer fluid and the additive begin to come into the casing pipe. A further increase in A_x to a value that is close to the maximum means that pure cement slurry begins to inflow into the casing pipe. This point in time will indicate the end of cementing.

Example. In the experiments carried out for studying the quality of the cementing [process] in a well with a depth of 3900 m and a borehole cased with a 254 mm-pipe, a 506 m length of producing string with a 60.3 mm diameter was lowered into a 146 mm-casing pipe that was 510 m in length, and this was cemented. The lower part of the casing pipe was capped and the casing pipe was filled with a drill fluid, the density of which was 1.35 g/cm^3. The control head had a specialized end for reverse circulation.

The downhole device of the ACBL-36 apparatus was lowered with the use of a hoist cable to a depth of 491 m inside the producing string equipped with a lubricator. Then 0.5 m^3 of aerated spacer fluid with an aeration level of 4.5 calculated according to the method given below was pumped into the space between the casing pipe and the producing string.

The density of the gaseous phase under the bottomhole conditions was determined approximately as the mass ratio of 1 kmole of air to the molar volume of the air, equal to 0.2 m^3/kmole:

$$\rho_2 = \frac{29}{0,2} = 145 \text{ кг/м}^3,$$

where 29 kg/kmol is the mass of 1 kmole of air.

The water solubility of air is determined from:

$$C = \frac{\mu_2 G}{\rho R} \cdot \frac{P}{T},$$

where μ_2 = mass of 1 kmole of air;

G = maximal volume of the air dissolved in 1 m^3 of water;

P = bottomhole pressure;

R = gas constant;

T = absolute temperature;

ρ'_1 = density of the water in the spacer fluid.

It is known that the maximal gas solubility in 1 m^3 of water under thermobaric conditions is 4 m^3/m^3. The volume of water $\rho'_1 = 1000$ kg/m^3 is taken at T = 15.55 °C and P = 1 kgf/cm^2.

$$C = \frac{29 \cdot 4 \cdot 1}{1000 \cdot 289 \cdot 0{,}082} = 0{,}005$$

From this, the mole fraction of the water vapor under the bottomhole conditions can be found. The pressure of the vapor saturation is usually taken as 1 kgf/cm^2 according to the Osborne-Meyers formula. At a bottomhole pressure of 51 kg/cm^2, we have ($\psi = \frac{P_H}{P}$) $\psi = \frac{1}{51} = 0{,}02.$

The concentration of the water in the gaseous phase is determined from the formula

$$K = \frac{1}{1 + \frac{1 - \psi}{\psi} \cdot \frac{\mu_3}{\mu_3}},$$

where μ_3 is the mass of 1 kmol of the gas mixture;

$$K = \frac{1}{1 + \frac{1 - 0{,}02}{0{,}02} \cdot \frac{29}{18}} = 0{,}0125.$$

The volume of the gas under the bottomhole conditions should be 0.5% of the volume of the fluid phase, i.e. 0.0025 m^3.

In all: the volume of the spacer fluid $V_{s.f.} = 0.5 + 0.0025 = 0.5025$ m^3; the weight of the air G_g = 145 • 0.0025 = 0.38 kg; the weight of the water G_w = 0.5 • 1000 = 500 kg.

The density of the spacer fluid under the bottomhole conditions should be

$$\rho = \frac{500{,}18}{0{,}5025} = 995{,}4 \text{ кг/м}^3.$$

The ratio of the air volume to the water volume, taking into consideration mutual transition of the phases under the influence of T and P

$$\beta = \frac{\rho_1 - \rho}{\rho - \rho_2} = \frac{1000 - 995{,}4}{995{,}4 - 145} = 0{,}0054,$$

where ρ_1 = is the density of the fluid phase;

ρ_2 = is the density of the gaseous phase;

ρ = is the density of the spacer fluid.

The ratio of the air mass to the fluid phase mass

$$\delta = \frac{\beta \rho_2 (1-K) + C}{\rho(1-C) - \beta \rho_2 (1-K)} =$$

$$= \frac{0{,}0054 \cdot 145(1 - 0{,}0125 + 1000 \cdot 0{,}005}{1000(1 - 0{,}005) - 0{,}0054 \cdot 145(1 - 0{,}0125} =$$

$$= 0{,}0058$$

or

$$\delta = \frac{\mu_1}{\mu_2} = \frac{\rho_2 V_2}{\rho_1 V_1},$$

where V_1 = discharge of the gaseous phase;

V_2 = discharge of the fluid phase,

i.e.

$$0{,}0058 = \frac{1{,}29 \cdot V_2}{1000 \cdot V_1}.$$

The minimal level of the aeration is

$$\alpha = \frac{V_2}{V_1},$$

then

$$\frac{V_2}{V_1} = \alpha = \frac{1000 \cdot 0{,}058}{1{,}29} = 4{,}5.$$

Then, the calculated volume of a cement slurry in the amount of 5200 L was pumped in. Simultaneously, the apparatus ACBL-36 was switched on and calibrated, and A_x was at its maximum magnitude. Eight minutes after the beginning of cementing, the A_x amplitude rapidly (2 – 3 s) dropped to zero and remained at that level over about 30 s, and then it rapidly (5 – 6 s) reached the previous maximal magnitude. At this point in time, the cementing process was stopped. Immediately, the downhole device for the ACBL was raised to 250 m from the wellhead and the cemented producing strings were left to allow the cement harden completely.

After 24 hours, the downhole device for the ACBL-36 was lowered to the depth of 481 m from the wellhead and set on a cement column. After the experiment had ended, the cemented producing strings were lifted and processed. From this, the cement column was determined to be present at a depth lower than 483 m from the wellhead.

The use of the described method allows the realization of a reverse cementing process with the ability to end the process at exactly the desired moment. It allows a significant reduction in the expenditure of time and money connected with drilling out extra cement columns in casing pipes.

Fluid	Density, in g/cm^3	Pressure, in MPa	Volume gas content, in %	A_x amplitude, in r.u. (relative units)
Process water	1.00	0.0 0.2 0.5 1.0	0.50 0.25 0.10 0.05	0.00 0.52 0.85 0.94

		5.0	0.01	0.99
Drilling mud	1.16	0.0	1.20	0.00
		0.2	0.60	0.00
		0.3	0.40	0.25
		1.0	0.12	0.78
		5.0	0.02	0.96
Heavy mud	1.86	0.0	7.50	0.00
		1.5	0.50	0.00
		1.7	0.44	0.08
		5.0	0.15	0.71
		10.0	0.08	0.87
Portland cement-based cement slurry	1.83	0.0	3.50	0.00
		0.7	0.50	0.00
		0.8	0.44	0.09
		2.0	0.18	0.58
		10.0	0.04	0.93

Claim

A method for the reverse cementing of casing pipes, comprising a labeled spacer fluid being pumped into the annular space prior to the pumping in of a cement slurry and tthe point in time when the cement slurry inflows into the casing pipe being subsequently recorded by using geophysical equipment, wherein in order to improve the reliability of the determination of the point in time when the cement slurry inflows into the casing pipe, the spacer fluid is labeled by aeration and the volume content of the gas therein is kept at the level of not less than 0.5% under the conditions of the well bottom, and acoustic waves are generated and recorded at the bottomhole in the casing pipe, and the point in time of the spacer fluid inflow is determined by when the acoustic waves have an amplitude of zero magnitude.