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The Research of Continuous Sand Washing on Well Dislocation Sand Spit

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Abstract: **In the process of workover, some dislocation wells prone sand and rock spitting phenomenon which resulting in no advancing in sand washing, stuck tubing string, the channel cannot be opened up, the fracture cannot be sealed and other problems that holds the repairing success rate low. This phenomenon has huge impact on the district block injection and production adjustment. Predicting the sand spitting state for dislocation well in advance, taking appropriate measures to continuously flush the settling sand and the spit rock at the bottom of the well to the ground, are the keys to restoration of governance of dislocation well. In this paper, by numerical simulation, the form of sand and rock spitting of the dislocation wells are analyzed by numerical simulation, measures which could effectively repair the wells are proposed.**

Keywords: Dislocation; Sand spit; Rock spit; Numerical simulation; Continuous sand washing

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1. Introduction

During the construction of oil wells, sands jam-up in wellbore volume which needs to be addressed often occurs, the situations can be divided into two categories, one is fracturing or sand sinking with small particle size, no ejection pressure and other characteristics, which is easier to be deal with; the other category is, the casing is damaged, the formation sand, rock go into the wellbore, with larger particle size, the presence of ejection pressure, the treatment is more difficult relatively, the success rate is low. For sand production wells, several problems need to be solved: First, no footage grinding in punch jobs, often accompanied by stuck string phenomenon; the second is fast return of rock dust after the well is open, you cannot pour a single; Third, the follow-up of sand washed sand to fracture fast, difficult to drill a passage [1-2]. This paper analyzed the maximum size of sand particle in the washing liquid to determine a reasonable sand washing liquid density, using targeted continuous sand washing technology, enhancing understanding for the grit, sand spit of the well, improving the success rate of treatment, which has great significance to restore oil well normal production, ensure capacity construction of production blocks.

2. Analysis of Sand Spit for Sleeve Dislocation Well

The dislocation casing damages occurs in oil well are mainly caused by strong shear stress, flooding in a large area of shale, tilt of a large area, slip layer under high pressure. From the perspective of the sleeve bearing, when the casing shear stress is greater than the casing's critical shear stress values, the dislocation would happen:

$$\tau = \frac{4 d_{\mathrm{w}} h p}{\pi (d_{\mathrm{w}}^2 - d_{\mathrm{n}}^2)} \geq [\tau]_{xu} \quad (1)$$

Where:

d_w is the outer diameter of the casing;

d_n is the inner diameter of the casing;

h is the depth of the dislocation of the casing;

p is the pressure of the casing.

After the casing dislocation happen, rocks around the dislocation area can be damaged with external power input, so the cavity is formed near the fracture area. Once the cavity is formed, it will cause stress concentration, further destruction will happened to the rock structure [3-4], resulting in spit of sand. When the layer of sand spit a lot of rock, upper layer would lose support, the original balance is broken, resulting in vertical deformation, and even collapse, the collapse of the upper cladding layer will produce an arch profile, new balance is achieved, spitting of sand and rock ends.

3. Analysis of the Maximum Particle Size in the Washing Liquid

After crushing the rock, a lot of rocks will enter the casing through the dislocation fracture, the rocks with smaller size can be carried to the ground by the sand washing fluid, but when the rock size exceeds a certain value, because the buoyant force to the rock cannot overcome its own gravity, these rocks will be piled near the fracture area, greatly reducing the efficiency of sand washing [5].

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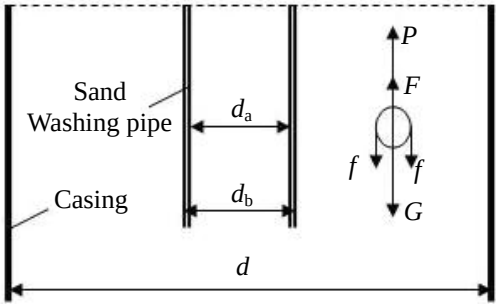

Figure 1. Diagram of forces the rock bearing in the process of washing.

With the analysis, the rock in the washing process are, bearing the hydraulic and buoyant force pointing up, bearing the friction and gravity force pointing down, if net force pointed up, the rock can be bring out of the wellhead:

$$P_c + F \geq f + G \qquad (2)$$

Where:

P_c is the hydraulic force of the washing liquid;

F is the buoyant force of the rock;

f is the fraction force of the rock;

G is the gravity force of the rock.

According to the fluid dynamics, flow and pressure have the following relationship:

$$\frac{Q}{A_1} = \sqrt{\frac{2\Delta P}{\rho_l\left[1-\left(\frac{A_2}{A_1}\right)^2\right]}} \qquad (3)$$

Where:

Q is flow rate in unit of m^3/s;

ΔP is the pressure difference, MPa;

$A_1 = \frac{\pi d_a^2}{4}$ is the cross section of the washing pipe, m^2;

$A_2 = \frac{\pi\left(d^2 - d_b^2\right)}{4}$ is the annular cross section, m^2;

ρ_l is the density of the sand washing liquid in unit of kg/m^3;

d_n is the inner diameter of the casing, mm;

d_a is the inner diameter of the sand washing pipe, mm;

d_b is the outer diameter of the sand washing pipe, mm. with

$$F = \frac{4}{3}\pi r_0^3 \rho_l g \qquad (4)$$

$$G = \frac{4}{3}\pi r_0^3 \rho_s g \qquad (5)$$

$$f = \frac{1}{2}\pi r_0^2 \rho_l C_d V_s^2 \qquad (6)$$

Where:

r_0 is the equivalent radius of rocks, m;

ρ_s is the density of the rock, kg/m^3;

C_d is the bypassing resistance coefficient of the flow;

$V_s = \frac{0.0408Q}{f_a\left(d_n^2 - d_b^2\right)}$ is the velocity of the rock, m/s;

$f_a = 1 - \left(\frac{2r_0}{d_n}\right)^{2.25}$ is the speed correction factor.

With the equations above, taking the extreme condition, one can get:

$$\Delta P\pi r_0^2 + \frac{4}{3}\pi r_0^3 \rho_l g = \frac{4}{3}\pi r_0^3 \rho_s g + \frac{1}{2}\pi r_0^2 \rho_l C_d V_s^2 \qquad (7)$$

$$\Delta P - \frac{1}{2}\rho_l C_d V_s^2 = \frac{4}{3} r_0 \left(\rho_s - \rho_l\right) g \qquad (8)$$

$$r_0 = \frac{6\Delta P - \rho_l C_d V_s^2}{8\left(\rho_s - \rho_l\right) g} \qquad (9)$$

4. Optimizing the Density of Sand Washing Liquid

In the process of continuously sand washing, not only the rocks need to be carried out by the fluid, but also the continuous sand phenomenon [6-7] should be avoided by not changing the pressure dramatically. The correlation between the rock density in the annulus and the drilling fluid velocity can be expressed as following:

$$\varepsilon = \frac{(1-\varphi)m}{(1-\zeta)(1+\zeta)} \frac{dH/dt}{V_m} \frac{\varepsilon_d}{1-\varepsilon_d} \qquad (10)$$

Where:

ε is the liquid containing ratio in the flow interface of the annulus;

ε_d is the liquid containing ratio in the flow cross-section at the wellhead;

$\frac{dH}{dt}$ is the mechanical drilling speed in unit of m/s;

ζ is the ratio of the well diameter to the drilling string diameter;

φ is the formation porosity;

m is the correction factor;

V_m is the circulating fluid return speed in unit of m/s.

Here we believe that the rock fragments needs to consume some energy from the mean flow while suspending in the flow, and transporting to the wellbore, thereby the flow resistance is increased [8] (Willy Kanuo Fu, Wilson's two-phase liquid-solid flow theory), the two-phase liquid-solid flow losses in the annulus

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can be expressed as:

$$\Delta P_{sm} = \Delta P_m + \Delta P_s \quad (11)$$

Where:

ΔP_{sm} is the total pressure loss of the two-phase liquid-solid flow in the well, MPa;

ΔP_m is the single-phase pressure loss of the drilling fluid, MPa;

ΔP_s is the pressure loss related with suspension and transportation of the rock fragments, MPa.

The minimum proportion of sand-washing mud can be derived by assuming the additional energy loss caused by the existence of rock fragments was used for maintaining its suspending status:

$$\rho_l g \geq \Delta P_{sm} / L_f \quad (12)$$

Where:

ρ_l is the mud density, g/cm^3;

L_f is the distance from the dislocation to the wellhead, m.

5. Continuous sand washing technique

Continuous sand washing means injecting sand washing liquid continuously to the well without stopping the pump, which will reduce or eliminate sand dropping back, will improve efficiency and success rate of the sand washing. Depending on well conditions, appropriate measures of sand washing should be applied to improve the success rate of construction [9-11].

(1) Wheel drive continuous sand washing technique

For the wells which have active large fracture, rock and sand spit, wheel drive continuous sand washing technology is often applied. The technology relies on the turntable plate to supply power, and the plate is connected with a dedicated ground sand washing system, using a single string of sand washing column, and a variety of sand washing tools are connected to the string down in the well, some tools, like milling cone, grinding shoes, tip cone milling, grinding and other rock drilling and milling tools, are used to fulfill the construction requirements.

Typical construction parameters:
Drilling pressure 20-30 KN;
Flow rate 1.2-1.5m3/min;
Pump pressure 5-8Mpa.

(2) Screw drill drive continuous sand washing technology

Figure 2. normal milling and sand washing tools

For the wells with large amount of sand spit, small sand particles without dislocation, the screw drill is connected to the bottom of the sand washing system to perform continuously sand washing. The technology which relies on the screw providing drilling and grinding power, can be connected to a dedicated ground sand washing system, using a single string of sand washing column, and the screw drill and other sand washing tools are connected to the string down in the well to achieve the construction requirements.

Typical construction parameters:
Drilling pressure 10-20 KN;
Flow rate 0.5-0.7m3/min;
Pump pressure 3-5MPa.

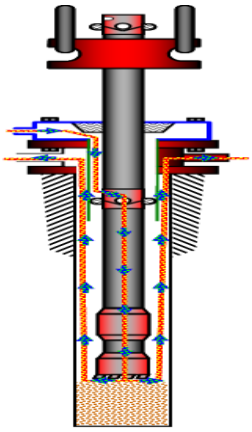

Figure 3. Screw drill drive continuous sand washing

(3) Continuous coiled tubing sand washing technology

For the wells with small sand particles sinking at the bottom, it is good to use continuous coiled tubing sand washing technology. The technology has high construction efficiency, high sand washing speed and other characteristics. This technology mainly relies on continuous flushing swivel head, nozzles and other tools to achieve sand washing construction [12].

Typical construction parameters:
Tube size 2″, 23/7″;
Flow rate 0.8-1.5 m3/min;
Pump pressure 20-30 Mpa.

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Figure 4. Continuous coiled tubing sand washing

(4) Chemical slug sand washing technology

Because of special injection medium, the returned effluent has high viscosity jamming the well by forming colloid which prevents the sand washing to proceed. In such situation, special chemical slug sand washing technology needs to be applied, the basic principle is using continuous sand washing apparatus and workover fluids flush out sand particles and rocks floating within the wellbore, and using thinner or viscosity reducer to soak the clogging parts, once the blockage reduce viscosity and strength, the sand washing procedure could be resumed. The lower part of the string has rock-breaking tools with water hole attached, and according to the status, sufficient number of wells collars are equipped to increase the capacity of anti-pressure for the tubing string.

Typical construction parameters:

Drilling pressure 10-20KN;

Flow rate: 0.611.0m3/min;

Pump pressure 5-8 MPa;

Clearing the plug time 10-20min.

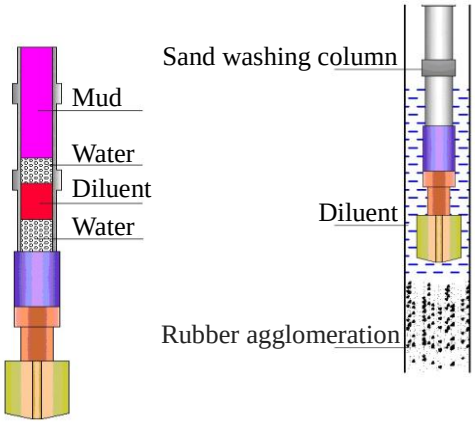

Figure 5. Chemical slug sand washing technology

6. Field Applications

Wheel drive, screw drill drive, coiled tubing sand washing technologies are well applied in the field. Among these technologies, because of its high efficiency and more environmental friendly performance, the coiled tubing sand washing technology is used more widely. One the other hand, the chemical slug sand washing technology is a dedicated technology which is currently in the experimental stage, aimed to solve the problem with three mining blocks class sand spit well, field test applications have shown some good results.

For example, well No. xx-xx, the lead-mode print indicates sand existence at 707.0 m, the mud density is 1.5g/cm3 which cannot be washed, with calculation, it is believed that the returned fluid viscosity is high which blocked the wellbore. With special sand washing tools consist of Φ118mm three drag bit + single valve + Φ105mm drill collar + Φ73mm drill pipe dropped down into the well, circulated fresh water into the well to shift the mud out, then pumped 2.0 m3 fresh water to clean the blockage top, then used 2.0 m3 thinner and viscosity reducer to reduce the blockage's viscosity, 2.0 m3 water acts as a protective liquid, 1.5g/cm3 mud. Circulation pump with flow rate of 0.5 m3/min, 2.5 m3 of liquid is pumped in, soak for 10 min, only small milling footage of 0.2 m. 0.5 m3 of liquid is pumped in again, soaking for 20 min, milling footage is more obvious, wellhead flooding increased, with pump working, the blockage is opened and the washing equipment rushed to 847.3 m encountered blockage again, lead-mode print indicated the casing deformed and broken, diameter is shrunk to Φ107 mm. With the nib-type milling cone used to reshape the casing, the passage diameter opened up to Φ118 mm, removed the falling objects, used expansion pipe to reinforce the casing, after the pressure test the workover is complete.

Figure 6. the sand and rock spit from the well

7. Conclusion

This article analyzes the mechanism of the sand and rock spit theoretically and provides the corresponding methods for specific working conditions. The results have significant impact on the sand washing process of workover, which will help to determine the working fluid density for specific circumstances. By using a dedicated continuous sand washing technology, the pump do not need to be stopped which will largely reduce the operating time, the labor intensity, the formation damage, and the construction costs, and improve the construction efficiency.

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