Device for removing proppant deposits formed in wells after hydraulic fracturing

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Abstract. The sediment of the mechanical impurities, salts, undecomposed gel, destroyed proppant is systematically accumulated after the hydraulic fracturing in the horizontal well. This process is negative for the well operation and requires additional flushing to remove sediment. If this sediment is not removed, then ultra viscous gelatinous crust is formed. The energy of the jet of the working fluid is insufficient to effectively destroy the resulting gelatinous mass in the wellbore. The paper analyzes the existing technological solutions and proposes a device developed by the authors, which allows the destruction of proppant sediments. Application of the device described in the paper will contribute to more efficient production of hydrocarbons after hydraulic fracturing.

1. Introduction
Nowadays, the structure of hydrocarbon reserves is changing for the worse [1]. The principle problems of oil and gas companies are to reduce the cost of oil production in the context of volatile prices for hydrocarbons and to maximize the hydrocarbon recovery factor at old fields [2]. The use of new technologies of the intensification of output will allow Russian petroleum companies to remain competitive on the world market during decades [3]. One of the most effective technologies for production stimulation is hydraulic fracturing. Frequently, well development after hydraulic fracturing leads to an active flow of proppant from the formed fractures in the reservoir [4]. The proppant, together with the undistorted gel, settles in the wellbore. In order to conduct a successful well development, it is necessary to limit the magnitude of the reservoir depression, flow rate, and pressure gradients. During the operation of the well, complications may appear that makes it difficult to remove the proppant crust by flushing. The crust is a proppant layer with reduced permeability. A decrease in permeability occurs only in the presence of smaller impurities (sand, suspension in solution, the use of bound polymers without breakers, carbonate chips) [5].

The reasons for crust formation are geological and technological factors. The crust is formed as a result of the precipitation of small proppant particles, mechanical impurities from the working fluids of hydraulic fracturing. In the formation of a hard-to-break crust, carbonate, clayey rocks, not destroyed under the influence of reservoir temperature, hydraulic fracturing reagents, and mineral salts act as a cementing material. In some cases, viscous oil emulsions and resins are the "cement" for crust formation [6].

The formation of cement materials with the formation of proppant crust is connected with the partial destruction of the well bottom zone, or with the elastic deformations of casing string and the flaking of
the lamellar remainders of concrete block. They are formed with the insufficiently thorough cleaning of borehole during drilling out of cement bridges. In directional wells with the high values of zenith angle and curvature intensity, “the obstructions” can be formed from different sediments, including from the fragments of cable bands, which settle on the well bottom hole. In 80% of cases, the reasons for the formation of a crust or plug in horizontal sections of wells are eliminated by compliance with technologies in preparation for hydraulic fracturing: correct cleaning of the wellbore with scraper and brush assemblies, use of clean and correctly inhibited fluids, maintaining constant repression to the formation. High-quality cleaning requires additional costs, but it has a positive effect on the development after hydraulic fracturing and on the turnaround time of the well.

2. Materials and methods
This paper analyzes the experience of using technological equipment for flushing a wellbore after hydraulic fracturing. The studies on the development of hydropercussion device with the ability to adjust the angle of inclination were carried out to solve the problem of removing the proppant crust from the horizontal section of the wellbore. The survey of literature and patent analysis is carried out. The device for the removal of crust from the horizontal section of wellbore is developed on the basis of the specific deficiencies in the known technical solutions.

3. Research results
Let us consider the possible methods of destruction of the hard-to-break crust formed in vertical and directional wells. Theoretically, the proppant crust can be drilled out using one of the types of rock cutting tools. However, using a rotary hydraulic power unit in this case will be ineffective from an economic and technical point of view.

Certain successes were achieved when flushing the contaminated area with a circulating fluid flow by generating hydrodynamic impulses. Schematically process is represented in the Figure 1. To obtain a positive effect when using this method in the wellbore, it is necessary to create optimal conditions [7]. However, the costs of well workover and maintenance are increasing. In particular, the costs for the excess consumption of the flushing agent and for the operation of the equipment increase.

To use the assembly for generating hydrodynamic impulses in horizontal wells, it is necessary to modify the device for more efficient operation in conditions of proppant deposition at the bottom of the inner surface of the horizontal wellbore. In such conditions, it is more effective to destroy the sediment layer mechanically. The use of the existing technical solutions does not make it possible to completely move away proppant crust in the wellbore (Figure 2).

Figure 3 shows an assembly that cleans the inner cavity of the well [7]. The jet nozzles of the cleaning head are located on the exterior part of the device. The packing ring installed on the body of the device compresses the clearance between the base of the device and the cleaned wall. The channels of device housing and cleaning head communicate with each other. The cleaning element of head is established with the possibility of the limited axial displacement relative to housing. The breaker mechanism and the adapter use a common hydraulic channel. The described assembly gets down to the interval of complication.
Figure 1. The result of the impact of hydrodynamic impulses in vertical and directional wells

Figure 2. Formation of a proppant crust at the bottom of the inner surface of a horizontal wellbore

1 – housing; 2 – sphere; 3 – input cavity; 4 – output cavity; 5 – axial channel; 6 – ledge; 7 – cleaning head element; 8 – groove; 9 – toroidal camera; 10, 11 – the cutting elements; 12 – spring; 13 – nut; 14 – casing; 15 – the adapter nut; 16 – branch pipe; 17 – seal.

Figure 3. Diagram of a device for removing mechanical impurities deposits in a wellbore

The device moves translationally due to the pressure of the flushing agent until it comes into contact with the sediment layer. After the stop by the knives of cone or by the scraping elements of front head, the annular channel is formed. The liquid enters the nozzle holes of front head through this channel. The flow of the flushing agent acts on the deposits, simultaneously rotating the head, which removes the
deposits washed away by the flow of working fluid with knives and scrapers. Often deposits have the increased strength; therefore it is impossible to move them away by the represented device. When returning the device to the initial position the difficulties can arise.

A coiled tubing conveyed downhole assembly named hydraulic hammer is used for the destruction of dense proppant plugs. The analysis of the hydraulic shock devices operation with cleaning of the bottom of gas and gas-condensate wellbores showed that the hydraulic hammer is highly effective. The schematic of hydraulic hammer is shown in the Figure 4. Configuration consists of hollow housing which contains circulating openings, seats, front valve, annular piston, fixed on the hollow spring-opposed stock, crown with the teeth, choke and jet nozzle. The stem is located in the housing. A seat is provided between the housing of the hydropercussion device and the adapter. Hollow stock is spring-opposed and passes into the axial channel of adapter. The crown is connected to an annular piston, which forms an end channel with the seat. The piston closes the housing circulation openings. The design of the annular gap between the stem and the adapter provides for a hydraulic connection with the stem and seat [8].

![Diagram of a hydropercussion device](image)

1 – the base of hydraulic hammer; 2 – landing groove; 3 – transition element; 5 – annular piston; 6 – conical groove; 7 – conical surface; 8 – circulating openings; 9 – axial channel; 10 – hollow stock; 11 – the bearing disk; 12 – spring element; 13 – annular slot; 14 – radial channel; 15 – axial channel; 16 – crown; 17 – teeth; 18 – jet nozzle; 19 – annular chamber; 20 – radial channels; 21 – axial channel; 22 – opening; 23 – choke; 24 – the destructive teeth; 25 – fastener with the tapped hole

Figure 4. Diagram of a hydropercussion device

The application of this device makes it possible to ensure the mechanical destruction of sandy-argillaceous, or proppant plug due to the impact action by the teeth of crown on the layer of deposits. For the work of the device, the percussion device, which receives excess pressure with the sectional area of stepped piston under the seat, which has larger diameter, is used. Figure 5 schematically shows a fracture and sediment removal assembly adapted for use in a horizontal wellbore. The configuration consists of a hydropercussion device 1, which is connected through a rotary kinematic pair 2 with coiled
tubing 3. Joint 2 is equipped with a spring centralizer 4. The centralizer can be folded relative to the housing, freeing the annular channel for the passage of the working fluid with mechanical particles. The feature of the assembly is to change the angle of inclination of the hydropercussion device 1 in the rotary kinematic pair 2. The internal diameter of the coiled tubing 3 is considered to the selecting of the angle of inclination. Destructive bits 5 should come into contact with a layer of deposits of destroyed proppant particles 6, but not affect the metal of the well production casing 7. This position of the hydraulic hammer, oriented towards the bottom, provides an optimal position in relation to the layer.

Figure 5. Diagram of the developed device for effective destruction of the formed gel-like mass in the horizontal wellbore

The dimensions of hydro-percussion device are selected for the purpose of the guarantee of free displacement, effective work and safe extraction of device from the wellbore after the finishing of cleaning processes.

Description of hydro-percussion device operation

The hydro-percussion device is connected to the threaded joint of the coiled tubing 3 due to the rotational kinematic pair 2. After checking the tightness of the assembly, the device is lowered into the well down to the horizontal wellbore 7. To supply flushing fluid to the hydro-percussion device, a special unit is connected. The flushing fluid is supplied at a design pressure and at a certain flow rate.

Hydro-percussion device 1 works due to the progressive displacement along the axis of piston. In order to return the piston to its original position, a spring is installed. For mechanical action on the layer of deposits, the piston is equipped with a toothed crown 5. Piston is deflected from its initial position because of an increase in the pressure of washing agent in coiled tubing 3 and an instantaneous increase in the flow rate of washing agent from the hydro-percussion device 1. When the piston with a crown deviates from its initial position, additional openings are freed. Washing liquid leaves through these openings into the wellbore. Pressure in the channel of coiled tubing 3 falls; therefore working tool returns to the initial position. Simultaneously with the return of the piston to its original position, the supply of the working agent through the additional channels is stopped. The working tool in the form of a destructive crown with teeth acts on the layer of deposits in an automatic mode, maintaining the supply of the working agent under the design pressure.
After analyzing the results of the practical application of coiled tubing for flushing plugs in vertical and directional wells, it was revealed that the optimal flow rate of a working agent through coiled tubing with a diameter of 25.4 mm should be 5 liter per second [1-8]. For the more qualitative delivery of destroyed proppant and mechanical particles to the wellhead it is necessary to use single-component and two-component two-phase foams. The creation of foam systems is ensured by alternately supplying the working agent and a portion of gas to the coiled tubing 3. Due to the fact that the foam has a high bearing capacity, during flushing, the destroyed proppant particles are transported to the wellhead by the reverse flow of the foam agent. The criteria of the optimum use of a hydro-percussion device are given in the Table 1.

Table 1. The technical characteristics of the device

| Parameter                                      | Value   |
|------------------------------------------------|---------|
| Optimum fluid flow through the hydraulic hammer, liter per minute | 60 – 100 |
| The limit of pressure of operating agent, MPa | 33      |
| Maximum diameter of a hydropercussion device, mm | 80      |
| Operating agent                                | Water based solution, foam systems |
| Diameters of coiled tubing                     | 50.8 and 25.4 |
| The limit of temperature in the working area °C | 140     |

4. Conclusion
A hydropercussion device, adapted for use in horizontal sections of the well, has been developed, which makes it possible to destroy the proppant crust in the shortest possible time and increase the rate of fluid recovery. Direct flushing using hydropercussion device creates a stable circulation. The design of the device ensures minimal losses of flushing fluid. The use of the proposed technical means for treating a horizontal wellbore, after hydraulic fracturing at the stage of development, makes it possible to successfully operate wells with design technological parameters.

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