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Development of Technological Complex for Removing Gel and Proppant from Well Bore

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***Abstract*—The problems arising from the backflow of proppant, rock particles, non-decomposed liquid from hydraulic fractures into the well bore are considered in the paper. The urgency of developing a device for flushing out in the horizontal well after formation hydrofracturing is proved. It is shown that solidified and viscoelastic particles of gel stick to the walls of a well. Later these zones of particles’ deposits decrease potential flow rates. On the basis of the conducted investigation, the authors developed a device for removing gel and damaged proppant which allows for cleanout of horizontal well bore after formation hydrofracturing. The main advantage of the proposed device is joint hydraulic and mechanic effect on deposits. In the operation of the unit, the rotation of the crown under dynamic head makes it possible to clean efficiently the surface over the entire circumference of the tube. It is proposed to use foam to act efficiently on deposits. Foam can be generated by the jet pump developed by the authors. As the treatment proceeds, the device can move in axial direction through the shifting of the coiled tubing. On completion of well flushing out, the nozzle cease to rotate and returns to its original position thus preventing from internal fouling of the device.**

***Keywords*—hydraulic fracturing; proppant; gel; hydraulic hammer; coiled tubing; jet pump; foam**

I. INTRODUCTION

Currently, the problem of proppant backflow out of the well after a hydraulic fracturing is very relevant. Such problem is encountered at the fields of Tatarstan, Bashkiria, Western Siberia, etc. There are many cases where tons of proppant flow back out of a fracture into a well, which decreases the potential of productive formations. In practice, the authors also observed the backflow of a significant amount of undecomposed hydraulic fracturing fluid. Some of the carrier fluid is not destructed even under the influence of the destructor. A mixture of mechanical particles, fragments of proppant, and undecomposed gel forms on the lower part of a horizontal well “sludge” – a hard to remove mixture. Subsequently the remains of solidified gel reduce the well productivity after hydraulic fracturing [1]. To improve the performance of such wells, it is necessary to mechanically and hydraulically influence deposits, and for better lifting of the destroyed particles one should alternately pump foam and flushing fluid to the well.

II. RESULTS AND THEIR DISCUSSION

In this paper, we performed an analysis of hydraulic fracturing at Western Siberia fields since 1991, which showed the following results: the amount of injected proppant per 1 meter of fracture increased every year, and in 2017 at some fields it reached 11-13 tons / m of formation thickness (Fig. 1). The increase in the mass of the injected proppant was made possible thanks to a set of measures aimed at improving the technology of hydraulic fracturing [2].

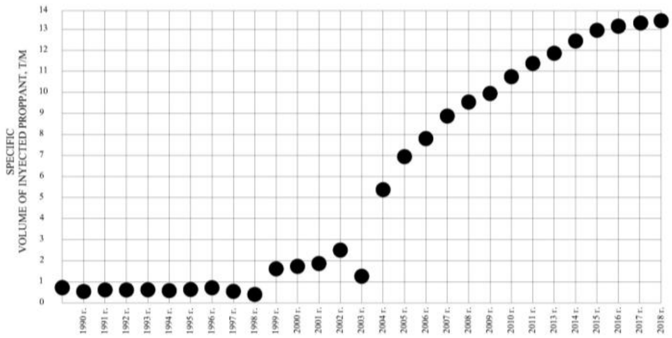

Fig. 1. The change in the average mass of the injected proppant per 1 meter thickness of the reservoir.

In this regard, during the development of the well after hydraulic fracturing, there may be cases of proppant backflow from the fracture. Together with the proppant, an undamaged gel, which was used to deliver the proppant to the fracture, is also removed from the fracture. The proppant and gel accumulate in a horizontal section of the wellbore. This is mainly due to the wrong choice of well development technology. Over time, the proppant layer is covered with crust, which increases its strength. In some cases, the particles of the viscous components of the oil emulsion, gel, resin with the density higher than that of the fluid in the well can serve as the "cement" (Fig. 2).

The resulting crust is difficult to destroy, for example, by a hydraulic jet. To remove proppant plugs, the appropriate equipment must be available.

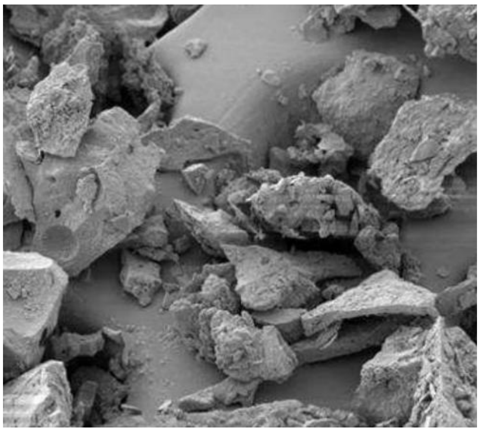

Fig. 2. Particles of gel, damaged proppant and mechanical impurities in the wellbore.

The authors have developed a hydraulic hammer that allows one to effectively deal with these deposits. Fig. 3 shows the design of the device for the destruction and removal of a layer of deposits, adapted to the conditions of use in horizontal sections of the well [3].

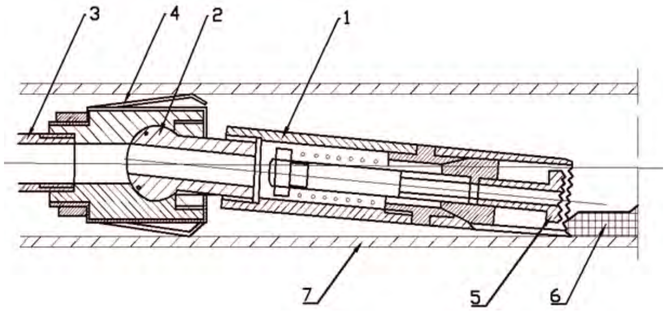

Fig. 3. The design of the device for the destruction and removal of sediment, adapted to the conditions of use in horizontal sections of wells.

1 – hydraulic hammer; 2 – swivel joint; 3 – coiled tubing; 4 – spring centralizer; 5 – destructive crown; 6 – deposit layer; 7 – metal casing

III. Operation of Hydraulic Hammer

Swivel joint 2 assembled with hydraulic hammer 1 is connected to the threaded end of coiled tubing string 3 and is introduced into the horizontal section of well 7. A pump unit is attached to coiled tubing string 3 of the coiled tubing unit, and working fluid is fed into the device under pressure. Hydraulic hammer 1 begins to work when the piston with destructive crown 5 at its end starts to perform reciprocating movement (Fig. 4).

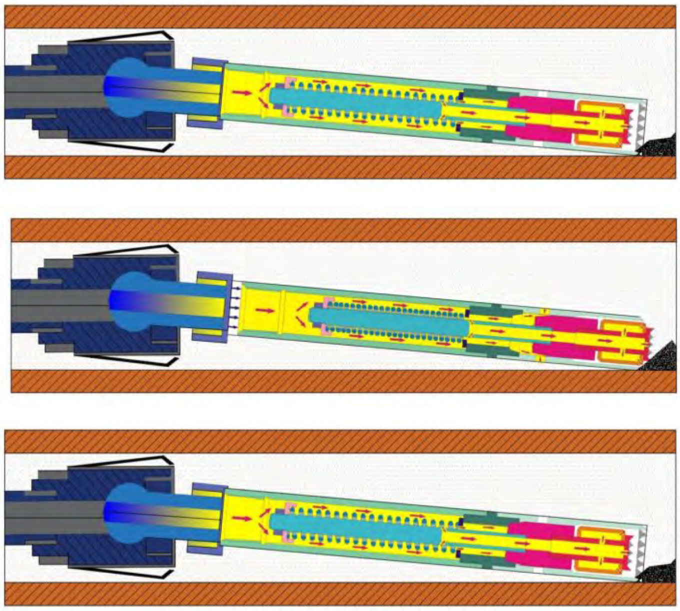

Fig. 4. The principle of operation of the hydraulic hammer.

This occurs when elastic volume of the working fluid accumulates in coiled tubing string 3, and the working fluid flow rate from hydraulic hammer 1 increases sharply due to the opening of additional channels during working tool travel. The pressure drop in the axial channel of coiled tubing string 3 leads to the return of the working tool to its original position, at the same moment the injection of the working fluid through the additional hydraulic channel is terminated. The deposit layer is automatically treated by the working tool provided the working fluid is injected under pressure.

The practice of using coiled tubing units shows that the optimal flow rate of the working fluid through a coiled tubing string with a diameter of 50 mm is Q = 5 l/s. To ensure the removal of particles, one can use foam systems. Foam can be generated by alternately feeding a portion of the working fluid and a gas pack into the axial channel of coiled tubing string 3. The foam is generated in the axial channel of the horizontal or inclined section 7. The known carrying capacity of the foam allows for the transportation of mechanical particles to the surface by reverse flow of the foam. The problem can be solved by using the jet pump developed by the authors (Fig. 5) to generate foam.

IV. Operation of Jet Pump

Passive medium supply pipe 2 is connected to the discharge line of the compressor through the quick connect coupling. Active medium supply pipe 18 is connected to the pump unit. The active medium is fed into axial channel 17 of supply pipe 18, from which it is supplied through supply channel 22 of sleeve 19 through slot gap 21 into tangential channel 16 and, and then it goes inside suction chamber 1. The flow enters into the axial passage of mixing chamber 5 along curved surface 13 of nozzle 11. In doing so the swirling of the flow takes place, and the radius of the flow swirling decreases. Since nozzle 11 is mounted freely in nozzle holder 10, then nozzle 11 may also be rotated due to the interaction with the flow. According to the equation of continuity of flow when swirling of flow takes place with the reduction of the radius of swirling, the speed of the flow increases and the pressure at the center is reduced. The flow of passive medium through conical axial channel 12 of nozzle 11 is drawn into suction chamber 1 and it interacts with active medium, which envelops the gas stream and compresses it.

As the mixture of active and passive media moves, they become more and more mixed. The mixture acquires the necessary kinetic energy which subsequently is converted into potential energy of pressure when the flow passes through diffuser 7. Then the mixture is transported to the consumer.

Provision is made for the adjustment of the flow rate and velocity of the active medium to optimize operating mode of the jet pump. This is accomplished by the movement of shaped bushing 19 in the axial direction caused by the transmission of rotation torque through screws 27 on cams 26 installed inside annular groove 25 of shaped bushing 19. Thereby flat conical tip 20 is inserted or is ejected from tangential channel 16 causing the change of the cross section of slot gap 21, and accordingly, the change of the flow rate of active medium fed inside suction chamber 1.

Axial movement of nipple 9 together with nozzle holder 10 and nozzle 11 into suction chamber 1 with the change of the distance between nozzle 11 and mixing chamber 5 is performed by rotating cup 30 around the body of pipe socket 2 with the interaction of fingers 29 with nipple 9 along annular groove 31. In doing this, the operation mode of the jet pump varies. The jet pump tune-up for optimal operation can be made directly while operating. The shutdown of the process and dismantling of the device from the installation site are not required in order to reconfigure and to change the mode of operation.

The use of a jet pump will provide the following benefits [4]:

- the possibility to control gas compression, to generate aerated fluid through axial movement of the nozzle relative to the mixing chamber;

- the possibility to control the flow rate of active medium injection to optimize the operation of the device by changing the area of passage of the slot gap through the movement of the shaped bushing in the axial channel;

- the possibility to enhance the efficiency of mixing and compressing of the two-phase aerated fluids through the feed of passive medium via the axial channel of the supply pipe to the nozzle;

- the possibility to feed active medium through the supply pipe and the slot gap into the mixing camera perpendicularly to the axis of the nozzle with swirling in tangential channels and with the change of swirling radius from larger diameter to the smaller one and with the decrease of pressure in the center of the flow;

- the possibility to suck gas to the vortex, generated by rotating active medium (liquid) and to mix them in the mixing chamber.

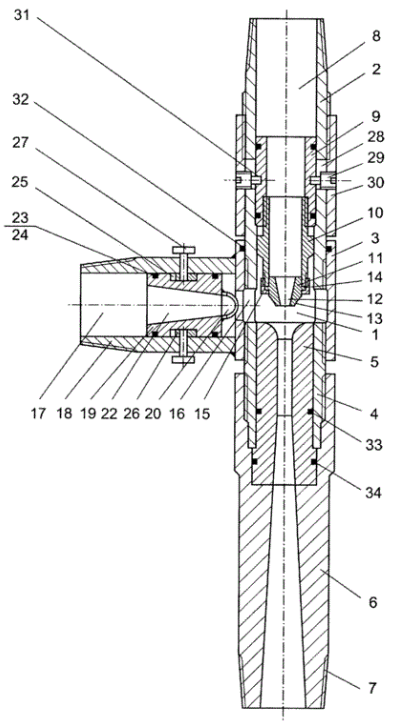

Fig. 5. Jet pump.

1 – suction chamber; 2 – passive medium supply pipe; 3 – pipe coupling ; 4 – casing; 5 – mixing chamber, 6 – diffusor; 7 – connecting thread; 8 – axial channel; 9 – nipple; 10 – nozzle holder; 11 – nozzle; 12 – conical axial channel; 13 – outer curved surface; 14 – circumferential ridge; 15 – sleeve nut; 16 – tangential channels; 17 – axial channel; 18 – active medium supply pipe; 19 – shaped bushing; 20 – conical flat tip; 21 – slot gap; 22 – supply axial channel; 23 – annular grooves; 24 – gasket ring; 25 – annular groove; 26 – cams; 27 – screws; 28 – two longitudinal grooves; 29 – fingers; 30 – cup body; 31 – outer side of annular groove; 32, 33, 34 – gasket rings.

The control over the process is carried out in automatic or semi-automatic mode using specialized devices. These devices are included in the wellhead equipment (Fig. 6).

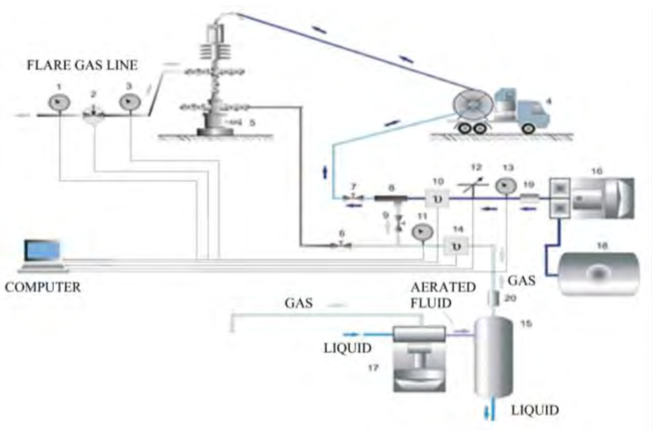

Fig. 6. Well head equipment for removing deposits.

1, 3, 11, 13 – pressure gauges; 2 – flow line valve; 4 – coiled tubing unit; 5 – well; 6, 7, 9 – flow line valves; 10, 14 – flow meters; 12 – thermometer; 15 – separator; 16 – cementing unit; 17 – booster unit; 18 – tank with foaming fluid; 19, 20 – back pressure valves

The well head is equipped with control equipment. A personal computer serves as a control device operating in real time mode. Using this type of wellhead equipment makes it possible to monitor the following parameters: gas flow rate and gas pressure in the pipeline that is used to supply gas component into well 5, as well as the flow rate, temperature and pressure of surfactants in the pipeline for surfactants feed into coiled tubing string.

For this purpose, flow rate transducer 14 and pressure transducer 11 will be installed at the sockets of the first transportation line, at the straight segment of the pipeline. According to the technology, there are several options to supply gas to the booster unit: from the neighboring well and from the gathering line.

The necessary amount of foaming fluid is fed by cementing unit 16 from tank 18 through flow tee 8 to coiled tubing unit 4. Temperature transducer 12, flow rate transducer 10, and pressure transducer 13 of the foaming fluid will be installed at the straight segment of the pipeline into the sockets of the second transportation line, to monitor dynamical parameters of liquid in foaming fluid supply pipeline.

According to the design, it is planned to install flow line valves 6, 7, 9, and valves 19, 20 at the first and second transportation lines, and also at the segment of these lines connection. To ensure automatic operation gas regulators (which include valves) are supposed to be installed instead of valves 19 and 20 to monitor the volume of the supplied foaming fluid and gas.

To monitor and control dynamical process, two pressure gauges 1 and 3 and remotely controlled valve 2 are installed at the flare gas flow line. The main purpose of the remotely controlled valve is the managing of backpressure applied to the formation when cleaning the wellbore from sand and clay obstruction. The aim is achieved by changing the cross-sectional area of the pipeline by the use of the remotely controlled valve.

V. CONCLUSION

Operating practice shows that the accumulation of deposits of mechanical particles, salts, proppant plugs, and mud cakes in horizontal wells occurs on a regular basis. This requires prompt intervention to remove proppant deposits from lower segments of the well. Experience shows that action of only working liquid jet upon the layer of deposits does not always ensure destruction of the proppant layer. In this regard, technical means were developed to efficiently remove and destroy layers of deposits, which will allow for more efficient well operation. Claims on an invention for the described devices are submitted to the Russian Federal Service for Intellectual Property [1].

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