Reduction of well stimulation period after hydraulic fracturing

A E Verisokin¹, T A Gun'kina¹, V A Vasil'yev¹, A I Shchechin¹, D Yu Serdyukov²

¹Institute of Oil and Gas, NCFU, 1, Pushkin Str., Stavropol, 355009, Russia
²NGDU Rechitsaneft, RUP PO Belorusneft, 43 Lenin Str., Rechitsa, 247500, Belarus

E-mail: verisokin.aleksandr@mail.ru

Abstract. This article discusses the problems associated with the removal of proppant, mechanical particles of the rock and undecomposed fluid from the hydraulic fracture into the well. The necessity of developing a device for washing the perforation interval has been identified and justified. It is shown that hardened and viscoelastic gel particles fall into perforations and adhere to the walls of channels and wells. Subsequently, these zones of gel deposition reduce permeability in perforation channels. The author has developed the design of a device for decolmation (declogging), which reduces the time for well development after hydraulic fracturing. To increase the productivity of the considered wells, it is necessary to flush them with the presented device in the mode of maximum approximation to deposits. To carry particles better to the surface, it is proposed to use foam systems generated by the jet pump, which is described in this article.

1. Introduction

Today, more and more attention is paid to the development of hard-to-recover reserves in the world. Such reserves include oil in sufficiently dense rocks, which lie in poorly permeable reservoirs. At the same time, emphasis is placed on the introduction of new technologies for the intensification of production, which have successfully been used in oil fields with highly permeable reservoirs. One such effective technique is hydraulic fracturing (Fracking). During the hydraulic fracturing operation, a branched drainage system is formed in the bottom-hole zone of the reservoir by supplying the hydraulic fluid under high pressure [1]. The development of many well-known hydrocarbon deposits with permeable reservoirs of less than 5 - 10 * 10⁻³ μm² shows that hydraulic fracturing is almost the only method that can be used to develop such reserves. Additional requirements are imposed on the operation of low-permeable reservoirs, which in some cases casts doubt on the economic feasibility of hydraulic fracturing and significantly increases the risk of failure of the operation.

A significant part of fracking operations is carried out in our country. Currently in Russia more than 50% of wells undergo hydraulic fracturing. For example, in the fields of Western Siberia, more than 25 thousand hydraulic fractures have been carried out. Every year, the importance of hydraulic fracturing, both in the world and Russian practice, will continue to increase. In turn, the technology and technique of the hydraulic fracturing method will be more complicated. Nevertheless, despite the huge amount of research on hydraulic fracturing, the technology of this operation has many unresolved scientific problems. Presently, in Western Siberian fields, in 80% of the cases, there are complications in well development after hydraulic fracturing. The main part of production wells
operates under conditions of formation of “products” of hydraulic fracturing at the bottom with partial or complete overlapping of the perforation interval. Eliminating gel residues from the well is a daunting task.

According to the results of field observations, it was proved that the proppant backflow from the fracture to the well is maximum at the stage of well development. This necessitates the development of new progressive technical means for improving the methods of well development after hydraulic fracturing.

2. Materials and methods
The research materials compiled the results of hydraulic fracturing in the fields of Western Siberia in reservoirs of medium and low permeability. To solve the problem of blocking perforation channels with an undecomposed gel and reducing the development time after hydraulic fracturing, numerous theoretical and analytical studies were carried out to develop a set of devices. A literature review and patent analysis on the issue under study were carried out. Criticism of analogues has been carried out and more advanced devices have been developed for flushing perforation channels and perforation intervals of wells from “silt” carried out from fractured and destroyed proppant.

3. Research results
The removal of proppant from the well leads to a breakdown of the electric centrifugal pump, as well as to a decrease in well productivity. The image of the wellbore in the perforation interval after mudding with an undecomposed gel with proppant particles is shown in Figure 1.

Figure 1. Wellbore in the perforation interval after mudding

It should also be noted that in case of poor cementing of the well, during hydraulic fracturing, part of the proppant enters the voids in the cement ring, and during development it is taken out. In addition to gel sedimentation on the walls of the well, this chemical liquid also settles in perforation channels, clogging them.

Oil and gas industry experts believe that some of the carrier fluid does not collapse even under the influence of modern destructors - additives that contribute to a controlled decrease in fracture fluid viscosity and its removal from the hydraulic fracture [2-5]. If the viscoelastic “islands” remain inside the crack for a long time, then they harden. In the future, these sections of the fracture will have a reduced permeability and adversely affect the productivity of the well after hydraulic fracturing [6-8].
Solid and viscoelastic particles of the destructors also enter the perforation channels and adhere to the walls of the well. These deposits reduce permeability in perforated channels. To improve the productivity of such wells, flushing should be applied with the highest proximity to complications. You can get rid of such zones with the help of a device for reclamation of wells, which is shown in Figure 3. The device consists of a casing 1 with a cylindrical axial channel 2, an adapter 3 closed on top with a blind bottom 4 with a conical protrusion 5, which goes into a cylindrical axial channel 2 in the conical axial channel 6, the angle formed is equal to the angle of inclination of the conical protrusion 5.

In the body of the adapter 3 above the blind bottom 4, several tangential channels 7 are made, hydraulically connecting the axial channel 8 of the adapter 3 with the cylindrical axial channel 2 of the casing 1 (Figure 3). A bore is made at the lower end of the casing 1, in which a support seat 9 is installed. Inside the axial channels, cylindrical 2 and conical 6, hollow pipes 10 are provided, equipped with an annular protrusion 11, on which a thrust sleeve 12 is mounted, which is installed with the possibility of contact with the inner surfaces of the conical 6 and cylindrical 2 axial channels of the casing 1. The upper end of the hollow pipe 10 is located freely between the inner wall of the cylindrical axial channel 2 of the casing 1 and the conical protrusion 5. At the lower end of the hollow pipe 10 an end valve 13 with a spherical surface is mounted, resting on the counter spherical surface in the support seat 9. At the same time, the end valve 13 is provided with a supply tube 14 passing through the axial channel of the support seat 9 and connected to the sleeve 15 covering the cylinder 16. In the axial channel of the cylinder 16, a drainage tube 17 is installed, provided with an annular protrusion 18, in the axial channel 19 of which a nozzle 20 is installed. An annular chamber 21 is formed between the drainage tube 17 and the inner surface of the cylinder 16, in which a spring 22 is placed, which compresses an annular protrusion 18 of the drainage tube 17 to the end of the nut 23 connected with the cylinder 16.

An inner annular bore 24 is made in the sleeve 15, which is connected by the bypass hole 25 with the axial channel 26 of the supply tube 14 and the holes 27 in the body of the cylinder 16 with its axial channel 28 between the nut 23 and the annular protrusion 18 of the drain tube 17. In the its body there are radial holes 29 for hydraulic connection of the axial channel 28 of the cylinder 16 with the axial channel 19 of the drainage tube 17 located in the initial position under the nut 23. The cylinder 16 is fixed in the sleeve 15 with a lock nut 30. The axial channel 19 of the drainage tube 17 extends outside the cylinder 16 and 31. In the closed plug adapter, body 3 is threaded for connection to the coiled tubing 32 of the coiled tubing unit.
The annular bore 24 in the sleeve 15 is protected from aggressive media by the seals 33 and 34. The annular gap between the drain pipe 17 and the cylinder16 is insulated by a seal 35, which is mounted on the annular projection 18. The annular gap between the nut 23 and the drain pipe 17 is closed by the seal 36. The principle of operation of the device is described in [9].

**Figure 3.** The design of the device in the context, in the initial position of the parts (longitudinal section)

The use of this device will increase the effect of the working agent jet on deposits by using its total flow rate, which is directed through the nozzle, as well as isolate the internal cavity of the device from the ingress of formation fluid and particles of the destroyed proppant at the end of the flushing process.

The arrangement of the device in the well is shown in Figure 4. The technological feature of this device is that it can be lowered through tubing using a coiled tubing installation.

Technical characteristics of the flushed wells are shown in table 1.

In the fields of Western Siberia, flexible tubings (FT) are increasingly used to eliminate the “products” of hydraulic fracturing in the wellbore that fall to the bottom. It is proposed to use foam systems for flushing the well.
The use of foam systems is due to the following advantages:
- when technological fluids get into the formation, reservoir properties of the bottom-hole formation zone (BHF) are preserved;
- the use of foam systems allows you to quickly adjust the pressure at the bottom of the well, so you can quickly switch from repressing to depression;
- the foam has excellent bearing capacity, which improves the cleaning of the perforation interval from particles of gel and proppant after hydraulic fracturing.

However, the use of foam systems as a circulating agent in a well is accompanied by increased complexity. Special equipment must be used to create foam. For better foam generation, the author has developed a jet pump design. The scheme of the inkjet apparatus is shown in Figure 5. A detailed principle of the pump is given in [9].

4. Conclusion
1. In oil fields, large volumes of proppant, mechanical particles, and undecomposed hydraulic fracturing fluid exit the well. Some of the carrier fluid is not disintegrated even under the influence of a destructor. A mixture of mechanical particles, proppant fragments with an undecomposed gel forms
a difficult-to-remove mixture in the perforation channels and on the walls of the well - “sludge”. Subsequently, these hardened residues reduce the permeability in the perforation channels. To improve the productivity of such wells, it is necessary to flush them with the closest possible complication. You can get rid of such complications with the help of the proposed set of devices for well development after hydraulic fracturing.

2. A device for well reclamation has been developed: Patent No. 2651869, Application No. 2017109500.

3. A jet pump has been developed for better foam generation: Patent No. 2643882, Application No. 2017114222.

Figure 5. Jet pump: 1 - receiving chamber, 2 - passive medium, 3 - connecting sleeve; 4 - connected to the casing, 5 - mixing chamber, 6 - diffuser, 7 - connecting thread, 8 - axial channel, 9 – nipple, 10 - nozzle holder, 11 - nozzle, 12 - conical axial channel, 13 - curved surface, 14 - annular protrusion 15 - union nut, 16 - tangential channel, 17 - axial channel, 18 – pipe, 19 - figured sleeve, 20 - flat tip, 21 - slit gap, 22 - axial channel, 23 - annular grooves, 24 - sealing rings , 25 - annular groove, 26 - cams, 27 - screws , 28 - two longitudinal grooves, 29 - fingers, 30 - cylinder, 31 - annular groove, 32, 33, 34

References
[1] Verisokin A, Vasil’yev V and Gun’kina T 2019 Packer design research used in hydraulic fracturing IOP Conf. Series: Earth and Environmental Science 378 7
[2] Zinchenko I 2007 The use of hydraulic fracturing for stimulation of inflow in gas condensate wells of the Yamburgskoye field and prospects for the application of the method in the process of further development of deposits (Moscow - IRC Gazprom LLC)
[3] Anderson J, Simpson M and Bosinski P 2003 Producing Natural Gas from Coal. Oilfield Review, Autumn 9 23-30
[4] Kanevskaya R 1998 *Foreign and domestic experience of hydraulic fracturing* (Moscow – VNIIOENG)
[5] Keybal A and Keybal A 2009 Reasons for proppant backflow to the wellbore after hydraulic fracturing of the reservoir *Drilling and Oil* 11 48-52
[6] Merkulov A 2007 Impulse technologies for stimulation and hydraulic fracturing (Part I) *Oil industry* 9 127-129
[7] Sudo R 2007 Development of low-permeable formations in the fields of RITEK OJSC using hydraulic fracturing *Oil industry* 3 48-50
[8] Fakhretdinov R and Brovchuk A 2007 The results of the use of hydraulic fracturing for the development of the southern licensed territory of the Priobskoye oil field *Oil industry* 3 44-47
[9] Verisokin A 2018 The proppant test procedure for hydraulic fracturing *Science and Technology in the gas industry* 2 62-69