Development of oil well development technology using jet pumps after hydraulic fracturing

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Abstract. For the development of production wells with degraded filtration parameters in domestic and foreign practice, various methods are used. But, as the practice of work has shown, the most effective means of development and research of production wells are jet devices, which are distinguished by their simplicity of design and the possibility of their use in various mining and geological conditions. The article proposes technology and technical means to improve the connection between the well and the reservoir, increase the coverage of the fractured space, reduce material and time costs during well development. It is shown that complex technological solutions during development after hydraulic fracturing lead to an increase in the production rate of oil wells.

1. Introduction

The principle of well development by jet devices is based on the creation of controlled cyclic drawdowns on the formation, which allows for complete cleaning of the near-wellbore formation zone from filtrate and drilling fluid particles in a short time, as well as spent chemicals and reaction products after physical and chemical impacts on the formation. During the operation of the jet pump, it is possible to create technically controlled drawdowns, register them with depth gauges, record pressure recovery curves with closing the well at the bottom, take deep and surface samples of formation fluids. Thus, accelerated development of objects is achieved without the use of a swab or expensive nitrogen compressor units [1–8].

Works on the development of wells and the study of reservoirs using the technologies below were carried out in many exploration areas and fields in Western and Eastern Siberia with high geological efficiency.

For the first time, weakly cemented reservoirs with high-viscosity oils and productive reservoirs with abnormally high reservoir pressures were tested using jet pumps.
2. Materials and methods
When performing the work, methods of mathematical statistics were used, computational experiments were carried out. The field and theoretical data on the problem under consideration are analyzed and summarized.

Technical means used in the development of wells with jet devices
A single hydraulic pumping cycle, including a jet pump, consisting of two blocks:

1. Ground equipment:
   - high-performance pump;
   - measured capacity;
   - wellhead fittings;
   - fast-mounted liquid supply lines;
   - equipment that cleans the working fluid;
   - wellhead filter.

2. Underground equipment:
   - jet apparatus;
   - packer;
   - check valve;
   - recording devices (measure pressure, temperature, fluid flow, etc.);
   - tubing;
   - Downhole filter.

3. Results
It is possible to induce inflow using a jet pump by reducing the pressure in the under-packer area below the hydrostatic pressure. In the jet apparatus, flows with different pressures are mixed and exchanged, which leads to the formation of a mixed flow with variable pressure indicators. The flow of reservoir fluid, which is connected with the working agent, is commonly called injected.

In jet pumps, the potential energy of the working fluid is converted into kinetic energy. At the same time, the injected flow partially acquires kinetic energy. When the fluids pass through the jet pump, the flow rates are equalized and the kinetic energy of the mixed fluid flow is again converted into potential energy. The main characteristic of the jet pump is shown in figure 1.

Only high-pressure jet pumps can be used for well development. Such pumps have an area ratio of the mixing chamber \( f_c \) and the working nozzle \( f_p \) less than four (\( f_c / f_p < 4 \)).

The jet pump in the well is installed on a tubing string with a packer assembly (Fig. 2). The working agent is supplied from the wellhead through tubing to the working nozzle of the jet apparatus. Then the fluid flow enters the mixing chamber with a diffuser and enters the wellhead through the annulus.

The injected flow in the form of reservoir fluid through the suction unit enters the mixing chamber of the device, where it mixes with the working agent. The suction unit is formed by a string of tubing located below the apparatus.

Inkjet devices have several modifications, they differ from each other in design solutions. In the practice of operating such devices, the most widespread are:

- plug-in pumps, a feature of which is the descent of the well after the installation of tubing;
- non-inserted pumps, which are installed in the well on the tubing;
- continuous pumps with a special cavity for lowering geophysical instruments through the pump;
- impassable pumps, in which a special cavity for geophysical instruments is not provided;
- jet direct flushing devices, in which the supply of the working agent is carried out through tubing;
- jet backwash apparatus, in which the supply of the working agent is carried out in the annulus;
- single-row pumps with one nozzle and one receiving chamber;
- multi-row pumps - have several nozzles and receiving chambers.
In certain cases, a combination of jet pump designs is possible. When operating the pump in a well, it is necessary to comply with the requirements of the operating instructions and not exceed the permitted range of pressures and temperatures.

To develop wells after hydraulic fracturing and increase the permeability of the bottomhole zone in horizontal wells with low-permeability formations, a type of work using a jet pump and a hydraulic vibrator is proposed. The technology of using a vibrator and a jet pump is designed to compact the proppant, increase the injectivity and productivity of the well, conduct an inflow call, bring the well to an effective operating mode and carry out hydrodynamic studies in steady and non-steady filtration modes. To create a pulse-shock effect, a hydraulic spool vibrator was developed (figure 3). Downhole hydraulic vibrator contains housing and a barrel with slots and an axial channel installed in it on bearings. The bottom body is made muffled with radial holes opposite which a reflector is installed.
In the barrel of the device, a rotating nozzle is provided, which has a channel and profiled blades and vanes. The descent of the device into the well is proposed to be carried out after successful hydraulic fracturing and flushing of the perforation interval. Thanks to the operation of the presented device, the proppant pack is compacted in hydraulic fracturing cracks by pressure jet pressure pulses. The hydraulic spool vibrator is lowered into the well on the tubing and installed in such a way that it is in the formation perforation interval.

**Figure 2.** The layout of the jet pump in the well.
To carry out hydrovibrotreatment of the formation, the working fluid $Q_p$ is supplied through the central axial channel of the hydraulic spool vibrator. Ground pumping units develop a pressure of the order of 4 - 7 MPa, while the injectivity of the pumps is determined by cycles. The practice of operating a hydraulic spool vibrator shows that the optimal mode of its operation is achieved at a flow rate of flushing fluid from 7 to 9 l/s. At such costs, the working agent $Q_p$ acquires a high speed inside the channels of the device and generates high pressure pulses with a variable frequency. Thus, at the installation depth of the hydraulic spool vibrator, zones of high and low pressure are alternately formed relative to the formation perforation holes. Under these conditions, the filtration flow of the working agent and the well wall are subjected to impulse treatment, and the energy of elastic hydraulic vibrations is transferred to the bottomhole formation zone, which contributes to high-quality and efficient proppant compaction in the hydraulic fracture.

For the development of wells after hydraulic intervention and removal of the proppant plug in the wells, we use a jet pump lowered onto flexible tubing with a diameter of 38 mm. The method of development, intensification of oil and gas inflows in wells includes a small-sized jet pump with a sleeve packer (figure 4). Under the jet pump there is a container with a small-sized autonomous downhole electronic device installed in it, through which the process of development and exploration of the well is controlled.

Implementation of the proposed technology is possible due to the creation of controlled cyclic pressure drawdowns on the formation by a jet pump. The technology of joint use of a vibrator and a jet pump in horizontal wells is shown in figure 5.
Due to the use of a hydraulic vibrator and a jet pump, the effect of the skin factor in the BFZ after treatment is minimal.

**Figure 4.** Jet pump diagram: 1 - electronic depth gauge; 2 - container; 3 - cuff; 4 - working nozzle; 5 - mixing chamber; 6 - diffuser; 7 - body of the jet pump; 8 - flexible tubing; Q_p - working flow; Q_n - flow rate at the pump intake (injected fluid from the reservoir); Q_m - mixture consumption

**Figure 5.** Layout scheme of a straight-through jet pump in a well.
4. Conclusion
1. The use of the hydraulic spool vibrator described in the work makes it possible to achieve compaction of the proppant pack of a hydraulic fracture. The effect is achieved by creating a pulse-shock effect. The use of the proposed device increases the injectivity and productivity of the well.

2. Well development using jet devices allows not only to significantly reduce the cycle time for putting new wells into operation, but also to reduce the risks of accidents at wells by reducing the number of tripping operations. A significant increase in the overhaul period and well flow rate was established with the combined use of technological solutions for proppant compaction in the perforation zone and, accordingly, “sparing” well development with jet devices.

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