Restoring the intake capacity of injection wells by means of shock-wave exposure

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Abstract. New technology is proposed for restoring the intake capacity of injection wells, providing an opportunity to reduce the operation time, the amount of household waste, equipment used, the degree of environmental pollution and land loss in the absence of round trip operations.

1. Introduction

In order to maintain the design indicators of oil production during the development of oil fields, it is important to restore the intake capacity of injection wells in the conditions of using a reservoir pressure maintenance system (RPM) by produced water injecting [1-8]. Over time, the pore space of the bottom-hole zone of injection wells is clogged with oil and suspended particulate matters (SPM).

Technologies based on the creation of draw-down pressure are used to restore the intake capacity [9]. They differ in complexity of implementation and low technical and economic efficiency.

In [10], a new method of restoring the intake capacity, based on the creation of instantaneous draw-down pressures by relieving pressure at the wellhead. A rarefaction wave reaching the bottom causes a pressure pulse and the colmatant is detached from the rock. The induced inflow during repeated exposures brings the colmatant to the surface with an outpouring of liquid.

Hydro-swabbing, or the variable pressure method [11], is performed by periodically increasing the draw-down pressure with a liquid, preventing hydraulic fracturing, followed by the rapid opening of the wellhead. The effectiveness of the method is to create a draw-down pressure. Alternating significant pressure gradients destroy the structural bonds of emulsions and deposits in the pores of the bottom-hole zone, and high flow rates contribute to the removal of contaminants into the well-bore.

The basis of pulse-wave exposure on the reservoir can be considered a hydro-swabbing method, when applied, the wellhead pressure of the injected or poured liquid is sharply changed to create shock waves propagating through the column. In the case of shock wave transmission from the surface, the well fluid, most of which is water, due to its high density and low compressibility, is a favorable medium for the transmission of pressure drops over long distances.

It is generally accepted that for greater impact on the bottom-hole zone of the well, it is necessary to place equipment in the immediate vicinity of the processing object. The location of energy sources on the earth surface is recognized as non-optimal, primarily due to the refraction of waves in the earth stratum and their attenuation. This is true for the transmission of heat energy, for example, because the casing and tubing strings have high thermal conductivity and dissipate heat.
The tubing walls with considerable elasticity, contribute to a kind of "canalization" of the wavefront trajectory. This is true for infra-low frequency waves with low attenuation. Losses from the attenuation of Rayleigh waves and transverse waves, which are the main losses in the seismic method, are excluded.

The speed of the shock wave in the column is close to the sound speed. Pipes, having a large mass and, therefore, high inertia, do not have time to deform due to pressure drops during the passage of a shock wave. Therefore, gusts of the column and destruction of the cement stone are unlikely and were not observed during the testing process.

Shock-wave exposure forms processes in the oil reservoir that cannot be explained only by the influence of pressure and temperature. The shock wave affects the molecular chains, resulting in local overloads that can exceed the strength of the chemical bond.

The following options for creating impacts at the wellhead with subsequent energy transfer using a shock wave to the bottom have been developed [12]:

- propagation of molecular-wave vibrations along the metal of the pipe string, contributing to the separation of asphalt-resin-paraffin deposits (ARPD);
- use of an emitter at the wellhead that is mechanically connected to the tubing system to transfer energy to the perforation interval;
- implementation of a water hammer in the upper part of the column, its transmission along the liquid column and deviation in the perforation zone;
- alternation of periodic pressure pulses with well flushing;
- formation of a standing shock wave by alternating pressure and rarefaction at the wellhead;
- the formation of pressure drops between the near-wellbore area of the reservoir and the cavity of the wells with a gradual and uniform cleanup of the well-bore zone along the entire length of the perforated interval;
- the formation of pressure drops between the near-wellbore area of the reservoir and the cavity of the wells by periodic opening in time with the wellhead for the outflow of well-bore fluid and its filling;
- the formation of pressure drops between the near-wellbore area of the reservoir and the cavity of the wells by periodic programmable wellhead opening time;
- the amplification of the shock wave by using hydro-pneumatic accumulators for energy storage;
- pulse pumping of the working agent is alternated with exposure and dynamic spout;
- generating an elastic shock wave at the wellhead by pulsed injection of a metered volume of liquid and maintaining vibrations of the liquid column;
- the formation of pressure drops between the near-wellbore area of the reservoir and the cavity of the wells by periodic opening in time with the speed that provides a sharp drop in pressure at the wellhead to atmospheric, and closing – at a speed 2-5 times slower than the speed of its opening;
- synchronizing the closing and opening of the wellhead in phase with periodic decreases and increases in pressure in the bottom-hole zone during the formation of a shock wave, installing a check valve above the packer to allow flushing of the well between pulse-wave processing operations;
- pulsed injection through the annulus and spout through the tubing during the formation of a shock wave in wells with low reservoir pressure.

Most of these solutions offer to increase the pressure in the well and creating hydraulic shocks in the fluid column by periodically switching the wellhead equipment. In this case, the column of borehole fluid is subjected to a shock impact that extends to the bottom and can affect the filtration properties of the near-wellbore area of the formation.

2. Materials and methods

In comparison with other methods, the treatment of wells by pulsed-wave action from the surface without the use of lifting operations is characterized by low material and time costs. No expensive equipment is required. Concerning the special equipment, only modified wellhead strapping is used, in some cases a shock pulse generator and a pumping unit. The duration of treatment is usually from 3 to
8 hours.

Water impacts that are consistent in frequency with the speed of the shock wave and the depth of
the well are amplified by resonance. Attenuation losses for infra-low frequency waves are on the order
of 10-12 % per kilometer of the well length.

Technologies based on the listed patents provide an opportunity for directional processing of inter-
layers that are not uniform in permeability to align the inflow or injectability, as well as selective
processing of watered inter-layers. Pulse-wave processing helps to reduce the water content of the
bottom-hole zone (BHZ).

The power of the shock wave, that is generated when the wellhead is opened, is proportional to the
rate of liquid outflow, which, in turn, depends on the difference in down-hole and atmospheric
pressure and the cross-section of the channel for liquid outflow.

According to the calculation, initially, the outflow rate will be 141 m/s. Practically, this speed is
lower because it depends on the hydraulic resistance of the discharge hose. Due to the decrease in
pressure, the spout rate decreases, which reduces the power of the water shock wave. On the
supposition that the difference in the velocity of the liquid outflow during the formation of the water
hammer was 20 m/s. Then the power of the shock wave formed at the well-head will be 1200 kW.

In the process of moving through the tubing, the energy of the pressure wave movement is
significantly reduced due to hydraulic friction, which depends mainly on the column cross-section,
resulting in the loss of pressure of the moving liquid. When the sump is reached, the kinetic energy of
the liquid is converted into the potential energy of its elastic rarefaction, i.e. the pressure wave creates
a new water hammer, that directly affects the near-wellbore area of the reservoir. The duration of the
rarefaction stage does not depend on the force of the water hammer, but is determined only by the time
of propagation of the shock wave along the column.

The water hammer generated by the spout of the well fluid develops a rarefaction wave, not a
compression wave. Therefore, the spout helps to maintain the high-speed pressure of the shock wave.

The figure shows the wellhead pressure waveforms obtained using the PDMTI-60 pressure sensor
and «Software for Vellemen PC scope, PCS64i» program.

3. Results and Discussion

Figure 1 a shows that when the well is depressurized, the wellhead pressure drops to atmospheric
pressure, and then, when the well is closed, it is almost restored. After a period of time required for the
wave to pass to the sump and back, a pressure pulse is formed at the wellhead, which in amplitude can
be greater than the differential that generates the wave. The passage of a single pulse is accompanied
by damped pressure fluctuations.

Figure 1b shows repeated pulses generated during regular depressurization of the wellhead. It is
important to open the wellhead at the moment of the maximum amplitude of the reflected pulse to
obtain the greatest pressure drop moving through the well.

Figure c shows the formation of a wave in a well with a high permeability of the bottom-hole zone.
High attenuation is associated with a significant transfer of wave energy to the reservoir.

If there is the pulse-wave exposure from the wellhead, under the condition of sufficient pressure in
the cavity wells, the repetition rate of the pulse-wave exposure is 12-20 times per minute and is
determined by the speed of the shock wave and the depth of the well.
Figure 1. Wellhead pressure diagrams: a - for a short single spout; b - for short repeated spouts; c - for a short single spout in a well with high permeability of the near-wellbore area of the reservoir.

The coverage area of the hydraulic shock is limited to rocks adjacent to the well since the force of the hydrodynamic impulse quickly fades as it moves away due to the high elastic capacity of the system and hydraulic resistances in the pores of the rocks. The depression effect caused by a rarefaction shock wave is nondurable due to the high speed of the wave movement. Cracks in the formation do not have time to deform. The rarefaction wave, moving along the well cavity from the wellhead to the bottom and back, creates differences in the bottom-hole zone. When processing, for example, an injection well, the wave does not penetrate into the depth of the formation, the shock wave energy is transmitted only to the surface layer of rock in the perforation zone, the loose crust of deposits is torn off from the surface of the bottom-hole zone, the formation is not processed in depth, although for most injection wells such processing is sufficient and gives satisfactory results.

Processing of pores and cracks in the depth of the formation is possible with intensive fluid movement through the bottom-hole zone. Considering that the impact of elastic waves separates rock particles from the walls of the cracks due to vibrations near the center of equilibrium, but does not move in space, a powerful alternating action is required that has energy sufficient to carry the bridging agent from the formation into the well - the “washing” effect.

The shock wave exposure from the wellhead compares favorably with the implosion technology in that when using the latter, after each single shock exposure, it is necessary to lift the column to replace the membrane or the destroyed capsule or create a vacuum in the container opposite the perforation without lifting it to the surface. From the wellhead, it is possible to repeat the pulse-wave exposure with a frequency determined by the time of bringing the source of hydraulic impulses to its original state.

4. Conclusion
When processing wells due to the non-use of lifting operations, the advantages of the technology are as follows:
- due to the short duration of the operation, there is no need to arrange household premises. Consequently, the amount of household waste is reduced;
- the absence of down-lifting operations can dramatically reduce the amount of equipment used in the well, which pollutes the soil and atmosphere;
- since most technologies use 2-3 cars, there is little air pollution and ground damage during transportation of equipment and people.
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