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# Selective ultrasonic treatment of perforation zones in horizontal oil wells for water cut reduction

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ABSTRACT

A technique for treatment of perforation zones of horizontal oil wells for water cut reduction based on selective ultrasonic treatment was suggested. The technique involves online geophysical studies of horizontal wells, determination of treatment intervals based on these studies, selective ultrasonic treatment of the chosen interval and subsequent pump-out using a specially designed jet pump. The technology does not involve reduction of the flow in the well. The developed innovative technique of water cut reduction using selective ultrasonic treatment is studied within this article. Theoretical estimations and computer modeling revealed that the position of the downhole ultrasonic tool near the sidewall of the well leads to more homogeneous distribution of the induced acoustical field and wider penetration of the acoustical waves. The developed method was tested on a horizontal well in Western Siberia, which was characterized by high water cut. Based on geophysical studies only zones with low water and high oil production were treated, this lead to a decrease of the water cut by 20% and an increase of oil production by 91% after treatment of the test well.

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## 1. Introduction

The structure of the reserves of natural resources in Russia often does not allow economically efficient production of oil using the traditional methods of extraction [1–7]. Primarily this refers to reservoirs with low permeability since a big part of oil reserves would be uninvolved in the commercial development in case of extraction through vertical wells. In these circumstances improvement of the extraction efficiency may be achieved by the use of horizontal wells, which have an increased formation exposing surface, i.e. allow decreasing the filtration resistance in the perforation zones [8]. Horizontal wells not only have a higher oil production, they enable the producers to increase the recovery factor, which shows the efficiency of the recovery.

Horizontal wells are especially effective for fractured reservoirs with horizontal permeability; for areas with limited space for installation of drilling equipment; for Enhanced Oil Recovery (EOR) from reservoirs on a late stage of exploitation; in case of intensive formation of gas or water cones [9]. Horizontal strings, which go through several hundred meters of the producing reservoir, can open fractured zones with higher permeability in an inhomogeneous reservoir, this often lead to a significant advantage of horizontal wells above vertical wells in terms of production. Moreover, horizontal wells enable the producers to develop fields with extensive gas and oil reserves under a gas cap and water oil reserves with a much lower amount of wells and work with lower depressions during the development. Horizontal drilling techniques also contribute to the extraction of oil under pressures much closer to the initial pressures in the reservoirs, which is much more efficient and safe for the environment. A significant increase of the reservoir pressure comparing to the initial pressure lead to faster watering of the wells, decrease of the potential zones of exploitation during the second and third stages of exploitation. It is especially important to use horizontal drilling in case of inhomogeneous reservoirs. Thus the drilling and exploitation of horizontal wells is currently one of the most important topics of scientific and technical research in the area of oil production.

The analysis of the performance of horizontal wells show [10], that they mostly fulfill their tasks: provide higher production with lower water cut. Most of the horizontal wells produce oil with no

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or minimal water content (up to 20%), a low percentage of the horizontal wells produce fluid with water content of up to 60% and only single wells have a water cut of more than 80%. This is observed in particular in Western Siberia, in particular in cases, when the reservoir has a complicated profile. The dynamics of the performance of the horizontal wells of one of the reservoir in Western Siberia is shown in Fig. 1 [11].

One of the reasons of the tendency shown above is the deviation of the real trajectory of the well from the planned ideal trajectory. As a result of such deviation the well may come very close to the oil water contact, as shown on Fig. 2. In case the well is located as shown on Fig. 2b, watering of the well is inevitably.

In order to reduce the water cut it is first of all necessary to carry out geophysical studies. Currently well tractors or coiled tubing is used to deliver the geophysical probes to the horizontal strings. The probe is used to determine very precisely the locations of fluid influx and their orientation, to determine the water content and to build a "map" of fluid distribution. Onward annular chemical packers or the technology of expandable zonal isolation profiler (EZIP), based on expandable elastomers, are used to isolate the zones of water influx. Both technologies are based on limitation of flow into the well [12,13].

The methodology described above has two major drawbacks. First of all, the geophysical studies are carried out with offline probes and the interpretation is done after extraction of the tool. No online acquisition of the data is possible, thus an additional pulling-and-running operation is required, which is quite costly, especially for horizontal wells. The second drawback is the fact, that both technologies of water flow reduction are based on general reduction of the flow of the well, which might lead to the impossibility to recover a part of the potentially recoverable oil, thus decrease of the recovery factor is possible.

Over the last few years there has been a developing interest in physical EOR techniques. This might be explained by the fact, that these methods involve the use of various physical fields instead of matter to affect the reservoir and do not require the use of chemical reagents, which might be very harmful for the environment. Moreover, such technologies are often more cost and energy effective compared to other methods [14]. According to [15–17] the acoustical method of EOR (including ultrasonic EOR) is one of the most promising wave methods, this method has been widely studied over the last 20 years [18,19] and was mainly used during capital or operational workover of wells in order to increase the production. The results of such treatments were very promising in most of the cases [14,20,21]. The effect of ultrasound on the well and the reservoir which leads to enhanced production, is based on two aspects of sonication that are relevant (1) enhancement of the flow of oil through the rocks into the pumping pool (including enhancement of flow because of removing of the deposits from the wellbore perforation zone) and (2) reduction of the viscosity of the oil that would make it easier to pump [14,20,21]. The methodology is particularly useful for older wells which are in the later stages of reduced yields.

However so far the use of ultrasonic treatment for water cut reduction was never reported in the literature, the changes in the water cut of oil wells after ultrasonic treatment was only reported as a side effect in a few papers [14,21]. It has been shown in [14] that selective treatment of the wellbore perforation zones with ultrasound result in a decrease of the water cut. The average changes of the water cut after selective ultrasonic treatment of 30 vertical wells in Western Siberia are shown in Fig. 3.

Ultrasonic treatment was done during capital workover of the well, together with optimization of pumping equipment. The changes of the water cut are compared with the average changes of the water cut observed after optimization of pumping equipment of 30 vertical wells without ultrasonic treatment. During ultrasonic treatment the oil bearing layers were treated using an ultrasonic downhole tool, fed by a 10 kW surface ultrasonic generator. More detailed the technique is described in [14]. The decrease of the water cut is achieved due to cleaning of the wellbore perforation zone only in the oil bearing layers, while the water bearing layers are not treated. The treatment intervals are determined based on the results of geophysical studies, carried out prior to the treatment. The technique does not involve flow limitation.

Bearing this in mind an innovative technique for treatment of perforation zones of oil wells for water cut reduction based on selective ultrasonic treatment was suggested. The technique involve online geophysical studies of horizontal wells, determination of treatment intervals based on this studies, selective

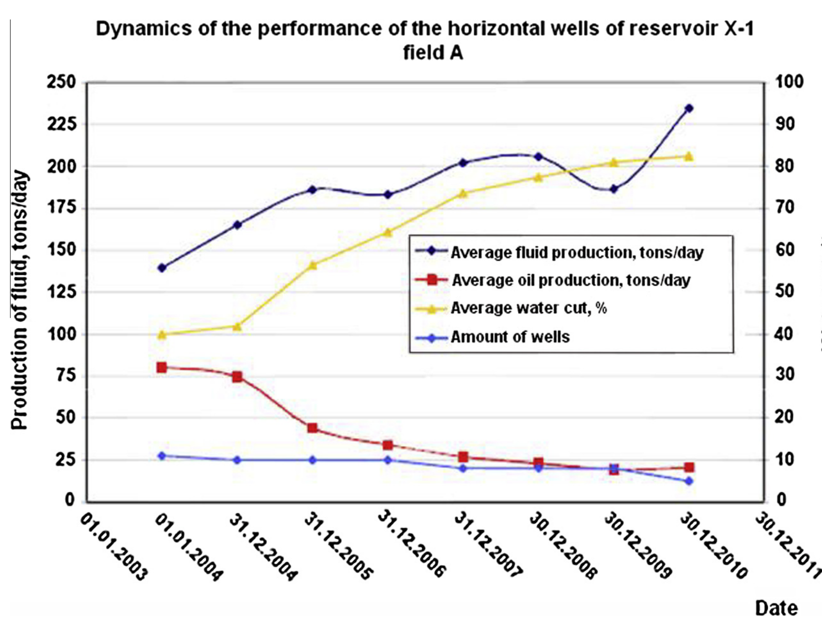


**Fig. 1.** Dynamics of the performance of horizontal wells on one field in Western Siberia.

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