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Analysis and Comparison of Existing Oil Production Methods to Increase Oil Recovery Coefficient of Highly Viscous Oil Wells

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ABSTRACT: The article provides a comparison and selection of optimal methods for oil production to increase well production. The table shows the necessary data for comparing indicators. The production method for fields with high viscosity oil is given.

KEY WORDS: field, horizon, porosity, permeability, model, reservoir, sandstone, water flooding, pressure, dependence, rate, intensity, terrigen.

I. INTRODUCTION

Every year forecasts arise for how many more years humanity will have oil and gas. These forecasts are very different: someone calls 20 years, someone 50 years, and someone even 100 years. Let's talk about how much oil we have left, in what reserves and how we can produce it.

Oil and gas reserves can be divided into several categories. Traditional reserves include those that are economically viable to mine with current technologies that are already developed and available. Hard to call those reserves that can not be obtained without the intervention of additional efforts. Non-traditional reserves are also distinguished - those reserves for which mankind now does not know the mining technologies. Initially, oil began to be extracted using the fountain production method: engineers drilled a well, after which, without the help of any pumps, oil itself flowed to the surface. Subsequently, it was transported and processed. In this way, it is possible to produce oil for a fairly short time, because then the pressure in the reservoir quickly drops, and we cannot provide gravity.

At the next stage, mechanized oil production is switched on, for which it is necessary to install either a sucker rod pump for low-production wells or a submersible pump for higher-production wells. These development methods make it possible to extract only 10–20% of all reserves, after which methods for maintaining pressure should be included. Traditionally, water injection is used for this. When we drill a grid of wells, into some of the wells called injection wells, we pump water and push oil to the producing wells. But even in this case we can get 30–40%, maximum 50%, depending on the quality of the tank.

To increase the development efficiency, it is necessary to apply oil recovery enhancement methods, the potential of which depends on the type of a particular method. The standard oil recovery ratio is 30–35%. This means that about 70% of the oil remains underground. This is due to the fact that development methods are not optimized now.

Chemical methods for enhancing oil recovery associated with the addition of chemical additives are distinguished. Traditionally, surface-active substances (surfactants) are used, which reduce interfacial tension at the oil-water interface and allow the production of additional oil. Polymer additives increase the viscosity of the aqueous phase and the coverage of the formation. Nowadays, technologies for adding nanoparticles to the aqueous phase together with various polymers are being actively developed. This allows you to significantly increase the recovery factor. The main problem

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of applying chemical oil recovery enhancement methods is related to the cost of reagents and the maximum efficiency limit, that is, we can increase the oil recovery coefficient by only 5–10%.
There are thermochemical methods for increasing oil recovery, where we use heat: either injection of a heated reagent or generation of heat inside the reservoir. This allows, firstly, to change the viscosity of oil and its physico-chemical properties, and secondly, to significantly increase the oil recovery coefficient.

II. METHODOLOGY

Now we will consider two main thermal methods that are already used. The first is the steam and thermal effect, it is used in the development of heavy oils. Canadians use this technology to develop bitumen sands, and now this technology is actively used in Russia. Heavy oil has a very high viscosity, under normal conditions it is a kind of rubbery substance that does not flow. For its extraction, it is necessary to lower its viscosity. There are several methods for how we can do this. Steam can be injected by heating the formation and lowering the viscosity of the oil.
What needs to be done to inject steam? First, we must prepare the water to heat it and generate steam. That is, we must purify water, which can either be extracted from water-saturated formations or taken on the surface, then heated and pumped. Depending on the depth of the field, we will lose a lot of heat when injected. Therefore, hybrid methods are now being applied. In hybrid methods, steam and air are injected together, which allows using chemical reactions in the formation to warm it to higher temperatures and increase the oil recovery coefficient. In this case, we pump in a free reagent, that is, compressed air, and generate energy inside the formation.
The second method can be illustrated by speaking of the Bazhenov suite. The Bazhenov Formation in Russia is the largest source of unconventional hydrocarbons. Within the framework of this field, it is possible to distinguish traditional low-permeability reservoirs where it is possible to drill a horizontal well, make a multi-stage hydraulic fracturing, and carry out production by standard methods. In addition, a very large amount of organic matter in the form of solid hydrocarbons, the so-called kerogen, is present in the Bazhenov formation. Depending on the area of deposits, kerogen can make up to 50% of all organic matter. And kerogen is a non-fluid substance, even at high temperatures, at which the Bazhenov Formation lies, from 80 to 110 degrees. And it is impossible to get it by traditional methods.
To solve such problems all over the world, the development of thermo chemical methods related to the injection of coolant is currently underway. For these purposes, you can use water, because it has the maximum heat capacity and is readily available. Water is heated on the surface, in some cases to a supercritical state, that is, temperatures above 373 degrees. After water is injected into the formation, the formation is heated up, and solid organic matter is converted into liquid hydrocarbons, which we can then produce. Commercially available technology does not currently exist. Trials are being conducted on similar technologies abroad.
The second technology, which is now actively developing, is associated with the injection of high-pressure air. And the principle of exposure is very similar. Warming up the reservoir, we first of all displace the oil that is already there. By warming the formation, we accelerate the process of converting organic matter into liquid hydrocarbons. In principle, one could wait 20-30 million years, and the organic matter is converted into oil itself, after which we can extract it. But we want to significantly accelerate this process. During in-situ combustion, the hot front displaces the oil in front of it and warms the surrounding interlayers. In this way, synthetic oil can be generated, the parameters of which we can vary by choosing the right temperature and exposure time.
All this can be called unconventional technologies for unconventional reserves. Now they are in the development stage in the laboratory and in the development stage in numerical modeling. A whole series of scientific problems arises that have not yet been solved. For example, this is filtration in a porous medium with a characteristic pore size of units and tens of nanometers. It is necessary to take into account the filtration of steam and hot liquid, that is, multiphase filtration. All these processes occur simultaneously, and it is rather difficult to model it both in the laboratory and numerically. Also, chemical reaction models have not been created, and there is no methodology on how to create them. The whole world is now dealing with these issues.
Another promising technology that is currently being developed is gas methods of exposure. Oil is usually produced along with associated petroleum gas. Often the fields are located in remote regions, and the utilization of associated gas is not economically feasible. That is, you must either build a pipeline or come up with some kind of transportation system. Accordingly, gas methods of increasing oil recovery are being actively developed. An example is mixing displacement — pumping associated non-fat gas to maintain pressure in the formation instead of water. In some modes, depending on the physicochemical properties of the oil, we can use mixing displacement when we are fully mixing between gas and oil, and then a single-phase filtration mode can be implemented. This allows you to significantly increase the oil recovery ratio.

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Also among gas methods of increasing oil recovery, it is worth noting the injection of carbon dioxide. We all know about the greenhouse effect and climate warming. Humanity generates a lot of carbon dioxide. One of the utilization technologies that has already been developed in the United States is the injection of carbon dioxide into the fields to increase oil recovery and associated greenhouse gas utilization. Including with reference to both traditional deposits, and not to traditional. In the Bazhenov formation, we consider the technology of cyclic carbon dioxide injection, which allows one and a half to two times to increase the oil recovery coefficient compared to the oil recovery coefficient for multistage hydraulic fracturing and horizontal drilling.

If 10-30 years ago, the resource factor was a determining factor for companies, that is, the main task was to find a field, evaluate it and effectively develop it, now the technological factor is more important. Because most of the large deposits have already been explored, their position is known, licenses are already distributed. Now we need technology for effective development. It is necessary to extract maximum oil and make it economically feasible. Now there is a wide range of studies both in our center and around the world to improve the technological and economic efficiency of enhanced oil recovery methods.

III. RESULTS

Periodic steam-thermal treatments (PTTs) of bottom-hole zones of wells (CCD) are the most widely used thermal method for developing deposits of high-viscosity and heavy oils. This is largely due to the fact that PTTs are used both as an independent method for producing highly viscous oils and as a method of influencing the bottom-hole formation zone in combination with the areal injection of coolant: steam or hot water. At the same time, this method also has a number of drawbacks, and first of all, the limited impact on the formation (in fact, CCD processing is carried out) and the decrease in the efficiency of steam-heat treatment from cycle to cycle of steam injection.

Table 3. Technological indicators of the development option for PTT without CHOPS

Parameter	Cycle number									
	1	2	3	4	5	6	7	8	9	10
Duration of steam injection, days	14	14	14	14	14	14	14	14	14	14
The amount of steam injected per day, m 3	116,65	190,84	221,81	240,68	248,94	256,31	262,39	272,09	273,84	273,21
Warm-up time, days	10	10	10	10	10	10	10	10	10	10
The duration of oil production, days	150	150	150	150	150	150	150	150	150	150
The amount of extracted water per cycle, m 3	35,73	80,6	126,01	158,1	175,44	209,13	237,63	224,44	244,46	254,45
The amount of extracted oil per cycle, m3	1051,92	1312,9	1406,96	1456,37	1507,46	1512,12	1541,95	1591,79	1586,41	1615,6
Amount of additionally extracted oil per cycle, m3	181,92	442,9	536,96	586,37	637,46	642,12	671,95	721,79	716,41	745,6
Amount of additionally extracted oil to the amount of injected steam, m3 / m3	1,56	2,32	2,42	2,44	2,56	2,51	2,56	2,65	2,62	2,73

Table 2. Technological indicators of the development option PTT + CHOPS

Parameter	Cycle number									
	1	2	3	4	5	6	7	8	9	10
Duration of steam injection, days.	14	14	14	14	14	14	14	14	14	14
The amount of steam injected per day, m3	336,6	376,3	392,7	412,9	423,5	429,52	435,5	443,3	448,6	455,9
Warm-up time, days	10	10	10	10	10	10	10	10	10	10

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The duration of oil production, days	150	150	150	150	150	150	150	150	150	150
Amount of extracted water per cycle, m3	96,8	178	169,5	220,6	235	294,94	343,4	359,5	438,1	429,2
The amount of extracted oil per cycle, m3	1237	2296,6	2436,7	2504,5	2579,8	2563,5	2596,4	2620,2	2641,1	2670,1
Amount of additionally extracted oil per cycle, m3	185,1	983,7	1029,8	1048,2	1072,4	1051,4	1064,5	1028,4	1054,7	1054,5
Amount of additionally extracted oil to the amount of injected steam, m3 / m3	0,55	2,61	2,62	2,5	2,53	2,45	2,42	2,32	2,35	2,31

IV. CONCLUSIONS

Accordingly, in the implementation of PTT as the main method of exposure, it is impossible to achieve high oil recovery rates from the reservoirs even when using horizontal and multilateral wells. One of the promising directions for eliminating the indicated disadvantages of PTT and increasing the efficiency of steam and heat treatments is the combination of PTT with CHOPS - “cold” oil production with sand. CHOPS is widely used in many fields in the world as a highly economical method for the production of high-viscosity and heavy oil with one, but a significant drawback - low oil recovery. It is known that this method involves maintaining significant depressions at the bottom of production wells to destroy poorly cemented reservoirs and create so-called “wormholes” in the reservoir — flow channels to the wells of a mixture of oil and sand. The wormhole system at the bottom of the wells significantly improves the filtration properties of the reservoirs and causes a multiple (sometimes an order of magnitude) increase in well production. In this regard, the question arises: could “wormholes” in the CCD be the necessary element to increase the efficiency of PTT and increase both the size of the steam and heat treatment zone, and the completeness of oil recovery from these zones? In this case, at the initial stage of the process of impacting a highly viscous oil reservoir, sand and oil can be extracted from producing wells (CHOPS), and then PTT of their bottom-hole zones is already carried out. Such a combined impact can be attractive both from a technological and economic point of view, since it can not only further increase the well productivity and the formation coverage by the impact process during the PTT, but also lead to a faster payback of the process itself through the implementation of “cold” production CHOPS before the more costly process of thermal stimulation (PTT). Such a combined impact may turn out to be attractive, both from a technological and economic point of view, since it allows not only to additionally increase well productivity and formation coverage by the impact process, but also lead to a faster payback of the development project itself due to oil production even before more costly process of thermal impact on the reservoir. The production rates and accumulated oil production in this case significantly exceed the same values when conducting PTT in similar conditions in a wide range of reservoir properties and properties of reservoir fluids. The main factors affecting the performance of the CHOPS + PTT process are the parameters of the “wormholes” formed during the CHOPS (their diameter, density at the bottom of the wells and the dependence of these parameters on distance and on the well), as well as filtering processes taking place in the “wormholes”.

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