Assessment of CO_2 flooding as enhanced oil recovery

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Abstract. This article discusses evaluating CO_2 injection as an enhanced oil recovery method. Carbon dioxide injection is a secondary and tertiary enhanced oil recovery method and is used in the final stage of development. Carbon dioxide mixes well with oil and can dissolve heavy components. Also, CO_2 maintains reservoir pressure, which prevents the flow rate from dropping. In order for carbon dioxide and oil to mix, it must be brought to a critical state by increasing the temperature and pressure. After reaching the required conditions, both substances are fully compatible. The result of this combination is a medium that can easily seep through a porous medium. In fact, gas injection would be appropriate to use in a carbonate reservoir, and in our country and all over the world there are many oil fields that are located in carbonate rock. This work is based on data on a field located in the Krasnoyarsk region, which is part of the Angara fold zones. The field itself is represented mainly by carbonate reservoirs. Also, application of this method for Kazakhstan oilfield will be considered, using an example Zhetybay oilfield.

1 Introduction

The main part of the current world oil production is accounted for by fields that are at the last stage of development. Increasing recoverable oil reserves from these reservoirs is a leading task in the oil and gas industry. And one of the most effective ways to do this is to injecting gas with a further miscibility of the process. Injecting gas into a reservoir is a good decision for maintenance of reservoir pressure and vaporization of heavy components.

This process is based on the injection of a CO_2, in which the reagent is mixed with the initially oil in place. During the light gases injection, they mixed with reservoir oil, increasing the volume of oil and reducing its viscosity. The use of carbon dioxide is achieved by extracting the petroleum fractions and called Vaporizing Gas Drive.

Body part. Sedimentary rocks are most suitable for hydrocarbons accumulation out of three rock types. Sedimentary rocks, due to composition, consists of several subgroups. They differ from each other in case of mineralogy. Carbonate rocks gained their name,

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because of minerals based on the CO^{3-} ion. As good example, we can take such rocks as dolomite and limestone. Another subgroup called Siliclastic group, due to its composition, where the major part is silicate materials: as sandstones and conglomerates.

Type of carbonate reservoirs are chosen, because big amount of world's oil reserves are found in it. As any type of rock, it has its own specifications. Carbonate layers are made of reefs, clastic limestone, chemogenic limestone, and dolomites. However, most often, their structure includes limestones and dolomites. Their distinctive feature is the filtration and reservoir system, which has a complex structure, as well as the deposits contained in them, which interact with the surface of the reservoir rock in a very specific way. Main difference between sedimentary rock types as carbonate and siliclastics being able to affect to carbonate layers filtration and volume properties with different types of acid treatment. Even in carbonate rock layers big amount of oil accumulated, siliclastic rock layers are widespread. Mean value of porosity values is about 20%, when permeability is one out of tens, hundreds of square mm. When this type is spread locally in some areas, carbonate rock layered oilfields sizes are imposing [1].

The oilfield which is researching is oil-gas-condensate reservoir of Upper-Proterozoic period and located in Krasnoyarsk Region. This oilfield is located between rivers Angar and Podkamennnaya Tunguska. It is also called Angar zone of folds. There are also neighbor oilfields as Ilbokichskoye and Agaleevskoye. To talk from tectonic side, the productive zones are is located on Southern West of Siberian platform. There are two surfaces, from which this area is consisted of, the crystal base and sedimentary cover. The last one is divided into 2 structural periods: the Riphean and the Vend-Devonian periods. Essential to note that, some terms including Riphean and some other ages only belong to Proterozoic stratigraphy of Russia. Geological structure is made partially by metamorphic formations of Archean and Proterozoic eons and sedimentary formations are Proterozoic and Paleozoic eras. There was observed the Riphean, Vend, Cambrian and Ordovician deposits, in the first two there are an effective reservoir and horizon. The reason of such phenomena is because of oskobinskoye and vanavarskoye age deposits. In here, there are B-3, B-9 and B-1 layers were outstanding. These deposits are presented with carbonate and siliclastic rocks, which has simple and dual porosity. To talk about Riphean deposits, there are 3 effective horizons called P-0, P-1 and P-2, and they are separated from each other with shale lines. Riphean deposits are mostly carbonate and cavern- fracture and rarely cavern-pore-fracture type of matrix. It is important to note that; productive horizon is mostly located in Riphean dolomites. After some operations, like intensive paleohypergenesis, it was formed extra pores, micro and macro fractures and caverns [1].

For the simulation this oilfield was chosen, because fluid and reservoir conditions are available in open source. Let's try to choose relevant method for rock conditions. Carbonate rock layers usually have low porosity and can have fractures. Implementing EOR technologies in a carbonate reservoir, the injected reagent will in most cases pass through a system of fractures and faults, and bypass the oil in the rock matrix. Gas injection is still the most common way for this type of lithology [2].

On the other hand, the screening criteria is a totally significant for superficial inspection in order to find out, if reservoir conditions are suitable or not. The depth, viscosity, permeability were considered to provide gas injection. To make sure, materials were taken from various sources and compared. From table below is illustrated a reservoir characteristics and oil properties.

Table 1. Reservoir characteristics and oil properties.

Oil properties			Reservoir characteristics			
Viscosity, (cP)	Gravity, (API)	Composition	Formation type	Average permeability, (md)	Depth , (feet)	Temperature, (K)
0.5	41˚	High percent of C1 to C7	Carbonate	<10, NC	>6000	373, NC

Enhanced oil recovery methods are a tertiary methods, which increase amount recoverable oil. From figure below, we can identify, that in order to inject a gases to achieve miscibility, require to fluid is locate deeper than 6000 ft , and has a value of viscosity smaller than 10 cp. To inject carbon dioxide the small value of depth is suitable, it means in order to achieve miscibility enough low value of pressure [3].

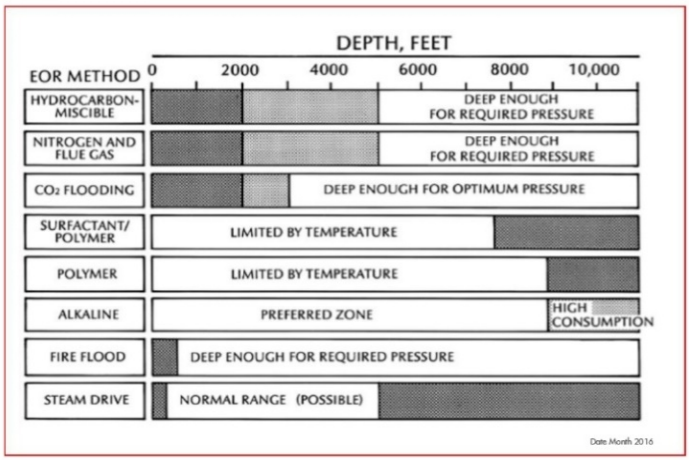

Fig. 1. EOR screening with depth criteria.

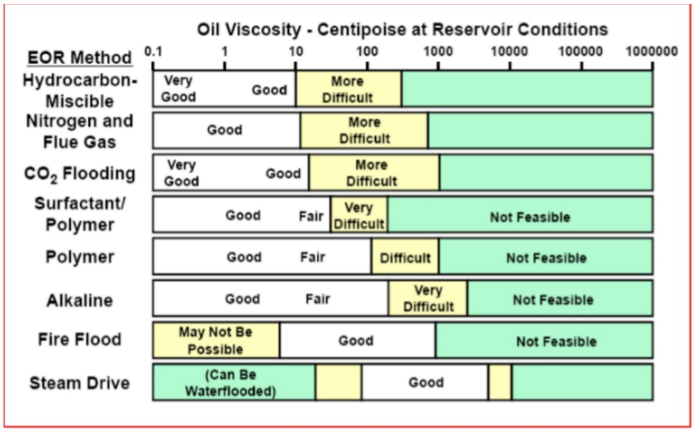

Fig. 2. EOR screening with viscosity criteria.

When we inject CO_2 into an oil reservoir, it becomes mutually soluble with the residual crude oil as light hydrocarbons from the oil dissolve in the CO_2 and CO_2 dissolves in the oil. This occurs most readily when the CO_2 density is high (when it is compressed) and when the oil contains a significant volume of "light" (i.e., lower carbon) hydrocarbons (typically a low-density crude oil). Below some minimum pressure, CO_2 and oil will no longer be miscible. As the temperature increases (and the CO_2 density decreases), or as the oil density increases (as the light hydrocarbon fraction decreases), the minimum pressure needed to attain oil/CO_2 miscibility increases. For this reason, oil field operators must consider the pressure of a depleted oil reservoir when evaluating its suitability for CO_2 enhanced oil recovery. Low pressured reservoirs may need to be re-pressurized by injecting water [3].

According to field simulation model was constructed in ECLIPSE 300 software. ECLIPSE 300 is usually used for constructing models where compositional change take place, which is similar to the purpose of this work. 5 spot wells were constructed, 1 injection well, 4 production wells. Fig. 3 shows the profile of oil saturation for CO_2, and injection process.

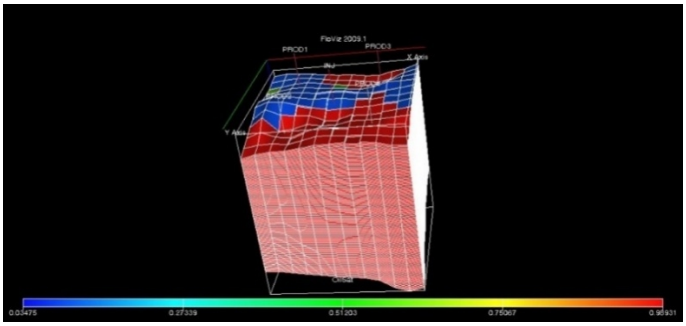

Fig. 3. Oil saturation profile for CO_2.

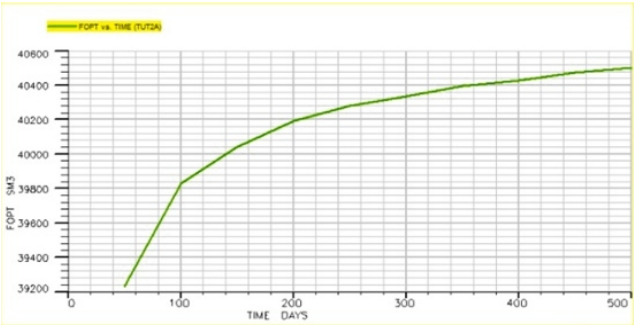

Fig. 4. Field Oil Production Total for CO_2.

From Fig. 4 we can see an increase in the field total oil production, it means the CO_2 good affects to reservoir, dissolving heavy components, after that mixing with oil [4]. Aim of this work is based on application of this method to Kazakhstani oilfield. The Kazakhstan field, which coincides with the characteristics of the formation with the Krasnoyarsk region, is Zhetybay. At the Zhetybay field, drilled wells have uncovered the thickness of the Paleo-Meso-Cenozoic sediments with a maximum depth of 4502 m, represented by rocks of the undifferentiated Carboniferous, Triassic, Jurassic, Cretaceous, Paleogene and Neogene systems. The uncovered section of carboniferous deposits in well 25 in the range of 3722-4502 m is represented by an interbedded layer of dense dark gray multi-grained polymictic

sandstones with interbeds of gravelites and small-pebble conglomerates, siltstones, black clay shales, fine-grained carbonate rocks and carbonated tuffs. Rocks are cataclysmic, cracks are sometimes made of carbonate materials, the angle of incidence of the layers is 30-45° [5].

Table 2. Current properties of reservoir oil on the horizon.

Horizon	Pr, MPa	Psat, MPa	Gas content		Formation volume factor	Oil shrinkage, %	Oil density at reservoir condition, g/sm^3	Oil viscosity at reservoir condition, mPa*s	Compressibility factor *10^{-4} /MPa	Coefficient gas solubility m^3/m^3 MPa
			m^3/t	m^3/m 3						
J-2	15.9	15.7	88	76	1.220	18	0.778	2.98		4.84
J-3	15.9	15.7	88	76.5	1.220	18	0.778	2.98		4.84
J-4	16.6	12.4	70.6	62.1	1.178	16.0	0.807	3.99	16.1	5.01
J-5	16.6	12.4	70.6	62.1	1.178	16.0	0.807	3.99	16.1	5.01
J-6	16.8	13.5	75.5	67	1.216	17.8	0.805	3.99	17.6	4.96
J-7	17.5	14.2	99.3	85.3	1.251	19.7	0.768	1.7	17.2	6.01
J-8	18.2	14.2	99.3	85.3	1.251	19.7	0.768	1.7	17.2	6.01
J-9	18.8	14.2	108.9	92.6	1.282	22.0	0.749	1.44	15.6	6.52
J-10	19.4	14.4	123.6	103.7	1.330	24.9	0.720	1.33	15.1	7.20
J-11	19.9	14.4	123.6	103.7	1.330	24.9	0.720	1.33	15.1	7.20
J-12	20.5	14.4	113.8	96.1	1.300	23.0	0.751	1.30	15.1	6.67
J-13	20.9	14.4	113.8	96.1	1.300	23.0	0.751	1.30	15.1	6.67

J-13 horizon is suitable for carbon dioxide flooding according to Table 2. This decision was applied based on the viscosity, density of oil, gas content, saturation, and reservoir conditions [5].

Conclusions

In this article data were taken from the field located in the Krasnoyarsk region, which is part of the Angar fold zones. The lithology of this field is a carbonate, and has a fractured-cavernous structure.Also, it is worth noting that in order to conduct carbon dioxide injection, the reservoir must have a certain conditions, which are shown in the screening table. The gas displacement is great for reservoirs that are deeper than 6,000 ftand not containing heavy hydrocarbons. After that, CO_2 flooding was held in simulation, obtaining FOPT graph with time. Most of Kazakhstani oilfields are located in carbonate layers, Zhetybay field has comprehensive rocks, such as a multi-grained polymictic sandstones with interbeds of gravelites and small-pebble conglomerates, siltstones, black clay shales, fine-grained carbonate rocks and carbonated tuffs. Actually, rocks of Zhetybay field are strong,

therefore carbon dioxide flooding is suitable for enhanced oil recovery. According to Table 2, J-13 horizon was chosen to provide gas flooding. The parameters are similar to those for Krasnoyarsk region, viscosity, deep, density of oil, reservoir conditions are compatible. To conclude, CO_2 injection are recommended for Zhetybay field.

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