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STUDY ON CO_2 SOAKING TIME AND "HUFF AND PUFF" INJECTION CYCLE EFFECT IN TIGHT PERMEABILITY RESERVOIR

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ABSTRAK

Industri migas berupaya untuk meningkatkan produksi minyak menggunakan beberapa metode. Salah satunya yaitu injeksi CO_2 *merupakan teknologi lebih lanjut yang terbukti dapat meningkatkan produksi minyak di beberapa lapangan minyak di dunia. Parameter utama dalam injeksi* CO_2 *adalah pengurangan viskositas dan pengembangan minyak di mana nantinya akan meningkatkan produksi minyak. Injeksi* CO_2 *juga mempunyai tingkat kemungkinan yang tinggi untuk dapat diaplikasikan di lapangan-lapangan minyak Indonesia karena lapangan-lapangan tersebut memiliki sumber-sumber* CO_2 *yang cukup besar di sekitarnya. Lapangan R merupakan salah satu kandidat yang cocok untuk injeksi* CO_2*. Lapangan ini memiliki tekanan dan perolehan minyak yang rendah akibat permeabilitas yang rendah (1-26.2 mD). Teknik injeksi* CO_2 *yang digunakan pada studi ini yaitu huff and puff yang terdiri dari fasa injeksi, penutupan sumur, dan produksi. Simulasi dilakukan menggunakan simulator komposisional. Terdapat dua parameter yang akan dianalisis, yaitu soaking time, dan siklus injeksi. Tujuan dari studi ini yaitu untuk mengetahui performa dari CO2 huff and puff untuk meningkatkan perolehan minyak pada reservoir dengan permeabilitas yang rendah. Hasil dari scenario soaking time menunujukkan kondisi optimal terjadi dalam 21 hari. Untuk scenario siklus injeksi, hasil optimal tercapai pada 2 siklus injeksi. Nilai faktor perolehan (RF) untuk masing-masing kondisi optimal mencapai 22.96% dari nilai baseline tanpa gas injeksi (RF 5.82%).*

Kata Kunci: *huff and puff, waktu soaking, siklus injeksi, injeksi* CO_2*, tight permeability reservoir*

ABSTRACT

Oil and gas industry is struggling to improve oil production using several methods. CO_2 injection is one of the advance proven technology to enhance oil production in numerous oil field in the world. Key parameters during CO_2 injection are viscosity reduction and oil swelling which can improve oil production. CO_2 injection also has high possibility to be applied in Indonesia's oil fields due to abundant CO_2 sources surrounding oil fields. R field is one of reservoir candidates that appropriate for CO_2 injection. It has a low pressure and low oil recovery due to low permeability (1-26,2 mD). The CO_2 injection technique used in this study was huff and puff that consist of injection, shut in, and production phases. The simulation was conducted using compositional simulator. There were two parameters chosen to be analyzed, which were soaking time and injection cycle. The objective of this study is to know the CO_2 huff and puff perfomance for improving oil recovery on low permeability reservoir. The result of the soaking time cases yields optimum condition in 21 days. For the case of injection cycle, the result for optimum condition is in 2 injection cycles. The recovery factor (RF) for both optimum condition reaches 22.96% from the baseline without gas injection (RF 5.82%).

Keywords: huff and puff, soaking time, injection cycle, CO_2 injection, tight permeability reservoir

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I. INTRODUCTION

Oil and gas industry are trying to find the advance and right technology to improve oil recovery with using either conventional or unconvenional cases recently. CO_2 injection is one of Enhance Oil Recovery (EOR) technology that quite popular in the world. CO_2 injection could capable of increasing the well productivity through viscosity reduction and oil swelling. Moreover, CO_2 injection is also suitable to be flooded into light oil, medium, oil, and heavy oil (Singh, Singhal, & Sim 2006).

CO_2 injection has high possibility to be applied in Indonesia's oil field. There are a lot of fields according to screening criteria that matches to the condition and rich CO_2 sources in Indonesia. For example, natural hydrocarbon gas reservoir in Natuna which contain 71% mole CO_2, and also natural gas processing plant in West Java with CO_2 percentage around 45%-75%. CO_2 source in Indonesia also can be collected from power plant and oil and gas industry that produced gas with less than 25% mole CO_2 (Muslim, et al., 2013).

CO_2 'huff n puff' is one of injection method that involves injecting miscible gas into a well and then after some soaking time, producing back from the same well (Hoffman, 2018; Hoffman & Rutledge,2019). This technique has been conducted successfully in some oil fields, such as Forest Reserve, in Trinidad and Tobago, which is the first field that applied with using CO_2 huff n puff (Singh, et al., 2006). In US, there are Big Sinking, U.S light oil with immiscible condition and South Louisiana, U.S light oil (Monger & Coma, 1988; Yu, et al., 2014) soak period, thicker interval, and lower prior water cut. IntroductionThis paper is a laboratory and field investigation of the CO_2 huff 'n' puff process for enhanced recovery of light crude oil. The results of continuous and cyclic CO_2 displacements with a 32 degrees API [0.87-g/cm^3] stock-tank oil in watered-out Berea cores are presented. Fourteen single-well cyclic CO_2 field tests in south presented. Fourteen single-well cyclic CO_2 field tests in south Louisiana sands are examined. Laboratory results demonstrate that the CO_2 huff 'n' puff process recovers water-flood residual oil. Incremental oil recovery process recovers waterflood residual oil. Incremental oil recovery increased with the amount of CO_2 injected and was not benefited by operating at the minimum miscibility pressure (MMP. Up to 9 % incremental RF could be gained when CO_2 huff n puff was used compared to production dependent only n hydraulic fracture stimulation (Pankaj, et al., 2018). Optimum injection pressure of CO_2 huff n puff prosses can be set around the minimum miscible pressure (MMP) between oil and CO_2, while the soaking time could be optimized for enhancing oil recovery (Song & Yang 2013; Yu et al. 2016). The number of huff n puff injection cycles can also be optimized to improve oil production (Li, et al., 2016; Meng, et al., 2015).

From this study, the optimum condition from soaking time and the number of injection cycles with using R field data will be determined. This field is classified having light oil reservoir, high oil saturation, and tight permeability. The objective of this study is to know the CO_2 huff and puff perfomance for improving oil recovery on low permeability reservoir.

II. METHODOLOGY

This simulation study was conducted using compositional simulator CMG GEM. The simulation model was carried out by using simple and heterogeneous model (Figure 1). The size of the grid is 15x15x2 with wide around 10 acres. The reservoir characteristics were written in Table 1 with reservoir fluid classified into light oil. CO_2 huff and puff injection simulation scheme (Figure 2) were conducted beginning in the date of

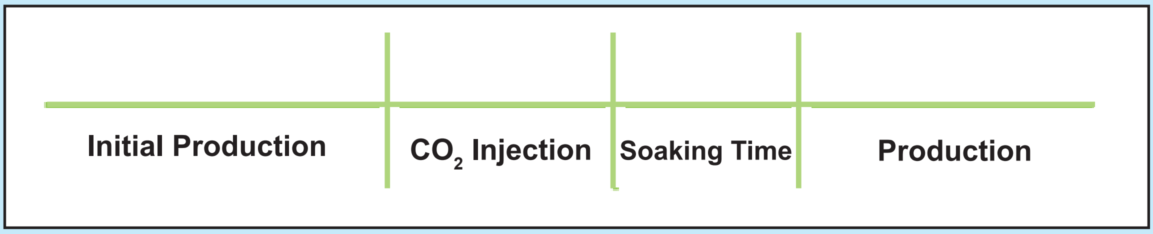

Figure 1
Conceptual simple simulation model.

Table 1
Reservoir characteristics

Parameter	Unit	Value
Initial Reservoir Pressure	Psi	1.267
Reservoir Temperature	°F	158,5
Depth	Ft	3.045
Thickness	Ft	10
Porosity	%	19-26
Permeability	mD	1-26,2
Oil Viscosity	cP	0,4-0,6

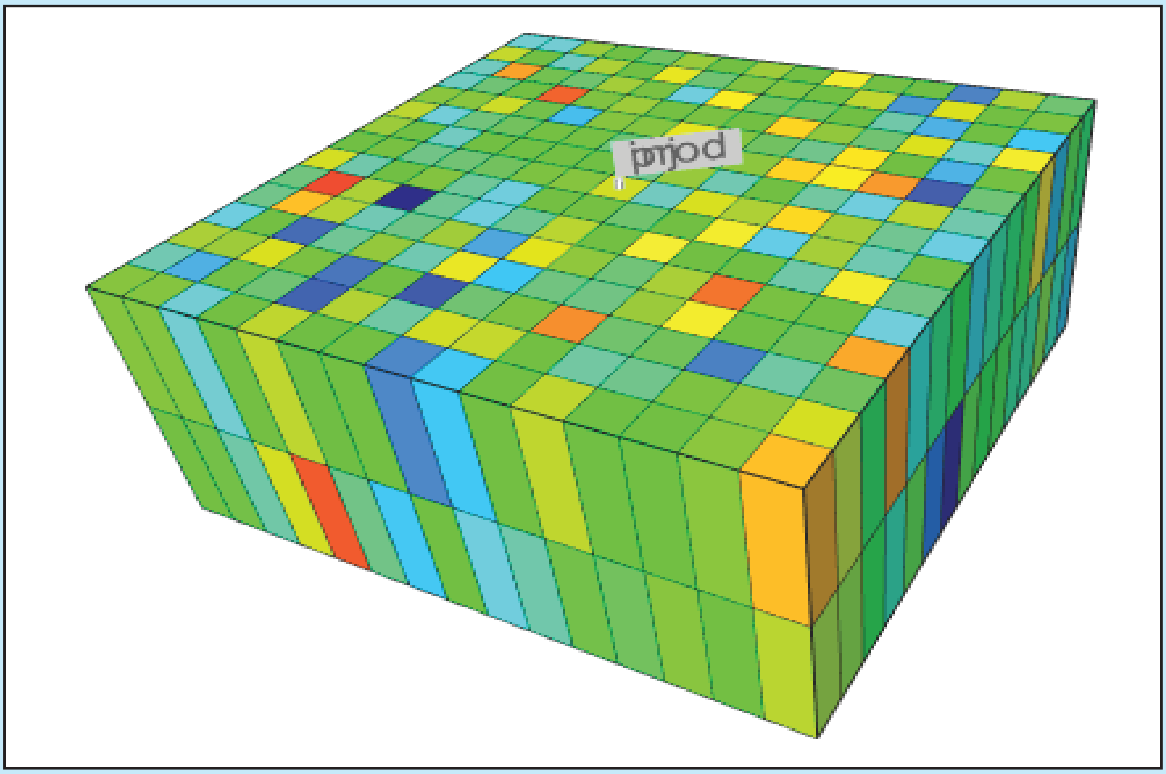

Figure 2
CO_2 Huff n Puff injection scheme.

18 March 2018 using immiscible condition. Initial recovery factor for this model is around 21,69%.

III. RESULTS AND DISCUSSION

A. Soaking Time Effect Analysis

Soaking time is one of major consideration for CO_2 huff and puff injection. This parameter is focused to the well time interval during shut-in state until reach the optimal condition, so CO_2 may dissolve to the oil. This condition will have impacts to the other oil characteristics, such as reduction of viscosity and interfacial tension.

To determine the optimum soaking time, the simulation was done with three different times interval, that is: 7 days, 21 days, and 35 days. The consideration of the number of the days refers to previous research of other fields that have implemented CO_2 huff and puff injection. For instance, South Luisiana Field with soaking time 18-52 days (Monger & Coma, 1988) soak period, thicker interval, and lower prior water cut. IntroductionThis paper is a laboratory and field investigation of the CO_2 huff 'n' puff process for enhanced recovery of light crude oil. The results of continuous and cyclic CO_2 displacements with a 32 degrees API [0.87-g/cm^3] stock-tank oil in watered-out Berea cores are presented. Fourteen single-well cyclic CO_2 field tests in south presented. Fourteen single-well cyclic CO_2 field tests in south Louisiana sands are examined. Laboratory results demonstrate that the CO_2 huff 'n' puff process recovers waterflood residual oil. Incremental oil recovery process recovers waterflood residual oil. Incremental oil recovery increased with the amount of CO_2 injected and was not benefited by operating at the minimum miscibility pressure (MMP, Texas Field with soaking time 10-17 days (Yu, et al., 2014), dan G field with soaking time 7-38 days. In each of soaking time cases, the other variables are quite the same, which is injection period, production period, and injection rate is at 11.8 MSCF/day.

Figure 3 shows that different soaking times are not linear after reaching optimum condition. It means additional days for soaking time are not always increasing oil recovery. In general, different soaking time will affect recovery factor, even not significantly. However, soaking time determination must be conducted to reach the optimum condition. Soaking time which is too early will cause the recovery factor not in optimum state.

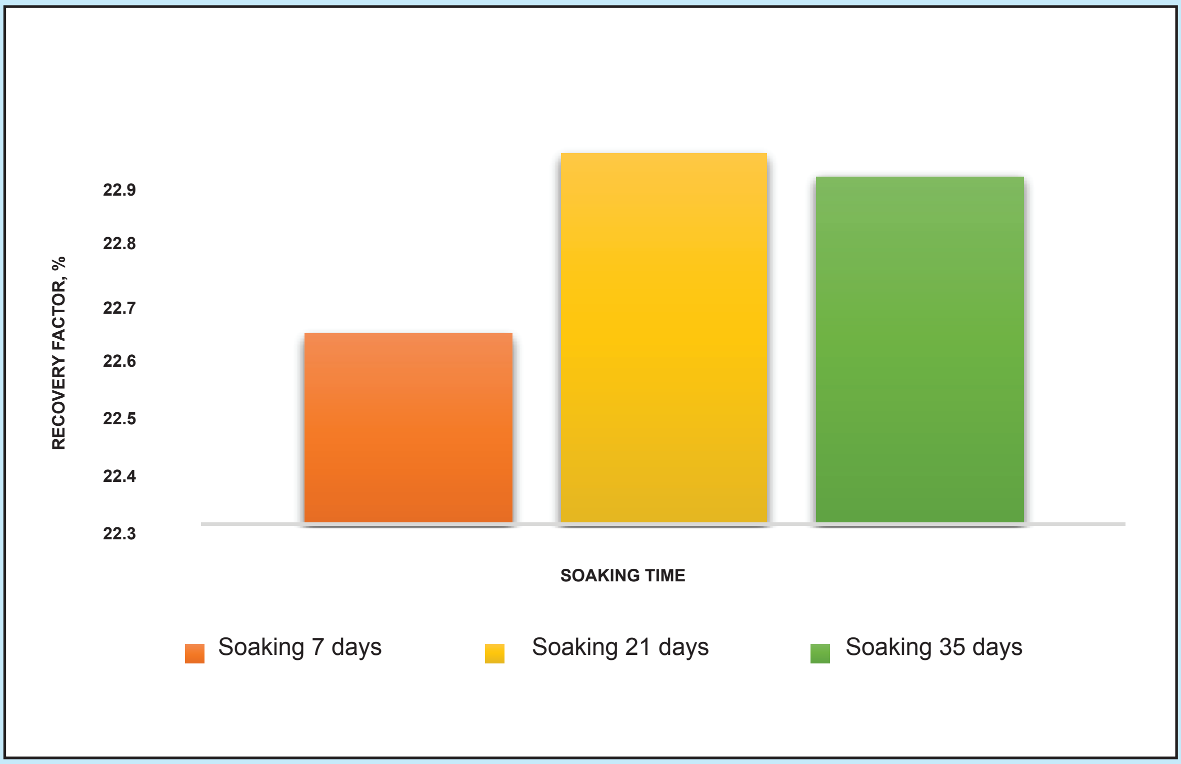

Figure 3
The comparison of recovery factor to soaking time cases.

It is caused by the time needed by CO_2 to dissolve in oil become less, as a result, CO_2 performances to change oil characteristics was decreased. Soaking time that is too long will not lead to the optimum recovery factor, for production time losses reason.

The viscosity reduction is not significant parameter because reservoir fluid used in the model is light oil and the initial viscosity is already low. As shown in Fig 4 and 5, CO_2 injection will not really affect the reduction of viscosity and interfacial tension of the light oil. However, soaking time affects oil viscosity reduction which also improve recovery factor.

Based on the recovery factor and cumulative production (Table 2) from each case, the optimum soaking time needed is 21 days. This soaking time are similar with the one used in other fields, which is 2-4 weeks from Singh et al. (2006). The optimum soaking time also depends on the reservoir characteristics and it caused by CO_2 can be dissolved more in this case, which resulting higher oil recovery.

B. The Huff n Puff Injection Cycle Effect Analysis

Huff n Puff injection cycle is the step from injection, soaking, and production that was done repeatedly. The number of cycles surely affects oil recovery. In these cases, the number of cycles used are different, that is 2 and 3 cycles. Injection rate and volume is constant in each of cases. Total time injection in each case is also similar, that is 150 days. Moreover, injection time are different in each

Table 2
Incremental cumulative oil production for each soaking time cases

Soaking Time (day)	Cumulative production (bbl)	Incremental of cumulative production (%)
N/A	23.762	-
7	24.8	4.37%
21	25.146	5.82%
35	25.114	5.69%

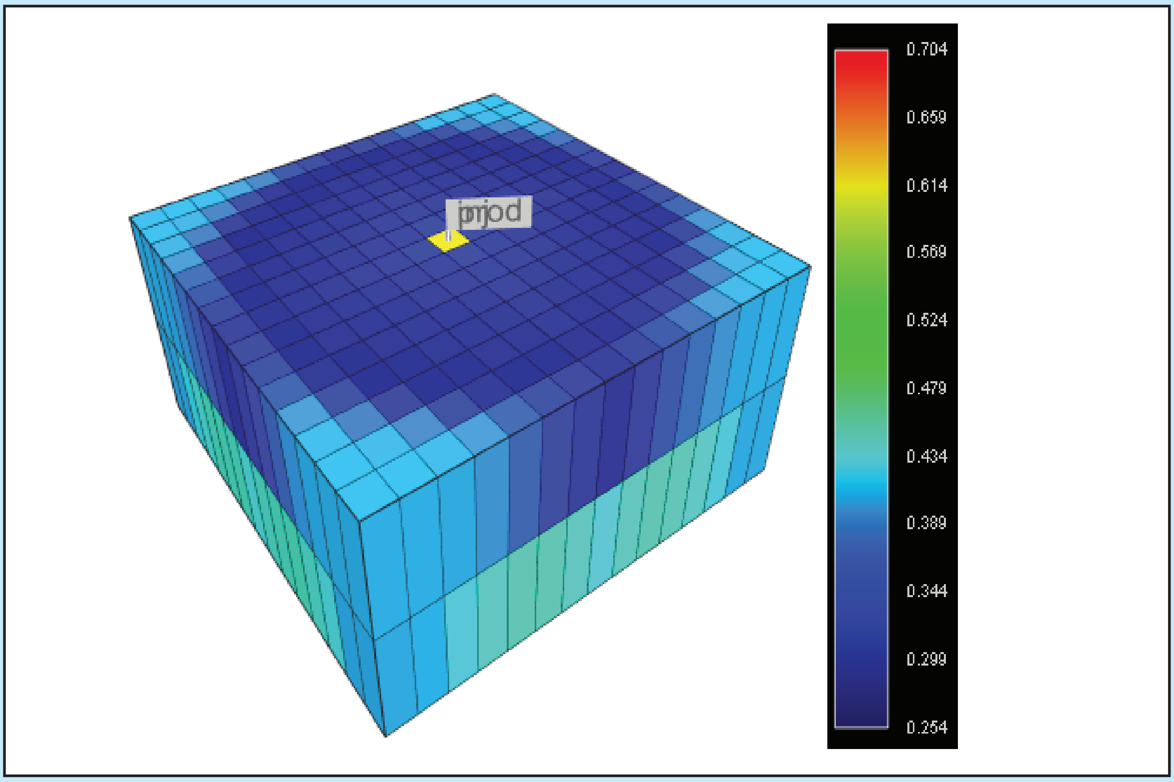

Figure 4
Oil viscosity (soaking time 21 days).

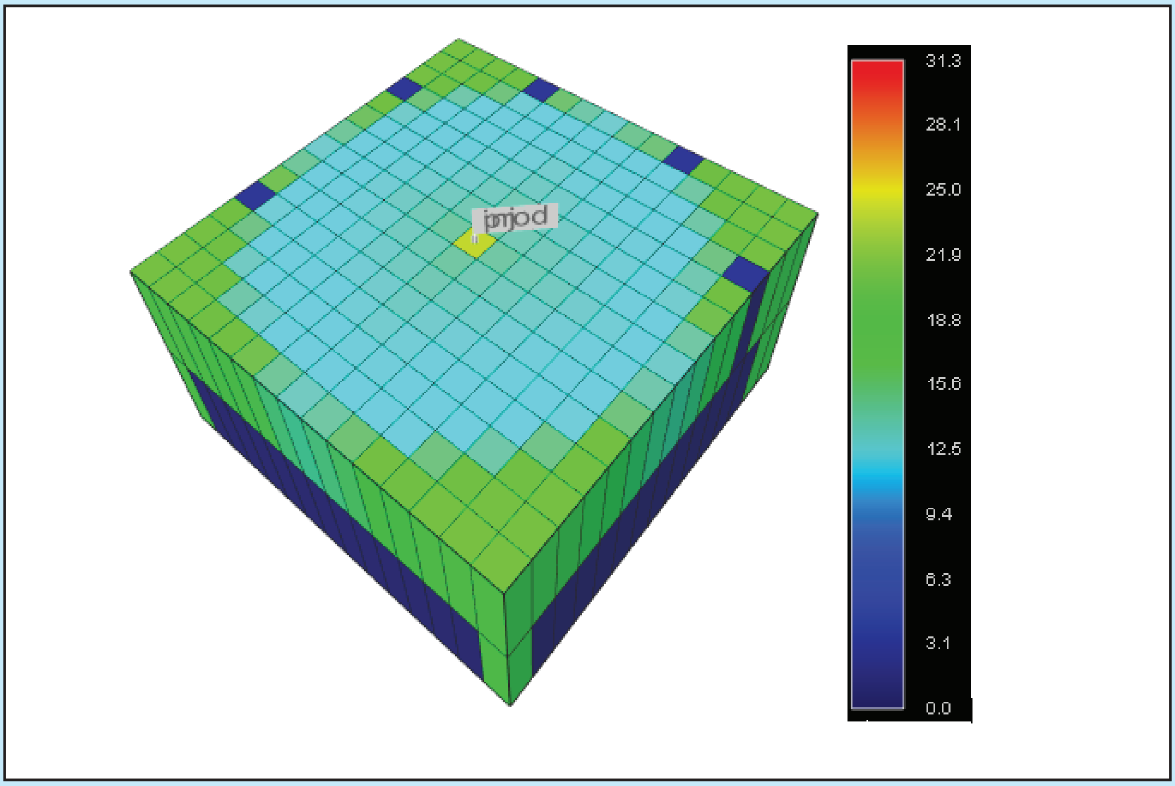

Figure 5
Interfacial tension (soaking time 21 days).

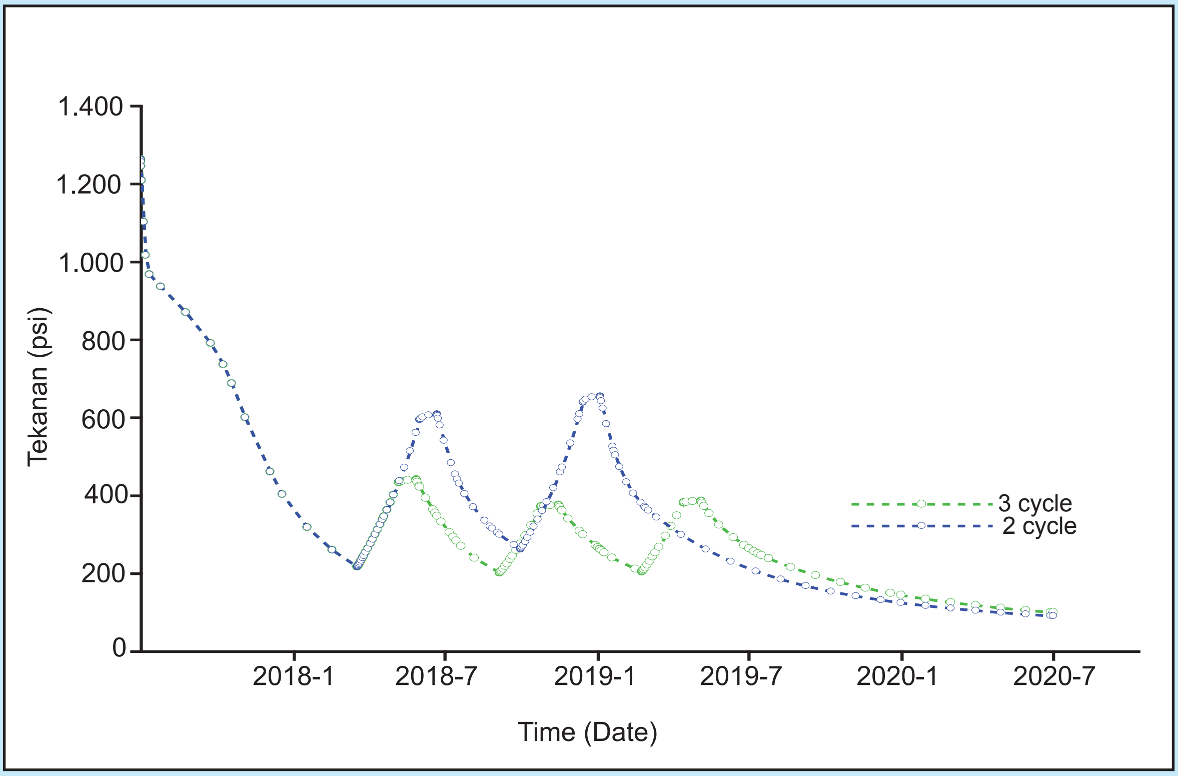

Figure 6
Pressure vs time in each of cycle.

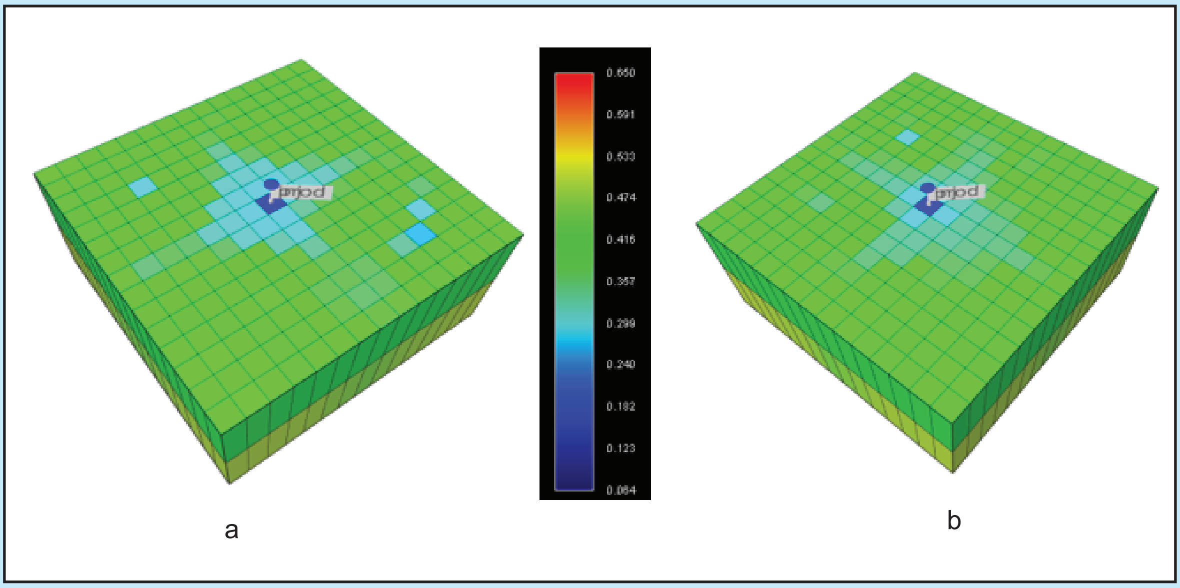

Figure 7
Oil saturation (a) 2 cycle (b) 3 cycle.

of cycles. Injection time in 2 cycles is 75 days and 3 cycles is 50 days.

The different injection time is affecting pressure and time. Pressure with 2 injection cycles is higher than in 3 cycles (Figure 6). This pressure will affect oil recovery. If the pressure is higher, the oil recovery will become higher. The oil recovery is 22.96% and 21.8% in 2 and 3 cycles, respectively. This result was supported by drainage radius that as illustrated in Figure 7, which in 2 cycles is higher than in 3 cycles schemes. The optimum number of cycles to increase oil recovery is using 2 cycles. It is also similar with the study of Fulin & Yun (2010) in Jiangsu Field. However, the optimum of number of cycles may different, which caused by reservoir conditions.

IV. CONCLUSION

In order to produce more oil from R field due to low permeability condition, the operational parameter such as optimum soaking time in 21 days and optimum cycle number with 2 cycles. Based on these simulation, oil recovery reach 5.82% or cummulative oil recovery of 25.146 bbl. Based on this study, the soaking time determination will have a great effect in the recovery factor. The huff n puff injection cycle determination also yields significant effect on the incremental oil production from huff n puff injection.

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