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Gas and Water Reinjection Strategy to Enhance Oil Productivity with Voidage Replacement

Bonavian Hasiholan, Dhaief Allah Dhaief Allah Ahmed Al-Saiedy

Abstract: ***During the last few years enhanced oil recovery (EOR) methods including water alternative gas (WAG) have been sufficient in recovering a portion of the unrecovered oil specifically when it is combined with other strategy such as voidage replacement. In this paper oil productivity enhancement is observed by implementing voidage replacement with WAG process. Secondary plan and WAG are simulated and evaluated by ECLIPSE-100 software. WAG achieved a recovery factor of 63% during 30 years of simulation prediction process with primary and secondary plans. Surface facility was designed to run under WAG & voidage replacement ratio (VRR) principles. VRR values of 1.5-1.2 & 2.0-1.4 were maintained in WAG-1 and WAG-360 scenarios respectively for the last five years of production life when it was at high VRR value before. That VRR drop essentially due to the WAG process and as it was correlated with the reservoir-X average pressure that was maintained at (3100-3300) psi in reservoir-X performance.***

I. INTRODCUTION

The energy generation is getting more complicated by the amelioration and advanced levels of technology all over the world and as a non-renewable energy, oil and gas industries have become the largest and most demanded source of energy generation [1]. The characteristics of the reservoir, availability of the process, environmental considerations, oil recovery factor as well as the cost of each process are the fundamental criteria to determine which reservoir to be an appropriate candidate for such operation [2]. Chemical methods have been applied in different places all over the world such as North Sea fields, China, and Canada fields [3]. The chemical process has acquired great success but unfortunately these processes are costly. The oil recovery was ameliorated in other techniques when the water injection was not effective as single phase injection due to the lack of the efficient displacement phenomena [4]. This is the cause to evaluate another methods such as the new technique tertiary recovery of oil, discussed in this paper is known as water alternating gas reinjection (WAG) with Voidage replacement principles[5-11]. Due to progressive shortage of the world petroleum reserves and no other sources of energy could have been used as effective as petroleum products and fractions as well as the world oil reserves is exponentially declining during the past years [6-8].

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Bonavian Hasiholan, Faculty of Engineering, Technology & Built Environment, UCSI University, 56000 Cheras Kuala Lumpur, Malaysia.

Dhaief Allah Dhaief Allah Ahmed Al-Saiedy, Faculty of Engineering, Technology & Built Environment, UCSI University, 56000 Cheras Kuala Lumpur, Malaysia.

Therefore, the residual oil that is trapped within the reservoir must be recovered in different processes that can be more economically and effectively performed [8]. As a solution WAG process as tertiary recovery combined with voidage replacement strategy was selected to be one of those processes when a good candidate sandstone reservoir with suitable petro physics properties is to be evaluated [5-11]. Particularly to enhance the sweep efficiency by injecting water and gas at the same time alternatively [5-11].

Reservoir simulation which is a form of numerical modelling was the main procedure in this researchpaper to illustrate and quantify reservoir-X phenomena physically, and extending the future performance of the project. Schlumberger Eclipse (100)-black oil simulator was used to simulate the process combining the voidage replacement principle with WAG procedures in reservoir-X in order to determine the appropriate facility, determine the most economical perforation method, number of production wells, injection pattern and suitable injection flow rate for both gas and water.

II. METHODOLOGY

Reservoir simulation tool

Schlumberger Eclipse-100 (Black oil) and Petrel software were used as the main tools in the project in order to perform an investigation, evaluation and observation of the effects among the reservoir model in each simulation data run for the primary, secondary and WAG recovery plans. Reservoir-X was subjected to be operated through three stages of production primary, secondary (water flooding) and tertiary recovery (WAG) injection as enhanced oil recovery process. The base case was basically operating the reservoir without any injection of secondary or EOR processes in order to obtain a comparison between the three stages and investigate how much incremental in the recovery factor over each stage. The history matching was not conducted for reservoir-X because it was considered as new discovered oil reservoir that has not been operated before, and need to be evaluated for acquisition possibility.

The original volume in place of reservoir-X for the three phases (oil, gas and water) can be summarized in table 2, based on the PRT file report that was calculated by ECLIPSE. This file was the first report of the ECLIPSE run of the first year (1 JAN 2011) as the initial volume of reservoir-X.

The initial conditions of reservoir-X was stated and described by equilibration which is the responsible about

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the initial pressure and saturation that need to be calculated by ECLIPSE under the keyword EQUIL. The reservoir has an approximate horizontal permeability of 200-400 md in X, Y directions while the vertical permeability according to petrel permeability maps with a 0.25 porosity fraction among the reservoir that was set in the data code.

Base case plan

The base case ten wells were fully completed from layer-1 till layer-8 as it is observed in K1, K2. Fully perforation scenario was selected as a base case and any modifications for the wells' location and perforations are going to be included in the scenarios for each case obtaining the best scenario in oil recovery and cost considerations to be selected as the best case.

Primary recovery plan

Additional two production wells (PROD11, PROD12) were introduced to the model according to the permeability and saturation maps with high oil flow rate 1500 STB/D as well as few changes were made on the producers such as changing some of the wells' locations (PROD7, PROD9 and PROD12) based on the high oil saturation zones.

Secondary recovery plan

The secondary recovery was conducted for the purpose of maintaining the pressure within the reservoir when the natural energy of the reservoir becomes less sufficient to withdraw the oil into the wellbores of the production wells as well as to displace the residual oil that has not been produced by the primary method. The time of initiating this plan was based on the recovery factor (RF) curve of the primary plan, thus the secondary recovery was performed when the recovery factor curve started to decline throughout the years of production. The injection was performed for one, two and three injections wells and it was found that two injection wells (INJ1 & INJ2) achieved better results than the other scenarios as the third water injection was found to be less effective and not economical step based on the water injection cost analysis with amount of oil recovered by that injection well.

WAG recovery plan

WAG process was applied after reaching the maximum result of the water flooding process based on the recovery factor curve the time of performing WAG method was decided. WAG process was conducted by two stages of the operation. By referring to the economic analysis of the injection cost through time it was selected to perform WAG for the last ten years of the reservoir operation life time. WAG Parameters were varied and changed such as the WAG cycle, injection pressure and injection flow rate. 90, 180 and 360 days of WAG cycling time were evaluated and the optimum result was selected. Figure 1 shows the distribution of WAG injection wells within the reservoir.

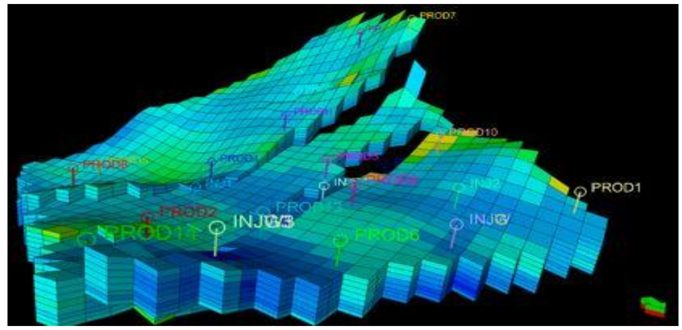

Fig . 1 WAG injection wells

The WAG injection wells (INJWG1, INJWG2 and INJWG3) was operated with injection rate 23,000 MSCF/D and 1800 STB/D for gas and water respectively. Voidage replacement strategy was used for the injection of water with adding the gas injection volume beside the water injected for the WAG injection

III. RESULT AND DISCUSSION

The major objective of oil industry development is increasing the recovery factor of the OOIP for more profits and energy supply. Figure 2 is showing the incremental recovery over the best scenario of each oil recovery plans. Primary and secondary plan's RF after modification reached up 50% and 54% respectively. Whereas, WAG-360 recovery was developed to approximately 63%. This recovery increment is basically due to the additional oil that was swept microscopically and macroscopically by gas and water respectively by the effects of the alternate water and gas injection. On other words, the volumetric (areal) sweep was enhanced macroscopically by the responsible injected fluid (water) and the vertical sweep was developed as well due to more areas that were contacted within the reservoir by the gas injected microscopically. Hence, the justification of that RF raise at year 20 of the process is the enhancement of sweep efficiency.

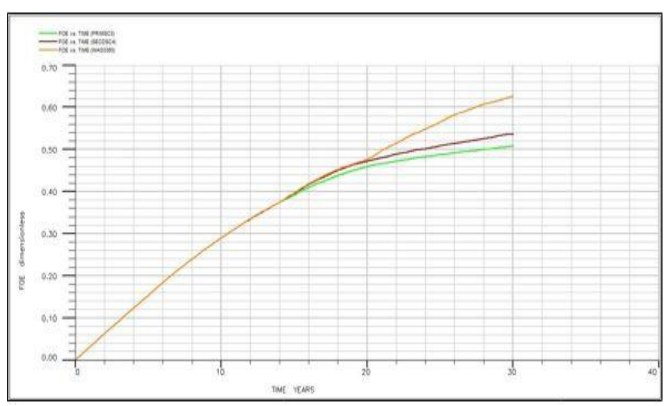

Fig . 2 Incremental RF of the three recovery plans

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The overall recovery of oil, gas and water of the three stages can be shown in Table 1 that can support the incremental recovery factor through the primary, secondary and WAG plans and shows the amount of water and gas injected back to the reservoir of each process as well as the difference between 180 days and 360 cycling period of WAG recovery can be observed.

Table 1. Total field production

Storage Fluid Stb	Recovery plan			
Recovery plan	Primary	Secondary	WAG180	WAG360
FOPT	64,473,432	68,213,544	79,257,544	79,431,616
FGPT	69,460,160	70,575,680	1.59E+8	1.62E+8
FWPT	12,773,504	15,428,752	24,897,038	26,589,886
FWIT	-	15,285,300	27,221,918	25,302,046
FGIT	-	-	1.29E+8	1.33E+8

Combination of voidage replacement strategy with water and gas reinjection to enhance the oil productivity was essentially the major aim of this research. Therefore, the voidage replacement ratio was calculated for every year of the WAG injection. VRR of only one WAG-1 injection can be observed as 2.13 VRR value in the first year of the injection (year 21) process ended with 1.20 ratio at year 30 as shown in figure 3. Hence, in details that means the injection volumes of water and gas were almost double of the production volume at the beginning of the process. Then it was gradually decreased to 1.20 ratio at the end of the process which quite near to the set value in the simulation data code, that drop in the voidage replacement ratio was due to the higher volume of production during the last five years of production that was accomplished by the WAG injection process. Frankly saying, a value of 1.0 VRR was not obtained as it is almost impossible be achieved in real activities.

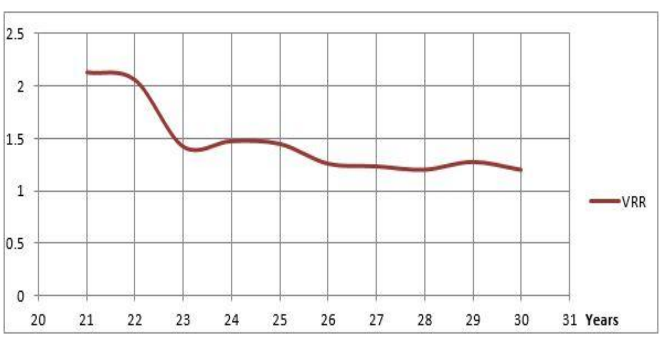

Fig . 3 Voidage replacement versus time with one WAG injection

Moreover, the stability of the curve on the last five years in a range of 1.20-1.30 VRR can be justified by the fact of WAG injection phenomena. In WAG injection it was proven that the effects of process will be efficiently noticed after several year due to the injection cycle time needed for the injected fluid to be spread within the reservoir and enhance the microscopic and macroscopic sweep efficiency by gas and water respectively. The result was not far away from the expected in WAG-360 voidage replacement ratio investigation, as it can be seen in figure 4 the ratio started at 7.2 injected to produced fluid and was terminated in VRR value of 1.4 on the last year of the WAG process. That severe increment in VRR ratio at the initiation time of the process can be clarified by the huge amount of water and gas injected through the three WAG injection wells (INJWG1, INJWG2 and INJWG3) for the last ten years.

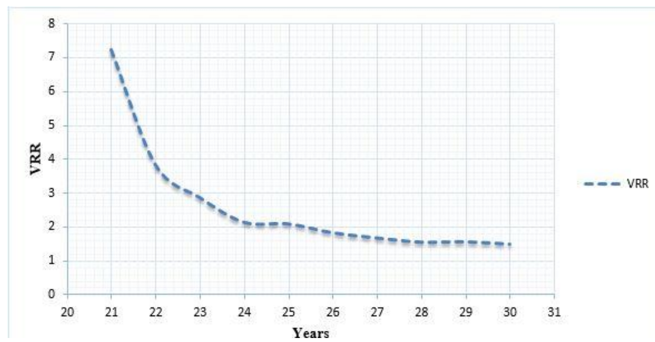

Fig . 4 VRR for three WAG injection well and 360 days cycles

Furthermore, a huge drop in VRR value to 4.0 just on the second year after the WAG operation started and the reason behind that drop is basically the incremental production of oil and gas as well as in water due to the WAG process effects on the residual reservoir fluids. The VRR continued in decreasing till it was kept below the unity value of 2.0 for the last five years of the production till it reached 1.4 on the last year which is reasonably accepted as it was set as 1.0 ratio in the code.

Reasonable similarity between the VRR of WAG1 injection and VRR of WAG-360 was noted in the behaviour of the VRR control and that confirms the successful of the strategy in the purpose of enhancing the oil recoverability. The curve of voidage ratio versus time interpretation was conducted in order to indicate that the reservoir pressure was significantly controlled by water and gas reinjection process. Furthermore, in a view of certainty reservoir average pressure analysis was performed as shown in figure 5, and it was compared with voidage replacement ratio with time for correlation between both plots.

According to Richard Baker ex-president of Epic (1997) [7] both reservoir average pressure with voidage replacement ratio should correlate with each other and that was achieved in this research in both VRR curves.

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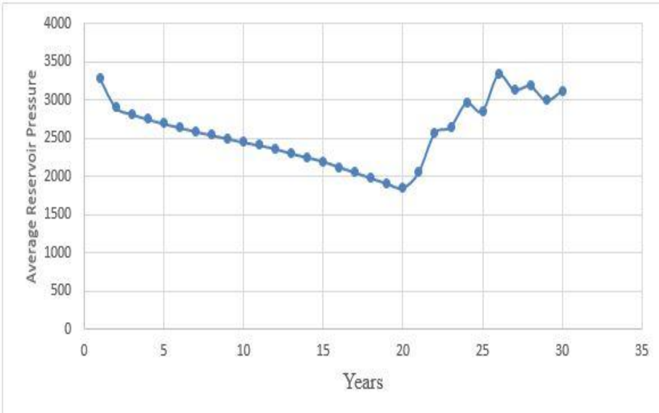

Fig . 5 Pressure decline curve and effect of WAG injection of reservoir-X

The VRR of WAG1, WAG-360 were maintained between (1.5-1.2) and (2.0-1.4) respectively for that last five years of the production operation as it can be observed in Figure 5 which identify the maintenance of average reservoir pressure between (3100- 3300) psi in figure 6 and the results were correlated.

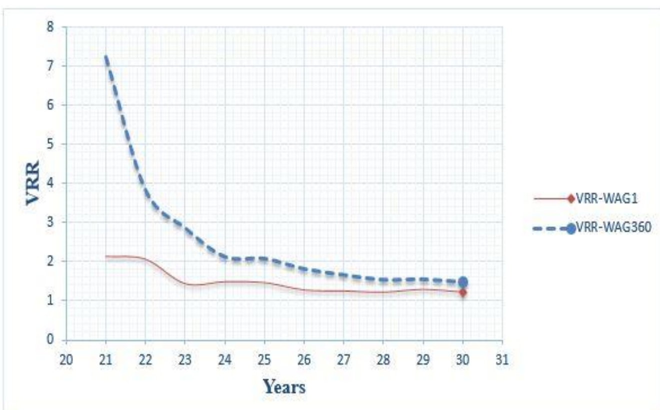

Fig . 6 VRR versus time for WAG-1 and WAG-360

IV. CONCLUSION

The RF was increased from 29% of the base case up to 63% in WAG-360 process passing over the primary and water flooding process. Furthermore, an economic analysis supported the outcomes of the project by obtaining a difference in the net profit value of $ 2,344,966,876 over the net income of the base case. The enhancement of oil recovery that was achieved basically is related to the enhanced macroscopic and microscopic sweep efficiencies by injecting water and gas alternatively. VRR versus time relationship gave a clear identification of the injection process monitoring correlated with reservoir average pressure as well as the total oil, gas and water production was controlled and evaluated throughout 30 years of the simulation process. According to the result obtained in the WAG-1 and WAG-360 scenarios it can be concluded that an enough water and gas is required to be injected to replace the specified fraction of the reservoir voidage volume (VRR=1). The VRR ratio was maintained on range of 1.5-1.2 and 2.0-1.4 in both scenarios respectively. The injection and production surface facilities were designed based on the production total of oil, gas and water as well as the availability of the treated water gas to be reinjected back to the reservoir. A double block injection system was designed according to the WAG reinjection conditions with considering the difference in injection pressure for water and gas as well as to be alternatively injected by the same wellhead injection. Moreover, three phase production separator designation was performed according to the actual data of the reservoir to end with 2 m separator radius and 7 m length (height) which is operationally suitable for voidage replacement combined with WAG outcomes.

REFERENCES

1. M. Kahia, M.S. Ben Aïssa, and L. Charfeddine, Energy **116**, 102 (2016).
2. S. Pan, J.Y. Zuo, K. Wang, Y. Chen, and O.C. Mullins, Fuel **180**, 384 (2016).
3. V. Alvarado and E. Manrique, Energies **3**, 1529 (2010).
4. R. Zolfaghari, A. Fakhru'l-Razi, L.C. Abdullah, S.S.E.H. Elnashaie, and A. Pendashteh, Sep. Purif. Technol. **170**, 377 (2016).
5. S. Chen, H. Li, D. Yang, and P. Tontiwachwuthikul, J. Can. Pet. Technol. 49, 75 (2010).
6. S.M. Fatemi, M. Sohrabi, M. Jamiolahmady, S. Ireland, and G. Robertson, Offshore Eur. 16 (2011).
7. H. Shahverdi and M. Sohrabi, SPE Improv. Oil Recover. Symp. 11 (2012).
8. H. Jiang, L. Nuryaningsih, and H. Adidharma, SPE West. Reg. Meet. 10 (2010).
9. Y. Ahmadi, S.E. Eshraghi, P. Bahrami, M. Hasanbeygi, Y. Kazemzadeh, and A. Vahedian, J. Pet. Sci. Eng. **133**, 123 (2015).
10. B. Chen and A.C. Reynolds, SPE J. **21**, 786 (2016).
11. G. Field, J.P. Srivastava, and L. Mahli, 1 (2010).