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by Drengmuslim Karya Ilmiah

Predicting of Oil Water Contact Level using Material Balance Modeling of a Multi-tank Reservoir

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Keywords: Oil Water Contact, Material Balance, Tank Model, Sand Production, Prediction, Reservoir Modeling.

Abstract: Nowadays, the increase in water production becomes a problem in the oil and gas industry. Besides being a problem, it also becomes extra energy to produce oil and gas. OWC is one of the keys for water production determination for each layer. If the perforation at production well is at OWC or below OWC, the production will be 100% water. In general, the log is used to determine OWC. Besides with log, tank modeling from the material balance equation is also used to determine OWC. WH field located 15 km from Bangko Field in Riau. This primary field has high water production with 97% water cut. Before tank modeling starts, each layer needs to be analyzed based on its reserves, production cumulative and remaining reserves to determine the productive layer, which can be developed in the future. Prediction can be done when history matching and calibration process for both historical data and simulated data by software. Prediction ends in August 2021, which is the end of development contract in WH field. From the results, it can be determined that from C sand, the OOWC and COWC are at 2922 ft and 2883 ft with the cumulative oil production is 6.78 MMSTB. From E sand also can be determined the OOWC at 2368 ft and COWC at 2325 ft with the cumulative oil production is 14.57 MMSTB. From K sand, the OOWC is at 2002 ft and COWC at 1911 ft with the cumulative oil production is 13.5 MMSTB. L sand the OOWC is at 2243 ft and COWC at 2191 ft with the cumulative oil production is 29.17 MMSTB. From the analysis, K sand has the most significant OWC movement, which is 91 ft and it is also validated with the current log data. This sand needs more care to maintain water production.

1 INTRODUCTION

Water production is one of the common problems of the past few years (Hudiman and Permadi, 2016). Water production is also one of the dilemmas in oil and gas industries, on the other side water is known as an energy source in reservoir flow (Daneshy, 2006). Production well at the beginning of development has a bigger oil production than water does. As time goes by, oil production will decrease because of several things, there are formation damage, pump mechanical failure, etc. This also caused by the increase in water production (increasing of water cut), where water movement is faster than oil. With this water production, it can decrease production efficiency and profit for the oil and gas company.

The method that has been used to maintain water production is by doing workover jobs, one of the jobs is by closing the zone, which is not productive or it has 100% water cut which called water shut off (Noordin, 2009). Water shut off method can be done by using a mechanical method (packer), cementing (squeeze), or using chemical mixtures. These methods can be used in order to maintain water production so it will increase oil production with low expenditures (Stashin, 1989).

Oil water contact is the key to determine water production when the production reaches 100% water cut, OWC must be at or above the perforation. Logging is the common method to determine OWC position either the original one (OOWC) or even current position of OWC (COWC). Besides that, there are several methods to determine OWC position, there are RFT, DST, and other good tests. The following methods including logging data are costly and have some limitations especially in certain reservoir issue (Ghahri et al., 2013). Material balance is a low-cost approach for determining OOWC or even COWC positions (Nwaokorie and Ukakuku, 2012). By material balance also we can study the movement of OWC it-

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self.

Material balance is one of several methods used estimating reserves for oil and gas reservoir and thus allows for making the critical decisions concerning development plans and strategies regarding the reservoir. It is also the simplest way to express the conservation of mass in a reservoir. The material balance is zero-dimensional, meaning that it is based on a tank model and does not take into account the geometry of the reservoir, the drainage areas, the position, and orientation of the wells. The other uses of this concept are to determine the size of an aquifer, encroachment angle of the aquifer, estimate the depth of fluid contact, etc (Dake, 1983).

The material balance equation mathematically defines the different producing mechanisms which effectively relates the reservoir fluid and rock expansion to the substance of fluid withdrawal. Several methods have been developed and published applying the material balance equation to the various types of reservoirs and solving the equation to obtain the initial oil in place (N) and the ratio of the initial gas to oil (m) in the reservoir (Havlena and Odeh, 1963). For water drive reservoir diagnostic plot, Campbell plot is used to determine the energy of the aquifer and the OOIP itself by using F/Eowf vs Np plot (Campbell and Campbell, 1978).

The general material balance equation for an oil reservoir is expressed as:

$$F = NE_t + W_e \tag{1}$$

Where the underground withdrawal F equals to the production of oil, water, and gas corrected to reservoir condition:

$$\begin{aligned} F = {} & N_p(B_o - B_g * R_s) + B_g * (G_p - G_i) \\ & + (W_p - W_i) * B_w \end{aligned} \tag{2}$$

And the original oil in place is N stock tank barrels and E is the unit per unit expansion of oil (and its dissolved gas), connate water, pore volume compaction, and the gas cap:

$$\begin{aligned} E = {} & (B_o - B_{oi}) + (R_{si} - R_s) * B_g + m \\ & * B_{oi}\left(\frac{B_g}{B_{gi}} - 1\right) \\ & + (1+m) * B_{oi} \\ & * \left(\frac{S_{Wc} * C_w + C_f}{1 - S_{wc}}\right) \\ & * (P_i - P) \end{aligned} \tag{3}$$

WH field is a primary field, which located in Riau Province. This field discovered in July 1972 with the OOIP is 184.457 MMSTB. In February 2017, the average water cut of this field reached 97%. High water cut becomes a dilemma in this field.

The purpose of this paper is making the tank model of each most productive layer from WH field by using IPM – MBAL software and predict the OWC movement until August 2021, which is the end of the contract for the WH field development. The prediction is used to determine the sand, which has a significant movement of OWC. The log data is needed to validate the OWC movement for each productive sand.

2 GEOLOGY AND RESERVOIR CONDITION

WH is located at Central Sumatera Basin, Indonesia, at Bangko Area in Riau Province. This formation consist of Brown Shale Formation at Pematang Valley as the source rock. The lithofacies of Brown Shale Formation is carbonaceous and algal-amorphous (Katz and Mertani, 1989). Where algal-amorphous is oil prone at the upper and middle part of Brown Shale Formation (Aman, Kamba, and Rangau). Carbonaceous is the gas and light condensate prone, which located at Kiri, Aman, Kamba, and Rangau. The transition facies between algal-amorphous and carbonaceous is also located at Aman, Kamba, and Rangau. Pematang group (fine and medium sandstone from Upper Red Formation) and Sihapas Group come as reservoir rock after the primary migration to the hinge margin basin caused by the Pematang topography, which is asymmetric. The result is, reservoir rocks along steep fault scarp margin and hinge margin, which formed Telisa, Duri, Bekasap, Bangko, Pematang, and Petani formation with a total of thickness reached 3300 ft.

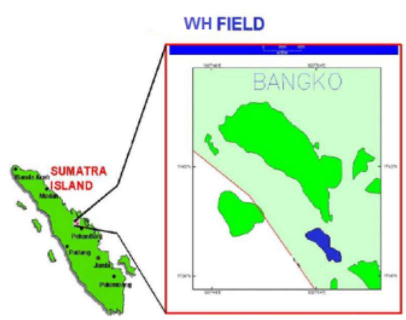

Figure 1: WH Field Map

WH field reservoir properties from the log data, core, single well-tracer, and volumetric data are as follows:

Table 1: WH Field Reservoir Properties

Formation GOR, SCF/STB	26.4
Oil Gravity, API	34.5
Gas Gravity, sp. Gravity	0.8
Water Salinity, ppm	20000
Connate Water Saturation, %	21
Porosity, %	25

3 METHODOLOGY

In this section, the methodology, which applied in this paper will be discussed in order to build the sand predictive material balance equation models by using IPM – MBAL software.

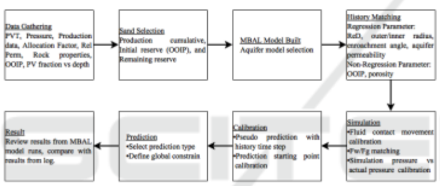

Figure 2: General IPM - MBAL Workflow

3.1 Data Gathering

Proper data acquisition has to be carried out in order to build a good material balance equation model or MBAL model. Most of these data are acquired at the early phase of field development. Either using well tests (RFT, MDT, Swab, PBU, etc) or core test (RCAL or SCAL) data acquired are, Pressure, Production data, PVT, Rock properties, OOIP from the volumetric calculation, and PV fraction vs depth. Porosity, permeability, and water connate saturated also are obtained from existing well logs and core data. Original oil in place (OOIP) obtained by calculating the rock properties (porosity, water connate saturation, formation volume factor) and net pay thickness and area from well-logs to get the OOIP mathematically. Effort should be made in order to understand the uncertainties related to the reservoir parameters, which used to calculate OOIP. In cases when the MBAL initialize volumes are different from the volumetric calculated volumes, basically due to the high uncertainty of the MBAL data which is used in the simulation.

3.2 Sand Selection

Sand selection is needed to filter which sand is suitable to model and develop in the future. The screening criteria of this section initial volumetric OOIP, production cumulative, and remaining reserves. In this case, when the remaining reserves are too low for a layer, it will not profit to develop. C, E, K, and L are the selected sand based on these screening criteria, which are suitable to model and develop.

3.3 Material Balance Model

The understanding of building a material balance model for each productive layer is needed to make a sand predictive model in material balance. It requires basic and fundamental knowledge related to the reservoir structure, type, and the aquifer effect to the reservoir itself. Several analytical models of the aquifer were tested in a bid to model the geometry of the reservoir. Carter Stacy, Van Everdingen, Van Everdingen modified, Hurst-Van Everdingen modified, etc are the available aquifer models at the software. After aquifer model selection (in this case, Hurst-Van Everdingen modified model was selected), the model already established to connect the reservoir volume. The predicted OOIP which generated by the software can be compared with the volumetric OOIP. In this case, the generated OOIP is matched to the volumetric OOIP for all layers (see Fig 2 for initialization model plots).

3.4 History Matching

With the aquifer model being the key of uncertainty, encroachment angle, ReD, aquifer permeability, and inner/outer ratio were regressed upon the reservoir pressure history matching process and production data assuming reservoir volume reproduced to stock tank condition. The regression needs to be done repeatedly until the deviation is lower than 5. It needs to be done in order to validate the model due to the aquifer model uncertainties.

3.5 Simulation

At this part, reservoir pressure over time is simulated from the production history data. This simulated reservoir pressure is compared to the measured reservoir pressure at the field from the input data to see the MBAL model could replicate the actual or current reservoir pressure which is given by the same reservoir energy and properties (see Fig 3 to Fig 6). Simulated OWC from the MBAL were calibrated with logged OWC for modeled sands (Fig 7).

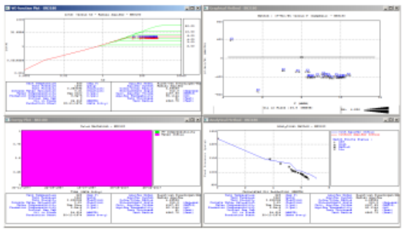

Figure 3: IPM – MBAL Initialization Output

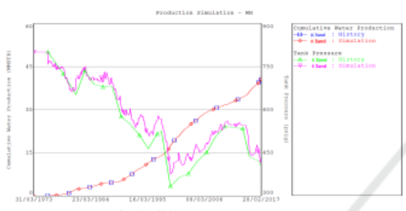

Figure 4: Pressure and Cumulative Production History Match from K Sand

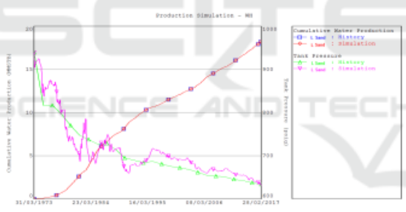

Figure 5: Pressure and Cumulative Production History Match from L Sand

Figure 6: Pressure and Cumulative Production History Match from E Sand

3.6 Calibration

Material balance model calibration is needed to match the end of history matching point with the prediction

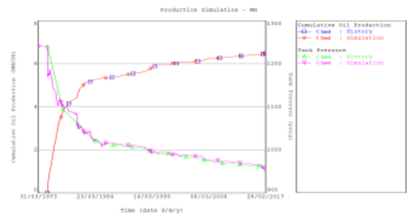

Figure 7: Pressure and Cumulative Production History Match from C Sand

starting point in order to make prediction more validated. In this section, pseudo-prediction will be generated by using the prediction tool. Since the goal is to predict using tank model, a well prediction model was not used in this case. For the constraint, history production rate and time will be used to generate pseudo-prediction to calibrate the model. Once both points matched, prediction can be generated next.

3.7 Prediction

After the model already matched and validated, the next thing is the prediction of the field performance. Prediction generated until the end of contract of this field development (August 2021). The models were further calibrated by running pseudo-prediction for existing sands. Results were compared with the outcome from another method in determining the height of OWC as shown in Fig 8.

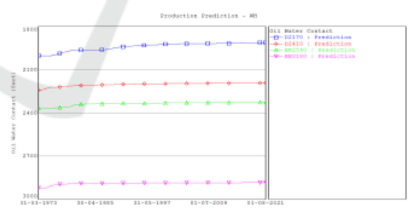

Figure 8: OWC Prediction

4 RESULT

Various results were discussed during the study which involved saturation reservoir with concurrently oil production from the oil rim. Well logs will be adopted to verify results from MBAL models. Table 3 shown material balance results the OWC from MBAL has compared well with the log data. For the production forecast, it predicted using no well prediction which assumpted the sand production rate is decline naturally due to the pressure loss at the reservoir. Prediction rate will be generated by software as long the reservoir pressure and aquifer is enough to provide energies. From the result, K sand has significant movement of OWC, the contact moves from 2002 ft at 1973 to 1911 ft at 2012. This 91 ft movement in 48 years from prediction makes this sand needs more concern due to the water production maintenance. The other sand has a certain movement less than 55 ft in 48 years.

Table 2: Predicted OOWC vs Log OOWC

Sand	MBAL OOWC (ft)	Log OOWC (ft)	Error (%)
C	2922	2925	0.103
E	2368	2366	0.085
K	2002	2002	0.000
L	2243	2246	0.134

Table 3: Predicted COWC vs Log COWC

Sand	MBAL COWC in 2021 (ft)	MBAL COWC in 2014(ft)	Log COWC in 2014 (ft)
C	2922	2925	0.103
E	2368	2366	0.085
K	2002	2002	0.000
L	2243	2246	0.134

5 CONCLUSION AND RECOMMENDATION

- Sand predictive Material Balance Models have been proved to be a quick alternative tool to determine OWC movement as reservoir simulation in the sand analysis.
- Good surveillance acquisition data is needed to provide input data. The accuracy of each data needs to be concerned as pre-requisite to make validate models.
- Sand K has the most significant move of OWC due to water production maintenance. It reached 91 ft in 48 years of prediction. The other sands have certain movement below 55 ft.
- Lift tables are needed and also validated to make well predictive models.

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APPENDIX

API	:	American Petroleum Institute
Bo	:	Current oil volume factor
Boi	:	Initial oil volume factor
Bg	:	Current gas volume factor
Bw	:	Current water volume factor
Cf	:	Formation compressibility
COWC	:	Current Oil Water Contact
Cw	:	Water compressibility
DST	:	Drill Stem Test
Et	:	Total expansion of fluid
F	:	Fahrenheit
FT	:	Feet
Gi	:	Cumulative gas injection
Gp	:	Cumulative gas production
IOIP	:	Initial Oil in Place
IPM	:	Integrated Production Modeling
M	:	Gas oil Ratio
MBAL	:	Material Balance Modeling Software
MSTB	:	Thousand Stock Tank Barrel
MMSTB	:	Million Stock Tank Barrel
N	:	Initial Oil in Place
OOIP	:	Original Oil in Place
OOWC	:	Original Oil Water Contact
OWC	:	Oil Water Contact
PBU	:	Pressure Build-Up Test
ppm	:	Part per Million
PSIG	:	Pound Square Inch Gauge
PV	:	Pore Volume
PVT	:	Pressure Volume Temperature
RCAL	:	Routine Core Analysis
RFT	:	Repeat Formation Test
Rs	:	Current solution gas oil ratio
Rsi	:	Initial solution gas oil ratio
SCAL	:	Special Core Analysis
SCF	:	Standard Cubic Feet
STB	:	Stock Tank Barrel
Swc	:	Connate water saturation
We	:	Water influx
Wi	:	Cumulative water injection
Wp	:	Cumulative water production

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