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Dynamic Data and Flowing Material Balance Method to Unlock Potential in New Game Reservoir with Limited and Low-Resolution Data

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Abstract. A new production zone CD carbonate was discovered in the Sidayu field by exploration well S-3ST. Post drill static evaluation shows the production zone has limited connected volume and low reservoir quality. However, converted S-3ST has excellent production performance. The differences between prognosis and actual production performance is the reason to re-evaluate the reservoir. New approach using dynamic data was proposed to re-estimate hydrocarbon in-place and reservoir properties. This approach is no needed for well interference activities that may take a long time, if reservoir permeability is low enough which will affect the economic value of the well, by combining rate and flowing pressure during production with no well downtime.

Keyword(s): Flowing Material Balance, Dynamic Data, Connected Volume, Potential

1 Introduction

The Sidayu Field is a new development field which located about ±4 km north of Ujung Pangkah Field area, in Gresik, East Java. The main objective of Sidayu Field is Kujung-1 and CD carbonate reservoir. This paper particularly focused on CD carbonate reservoir, which was produced for the first time in Pangkah PSC.

CD carbonate reservoir was discovered in 2015 by exploration well S-3ST, which managed to flow oil with limited gas based on DST. The carbonate reservoir was developed as patch reef with lateral distribution around 3.5 x 1.25km. It consists of intercalation coral-red algae-large benthic foraminifera dominated facies, which have experienced intense cementation until now. Therefore, the quality reservoir was relatively poor, with limited vuggy-mouldic porosity. However, it still can produce oil to the surface with a fairly good flow. Based on petrography, there are some evidence of microfractures development, possibly related to major fault controlling Sidayu structure. Due to limited potential and area, S-3ST will be converted as the only oil producer for CD carbonate in Sidayu Field.

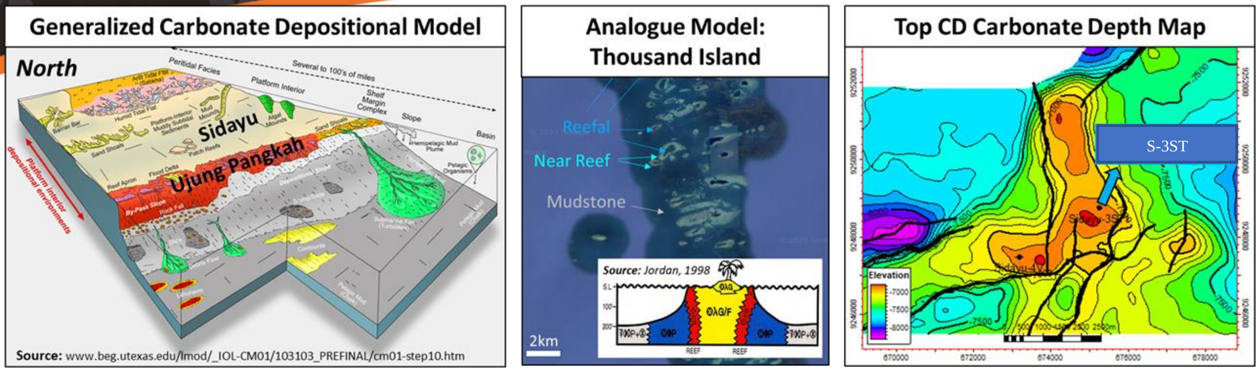

Figure 1 CD Carbonate Conceptual Model and Depth Map

In 2021 converted S-3ST well has produced with excellent performance better than prognosis. Not only the initial production, but also the cumulative production. Current cumulative production is already above the prognosis (as total estimation) up to 300% and to be increasing. The actual performance says the initial estimation is already invalid and need to be re-estimate, especially in hydrocarbon in-place estimation.

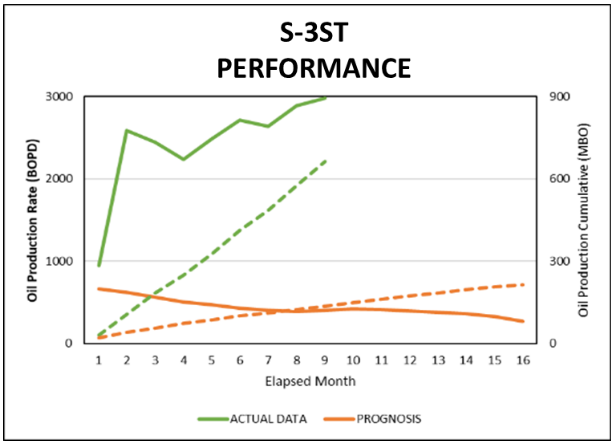

Figure 2 Production Performance S-3ST Prognosis vs Actual

Since converted to production, there is no additional survey or data acquisition related CD Carbonate in S-3ST that can be used to re-estimated the hydrocarbon in-place. In other way, the hydrocarbon in-place can be estimated using a material balance equation, but need a crucial data which is Static or Reservoir Pressure at certain time. Currently, S-3ST well is one of the wells that has major contribution of oil production not only in Sidayu field itself but also in a whole Pangkah PSC. Therefore, during obtained reservoir data for reservoir re-evaluation purposes, well interference activities should not be carried out which have a downtime risk. The only data that recorded are dynamic data such as flowing pressure and production rate.

This paper will be explained a new approach in reservoir evaluation by using dynamic data from S-3ST well without having shut-in the well. S-3ST well is also qualified to approach this method since flow rate and flowing pressure data are measured properly at the surface. The purpose of reservoir re-evaluation result from the new approach is to confirm estimated hydrocarbon in-place based on actual performance thus, it can un-lock potential well in Sidayu Field and be developed massively.

2 Methods

The traditional Material Balance calculation is a method to determine the estimated Hydrocarbon In-Place based on well reservoir pressure data as a function of cumulative production. To obtain the average reservoir pressure data during production, well shut-in activities are required. This activity may take a long time if the properties are low enough as was the case in S-3ST well.

The new approach to re-evaluation reservoir and estimated hydrocarbon in-place is by using Rate transient analysis with Flowing Material Balance (FMB). Flowing Material Balance was first developed by L. Mattar. R. McNeil at 1998 with a paper titled “Flowing Gas Material Balance”. Then optimized in 2005 by L.Mattar and Anderson which explained Dynamic Material Balance that applicable to both constant rate and variable rate production[2]. Flowing material balance method basically performing material balance calculation with the advantage of no need for well interferences to obtain an estimated reservoir pressure. Flowing material balance utilizes pseudo steady state flow and also flowing rate and flowing pressure to estimate hydrocarbon in-place.

The flow of hydrocarbons through a porous medium can be divided into transient and boundary-dominated flow periods. When a well has reached boundary-dominated flow, its behavior is governed by the pseudo-steady state equations. When a reservoir is in pseudo-steady state flow and the flow rate is constant, the pressure at all locations in the reservoir declines at the same rate [4]

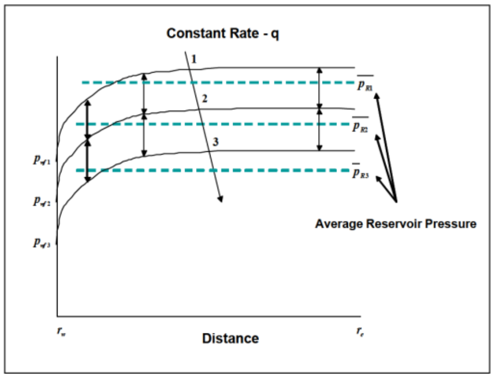

Figure 3 Pressure Drop in a Reservoir as a function of Radial: Distance and Time During Boundary Dominated Flow (L. Mattar, D. Anderson, 2005)

The Above figure shows that the pressure-drop measured at the wellbore is the same as the pressure drop that would be observed anywhere in the reservoir, including the location which represents average reservoir pressure. P_{R1}, P_{R2} and P_{R3} represent the average (static) reservoir pressure that would be obtained if the well was shut-in at times t_1, t_2, and t_3. It is evident, from Figure 1, that the change in average reservoir pressure is equal to the change in the *sandface* flowing pressure. The following are some of the equations used in calculations using a flowing material balance.

$$P_{R1} - P_{R2} = pwf_1 - pwf_2 \quad (1)$$

$$P_{R2} - P_{R3} = pwf_2 - pwf_3 \quad (2)$$

or

$$P_{R1} - pwf_1 = P_{R2} - pwf_2 = P_{R3} - pwf_3 \quad (3)$$

Thus, if *sandface* flowing pressure and average reservoir pressure are plotted as a function of time or cumulative production, they will have the same trend (dp/dt = constant). The development of the flowing material balance method also covers the existence of constant and dynamic data rates. The equation used is as follows:

Cumulative Production

$$(qxt = N_p) \tag{4}$$

Material Balance Equation

$$P_i - p_R = \frac{N_P}{C_o N} \tag{5}$$

Darcy Equation

$$b = \frac{141.2B\mu}{kh} + \left[ln\left(\frac{r_e}{r_{wa}}\right) - \frac{3}{4}\right] \tag{6}$$

Combining Equation

$$P_R - p_{wf} = b_{pss}q \tag{7}$$

Or

$$P_R = p_{wf} + b_{pss}q \tag{8}$$

Pseudo Steady State Flow

$$P_i - p_{wf} = \frac{qt}{C_o N} + b_{pss}q \tag{9}$$

3 Procedure and Process

Since Flowing Material Balance requires pseudo steady state boundary dominated flow conditions, this evaluation also included typecurve analysis as another procedure to determine the condition of the well. CD carbonate reservoir evaluation in S-3ST well assisted by using flowing material software.

In general, the workflow in evaluating flowing material balance is as follows:

1. Perform quality control of Production data (Rates and flowing pressure) to see which data can be used.
2. Collect Pressure/Fluid and Rock Properties/ Wellbore Information.
3. Performing FMB analysis by looking for PSS trends then stabilized productivity index and doing history matching data using flowing material balance model calculation

4 Result

Flowing Material Balance Matching Data

In S-3ST well, currently produces in a single phase, which is suitable case to apply flowing material balance analysis. The first thing to match is how the actual flowing production rate and flowing pressure behave against the model calculation. Figure 2 is the results of Matching flowing pressure data and flow rate data to the value of the connected volume using the flowing material balance method.

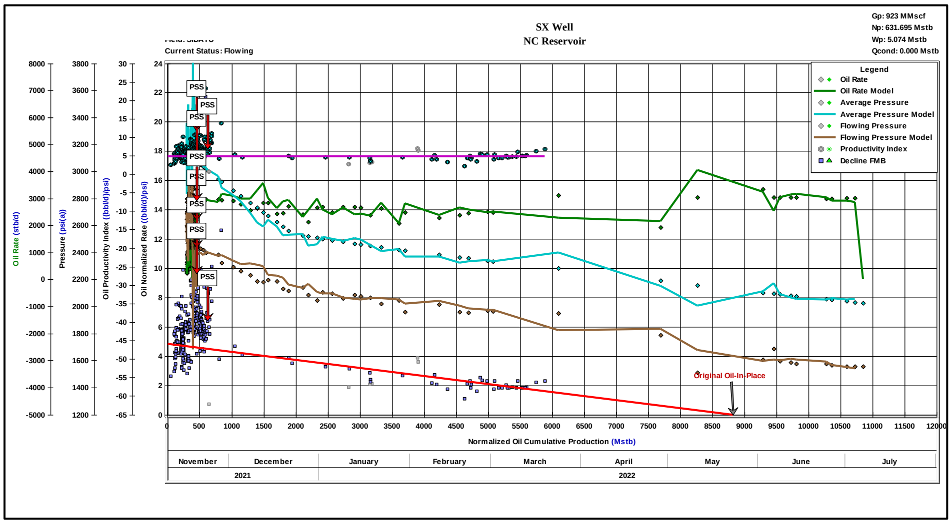

Figure 4 Flowing Material Balance Evaluation Result for CD carbonate reservoir in S-3ST

Type Curve Analysis

Typecurve analysis was also carried out to ensure the condition of wells that have entered pseudo steady state boundary dominated flow condition and also give an estimate of hydrocarbon in-place based on typecurve. If the number between typecurve and flowing material balance matches, the number of estimate hydrocarbon in-place can be used for further evaluation. Figure 3 is visualized the result of typecurve analysis in CD Carbonate Reservoir.

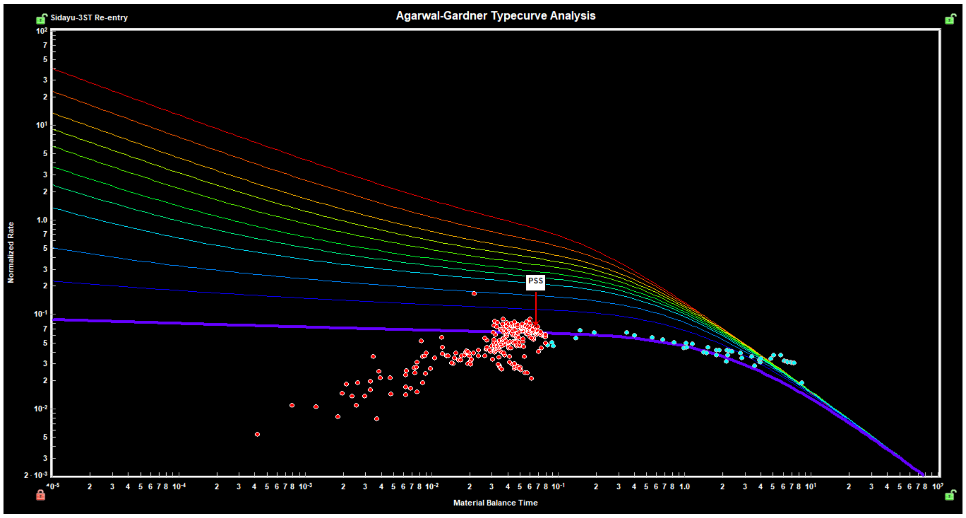

Figure 5 Typecurve Analysis Trend Result for CD carbonate reservoir in S-3ST

Based on G&G information, there are some uncertainty for CD carbonate in Sidayu Field. Static model uncertainty analysis was conducted to honour several possibilities. The result shows estimated initial oil in-place for CD carbonate by field is ±7.2 MMBO (consider as P50) and ±8.8 MMBO (consider as P10).

However, if we compare the static model volumetric in-place with the flowing material balance in-place, the flowing material balance in-place indicates ±8.8 MMBO, which is similar with P10 volumetric in-place number.

Due to limited data and high level of uncertainty, the estimated in-place from static model (field wise) cannot exceed hydrocarbon in-place estimation from flowing material balance which is derived from well result. It shows some hydrocarbon in-place potential that cannot be estimated by the static model. It suggests additional development wells to confirm this potential.

5 Summary and Recommendation

1. Flowing Material Balance method is a very useful as alternative way in performing reservoir evaluation during production with no well downtime and inexpensive during gathering data.
2. Flowing Material Balance will only give reliable result if the production data is in stable condition (Pseudo Steady State boundary dominated flow).
3. Estimate Hydrocarbon In-place from flowing material balance has a function to strengthen the confidence level when doing advanced reservoir simulation.
4. FMB will assist evaluation in the field where data is limited and has high level of uncertainty.

6 Nomenclature

B	= Formation volume factor, bbl/stb
b_{pss}	= Reservoir constant
C_o	= Oil compressibility, psi^{-1}
N	= Original oil in place, bbl
Np	= Cumulative Production
k	= Reservoir permeability, md
h	= Pay Thickness, ft
P_i	= Initial Pressure, psia
P_R	= Average reservoir pressure, psia
P_{wf}	= Flowing Pressure, psia
r_e	= Exterior radius, feet
r_{wa}	= Apparent wellbore radius, feet
μ	= Viscosity, cp
t	= Time, day

7 References

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