RESERVOIR MODELING FOR MISHRIF FORMATION IN NASIRIYAH OILFIELD

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ABSTRACT

Building a reservoir model is very important in the petroleum industry where it is considered the basic step for putting development plans of the field. The formation under study is Mishrif Formation in Nasiriyah oil field. To achieve a reasonable reservoir model that gives the actual performance, it is necessary to validate the model before using it for field development plans and this can be fulfilled by initialization results and history matching. This study involves building a reservoir model and validating it for Nasiriyah oilfield. Initial conditions including initial pressure, datum depth, and oil-water contact were used in the simulator. Oil-water contact is represented in the model as a surface. Fluid properties comprise of water and oil properties were employed for model construction. The validity of initialization results is achieved by a comparison between Oil Initially in Place (OIIP) values resulting from the geological model and reservoir model. The period of history matching is about ten years. The available production and pressure data were fed into the simulator. History matching is divided into three parts: production matching, pressure matching, and water cut matching. Good matching was resulted between calculated production rates by the simulator and observed production rates. Many runs of the simulator were conducted to obtain matching. Pressure matching is verified between calculated pressure by the simulator and the observed static pressure of the wells after multiplying the horizontal permeability by a factor 3.4. The field did not record water production during its production period and this was confirmed during history matching. The reservoir performance of Nasiriyah oil field indicated that the water drive is weak and the reservoir needs to support.

Keywords: Reservoir modeling; Nasiriyah oilfield; History matching; Pressure

INTRODUCTION

Reservoir modeling is a mathematical representation of fluid flow through porous media, usually in form partial differential equation incorporates Darcy's law, material balance, rock

and fluid properties (Islam et al., 2016). It is necessary for optimizing hydrocarbon recovery, predicting the phase of the fluid, saturation, pressure, production rate and bottom-hole pressure (BHP) through the time period, and providing a starting point for putting development plans of the field (Satter and Iqbal, 2016). The reservoir is modeled by incorporating dynamic data into a geological model which is composed of an individual of grids; each block has petrophysical and fluid properties. There is no change in property through a block, where each grid has an average property. The flow rate between adjacent cells is specified by the pressure difference between them, change in pressure and saturation through the reservoir is calculated over a time period. Dynamic model accuracy is affected by time steps and the number of grid blocks (Mattax and Dalton, 1990). Limited data available in early time will increase uncertainty in the estimation of reservoir behavior. Reducing uncertainty is obtained when additional information is added to the dynamic model. Updating reservoir modeling with new data improves performance, prediction of the reservoir, and displacement process and accurate field development (Kortekaas, 1998). (Abbas and Mahdi, 2020) mentioned that the petrophysical heterogeneity of the reservoir units within the Mishrif Formation is due to variations in porosity, water saturation and fluid volume. (Al-Baldawi, 2020) mentioned that the knowledge of the porosity-velocity association in carbonates can be used to establish wireline-log interpretation by predicting other parameters, such as pore size, diagenesis, and porosity patterns, in addition to parameters measured by wireline. The process of calibrating the simulation model is called history matching. The main purpose of it is improving and validating the reservoir simulation model to give reasonable future predictions under different development strategies by reducing the risk related to decisions that are made under the inevitable backdrop of uncertainty data (Gilman and Ozgen, 2013).

STUDY AREA

Nasiriyah oilfield is located to the east of the Euphrates river, about 38 km northwest of the Nasiriyah city. It was discovered in 1975 through a seismic survey, which was done by Iraq South Oil Company. The dimensions of the field are 34 km in length and 13 km in width. The structure is a longitudinal anticline with the northwest-southeast axis direction. The flanks' dip is very small toward the northeast and southwestern about (1° - 2°). The field is located in the south of Iraq between latitudes ($34^{\circ} 80'$ – $34^{\circ} 60'$) N and longitudes ($57^{\circ} 50'$ – $60^{\circ} 10'$) E. The first exploration well was drilled in 1978 and the results showed a good hydrocarbon existing in Mishrif, NuhrUmr, and Yamama formations, then four evaluation wells were drilled to determine oil field extension. All the first five wells were drilled from the duration

1978 to 1987. The drilling was resumed after 2010. The Mishrif Formation consists of bioclastic limestone rock and chalky limestone, the average thickness of this formation is about 170 m (EOC, 2001). The Mishrif Formation consists of two parts: upper Mishrif (MA) and lower Mishrif (MB) separated by shale. Oil is found in lower Mishrif and upper Mishrif is almost water zone. The Mishrif Formation in Nasiriyah oil field is overlain by the Kifl Formation with conformity contact and the lower contact of the formation is underlain by the Rumaila limestone formation (ENI Company, 2007). The Mishrif reservoir is a formation, a latest Cenomanian - Early Turonian in age is a regional shallow water limestone succession that shoals upward, due to progradation, from basinal deposits (Al-Mimar, 2018).

Table 1. OWC for Nasiriyah oilfield wells

Well	OWC (m)
NS-1	2073
NS-2	2069
NS-3	2075
NS-4	2065
NS-5	2056
NS-6	2062
NS-7	2061
NS-9	2058
NS-10	2060
NS-15	2045

METHODOLOGY

Initial Condition

The initial conditions that were used in building the model for the reservoir are:

- The initial reservoir pressure of 3698 psi at a datum depth of 2040 m.
- Bubble point pressure (Pb) of 2226 psi.
- The studied area with no flow at outer boundaries (closed reservoir).

Oil-Water Contact (OWC)

It is calculated from well log interpretation for wells, where it is selected at $S_w=100\%$ of all wells and represented it as a surface in the model. There is variation in OWC depth where the eastern part of the field is higher level than the middle and west parts, where its depth at well NS-15 is 2045 m while at well NS-3 is 2075 m, Table 1, and (Fig.1.)

Grid System

The Mishrif Formation was represented by a three-dimensional grid system ($139 \times 77 \times 67$) in I, J and K direction, where the grid size is 180 m in width and 180 m in length and the total number of cells is 717101.

Fig. 1. OWC of the Mishrif Formation

Each unit in the Mishrif Formation is divided into layers. The nonreservoir units (Top Mishrif, MA and Shale) are divided into eight layers for top Mishrif, eight layers for MA, and one layer for shale. The reservoir units (MB1-a, MB1-b, and MB2), the main reservoir units are MB1-a and MB1-b due to its petrophysical properties (low water saturation and high effective porosity). Although MB2 is a reservoir unit, it contains a low amount of oil due to its high water saturation. Reservoir units (MB1-a, MB1-b, and MB2) are divided into twenty layers for MB1-a, twenty layers for MB1-b, and ten layers for MB2. The total layers of Mishrif Formation are sixty-seven layers.

Formation Compressibility

Rock compressibility for the Mishrif Formation was calculated using Hall correlation (Ahmed, 2019) at an average porosity value 0.1658 and its value is $3.9 \times 10^{-6} \text{ psi}^{-1}$ as below:

$$C_f = (1.782 / \phi^{0.438}) \times 10^{-6} \dots\dots\dots (1)$$

Formation Water Properties

The properties of formation water which are recovered from the evaluation of well tests for wells (NS-1 and NS-2) are shown in Table 2. The average density and average salinity of water formation that were used in the model are 1.14 gm/cc and 193235 ppm, respectively.

Table 2. Formation water properties

Well name	NS-1	NS-2
Specific gravity in 60/60 °F	1.1226	1.1627
CL ⁻¹ (ppm)	96965	144840
TDS (ppm)	183779	202691
PH	4.8	5.79
R _w @60 °F	0.022	0.02

Water Formation Volume Factor

The water formation volume factor (B_w) for the Mishrif Formation was calculated using McCain correlation (McCain, 1991), as 1.02 bbl/STB.

Water Compressibility

Water compressibility (C_w) of the Mishrif Formation was calculated at $T=165$ °F, $S=220287.9$ mg/L and $p=3698$ psi and its value was 2.1×10^{-6} psi⁻¹ as below (McCain, 1991):

$$C_w = 1/(7.033 p + 0.5415S - 537.0T + 403300) \dots\dots\dots (2)$$

Oil Properties

Basic oil properties were used as PVT input data for the reservoir simulation model in the simulator.

PVT Data

Seven samples for the Mishrif Formation were assembled for NS-1, NS-2, NS-3, NS-4, and NS-5 wells, then the best sample is chosen which represents the physical and thermodynamic properties for the Mishrif reservoir in the reservoir model. The sample from well NS-1 at depth 2000 m represents the best sample was chosen in the reservoir model due to its gas-oil ratio (GOR) value which represents the average value as well as the value of the oil formation volume factor (B_o) and oil viscosity (μ_o). PVT data utilized in the simulation model are shown in Table 3.

Table 3. PVT for well NS-1

P (psia)	GOR (Scf/STB)	B_o (RB/STB)	μ_o (cP)
4978	551	1.2815	1.577
2226	551	1.3143	1.2236
1849	460	1.2714	1.2727
1565	402	1.2474	1.4344
1280	345	1.2241	1.6576
996	291	1.2016	1.9166
711	231	1.1769	2.223
427	168	1.151	2.5294
142	89	1.111	2.8358
14.7	0	1.0434	2.9737

Relative Permeability (k_r) and Capillary Pressure (P_c)

Three capillary pressures and three relative permeability curves are employed in the simulation model. According to the sample's depth, each unit has a capillary pressure and relative permeability curves. The relative permeability curves and capillary pressure curves are shown in Figs. 2 and 3, respectively.

RESULTS AND DISCUSSION

Initialization Results

The important step of the simulation is to determine OIIP using geological and dynamic models. The comparison between OIIP values resulting from the geological model (volumetric method) and reservoir model is necessary to check the validation of the model. Oil initially in place (OIIP) was calculated by the simulator using the dynamic method is 9.801×10^9 STB while OIIP calculated previously by using the volumetric method was 9.46×10^9 STB, the error percentage between them is 4%.

Fig. 2. Relative permeability curves

Fig. 3. Capillary pressure curves

History Matching

The Mishrif Formation in Nasiriyah Oilfield has relatively short-term historical production, where the actual production started in August 2009 with production rate 68000 STB/d then the production increased to about 86000 STB/day in 2018. Twenty-five wells were opened to flow. The period of history matching is about ten years. The available pressure measurements do not cover all historical production periods, the availability of production and pressure measurements were fed into the simulator.

Production Matching

Monthly oil production rates and operating days are entered into the program. All wells are verified the actual production rate. A good matching resulted between the calculated production rates by the simulator and the observed production rates as shown in Figs. 4,13 and 14.

Well Block Pressure Matching

The pressure matching process was restricted to match only the static pressures from modular formation dynamic tests (MDT) for some wells that are chosen according to the availability of pressure measurements. Many runs of the simulator were conducted to obtain matching. History matching is verified between calculated pressure by the simulator and the observed static pressure of the wells after multiplying the horizontal permeability by a factor of 3.4 as shown in Fig. 4 through Fig. 13. History matching of field pressure is shown in Fig. 15, there is a small discrepancy in the field pressure matching because the observed pressure data is represented only the area of the wells while the field pressure is calculated for the total area of the field. The discrepancies between simulated field pressure and observed data are noticed for the wells produced for a long time or with high oil production.

Water Cut Matching

The field does not record water production during its production period and this is confirmed during history matching as shown in Fig. 4 through Fig. 13. Although the period of the history matching is short about ten years, the reservoir shows a high-pressure drop at the end of the period of history matching especially in the middle of the field to the northwest (depleted area) compared to the initial pressure of the reservoir (Fig.16). This behavior indicates that the reservoir is produced under the volumetric drive. Fig. 17 shows the pressure distribution at the end of the history matching period

Fig. 4. History matching for well NS-1

Fig. 5. History matching for well NS-2

Fig. 6. History matching for well NS-3

Fig. 7. History matching for well NS-4

Fig. 8. History matching for well NS-5

Fig. 9. History matching for well NS-6

Fig. 10. History matching for well NS-7

Fig. 11. History matching for well NS-9

Fig. 12. History matching for well NS-10

Fig. 13. History matching for well NS-15

Fig. 14. History matching of field production

Fig. 15. History matching of field pressure

Fig. 16. Initial pressure of the field

Fig. 17. Pressure distribution of the field at the end of the period of history matching (at the end of 2018)

CONCLUSIONS

The difference between OIIP calculated from the geological model and the reservoir model may belong to the fact that the geological model utilized water saturation values resulted from computer processing interpretation (CPI) of well logs after distributing, also the geological model does not account for the rock compressibility in its effect on porosity, while the reservoir model used water saturation resulted from core analysis and rock compressibility used in its calculation. The reservoir behavior indicates that the main mechanism drive is

solution gas drive where the reservoir has a weak bottom aquifer or no aquifer. Good matching of well pressures is obtained after modifying the horizontal permeability

NOMENCLATURE

B_w = water formation volume factor, bbl/STB

C_f = Formation compressibility, psi^{-1}

CL^{-1} =chloride ion, ppm.

C_w =coefficient of isothermal compressibility of water, psi^{-1}

P = Pressure, psia

R_w = Water resistivity, ohm.m

S = salinity, mg/L

T = Temperature, °F

TDS =Total dissolved salt, ppm

ϕ = Porosity, fraction

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