International Journal of Advances in Engineering and Management (IJAEM)
Volume 4, Issue 2 Feb 2022, pp: 1616-1621www.ijaem.net ISSN: 2395-5252

3D-Modeling and Simulation of Pressure Distribution in Black Oil Reservoir Undergoing Water Injection.

[1]Nelson-Ordu, David Osorochi, [2]Prof. T.K.SAbamand[3]Prof. K.K Dagde.

[1,2](Department of Petroleum Engineering, Rivers State University, Nigeria)
[3](Department of Chemical Engineering, Rivers State University, Nigeria)

Submitted: 15-02-2022 Revised: 25-02-2022 Accepted: 28-02-2022

ABSTRACT
3D Pressure Distribution is a technique of determination and analysis of reservoir pressure for adequate reservoir managerial action. Evaluations of pressure distribution in a black oil reservoir have gained relevance and notable researches have been conducted in this direction in the oil and gas industries. This is necessitated on the note of the essentiality of pressure management in reservoir engineering. So, pressure maintenance if not adequately and effectively in place can limit the reservoir performance majorly in sand stone formation. However, a 3D model, based on mass conservation, Darcy' Law is developed to understudy the behavior of the reservoir. From the PVT modeling and other detailed calculations, it is then revealed that the average reservoir pressure is 3164psia at which it is expected to be maintained, GOR of 788.5scf/STB and 380scf/STB gas solubility and it's expected to produce at 12,000STB/D. The oil viscosity and formation volume factor are 2cp and 1.237bbl/STB respectively. The successive discretization of the reservoir made known the pressure distribution while it was linearized from there partial differential equation. The model was conveniently validated upon matching with conventional 3D pressure distribution model which also indicated a pressure drop of 601.226psia. Performance analysis revealed that two injectors are needed to conveniently maintain pressure and actively create front in the reservoir which enables production at the specified rate.

Keywords: Pressure, Black oil, Water Injection and reservoir.

I. INTRODUCTION

It is essential to note that machine-based world processes and systems are ran, operated and driven by energy which is naturally endowed and converted to the suitability and utility form for systemic and human utilization. Petroleum and Natural Gas Energy is of course no different(Aziz,1993). This of course necessitates the very essentiality of Engineering in the world at large and Nigeria in particular. This furthermore focuses on the Exploration and Exploitation of Petroleum in the deep subsurface of the earth.

Data sourced from World Atlas puts the country with a reserve of 37,062 billion barrels on the eleventh position after the United States of America with 39,230 billion barrels on the tenth position. (Akintayo, 2018) and natural gas reserve of about 180 trillion cu-ft, making it the largest in Africa and ranked ninth in the world with a 50 – 50 estimated distribution ratio between Non-Associated Gas (NAG) and Associated Gas.

InPetroleum Engineering, adequate understanding of reservoir pressure distribution is vital for reservoir performance and predicting future behavior. It is also an essential factor in reservoir management and also in solving drainage problems in oil and gas industries. Certain models have been developed and continued to be developed for solving drainage problems and for Efficient utilization of reservoir primary energy. Simulation which means, making something look real or mimicking a process look original can be applied in the modeling pressure distribution and behavior in a reservoir which is essentially a hydrocarbon storage system or fluid storage system (Fanchi, 2006). This discretization is concerned with the development of such a model.

Researchers have been on and continued to be proving that one of the best technology for

International Journal of Advances in Engineering and Management (IJAEM)
Volume 4, Issue 2 Feb 2022, pp: 1616-1621www.ijaem.net ISSN: 2395-5252

making reservoir performance prediction and fluid characterization in oil and gas industrial today is the modeling and simulation of fluid flow in porous media using simulators (Fanchi, 2001). The basic reservoir analysis provides necessary details and input data for simulation studies. This includes volumetric analysis, material balance analysis and decline curve analysis. For volumetric analysis; fluid volumes are estimated from variety of sources which include Geological and geophysical techniques through the use of static information (Tearpock and Bischke, 1991). Material Balance and Reservoir Simulation uses dynamic data to achieve result. In the final analysis, accurate characterization of the reservoir fluid volume must yield consistent result. So, the equation for volumetric estimate of oil and gas originally in place is given by

$$N = \frac{7758\,\emptyset A h_o S_{oi}}{B_{oi}} \qquad (1.1)$$

Where

$N = \text{Originaloilinplace, STB}$

$\emptyset = \text{Porosity, fraction}$

$A = \text{area, acres}$

$h_o = \text{paythicknessofoilzone, ft}$

$S_{oi} = \text{initialoilsaturation} = 1 - S_{ow}\text{, fraction}$

$B_{oi} = \text{initialoilformationvolumefactor}, \frac{RB}{STB}$

$$G = \frac{7758\,\emptyset A h_g S_{gi}}{B_{gi}} \qquad (1.2)$$

Where;

$G = \text{originalfreegasinplace, SCF}$

$h_o = \text{paythicknessofgaszone, ft}$

$S_{oi} = \text{initialgassaturation} = 1 - S_{ow}\text{, fraction}$

$B_{oi} = \text{initialgasformationvolumefactor, RB/SCF}$

The material Balance is based on the law of conservation of mass accounting for material entering and material leaving the system. Decline curve is based on the relationship of flow rate and time.

II. METHODOLOGY

2.1 Basic Principles

The basic principles and foundational theories upon which the predictor model will be developed will include; Conservation of mass, Continuity Equation, Darcy law, Buckley-Leverett Theory, Welge's Method, reservoir geometry assumptions and porous media fluid transport equations.

Formulation of the Physical Model

↓

Modeling

↓

Partial Differential Equations

↓

Discretization

↓

Non-linear Algebraic Equations

↓

Linearization

↓

Linear Matrix Equation

Figure2.1: Work Flow for Building the Model

2.2 Materials

2.2.1 Numerical Simulators

Due to the complexities and applicable conditions associated to this research certain simulators for this study includes Matlab R2007a, Petroleum Expert's PVTp ,Ms Excel VBA and.The Excel VBA simulator proved a useful tool in determination and simulation of certain desired unknowns across discrete points of the gas condensate reservoir system. The PVTp simulator which is integral to the IPM (Integrated Production Management) suite was used to accurately characterize the reservoir in terms of reservoir critical properties and also generate PVT properties of the black oil fluid system to be used for performance prediction modeling. The Navigator is adopted to present the pressure distribution for a black oil reservoir system as a function of deduced

International Journal of Advances in Engineering and Management (IJAEM)
Volume 4, Issue 2 Feb 2022, pp: 1616-1621www.ijaem.net ISSN: 2395-5252

pressure. Iterative solvers such as Matlab 2007a and Microsoft Excel 2013 also proved useful in stepwise updates of deduced reservoir parameters.

III. ROCK AND FLUID PROPERTIES

A sand stone formation of 25% porosity with an area extent of 2550acres and an average thickness of 800ft producing at the rate of 12,000STB/D with other rock and fluid properties such as permeability of 80md; oil Formation Volume Factor and viscosity are 1.2RB/STB and 2cp respectively, with the following pressure boundaries; 3500psi in$\Delta_x -$ directtion, 3200ps in $\Delta_y -$ directtion and 3000psi$\Delta_z -$ directtion. Furthermore, the reservoir under production and planned water injection scheme that's PVT and other rock and fluid properties is given in the table below 31. The expectation is to maintain pressure at 3164psia.The current producing gas oil ratio of the field (R_p) is 788.5 SCF/STB. Further expectations of the reservoir are to produce at the rate of 12,000STB/D with gas solubility of 380 SCF/STB. Other rock and fluid properties include:

Table3.1: Rock and Fluid Properties

PRESSURE	B_0	R_S	B_g
4000 (Pi)	1.2417	5.10	
3500	1.2480	510	
3330 (Pb)	1.2511	510	0.00087
3164.16134	1.237	380	0.00096
3000	1.222	450	0.00101
2700	1.2022	401	0.00107
2400	1.1822	352	0.00119
2100	1.1633	304	0.00137
1800	1.1450	257	0.00161
1500	1.1287	214	0.00196
1200	1.1115	167	0.00249
900	1.0940	122	0.002339
600	1.0763	78	0.00519
300	1.0583	35	0.01066

IV. RESULTS AND DISCUSSION

4.1 Presentation of Result

Table 4.1: Result of the Simulation of Pressure Distribution

Block Cells	Block Pressure notation	Block Pressure(psia)	Block Cells	Block Pressure notation	Block Cells (psia)
1	P_{111}	3195.908	16	P_{132}	3253.466
2	P_{211}	3105.574	17	P_{232}	3166.855
3	P_{311}	3197.024	18	P_{332}	3252.221
4	P_{121}	3114.08	19	P_{113}	3222.88
5	P_{221}	2562.935	20	P_{213}	3160.755
6	P_{321}	3114.082	21	P_{313}	3223.997
7	P_{131}	3187.249	22	P_{123}	3220.732
8	P_{231}	3050.53	23	P_{223}	3140.08
9	P_{331}	3186.139	24	P_{323}	3220.734
10	P_{112}	3255.792	25	P_{133}	3223.045
11	P_{212}	3177.575	26	P_{233}	3158.653
12	P_{312}	3257.069	27	P_{333}	3221.935
13	P_{122}	3238.389			

International Journal of Advances in Engineering and Management (IJAEM)
Volume 4, Issue 2 Feb 2022, pp: 1616-1621www.ijaem.net ISSN: 2395-5252

14	P_{222}	3086.262
15	P_{322}	3238.395

4.1.1 Discussion of Result

The Table (4.1) is the Pressure Distribution of the reservoir which was evaluated from the modeled equation, which shows the estimated pressure distribution in each of the grid blocks from which the Average Reservoir Pressure was estimated.

From the above Table 4.1, the block 5, 8, 14 denoted by P_{221} P_{231} P_{222} manifests pressure drop, which implies that the blocks are located at production whose pressure is most felt at block 5 denoted asP_{221} . The block 5 is directly at the production well with the ripple effects on block 8, 14, 2 etc.

The effect of injection is manifested at block 16, 18, 10, 21, 25 with block 16 denoted as P_{132} at pressure stand point of 3253.466psai. The rise in pressure of block 16 and others is as a result of water injection operation carried out in the reservoir.Haven achieved result of pressure distribution from the modeling and simulation conducted; the results can then be discussed and analyzed for validation purposes.

4.2 Effects of Production and water Injection on the Pressure Distribution in the Reservoir.

Figure 4.1 demonstrations the reservoir pressure distribution under the influence of production and water injection operation as a way of pressure maintenance.

The variation in the reservoir pressure is attributed to the variation in the production and water injection operations carried out in the reservoir. The sinusoidal shape of the graph due to a rise and fall of the reservoir pressure, where the highest pressure points shows block cells with the higher influence of injection while the lowest pressure points shows the influence of production/withdrawal of oil from the reservoir.Thelowerest pressure points accounts the position of the production well which implies that the production well is in grid block 5 as shown in figure 4.1 below.

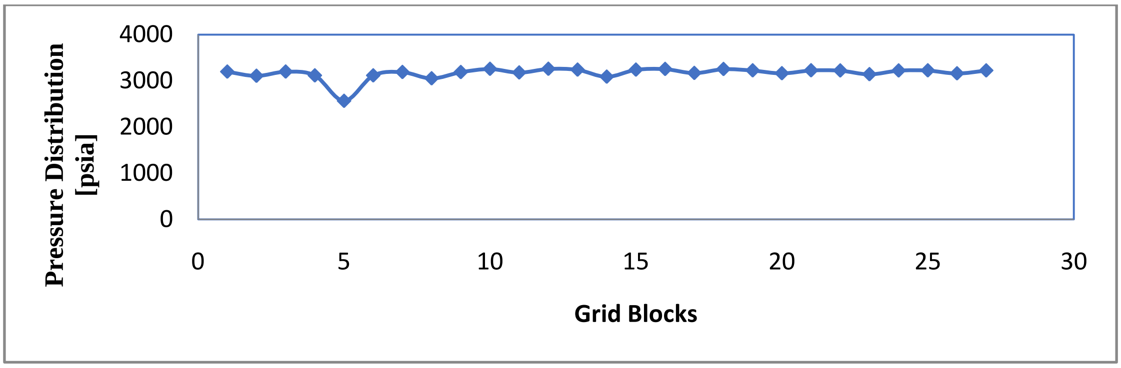

Figure4.1: Pressure Distribution versus Block cells.

The Figure4.1 is the nature and pattern of the pressure distribution in the reservoir. From above, grid block 5 houses the production well due to decline in pressure which account for the sharp in pressure drop of 2562.935psia producing at 12000STB/D. Also, the effects of the pressure drop are also noticed in grid blocks 14 and 23. Furthermore, the injection wells at grid block 3 and grid block 7 flowing at the rate of 9775STB/D each, with its effects in grid blocks 12, 16,21 and 25.

4.2 Determination of the Reservoir Bubble Point Pressure

This is estimated at the climax of the curve of oil formation volume factor versus thepressure distribution in the reservoir 3750psia. See figure 4.1.

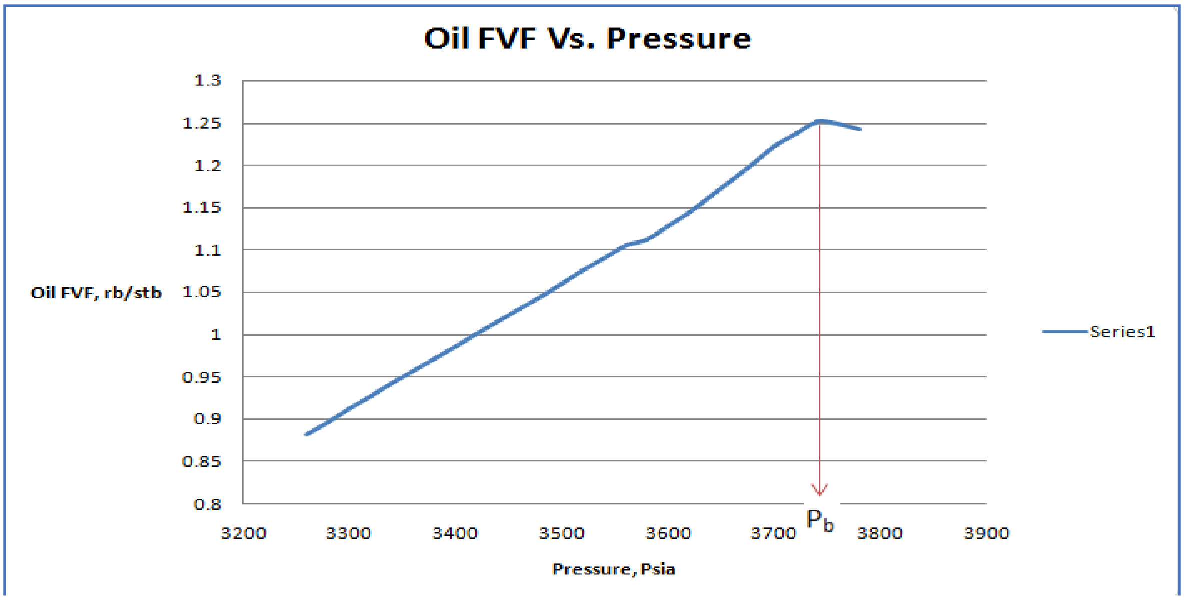

Figure4.2: Oil Formation Volume Factor versus Pressure.

The Bubble point pressure is investigated at the climax of the curve of Oil Formation volume factor versus Pressure. This is therefore, estimated at 37505psia.

A geometric view of distribution of pressure in the reservoir is as shown below, with production well indicated by the sharp drop of pressure due to the production.

V. CONCLUSION

This research is a detailed and thorough three-dimensional numerical models and simulation for a black oil volumetric reservoir where key parameter such as average reservoir pressures, optimum pressure maintenance, injection and production rate, front transport and water saturation profiling of the reservoir are evaluated. The 3D model can serve as monitoring and management tool for performance prediction in a sand stone black oil reservoir. Surface plots of the pressure distribution, increase and pressure depletion were generated considering the cells of the reservoir. Pressure plots showed a sharp fall at the production well and a rise at the injectors which was either rapid or gradual due to the production and injection rate.

REFERENCES

[1]. Abbas, F. (2000), Thermodynamics of Hydrocarbon Reservoirs, McGraw-Hill.

[2]. Abdrakhmanov, A. (2013). Modeling and Optimization of the Rich Gas-Condensate Reservoir: Upstream, Midstream and Downstream Integration (Master's Thesis, Department of Petroleum Engineering and Applied Geophysics, Norwegian University of Science and Technology, Norway.

[3]. Akintayo, O. (2018): Sweet Crude Reports, Nigerian National Petroleum Cooperation Bulletin, Nigeria.

[4]. Fanchi, J. R. (2006), Principles of applied reservoir simulation. Houston,Tex: GulfPub.

[5]. Fanchi, J.R.(1997), Principles of Applied Reservoir Simulation, , Gulf Pub, Houston

[6]. Tearpock, D.J. &Bischket, R.E.(1991): Applied Subsurface Geological Mapping , Englewood Ciff

[7]. Aziz, K. (1993): "Reservoir Simulation Grids: Opportunities and Problems," Journal of Petroleum Technology, pp. 658-663.

[8]. Carr, N.L., Kobayashi R., & Burrows D.B. (1954): "Viscosity of Hydrocarbon Gases Under Pressure," Transactions of AIME, Volume 201, pp. 264-272.

[9]. Carter, R.D. & Tracy G.W. (1960) "An Improved Method for Calculating Water Influx," Transactions ofAIME, Volume 219, pp. 415.

[10]. Dietrich, J.K. & Bondor P,L. (1976): "Three-Phase Oil Relative Permeability Models,"Proceedings of 51st Fall Technical Conference and Exhibition of Society ofPetroleum Engineers and AIME, New Orleans, LA, Oct. 3-6. SPE Paper 6044.

[11]. Li, K., &Firoozabadi, A. (2000). Phenomenological Modeling of Critical Condensate Saturation and Relative Permeabilities in Gas/Condensate Systems. SPE Journal, 5(02), 138-147.

[12]. Li, K., Chow, K., & Horne, R. N. (2006). Influence of Initial Water Saturation on Recovery by Spontaneous Imbibition in Gas/Water/rock Systems and the Calculation of Relative Permeability. SPE Reservoir Evaluation & Engineering, 9(04), 295-301.

[13]. Li, Z., &Firoozabadi, A. (2012). General Strategy for Stability Testing and Phase-Split Calculation in Two and Three Phases. SPE Journal, 17(04), 1-096.

[14]. Mansoori, G. A. (2009). A Unified Perspective on the Phase Behavior of Petroleum Fluids. International Journal of Oil, Gas and Coal Technology, 2(2),141-167.