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Investigation of Relationship of Interfacial Tension (IFT) And Velocity Dependent Relative Permeability (VDRP) To Liquid Saturation In Wellbores In Gas Condensate Reservoirs Under Dynamic Conditions

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Abstract— The study aims to understand the effects of interfacial tension (IFT) and velocity dependent relative permeability (VDRP) to gas production, especially once the wellbore pressure is below the dew point under dynamic conditions beyond the conventional steady-state assumptions. The main impact of this occurrence is liquid loading in the wellbore that may block the gas influx. The interfacial tension (IFT) and velocity dependent relative permeability (VDRP) alteration along with the liquid filling will affect gas production process. A realistic conceptual simulation model is developed by activating the IFT and VDRP options in the base case. The analysis enables us to outline how critical the effects of both parameters to liquid production. Firstly, the liquid drop-out from gas phase, then accumulation, while still immobile until they establish a condensate banking and block a part of the wellbore region so that the gas cannot flow up to the surface, resulting in impairment in well deliverability. This study uses three parameters of IFT, for instance, IFT 1, IFT 5, and IFT 10 as well as activates the VDRP option for another parameter in the scenarios. The scenario IFT 1 shows that liquid production increases up to 0.205%, scenario IFT 5 increases up to 0.371%, and scenario IFT 10 increases up to 0.422%. Meanwhile, the VDRP option exhibits that liquid production increase by up to 57.40%. The analysis indicates that liquid production significantly escalates while the IFT is getting higher, and VDRP options display the liquid loading even more due to the effects of IFT. The novelty of this study is the ability to analyze the dynamic condition of fluid behavior in the wellbore compared to the steady-state condition that has been investigated by several authors in the literature.

Keywords- *Liquid Loading, IFT, VDRP, Capillary Number, Condensate*

I. Introduction

The term "Liquid loading" has been known as one of the major issues impacting gas production. It happened due to the occurrence of liquid in the wellbore resulting from the drop of pressure, preventing the gas flow up to the surface, thus lowering the gas production. Much work on understanding the issue of liquid loading has been carried out, yet there are some limitations when it comes to the investigation of both IFT and VDRP option under dynamic conditions.

Most of the literature on liquid loading investigation has been performed on steady-state condition [1]–[9]. Several researchers also investigated the effect of IFT and VDRP, however their results only focused either on IFT or VDRP, and often neglecting the impact of dynamic condition on the process. Badrul, Ucok, &

Robert [1] measures relative permeability curves from near-critical fluid with the purpose to investigate the dependency of relative permeability on flow rate. They measured relative permeability at various interfacial tensions and flow velocity using a special-design High-Pressure High-Temperature Core Flood apparatus under steady-state condition. They found that the relative permeability is a strong function of interfacial tension. Tani, Yamada, & Ikeda [10] recommend to use VDRP model in gas condensate reservoir simulation. In their research, the VDRP concept was adopted to evaluate the impact of condensate banking phenomena and velocity effect using the actual field production data. Farahani, Ahmadi, & Sharifi [8] introduced the neighborhood algorithm-bayes (NAB) as well as other evolutionary optimization algorithm to history match both velocity dependent relative permeability and non-Darcy flow coefficient parameters for a gas condensate well.

This paper focuses on understanding the effect of interfacial tension (IFT) and velocity dependent relative permeability (VDRP) parameters on liquid occurrence under dynamic conditions. The main impact of this occurrence is liquid loading in the wellbore that may block the gas influx. The interfacial tension (IFT) and velocity dependent relative permeability (VDRP) alteration along with the liquid filling will affect gas production process.

II. RESEARCH METHODOLOGY

The research method is that field research uses secondary data from a field and modeling with a commercial simulator. Meanwhile, data collection techniques are such as data obtained from research results, reference books, journals, papers that fit the research topic. The model is a simple radial simulation, which contains secondary data. It is built and validated by a common characteristic of the vertical well in a retrograde reservoir thru phase envelope. Once, it is valid and solid, the parameter tests are conducted for Interfacial Tension (IFT), and Velocity Dependent Relative Permeability.

Three-dimensional numerical modeling is built to describe D Field using a compositional simulator, which takes into account the constituent components of hydrocarbons and phase changes for each component. In this simulation, there are several limitations, namely:

1. The model represents the condition of a field with radial geometry.
2. The model does not use geomechanics.
3. The model does not consider faults and other geological conditions.
4. Only used as a parameter test, so that the history of the previous production can be ignored.

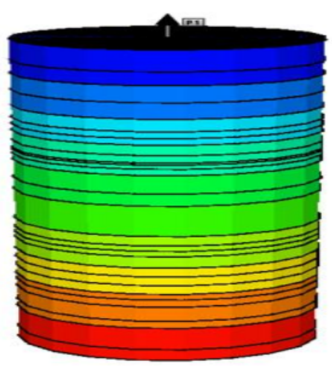

Figure 1 Three-Dimensional Radial Model

Table 1 Field Characteristics

#	Parameter	Unit	Value
1.	Initial Reservoir Pressure	psi	6,000
2.	Temperature reservoir	^oF	216
3.	Depth	ft	9,703
4.	Water saturation		0.2

Figure 1 shows a radial reservoir model for a vertical well (P1) in D Field, with the grid formed worth 30 x 1 x 28 with different thickness for each layer. Table 1, Table 2, and Table 3 show some characteristics of data in D Field.

From the data, it can be concluded that the D Field has heterogeneous reservoir characteristics. The well was opened on January 15, 2015. P1 well has eight layers which are perforated and produced.

Table 2 Fluid Characteristics

Component.	**Composition**	**Pc, Atm**	**Tc, F**	***Acent.Factor***	***MW***	**Parachors**
H_2S	0.0024	88.2	671.8	0.1	34.08	80.1
CO_2	0.0193	72.8	547.6	0.225	44.01	78.0
N_2C1	0.861	45.4	337.2	0.0095	16.62	75.259
C_2-C_3	0.072	45.7	583.6	0.1126	33.86	119.44
C_4-C_6	0.0228	34.9	809.5	0.2179	67.30	210.38
C_7-C_{15}	0.0199	30.4	1059.7	0.6046	127.07	361.35
C_{16}+	0.0026	14.6	1267.0	0.9803	274.61	704.87

Table 3 Thickness and Properties of Layers in the Model

Layer	Thickness (ft)	Porosity	Permeability
1	87.643	0.023	0.086
2	54.964	0.106	3.032
3	69.370	0.060	1.853
4	66.476	0.026	0.060
5	51.366	0.007	0.022
6	27.443	0.049	1.185
7	27.443	0.132	10.389
8	42.891	0.089	1.577
9	30.893	0.007	0.017
10	8.704	0.014	0.319
11	17.408	0.056	1.489
12	26.112	0.045	1.193
13	77.482	0.021	0.409
14	51.840	0.013	0.028
15	129.000	0.007	0.021
16	40.391	0.031	0.046
17	23.301	0.074	0.200
18	23.301	0.036	0.078
19	49.334	0.044	3.214
20	38.410	0.060	9.825

21	38.410	0.036	1.756
22	38.410	0.085	10.974
23	24.991	0.027	0.860
24	31.542	0.023	0.547
25	63.085	0.035	0.967
26	31.542	0.031	0.334
27	96.231	0.019	0.049
28	48.116	0.015	0.028

Table 4 below shows the results of initializing the D Field Radial Model.

Table 4 Initial parameter of the D-radial model

#	Parameter	Unit	Value
1.	Total bulk reservoir	Res ft3	3.73E+8
2.	Total pore volume	Res ft3	1.42E+7
3.	Total hydrocarbon pore volume	Res ft3	1.14E+7
4.	Original oil in place	Stb bbl	1.06E+5
5.	Original gas in place	Stb ft3	3.20E+9
#	Parameter	Unit	Value

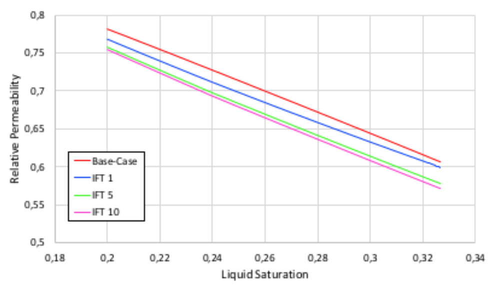

Figure 2 Relative permeability vs liquid saturation

III. RESULT AND DISCUSSION

Nallaparaju [11] mentioned the produced liquid accumulates in the well and forms a static liquid column, which gives back pressure to the formation pressure and causes a decrease in production until the production stops. The problem is caused by liquid loading is not appropriately handled.

The relative permeability of flowing phases is significantly affected by a liquid accumulation in pores under dew point pressure and the initial water saturation from reservoir rocks [12]. When the liquid saturation increases, the relative permeability of the gas decrease, therefore the productivity of the well decreases. Relative permeability is a function of IFT between gas and condensate, among other variables. Therefore, several laboratory studies state that the measurement of relative permeability is a function of IFT [13], [14].

A simulation is then performed to get a picture of the effect of the IFT and VDRP values on the relative permeability and liquid saturation. Interfacial tension (IFT) parameter analysis is performed by comparing the effect of several IFT values on the base case scenario. The IFT values inputted in this study are 1, 5, and 10.

Figure 2 shows the trend line between relative permeability of gas-condensate vs. liquid saturation that is affected by IFT, where the permeability curve is relatively higher when IFT is smaller. Increased relative permeability occurred for all phases, while IFT experienced a decline [14]. Therefore, over time, the relative permeability of a production well decreases, affecting the liquid saturation value, which increases. It is shown in Figure 3 that the relative permeability decreases with production time.

It leads to the conclusion that liquid saturation increases with decreasing pressure and the effect of IFT on the relative permeability of gas. However, it has been known since 1947 that relative permeability, in general, depends on the comparison of forces in the trapped phase, which is usually called the capillary number or Bond number. The key to the relative permeability of condensate gas depends on the saturation of the critical condensate at the capillary number or commonly referred to as trapping number [13].

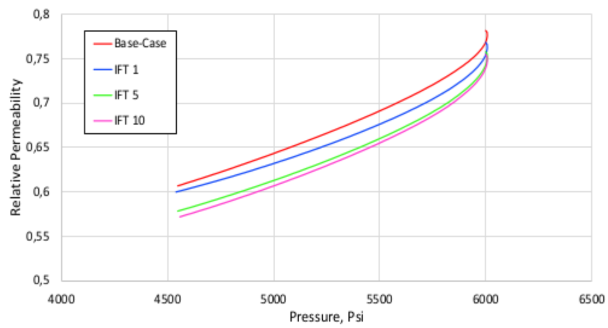

Figure 3 Relative permeability vs pressure

Table 5 below shows the values for each parameter that is included in the base case scenario for later simulation and analysis of their effect on liquid saturation in the well in question. Capillary numbers in the gas phase are marked with the symbol Ncbg with a value of 0.1, which is the threshold of the capillary number for the gas phase [15].

Table 5 Parameter values for VDRP option

Parameter	Value
Tg	24556
Tc	3000
Tw	250
Ʈg, Ʈc, Ʈw	1
Srg, Src, Srw	0
Krg, Krc, Krw	1
αg, αc, αw	4; 2,9; 1
Ncbg, Ncbc, Ncbw	0,1; 0; 0

Table 6 Percentage of increasing of the liquid production rate

Date	Flow Rate (bbl/day)				Percentage of Increasing		
	Base Case	IFT 1	IFT 5	IFT 10	IFT 1	IFT 5	Ift 10
15 Jan 2015	5.583	5.595	5.604	5.607	0.205%	0.371%	0.422%
15 Jan 2016	5.449	5.458	5.467	5.470	0.168%	0.335%	0.386%
15 Jan 2017	5.333	5.341	5.349	5.352	0.135%	0.300%	0.351%
15 Jan 2018	5.228	5.234	5.242	5.245	0.106%	0.267%	0.317%
15 Jan 2019	5.324	5.306	5.296	5.292	-0.349%	-0.534%	-0.604%
15 Jan 2020	5.951	5.962	4.921	4.924	0.176%	-17.323%	-17.272%
15 Jan 2021	5.205	4.948	4.922	5.932	-4.937%	-5.451%	13.961%

15 Jan 2022	5.844	4.856	4.829	5.870	-16.899%	-17.373%	0.448%
15 Jan 2023	5.760	4.719	4.678	5.786	-18.064%	-18.786%	0.449%
15 Jan 2024	5.667	4.505	5.493	5.706	-20.501%	-3.067%	0.692%
15 Jan 2025	6.011	4.409	5.569	5.473	-26.643%	-7.353%	-8.951%

As an experiment conducted by Tani, Yamada, & Ikeda [10], a plot is formed between liquid saturation to pressure. The results obtained, as shown in Fig. 4, prove that liquid saturation continues to increase with decreasing pressure until it slowly decreases even if it is not significant.

Based on the stated objective, parameter analysis is carried out to determine the effect of a parameter on increasing the production well's liquid production. It aims to minimize the liquid outcome to optimize the gas production at the well. Both parameters are activated in the base case scenario to analyze the effect of the two test parameters on liquid production.

A. Interfacial tension

As explained in the discussion above, the relative condensate gas permeability curve is different for each IFT value. An increase in relative permeability occurred for all phases, while IFT declined [14]. Thus, it can be concluded that when the relative gas permeability is low, there be an increase in the relative condensate permeability - accompanied by an increase in liquid production while IFT experiences an increase.

IFT value input process has been carried out into the simulator, what is conducted next is to analyze the forecast that has been given. Figure 5 shows that the higher the value of IFT, the faster the initial process of increasing liquid production. The base case shows that an increase in liquid production began in early 2021. In IFT 1, a significant increase in IFT almost did not occur. In contrast to IFT 5, in the middle of 2023, the increase in liquid production occurred significantly. Meanwhile, at IFT 10, the process of increasing liquid production occurred faster between the two cases, which occurred in mid-2020.

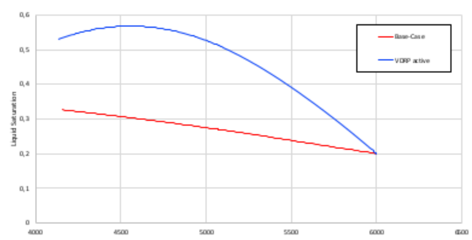

Figure 4 Liquid saturation trend along the pressure decline

To find out more clearly, table 6 shows the percentage increase in the flow rate of liquid products in the IFT scenario to the base case per year. It can be seen that, the higher the IFT value is, the higher the percentage increase in the liquid production flow rate. IFT 1 has the highest percentage of 0.205%, followed by IFT 5 with the highest percentage of 0.371%, and IFT 10 has the highest percentage of 0.422%.

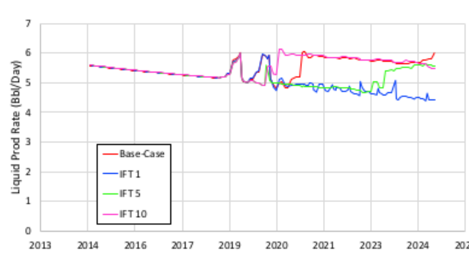

Figure 5 Effect of interfacial tension to the liquid flow rate

Figure 6 shows the cumulative liquid production in which IFT 1 and IFT 5 only have a minimum ratio in the cumulative production and began to look different in early 2024, while IFT 10 has the highest cumulative value compared to other scenarios. It can be seen roughly that an increase follows every increase in IFT in the volume of liquid production.

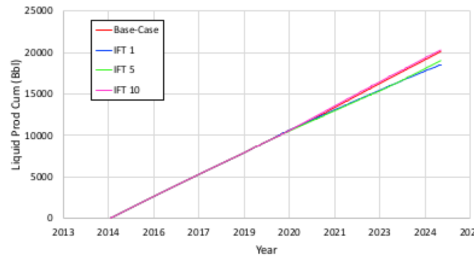

Figure 6 Effect of IFT to cumulative production

Velocity dependent relative permeability

As explained in the previous discussion, the activation of the VDRP option is focused on the capillary number, which is the force ratio in the trapped phase [13]. Activation of the VDRP option was executed, and an analysis of the results was provided by the work done by simulator.

It can be seen in Figure 7 that the base-case production flow rate is much lower than the scenario using VDRP. It is a result of liquid saturation, which has increased significantly compared to the base case scenario, as seen in the previous discussion.

Table 7 shows clearly the percentage increase in the rate of liquid production using VDRP when compared to the base case scenario. The increase reached 57.40%, more than half of the total liquid production in the base case scenario.

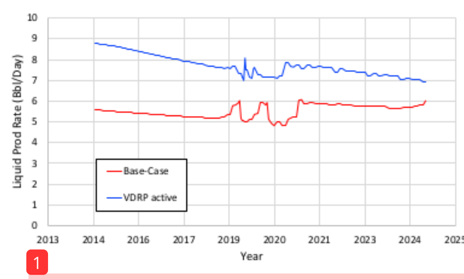

Figure 7 Effect of VDRP option to the liquid production

It gives an understanding that the activation of VDRP, in this case, significantly increases the effect of liquid production including a high increase in liquid saturation. In addition, high velocity has a negative impact caused by inertia [10].

Table 7 Percentage of the production rate incline with VDRP to the base case

Date	Flow Rate (bbl/day)		Percentage of increasing
	Base Case	With VDRP Option	
15 Jan 2015	5.58	8.79	57.40%
15 Jan 2016	5.45	8.51	56.25%
15 Jan 2017	5.33	8.17	53.16%
15 Jan 2018	5.23	7.83	49.78%
15 Jan 2019	5.32	7.59	42.63%
15 Jan 2020	5.95	7.25	21.81%

15 Jan 2021	5.21	7.64	46.71%
15 Jan 2022	5.84	7.61	30.15%
15 Jan 2023	5.76	7.41	28.58%
15 Jan 2024	5.67	7.21	27.23%
15 Jan 2025	6.01	6.92	15.12%

Figure 8 shows the cumulative amount of production from each scenario. It can be seen that there is a considerable difference between scenarios using VDRP compared to the base case scenario.

IV. CONCLUSION

This paper focuses on understanding the effect of interfacial tension (IFT) and velocity dependent relative permeability (VDRP) parameters on liquid occurrence under dynamic conditions. The effect of IFT on liquid saturation is directly proportional; the higher the value of IFT, the relative permeability decreases while liquid saturation increases. Whereas, in the case of VDRP, the value of liquid saturation increased significantly. Interfacial tension gives a different effect for each increase in value, tends to have a patternless increase. For the percentage increase in liquid with IFT values 1, 5, and 10, the maximum increase percentage ranges from 0.205% to 0.422%. velocity dependent relative permeability has an effect of up to 57.40% for liquid production.

V. ACKNOWLEDGMENT

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REFERENCES

[1] Badrul MJ, Ucok WS, Robert LL. Effect of Permeability Distribution and Interfacial Tension on Gas Condensate Relative Permeability: An Experimental Study. In: SPE Asia Pacific Oil and Gas Conference and Exhibition [Internet]. Society of Petroleum Engineers; 2003 [cited 2020 May 6]. Available from: http://www.onepetro.org/doi/10.2118/80551-MS

[2] Zhou D, Yuan H. A New Model for Predicting Gas-Well Liquid Loading. SPE Prod Oper. 2010 May 1;25(2):172–81.

[3] Schiferli W, Belfroid SPC, Savenko S, Veeken CAM, Hu B. Simulating Liquid Loading in Gas Wells. In: 7th North American Conference on Multiphase Technology. BHR Group; 2010.

[4] Shekhar S, Kelkar M, Hearn WJ, Hain LL. Improved Prediction of Liquid Loading in Gas Wells. SPE Prod Oper. 2017 Nov 1;32(4):539–50.

[5] Riza MF, Hasan AR, Kabir CS. A Pragmatic Approach to Understanding Liquid Loading in Gas Wells. SPE Prod Oper. 2016 Aug 1;31(3):185–96.

[6] Guo B, Ghalambor A, Xu C. A Systematic Approach to Predicting Liquid Loading in Gas Wells. In: SPE Production Operations Symposium [Internet]. Society of Petroleum Engineers; 2005 [cited 2020 May 6]. Available from: http://www.onepetro.org/doi/10.2118/94081-MS

[7] Zhou C, Wu X, Li H, Lin H, Liu X, Cao M. Optimization of methods for liquid loading prediction in deep condensate gas wells. J Pet Sci Eng. 2016 Oct 1;146:71–80.

[8] Farahani ZD, Ahmadi M, Sharifi M. History matching and uncertainty quantification for velocity dependent relative permeability parameters in a gas condensate reservoir. Arab J Geosci. 2019 Aug 1;12(15):1–19.

[9] Azamifard A, Hekmatzadeh M, Dabir B. Evaluation of gas condensate reservoir behavior using velocity dependent relative permeability during the numerical well test analysis. Petroleum. 2016 Jun 1;2(2):156–65.

[10] Tani K, Yamada T, Ikeda S. Application of Velocity-Dependent Relative Permeability for Modeling Gas-Condensate Reservoirs: Field Example. In: SPE Asia Pacific Oil and Gas Conference and Exhibition. Society of Petroleum Engineers; 2014. p. 320–30.

[11] Nallaparaju YD. Prediction of Liquid Loading in Gas Wells. In: SPE Annual Technical Conference and Exhibition. Society of Petroleum Engineers; 2012. p. 131–8.

[12] Nagarajan NR, Honarpour MM, Sampath K, Mcmichael D. COMPARISON OF GAS-CONDENSATE RELATIVE PERMEABILITY USING LIVE FLUID vs . MODEL FLUIDS. In: the International Symposium of the Society of Core Analysts. Abu Dhabi: Society of Core Analysts; 2004. p. 1–13.

[13] Pope GA, Wu W, Narayanaswamy G, Delshad M, Sharma MM, Wang P. Modeling Relative Permeability Effects in Gas-Condensate Reservoirs With a New Trapping Model. SPE Reserv Eval Eng. 2000 Apr 1;3(2):171–8.

[14] Kalla S, Leonardi SA, Berry DW, Poore LD, Sahoo H, Kudva RA, et al. Factors That Affect Gas-Condensate Relative Permeability. SPE Reserv Eval Eng. 2015 Feb 1;18(1):5–10.

[15] Agrawal S, Sharma MM. Liquid Loading Within Hydraulic Fractures And Its Impact on Unconventional Reservoir Productivity. In: SPE/AAPG/SEG Unconventional Resources Technology Conference [Internet]. Denver, Colorado: Society of Exploration Geophysicists, American Association of Petroleum Geologists, Society of Petroleum Engineers; 2013 [cited 2020 May 31]. p. 1314–8. Available from: http://library.seg.org/doi/abs/10.1190/urtec2013-132

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