International Journal of Advances in Engineering and Management (IJAEM)
Volume 6, Issue 2 Feb. 2024, pp: 86-93 www.ijaem.net ISSN: 2395-5252

Investigation of the Impact of Fracture Properties on Production in Tight Gas Formation

Nyelebuchi Amadichuku*, Ikechi Igwe, Ndidi Uzoigwe ,Orukwo Rachelle Ureh
Department of Petroleum Engineering,Rivers State University, 500101Port Harcourt ,Nigeria

Date of Submission: 03-02-2024 Date of Acceptance: 14-02-2024

Abstract

This work analyzed the impact of hydraulic fracture properties on well production performance WellFlo was used to build a horizontal wellbore model with base hydraulic fracture properties and quantify its production performance. A base model was established and sensitivity analyses conducted for different fracture skin and permeability on well production performance. Results shows that the reservoir delivers 127.5704MMscf/day of gas across the completion into the wellbore when the pressure drawdown was. Also, a gas production rate of 54.04MMscf/day at a flowing bottomhole pressure of 3945.72psia was obtained for the base model. Result reveals that as the fracture permeability increases, the intersection between the inflow and outflow performance curves moves upward, indicating an increase in gas production rate, while that for the fracture skin move downward as the fracture skin increases, indicating a decrease in gas production rate. Gas production rate increase was most noticeable with an increase in the fracture permeability from 5000mD, 10000mD, 20000mD and 30000mD with a corresponding gas production rate of 47.21MMscf/day, 49.84MMscf/day and 51.87MMscf/day. However, with a further increase in fracture permeability from 40000mD to 60000mD, no appreciable increase in gas production rate was obained. For a fracture skin of 1, 2, 3, 4 and 5, there was a decrease in gas production rate as 54.0MMscf/day, 52.05MMscf/day, 50.18MMscf/day, 48.43MMscf/day, and 46.78MMscf/day. The formation fracture permeability should be high but not so high to minimize the erosion of the completion equipment due to high fluid velocity.

Keywords: Fracture, Skin, Permeability, Inflow, Outflow, Production.

I. Introduction

Fossil fuels have remained one of the major source of the world's energy demand and while conventional reservoirs are at declining phase, unconventional reservoir are currently been explored and exploited (Ostojic *et al.*, 2012). Tight gas reservoirs are one of most common types of unconventional reservoirs and are described as the one with permeability less than 0.1 md irrespective of their depositional mechanisms (Zee Ma *et al.*, 2016). Tight gas reservoirs have been characterized with low porosity, low permeability, high heterogeneity, extensive hydrocarbon generation, and complex pressure system (Wang *et al.*, 2016). The tight gas is very difficult to be produced economically because of its low permeability and requires hydraulic fracture treatment to increase the gas recovery (Kalra *et al.*, 2018; Medavarapu *et al.*, 2017; Taha *et al.*, 2013; Holditch, 2006). Hydraulic fracture treatment involves the injection of fluid in the formation which creates permeable channels (fractures) into the formation and results in an increased productivity of the reservoir fluids. For successful development of low permeability reservoir, it is necessary to maximize productivity by analyzing the flow characteristic and reservoir property and effective fracture treatment design which influences the well performance (Guo *et al.*, 2017). The fracture design parameters are important to optimize the production of tight gas (Rafiee *et al.*, 2012). When a low-permeability reservoir is hydraulically fractured, a fracture network system is formed comprising primary and secondary fractures (Cipolla *et al.*, 2010). Gringarten and Ramrey (1973) designed an analytic model to simulate the behavior of hydraulically fractured reservoir on the constant surface pressure and concluded that determining the optimum number of treatments, spacing, and eventual completion efficiency is critical to the success of horizontal well development. Cheng, (2012a, b) compared the well performance when changing the distance between hydraulic fractures and found that there was production enhancement by adding more fractures but no significant effect for small spacing.

Tight gas reservoirs require hydraulic fracture treatment to produce the gas at higher rates and it is clear that the hydraulic fracture productivity plays an important role. The productivity of hydraulic fractures largely depends upon the fracture length, fracture height, and fracture permeability (Guo *et al.*, 2007). McGuire and Sikora, (1960) presented fracture length and conductivity as the main factor that decide the productivity of hydraulic fractured well and concluded that the fracture length is the production controlling factor in low permeable and its increase will increase production. Apart from the mentioned productivity controlling factors of hydraulic fracture, the fracture skin and permeability are also a major concern which can cause a drastic change in the productivity of hydraulic fracturing. Hence, this work will evaluate the effect of fracture skin and permeability on production of a tight gas reservoir

II. Methodology

2.1 Materials and Data

Weatherford WellFlo simulator with the following input data were used; Fluid properties data**(**Gas gravity,Water salinity,Mole fraction of gaseous impurities,Water/gas ratio), Reservoir data(Reservoir pressure and temperature,Mid perforation depth, Reservoir permeability, Thickness, Wellbore radius), Relative permeability data(Gas/water end point permeability, Oil/water end point permeability), Fracture properties(Length, width and height,Number of fractures,Fracture dimensions and fracture permeability,Fracture spacing). The input data for the properties are presented in Table 1 to Table 8.

Table 1: Fluid properties data

Properties	Specification
Gas gravity	0.65
Water salinity	30000ppm
H2S	0%
CO2	0%
N2	0%

Table 2: Downhole equipment data

	From MD	To MD	Internal diameter (inches)	External diameter (inches)
Casing_1	20	7500	6.184	7
Casing_2	7500	12000	6.184	7
Tubing	20	7500	2.992	3.5

Table 3: Fracture properties data

Fracture properties	Fracture			
	1	2	3	4
Fracture spacing (ft)	600	600	600	600
Fracture width (ft)	0.02	0.02	0.02	0.02
Fracture half length (ft)	450	450	450	450
Fracture height (ft)	200	200	200	200
Near -Wellbore fracture permeability (mD)	55000	55000	55000	55000
Near -Wellbore fracture width (ft)	0.01	0.01	0.01	0.01
Fracture permeability (mD)	60000	60000	60000	60000
Measured skin	1	1	1	1

Table 4: Temperature survey data

Measured Depth (ft)	Formation Temperature (°F)
20	80
1000	95
2000	105
3000	115
4000	125
12000	196

Table 5: Gas/Water Endpoint permeability data

Parameter	Value
Krg	1
krw	0.5
Swi	0.25
Srg	0.3
m	3.5
n	2

Table 6: Gas/Oil Endpoint permeability data

Parameter	Value
Kro	0.75
krg	0.85
Sgc	0.15
Srog	0.15
m	1.7
n	2.4

Table 7: Oil/Water Endpoint permeability data

Parameter	Value
Kro	1
krw	0.5
Swi	0.25
Sor	0.3
m	3.5
n	2

Table 8: Reservoir properties data

Reservoir properties	Value
Reservoir pressure	6000psia
Reservoir temperature	196°F
Reservoir permeability	1.2mD
Reservoir thickness	100ft
Mid perforation depth	12000ft

International Journal of Advances in Engineering and Management (IJAEM)
Volume 6, Issue 2 Feb. 2024, pp: 86-93 www.ijaem.net ISSN: 2395-5252

Wellbore radius	0.42ft
Water/gas ratio	1 STB/MMscf
Equivalent radius	912.10ft
Horizontal lateral length	

2.2 Simulation Process

WellFlo was used to develop base model with fracture properties presented in Table 3.Tubing flow type and Multifrac well orientation with Backpressure model was selected as the IPR model and the Grey's correlation with Carr et al. correlation for the vertical lift performance and gas viscosity estimation. The fluid properties and the downhole equipment data in Table 1 and Table 2 were entered in the PVT section and for outflow from the well. Reservoir properties and relative permeability data shown in Table 5,6,7 and 8 were entered in their section. Nodal system analysis task was implemented and sensitivities were conducted for fracture permeability of 5000mD, 10000mD, 20000mD, 30000mD, 40000mD, 50000mD and 60000mD and fracture skin of 1, 2, 3,4 and 5 respectively. The simulation workflow is presented in figure 1.

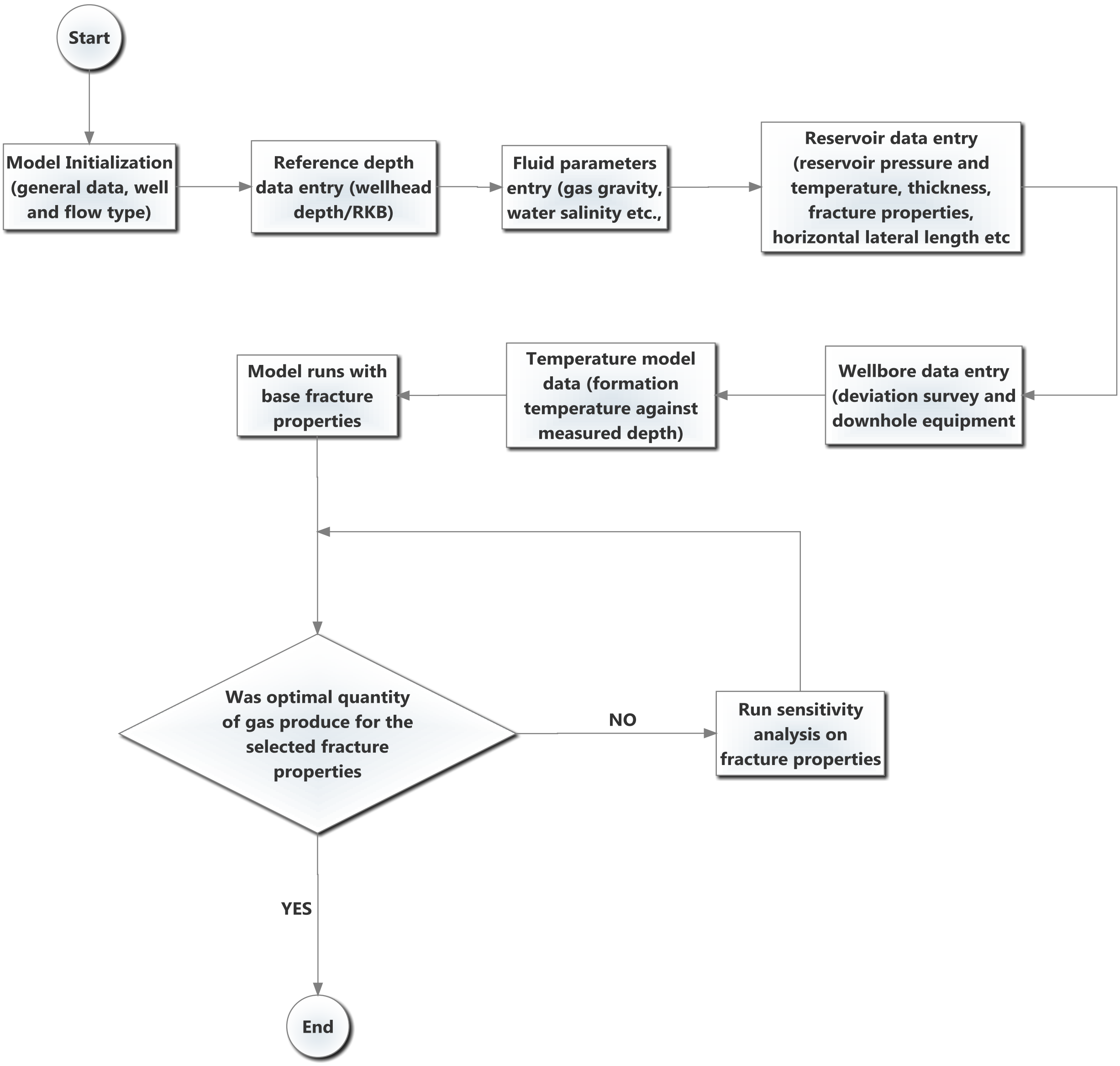

Figure 3.1: Simulation workflow

International Journal of Advances in Engineering and Management (IJAEM)
Volume 6, Issue 2 Feb. 2024, pp: 86-93 www.ijaem.net ISSN: 2395-5252

III. Results

3.1 Well Inflow Performance Relationship (IPR) Curve for the base model

The well Inflow Performance Relationship (IPR) curve for the base model is presented in figure 2. The trend shows an increase in gas production rate as the bottom hole pressure decreases, that is an inverse relationship between the flowing bottom hole pressure and the gas production rate. This was because as the flowing bottom hole pressure decreases, the pressure drawdown in the vicinity of the wellbore increases, thereby giving room for more inflow into the wellbore. Results shows that the reservoir deliver 127.5704MMscf/day of gas across the completion into the wellbore when the pressure drawdown was maximum that is if the bottomhole flowing pressure is reduced to zero for the base model.

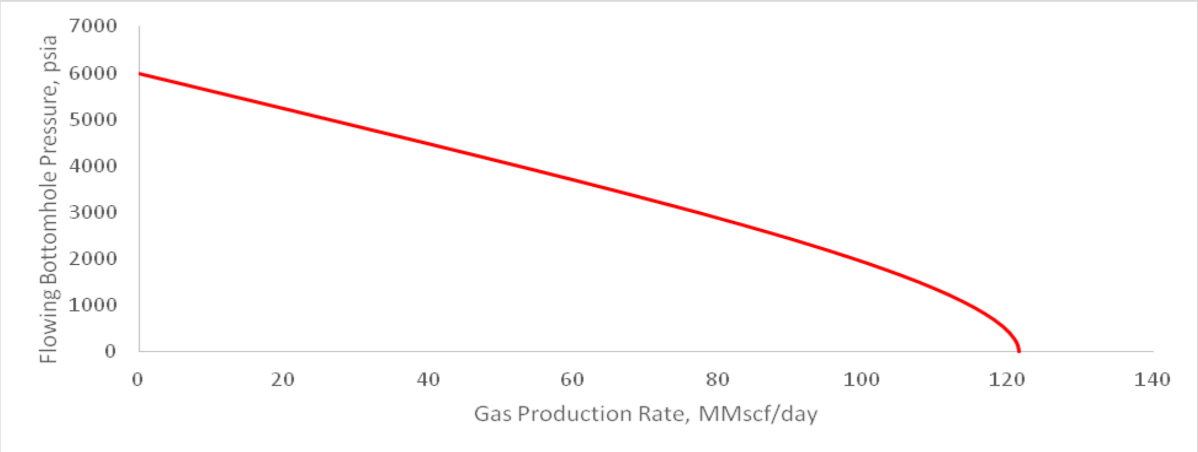

Figure 2: Well Inflow Performance Relationship curve

3.2 Well production performance for the base model

Figure 3 shows the well performance curves (inflow and outflow curves) for the base case model. Result reveals that the well was producing 54.04MMscf/day of gas at a flowing bottomhole pressure of 3945.72psia.

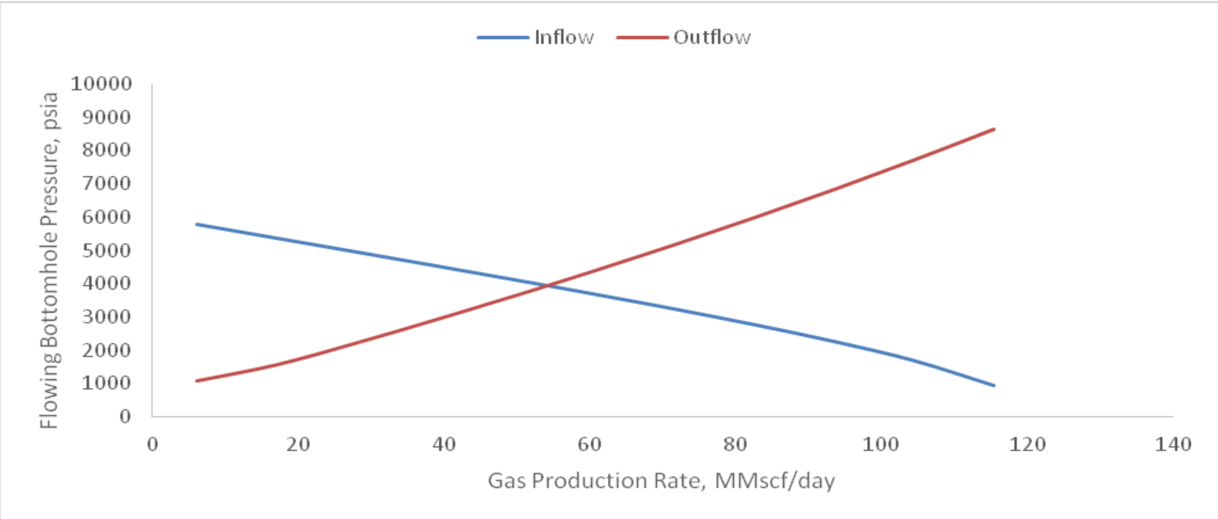

Figure 3: Well production performance for the base model

3.3 Inflow and Outflow performance for different fracture permeability

Figure 4 shows the well performance curves for the different fracture permeability on production performance. Result reveals that as the fracture permeability increases, the intersection between the inflow and outflow performance curves move upward, indicating an increase in gas production rate.

International Journal of Advances in Engineering and Management (IJAEM)
Volume 6, Issue 2 Feb. 2024, pp: 86-93 www.ijaem.net ISSN: 2395-5252

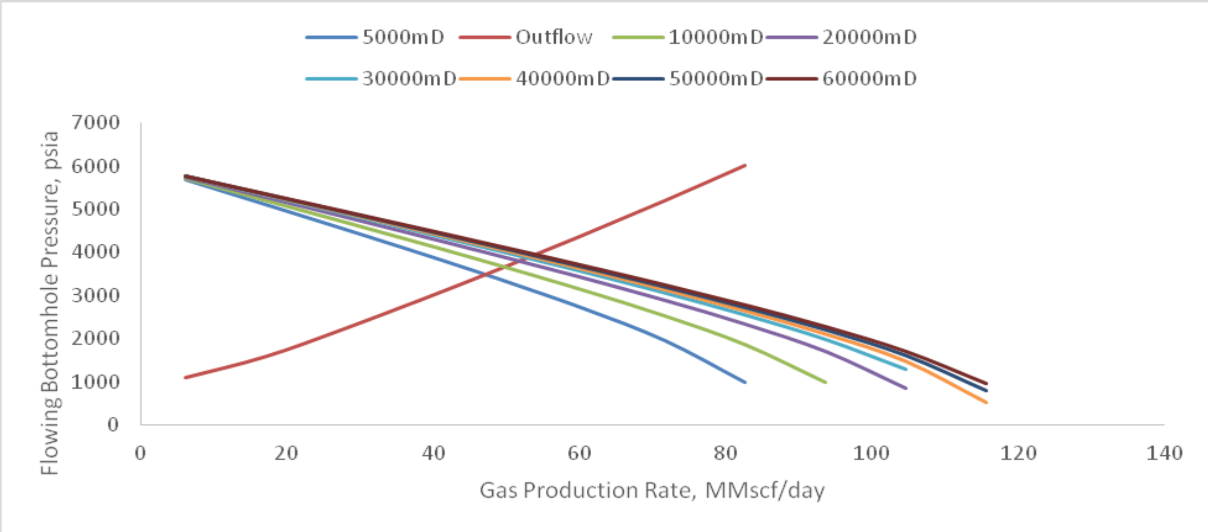

Figure 4: Inflow/Outflow curves for different fracture permeability

The fracture permeability against gas production rate is presented in figure 5. Result shows that as the fracture permeability increase, the gas production rate from the well also increases. This was most noticeable with an increase in the fracture permeability from 5000mD, 10000mD, 20000mD and 30000mD with a corresponding gas production rate of 47.21MMscf/day, 49.84MMscf/day and 51.87MMscf/day. However, with a further increase in fracture permeability from 40000mD to 60000mD, no appreciable increase in gas production rate was observed. This was as a result of the fact that as the fracture permeability increases, the fluid velocity around the fractures will also increase. This may result in the erosion of the formation sand by the sand-carrying fluid and thus a reduction in the gas production rate.

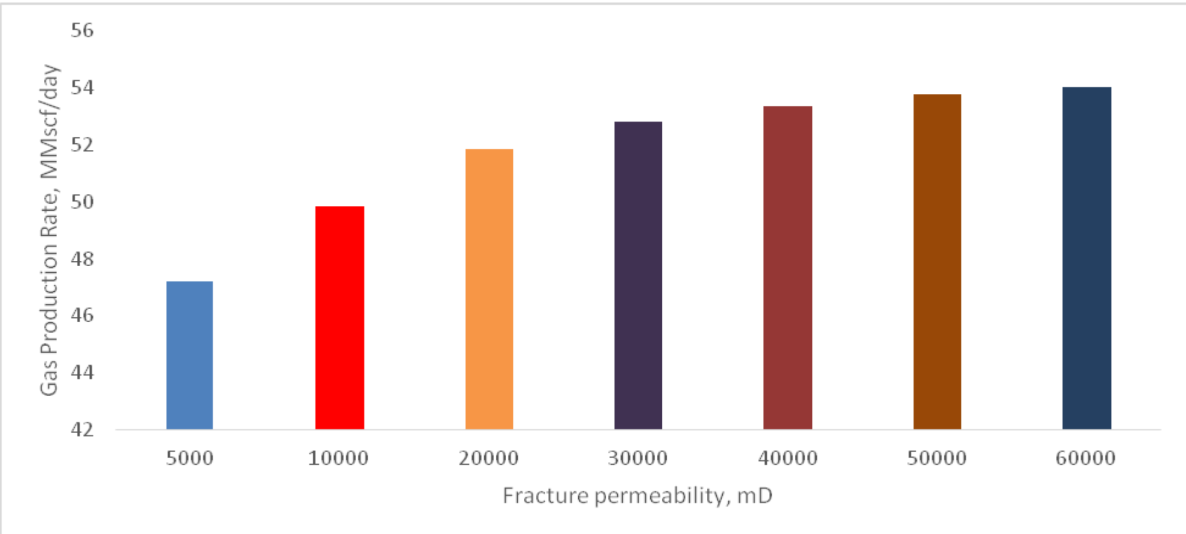

Figure 5: Fracture permeability against gas production rate

3.4 Inflow and Outflow performance for different fracture skin

The well performance curves for different fracture skin on the operating point of the well are shown in figure 6. Result reveals that the fracture skin only has an effect on the inflow performance curves since it was located on the inflow side of the production system.As the fracture skin increases, the intersection between the inflow and outflow performance curves move downward, indicating a decrease in gas production rate.

International Journal of Advances in Engineering and Management (IJAEM)
Volume 6, Issue 2 Feb. 2024, pp: 86-93 www.ijaem.net ISSN: 2395-5252

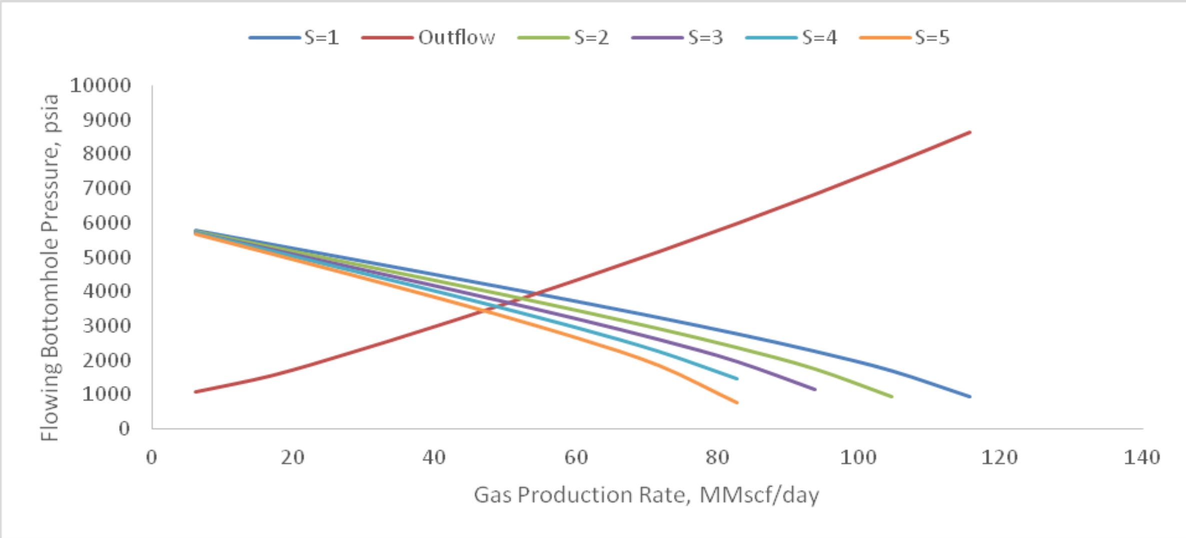

Figure 6: Inflow/Outflow performance curve for different fracture skin

The fracture skin against gas production rate is presented in figure 7. As the fracture skin increase, the gas production rate from the well decreases. This was as a result of the damage zone in the fractures which result in high pressure loses as fluid moves along the conducting fractures. For a fracture skin of 1, 2, 3, 4 and 5, the result obtained reveals a gas production rate of 54.04MMscf/day, 52.05MMscf/day, 50.18MMscf/day, 48.43MMscf/day, and 46.78MMscf/day.

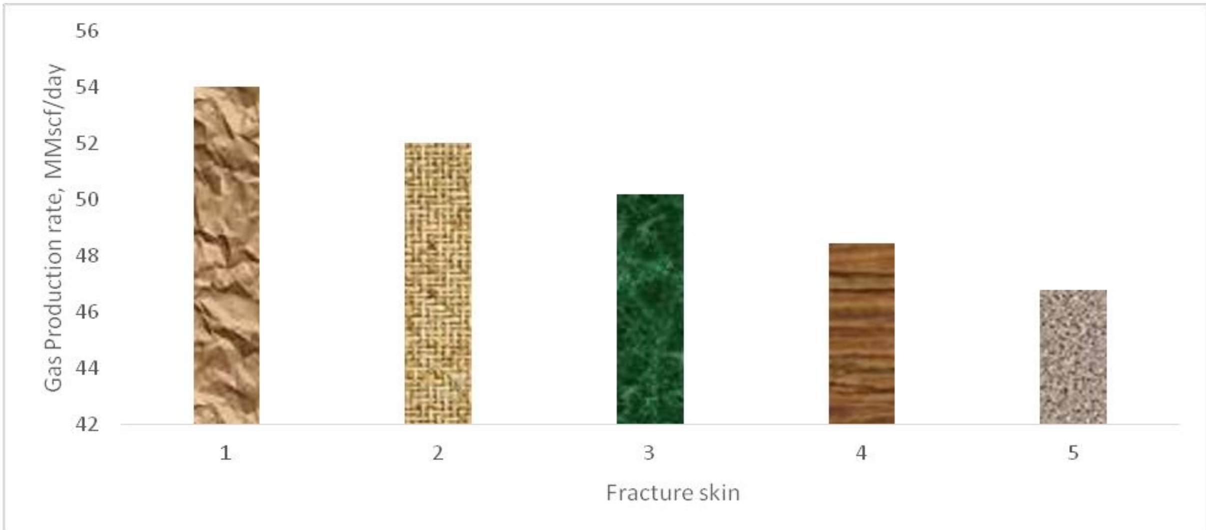

Figure 7: Gas production rate against fracture skin

IV. Conclusion

In this work, the effect of hydraulic fracture properties on well production performance was investigated. WellFlo well modelling tool was used to build a horizontal wellbore model with base hydraulic fracture properties. With the base model established, sensitivity analyses were conducted to determine the impact of different fracture skin and permeability on well production performance.As the fracture permeability increases, the intersection between the inflow and outflow performance curves moves upward, indicating an increase in gas production rate, while that for the fracture skin move downward as the fracture skin increases, indicating a decrease in gas production rate.

References

[1]. Cheng, Y. (2012a). Impacts of the number of perforation clusters and cluster spacing on production performance of horizontal shale-gas wells. SPE Reservoir Evaluation and Engineering, 15, 31–40.

[2]. Cheng, Y. (2012b). Mechanical interaction of multiple fractures-exploring impacts of the selection of the spacing/number of perforation clusters on horizontal shale-gas wells. SPE Journal, 17, 992–1001.
[3]. Cipolla, C. L., and Wright, C. A. (2000). State-of-the-Art in Hydraulic Fracture Diagnostics.
[4]. Paper SPE 64434 presented at the SPE Asia pacific Oil and Gas Conference and Exhibition, Brisbane, Australia, 16-18 October.
[5]. Cipolla, C. L., Warpinski, N. R., Mayerhofer, M. J., Lolon, E. P. and Vincent, M. C. (2010). The Relationship between fracture complexity, reservoir properties, and fracture treatment design. Journal of Society of Petroleum Engineering, 25(4), 438–452.
[6]. Gringarten, A. C., and Ramey, J. R. (1973). The Use of source and Green's functions in solving unsteady-flow problems in reservoirs. Society Petroleum Engineering Journal, 13 (5), 285-296.
[7]. Guo, B., Lyons, W. C., and Ghalambor, A. (2007). Petroleum production engineering: A computer-assisted approach. (1st Ed.) Gulf Professional Publishing.
[8]. Holditch, S. A. (2006). Tight gas sands. Journal of Petroleum Technology, 58(06), 1–7.
[9]. Karra, S., Kang, Q., Frash, L., Chen, L., Lei, Z., O'Malley, D., and Makedonska, N. (2016).
[10]. Understanding hydraulic fracturing: a multi-scale problem. Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering, 374(2078).
[11]. McGuire, W. J., and Sikora, V. J. (1960). The effect of vertical fractures on well productivity. Journal of Petroleum, 12(10), 1–3.
[12]. Medavarapu, K., Das, S., Ch, S., and Nainwal, S. P. (2017). Optimization of fracturing technique for successful exploitation of tight gas reservoirs of Mandapeta field. In: SPE Oil and Gas India Conference and Exhibition, 4–6 April, Mumbai, India.
[13]. Ostojic, J., Rezaee, R., and Bahrami, H. (2012). Production performance of hydraulic fractures in tight gas sands, a numerical simulation approach. Journal of Petroleum Science and Engineering, 88-89, 75-81.
[14]. Rafiee, M., Soliman, M. Y., and Pirayesh, E. (2012). Hydraulic Fracturing Design and Optimization: A Modification to Zipper Frac. Proc., the SPE Annual Technical Conference and Exhibition, San Antonio, Texas, 7-10 October. SPE-159786-MS.
[15]. Taha, M., Khokhar, S. Y., Iqbal, M. S., Chughtai, S., Umair, M., and Virk, M. A. (2013).
[16]. Effective exploitation of tight gas reservoirs using Integrated Asset Modelling (IAM) approach. In: SPE/PAPG Annual Technical Conference, 26-27 November, Islamabad, Wang, R., Song, H., Tang, H., Wang, Y., Killough, J., and Huang, G. (2016). Analytical
[17]. modeling of gas production rate in tight channel sand formation and optimization of artificial fracture. Springer Plus, 5, 540.
[18]. Zee Ma, Y., Moore, W. R., Gomez, E., Clark, W. J., and Zhang, J. (2016). Chapter 14 – Tight Gas Sandstone Reservoirs, Part 1: Overview and Lithofacies. In: Zee Ma, Y., Holditch, S.A. (Eds.). Unconventional Oil and Gas Resources Handbook. Gulf Professional Publishing, Boston, 405–427.