Advanced Management Science, 4(2), 108-110, 2015
ISSN: 2222-4955 (Print), ISSN: 2222-4963 (Online)
DOI: 10.7508/ams.2015.02.005

Validity of Hydraulic Fractures in the KL Volcanic Gas Reservoir

Feng Zhang[1], Wenlu Yang[2]*, Jiangling Hong[1], Nan Zhao[1], Yanling Li[1], Xiaolei Wang[1], Xing Chen[2]

[1]No.1 Gas Prodution Plant of PetroChina Xinjiang Oilfield Company, Kelamayi 834000, China
[2]Postgraduate School of Southwest Petroleum University, Chengdu 610500, China

Abstract: The volcanic formation is an important unconventional reservoir. KL volcanic gas reservoirs were discovered and the buried depth is about 3600 m. In this paper, complicated storage space and complex pore structure was briefly described. Then, volcanic mechanical properties were tested by tri-axial device; the static Young modulus is about 36 -52 GPa and Poisson ratio 0.194 to 0.205 respectively. Finally, based on fracturing pressure information, the in-situ stresses were interpreted about 51.7-64.4 MPa; multiple fracture number is about 2 or 3 and the fluid leak-off coefficient can reach 7.8-9.2E-4 $m/m^{1/2}$; the dynamic fractures length varies from 75-107 m with average 88.53m, the effective fracture length is about 63.8m and the fracture conductivity is 12.34 D.cm by interpretation of well testing. Obviously, the effective fracture length are less than dynamic fracturing length.

Keywords: Volcanic rock, hydraulic fracturing, fracture parameter, optimization

I. Introduction

It has been about 100 years since the volcanic reservoirs are studied [1]. Recently, some volcanic reservoirs were gradually explored and have proven the excellent reservoir in American, Japan and China. The practice and review of development in Minami-Magaoka volcanic gas reservoir in Japan [2, 3] has promoted hydraulically fracturing technologies the volcanic rock. In China, study of fracturing pressure analysis in deep volcanic reservoirs of Da Qing oil flield [4] and fractures evolution and development in trachyte of Liao He oilfield [5] have been made. At present, the proved geological reserve of volcanic reservoirs in China is more than one billion tone, which becomes an important special unconventional reservoirs [6].

KL volcanic gas reservoirs were discovered in recent years and the buried depth o is about 3600 meters. The statistics have shown that the gas production differences between the wells after stimulation are large, which asks for the general systematic analysis and evaluation about the fracturing technologies to find the main control factors affecting the production of fractured wells and technology approaches to improve the stimulation effect.

II. The Gas Reservoir Characteristics

A. Basic Characteristics

KL volcanic gas reservoir [7] was formed in the telophase of Carboniferous. The formation has intense severe heterogeneity from micro to macro characteristics because of complicated reservoir space and complex pore structures as well as strong influences from the secondary diagenesis.

Based on the rock core and FMI interpretation, the natural fractures have an obvious direction with 1-10 natural fractures per meter and the length density is 0-5m/m2 as well as the width 0-30μm respectively. The plane porosity of natural fractures is 0-0.5%, opening natural fractures is about 70.35%.

The core tested the main porosity range is 4-14% with average 9.12%, and permeability is 0.01-0.5mD with average 0.15 mD.

B. Rock Mechanical Parameters

The experiment results of rock mechanics properties are shown in the Table 1. The static Young modulus is in the range from 36 to 52 GPa, and the Poisson ratio is from 0.194 to 0.2054.

Table 1. Rock mechanical parameters with tri-axial stresses.

Sample	Conf. stress, MPa	Young modulus, GPa		Poisson Ratio	
A-1	40	49.06	Avg. 52.7	0.2048	Avg. 0.2023
A-1	50	53.25		0.2010	
A-2	50	55.88		0.2012	
B-1	50	42.78	Avg. 46.7	0.2076	Avg. 0.2054
B-2	50	50.71		0.2032	
C-1	50	37.94	Avg. 36.1	0.204	Avg. 0.194
C-2	40	33.65		0.186	
C-3	50	36.78		0.193	

Corresponding author: 544701552@qq.com

C. *In-situ Stresses from Interpretation of Fracturing Data*

Hydraulic fracturing pressure from well KL402 is shown in the Figure 1. In base of hydraulic fracturing pressure analysis [8, 9], the interpreted close stress (horizontal minimum stress) results have been given in the Table 2.

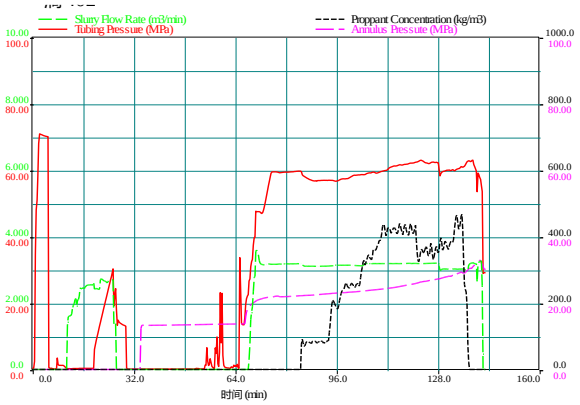


Figure 1. The fracturing pressure variation from well KL402.

Table 2. Horizontal stress calculated by the fitting of the fracturing data.

Well name	Close time min	Close Pres.	
		MPa	MPa/m
K103	11.2	41.38	0.0133
K1	20.1	54.89	0.0157
KL17	7.5	55.85	0.0154
KL18	17.9	48.42	0.0138

III. THE EFFECTIVE OF HYDRAULIC FRACTURE PARAMETERS

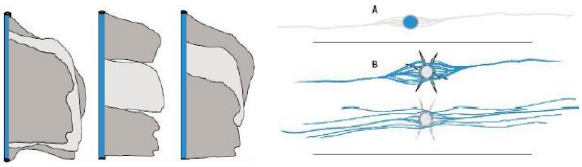
A. *The Fracture Geometries*

Usually, the artificial fracture surface is always perpendicular to the direction of minimum stress. However, the natural fractures in KL reservoir are development, and the fitting results of the stimulation data and G function have proven the possibility of the multiple fractures in practice [10].

a) The fitting results of the fracturing pressure in Well KL1424 show the net pressure increased rapidly from 9.0 MPa to 13.0 MPa during slurry stage, the fractures number is no less than 3 and leak coefficient is about 9.2E-4m/min1/2.

b) The interpretation from fracturing testing in Well KL1 has displayed the number of the fractures number is 2 and the loss coefficient is about 7.8E-4m/min1/2.

Combining with the status of natural cracks and the principles of minimum main stress, it was proven that the induced fractures geometry is very complex during hydraulically fracturing.



(A) Multi-fractures near wellbore (B) Fractures far from the wellbore

Figure 2. The sketch map of geometry during hydraulic fracturing.

B. *The Fractures Propagation*

In the fracturing treatment, the relationships between net pressure and time are given by coupling fluid flow equations in fracture, crack open width equation and continuity equations [10].

$$p_w(t) \propto t^e \begin{cases} \dfrac{1}{4(n+1)} < e < \dfrac{1}{2n+3}, PKN \\ \dfrac{-n}{n+2} < e < \dfrac{-n}{2(n+1)}, KGD \\ \dfrac{-n}{n+2} < e < \dfrac{-3n}{8(n+1)}, Penny \end{cases} \quad (1)$$

In KL volcanic gas reservoir, the hydraulic fracture propagation is divided into 3 types:

(1) The fracturing pressure variation is regular (pore type dominates, such as well KL171, KL173, KL1813, KL401 and so on);

(2) The fracturing pressure increases gently (fracture-pore type, such as KL17, KL1823);

(3) The fracturing pressure increases sharply and screen-out in maturation period (fractured reservoir, such as KL18, KL22).

C. *Validity of Artificial Fractures*

(1) Fractures parameters from fitting fracturing pressure information

Based on the interpreted models from fitting analysis of the fracturing pressure [11, 12], the fractures parameters are given in Table 3. The dynamic average length is about 88.53m.

Table 3. Hydraulic fracture parameters fitted by pressures in KL.

Well	Dynamic length/m	Propped length/m	Upper bound of dynamic height/m	Lower bound of dynamic height/m
K103(1)	75.14	73.11	19.53	18.83
K103(2)	83.06	80.42	24.52	19.61
KL1424	107.4	104.7	34.80	25.53

(2) Fractures parameters from interpretation of well testing

The hydraulic fractures parameters also be gained by well testing interpretation theory in double medium, the results are given in Table 4.

Table 4. Hydraulic fracture parameters interpreted by well testing.

Well	Depth/m	Propped length/m	Frcd/um2 cm
KL403	3594-3606	85.7	13.4
KL17	3633-3670	22.6	10.1
KL171	3670-3690	39.0	13.15
KL182	3635-3650	108.0	12.72
Average		63.8	12.34

IV. CONCLUSIONS

For KL volcanic gas reservoir, the effective porosity varies 6-15% with average 10.69% and permeability distribute 0.1-5.0 mD with average 1.476 mD by logging. It has a complex pore structure and multiple types' storage spaces, but relies mainly on natural crack-pore. The natural fractures exists three directions, and 70.35% of total cracks are opening.

The results from tri-axial experiment show that the values of Young modulus and Poisson ratio are 36-52 GPa and 0.194-0.2054 respectively.

The closure pressures of KL volcanic formation is about 51.7-64.4 MPa though fracturing pressure analysis in KL volcanic gas reservoir, multiple fracture number is about 2 or 3 and the fluid loss coefficient can reach 7.8-9.2E-4 m/m1/2.

According to the fitting results of fracturing data, the dynamic fractures length varies from 75-107 m with average 88.53m, while the average value of fractures length is 63.8 m, the fracture conductivity is 12.34 D.cm by interpretation of well testing. Obviously, the differences between dynamic fractures length and effective length are large. This is an important reasons result in great gas production differences.

ACKNOWLEDGEMENTS

The research work was supported by National Science and Technology Major Project of China under Grant No. 2011ZX05014-06-04 and Science and Technology Project of Xinjiang Oilfield Branch Company of CNPC.

REFERENCES

[1] Q. Z. Wang, "Study on igneous rock reservoir," *J. Journal of Xi'an Petroleum University* (Natural Science Edition), vol. 19, no. 2, pp. 13-16, 2004.

[2] L. Weiijers, "The first successful fracture treatment campaign conducted in Japan: stimulation challenges in a deep naturally fractured volcanic rock," in *Proceedings of the SPE Annual Technical Conference*, Texas, 2002.

[3] L. Weijers, L. G. Griffin, H. Sug, K. K. Chong, J. M. Terracina, and B. W. McDaniel, "Hydraulic fracturing in a deep, naturally fractured volcanic rock in Japen—Design consideration and execution results," in *Proceedings of the SPE Asia Pacific Oil and Gas Conference*, Melbourne, 2002.

[4] C. B. Fen, C. Y. Xie, and Y. P. Zhang, "Fracturing technology of deep fractured volcanic gas reservoirs in Daqing oilfield," *J. Natural Gas Industry*, vol. 26, no.6, pp. 108-110, 2006.

[5] Z. H. Ma, "Study and forecast of volcanic rock reservoir in Huangshatuo Area," *J. Fault-block Oil & Gas Reservoir*, vol. 10, no. 3, pp. 5-8, 2003.

[6] G. M. Yu, J. Z. Li, and D. H. Liu, "Characteristics of geology & development in volcanic reservoir," *J. Special Oil & Gas Reservoir*, vol. 5, no. 2, pp. 60-64, 1998.

[7] Study on formation characteristics of volcanic gas reservoir in DX14 Area, (Research Report), 2009

[8] M. J. Ecnomides and K. G. Nolte, "Modern Fracturing—Enhancing natural gas production," *Petroleum Industry Press*, Beijing, 2007.

[9] G. Y. Mao, "Analysis of pressure in hydraulically fracturing," M. S. thesis, Southwest Petroleum University, 2008.

[10] X. L. Wang, H. Liu, Y. Da, G. Y. Li, L. P. Zhao, and R. Ren, "Stimulation technology of Kelameili volcanic gas reservoirs," *J. Natural Gas Industry*, vol. 30, no. 2, pp. 63-65, 2010.

[11] Y. P. Zhang, S. C. Zhang, and X. F. Wei, "Study and application of fracture diagnostic technology for naturally fractured volcanic gas reservoir," *J. Petroleum Geology & Oilfield Development in Daqing*, vol. 27, no. 2, pp. 91-93, 2008.

[12] H. Mukherjee, S. Larkin, and W. Kordziel, "Extension of fracture pressure Decline Curve Analysis to Fissured formations," in *the Rocky Mountain Regional Meeting And Low-Permeability Reservoirs Symposium*, Colorado, April, 1991.