Optimization of the Effective Parameters on Hydraulic Fracturing Designing in an Iranian Sand Stone Reservoir

Reza Masoomi[#1], Iniko Bassey [#2], Dolgow Sergie Viktorovich[#3]
[#]Faculty of Oil and Gas, Kuban State University of Technology, Krasnodar, Russia
[1] r.masoomi451@yahoo.com
[2] index_2k6@yahoo.com
[3] s.dolgow2013@yandex.com

Abstract- Hydraulic fracturing operation is one of the key technologies in order to stimulate oil and gas wells in sand stone reservoirs. Field data relating to the hydraulic fracturing operation are mostly available as pressure-time curves. The optimization of the hydraulic fracturing parameters is not possible with only this information. So the designing and controlling the development process of hydraulic fracturing are possible only with rely on complex mathematical and numerical models.

The aim of this study is to optimize the effective parameters on designing of the hydraulic fracturing process in an Iranian oil reservoir with sandstone reservoir rocks. For this purpose the parameters of pump flow rate and hydraulic fracture half length have been optimized. In this study first variable pump flow rates scenarios have been investigated. The scenarios to determine the optimum value for hydraulic fracturing half length have been designed after determining of the optimal pump flow rate.

In this study the calculation results in addition to the pseudo three-dimensional hydraulic fracturing model (P3D) have also provided with the hydraulic fracturing two-dimensional modeling including PKN, KGD and Radial models.

Keywords- Hydraulic fracturing, pump flow rate, fracture length, cumulative oil recovery

I. Introduction

Permeability of the reservoir rock is considered desirable when pores of the reservoir rock are connected to each other and also in case of easily flow into the wellbore. But in the case of low permeabilities, fluid is not easily able to move through the reservoir rock to the wellbore. In these cases, rock channels don’t allow as they should to fluid flow into the wellbore and the well will not produce economically, because oil or gas is not produced to the extent necessary from the well. That’s why we need to create fractures and artificial channels in the reservoir rocks. In fact, these channels which are created by hydraulic fracturing operation, can improve the power of the reservoir rock to lead the reservoir fluid in to the wellbore. Thus hydraulic fracturing is one of key technologies to enhance the productivity of oil and gas wells. Hydraulic fracturing is the process in which a viscous fluid is injected in to the formation under high pressure and with a relatively high flow rate so that a crack would be created and expanded. Hydraulic fracturing process of underground formations has been widely considered during the last few decades in various fields of engineering. In the oil and gas industry this technique is used to create large cracks with high hydraulic conductivity for increasing flow rate of oil and gas through the low permeable hydrocarbon reservoirs to the drilled wells. In the field of environmental engineering, this technique is an effective method in increasing the efficiency of the soil In-situ remediation methods. Extraction of geothermal energy by creating hydraulic fracturing in the dry and hot rocks and use of fluid cycle are other uses of this process. This method is only reliable method for measuring residual stresses field that are widely used due to its simplicity. Other important applications of this technology include such items as: Underground disposal of waste and toxic fluids, stimulation of water wells to produce water and in mining industries as a backup system in large-scale excavation of ores [1,2].

Despite all the above applications that hydraulic fracturing comes to them as a useful method, in some cases is considered as a destructive and undesirable. For example in the field of dam construction, hydraulic fracturing can cause cracks in the core of the earth dams. Leaking and in some cases failure of earth dam are consequences of these cracks [3].

Decomposition of buried radioactive materials in the soil and saturated rock generates heat and thereby cause expanding both soil and water in the field of nuclear waste’s land disposal. But this can lead to cracks in the soil because the water expansion coefficient has increased [4]. Also in designing of slurry injection process, hydraulic fractures that may occur during penetrating or consolidation slurry injection can significantly decrease the ability of slurry for sealing or improving the resistance [5].

Therefore needing for understanding the mechanisms of hydraulic fractures initiation and propagation in the various field of engineering has made that the analysis of this phenomenon and trying for achieving a suitable model to its simulating, strongly be considered. However, the importance of hydraulic fracturing process in oil and gas industry to achieve the hydrocarbon reserves or increase their production is the main motive to create such models.

II. Hydraulic fracturing in oil and gas industries

The first application of hydraulic fracturing for increasing the extraction of oil and gas from the underground reservoirs was in Hugoton field in western Kansas. In 1947 hydraulic fracturing conducted to comparing with acidizing technology on a gas well in this region by the Pan American Petroleum Corporation. At that time no one imagined that this will be the beginning of a great movement and new technologies for well stimulation. Perhaps the most optimistic observers didn't think that before 1981 about one million hydraulic fracturing operations performed worldwide. After that and until the mid-1960s, hydraulic fracturing became dominant method for stimulation of oil and gas wells in this area and the other areas [2,6] .

Only in the United State about 40% of oil wells and 70% of gas wells were completed by hydraulic fracturing since 1993 to2005. Moreover in Algeria about 20 hydraulic fracturing operations in Hessy M. field since 1970 to 1980 and additionally about 150 wells were completed by hydraulic fracturing until 2005. Producing countries in the Middle East especially Iran's competitors have greatly increase investments in hydraulic fracturing technology since 2000. Now in most producing countries in the Middle East hydraulic fracturing is used for well completion in most oil and gas wells. Unfortunately in our country hydraulic fracturing has not seriously considered except in a few cases. Hydraulic fracturing is a process of fluid injection into the well and makes a tensile stress in formation which is exposed to the fluid pressure such that leads to local stresses in formation in order to overcome the tensile strength. This creates fractures in formation which start from the wellbore and can propagate until fluid is injected continuously with a high rate. Propant (such as sand and ceramic balls) is also injected with the fluid so that during stopping of fluid pumping, created fractures remain as a permeable path for fluid flowing into the wellbore. In hydraulic fracturing should enough pressure apply for beginning of formation failure or breaking and also exposed pressure should continue to allow the fractures grow and spread. Naturally fracture injection process needs more pressure than fracture expansion stage. Generally there are two reasons for applying hydraulic fracturing in wells: 1) Increasing the productivity Index (PI), 2) Improving ultimate recovery factor.

III. Designing and modeling of hydraulic fracturing

So far extensive efforts have been done to provide models for designing hydraulic fracturing especially in recent decades. Most of these models have had drawbacks minimum in three directions that include:

a) Assumptions that computational models have been proposed on base of them are general.

b) Complicated programming.

c) The instability in input and output indexes especially in comparison to the actual operating conditions.

However some models have good quality but this good quality is only seen in limited areas. One of the simplest models that are two-dimensional (2D) is the KGD model that considers the fracture width as a function of length. Another simplest model that is tow-dimensional (2D) is the PKN model which considers fracture width as a function of fracture height. Due to the length and height of the fracture expand during operation, accepting the being constant fracture height was not justified. So Cleary proposed a new Three-dimensional pseudo hydraulic fracturing. In the model proposed by Cleary fracture width has been considered as a function of the smaller dimension (length or height) with considering the fracture length and height changes during operation [7,8] .

Data required should be carefully collected for studying the possibility of performing hydraulic fracturing on selected wells. These data are generally divided into five categories:

A) Well static data, B) Well fluid data, C) Formation data, D) The reservoir parameters, E) PVT data.

IV. Investigating of hydraulic fracturing in oil reservoir "Z" in southern Iran

A large number of Iran's hydrocarbon reservoir with oil production dating back of several years, are now in a declining period of their production. This has prompted the authorities and petroleum engineers to use effective methods for increasing production. In addition some reservoirs have the good initial oil inplace but they have not a desirable flow capacity. That is why the well stimulation operations seem to be necessary for increasing the permeability.

A. Studied field characteristics

Studied field is an asymmetric anticline with a length of 11 km and width of 3 km. This is a single-porosity sandstone field with 16 oil layers. Its oil is a relatively heavy with API grade of 25. Gas-Oil ratio in this reservoir has estimated at 700 scf/STB and oil formation volume factor (FVF) is about 1.4 Rbbl/STB. (Table 3) This is a newly explored oil field and now is in a stage of development.

Studied field is in undersaturation conditions and there is no gas cap in studied reservoir. Its reservoir rock is oil wet. Studied field has 16 oil layers with thickness of totally 196 m or 643 feet. Three-dimensional structure of “Z” oil reservoir with 16 oil layers has presented in Fig. 1.

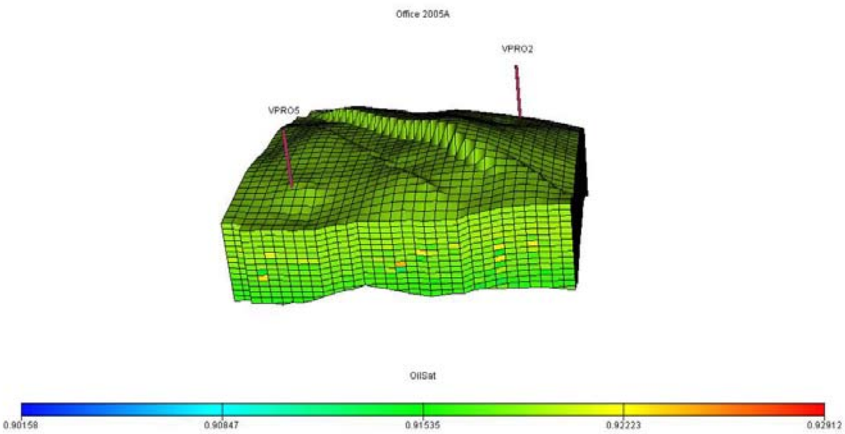

Fig. 1. Three-dimensional structure of “Z” oil reservoir in southern Iran

The average pressure of studied reservoir is about 3535 psia. The datum depth of calculations is about 7100 feet in this reservoir. Oil-Water contact in this reservoir has estimated at 7453.1 feet and Gas-Oil contact is estimated about 1725 feet. The datum depth for aquifer calculations has estimated at 7500 feet in this reservoir. Aquifer characteristics are presented in Table I. The calculations of water influx through the aquifer to the oil reservoir and aquifer productivity index have been done by Fetkovich’s aquifer model in this study [9].

TABLE I. Aquifer Properties

Property	**Value**	**Unit**
$P_{i,aquifer}$	$P_{av,res}$	psia
$V_{i,aquifer}$	2E+09	STB
C_t	6.5E-006	1/psi
$PI_{aquifer}$	10^4	STB/day/psi

Fig. 2 shows distribution of water saturation in the three-dimensional structure of studied reservoir. Also how and direction to contact of aquifer to the reservoir is shown in Fig. 2.

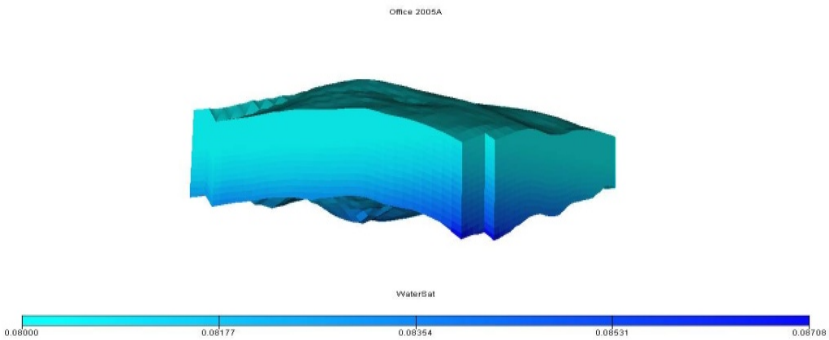

Fig. 2. Distribution of water saturation in the three-dimensional structure of the studied reservoir

B. A summary of the geology and fluid properties of the studied field

A summary of the geology and properties of the studied field is presented in Table II.

Table II. Fluid General Characteristics of the Studied Field

Properties	**Value**	**Properties**	**Value**
API	25	FVF , RbbL/STB Oil	1.4
Total thickness , ft	642	Oil Viscosity , cp	0.68
GOR , SCF/STB	700	Gas Viscosity , cp	0.021
Rock Compressibility,psi^{-1}	$2.8 * 10^{-6}$	Reservoir Temperature , °F	140
Average Porosity , %	12.5	Bubble Point Pressure , Psia	1995
Average Permeability@ Permx	154.55	Average Reservoir Pressure@ datum depth , Psia	5290
Average Permeability@ Permz	2.1	Oil in Place,STB	$3.2*10^{8}$
Initial Oil Saturation , %	79		

C. Characteristics of the field static model

A summary of characteristics of the field static model is presented in Table III.

Table III. Characteristics of the Field Static Model

Properties	**Value**	**Properties**	**Value**
Number of gridblocks in the X direction	32	Gridblock length in X direction, ft	357.29
Number of gridblocks in the Y direction	32	Gridblock length in Y direction, ft	360.61
Number of gridblocks in the Z direction	16	Gridblock length in Z direction, ft	0.4-20
Number of oil layers	16	Number of cells	16384

D. PVT data of the studied field

In this study LBC correlation method has been used for calculation of oil viscosity. LBC correlation method is used in a large number of compositional simulations. Lohrenz etal. (1964) supposed a method for calculating the hydrocarbon mixtures and reservoir fluids [10] . Their method was similar to Jossi etal (1962) for pure fluids. LBC correlation method is a polynomial of degree 6 at residual density. This makes increasing the sensitivity of viscosity than other parameters changes.

$$[(\mu - \mu_o)\xi + 10^{-4}]^{\frac{1}{4}} = d_0 + d_1\rho_r + d_2\rho_r^2 + d_3\rho_r^3 + d_4\rho_r^4 \quad (1)$$

Where μ_o is the dilute gas viscosity, ξ, residual viscosity and ρ_r is the fluid residual density that defined as follows:

$$\rho_r = \frac{\rho}{\rho_c} \quad (2)$$

Where ρ_c is the fluid critical density. Coefficients d_i in above equation is as follows:

d_0= 0.1023 d_1=0.023364 d_2=0.058533 d_3=-0.040758 d_4=0.0093324

Lohrenz etal. (1964) introduced the following equations for calculating viscosity of dilute gas and residual viscosity:

$$\zeta = \frac{(\sum_{i=1}^{n} x_i T_{c,i})^{\frac{1}{6}}}{(\sum_{i=1}^{n} x_i M_{w,i})^{\frac{1}{2}}(\sum_{i=1}^{n} x_i P_{c,i})^{\frac{2}{3}}} \quad (3)$$

$$\mu_0 = \frac{\sum_{i=1}^{n} x_i \mu_{0,i}\sqrt{M_{w,i}}}{\sum_{i=1}^{n} x_i \sqrt{M_{w,i}}} \quad (4)$$

Where T_{ci} is the critical temperature, P_{ci}, critical pressure, M_{wi}, molecular weight and i is the mole fraction of component “i” in the mixture. A PVT simulator has been used in this study to simulate the behavior of reservoir fluid at different temperatures and pressures. Also the SRK Three-parameter equation of state (EOS) has been used for the regression of both experimental and software data and coefficients of EOS have been altered in a way that consistent with experimental data and able to predict the behavior of reservoir fluid at different pressure and temperature. In this study first it has been tried to obtain a good match with no change in composition of the considered sample, but because the result was not perfect, so C_{7^+} was divided to two groups of C_{7^+} and C_{14^+}. Then for better result C_{14^+} was divided to two groups of C_{14^+} and C_{25^+}. This grouping is presented in Table IV. The splitting method by solving method of Whitson and EOS of Lee-Kessler has been used. The result of matching EOS parameters with the actual laboratory data are presented in Fig. 3 to 5.

Table IV. Reservoir Fluid Composition After Grouping Process

Component	Mole fraction	Component	Mole fraction
C_1	6.2914	C_6	2.5673
C_2	2.0953	C_7^+	42.403
C_3	2.1477	C_{14}^+	28.514
IC_4	0.72337	C_{25}^+	9.3076
NC_4	1.9261	H_2S	0.5706
IC_5	1.218	CO_2	0.63909
NC_5	1.5962		

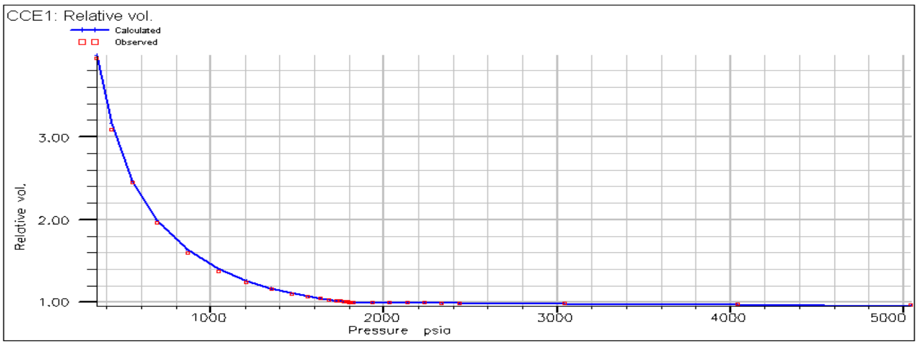

Fig. 3. The adjustment of relative volume as a function of pressure

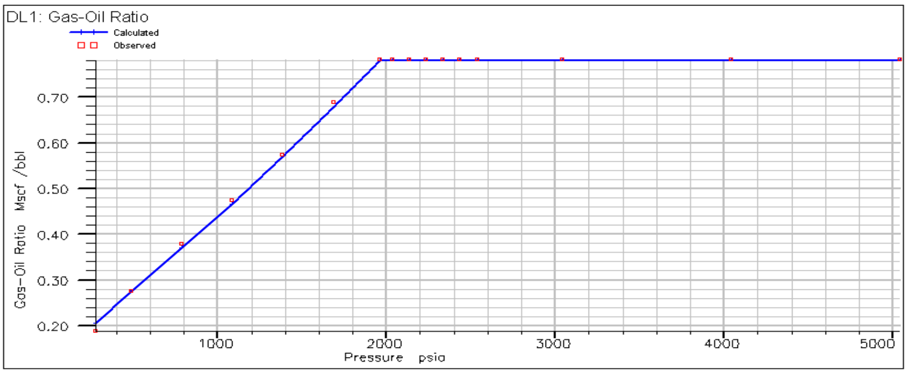

Fig. 4. Matching of dissolved gas in the oil as a function of pressure

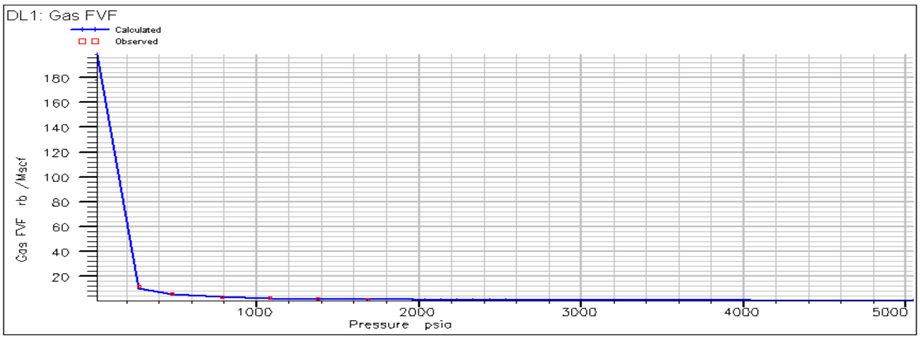

Fig. 5. Matching of gas volumetric coefficient as a function of pressure

V. Modeling and optimization of hydraulic fracturing process by analyzing variable scenarios in "z" oil reservoir in southern Iran

In this study the hydraulic fracturing process has been modeled for two sandstone pay zones at depths of 8255 and 8425 feet in oil well "A" which is located in oil reservoir "Z".

The aim of this study is to optimize the effective parameters on designing of the hydraulic fracturing process in an Iranian oil reservoir with sandstone reservoir rocks. For this purpose the parameters of pump flow rate and hydraulic fracture half length have been optimized. In this study first variable pump flow rates scenarios have been investigated. The scenarios to determine the optimum value for hydraulic fracturing half length have been designed after determining of the optimal pump flow rate.

In this study the calculation results in addition to the pseudo three-dimensional hydraulic fracturing model (P3D) have also provided with the hydraulic fracturing two-dimensional modeling including PKN, KGD and Radial models.

A. Investigation of pump flow rate scenarios in hydraulic fracturing process

The purpose of considering this scenario is finding the optimal pump flow rate to create hydraulic fractures. In this scenario hydraulic fracturing fluid is injected to the considered pay zones with variable rates. Then well productivity is measured over a period of one year to select the optimum value for pump flow rate. The scenario which has showed the highest well productivity is selected as the optimal scenario. In this study hydraulic fracturing fluid has been injected to the considered pay zones in oil well "A" in sand stone reservoir "Z" in southern Iran with rates of 15, 25, 35 and 45 bbl/min. Notably operation conditions are considered the same in all scenarios related to optimizing the pump flow rate. The maximum fracture half length has been considered 1000 feet for all scenarios in this section. In this study the calculated results in addition to the pseudo three-dimensional model (P3D) have also provided with two-dimensional models of hydraulic fracturing including PKN, KGD and Radial models. Since in the two-dimensional models PKN and KGD the fracture height is assumed to be constant during hydraulic fracturing process, the pseudo three-dimensional model (P3D) is more reliable. Because in pseudo 3D model by considering the fracture's length and height changes during the operation, the fracture width is considered as a function of the smaller dimension (length or height). Therefore in this study the results of hydraulic fracturing modeling with pseudo 3D model are base to select the optimal values for the considered parameters.

1) Scenario A-1: Pump flow rate equals to 15 bbl/min

In this scenario the pump flow rate for hydraulic fracturing operation has been considered 15 bbl/min for pseudo 3D model of hydraulic fracturing. Then well productivity has been simulated over a period of one year. The simulation results of this scenario are presented in Figure 6 and Table V. Also the pump flow rate has been determined with the two-dimensional PKN, KGD and Radial models. The results of these calculations are presented in Table V.

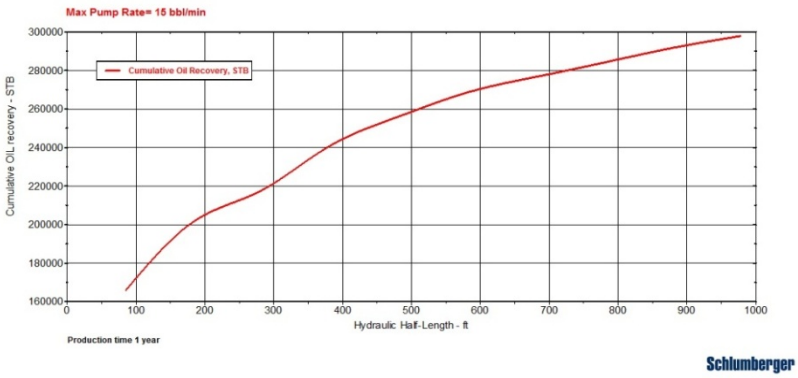

Fig. 6. The predicted cumulative oil production over a period of one year with pump flow rate of 15 bbl/min

Table V. Summary of Hydraulic Fracturing in Depths of 8255 and 8425 ft with Pump Flow Rate of 15 bbl/min for Well "A".

Model	Fracture length, ft	FOPT, STB	F_{cd}
PKN	998.9	333819	1.20
KGD	994.70	385634	2.13
RAD	978.67	310224	2.0
P3D	977.53	297754	0.97

2) Scenario A-2: Pump flow rate equals to 25 bbl/min

In this scenario the pump flow rate for hydraulic fracturing operation has been considered 25 bbl/min for pseudo 3D model of hydraulic fracturing. Then well productivity has been simulated over a period of one year. The simulation results of this scenario are presented in Figure 7 and Table VI. Also the pump flow rate has been determined with the two-dimensional PKN, KGD and Radial models. The results of these calculations are presented in Table VI.

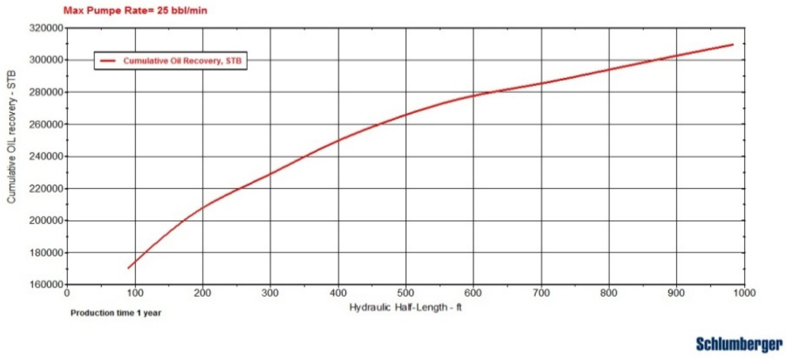

Fig. 7. The predicted cumulative oil production over a period of one year with pump flow rate of 25 bbl/min for well "A"

Table VI. Summary of Hydraulic Fracturing in Depths of 8255 and 8425 ft with Pump Flow Rate of 25 bbl/min for Well "A"

Model	Fracture length, ft	FOPT, STB	F_{cd}
PKN	999.29	344049	1.34
KGD	995.68	394265	2.35
RAD	980.83	313763	2.15
P3D	983.15	309450	1.07

3) Scenario A-3: Pump flow rate equals to 35 bbl/min

In this scenario the pump flow rate for hydraulic fracturing operation has been considered 35 bbl/min for pseudo 3D model of hydraulic fracturing. Then well productivity has been simulated over a period of one year. The simulation results of this scenario are presented in Figure 8 and Table VII. Also the pump flow rate has been determined with the two-dimensional PKN, KGD and Radial models. The results of these calculations are presented in Table VII.

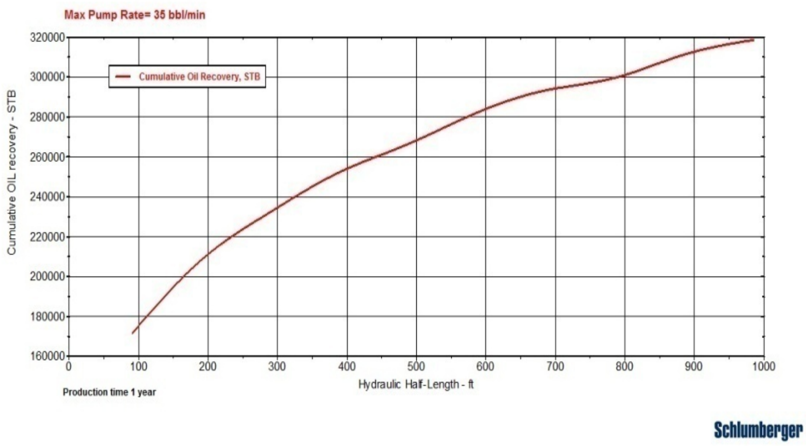

Fig. 8. The predicted cumulative oil production over a period of one year with pump flow rate of 35 bbl/min for well "A"

Table VII. Summary of Hydraulic Fracturing in Depths of 8255 and 8425 ft with Pump Flow Rate of 35 bbl/min for Well "A"

Model	Fracture length, ft	FOPT, STB	F_{cd}
PKN	999.44	349327	1.42
KGD	996.2	399405	2.50
RAD	983.83	321960	1.96
P3D	985.75	318558	1.12

4) ScenarioA-4: Pump flow rate equals to 45 bbl/min

In this scenario the pump flow rate for hydraulic fracturing operation has been considered 45 bbl/min for pseudo 3D model of hydraulic fracturing. Then well productivity has been simulated over a period of one year. The simulation results of this scenario are presented in Figure 9 and Table VIII. Also the pump flow rate has been determined with the two-dimensional PKN, KGD and Radial models. The results of these calculations are presented in Table VIII.

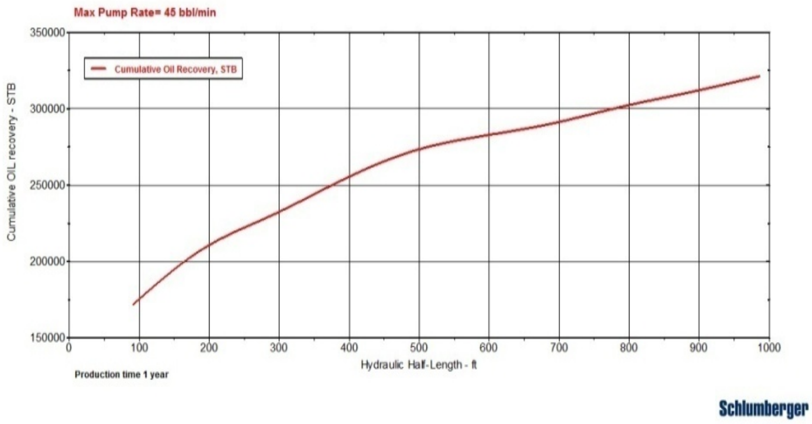

Fig. 9. The predicted cumulative oil production over a period of one year with pump flow rate of 45 bbl/min for well “A”

Table VIII. Summary of Hydraulic Fracturing in Depths of 8255 and 8425 ft with Pump Flow Rate of 45 bbl/min for Well “A”

Model	Fracture length, ft	FOPT, STB	F_{cd}
PKN	999.4	348970	1.41
KGD	996.10	398402	2.47
RAD	982.74	318812	1.99
P3D	986.33	321080	1.18

By comparing the scenarios related to determining the optimum pump flow rate these were calculated that by increasing the pump flow rate the productivity of well “A” has significant increasing. But after an optimal value for pump flow rate the productivity improvement gradient has been dropped. In other words by increasing the pump flow rate above the optimal value, the productivity of considered well had little increasing. In this study by increasing pump flow rate from 15 to 35 bbl/min the well productivity has been significantly increased (about 20804 STB). In the fourth scenario in this section increasing the pump flow rate from 35 to 45 bbl/min has been had little impact (about 2522 STB) on the productivity of well “A”. Therefore in this study the pump flow rate of 35 bbl/min has been considered as optimum value of pump flow rate for oil well “A”.

B. Second scenario: Analyzing the effect of fracture half length parameter on improving productivity of well “A” in studied oil reservoir

The purpose of analyzing this scenario is to optimizing the fracture half length in well “A” located in oil reservoir “Z” in southern Iran. In this section with analysis of the fracture half length’s impact on improving the productivity of studied well in a standard range of hydraulic fracturing operation, between 500 to 1100 ft, the optimal value for the fracture half length is determined [11] . In this study the purpose of the hydraulic fracturing length is the created fracture along one side of the well which is able to fluid flow or half of the created fracture length on both sides of the well which is able to fluid flow. In this study three scenarios have been proposed to optimize the hydraulic fracturing half length. Hydraulic fracturing half lengths have been considered 550, 850 and 1150 ft in these scenarios. It should be noted that the operation conditions have been considered the same for all scenarios in this section. In all scenarios the pump flow rate has been considered 35 bbl/min equals to optimal value determined from the previous section. In this study the calculated results in addition to the pseudo three-dimensional model (P3D) have also provided with two-dimensional models of hydraulic fracturing including PKN, KGD and Radial models.

1) Scenario B-1: Fracture half length equals to 550 ft

In this scenario the fracture half length has been considered 550 ft for pseudo 3D model (P3D). The pump flow rate has been considered 35 bbl/min (The optimized value from the previous section). Then the productivity of well “A” has simulated for a period of one year with using pseudo 3D modeling (P3D) of hydraulic fracturing. The results of this simulation are presented in Figure 10 and Table IX. Also the fracture length has determined with the two-dimensional models including PKN, KGD and Radial models at the same operation conditions. The results of these calculations are presented in Table IX.

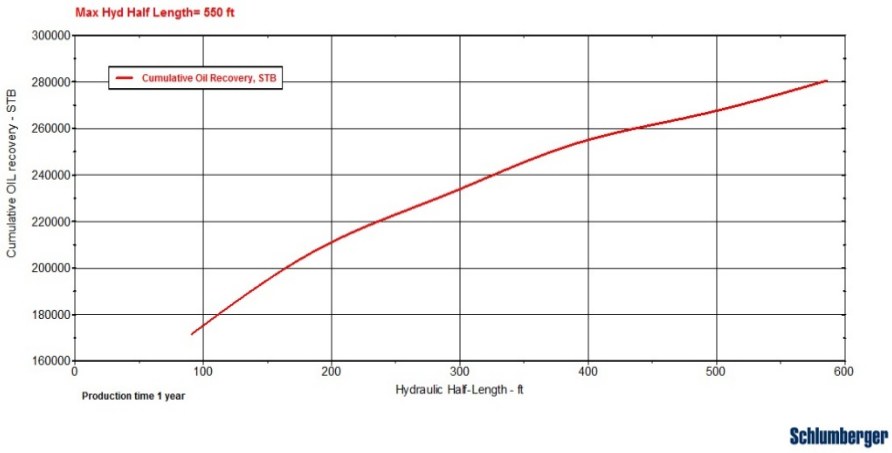

Fig. 10. The predicted cumulative oil production over a period of one year with fracture half length of 550 ft for well "A"

Table IX. Summary of Hydraulic Fracturing in Depths of 8255 and 8425 ft with Fracture Half Length 0f 550 ft for Well "A"

Model	Hydraulic X_f, ft	Propped X_f, ft	FOPT, STB	F_{cd}
PKN	600	599	305877	1.94
KGD	600	595.7	333385	3.10
RAD	500	489.3	299658	1.88
P3D	600	586	280456	1.38

2) Scenario B-2: Fracture half length equals to 850 ft

In this scenario the fracture half length has been considered 850 ft for pseudo 3D model (P3D). The pump flow rate has been considered 35 bbl/min (The optimized value from the previous section). Then the productivity of well "A" has simulated for a period of one year with using pseudo 3D modeling (P3D) of hydraulic fracturing. The results of this simulation are presented in Figure 11 and Table X. Also the fracture length has determined with the two-dimensional models including PKN, KGD and Radial models at the same operation conditions. The results of these calculations are presented in Table X.

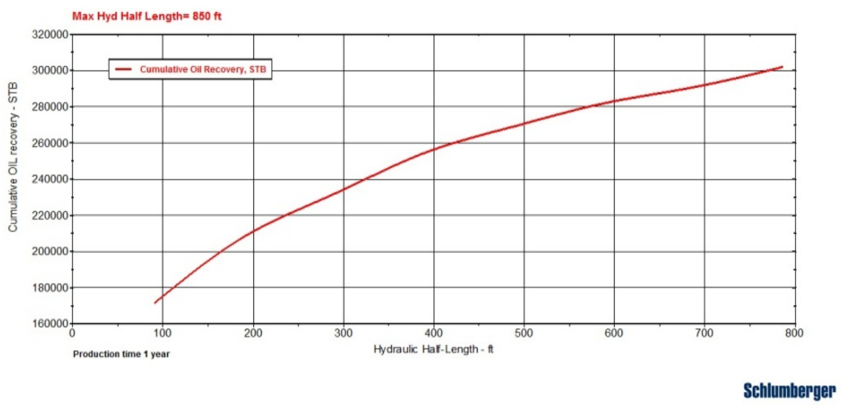

Fig. 11. The predicted cumulative oil production over a period of one year with fracture half length of 850 ft for well "A"

Table X. Summary of Hydraulic Fracturing in Depths of 8255 and 8425 ft with Fracture Half Length 0f 850 ft for Well "A"

Model	Hydraulic X_f, ft	Propped X_f, ft	FOPT, STB	F_{cd}
PKN	800	799	328139	1.61
KGD	800	796	368495	2.76
RAD	500	490	323764	2.0
P3D	700	685	301819	1.26

3) Scenario B-3: Fracture half length equals to 1150 ft

In this scenario the fracture half length has been considered 1150 ft for pseudo 3D model (P3D). The pump flow rate has been considered 35 bbl/min (The optimized value from the previous section). Then the productivity of well "A" has simulated for a period of one year with using pseudo 3D modeling (P3D) of hydraulic fracturing. The results of this simulation are presented in Figure 12 and Table XI. Also the fracture length has determined with the two-dimensional models including PKN, KGD and Radial models at the same operation conditions. The results of these calculations are presented in Table XI.

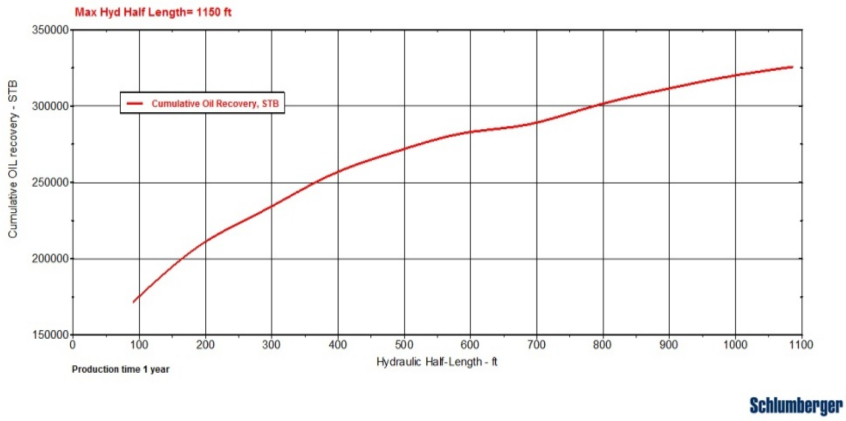

Fig. 12. The predicted cumulative oil production over a period of one year with fracture half length of 1150 ft for well "A"

Table XI. Summary of Hydraulic Fracturing in Depths of 8255 and 8425 ft with Fracture Half Length 0f 1150 ft for Well "A"

Model	Hydraulic X_f, ft	Propped X_f, ft	FOPT, STB	F_{cd}
PKN	1100	1099.50	339295	1.51
KGD	1100	1096	383841	2.59
RAD	500	490	322954	1.87
P3D	800	785	309316	1.17

By comparing scenarios related to fracture half length for studied oil well this result concluded that by increasing the fracture half length the productivity is improved. In oil well "A" the increasing fracture half length from 550 to 850 ft has been significantly increased cumulative oil recovery. This increasing in cumulative oil recovery is estimated about 21396 STB. Also in this study it has been observed that by increasing the fracture half length from 850 to 1150 ft the well productivity slope has been significantly reduced. The increasing in cumulative oil recovery by increasing fracture half length from 850 to 1150 ft is estimated about 7497 STB. Therefore in this study the fracture half length of 850 ft has been considered as optimum value of fracture half length for oil well "A". Among the reasons for significant difference in cumulative oil recovery in scenarios B-1 and B-2 are increasing the well effective radius due to reducing skin factor and also increasing the permeability around the wellbore area, because the well apparent radius is directly related to the fracture half length. In scenario 2-B the fracture half length has increased about 300 ft in comparison with scenario 2-A. At higher values of fracture half length the reservoir pressure drop rapidly increases, so the well productivity slope decreases. This phenomenon has been observed in scenario 2-C where the fracture half length has increased to 1150 ft.

VI. CONCLUSION

1. In this study the hydraulic fracturing process has been modeled and optimized on the two sand pay zones at depths 8255 and 8425 ft in oil well "A" located in reservoir "Z" in southern Iran.

2. In this study by increasing the pump flow rate to 35 bbl/min the cumulative oil recovery has significantly increased in the studied well.

3. Increasing the pump flow rate above 35 bbl/min has had little impact on the cumulative oil recovery. So the pump flow rate of 35 bbl/min has selected as optimum flow rate for designing the hydraulic fracturing operation.

4. In this study by increasing the fracture half length from 550 to 850 ft the cumulative oil recovery has been significantly increased.

5. Increasing the fracture half length above 850 ft has had little impact on the cumulative oil recovery. So the fracture half length of 850 ft has selected as optimum flow rate for designing the hydraulic fracturing operation.

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