IJCPE
Iraqi Journal of Chemical and Petroleum Engineering

Iraqi Journal of Chemical and Petroleum Engineering
Vol.18 No.4 (December 2017) 25 - 33
ISSN: 1997-4884

University of Baghdad
College of Engineering

Evaluation of Acid and Hydraulic Fracturing Treatment in Halfaya Oil Field-Sadi Formation

Jalal Abdulwahid Al-Sudani and Khalid Munaf Husain
University of Baghdad - Petroleum Engineering

Abstract

Sadi formation is one of the main productive formations in some of Iraqi oil fields. This formation is characterized by its low permeability values leading to low production rates that could be obtained by the natural flow.

Thus, Sadi formation in Halfaya oil field has been selected to study the success of both of "Acid fracturing" and "Hydraulic fracturing" treatments to increase the production rate in this reservoir.

In acid fracturing, four different scenarios have been selected to verify the effect of the injected fluid acid type, concentration and their effect on the damage severity along the entire reservoir.

The reservoir damage severity has been taken as "Shallow–Medium– Severe" and (Medium–Severe-sallow) for better fluid invasion.

While, in hydraulic fracturing, a three cases have been selected using three different main fracturing fluid and three different proppant size and types, to verify their effects on fracturing efficiency, and dimensionless fracture conductivity.

The results show that both treatments have successful results, but the hydraulic fracturing gives about (1.5) times greater than acid fracturing.

However, the maximum dimensionless fracture conductivity reached by all the treatments was about (Fcd = 4) , with fracture efficiency reached to (82%).

Key words: Hydraulic Fracturing, Acidizing, Well Damage, Stimulation

Introduction

Well stimulation process is the most conventional way that could be adapted to increase well productivity; well stimulation could be performed either by “Acidizing” or through “Hydraulic Fracturing "of the productive formation.

The first term of “Acidizing” may refers to “Matrix acidizing” process if the injected acids used below the formation fracturing pressure and “Acid fracturing” process if the injected acids used above the formation fracturing pressure.

However Hydraulic fracturing refer to treatment method which aim is to increase well productivity by creating fracture conductivity in the reservoir formation.

In 1896 , a new patent by Heman Frasch (1), when he used hydrochloric acid for treatment limestone formation ,this reaction will produce two soluble Chemical compounds : calcium chloride and carbon dioxide , and after this process the acid remove from well in the same way of producing well fluids.

Harris (2) in 1961, brought the use of acetic acid to the stimulation operation. Because acetic acid is less corrosive than HCl, it was suggested that it could replace HCl in specific applications, especially at high temperatures. Later, formic acid was also found to take place in solving certain problems immanent to acidizing with HCl. While, Harris (3) in 1966, described the effects of acid concentration and the practical appearance of using high concentrations of HCl **.** Experimental studies showed that the properties of mixture containing greater than 15% HCl had considerably different properties than solutions with lower concentration of HCl.

Practical experience proved in many cases that , the different properties of higher-concentration HCl solutions were beneficial to acidizing carbonates. It was approved that deeper acid penetration could be achieved with the higher-concentration solutions. Use of mixtures such as 20%HCl and 28%HCl became common.

Hydraulic fracturing is probably the most widely used stimulation technique in the world today. Hydraulic fracturing is a well-known technology, which was originally applied to overcome near wellbore skin damage and to increase oil and gas productivity by making conductive fractures in the reservoir.

Jurairat (4), used Forcheimer equation to estimate fracture conductivity for both before and after acidizing. The cell pressure and pressure drop were recorded at each flow rate under each closure stress. By calculating fracture conductivity profile can be evaluated the effect of the acid on the fracture conductivity.

Economides and Nolte, (5), prevailed that the two common methods of Hydraulic fracturing are acid fracturing and proppant fracturing. The combined aim for the two methods is to increase well productivity by creating fracture conductivity in the reservoir formation.

For assessment which method of hydraulic fracturing stimulation is giving the best response in carbonate formation, it can be obtained by making a comparison between Applying acid fracturing and proppant fracturing and evaluate the results.

They are indicated that the hydraulic fracturing has been expanded to such applications as reservoir stimulation for increased hydrocarbon deliverability, increased drainage area, and decreased pressure drop around the well to minimize problems with asphaltene5 and/or paraffin deposition.

Rajappa et al. (6), prevailed that Propped hydraulic fracturing provided higher estimated optimal recovery and higher production rates, but it is more expensive than acid fracturing jobs.

Experimental Work

In this study, two major techniques have been employed to increase well production rates in Halfaya field/Sadi reservoir. These techniques are:

1- Acid fracturing treatment.
2- Hydraulic fracturing treatment.

Advance computer software "Stim and Frac" have been used to design, analyze and forecast the production capacity that may be obtained throughout utilizing these techniques.

1- Acid fracturing treatment

As well as the formation temperature (155 °F) is suitable for this job trail. However, the activity of this process is high affected by acid concentration and the divergent type and the severity of formation damage.

Therefore, several cases have been created for several of formation damage severity and also for different acid concentrations to verify its efficiency in increasing reservoir production capacity.These cases can be listed as follows;

Case-1; Well completion: Open hole, Damage only, main treatment acid: 15% HCl, skin type: shallow to medium damage, treatment stages: 3 stages preflush, input data: foam injection: shallow-med-deep.

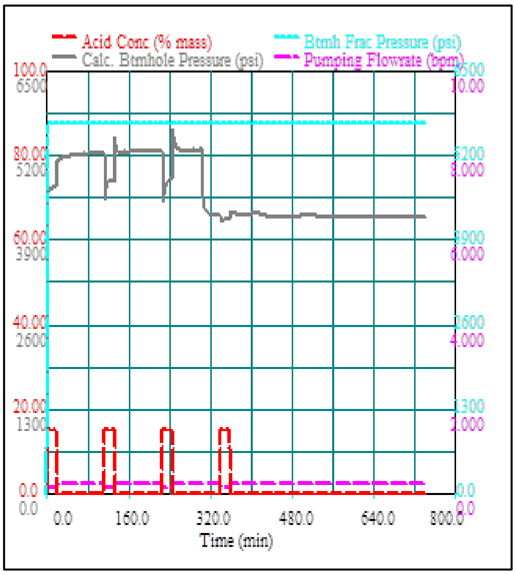

Fig. 1, real-time operation for acid fracturing, case 1

Case-2; Well completion: Open hole with deep wellbore damage only, main treatment acid: 15% HCl, skin type: shallow to medium damage, treatment stages: 3 stage preflush, input data: foam injection: Shallow-med-deep, 3 stage preflush.

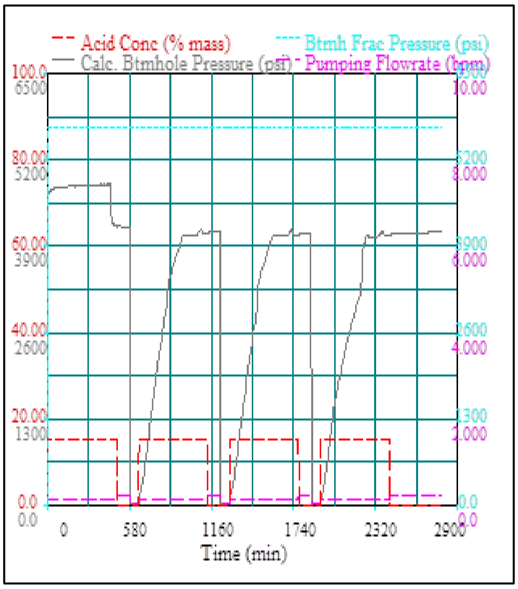

Fig. 2, real-time operation for acid fracturing, case 2

Case-3;Well completion: Open hole with deep wellbore damage only, main treatment acid: 15% HCl, skin type: shallow to medium damage, treatment stages: 3 stages preflush, input data: no foam, 3 stage preflush shallow-med-deep.

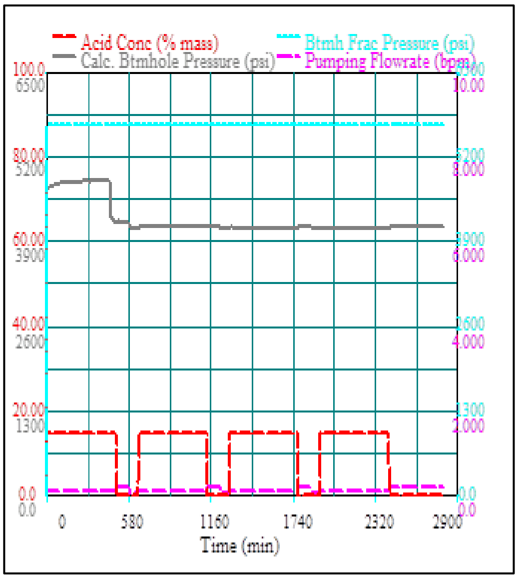

Fig. 3, real-time operation for acid fracturing, case 3

Case-4;Well completion: Open hole with both of deep wellbore damage only and Asphaltene accumulation, main treatment acid: 20% HCl, skin type: shallow to medium damage, treatment stages: 3 stages preflush, input data: 3 stage preflush med-deep.

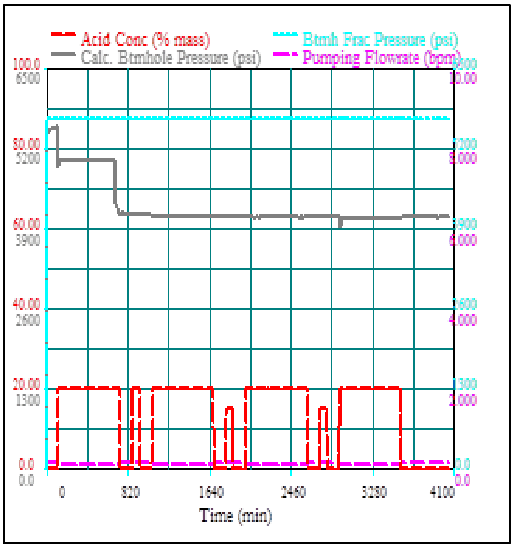

Fig. 4, real-time operation for acid fracturing, case 4

Table 1, comparison in operational results between the four cases after acid fracturing

Items	Case 1	Case 2	Case 3	Case 4
Initial skin	8.73	8.73	8.73	17.45
Final skin	-4.33	-6.06	-6.53	-6.84
Max. surface pressure. psi	1248	944	944	1725
Max. acid fracturing time. min.	741	2801	2801	4061
No. of preflash	3	3	3	3
Invasion inch	240	280	400	485

1.1- <u>Production comparison between the four cases:</u>

Table 2, comparison the cumulative oil production between the four cases

Time	Case 1	Case 2	Case 3	Case 4
days	Mbbls	Mbbls	Mbbls	Mbbls
365	101.81	101.62	101.75	102.28
730	264.29	262.66	263.20	267.48
1095	414.05	542.06	410.81	564.78

2- Hydraulic Fracturing

Using pumping rate of 30 gal/min. to reach dimensions fracture conductivity of (F_{CD} = 4.0), three cases have been generated for different fracturing fluids and proppant size and type, these cases can be summarized as follows.

<u>Case-1</u>

In this case the flowing materials has been used HMP10Cp2k as Slurry fluid. While, the Proppant type was Arizona sand 12/200 mesh. The FcD Goal was 4.0.

Fig. (5), shows that the fracture length is increasing with progress of hydraulic fracturing process. And the maximum value reached to about 220 ft after 40.5 minutes of treatment.

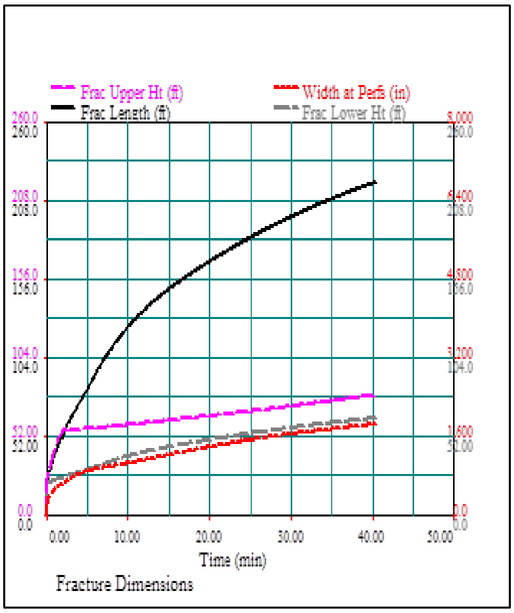

Fig. 5, fracture dimensions

Case-2

In this case the flowing materials has been used N2 GW27 40 75 as Slurry fluid. While, the Proppant type was Arizona sand 16/30 mesh. The FcD Goal was 4.0.

Fig. (6), shows that the fracture length is increasing with progress of hydraulic fracturing process, and the maximum value reached to about 228 ft after 20 minutes of treatment.

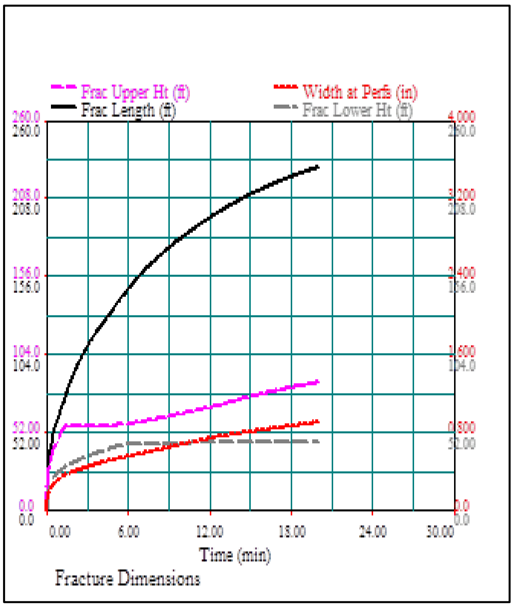

Fig. 6, fracture dimensions

Case-3

In this case the flowing materials has been used "Spec 2500 1 "as Slurry fluid. While, Proppant type was Arizona sand 16/30. The FcD Goal was 4.0.

Fig. (7), shows that the fracture length is increasing with progress of hydraulic fracturing process, and the maximum value reached to about 223.5 ft after 21.5 minutes of treatment.

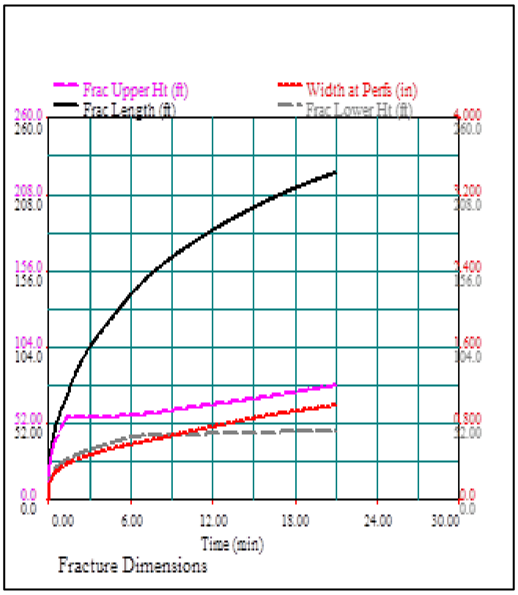

Fig. 7, fracture dimensions

Hence, Fig. (8) Shows the dimensions of the fracture and the proppant concentration in 3D view, which can be performed by any of the three cases mentioned above.

2.1 Comparison of fracture efficiency between the three cases :

Table 3, comparison between the three cases in slurry efficiency and proppant average concentration

Case	1	2	3
Fracture Slurry Efficiency	82 %	78 %	75 %
Avg. Proppant Concentration (lb/ft^2)	4.74	2.14	2.39

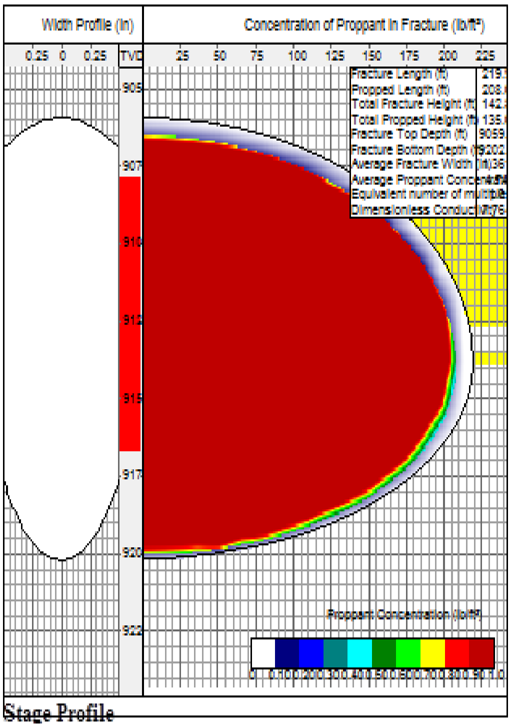

Fig. 8, fracture width and proppant concentration

Table 4, production forecast of hydraulic fracturing

Time days	Cumulative Oil Production Mbbls	Oil Rate bbl/day	Cal. BHP Psi
0	0	0	4111
10	18.91	1595	1927
20	33.96	1418	1780
30	47.87	1317	1650
51	74.58	1213	1430
91	120.5	1088	1140
120	150.7	970.7	1004
182	207.4	872.3	839.5
228	245.1	799.8	746.7
273	280.3	741	671.9
365	345.1	645.9	541
547	451.3	538	500
730	541.5	455.8	500
1000	654.2	379.2	500

Table 5, comparing cumulative production between acid fracturing and hydraulic fracturing treatments

Time (days)	Cumulative oil production after Acid fracturing Mbbls	Cumulative oil production after hydraulic fracturing Mbbls
120	28.662	150.7
365	102.288	451.3
730	267.489	541.5
1000	421.823	654.2

Table (5.3),we selected case 4 from acid fracturing treatment to compare with hydraulic fracturing in cumulative oil Production after, 120 , 360 ,730 and 1000 days , It can easily be noted that the different is very clear that The preference tend to favor hydraulic fracturing.

This evidence prove that hydraulic fracturing treatments gives best results than acid fracturing, for Sadi reservoir in Halfaya oil field.

Results and Discussion

In this section, a detailed discussion for efficiency and production rate resulted from the treatments of acid fracturing and hydraulic fracturing, as follows.

1- Acid fracturing

*Case 1;*Fig.(1) shows the events of the stages of acid fracturing process, it can be noted that the bottom hole pressure reaches near the fracturing formation pressure to allow open the effective wormholes, and to achieve the active stimulation process.

However, table (1) shows that the skin improvement achieved from (S= 8.73) before the fracturing and reached to (S = - 4.33) after fracturing treatment , which is obtained by maximum surface pressure of (1248 psi) .in addition it can be seen that the maximum calculated bottom hole pressure value which approached to the fracture pressure is 5650 psi. While, the pumping rate remained constant at 30 bpm during treatment operation.

The viscoelastic divergent fluid used in this treatment allows better spending along the stimulated interval.

In this case the hydrocarbon production during the first year, increased from 211 bbl/day to 320 bbl /day. This is about 50% more than the initial production rate. After two years, the production rate rises to reach 100% than the initial production rate. This increment attributed to the affect of removing almost fines deposited by the spent acid, while acidizing process, Table (2) shows the hydrocarbon cumulative production for three years.

*Case 2;*Fig.(2) shows the events of the stages of acid fracturing process, it can be noted that the bottom hole pressure reaches near the fracturing formation pressure to allow open the effective wormholes, and to achieve the active stimulation process. However, table (1) shows that the skin improvement achieved from (S = 8.73) before the fracturing and reached to (S = -6.06) after fracturing treatment , which is obtained by maximum surface pressure of (944 psi). in addition it can be seen that the maximum calculated bottom hole pressure value which approached to the fracture pressure is 4875 psi. While, the pumping rate remained constant at 30 bpm during treatment operation.

The viscoelastic divergent fluid used in this treatment allows better spending along the stimulated interval.

The hydrocarbon production during the first year, increased from 210 bbl/day to 319 bbl /day. This is about 50% more than the initial production rate.

After two years, the production rate rises to reach 100% than the initial production rate. This increment attributed to the affect of removing almost fines deposited by the spent acid, while acidizing process, Table (2) shows the hydrocarbon cumulative production for three years.

Case 3; Fig.(3) shows the events of the stages of acid fracturing process, it can be noted that the bottom hole pressure reaches near the fracturing formation pressure to allow open the effective wormholes, and to achieve the active stimulation process. However, table (1) shows that the skin improvement achieved from (S = 8.73) before the fracturing and reached to (S = -6.53) after fracturing treatment, which is obtained by maximum surface pressure of (944 psi). In addition it can be seen that the maximum calculated bottom hole pressure value which approached to the fracture pressure is 4850 psi, while pumping rate remained constant at 30 bpm during treatment operation. The viscoelastic divergent fluid used in this treatment allows better spending along the stimulated interval.

The hydrocarbon production during the first year, increased from 210 bbl/day to 320 bbl/day. This is about 50% more than the initial production rate. After two years, the production rate rises to reach 100% than the initial production rate. This increment attributed to the affect of removing almost fines deposited by the spent acid, while acidizing process, Table (2) shows the hydrocarbon cumulative production for three years.

Case 4; Fig.(4) shows the events of the stages of acid fracturing process, it can be noted that the bottom hole pressure reaches near the fracturing formation pressure to allow open the effective wormholes, and to achieve the active stimulation process.

However, table (1) shows that the skin improvement achieved from (S =

17.45) before the fracturing and reached to (S = - 6.84) after fracturing treatment, which is obtained by maximum surface pressure of (1725 psi) . in addition it can be seen that the maximum calculated bottom hole pressure value which approached to the fracture pressure is (5525 psi). While, the pumping rate remained constant at 30 bpm during treatment operation. The viscoelastic divergent fluid used in this treatment allows better spending along the stimulated interval.

The hydrocarbon production during the first year, increased from 213 bbl/day to 322 bbl/day. This is about 50% more than the initial production rate. After two years, the production rate rises to reach 100% than the initial product ion rate. This increment attributed to the affect of removing almost fines deposited by the spent acid, while acidizing process, Table (2) shows the hydrocarbon cumulative production for three years.

Examining table (2) it can be noted that the results of the four cases, convergent and it can be considered the highest one, which is the case No. 4. The results of case four will be taken to be compared with hydraulic fracture treatment results.

2- Hydraulic fracturing

Table (3), through observation of the Fracture Slurry Efficiency values for the three cases, it's very clear that they are convergent and there is no much difference. It seems that a doubling of the proppant concentration made little impact in increasing efficiency, as in case 1 in which the proppant concentration almost double of case 2 and case 3.

After hydraulic fracturing treatment completed the production forecast table (4) show that, the average production rates were 150 % of the initial production rate after one year of production. And the average reservoir pressure remained over 2000 psi. While the cumulative hydrocarbon production after 1000 days reached 654.2 Mbbls.

Meanwhile, table (5) shows clear comparison for the cumulative production between acid fracturing treatment and hydraulic fracturing treatment. The hydraulic fracturing gave about five times greater than acid fracturing during the first one year, and more than two times greater for a period of two years of production and reached to one half times greater for a period of three years.

Conclusions

The study shows the comparable success of hydraulic fracturing treatment in low permeability reservoir than fracturing acidizing. However, it also shows that the fracturing acidizing can be used effectively when divergent acid agent may used to provide a good acid dispersion.

Therefore, these two application needs to be one of a successful jobs that can be adapted in all Iraqi fields, that are producing from Sadi formation.

Acknowledgment

The authors would like to thanks the software manufacturing company for their assistance in providing a limited license file to perform this study.

Nomenclature

F_{CD}: Dimensionless fracture conductivity

S: Skin factor (Dimensionless)

References

1- Frasch,H., “Increasing the flow of oil well,” U.S. Patent No. 556,669 March 17, 1896
2- Harris,O.E.,A.R.:"Application of Acetic Acid to Well Completion Stimulation and Reconditioning." Journal of Petroleum Technology.637, (1961).
3- Harris, O. E., A. R. Hendrickson, and A. W. Coulter:" High Concentration Acid Aids Stimulation Results in Carbonate Formations" Journal of Petroleum Technology. (October 1966).
4- Jurairat Densirimongkol., "The Role of Acidizing in Proppant Fracturing IN Carbonate Reservoirs", M.SC. Texas A&M University (August 2009).
5- Economides, M.J. and Nolte, K.G.: Reservoir Stimulation, Third Edition, 750 p. (hardbound) Wiley, NY and Chichester, (March 2000).
6- Rajappa, et al. “Propped Fracture Treatments in Lower Green River Formation of the Altamont-bluebell field” Utah. SPE-123526. SPE Rocky Petroleum Technology Conference, Denver-Colorado (April, 14-2009)