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Selection of the best acid formulation for acidizing dolomite formation in Gialo-59 oil field

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Abstract-- Acidizing is a process of restoring the original permeability around the wellbore which was reduced by the damaging effect resulting from either drilling or production mechanism. The acid treatment is dependent on the extent and magnitude of the damage near the wellbore. The treatment process consists of specifying the required acid volume, the acid concentration, the acid injection rate, and the acid injection pressure. In this study, the screening process was aided to determine the most suitable acid injection parameters needed for the optimization of performance in restoring the well original permeability, this study was approached by selecting two producing oil wells that experienced formation damage. The screening was done by comparing the oil production rate from these wells before and after the acid treatment. The outcome of this investigation demonstrates that the skin factor has a limiting value that regulates the pace of acid injection and that the volume of acid injection is inversely related to the acid concentration. 15% was found to be the ideal acid concentration for the dolomite acid treatment. It was discovered that limiting the value of 20 skin factors was the maximum value for maximum acid performance because this value makes the acid injection rate very as a result, in high acid injection time, which causes the acid to spend more time near the wellbore and less time covering the entire damage area.

Keywords: Stimulation, Acidizing treatment, Well damage.

I. Introduction

Matrix stimulation is a technique that has been used extensively since the 1930s to improve production from oil and gas wells and to improve injection into injection wells. [1] When a well is not producing as expected, the formation may be "damaged”. If the evaluation indicates of reservoir can deliver more fluid, stimulation may be needed. If the reservoir permeability is low, the well is a candidate for stimulation by hydraulic fracturing.[2] However, if the damage has reduced the well's productivity matrix acidizing is the appropriate treatment. Typically, damage is associated with a partial plugging of the formation around the wellbore. [3] This reduces the original permeability in the damaged area. Either this damage must be removed or new bypassing channels, such as "wormholes" must be created. To remove damage, fluids are injected into the natural porosity of the reservoir at " matrix"/sub fracturing/ rates and pressures. This relatively low rates and pressures are necessary to remove the damage located just around the well bore. The flow rate is also limited to prevent fracturing of the formation, which would result in uncontrollable stimulation of only part of the reservoir. When using acid for removal of suspected damage, scale, clays, or some formation rock may be dissolved from the existing flow channels. Only small increases in productivity will result unless damage exists [4].

II. Overview of Gialo oil field

Gialo oil field is located in the western part of the sirte basin in north central at Libya as shown in figure 1. Geographically it’s located between Latitude / longitude: 29° 1’ 60 ″N / 21° 33’ 0 ’ЕN. [5]

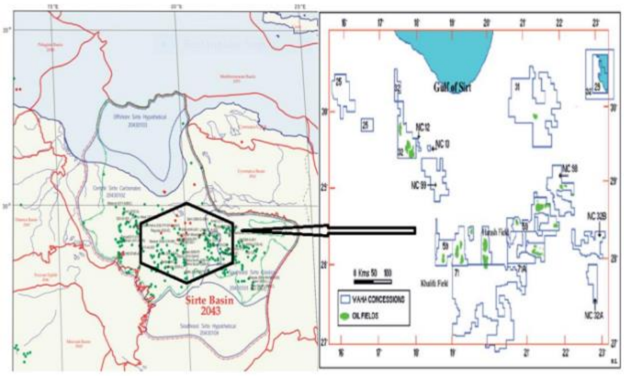

Figure 1: Gialo oil field [5]

Reservoir description and properties

The jakhira reservoir lies at depth of about 3200 ft. K.B. in the Gialo field. Production from it was initiated in august 1972. The Jakhira limestone is composed of bio-calcarenite, nummulitic and calcilutite material with good integer Vanular and excellent vuggy and chalky porosity. It shows a uniform, light brown oil stain. The structure is defined on its north flank by a major fault. The mean objective of this study is to find out the beast acid treatment for the Oil wells in Waha Field if their damaged by scales the scenario of acid treatment done by varying of acid parameters such acid type, acid formulation acid injection rate and acid injection pressure with change in the value of skin factor. [5]

Matrix acidizing of carbonate

The (H+) ion of a dissociated acid is the active species that attacks a carbonate mineral. An acid reacts with a carbonate to form calcium or magnesium chloride ($CaCl_2$) or ($MgCl_2$), carbon dioxide gas (CO_2), and water. The reaction products are soluble and pose no reprecipitation problems.[5]. For example, when HCl acid reacts with calcite or dolomite, the balanced reactions are:

$$CaCO_3 + 2HCl \rightarrow CaCl_2 + H_2O + CO_2$$

$$CaMg(CO_3)_2 + 4HCl \rightarrow CaCl_2 + MgCl_2 + 2H_2O + 2CO_2$$

Except for special applications, HCl acid should be used for matrix acidizing of carbonates. Normally, 15% HCl is used but 28% is sometimes preferred in lower permeability formations. A 28% HCl may also provide some benefit in that the spent acid contains a higher concentration of $CaCl_2$ or $CaCl_2/MgCl_2$. The increase in concentration results in a higher viscosity, which partially reduces fluid leak-off from the wormhole. The primary advantages of HCl acid are its moderate cost and complete spending at reservoir conditions. The principal disadvantage of HCl acid is its corrosivity. HCl is more corrosive than other acids and generates a pitting type of corrosion. In addition, corrosion inhibition of HCl acid above 250°F is difficult. Also, aluminum, chrome, or zinc plated metals (often found on pumps) are severely attacked by HCl acid. [5]

III. Methodology and Analysis of Results

In This study we analysis two wells (E-74,E-349,) in Gialo Field. The our analysis done by using sensitivity analysis by varying the acid concentration to the get the best acid treatment for those wells which lead to generate the data base which reduce any additional cost when we want to do acid stimulation design in future for these wells.

Design procedure of acid treatment

Acid volume

The Minimum volume of acid required to dissolve the rock Vs calculated using Equation 1 the calculation done be assume different penetration radius and different acid concentrations.

$$V_s = \pi(r_s^2 - r_w^2)\left(\text{Ø}_{total} + (1 - \text{Ø}_{eff})\left(\frac{X_{mineral}}{X_{acid}}\right)\right) \quad \ldots \text{Eq.1}$$

Where

rs: radius of damaged zone, ft. rw: well, bore radius, ft. Øtotal: Total porosity. Øeff: effective porosity. Xmineral: the volume fraction of the rock that is soluble in acid. Xacid: dissolving power of HCl or HF acid with carbonate or sandstone. Vs : Minimum volume of acid required to dissolve the rock. gal/ft

Acid injection rate

The maximum acid injection rate which we used to inject the acid without fracture the formation was calculated using the Equation2: The maximum acid injection rate calculated for sever times by assume different values of skin factor

$$Q_{inj} = \frac{4.917 \times 10^{-6} \times K \times h(P_{frac} - P_{safty} - P_{hyd})}{\beta_{acid} \times \mu_{acid} \times \ln\left(\frac{r_s}{r_w} + s\right)} \quad \ldots \text{Eq.2}$$

Where K: average formation permeability, md. h: perforated interval, ft. Pfrac: fraction pressure, psi. Phyd: hydrostatic pressure, psi. Psafty:safty pressure =100psi. µ: acid viscosity's. s: skin factor. Qinj: acid injection flow rate, bbl/min.

Acid injection pressure

The maximum pressure to inject the acid can be calculated by using the Equation 3.

$$P_{max} = \Delta P_{fric} + P_{frac} - P_{hyd} + \Delta P_{per} \quad \ldots \text{Eq.3}$$

Where Pmax : Maximum injection pressure, psi ΔPfric : Pressure difference due to friction, psi Pfrac: Fracture pressure, psi Phyd: Hydrostatic pressure, psi $\Delta Pper$: Pressure difference due to perforation, psi Pressure drop due frication can be calculate using Equation 4 and Equation 5 used to calculate the velocity of acid inside the tubing.

$$\Delta P_{fric} = \frac{\mu \times ve}{1500 d^2} \quad \ldots \text{Eq.4}$$

$$Ve = \frac{QINJ}{2.448 d^2} \quad \ldots \text{Eq.5}$$

Fracture pressure can be calculated using total depth and fracture gradient pressure by using Equation 6.

$$P_{frac} = 0.78 \times D \quad \ldots \text{Eq.6}$$

Hydrostatic pressure can be calculated using total depth of well and specific gravity of the acid by using Equation 7&8.

$$P_{hyd} = \frac{\gamma \times 62.4 \times D}{144} \quad \ldots \text{Eq.7}$$

$$\Delta P_{per} = \frac{0.237 \times \rho_{tot} \times q_{inj}}{cp \times N \times d^2} \quad \ldots \text{Eq.8}$$

Where µ: acid viscosity,cp. Ve: acid velocity,ft/sec d: perforation diameter, inch D: formation depth,ft. N:total number of shot CP : perforation coefficient. The value of (ΔP perforation) were assumed to be zero where it's value didn't exceed 20 psi for all wells)

Pump pressure to inject finally, the required pump pressure was calculated at different bottom hole pressures using the following Equation9.

$$P_{PUMP} = \Delta P_{perf} + \Delta P_{fric} - P_{hyd} + P_{bottom} \quad \ldots \text{Eq.9}$$

Where: Pump injection pressure, psi Pbottom : Bottom pressure, psi Phyd : Hydrostatic pressure, psi ΔPperf : Pressure difference due to perforation.

Well by well Analysis

Well (E-74)

Table 1: Volume of acid needed at different concentrations for well E-74

rs, ft	Vs (gal/ft) for 7% acid	Vs (gal/ft) for 12% acid	Vs (gal/ft) for 15% acid	Vs (gal/ft) for 22% acid	Vs (gal/ft) for 28% acid
1	44.349368	27.369329	22.61491982	16.5638536	13.78530278
1.5	119.27392	73.60755208	60.82096088	44.54711755	37.07443438
2	224.1683	138.3410644	114.3094184	83.72368708	69.67921863
2.5	359.03262	221.5698659	183.0802923	134.0935622	111.5996555
3	523.86672	323.2939567	267.1335826	195.6567429	162.835745
3.5	718.6	443.5133	366.4692	268.41322	223.387
4	943.4444	582.2280059	481.0874125	352.363021	293.254882
4.5	1198.188008	739.4379644	610.9879521	447.5061184	372.4379295
5	1482.90	915.143212	756.1709082	553.8425214	460.9366296

Table 2: Injected acid flow rate at different skin values for well E-74

rs	Qinj (bbl/min) s=0	Qinj (bbl/min) s=5	Qinj (bbl/min) s=10	Qinj (bbl/min) s=20	Qinj (bbl/min) s=30	Qinj (bbl/min) s=40	Qinj (bbl/min) s=50
1	5.0200	0.991754	0.550229	0.291066	0.197868	0.149878	0.120623
1.5	3.77621	0.931161	0.531056	0.285611	0.195332	0.148418	0.119676
2	3.21163	0.892474	0.518244	0.281864	0.193572	0.1474	0.119012
2.5	2.87788	0.86461	0.508724	0.279024	0.192228	0.14662	0.118503
3	2.65265	0.843103	0.501201	0.276746	0.191144	0.145988	0.11809
3.5	2.48801	0.825737	0.495013	0.274848	0.190237	0.145458	0.117743
4	2.36108	0.811262	0.489774	0.273225	0.189458	0.145003	0.117445
4.5	2.2594	0.798909	0.485244	0.27181	0.188777	0.144603	0.117182
5	2.17559	0.788173	0.481262	0.270556	0.188171	0.144247	0.116949

Table 3: Velocity of acid at different skin values for well E-74.

Ve (ft/sec) s=0	Ve (ft/sec) s=5	Ve (ft/sec) s=10	Ve (ft/sec) s=20	Ve (ft/sec) s=30	Ve (ft/sec) s=40	Ve (ft/sec) s=50
6.012686	1.187865	0.659032	0.348622	0.236995	0.179515	0.144475
4.522931	1.11529	0.636068	0.342088	0.233957	0.177767	0.14334
3.846701	1.068953	0.620722	0.3376	0.231849	0.176547	0.142546
3.446958	1.035579	0.60932	0.334198	0.23024	0.175612	0.141936
3.17719	1.009819	0.60031	0.331469	0.228941	0.174856	0.141442
2.980003	0.989019	0.592897	0.329197	0.227855	0.174221	0.141026
2.827967	0.971682	0.586622	0.327253	0.226922	0.173676	0.140668
2.706184	0.956886	0.581197	0.325558	0.226106	0.173197	0.140354
2.605803	0.944027	0.576428	0.324056	0.22538	0.172771	0.140074

Table 4: Pressure drop due to fraction Dpf different skin values for well E-74.

ΔP_{fric} (Psia) s=0	ΔP_{fric} (Psia) s=5	ΔP_{fric} (Psia) s=10	ΔP_{fric} (Psia) s=20	ΔP_{fric} (Psia) s=30	ΔP_{fric} (Psia) s=40	ΔP_{fric} (Psia) s=50
78.87643	15.58281	8.645396	4.573334	3.108977	2.354938	1.895268
59.33332	14.63075	8.344153	4.48763	3.069131	2.332005	1.880385
50.46232	14.02288	8.142842	4.428745	3.041474	2.316003	1.869967
45.21834	13.58507	7.993259	4.384123	3.020362	2.303741	1.861965
41.67944	13.24715	7.875061	4.348327	3.003329	2.293819	1.855478
39.09268	12.97428	7.777819	4.318514	2.989077	2.285496	1.850028
37.09821	12.74684	7.695505	4.293018	2.97684	2.278335	1.845333
35.50062	12.55275	7.624331	4.270777	2.966129	2.272055	1.841212
34.18379	12.38406	7.561771	4.251077	2.956613	2.266467	1.837541

Table 5: Fraction and hydraulic pressures for well E-74.

P_{frac} (Psia)	P_{hyd} (Psia)
4802.46	2998.869

Table 6: Maximum pressure of injected acid at different skin values for well E-74.

P_{max} (Psia) s=0	P_{max} (Psia) s=5	P_{max} (Psia) s=10	P_{max} (Psia) s=20	P_{max} (Psia) s=30	P_{max} (Psia) s=40	P_{max} (Psia) s=50
1882.467	1819.173	1812.2359	1808.1639	1806.6995	1805.9455	1805.4858
1862.924	1818.221	1811.9347	1808.0782	1806.6597	1805.9225	1805.47092
1854.053	1817.613	1811.7334	1808.0193	1806.632	1805.9065	1805.4605
1848.809	1817.176	1811.5838	1807.9747	1806.6109	1805.8943	1805.4525
1845.27	1816.838	1811.4656	1807.9389	1806.5939	1805.8844	1805.44601
1842.683	1816.565	1811.3684	1807.909	1806.5796	1805.876	1805.44056
1840.689	1816.337	1811.286	1807.8836	1806.5674	1805.8689	1805.43587
1839.091	1816.143	1811.2149	1807.8613	1806.5567	1805.8626	1805.43175
1837.774	1815.975	1811.1523	1807.8416	1806.5471	1805.857	1805.42807

The procedure of sensitivity analysis

We calculate the minimum acid volume required to cover the damage zone by using equation.1 the sensitivity done by varying the acid concentration which reflects in change dissolving power value.

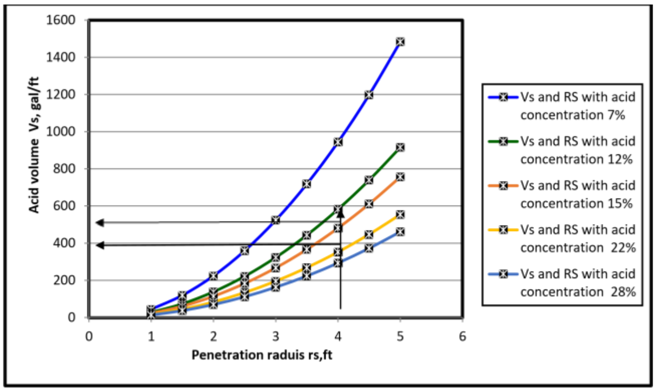

Figure 2: Acid volume vs penetration radius of acid with different acid concentration.

The volume of acid needed to penetrate the damage zone to 4 ft for acid concentration 15 % is equal 420 gal/ft while at same damage radius if we select acid concentration 22% is equal to 370 gal/ft the volume of acid is less but the cost of acid increase with concentration .

The second step in sensitivity analysis we calculate the acid injection rate by varying the skin factor value for different values 0, 5, 10,20,30,40 and 50 and we assume the damage zone is radius 5 ft.

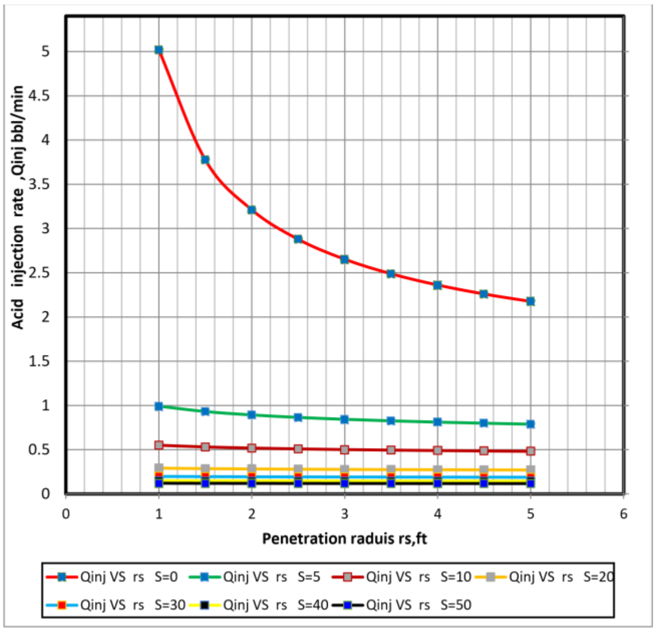

Figure 3: Acid injection rate vs penetration radius of acid with different acid concentration.

The result from sensitivity analysis shown the acid injection rate has Exponential curve for skin factor equal to 10 but for the skin factor equal to 5 and 10 there are inversely relation between acid injection rate and penetration radius ,the acid injection rate almost constant from skin value equal to 20 up to 50 for all penetration radius.

The third step in sensitivity analysis we calculate the acid injection pressure by varying the skin factor value for different values 0, 5, 10,20,30,40 and 50 and we assume the damage zone is radius 5 ft. The result from sensitivity analysis shown the acid injection pressure has Exponential curve for skin factor equal to 10 but for the skin factor equal to 5 and 10 there are inversely relation between acid injection pressure and penetration radius, the acid injection pressure almost constant from skin value equal to 20 up to 50 for all penetration radius.

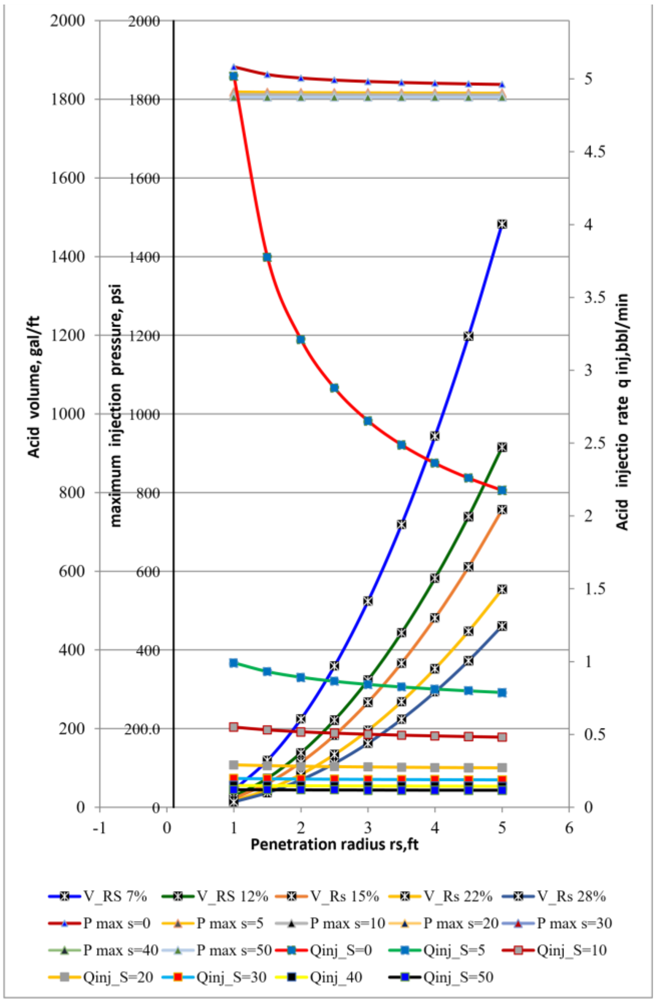

Figure 4: Volume and flow rate of acid at different skin values vs skin radius for well E74.

Table 7: Bottom hole pressure and required acid pump pressure for well E-74.

P_{bottom} Psia	P_{PUMP} Psia
1250	-1669.993
1800	-1139.536
2300	-648.4072
2700	-253.6511
3000	42.809973
3500	540.22321
4000	1038.2287
4500	1536.6312
4802.46	1837.7743

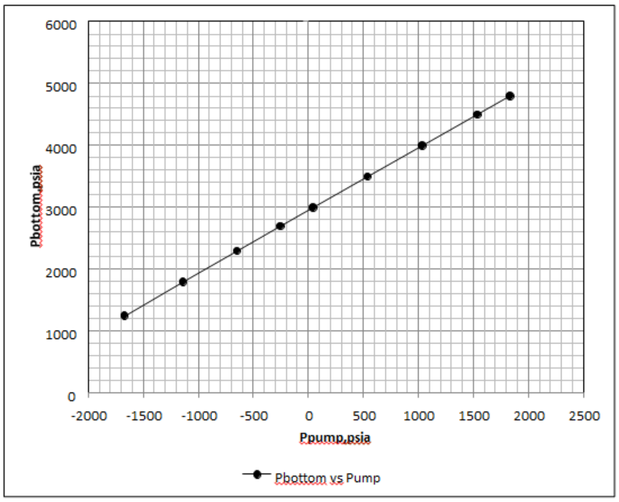

Figure 5: Bottom hole pressure vs acid pump pressure for well E-74.

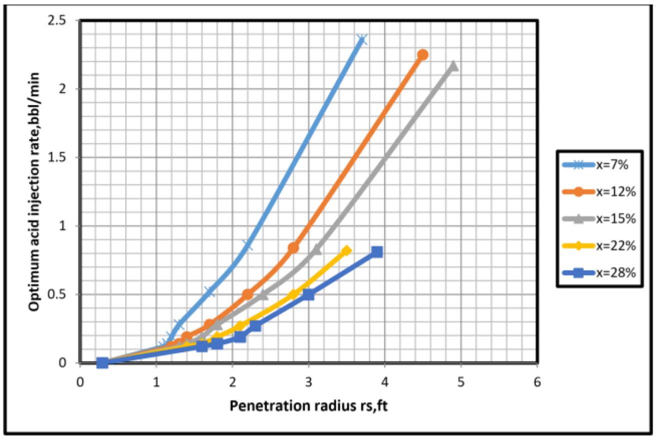

Figure 6: The optimum injection rate vs optimum acid penetration radius at different dissolving power for well E-74.

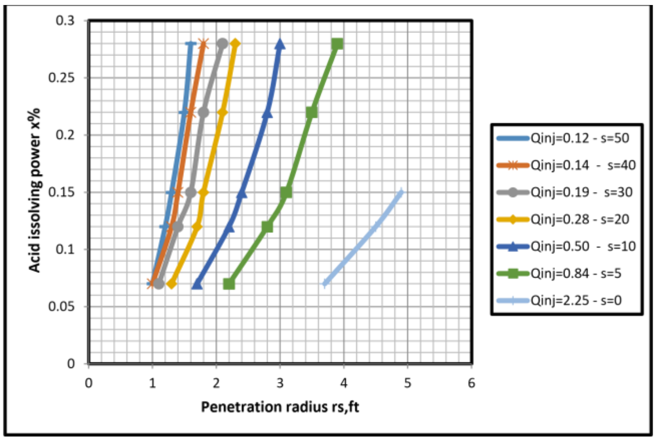

Figure 7: the optimum dissolving power vs optimum penetration radius at optimum injection for different skin factor for well E-74.

Well E-349

Table 8: Volume of acid needed at different concentrations for well E-349.

rs, ft	Vs (gal/ft) for 7% acid	VS (gal/ft) for 12% acid	Vs (gal/ft) for 15% acid	Vs (gal/ft) for 22% acid	Vs (gal/ft) for 28% acid
1	55.4302354	34.2142054	28.27371699	20.71309538	17.24138137
1.5	131.176455	80.9684129	66.91016099	49.01784038	40.80197887
2	237.221163	146.4243034	121.0011826	88.64448338	73.78681537
2.5	373.564359	230.5818769	190.5467818	139.5930244	116.1958909
3	540.206043	333.4411334	275.5469586	201.8634634	168.0292054
3.5	737.146215	455.0020729	376.001713	275.4558004	229.2867589
4	964.384875	595.2646954	491.911045	360.3700354	299.9685514
4.5	1221.92202	754.2290009	623.2749546	456.6061684	380.0745829
5	1509.75766	931.8949894	770.0934418	564.1641994	469.6048534

Table 9: Injected acid flow rate at different skin values for well E-349.

rs, ft	Qinj (bbl/min) s=0	Qinj (bbl/min) s=5	Qinj (bbl/min) s=10	Qinj (bbl/min) s=20	Qinj (bbl/min) s=30	Qinj (bbl/min) s=40	Qinj (bbl/min) s=50
1	32.04112	6.330068	3.511945	1.857786	1.262933	0.956626	0.769898
1.5	24.10233	5.943323	3.389574	1.822972	1.246747	0.947311	0.763853
2	20.49876	5.696392	3.307797	1.799051	1.235512	0.94081	0.759621
2.5	18.36856	5.518547	3.247033	1.780925	1.226936	0.935829	0.75637
3	16.93099	5.381275	3.199019	1.766384	1.220017	0.931798	0.753735
3.5	15.8802	5.270431	3.159517	1.754273	1.214227	0.928417	0.751521
4	15.07001	5.17804	3.126079	1.743916	1.209256	0.925508	0.749614
4.5	14.42103	5.099194	3.097167	1.734881	1.204905	0.922958	0.74794
5	13.88611	5.03067	3.071753	1.726879	1.201039	0.920688	0.746448

Table 10: Velocity of acid at different skin values for well E-349.

Ve (ft/sec) s=0	Ve (ft/sec) s=5	Ve (ft/sec) s=10	Ve (ft/sec) s=20	Ve (ft/sec) s=30	Ve (ft/sec) s=40	Ve (ft/sec) s=50
38.37696	7.581782	4.206401	2.225147	1.512667	1.145791	0.922139
28.86835	7.118561	4.059832	2.183448	1.49328	1.134633	0.914898
24.55221	6.822802	3.961884	2.154797	1.479823	1.126847	0.909829
22.00078	6.609789	3.889105	2.133087	1.469551	1.120881	0.905936
20.27894	6.445373	3.831596	2.11567	1.461264	1.116053	0.902779
19.02036	6.312611	3.784283	2.101165	1.454329	1.112003	0.900128
18.04996	6.201951	3.744233	2.08876	1.448376	1.108519	0.897843
17.27266	6.107513	3.709604	2.077938	1.443164	1.105464	0.895838
16.63197	6.02544	3.679165	2.068353	1.438534	1.102745	0.894052

Table 11: Pressure drop due to fraction Dpf different skin values for well E-349.

ΔP_{fric} (Psia) s=0	ΔP_{fric} (Psia) S=5	ΔP_{fric} (Psia) S=10	ΔP_{fric} (Psia) S=20	ΔP_{fric} (Psia) S=30	ΔP_{fric} (Psia) s=40	ΔP_{fric} (Psia) s=50
501.3976	99.0565	54.95691	29.07169	19.76309	14.96983	12.04781
377.167	93.00449	53.04198	28.52689	19.5098	14.82405	11.9532
320.7762	89.14037	51.76229	28.15257	19.33399	14.72233	11.88698
287.4416	86.35735	50.81142	27.86892	19.19979	14.64439	11.83611
264.9457	84.20924	50.06006	27.64137	19.09151	14.58131	11.79487
248.5023	82.4747	49.44191	27.45186	19.00091	14.5284	11.76023
235.824	81.02891	48.91866	27.28979	18.92313	14.48288	11.73039
225.6685	79.79507	48.46622	27.14841	18.85504	14.44296	11.70419
217.2978	78.72278	48.06854	27.02317	18.79455	14.40744	11.68085

Table 12: fraction and hydraulic pressures for well E-349.

P_{frac} (Psia)	P_{hyd} (Psia)
4782.96	2986.693

Table 13: Mmaximum pressure of injected acid at different skin values for well E-349.

P_{max} (Psia) s=0	P_{max} (Psia) s=5	P_{max} (Psia) s=10	P_{max} (Psia) s=20	P_{max} (Psia) s=30	P_{max} (Psia) s=40	P_{max} (Psia) s=50
2297.665	1895.324	1851.2241	1825.3389	1816.0303	1811.237	1808.315
2173.434	1889.272	1849.3092	1824.7941	1815.777	1811.0913	1808.22
2117.043	1885.408	1848.0295	1824.4198	1815.6012	1810.9895	1808.154
2083.709	1882.625	1847.0786	1824.1361	1815.467	1810.9116	1808.103
2061.213	1880.476	1846.3273	1823.9086	1815.3587	1810.8485	1808.062
2044.77	1878.742	1845.7091	1823.7191	1815.2681	1810.7956	1808.027
2032.091	1877.296	1845.1859	1823.557	1815.1903	1810.7501	1807.998
2021.936	1876.062	1844.7334	1823.4156	1815.1222	1810.7102	1807.971
2013.565	1874.99	1844.3357	1823.2904	1815.0617	1810.6746	1807.948

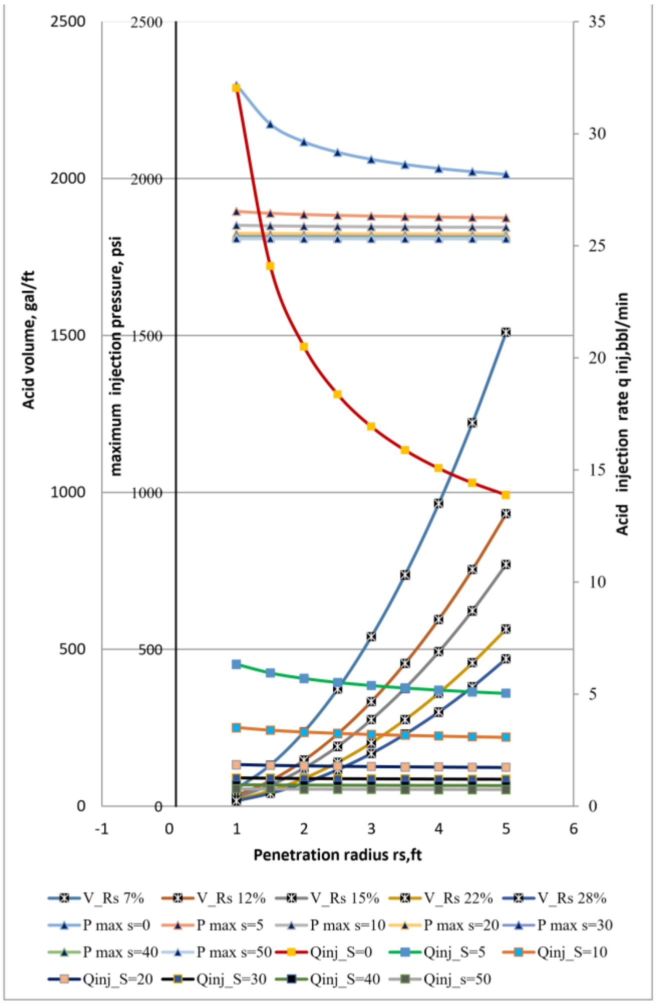

Figure 8: volume and flow rate of acid at different skin values vs skin radius for well E349.

Table 14: Bottom hole pressure and required acid pump pressure for well

P_{bottom} Psia	P_{PUMP} Psia
1300	-1185.295
1900	-709.5258
2400	-265.9166
2900	200.7488
3300	578.2529
3700	961.8095
4100	1349.131
4500	1738.976
4782.96	2013.565

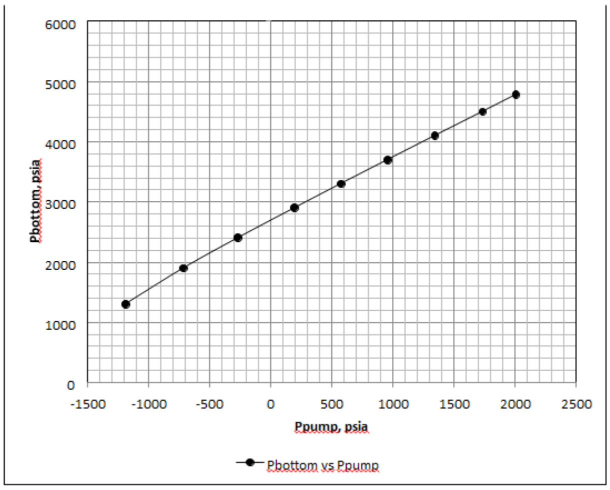

Figure 9: Bottom hole pressure vs acid pump pressure for well E-349.

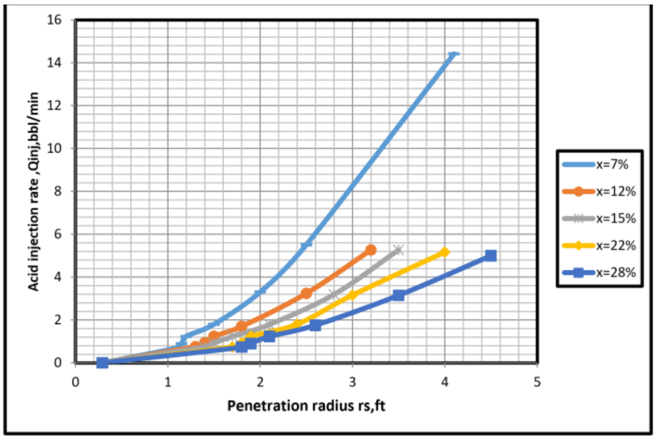

Figure 10: The optimum injection rate vs optimum acid penetration radius at different dissolving power for well E-349.

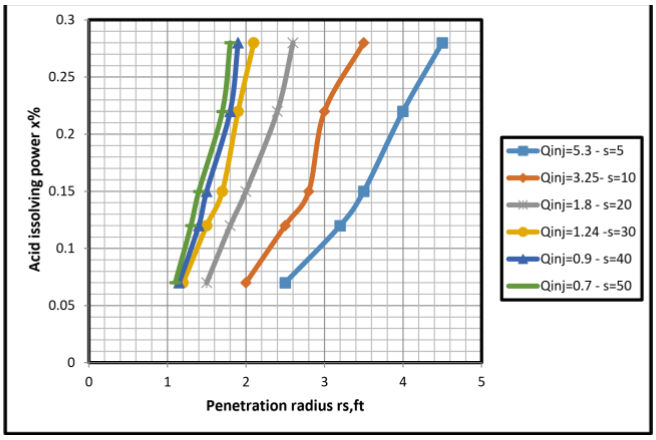

Figure 11: The optimum dissolving power vs optimum penetration radius at optimum injection for different skin factor for well E-349.

IV. Conclusions

1. The result of this study indicates that as the skin value increased, the acid injection rate decreased.
2. It was also found that there is a limiting value for the skin factor which controls the acid injection rate.
3. It was also found that the acid injection volume is inversely proportional to the acid concentration.
4. The best optimum acid concentration was found to be 15 % for the dolomite acid treatment.
5. It was found that limiting the value of 20 skin factors was the maximum value for maximum acid performance.
6. This 20 skin value makes the acid injection rate to be very slow which in turn results in high acid injection time causing the acid to spend near the wellbore as not covering the entire damage area.

V. Recommendation

1. We recommend that laboratory work should be conducted in order to confirm our analysis.

2.After acidizing job is conducted for these wells, post buildup test analysis should be made in order to make sure that treatment of acid is effective.

Acknowledgment

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