The Impact of Acidizing on Carbonate and Sandstone Reservoirs

Haiat K. Alhaj[1], Nosaima Nuri Elazzabi[2], Kamila Dourar[3], Eman Ali Kamour[4]
[1,2,3,4]Department of Petroleum Engineering, University of Tripoli, Libya
1hayatkhalifa@yahoo.com تاريخ الاستلام 2024/06/28

Abstract

Formation damage is the impairment of permeability of rocks inside a petroleum reservoir. Near wellbore formation damages have a great impact on productivity index. Acidizing is a stimulation method to remove the effect of the damage through reacting with damaged materials to restore or improve permeability around the wellbore. Acid can be injected into the damaged formation below the fracture gradient of the formation which is called matrix acidizing. Acidizing operations is not only for treating the damaged formation, but also could be used for cleaning wellbore, production tubing and perforations from deposited scales, The main objective of this study is to evaluate the impact of acidizing on couple of Libyan fields for Libyan Oil and Gas Company, PROSPER Software was used to estimate productivity index (PI) using Vogel's model, also determining other parameters such as permeability, net pay, viscosity, formation volume factor and drainage radius. To determine the Skin Factor (S) based on Darcy's, then to calculate Skin damage (Sd). The work was done with four wells, two oil wells from X field which is an offshore carbonate field were treated with matrix acidizing, the wells are well (1) and well (2). The others are oil wells from Y field which is an on-land sandstone field that were treated with acid wash, the wells are well (3) and well (4). As a result of analyzing the data, the conclusion come to be that the Skin factor decreased for well well (1) by 76.9 %, for well well (2) by

57.6%, for well well (3) by 10.3%, and for well well (4) a slight decrease of 3.2% was observed .

Keywords — Damage, Permeability, Skin, Stimulation, Acidizing .

1 .Introduction

Petroleum reservoir is a geological structure formed from porous and permeable rocks where hydrocarbons (oil and gas) are stored within the pores. Permeability and porosity are the most important properties of the reservoir rocks which reflect the capacity and productivity of the reservoir. Permeability is the ability of the reservoir rocks to transmit fluids through the connections (pore throats) between the reservoir pores. Formation damage can be defined as any flow restriction that results in the reduction of natural permeability around the wellbore [3]. Formation damage results from various mechanisms during drilling, cementing, production, workover, and stimulation operations hroughout the life of the oil well. These mechanisms could be mechanical, chemical, biological, and thermal, and will result in natural or native

reservoir permeability damage.[2]

2. Acidizing

Is the process used in oil extraction to enhance permeability and improve flow rate by pumping

acid solution into a wellbore or reservoir formation. The process is divided into:

i. Matrix acidizing: is commonly used in carbonate reservoirs, where the acid can dissolve the minerals such as calcium carbonate that make up the rock.

By dissolving these minerals, the acid creates channels and pathways for the oil or gas to flow more easily from the reservoir to the wellbore.

ii. Acid washing: its objective is simply tubular and wellbore cleaning. Treatment of the formation is not intended. Acid washing is most commonly performed with HCl acid mixtures to clean out scale (such as calcium carbonate), rust, and other debris restricting flow in the well.

iii. Acid fracturing involves pumping acid into the formation at high pressure (above formation frac pressure).

2.1 Types of Acids Used in Acidizing:

- Inorganic (Mineral) acids [2]:
  - i. Hydrochloric acid (HCL): strong acid dissolves carbonate materials such as (Dol/L.S). and the concentration ranges (15%-28%). they are used in sandstone with 5% up to 15% as a Pre-flush.
  - ii. Hydrofluoric (HF): A strong acid is highly used in sandstone to dissolve siliceous materials (quartz, feldspar, and clay).

- Organic acids:
  - i. Acetic acid (CH3COOH): Weak acid, less corrosive compared to HCL, CON ranges around 10%. And has a greater cost compared to HCl and formic acids
  - ii. Formic acid (HCOOH): Weak acid, it’s the same as acetic acid except that it has less ability to inhibit corrosion at high-temperature conditions.

3. Methodology:

The methodology of this study involves determining the impact of the acid treatment as a matrix acidizing was done on the carbonate wells and an acid wash on the sandstone wells by using the obtained data to evaluate the Productivity index (PI) and the skin factor before and after the acid treatment.

3.1 Total Skin Effect S_T:

Formation damage occurs within the reservoir in a short radius around the wellbore which causes a reduction in permeability or relative permeability of hydrocarbons This causes the reduction of bottom hole flowing pressure (Pwf) and creates additional pressure drop as explained in Figure (1).

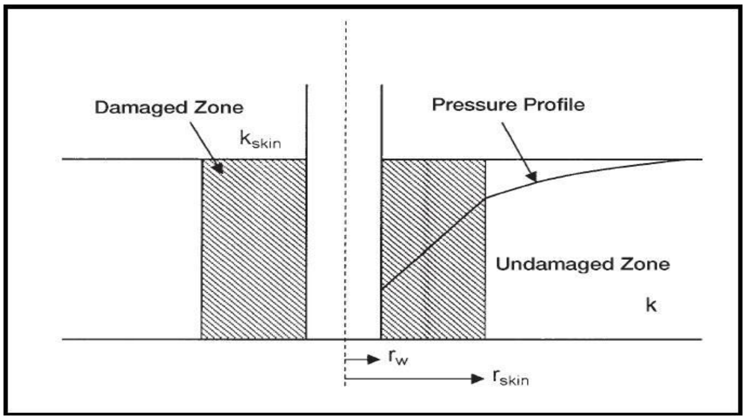

Figure 1. Skin Effect

The formation damage has reduced the permeability from (k) to (ks), the bottom hole flowing pressure has been reduced from (Pwf ideal) to (Pwf real). Δpskin as a function of skin for measuring the formation damage around the wellbore which is called the Skin effect (S).

Hawkins (1956) suggested that the permeability in the skin zone k_{skin} is uniform and the pressure drop across the zone can be approximated by Darcy's equation [4]:

$$\mathbf{Q = \frac{7.08 \times 10^{-3}\, K\, h\, (Ps - Pwf)}{\mu\beta\, \left(\ln \frac{re}{rw} - 0.75 + S\right)}}$$

Hawkins proposed the following approach.

$$\Delta P_{skin} = [\Delta P \text{ in skin zone due to } k_{skin}] - [\Delta P \text{ in skin zone due to } k]$$

Applying Darcy's equation gives:

$$\Delta P_{skin} = \left(\frac{Q\, \beta o\, \mu o}{0.00708\, kh}\right)\left[\frac{k}{kskin} - 1\right] ln\left(\frac{rskin}{rw}\right)$$

The above expression for determining the additional pressure drop in the skin zone is commonly expressed in the following form:

$$\Delta P_{skin} = \frac{141.2\, Q\, \beta\, \mu}{kh}\, s$$

The difference between (Pwf ideal) and (Pwf real) is the pressure drop across the skin zone as shown .

$$\Delta Ps = \mathbf{Pwf\ ideal\ - Pwf\ real}$$

By rearranging the equations, the final form of Howkings relationship will be:

$$\mathbf{S = \left(\frac{k}{ks} - 1\right) ln \left(\frac{rs}{rw}\right)}$$

Typically, the value of skin is raged between (-5) for a hydraulically stimulated well to infinity value for a completely damaged or plugged well, (-5,∞).

The total skin effect/factor is made up of many components, including skin due to damage/stimulation, partial penetration, perforation and more.

$$S_T = \frac{ht}{hp} S_d + (S_{pp} + S_p)$$

3.2 Partial Penetration Skin Factor (Spp):

Partial completion is commonly used to avoid water or gas coining. For a limited entry or incompletely perforated interval wells, the total skin factor, ST, determined from a pressure transient test is related to the true skin factor, Sd caused by formation damage and apparent skin factor, Sp, caused by an incompletely perforated producing interval (limited fluid entry). The relationship between these factors for the perforation interval located at the middle of the producing formation is presented by Saidikowski Ali (1968) which is described in the following equation:

$$S_{pp} = (\frac{ht}{hp} - 1)\ [\ln (\frac{ht}{rw} \sqrt{\frac{Kh}{Kv}}) - 2]$$

Brons and Marting also proposed the following equation to determine the pseudo skin factor due to partial penetration:

$$S_{pp} = (\frac{ht}{hp} - 1)\ [\ln (\frac{ht}{rw} \sqrt{\frac{Kh}{Kv}}) - G_{(b)}]$$

$$G_{(b)} = 2.948 - 7.363 (\frac{hp}{h}) + 11.45 (\frac{hp}{h})^2 - 4.675 (\frac{hp}{h})$$

3.3 Perforation Skin Factor (S_{perf}):

The perforation skin factor is a measure of the actual pressure drop across a perforated completion, for evaluating the productivity of a well and can be affected by various factors related to perforation-tunnel geometry, drilling and perforation damage, and formation-permeability anisotropy. McLeod has modified the Jones Glaze and Blount equations to represent the pressure loss for oil flow across perforations [1], as follows:

$$\{\Delta P_{perf} = a q_p^2 + b q_p\} \qquad \{q_p = \frac{q}{N}\} \qquad \{N = h_p \times SPF\}$$

Rewriting the above equation in terms of perforation parameters to become:

$$a = \frac{2.3 \times 10^{-14} \times \beta \times \beta o^2 \times \rho o \left(\frac{1}{rp} - \frac{1}{rc}\right)}{Lp^2}$$

$$b = \frac{\mu o \times \beta o \ln\left(\frac{rc}{rp}\right)}{.00708 \times Lp \times Kp}$$

(where a and b are constants)

$$Kp = 0.1 \times Ke \qquad \text{(Overbalance)}$$

$$Kp = 0.4 \times Ke \qquad \text{(Underbalance)}$$

$$rc = rp + \frac{0.5}{12}$$

$$\beta = \frac{2.33 \times 10^{10}}{Kp^{1.201}}$$

3.4 Productivity Index (PI):

This is defined as the ratio of the producing rate of a well to its pressure drawdown at that particular rate. This is expressed mathematically as: [4]

$$\mathbf{PI}_{(actual)} = \frac{Q}{Ps - Pwf}$$

Where:

$$\mathbf{PI}_{(theoretical)} = \frac{7.08\times10^{-3}\ K\ h}{\mu\beta\left(ln\frac{re}{rw} - 0.75 + S\right)}$$

4. Case Study:

This Paper is conducted in Libyan fields, and the study is concerned with estimating and evaluating the impact of acidizing on carbonate and sandstone fields, the names of the fields and the wells are not mentioned in this paper due to the confidentiality of the publication. and the data was collected and located from carbonate reservoirs which are offshore wells "well (1) and well (2)". Matrix acidizing was applied to the wells for the purpose of increasing their productivity, thus increasing their production. and also, from sandstone reservoirs which are onshore wells "well (3) and well (4), The wellbore of these wells was cleaned with an acid wash after they were closed for a very long time, to enable the well to restart producing.

5. Results and Discussion:

In this paper, the required data has been collected for both onshore and offshore fields for analysis as PVT, SGS, RT, Perforation data, production, and pressure history for the fields, then building the models began with PVT modeling for the reservoir fluids afterward equipment data modeling and finally IPR modeling. Darcy's equation was the key to this study in estimating the skin factor for fields comparing the productivity index before and after the acidizing for each of the four wells. and finally calculating the skin caused by damage. Matrix acidizing job was done on the carbonate reservoir well (1), and well (2), and an acid wash job was done on the sandstone reservoir well (3), and well (4).

Overall, all four wells have been successfully acidized.

- **Well (1)** shows an increase in PI value and a decrease in skin damage, As shown in Table (1) and Figure (2).

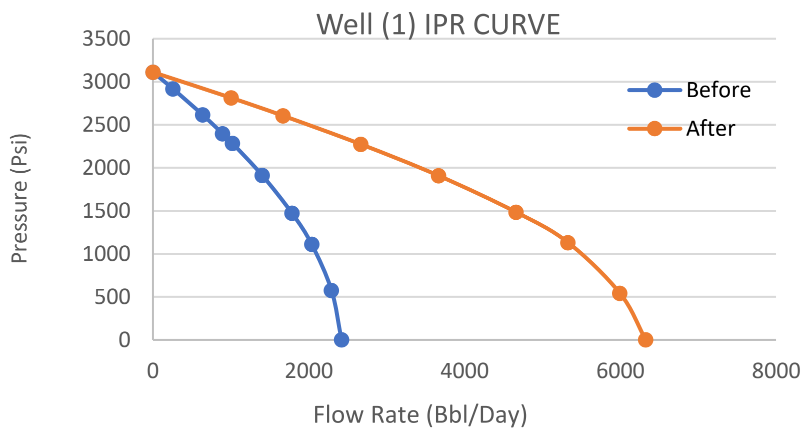

Figure 2 Well (1) IPR Curve

- **Well (2)** shows an increase in PI value with a decrease in skin damage. As shown in Table (1) and Figure (3).

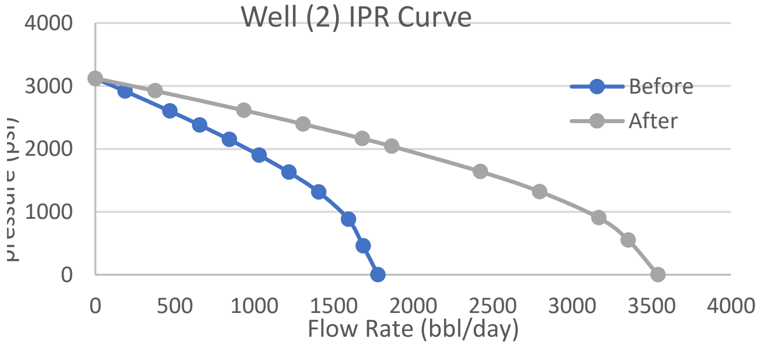

Figure 3 Well (2) IPR Curve

- **Well (3)** there was a re-acidizing job, the first job showed no improvement which indicates that the treatment was not successfully done due to well-slugging. the second job showed an improvement with a slight increase in PI value and a decrease in skin factor. These high skin values are due to the fact that the well was shut in for a long time before the acid job. As shown in Table (1) and Figure (4).

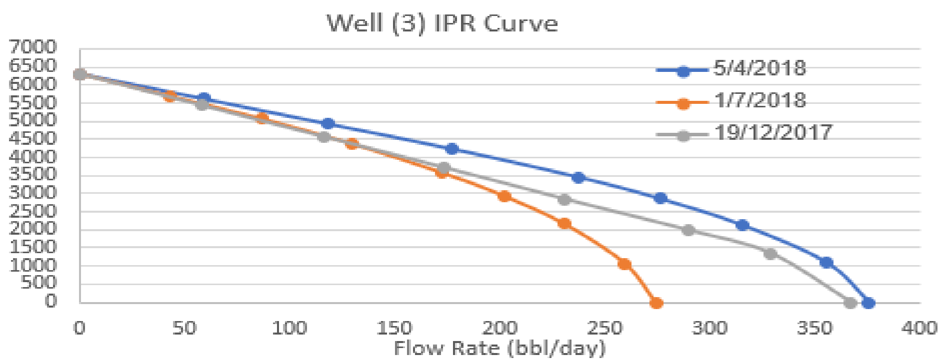

Figure 4 Well (3) IPR Curve

- **Well (4)** The results show a slight reduction in skin damage, on the other hand, the PI value decreased due to gas breakthrough and water breakthrough. As shown in Table (1) and Figure (5).

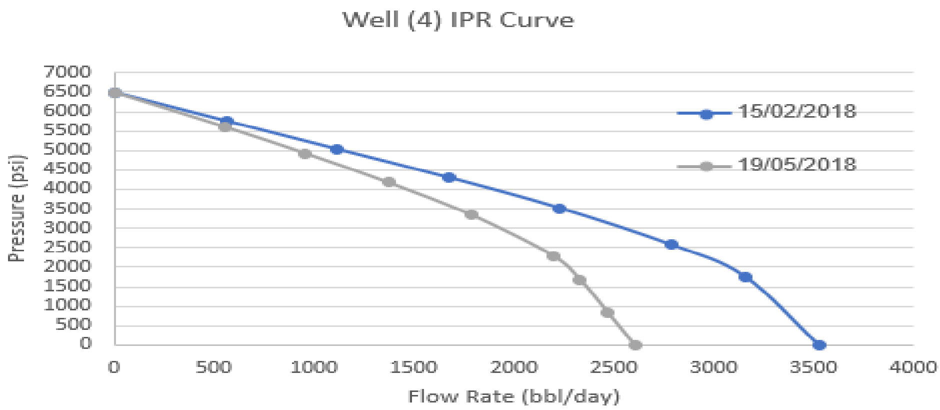

Figure 5 Well (4) IPR Curve

Table 1. Skin Damage and Bottom Hole Pressure Results

		PI (Before) bpd/psi	PI (After) bpd/psi	Skin factor (Before)	Skin factor (After)	Skin damage (Before)	Skin damage (After)	P_{wf} (Before) psi	P_{wf} (After) psi
Well (1)		1.36	3.45	+26	+6	+17.6	+1.4	2343.1	2626.7
Well (2)		0.9383	1.93	+49.5	+20	+31	+10.8	1991	2087
Well (3)		0.0666	0.085	+184	+165	+119	+106	4833	2980
Well (4)		0.766	0.64	+49	+45	+18	+16	5158	4792

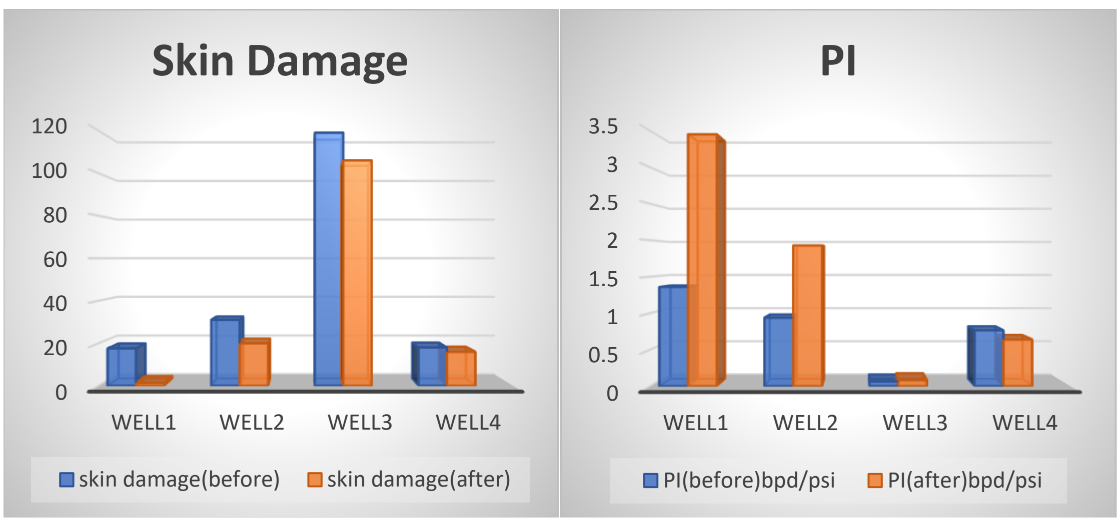

Figure 6 Productivity Index & Skin Damage for Each Well

6. Conclusions:

1) Formation damage could have occurred at various operations such as drilling, completion, production, and EOR.

2) Acid job is used to improve a well's productivity by dissolving materials from lower permeability or plugged areas.
3) Various types of acids are used in acidizing and each is suitable for specific types of rocks and conditions. This process is typically carried out with hydrochloric acid mixtures and is most commonly used for matrix acidizing and cleaning the wellbore
4) Acidizing can be performed in different forms, including matrix acidizing and acid wash, depending on the specific reservoir conditions and objectives.
5) Acidizing jobs typically involve evaluating the overall success of the acid treatment in enhancing well productivity. By increasing production rates, improvement in flow characteristics, and reduction in formation damage.
6) Acidizing must be transported with proper planning, execution, and environmental safeguards, so it could be a valuable tool for maximizing hydrocarbon recovery from reservoirs.

7. Recommendations:

- It is recommended to redo the acid job in wells (2) and well (3) due to the relatively high skin damage even after the treatment.
- Using a PLT in well (4) to determine the water breakthrough to exclude the area. Since PLT cannot be used with a low flow rate, improving the flow rate is necessary before using PLT.
- Careful consideration and proactive measures are necessary when utilizing N2 as a post-flush agent in acidizing operations.

Nomenclatures

G(b) = function of the fractional penetration (hp/h).

h = thickness (ft).

ht = total formation thickness (ft).

hp = perforated interval height (ft).

K = permeability (md).

Kh = horizontal permeability (md).

Kv = vertical permeability (md).

Ke = effective permeability (md).

Kp = perforation permeability (md).

Ks = around wellbore permeability (md).

L_p = perforation thickness (ft).

N = number of shots in a perforated interval.

ΔP_{skin} = change in reservoir pressure (psi).

ΔP_{perf} = pressure drop due to perforation (psi).

PI = Productivity Index (bbl/STB/Psi).

Ps = static pressure (psi).

Pwf = flowing bottom-hole pressure (psi).

Q = flow rate (bbl/day).

rc = compacted radius (ft).

rp = perforation radius (ft).

re = reservoir drainage radius (ft).

rs = skin radius (ft).

rw = wellbore radius (ft).

S = skin factor.

SPF = Shots Per Foot (shot density).

β = turbulence factor.

β_o = oil formation volume factor (bbl/STB).

μ_o = oil viscosity (cp).

References

1. Hemanta Mukherjee Denver, Well Performance Manual, June 7-1991.
2. Huner Kareem Haias, Pshtiwan Tahsin Mohammed Jaf., "Matrix Acidizing of Carbonate Formations: A Case Study" " International Journal of Engineering and Techniques, Volume 4 Issue 2, Mar-Apr 2018.
3. Larry Lake, Robert F. Mitchell, Edward D. Holstein, John R. Fanchi, Ken Arnold, Hal R. Warner, Petroleum Engineering Handbook,2006.
4. Tarek Ahmed, Reservoir Engineering Handbook, 4th ed, Gulf Professional Publishing, January 12-2010.