Available online at http://ijcpe.uobaghdad.edu.iq and www.iasj.net
Iraqi Journal of Chemical and Petroleum Engineering
Vol.23 No.4 (December 2022) 7 – 16
EISSN: 2618-0707, PISSN: 1997-4884

Well Performance Following Matrix Acidizing Treatment: Case Study of the Mi4 Unit in Ahdeb Oil Field

Usama Alameedy[a], Ayad A. Al-Haleem[a] , and Abdulameer almalichy[b]

[a] *Petroleum Engineering Department-College of Engineering-University of Baghdad.*
[b] *Petroleum Engineering Department- College of Earth Science and Engineering- University of Miskolc.*

Abstract

The productivity of oil wells may be improved by determining the value of enhancing well productivity and the likely reasons or sources of formation damage after the well has been recognized as underperforming. Oil well productivity may be improved, but the economics of this gradual improvement may be compromised. It is important to analyze the influence of the skin effect on the recovery of the reserve.

The acid treatment evaluated for the well AD-12, primarily for the zone Mi4; using a license of Stimpro Stimulation Software to validate the experimental work to the field scale, this software is considered the most comprehensive instrument for planning and monitoring matrix acid treatments and utilizing actual data to provide a far better knowledge of the well's reaction, with methods that represent the reality of what is happening in the reservoir before, during, and after matrix acid treatments, through the post-treatment skin factor, which is the most frequently utilized statistic for analyzing stimulation treatments and relies on the geometry of the wormholed zone. Referring to the previous buildup tests for Ad-12, the skin value of -3.97 is approximately identical to or slightly larger than the skin value estimated by the acid treatment simulation using Stimpro. Moreover, when the simulator was performed, the invading fluid revealed two distinct depths of investigation inside the treated zone. While the fluid invasion in the bottom area has invaded deeply at a distance of 95 inches despite the top layer wormhole penetrating to a depth of 32 inches.

Keywords: Mishrif Reservoir, Skin factor, acid treatment, matrix acidizing, and StimPro.

Received on 12/06/2022, Accepted on 03/08/2022, Published on 30/12/2022

https://doi.org/10.31699/IJCPE.2022.4.2

1- Introduction

The term "formation damage" refers to a reduction in the permeability of the original rock as a consequence of some alteration, such as clay swelling, fines migration, particle clogging, or changes in wettability. Due to scale precipitation, asphaltene deposition, and other causes, formation damage may also occur throughout the productive or injective life of the well.

Matrix acidizing treatments restore damage to the formation caused by earlier well operations. The ultimate objective of these treatments is often to restore the original formation's permeability. On the other hand, a matrix acidifying treatment may significantly enhance the formation process in sandstones and shales [1]. The permeability may be considerably improved to values much larger than the initial permeability, up to a distance of possibly tens of feet from the wellbore. Consequently, while hydraulic fracturing is usually projected to provide better results in sandstones or shales than matrix acidizing in carbonate rocks, both procedures are competitive [2]. More work is required to determine the most effective option. As described as a technique of well stimulation, matrix acidizing involves introducing an acid solution into the formation to dissolve a few minerals present and, as a result, restore or increase permeability around the wellbore, among other things [1]. Due to the low velocity of the acid injection, the pressure is maintained below the formation breakdown pressure, and as a result, the reservoir rock does not fracture. Candidate selection and stimulation methods are aided by a decision tree (Fig. **1**). The productivity achievement determines the stimulation approach [3].

To meet the productivity objective, matrix stimulation should provide a skin effect of 10 % of the initial damage skin effect for sandstones and 2 to 3 % for carbonates. Aside from hydraulic fracturing, there is no other stimulation method for sandstone reservoirs. Acid fracturing may be cost-effective to boost productivity in carbonate reservoirs (limestones or dolomites). In both circumstances, the reservoir experiences a hydraulic fracture [2].

2- Design of the Stimulation Treatment Sequence

If the well has been recognized as underperforming, then the monetary value of increasing well productivity and the likely formation damage sources have been evaluated [4]–[7]. The engineer must next identify the corrective action. Two nonfracture procedures are utilized to increase oil and gas well productivity. The wellbore is cleaned using chemical and/or mechanical techniques. In

Corresponding Authors: Name: Usama Alameedy, Email: usama.sahib@coeng.uobaghdad.edu.iq, Name: Ayad A. Al-Haleem, Email: dr.ayad.a.h@coeng.uobaghdad.edu.iq, Name: Abdulameer almalichy, Email: Almalichy.Abdulameer.mohsin.kadhim@student.uni-miskolc.hu

order to stimulate the matrix, fluids are pumped into the formation near the wellbore [2]. Typically, matrix stimulation treatments administered below fracture pressure via tubing, drillpipe, or coiled tubing consist of a series of fluids, known as stages. A minimum treatment includes a preflush stage with a nondamaging, nonreactive fluid to set an injection rate, a stage of the main treating fluid, and an overflush stage to remove the main treating fluid from the tubing and displace it into the vicinity of the wellbore. Other auxiliary steps are used in the majority of therapies to improve their efficacy. The next sections examine the selection of chemicals for the stages and the design of the treatment sequence (pumping schedule). [8].

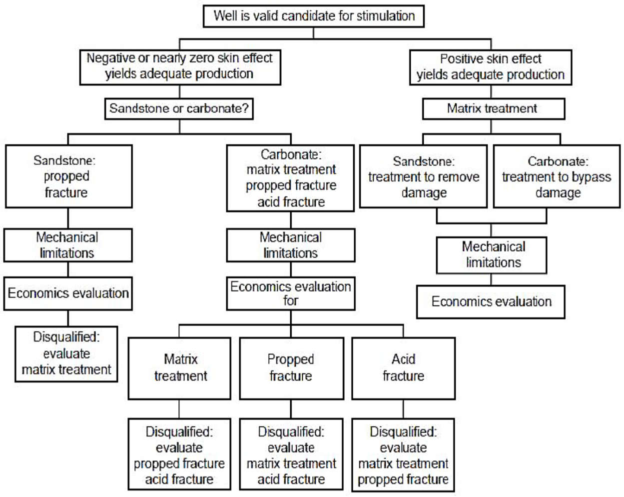


Fig. 1. Candidate Selection and Stimulation Methods [2]

a) Preflush

Preflushes of hydrochloric acid are used to prepare or condition the formation that will be stimulated so that the acid will be accepted in the most favorable parts. The primary goal of the Preflush is to displace the brine from the wellbore to prevent contact between the hydrofluoric acid and the brine of formation, which contains potassium, sodium, and calcium, which causes precipitation [9].

b) Main (Acid) treatment

This stage's goal is to repair the well's damage. The appropriate injection rate is determined by the acidizing task matrix's acidizing or acid fracturing type. In carbonates, wormhole propagation speed increases with injection rate, so a high injection rate is required for rapid wormhole propagation. When acidizing in areas of high-water saturation, low pump rates are also advised. The maximum permitted pressure for the tubing, the surface equipment, and the pump must be considered to determine whether the formation can withstand larger forces [2].

c) Postflush (overflush)

The overflush moves the primary acid flush at least four feet away from the wellbore. Since retarded acid's reaction time on creation is longer than its injection period, it might aid in acid penetration. Instead of using potassium chloride as a post flush in acidizing sandstone formations with hydrofluoric acid, ammonium chloride, $NH4Cl$, is advised [1].

3- Monitoring the Performance of Acidizing Treatment

The post-treatment skin factor is the most often utilized statistic for analyzing stimulation treatments. In matrix acidizing processes in carbonates, the skin factor relies on the geometry of the wormholed zone. Analyzing the injection rate and pressure during injection is recommended for monitoring a matrix acidizing treatment in a carbonate reservoir, in the same way as monitoring a sandstone acidizing treatment is advised [1]. In carbonates, the pressure loss across the wormhole zone is assumed to be insignificant, which means that the wormhole impact on the wellbore skin effect is equivalent to extending the wellbore [10]. The skin's evolution after a carbonate matrix acidizing treatment may be anticipated using wormhole propagation models under this assumption.

As the wormhole penetration radius increases in a damaged well with a permeability k, the skin effect is proportional to the wormhole penetration radius as follow:

$$s = \frac{k}{k_s} ln\frac{r_s}{r_{wh}} - ln\frac{r_s}{r_w} \tag{1}$$

As long as the radius of wormhole penetration is greater than the radius of damage, Eq. (1) remains valid. Alternatively, if the well was initially undamaged or if the wormhole radius was higher than the original damage radius, the skin effect during acidification is assumed to be infinite, and the following Eq. (1) is used to represent this:

$$s = -ln\frac{r_{wh}}{r_w} \tag{2}$$

Eqs. (1) and (2), which assume that the injection rate is kept constant during the treatment for the damaged zone, are used to determine the skin impact expected by the volumetric model during the injection,

$$s = -\frac{k}{2k_s} ln\left[\left(\frac{r_w}{r_s}\right)^2 + \frac{V}{PV_{bt}\pi r_s^2 \phi h}\right] - ln\frac{r_s}{r_w} \tag{3}$$

Furthermore, since wormholes that penetrate beyond the affected zone or there is no damage,

$$s = -\frac{1}{2} ln\left[1 + \frac{V}{PV_{bt}\pi r_s^2 \phi h}\right] \tag{4}$$

Both Buijse-Glasbergen and Furui models are used to calculate the radius of the wormhole region for discrete injection times. The skin factor is calculated using Equation 1or Eq. (2) for each rwh obtained using these models.

4- Max. Δp, Max.-Rate-Procedure by Paccaloni

The [11] approach estimates a steady-state skin effect in accordance with Darcy's law to keep track of the development of stimulation treatments. The two most important components of Paccaloni's maximum Δp, maximum-rate technique is:

1. The largest pwf achievable without breaking the formation should be achieved by injecting the acid at the maximum pace possible.
2. Treatments should be evaluated in real-time to ensure the maximum rate aim is fulfilled and detect when enough acid is injected into the formation.

$$s = \frac{0.00708kh\Delta p}{\mu q_i} - \ln\frac{r_s}{r_w} \quad (5)$$

Where k denotes the formation's permeability, h indicates the thickness of the pay zone, rw represents the wellbore radius, and rs defines the radius impacted by acid injection. Typical oilfield units for all of the variables. Fig. **2** depicts the treatment of the matrix stimulation design chart. Acid injection rate (qi) and pressure drop Δp are linked to skin variables in Eq. (5). Wang et. Al. [12] builds a pti vs. qi graph using skin factor as a parameter to track a stimulation treatment. A series of parallel lines with varying skin factor values can be seen on the chart, as long as the skin factor is assumed to be the only variable under consideration. The wellhead pressure and injection rate indicate the treatment, and the skin effect may be seen on the chart. This chart also shows the relationship between fracture pressure and injection rate, keeping the rate as high as feasible without breaking the formation.

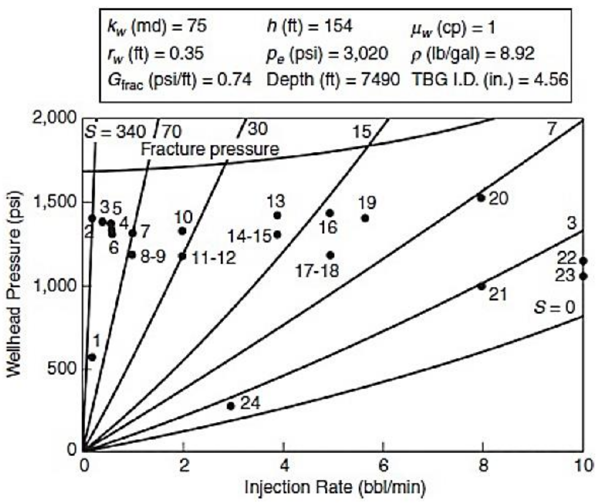


Fig. 2. Treatment of the Matrix Stimulation Design Chart [13]

According to Prouvost and Economides [14] and validated by Paccaloni and Tambini [13], it is possible to overstate the skin impact using the Paccaloni approach since it neglects transient flow effects. When the pace of change is sudden, this miscalculation might be catastrophic. However, it's not a big problem for most treatments since the inaccuracy is pretty constant, and the development of the skin impact is more essential than its absolute value itself. Prouvost and Economides [14] developed a method for precisely calculating the changing skin effect during matrix acidization. A thorough post-treatment analysis might benefit from using this method if a defined injection schedule is available. This approach is considered to be among the most helpful design strategies because of the following advantages:

- It is possible to evaluate the degree of formation damage using an injection test.
- It is likely to estimate the pumping parameters at starting an acidizing matrix process.
- Can determine if acid amounts utilized are insufficient, appropriate, or excessive.
- At the well site, it is possible to make an informed and timely choice, increasing the likelihood of success.

5- Stimpro Stimulation Software

The Stimpro system is intended to give the most complete tools for the planning and analysis of matrix acid treatment. Stimpro's matrix acid simulator, on the other hand, focuses on the practical use of real treatment data. The utilization of actual data provides a far better knowledge of the well's reaction, with methods that represent the reality of what is happening in the reservoir before, during, and after matrix acid treatments (Fig. **3**). Operation modes on the Main screen include design and analysis of matrix acid treatment, as well as reservoir modelling. Acidizing Design Mode, Acidizing Analysis Mode, and Production Analysis Mode are the three options available to users[15].

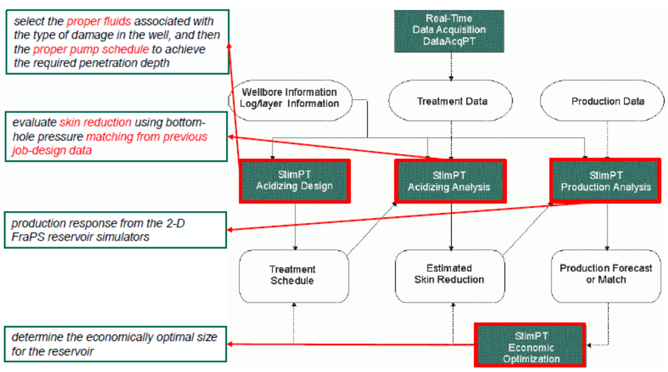


Fig. 3. StimPro's Capabilities [15]

a. Acidizing Design Mode

Using the Acidizing Design option, a treatment schedule can be generated rapidly and effectively. Stimpro will develop a pumping schedule after assisting in the selection of the proper fluids and acids for the reservoir's damage. The reservoir penetration may also be specified in this mode.

b. Acidizing Analysis Mode

Pre-treatment design and real-time data analysis are the main priorities of the Acidizing Analysis mode. The real-data analysis may be done in real-time or post-job, using treatment data that has already been gathered before the project started.

c. Production Analysis Mode

Wells with or without matrix acid treatments may have their production behavior predicted or matched using the Production Analysis option. Using this method, Stimpro feeds a reservoir simulator with the acid concentration profile it generated using its hydraulic fracture propagation and acid transport models. This is a critical step in establishing the efficacy of previous treatments and the related economics of future ones.

6- Results and Discussion

In Stimpro Software's acidization model, sandstones and carbonates respond differently to acidizing, which is taken into account. As a result of acidizing, new channels (wormholes) are formed in carbonates, bypassing damage to the wellbore and allowing water to flow into the well. As an alternative to developing new pore channels, acidizing sandstone displaces the particles that block the existing channels.

Acid tends to migrate in a front around the wellbore in sandstone reservoirs. The kinetics of dissolution in sandstones is surface-reaction restricted, which accounts for a major part of the variance in behavior. Carbonates, on the other hand, have a considerably more unstable process. HCl and HF acid are often used in sandstone treatment to reopen and expand pore channels obstructed by clays and siliceous fines. In order to prevent the clays from extracting protons from HF, HCl dissolves any carbonates in the matrix, and HF dissolves slow and fast-reacting silicates and carbonates.

The ability to calculate the optimal acid treatment volumes and concentrations is typically a determining factor in treatment efficacy. The precipitation of amorphous silica may occur as a consequence of secondary reactions from spent acid rather than decreasing the skin's appearance. There are times when excessively powerful acids might weaken and destabilize formation faces.

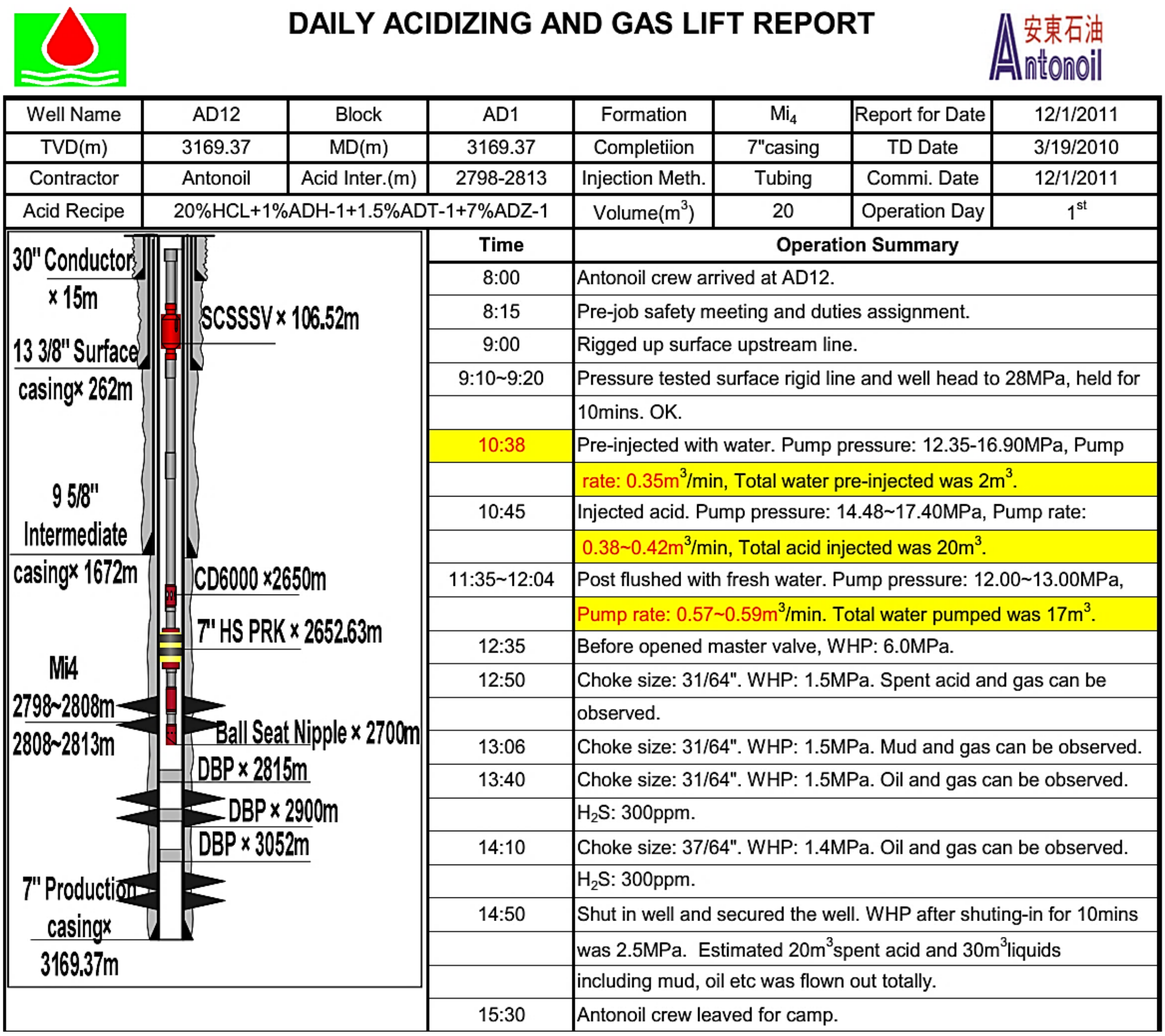
Engineers may use the Acidizing Design mode to rapidly and effectively develop a treatment program depending on the requirements of the reservoir. Stimpro will build a pumping schedule after selecting the proper fluids and acids for the reservoir damage type. It will then be able to indicate the desired reservoir penetration.

The order in which the fluid patches are administered and their exact time of application are essential factors for designing a stimulation treatment. After the technique of major acid injection, the pre-and post-flushing phases are the most prevalent components of a treatment sequence. It was decided to do the acidizing job on Dec. 2nd, 2011, for the well Ad-12 targeting the Mishrif reservoir, particularly the Mi4 unit, to remove drilling and completion mud damage to the pay zone and improve the performance of the formation by enhancing the permeability; consequently, boost oil production. The whole matrix acidizing job, including the data necessary for operation and the outcomes in a summary report, is clearly shown in Fig. **4**. The acid job began with a pre-injection of water. Pump pressure: 12.35-16.90 MPa (1791-2451 psi); Pump flow rate: 0.35 m^3/min (2.94 bbl/min); Total pre-injected water volume: 2 m^3 (16.78 bbl). followed by the first injection of acid fluid with Pump pressure was 14.48-17.40 MPa (2100-2523 psi), pump rate was 0.38-0.42 m^3/min (3.19-3.522 bbl/min), and total acid pumped was 20 m^3. The last step was flushed with new water thereafter, by Pump pressure: 12.00-13.00 MPa (1740-1885 psi); Pump flow rate: 0.57-0.59 m^3/min (4.78-4.95 bbl/min); Total volume pumped: 17 m^3 (142.5 bbl).

In the following scenario, an acidizing carbonate treatment is investigated with Stimpro to illustrate pressure matching of measured and simulated data, skin evolution assessment, and a general analysis of an acidizing carbonate treatment. To begin, create a new file to enter the details such as the well survey, fluid type and specifications, and treatment schedule. Examine all inputs by clicking the Next button to go through the various options. A vertical well Ad-12 with perforated casing completion has a total depth of 3169.37 m from where the acid operation was pumped into the perforation depths (2798.0-2808.0) m and (2808.0-2813.0) m. The reservoir (Mi4) was composed of limestone mainly divided into two sections with a porosity of 0.17-0.19, a pore fluid viscosity of 1.5-1.7 cp, a pore pressure gradient of 0.51 psi/ft, and a fracture pressure gradient of 0.751-0.76 psi/ft respectively. There was a Preflush of 2 percent potassium chloride brine, followed by the pumping of 20 percent hydrochloric acid. Before shutting down, the same brine injected to perform an overflush. The total amount of acid used in the job was 34.5 m^3. Surface pressure and pumping rate were recorded during the job. All the entered data is shown in considerable detail in Table **1** to Table **10**.

Table 1. Acidizing Summary

Reservoir Temperature (°F)	200	Average Reservoir Pressure (psi)	4,694
Pore Fluid Permeability (mD)	15-60	Porosity	0.190
Reservoir Viscosity (cp)	1.637	Frac Pressure (psi)	6,995
TVD to Top of Open Section (m)	2,798	TVD to Bott. of Open Section (m)	2,813
Acidizing Type	Carbonate	Acid Volume (bbls)	103.9
Avg. Surface Pressure (psi)	2,534	Max. Surface Pressure (psi)	2,627
Initial Skin	0	Final Skin	-3.97


DAILY ACIDIZING AND GAS LIFT REPORT

Well Name	AD12	Block	AD1	Formation	Mi_4	Report for Date	12/1/2011
TVD(m)	3169.37	MD(m)	3169.37	Completiion	7"casing	TD Date	3/19/2010
Contractor	Antonoil	Acid Inter.(m)	2798-2813	Injection Meth.	Tubing	Commi. Date	12/1/2011
Acid Recipe	20%HCL+1%ADH-1+1.5%ADT-1+7%ADZ-1			Volume(m^3)	20	Operation Day	1st

Time	Operation Summary
8:00	Antonoil crew arrived at AD12.
8:15	Pre-job safety meeting and duties assignment.
9:00	Rigged up surface upstream line.
9:10~9:20	Pressure tested surface rigid line and well head to 28MPa, held for 10mins. OK.
10:38	Pre-injected with water. Pump pressure: 12.35-16.90MPa, Pump rate: 0.35m^3/min, Total water pre-injected was 2m^3.
10:45	Injected acid. Pump pressure: 14.48~17.40MPa, Pump rate: 0.38~0.42m^3/min, Total acid injected was 20m^3.
11:35~12:04	Post flushed with fresh water. Pump pressure: 12.00~13.00MPa, Pump rate: 0.57~0.59m^3/min. Total water pumped was 17m^3.
12:35	Before opened master valve, WHP: 6.0MPa.
12:50	Choke size: 31/64". WHP: 1.5MPa. Spent acid and gas can be observed.
13:06	Choke size: 31/64". WHP: 1.5MPa. Mud and gas can be observed.
13:40	Choke size: 31/64". WHP: 1.5MPa. Oil and gas can be observed. H_2S: 300ppm.
14:10	Choke size: 37/64". WHP: 1.4MPa. Oil and gas can be observed. H_2S: 300ppm.
14:50	Shut in well and secured the well. WHP after shuting-in for 10mins was 2.5MPa. Estimated 20m^3spent acid and 30m^3liquids including mud, oil etc was flown out totally.
15:30	Antonoil crew leaved for camp.

Fig. 4. Daily Acidizing Report for Well Ad-12

Table 2. Fluid Parameters

Fluid Name	2% KCl Brine	Fresh water	15% HCl Gelled Acid
Description	Preflush/Overflush Fluid	fresh water	Gelled Acid
HCl Conc. (% mass)	0.0	0.0	20.0
Fluid Density	1.000	1.000	1.080
Diffusivity (ft^2/min)	4.30e-06	4.30e-06	4.30e-06
Retardation factor	1.00	1.00	1.00
Filtercake Porosity	0.01	0.01	0.01
Filtercake Permeability (mD)	1.00e-04	1.00e-04	1.00e-04
Initial Viscosity (cp)	1.00	1.00	
Initial n'			1.000
Initial k' (lbf·s^n/ft²)			2.10e-05
Wellbore Friction Multiplier	1.00	1.00	1.00

Table 3. Formation Layer Parameters

Layer #	Top of zone MD (m)	Lithology	Pore Fluid Permeability (mD)	Reservoir Viscosity (cp)	Compressibility (1/psi)	Porosity	Pore Pressure (psi)	Frac Pressure (psi)
1	0.0	Shale	0.00e+00	2.000	5.00e-06	0.000	3,045	5,000
2	2,798.0	Limestone	15	1.500	5.00e-06	0.170	4,686	6,900
3	2,802.7	Limestone	60	1.700	5.00e-06	0.190	4,698	7,001
4	2,813.0	Shale	0.00e+00	0.030	2.49e-04	0.000	4,015	7,383

Table 4. Damage Profile

Int	MD (m)	Damage Severity	Original Skin	Damage Penetration	Damage Depth(ft)	Damage Composition
1	0	Light	0.0	Shallow	0.00	Shale
2	2,800	Light	3.0	Shallow	0.20	Limestone
3	2,807	Light	3.0	Medium	0.30	Limestone
4	2,813	Light	0.0	Shallow	0.00	Shale

Table 5. Drilled Hole Configuration

Length (m)	Segment Type	Eff Diam (in)	Bit Diam (in)
2,814	Open Hole	8.500	8.500

Table 6. Casing Configuration

Length (m)	Segment Type	Casing ID (in)	Casing OD (in)	Weight (lb/ft)	Grade
2,814	Cemented Casing	6.520	7.000	17.000	N-80

Table 7. Surface Line and Tubing Configuration

Length (m)	Segment Type	Tubing ID (in)	Tubing OD (in)	Weight (lb/ft)	Grade
2,700	Tubing	2.362	2.875	4.600	N-80
2	Packer	2.370	6.500	0.000	

Table 8. Path Summary

Segment Type	Length (m)	MD (m)	TVD (m)	Dev (deg)	Pipe ID (in)
Tubing	2,700	2,700	2,700	0.0	2.362
Casing	113	2,813	2,813	0.0	6.520

Table 9: Rock Thermal Properties

Rock Type	Sandstone	Limestone	Shale
Specific Gravity (sg)	2.71	2.72	2.71
Specific Heat*	0.260	0.210	0.200
Thermal Conductivity**	2.57	0.910	1.01

Table 10. Fluid Thermal Properties

Fluid Name	2% KCl Brine	Fresh water	15% HCl Gelled Acid
Specific Gravity (sg)	1.000	1.000	1.08

Parameters for Heat Transfer Model

Surface Fluid Temperature	70.00	(°F)
Surface Rock Temperature	70.00	(°F)
Reservoir Temperature	200	(°F)
Wellbore Heat Transfer Multiplier	1.00	

The Stimpro acidizing model considers the intrinsic variances in matrix acid for carbonates and sandstones. As wormholes grow in carbonates, matrix stimulation is more effective because it allows the formation to be penetrating farther than the damaged near-wellbore area allows. Wormhole development in carbonate acidizing may be calculated using two different models in this new edition of Stimpro: A semi-empirical method by [16] is used as the default model, whereas Péclet number theory is used for the alternate model [17]. Carbonate matrix acidizing treatment is optimized by considering both the wormhole skin and the transient radial flow pressure.

- Pressure Matching

Once all the necessary data and parameters have been input, we begin the simulation using the Semi-empirical model with $PV_{\mathrm{bt-opt}}$= 0.55 and $V_{i-\mathrm{opt}}$=0.0322 ft/min stored in the Software database [16]. Afterward, a comparison of the pressure match plot between calculated and measured wellhead pressure is performed and a comparison between calculated and measured bottom-hole pressure.

Treatment data with bottom hole and fracture pressures may be shown in Fig. **5**, which displays the results of our studies; fluctuating fluid diverting effects cause bottom-hole pressure to vary. For matrix acid treatments, jobs were typically pumping below the hydraulic fracture pressure of the formation pressure.

The model's reaction to its experimental work data built-in Software is overstated since the modeled pressure values are substantially lower than the actual data. Therefore, the simulated pressure data does not very well match the observed pressure data. Utilizing our experimental [9] data $PV_{\mathrm{bt-opt}}$=2.5 and $V_{i-\mathrm{opt}}$=0.0206 ft/min as input data to enhance the pressure match. Thus, a more accurate match between estimated and observed surface pressures is achieved (Fig. **6**).

Once sufficient pressure data has been obtained, the changing skin may be anticipated. Figure 5.33 demonstrates that the treatment reduced the wellbore skin from around ٣ at the start of the operation to approximately -3.6 at the end of job. Most likely, deep-penetrated wormholes were generated in the carbonate formation, ensuring the effectiveness of this acid treatment.

The Fig. **7** illustrates the estimated skin, injection rate, and acid concentration of fluid for three phases of treatment, all of which are proportional to the time spent acidifying the matrix. Referring to the buildup analysis for Ad-12 [9], the skin value of -3.97 is approximately identical to or slightly larger than the skin value estimated by the acid treatment simulation using STIMPRO software.

The depth profile is shown in Fig. **8** summarizes the reservoir parameters, formation damage, and the model computation of fluid invasion via the flushed formation in three phases. As can be discriminated, the treated zones are divided into two layers based on the Formation Layer Parameters (Table **5** to Table **9**); the first layer is 4.7 m thick with a permeability of 15 md and a porosity of 0.17; the second layer is 10.3 m thickness with a permeability of 65 md and a porosity of 0.19. When the simulator was performed, the invading fluid revealed two distinct depths of investigation inside the treated zone. The fluid invasion in the bottom area has remained steady at a distance of 95 inches (7.91 ft) despite the top layer wormhole penetrating to a depth of 32 inches (2.67 ft).

The effective permeability of two layers is 15-60 md; accordingly, utilizing Eq. (5) to compute wellhead or bottom hole injection pressure for various skin factor (S) values since assuming acid injection rates. As a result, the computation is shown in the Fig. **9**, which plots many curves of injection rate vs. wellhead pressure, one for each skin component (s). It is found that most predicted wellhead pressures are less than the fracture pressure, indicating that the acid job treatment may be conducted safely without breaking the formation. The only problem is that if there is formation damage to the skin of 5, and the injection rate exceeds 5 bpm, the bed will frack, indicating that the treatment job will fail.

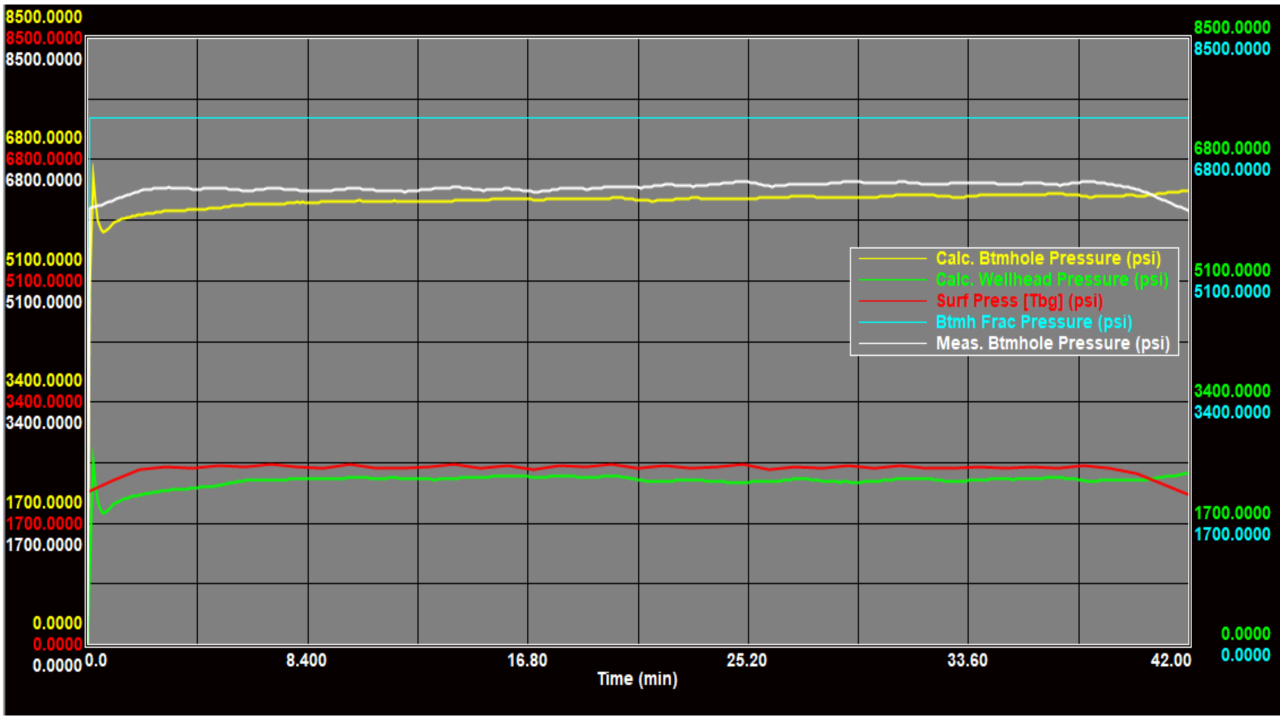


Fig. 5. The Pressure Match between Actual and Calculated for Surface and Bottom Hole of Stimulated Well Ad-12

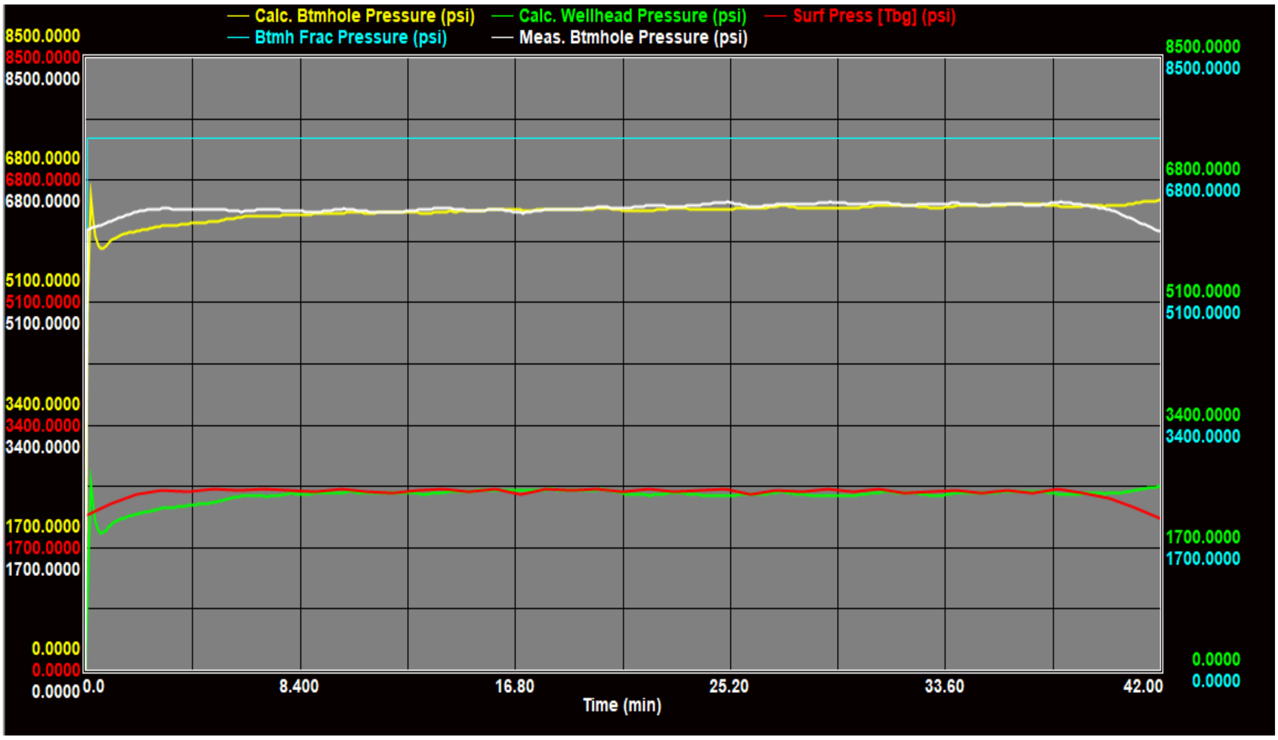


Fig. 6. The Pressure Match between Actual and Calculated for Surface and Bottom Hole of Stimulated Well Ad-12, using Our Data Set

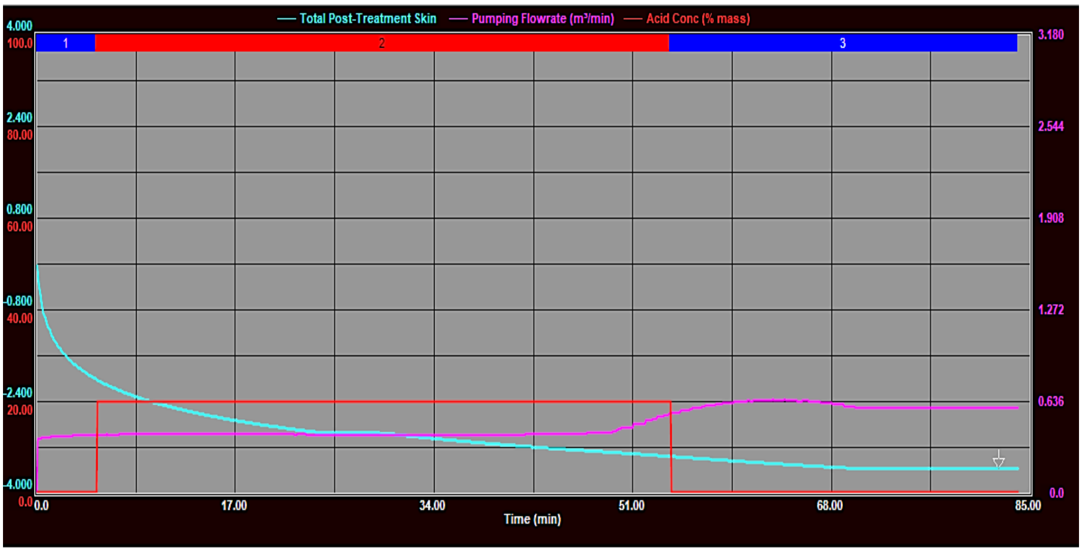


Fig. 7. Skin Factor Computation for Well Ad-12

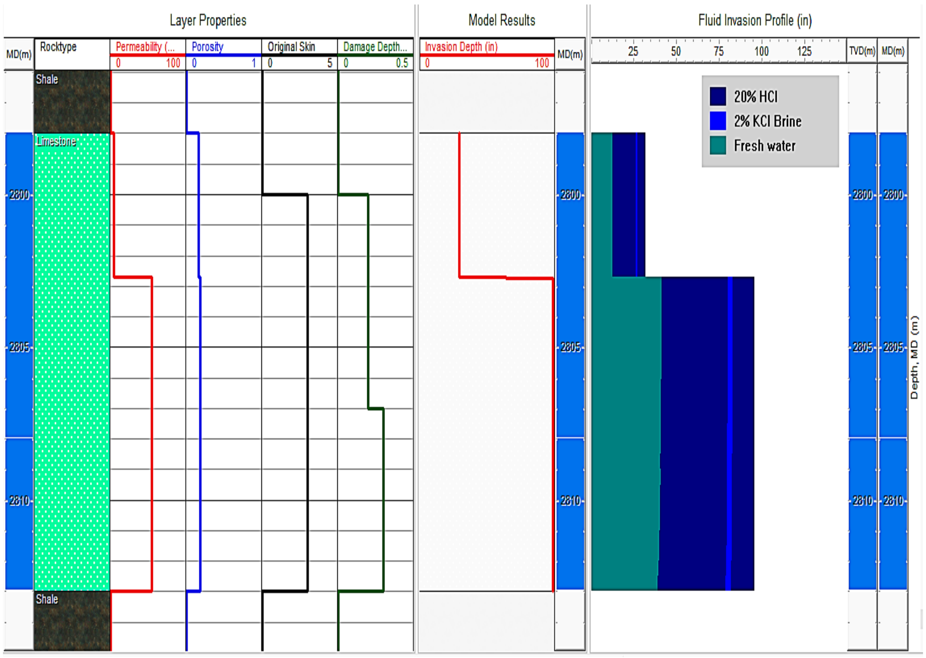


Fig. 8. Invasion Profile, Layer Properties and Model Treatments Schedule for Well Ad-12

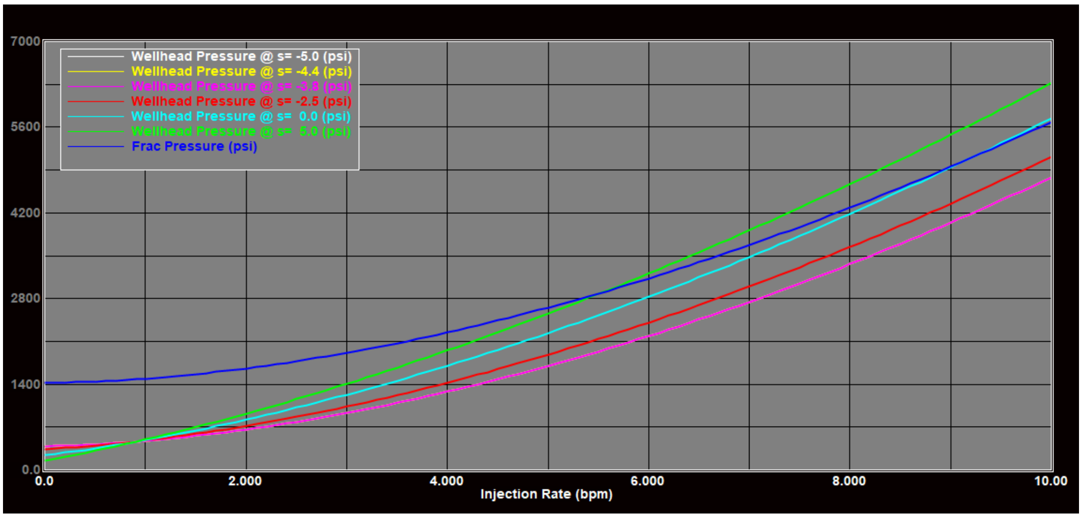


Fig. 9. Treatment of the Matrix Stimulation Design Chart for Well Ad-12

7- Conclusions

In Stimpro Software, the model's response to its experimental work data has been overestimated since the predicted pressure levels are far lower than the real data. As a result, the simulated data on pressure does not match the actual data on pressure very well. Experiment with a pressure match of PV_{Bt} =2.5 and v_i= 0.206 ft/min, using our experimental data as input data. As a result, the predicted and measured surface pressures are more closely matched.

The changing skin may be predicted if enough pressure data is collected. Wellbore skin was decreased from around 3 at the commencement of the operation down to about -3.6 at the completion of the project. The acid treatment's success was presumably ensured by creating deep-penetration wormholes in the carbonate deposit.

STIMPRO's acid treatment simulation predicted a skin value of -3.97 for Ad-12, which is close to or slightly bigger than the skin value predicted by the buildup analysis.

References

[1] M. J. Economides, A. D. Hill, C. Ehlig-and Economides, and D. Zhu, *Petroleum Production Systems*, SECODN EDI. PENTICE HALL, 2013.

[2] M. J. Economides and K. G. Nolte, *Rerservoir Stimulation*, 3rd ed. Wiley, 2000.

[3] M. J. Economides, A. D. Hill, and C. Ehlig-and Economides, *Petroleum Production Systems*. 1994.

[4] U. S. Alameedy, "Evaluation of Hydrocarbon Saturation Using Carbon Oxygen (CO) Ratio and Sigma Tool," *Iraqi J. Chem. Pet. Eng.*, vol. 15, no. 3 SE-Articles, pp. 61–69, Sep. 2014.

[5] J. A. Al-Sudani and K. M. Husain, "Evaluation of Acid and Hydraulic Fracturing Treatment in Halfaya Oil Field-Sadi Formation," *Iraqi J. Chem. Pet. Eng.*, vol. 18, no. 4 SE-Articles, pp. 25–33, Dec. 2017.

[6] M. Najeeb, F. S. Kadhim, and G. N. Saed, "Using Different Methods to Predict Oil in Place in Mishrif Formation / Amara Oil Field," *Iraqi J. Chem. Pet. Eng.*, vol. 21, no. 1 SE-Articles, pp. 33–38, Mar. 2020, doi: 10.31699/IJCPE.2020.1.5.

[7] U. Alameedy, "EXPERIMENTAL STUDY AND ANALYSIS OF MATRIX ACIDIZING FOR MISHRIF FORMATION-AHDEB OIL FIELD," PhD, Dissertation, University of Baghdad, 2022, doi:10.13140/RG.2.2.25412.91525.

[8] T. O. Allen and A. P. Roberts, *Production Operations*, 3rd printi. Tulsa, Oklahoma: Vol.2., 1978.

[9] U. Alameedy and A. Al-haleem, "The Impact of Matrix Acidizing on the Petrophysical Properties of the Mishrif Formation: Experimental Investigation," *Iraqi Geol. J.*, vol. 55, no. 1E, pp. 41–53, May 2022, doi: 10.46717/igj.55.1E.4Ms-2022-05-20.

[10] U. Alameedy, A. A. Alhaleem, A. Isah, A. Al-Yaseri, M. Mahmoud, and I. S. Salih, "Effect of acid treatment on the geomechanical properties of rocks: an experimental investigation in Ahdeb oil field," *J. Pet. Explor. Prod. Technol.*, Jul. 2022, doi: 10.1007/s13202-022-01533-x.

[11] G. Paccaloni, M. Tambini, and M. Galoppini, "Key Factors for Enhanced Results of Matrix Stimulation Treatments," Feb. 1988, doi: 10.2118/17154-MS.

[12] Y. Wang, A. D. Hill, and R. S. Schechter, "The Optimum Injection Rate for Matrix Acidizing of Carbonate Formations," *SPE Annual Technical Conference and Exhibition*. p. SPE-26578-MS, Oct. 03, 1993, doi: 10.2118/26578-MS.

[13] G. Paccaloni and M. Tambini, "Advances in Matrix Stimulation Technology," *J. Pet. Technol.*, vol. 45, no. 03, pp. 256–263, Mar. 1993, doi: 10.2118/20623-PA.

[14] L. P. Prouvost and M. J. Economides, "Applications of Real-Time Matrix-Acidizing Evaluation Method," *SPE Prod. Eng.*, vol. 4, no. 04, pp. 401–407, Nov. 1989, doi: 10.2118/17156-PA.

[15] Carbo, "Tutorial manual." 2021.

[16] M. Buijse and G. Glasbergen, "A Semi-Empirical Model To Calculate Wormhole Growth in Carbonate Acidizing," Oct. 2005, doi: 10.2118/96892-MS.

[17] G. Daccord, E. Touboul, and R. Lenormand, "Carbonate Acidizing: Toward a Quantitative Model of the Wormholing Phenomenon," *SPE Prod. Eng.*, vol. 4, no. 01, pp. 63–68, Feb. 1989, doi: 10.2118/16887-PA.

أداء البئر بعد معالجة تحميض الحشو الصخري: دراسة حالة لوحدة Mi4 في حقل نفط الأحدب

أسامة العميدي[1], اياد عبد الحليم[1] و عبد الامير المالكي[2]

١ قسم هندسة النفط–كلية الهندسة – جامعة بغداد
٢ قسم هندسة النفط –كلية علوم وهندسة الارض – جامعة ميسكولك

الخلاصة

يمكن تحسين إنتاجية آبار النفط من خلال تحديد قيمة تحسين إنتاجية البئر والأسباب المحتملة أو مصادر الضرر الناتج عن التكوين بعد التعرف على أن أداء البئر ضعيف. قد تتحسن إنتاجية آبار النفط، لكن اقتصاديات هذا التحسن التدريجي قد تتعرض للخطر. من المهم تحليل تأثير تأثيرٍ Skin على الحد الاقتصادي واستعادة الاحتياطي. قد تتعرض اقتصاديات التحسن التدريجي لتأثير Skin للخطر.

نتيجة المعالجة بالحامض، تتشكل قنوات جديدة (ثقوب دودية) في الصخور الكربونية، متجاوزة الأضرار التي لحقت بجوف البئر وتسمح بتدفق المياه إلى البئر. باستخدام برنامج Stimpro يتم جدولة الضخ زمنيا بعد اختيار السوائل والأحماض المناسبة لنوع التضرر الطبقي. تقرر القيام بمهمة التحميض في ٢ ديسمبر ٢٠١١ للبئر Ad-12 الذي يستهدف مكمن مشرف، ولا سيما وحدة Mi4، لإزالة أضرار طين الحفر والانتهاء من منطقة الدفع وتحسين أداء التكوين من خلال تعزيز النفاذية، وبالتالي زيادة إنتاج النفط. يستخدم Stimpro لتحليل معالجة الصخور الكربونية محمضة وإظهار كيف تتوافق بيانات الضغط المقاسة والمحاكاة. للبدء، ستحتاج إلى جمع بيانات عن حالة البئر ونوع السوائل وخطة العلاج.

الكلمات الدالة: مكمن مشرف, المعالجة بالحامض.