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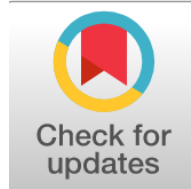
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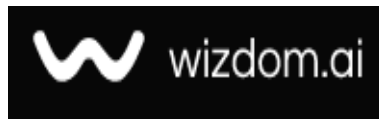
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Applied Model for Horizontal Well Matrix Acidizing

Model Terapan untuk Pengasaman Matriks Sumur Horisontal

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Abstract

General Background: Horizontal wells often exhibit low productivity due to formation damage induced by drilling, work-over, production, and injection operations, which impair the physical integrity around the wellbore. **Specific Background:** Matrix acidizing has been widely adopted to mitigate such damage, especially in complex horizontal well environments where acid distribution along the wellbore directly influences stimulation effectiveness. The process is particularly intricate in reservoirs with varying geological properties, necessitating a thorough understanding of acid-rock interactions and damage mechanisms. **Knowledge Gap:** Despite extensive historical use of acidizing since the late 19th century, challenges remain in optimizing acid placement, minimizing formation damage, and enhancing well productivity, especially in heterogeneous reservoirs. **Aims:** This study investigates the mechanisms of formation damage, evaluates the role of different acid types and additives in carbonate and sandstone reservoirs, and models acid distribution to improve stimulation outcomes in long horizontal wells. **Results:** The modeling approach effectively simulates acid placement and wormhole formation, demonstrating enhanced productivity and damage mitigation. Historical advancements, from early HCl treatments to modern mud acid applications, were analyzed to contextualize current practices. **Novelty:** The integration of advanced simulation techniques with an in-depth analysis of acid interactions offers new insights into optimizing matrix acidizing, particularly under variable reservoir conditions. **Implications:** The findings provide a framework for designing more efficient acidizing treatments, reducing operational costs, and improving hydrocarbon recovery. This research contributes to the broader understanding of formation damage control, guiding future strategies in well stimulation and reservoir management.

Highlights:

Formation Damage: Causes, impact, and mitigation strategies.

Acidizing Process: Optimization of acid placement and additive use.

Modeling Approach: Simulates acid flow for better well stimulation.

Keywords: Horizontal wells, Formation damage, Matrix acidizing, Acid-rock interaction, Well stimulation

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Introduction

Acid may be used to specific types of damage close to the wellbore in all type of formation, in-organic, organic and combination of these acids, along with surfactant are employ in different of well stimulation treatment in carbonate formation, acid may use to produce linear flow system by etching hydraulically – create fracture. Acid fracturing is not applicable to formation of sandstone [1,2].

There are two primary kinds of acidizing are characterized during injection rate and pressure. injection rate lower than fracture pressure are termed acidizing of matrix whereas those more than fracture pressure is termed fracture acidizing [3].

Acidizing of matrix: is utilized mainly to eliminate harm reasoned by drilling, work- over, completion, fluid injection, well-killing, and by scale deposits of material from production and water flooding, because excessively large surface area touched by treatment of acid in matrix, time required is extremely short. For this, it is hard to effect reservoir rocks above few feet from the wellbore. With the sandstone reservoirs, actually HF acid penetration is usually below 12 in" [4,5].

Elimination of avail plugged-in sandstone, or can outcome in a very big rise in well productivity, if there is no skin factor a matrix treatment in dolomite or limestone can stimulate natural production no more than one-half time, matrix treatment tends to leave zone fences right if pressures are preserved under fracture pressure. one of the problems in matrix acidizing is that fracture or breakdown pressure of the formation in specific well is not always known; because breakdown pressure will decrease with a decrease in pressure of reservoir. it is necessary to run breakdown test with clean water or oil to determine the fracture of specific zone prior to acidizing [6,7].

For breakdown test, the recommended method is to start clean oil or pumping water in to the reservoir at low rate like (0.25) to (0.5) bbl./min for thin zone and determine pressure of pumping, if desired injection rate is reached prior to "breakdown" at this pressure or ever lower pressure the acidizing process to be applied, the resulted pressure from acid in the well and surface pressure should be below the fracture pressure. [8,9].

Acid is fracking is type of hydraulic fracking which replace the proppants in the conventional hydraulic fracturing, the fracture face etching with acid, acidizing produce channel of linear flow from the reservoir to the well, acid fracturing of relatively homogenous carbonates may produce relative smooth fracture face [10,11].

Methods

The earliest oil wells acid treatment is believed to have happened as far back as 1895. Limestone acidizing with HCl (Herman Freasch, 1928) actively use HCl for cleaning pipes and other tools from calciferous scaling (John Grebe and Dow Chemical, 1932) used arsenic acid as corrosion inhibitor for acid treatment (HCl), acidizing with (HF) (Jesse Russel Wilson, 1933), Acidizing of a well with a mixture (HCl/ HF) for formation of huge amount of sand, (Dowell, 1940) Commercial use of Mud Acid (12% HCl and 3% HF), (McLeod's, 1984) provide guidelines for mud acid ratios as a function of the type and concentration of silicate minerals present in the reservoir.. The standard Oil Company used concentrated hydrochloric acid (HCl) to stimulate oil wells producing from carbonate formation in Lima, Ohio, at their Solar Refinery. The process of acidizing was used with marked results in the short term.

Though, the first acid handling in (1895) was possibly considered a novel idea that would not last very long, and acidizing was used very infrequently during the next 30 years probably due to the lack of an effective method for limiting acid corrosion. (Halliburton, 1933) carried out the first treatment of sandstone acidizing utilizing a hydrochloric mixture and hydrofluoric acid (HF), in a test well belonging to the King Royalty Co., near Archer City, Texas. Unfortunately, the results of first attempt were very discouraging. (Glasbergen and Buijse, 2005) established a fluid located simulator on the basis of the (Jones and Davies model, 1996). They verified good skin factor and pressure; the results are given matching in two cases studied by them.

(Mishra et al. 2007) study acidizing process in carbonate reservoir. They utilize variable injection rate with a transient reservoir outflow equation which is generally utilized in well testing. To calculate for the influence of the acid stimulation, they altered the skin factor at every level of time by supposing that the wormhole region pressure drops is negligible. (Furui et al., 2010) presented a combined acid located method. Their procedure is built on the (Mishra et al. 2007). Formation damage: could be explain as each lowering in permeability near the bore hole that is the result of many operations in the well such as drilling, production, and work over.

From study of dissimilar oil field and for long time show that industry spends 100 billion dollars to understanding and avoiding the formation damage. The formation damage occurs in different stuff: Drilling operation, Completion operation, attempted stimulation, Production operation, Injection operation, well intervention. The choice of good completion system depends upon the producing and well intervention necessities during the well's life. Cementing of casing is also one of the most basic stages in the drilling and completion of oil and gas wells process. Damage

during attempted stimulation: The damage during attempted stimulation caused by: precipitation and dissolution of Iron, Fracture fluid damage, migration of Fines, Damage mechanism. Formation failure: Types of acid Chemists knew a lot of acids and acid listed in the table below are the most common of which is sequenced according to their strength and that most of them have been thinking for use in the oil fields at different times. Table (1) list of acid according their strong.

OPERATION	% OF TOTAL DAMAGE	IMPACT REMOVABLE (1-5)	IMPORTANCE
Drilling	25%	2	50%
Completion	25%	3	75%
Attempted stimulation	15%	4	60%
Production	15%	3	45%
Well intervention	10%	4	40%
Injection	10%	2	20%

Table 1. *Damage risk assessment.*

Formula Type of acid	Weight of ionized hydrogen%	Type of formation
HF	5.0% strongest	NHAR UMRS , ZUBAIR .
H3PO4	3.06%	UMM ER RADHUMA, TAYARAT ,ETC .
HCL	2.75%	HARTHA , SADI , ETC
HCOOH	2.17%	TANUMA , KHASIB, ETC
H2SO4	2.05%	MISHRIF , RUMAILA ,ETC
CH3COOH	1.66%	AHMADI , MAUDDUD ,ETC
HNO3	1.58%	YAMMAM ,MISHRIF ,ETC
CH3CH2COOH	1.35% the weaker	TANUMA , RUMAILA ,ETC

Table 2. *List of acid according their strong*

Acids that used in oil acidification operation must be meet particular requirement and should have specific specification that is: must interact with the desired material that interacts and the resulting soluble material, it must be possible to prevent it from interacting or control over interaction with steel, it should be trading by non-dangerous and non-toxic, Must be relatively cheap and readily available in the study of the list of common eight acids note that there are four acids only meet four requirements above, which was: Hydrofluoric acid HF, Hydraulic acid HCL, Formic acid HCOOH, Acetic acid CH3COOH. Do not use these acids without additions only and these additions are used to prevent corrosion inhibitors or sedimentation However, these acids it is only the Stones major construction that brings them all acids that used in oil well stimulation.

2.1. ACIDZING FLUIDS

2.1. 1 HYDROFLUORIC ACID (HF):

Hydrofluoric acid used in oil wells and gas is usually a concentration of 3% mixed with 12% of hydrochloric acid and this mixture is used in the treatment of sandy rocks to dissolve the natural clay or MUDs, which have migrated to the configuration. The melting 1000 kg of slurry needs 12 cubic meters of acid concentration 4.2%. Sometimes the hydrofluoric acid does not use to stimulate sandstone formation that contain some of carbonates because speed of the reaction and made deposits [14].



Figure 1.

2.1.2. HYDROCHLORIC ACID (HCL):

The hydrochloric acid used in oil field usually at concentration 15% by weight. It can be changing the concentration from 5% to 32 % and the freezing temperature of hydrochloric acid at 15% concentration is (-32.87 C) Hydrochloric acid dissolves the limestone, dolomite and other carbonates according to the following equation:



Figure 2.

10 cubic meters of HCL at 15% concentration can dissolve (2200kg) or (0.784 cubic meter) of limestone with porosity equal to zero. the above reaction produces (2454 kg) of calcium chloride and (972 kg) or (493cubic meter) of carbon dioxide in standard condition of pressure and temperature in addition to produce (9100 kg) of water, (10 cubic meter) of 15% HCL can dissolve (2050kg) or (0.717 m³) of dolomite with porosity equal to zero, this interaction produces 10.2 cubic meters of 10.5% solution of a mixture of calcium chloride and 9% of magnesium chloride, which weighs 1162 kg \ cubic meters [15,16].

2.1.3. ACETIC ACID (CH₃COOH):

Weakly -ionized, a low reacting organic acid and it is easy to control the corrosion caused due to the fact that real power is less than the strength hydrochloric acid, it can dissolve the calcium carbonite according to the equation

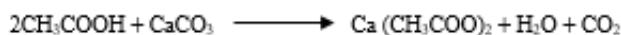


Figure 3.

(10 cubic meter) with 10% concentration of the acid can dissolve (1330 kg) of limestone The cost of dissolving a certain amount of limestone equivalent to three times the cost of dissolving the same amount by hydrochloric acid, however it is used widely in deep wells warm because it is easy to control the corrosion resulting and can usually be left in contact with the production pipeline and casing for days without erosion occurrence of unacceptable to these tubes as a result the acetic acid used as a perforation fluid in limestone [17].

2.1.4. FORMIC ACID (HCOOH):

Weakly -ionized, allow reacting organic acid and its properties are similar to acetic acid corrosion control are relatively more difficult, especially at high temperatures, has no common use enjoyed by acetic acid. There are another type of acid such sulfamic acid the major advantage of this acid it can be brining to the site in a powder form But the disadvantages of this acid it is more expensive than hydrochloric acid and cannot be used at temperature above 82 C.2.3 Type of acid additives: using acids can results several problem , including the acid can create particles that can result blocking Productive formation, Forming emulsions, forming mud (sludge), cause corrosion of steel, Surfactants, suspending agents, sequestering agents, Anti sludge agents, inhibitors, Fluid loss control agent.

There are some factor effects on acid reaction with the formation: Pressure, Temperature, Acid strength, Formation composition, Acid velocity, and Area-volume ratio [18].

2.2. HORIZONTAL WELL IN CARBONATE MATRIX ACIDIZING RESERVOIR

Process of matrix acidizing, the acid is injected in to the formation during production tube, drill pipe, or coiled tubing. The acid disolges the fluid of wellbore, forming interface between unlike fluids. The acid flow in the formation and create wormhole in the reservoir rock growing the injectivity of the touched portion of the formation. to simulate the process of acidizing above, all the processes are studied together.

2.2.1. MODEL OF WELLBORE FLOW:

Model of the flow of wellbore is advanced according to balance of material of wellbore and pressure drop estimation of wellbore. Injected of the fluids through the process of injection of acid are generally incompressible so incompressible flow of single phase in the wellbore is supposed to advance these equations. Liquid (single phase) flow through is injected of reservoir by a fully penetrating horizontal well is considered. It is also expected which all of the reservoir flow is perpendicular to the wellbore. q_w is the wellbore flow rate, and q_r is specific reservoir outflow i.e., per unit length Since the flow changes of rate along the wellbore is caused by the fluid flowing into the reservoir, p_w is pressure of wellbore at any point in the wellbore, by material balance, we have [1]:

$$\frac{\partial q_w}{\partial x} = -q_r$$

Figure 4.

Equation 2.1 states which the definite reservoir outflow, q_r (bbl/ft) should be equal to the reduction in flow rate of wellbore per unit length, q_w (bbl). Fig.1 diagram of a section of wellbore during a process of acidizing.

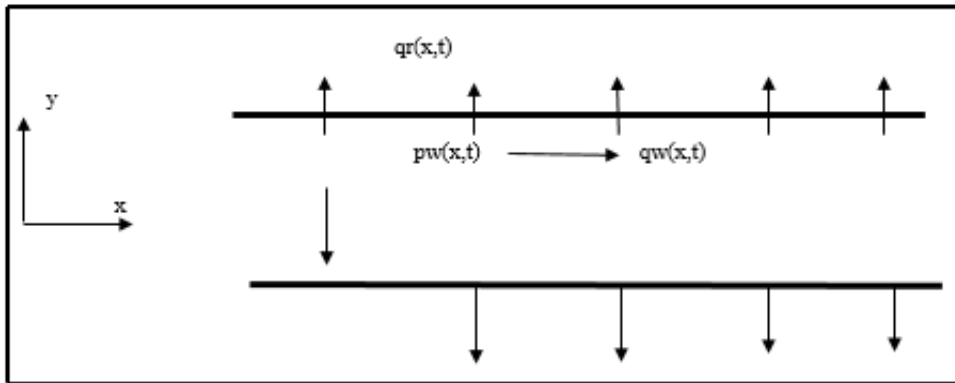


Figure 5. Diagram of a section of wellbore during a process of acidizing.

If fluid has a fixed density and constant flow occurs in a horizontal pipe, then drop of friction pressure is gained from the Fanning equation [1]:

$$\Delta P_f = \frac{2ff \rho u^2 L \text{ pipe}}{gc d} \quad (2)$$

Form the above equation in the differential can be written as [1]:

$$\frac{\partial p_w}{\partial x} = \frac{2ff \rho u^2}{gc d} \quad (3)$$

If u and ff in the above equation a defined as the fluid velocity and Fanning friction factor respectively [1]:

$$u = \frac{q_w}{A} \quad (4)$$

Eq. 3 is rearranged for the field units of oil as [1]:

$$\frac{\partial p_w}{\partial x} = -1.525 \frac{ff \rho q_w^2}{d^5} \quad (5)$$

Figure 6.

Hence p_w is the well pressure in (psi), x is the distance in (ft), ρ is the injected fluid density in (lbm/ft³), d is the well diameter in (inches), q_w is the flow rate inside the well in (bbl/d).

Equation 5 offers the pressure drop equation in a horizontal wellbore during the process of injection of acid. This equation will be together with the other equations of system to setup the model of matrix acidizing.

Friction factor of the Fanning according to the pipe roughness (ϵ) and on Reynolds number (NRe). Flow of fluid is considered as turbulent or laminar, depending on the value of (NRe), defined for a circular pipe as [10]:

$$ff = \frac{16}{NRe}$$

Figure 7.

Appropriate units must be used in the number estimation of Reynolds so that NRe is dimensionless. When Reynolds number is lower than 2000, laminar flow happens within the pipe. Reynolds number is larger than 4000, for turbulent flow. If number of Reynolds lies between 2000 and 4000, the flow is called transitional. Friction factor of The Fanning is most normally gained from the chart of friction factor of Moody. [10]:

$$NRe = \frac{d u \rho}{\mu}$$

Figure 8.

An explicit equation for the friction factor, for turbulent flow is the Chen equation [11,19]:

$$ff = \frac{16}{NRe} \quad (7)$$

An explicit equation for the friction factor, for turbulent flow is the Chen equation [11,19]:

$$\frac{1}{\sqrt{ff}} = -4 \log_{10} \left\{ \frac{\varepsilon}{3.7065} - \frac{5.0452}{NRe} \left[\frac{\varepsilon^{1.1098}}{2.8257} + \left(\frac{7.149}{NRe} \right)^{0.8981} \right] \right\} \quad (8)$$

Figure 9.

2.3. MODEL OF WORMHOLE

When the acid (HCl) is injected into rocks of carbonate, because of very great surface reaction rates, limits of mass transfer, the overall reaction rate, leading to greatly non-uniform dissolution shape, and few big channels are created known as wormholes. Wormholes bypass the damaged near area of wellbore and develop the conditions of flow. Fig. 2 show the wormhole propagation through damage zone. The volumetric model is according to the supposed that a constant fraction of the rock volume is dissolved in the area penetrated by wormholes. The volumetric model flow of radial, is:

$$rwh = \sqrt{r_w^2 + \frac{V/l}{\pi \phi P V b t}}$$

Figure 10.

Where rwh is wormhole distance tip from the center of wellbore, (v/l) is the acid injected volume per formation of unit length. The rock small fraction is dissolved when only a few wormholes are shaped; more branched wormhole structures dissolve greater the matrix fractions. In this model the key parameter is $PVbt$, the pore volumes number of acid needed to propagate a wormhole during a fixed distance. r_w is the wellbore radius, ϕ is the porosity and gc is gravitational constant [1,12,13].

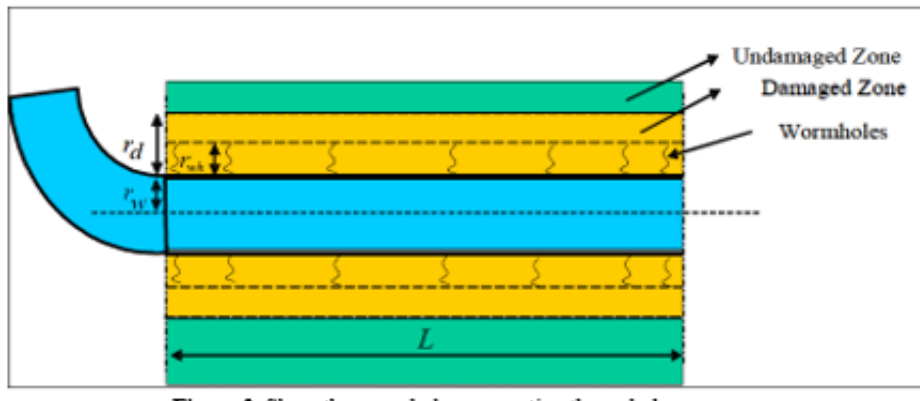


Figure 11. Show the wormhole propagation through damage zone

As we know that the temperature affects the time of acid consumption, whenever the temperature increased acid consumption, so the goal of this project is to reduce the effect of temperature on acid consumption, there are two type of heat sources that can add heat to acid

2.4. DESIGN PROCEDURE FOR MATRIX ACIDIZING OF CARBONATE

The design procedure for matrix acidizing of carbonate formation involve determining the type of acid, the volume, maximum injection rate and maximum injection pressure without fracture

2.4.1. DETERMINING THE FRACTURE PRESSURE BY

Applying the leak-off test and then record the surface pressure [10,20]:

$$P_{f.g} = \alpha + (P_o - \alpha) \cdot \frac{P_{res}}{d} \quad (10)$$

$P_{f.g}$ = fracture gradient (psi/ft)

α = constant (0.33 - 0.5)

Po = overburden pressure gradient (psi/ft)

Pres = reservoir pressure (Psi)

d = depth (ft)

2.4.2. DETERMINING THE MAXIMUM INJECTION RATE WITHOUT FRACTURE [11,21]

$$Q_{max} = 4.917 * 10^{-6} * K_{av} * h_n * \frac{(P_f.g + d - P_{res})}{\mu \ln(\frac{r_e}{r_w})}$$

Figure 12.

Qmax = Maximum injection rate (bbl/min)

Kav = Average permeability (md)

Hn = Formation thickness (ft)

μ = Acid viscosity (c.p)

Re = reservoir radius (ft)

Rw = well radius (ft)

In practice we applied injection rate (10%) less than the Qmax that calculated in equation 11 as a safety factor

2.4.3. DETERMINE MAXIMUM SURFACE PRESSURE TO INJECTION ACID WITHOUT FRACTURE [10,22]

$$P_{max} = (P_f.g - P_{hy}) * d + \Delta P_f \quad (12)$$

Phy = hydrostatic pressure (psi/ft)

Δ Pf = pressure losses by friction (psi)

Δ Pf can be calculated by using equation (2) or equation (13) [1,10]:

$$\Delta P_f = \frac{518 \rho^{0.79} q^{1.79} \mu^{0.207} L}{1.000 D^{4.79}}$$

Figure 13.

ρ = fluid density, g/cm³

q = rate of injection, bbl/min

μ = viscosity of fluid, cp

D = diameter of tubing, in.

L = length of tubing, ft.

The hydrostatic pressure of acid (Phy) can be calculated by using the Fig.3 show the wormhole propagation through damage zone.

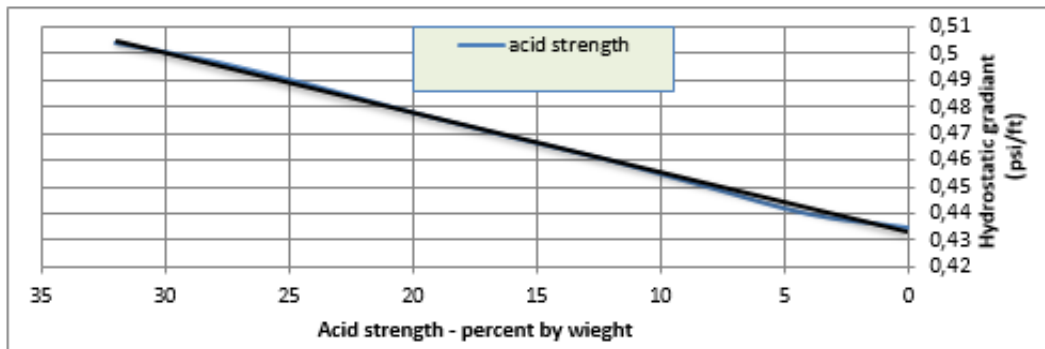


Figure 14. Determining the hydrostatic pressure of acid.

2.5. REQUIRED ACID VOLUME PER UNITE THICKNESS OF FORMATION (gal)

According to the model of wormhole propagation presented by Daccord et al. (1989), the volume of re acid quired per unit formation thickness can be evaluated using the following equation [10,23]:

$$V_h = \pi [(r_{wa}^2 - r_w^2) / (2 \cdot PV_{bt})] \quad (14)$$

V_h = Required acid volume per unite thickness of formation (ft³/ft)

PV_{bt} = is a number of pore volume of acid injected at the time of wormhole breakthrough the end of core.

2.5.1. VOLUME OF WATER:

The volume of water require to diluting the initial acid concentration can be determine by using the following equation [1]

$$V_s = \frac{V_w + PC_w + SG_w}{PC_o + SG_o}$$

Figure 15.

V_s = volume of strong acid (gal)

V_w = wanted volume of acid (gal)

PC_w = wanted acid concentration (%)

SG_w = specific gravity of wanted acid

PC_o = original acid concentration (%)

SG_o = original specific gravity

$$V(\text{water}) = V_w - V_s \quad (16)$$

2.5.2. WORMHOLE PROPAGATION RATE

For previous acid job the propagation rate of wormhole can be determine by using the (9) equation [1]

$$r_{wh} = \sqrt{r_w^2 + \frac{V_{I1}}{\pi \phi PV_{bt}}} \quad (17)$$

V/I = current injection volume ($\frac{ft^3}{ft}$)

$$(V/I) = \frac{\text{Total injection volume}(\frac{gal}{ft})}{\text{Total injection time}} * \text{current time} \quad (18)$$

Figure 16.

2.5.3. FRACTURE ACIDIZING PROCEDURE [1,10]

$$\sigma_v = \frac{1}{144} * \rho * D \quad (19)$$

σ_v = Vertical stress (psi)

ρ = Rock density (lb/ft³)

D = Depth (ft)

$$\sigma'_v = \sigma_v - \alpha P_p \quad (20)$$

σ'_v = Effective vertical stress (psi)

P_p = pore pressure (psi)

α = Biot's poro-elastic constant, approximately (0.7)

$$\sigma'_h = \frac{v}{1-v} * \sigma'_v \quad (21)$$

σ'_h = Horizontal stress (psi)

$$\sigma_h = \sigma'_h + \alpha P_p \quad (22)$$

$$\sigma_{h \max} = \sigma_{h \min} + \sigma_{\text{tec}} \quad (23)$$

$$P_{bd} = 3\sigma_{h \min} - \sigma_{h \max} + T_o - P_p \quad (24)$$

P_{bd} = Break-down pressure (psi)

T_o = tensile strength (psi) that can be determine by the following curve

$$P_{\max} = (P_{bd} - P_{hy}) + \Delta p_f \quad (25)$$

Figure 17.

2.5.4. EVALUATION OF STIMULATION PROCESS [1,24]

$$\frac{J_s}{J_o} = \frac{\left(\frac{K_s}{K}\right) * \log\left(\frac{r_w}{r_{wd}}\right)}{\log\left(\frac{r_w}{r_{wd}}\right) + \left(\frac{K_s}{K}\right) * \log\left(\frac{r_w}{r_{wd}}\right)}$$

Figure 18.

K_s = permeability of damage zone

K = Normal permeability of the reservoir

J_s = Productivity index of damage strata

J_o = Productivity of non-damage strata

Result and Discussion

3.1. ACID STIMULATION JOB IN NHR-UMR FORMATION WITH THE FOLLOWING RESERVOIR CHARACTERISTICS (SHOWN IN TABLE. 3.1) :

Properties	value
P reservoir	5000 psi
Xxc Thickness h	60 ft
Permeability K	50 md
Type of formation	S.S (sandstone)
Depth	9500 ft
SG of acid (HF)	1.07
	1.5 cp
D tubing	2 in
Rw	0.328 ft
Re	3000 ft
S (skin factor)	+15
Rwa	3 ft from the wellbore
Pvbt	0.9

	0.15
Total injection time	100 min

Table 3. Acid stimulation job in Nhr-Umr formation

A-From eq. (10)

$$FG = 0.33 + (1 - 0.33) * (5000 / 9500)$$

$$FG = 0.69 \text{ (psi/ft)}$$

$$PF = 0.69 * 9500 = 6485 \text{ psi}$$

From eq. (11)

$$Q_{\max} = 4.917 * 10^{-6} * 50 * 60 * \left\{ \frac{(6485 - 5000)}{1.5 + \ln\left(\frac{2000}{0.328}\right) + 1.5} \right\}$$

$$Q_{\max} = 1.013 \text{ (bbl/min)}$$

B- From eq. (13)

$$\Delta PF = \frac{518 * (1.07)^{0.79} * (1.013)^{1.79} * (1.5)^{0.287} * 9500}{1000 * (2)^{4.7}}$$

$$\Delta PF = 222 \text{ psi}$$

C- From fig. (3)

$$P_{hy} = 0.438 \text{ (psi/ft)} * 9500 \text{ (ft)} * (1.07) = 4453 \text{ psi}$$

5-From eq. (12)

$$P_{\max} = (6485 - 4453) + 222$$

$$P_{\max} = 2254.7 \text{ psi}$$

6- from eq. (14)

$$V_h = * 0.15 [(3)^2 - (0.328)^2] * 0.9 ; V_h = 3.771 \frac{ft^3}{ft} ; V_h = 28.2 \frac{gal}{ft}$$

Figure 19.

$$V_h = * 0.15 [(3)^2 - (0.328)^2] * 0.9 ; V_h = 3.771 \text{ (ft}^3\text{)(ft)} ; V_h = 28.2 \text{ gal /ft}$$

$$\text{Total volume} = V_h \text{ (gal/ft)} * \text{thickness (ft)} = 28.2 * 60 = 1692 \text{ gal}$$

The volume of water requires to dilute the initial acid concentration can be determined by using eq. (15) and (16). Another acidizing job: 5000 gal of (HCl) acid require to stimulate (MISHRIF) formation with concentration 15%, if you know that the primary concentration of acid is 30% SG w , (15% HCl) = 1.0725, SG o (30% HCl) = 1.149

Solution:

$$V_s = (5000 * 15 * 1.0725) / (30 * 1.149)$$

$$V_s = 2333 \text{ gal (volume of strong acid)}$$

$$V_{\text{water}} = 5000 - 2333$$

$$V_{\text{water}} = 2667 \text{ gal}$$

This calculation can be carried out by simple software called (iBook) If we change the original concentration of (HCl) acid all the other parameter will be change. Fig. (4) Show wormhole penetration rate. For previous acid job the propagation rate of wormhole can be determine by using the (9) equation. Current time divided from (0, 0.1, 0.2, 100 min.)

At $T = 0$ min and from eq. (18)

$$(V/I) = \frac{28.2 \frac{\text{gal}}{\text{ft}}}{100 \text{ min}} * 0 \text{ min} = 0 \text{ (gal/ft)}$$

$$rwh = \sqrt{(0.328)^2 + \frac{0}{0.9 + \pi * 0.15}} = 0.328 \text{ ft}$$

At $T = 0.1$ min

$$(V/I) = \frac{28.2 \frac{\text{gal}}{\text{ft}}}{100 \text{ min}} * 0.1 \text{ min} = 0.0282 \text{ (gal /ft)}$$

$$rwh = \sqrt{(0.328)^2 + \frac{0.0282}{0.9 + \pi * 0.15}} = 0.4172 \text{ ft}$$

Figure 20.

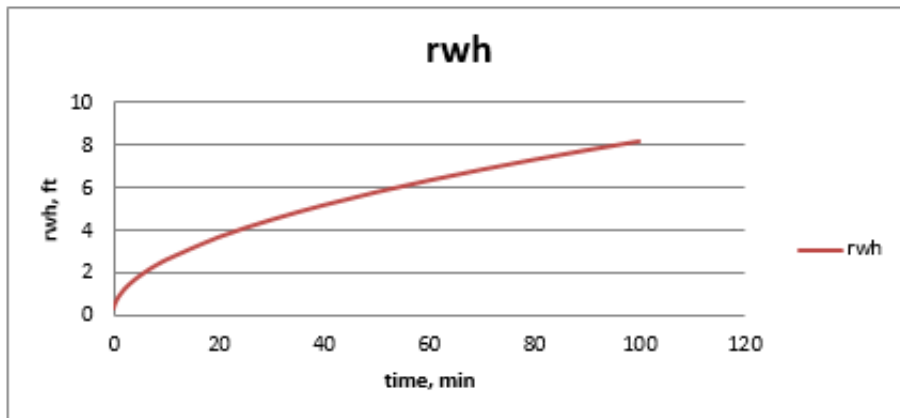


Figure 21. show wormhole penetration rate.

3.2. FRACTURE ACIDIZING PROCEDURE

Depth, D	10,000 ft
N	0.25
A	0.72
Desity,	165
Pore pressure, Pp	0.38 psi / ft
□□ tectonic	2000 psi
Tensile strength, To	1000 psi

Table 4. Carbonate stimulation job with the following data

Eq. (19) - (25) to be used:

$$\square\square v = (165 * 10000) / (144) = 11500 \text{ psi}$$

$$\square\square'v = 11500 - 0.72 * (0.38 * 10000)$$

$$\square\square'v = 8800 \text{ psi}$$

$$\square\square'h = 0.25 / (1 - 0.25) * 8800 = 2900 \text{ psi}$$

$$\square\square h = 2900 + 0.72 * (0.38 * 10000)$$

$$\square\square h (\text{min}) = 5700 \text{ psi}$$

$$\square\square h (\text{max}) = 5700 + 2000 = 7700 \text{ psi}$$

$$Pbd = 3 * (5700) - 7700 + 1000 - (0.38 * 10000)$$

Pbd = 6600 psi

During creating fracture we use some type of solid such(small balls of glass or sand) to prevent fracture to return to it is primary situation before fracture and then injected acid to stimulate the strata, hydraulic fracture treatment is used to avoid the spending of acid before it complete the stimulation.

3.3. EVALUATION OF STIMULATION PROCESS

Assume the following data: $r_s = 0.75$ ft , $r_w = 0.5833$ ft , $K = 100$ md, $K_s = 5$ md, $r_e = 1000$ ft. To determine value of productivity after eliminate the damage the following procedure should be follow productivity index equation to be used eq. (26) :

$$\frac{J_s}{J_o} = \frac{\left(\frac{5}{100}\right) * \log\left(\frac{1000}{0.5833}\right)}{\log\left(\frac{0.75}{0.5833}\right) + \left(\frac{5}{100}\right) * \log\left(\frac{1000}{0.5833}\right)}$$

$$\frac{J_s}{J_o} = 0.596$$

$$J_o = 1.675 J_s$$

Figure 22.

That mean the productivity of formation after eliminate the damage is more 1.675 than productivity of damage zone (i.e the acidizing process has been success).

There are another ways to evalute the acidification process such [1]:

Production test

Productivity index equation (PI)

$$PI = \frac{Q}{\Delta p} = \frac{0.00708 k h}{\mu \beta_o \ln\left(\frac{r_e}{r_w}\right)}$$

Figure 23.

At first calculate (PI-1) before starting stimulation and after completing stimulation process calculate (PI-2) and then, If (PI-2) > (PI-1) that mean the strata has been stimulated.

As the time increase the penetration rate(r_w) of acid increase until the acid have been spend. At the end of stimulation process the evaluation equation show the well has been stimulated by increase the productivity index ($J = 1.6 J_s$). Increase the acid concentration require for more volume of water to dilution.

Conclusion

The stimulation process is not a simple process, but you need to experience when planning and precision in carrying out in order to get the desired results. It is prohibited to use acids alone without additives because that may lead to increased damage to the strata and also lead to damage to surface equipment and subsurface. It should be abide concentration mentioned in the search because the increase concentration lead to dissolving large amounts of rocky material, which speeds up the process of acid consumption, most common reasons that lead to the damage of the strata both of drilling and completions process by an estimated 50%. It should be study the geological structure and petrophysical properties of the strata (porosity, permeability & type of formation) through coring hole core or by logging. Acidizing required to implement (leak of test) before the acidification process to calculate fracture pressure it is very important test. Drill stem test (DST) to be achieved before and after the acidification process to see the improvement that has occurred after the completion of the acidification process. An acidification process in miniature in the laboratory on a sample of the same class to be stimulated to see the compatibility between the acid layer and then a larger operation on the class in order to know the concentrations of additives for proper operation acidification. Additives to be used in order to reduce the filtrate from the drilling fluid, such as polymers. It should be hold two wash layer before and after the acidification process to remove reaction products.

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