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Analysis of Scale Problem using Acidizing Stimulation in Field Z Kalrez Petroleum (Seram) Ltd

Sumina Idrus[1*)]
Oil and Gas Production Engineering, Ambon State Polytechnic
* corresponding email: idrussumina@gmail.com

ABSTRACT

The annual decrease in production at well Z occurs due to scale deposits that impede fluid flow. Scale is a production problem due to the mixing of two types of water with different properties so that the solubility limit of the compound in the formation water is exceeded. To overcome the scale, stimulation is carried out with an acidizing method using a type of acid (HCL 10%). Evaluation was conducted to determine the effect of acidizing stimulation on scale based on productivity index (PI), inflow performance relationship (IPR) curve and comparison of stimulation methods. Evaluation of test results after acidizing stimulation of well Z experienced an increase in production. Productivity Index increased from 4.748 bbl/psi to 9.036 bbl/psi. Based on the IPR curve before acidizing, the maximum flow rate (Q max) = 324,107 bpd, increased to Qmax = 769,021 bpd.

Keywords: *Cost Benefit, Productivity Index, Scale, Acidizing Stimulation*

I. INTRODUCTION

Scale is a production problem in water systems caused by changes in pressure, temperature and pH that cause the ion balance to exceed solubility and form deposits in reservoirs, production zones, or along oil and gas production pipelines. By mixing two different types of water so that the solubility limit of the compound is exceeded in the resulting water mixture and scale deposits are formed (Diky & Syahrial 2017).

Kalrez Petroleum Seram ltd's "Z" well has considerable scale potential that has resulted in a decline in production over the years. In 2017, the indication of scale in the Z well was discovered when conducting well work in the form of unplugging the production circuit. The presence of solids in the reservoir can reduce the permeability of the rock thus reducing oil production. When scale sticks to flow pipes, it damages the pipes and complicates oil and gas production (Diky & Syahrial 2017).

Scale must be monitored continuously because when oil moisture content is low and dispersed water is small, the rate of scale formation is proportional to the rate of free water formation, depending on where the water in the formation becomes saturated. In an effort to restore and maintain the amount of production that has decreased due to scale, a work over operation is carried out. One of the work over jobs is to stimulate acidizing Agusandi, D. P. (2017).

Acidizing stimulation is a well improvement process that aims to increase the flow rate in the formation by injecting a certain amount of acid into the well. The main principle of this method is to dissolve materials that block reservoir flow by injecting acid into the well. Usually, the objective The purpose of acidification is to reduce formation damage and increase permeability by expanding rock pores and dissolving particles that inhibit flow in rock pores (Mety & Rahmact, 2015).

II. METHODS

The methods used in this study include field observations, formation water sampling and then analyzed quantitatively to obtain the data needed in the study.

2.1. Stiff & Davis Method

The Stiff & Davis method is used to determine the potential for calcium carbonate ($CaCO_3$) scale formation. Stiff & Davis have developed a formation water analysis method that can be applied to brine by taking into account the ion strength parameter as a correction to the total salt concentration and temperature (Henk, S., et al., 2022).

The approximate tendency of calcium carbonate scale formation can be determined based on the Scale Index (SI) value with the following conditions:

$$SI = pH - K - pCa - pAlk \qquad (1)$$

- If the SI value < 0 (negative), the system is not saturated by $CaCO_3$ and the tendency for scale formation is low.
- If the SI value > 0 (positive), then the system is saturated by $CaCO_3$ and there is a tendency to form scale. If the SI value = 0, then the system is at the saturation point, and scale will not form.

Table 1. Ionic Strength Conversion Factor

Ion	Conversion Factor
Na^+ (Sodium)	2,20 x 10^5
Ca^{2+} (Calcium)	5,00 x 10^5
Mg^{2+} (Magnesium)	8,20 x 10^5
Cl^- (Chloride)	1,40 x 10^5
HCO^{3-} (Bicarbonate)	0,82 x 10^5
$CO3^{2-}$ (Carbon Trioxide)	3,30 x 10^5
$SO4^{2-}$ (Sulfate)	2,10 x 10^5
$HCO3^-$ (Bicarbonate)	-

2.2. Skillman, McDonald & Stiff Method

The Skillman, McDonald & Stiff method was used to determine the tendency of calcium sulfate ($CaSO_4$) scale formation. The determination of $CaSO_4$ scale formation tendency using this method is based on the following equation: The estimation of the tendency of calcium sulfate ($CaSO_4$) scale formation is based on the results of S calculation, by comparing the actual concentrations of Ca^{2+} and SO_4^{2-} present in the formation water with the following conditions:

$$S = 1000 \left(\sqrt{x^2} - 4k - x \right) \quad (2)$$

The estimation of the tendency of calcium sulfate ($CaSO_4$) scale formation is based on the results of S calculation, by comparing the actual concentrations of Ca^{2+} and $SO4^{2-}$ present in the formation water with the following conditions:

- If the S value is smaller than both the actual concentrations of Ca^{2+} and $SO4^{2-}$, then it tends to form scale $CaSO_4$.
- If the S value is greater than both the actual concentrations of Ca^{2+} and $SO4^{2-}$, then the water is not saturated with $CaSO_4$ and the $CaSO_4$ scale is not formed.

2.3. Acidizing Method

This method is used to overcome the flow resistance that occurs in the reservoir by dissolving the material through acid injection into the well. The main objective of acidizing is to reduce the effect of permeability reduction (formation damage) that occurs around the wellbore. This is done by expanding rock pores and dissolving particles that inhibit flow in the rock (Mety, A., & Rahmact, S. 2015).

1. Determining the Price of Formation Fracture Pressure

   $$BHP_{rekah} = G_f \times D \quad (3)$$

2. Determining the Maximum Acid Injection

   $$\text{Hydrostatic Pressure} = 0{,}05 \times \rho_{acid} \times D \quad (4)$$

   $$\text{Surface Pressure} = BHP_{rekah} - \text{Hydrostatic Pressure} \quad (5)$$

3. Determination of Acid Injection

   $$VT = \frac{\text{ID tubing}^2}{1029{,}4} \times \text{Length} \quad (6)$$

4. Annulus Volume

   $$VA = \frac{\text{ID Casing}^2}{1029{,}4} \times \text{Length} \quad (7)$$

2.4. Cost Benefit Analysis Method

Cost/Benefit Analysis or CBA is one of the risk evaluation methods that helps users in selecting or determining the action options that need to be taken in dealing with a risk. This approach measures and compares the benefits and costs of various risk action options (Winsky, 2019).

1. Annual Equivalent Benefit
   $AEB = \Sigma(Bt/(1+r)^{t})$ .... (8)

2. Annual Equivalent Cost
   $AEC = \Sigma(Ct/(1+r)^{\wedge}t)$ ....(9)

III. RESULTS AND DISCUSSION

3.1. Formation Water Analysis

Scale formation in general is always related to formation water, so the characteristics of formation water must be known. The formation water data obtained in this study came from the analysis of Geoservices Laboratories Kalrez Petroleum (Seram) LTD.

Table 2. Formation water test samples

No	Parameters	Unit	Analysis Result
1.	Cations		
	Na^{+}	mg/I	9216
	Ca^{2+}	mg/I	119,9
	Mg^{2+}	mg/I	383.3
	Ba^{2+}	mg/I	4.6
	Fe^{3+}	mg/I	0.36
2	Anions		
	Cl^{-}	mg/I	14070
	SO_4^{2-}	mg/I	11
	CO_3^{2-}	mg/I	Nill
	HCO_3^{-}	mg/I	2521
3	TDS (calc)		26326,16
	H2S	mg/I	5,4

Table 3. Results of Formation Water Analysis

Component	Result mg/I	Conversion Factor	Ionic Strength
HCO_3^{-}	2521	$0,82\times10^{-5}$	0,0206722
CI^{-}	14070	$1,40\times10^{-5}$	0,19698
Ca^{2+}	119,9	$5,00\times10^{-5}$	0,005995
Mg^{2+}	383,3	$8,20\times10^{-5}$	0,031431
$SO4^{2-}$	11	$2,10\times10^{-5}$	0,000231
Na^{+}	9216	$2,20\times10^{-5}$	0,202752
Total Ionic Strength			0,4581

To determine the tendency of the formation of scale $CaCo_3$ and scale $BaSo_4$ in well Z, namely by calculating the value of scaling index (SI) and solubility of gypsum (S), using stiff & davis and Skillman, McDonald & Stiff methods. The first step that must be done is to determine the ionic strength value of each ion by multiplying the ion concentration with its conversion factor so that it will get the ionic strength results as in **Table 3.**

After getting the results of ionic strenght, continue to determine the value of the scaling index (SI) and solubility of gypsum (S) by entering the value in equations 1 and 2. The results of the SI value = 8.34 are positive, so in the Z well formed scale $CaCO_{3,}$ solubility of gypsum S = 0.01 the value of S is smaller than the two actual concentrations of Ca^{2+} and $SO4^{2-}$, then it tends to form scale $CaSO_4$.

3.2. Acidizing Stimulation

To overcome scale and maintain production rates, acidizing stimulation is carried out by injecting acid so that the scale can be dissolved.

Table 4. Well Z data

Parameters	Inch	Meters	Feet
Perforation length (open hole)		16,8	55
Wellbore diameter (initial)	2 3/8		0,19792
Scale thickness estimation	1		0,08333
Wellbore diameter (scale)	2 7/8		0,23958

The type of acid used to treat scale in the Z well of Kalrez Petroleum (seram) Ltd is 10% hydrochloric acid (HCL 10%). The formation fracturing pressure gradient is calculated to find out how much pressure i s needed in the acid injection process so that no fractures occur in the formation BHP_{rekah} = 91 psi. Next calculate the hydrostatic pressure and surface pressure in order to know the maximum rate of acid to be injected hydrostatic pressure = 54 psi and Surface pressure = 37 psi. The next step is to calculate the volume of acid to be injected so that the scale that inhibits perforation can be dissolved Vol. Displacement = 63 bbl.

a. Injectivity Test

Injectivity test was conducted by injecting 150bbl of water and chemical mixture into the well to clean the well and as an initial stage to estimate the injection rate that will be used t o pump acid so that the acid injected into the formation pressure does not exceed the formation fracturing pressure.

b. Mixing

The mixing process is basically making and processing a mixture of acids added with acid chemicals to make it suitable for scale countermeasures.

c. Preflush

Preflush aims to clean the oil in the perforation hole, because if HCL meets oil it will form clumps.

d. Acidizing Stimulation Design

The selection of the type of acid and additive used must be adjusted to the type of rock and formation damage in an oil and gas well. Before performing acidizing stimulation, it is necessary to know the design and calculation data required. The goal is to know some important parameters so that the implementation in the field runs as planned.

3.3. Evaluation of the Success of Acidizing Stimulation

3.3.1. Based on Productivity Index (PI)

Productivity Index (PI) expresses the ability of a productive formation to flow fluid to the bottom of the well at a certain drowdwon price. Acidizing stimulation is said to be successful if there is an increase in PI.

Table 5. Well Z data

Parameters	Inch	Meters	Feet
Perforation length (open hole)		16,8	55
Wellbore diameter (initial)	2 3/8		0,19792
Scale thickness estimation	1		0,08333
Wellbore diameter (scale)	2 7/8		0,23958

- PI Before Acidizing Stimulation

$$PI = \left[\frac{Q}{Ps - Pwf}\right]$$

$$= \left[\frac{89}{147{,}04 - 121{,}294}\right]$$

= 4,748 bbl/psi

- PI After Acidizing Stimulation

$$PI = \left[\frac{Q}{Ps - Pwf}\right]$$

$$= \left[\frac{120}{147{,}04 - 133{,}76}\right]$$

= 9,036 bbl/psi

3.3.2. Evaluation Based on Inflow Performance Relationship (IPR) Curve

Inflow Performance Relationship (IPR) curve is a plot between well bottom flow pressure (Pwf) and production rate (Q). In the Z well of Kalrez Petroleum Seram Ltd, the IPR curve was made using the Vogel method, because this method has good accuracy for two-phase flow.

Table 6. Assumed values of Pwf and Q before acidizing stimulation

Pwf (psi)	Q (bpd)
147.04	0
140	64.125
112	160.098
84	223.689
56	272.084
28	318.499
0	324.107

Table 7. Assumed values of Pwf and Q after acidizing stimulation

Pwf (psi)	Q (bpd)
147.04	0
140	152.153
112	379.872
84	530.512
56	645.584
28	725.087
0	769.021

To determine the Inflow Performance Relationship (IPR) curve, plot the graph of the Pwf assumption with the Q value before and after acidizing stimulation to see the comparison of acidizing stimulation. The results of the IPR curve before and after acidizing can be seen in **Figure 1.**

3.4. Comparison of 10% Hydrochloric Acid and 10% Formic Acid Methods from Cost Benefit Analysis

Benefit analysis, also known as cost benefit analysis, is a practical tool for estimating the profitability of a project by analyzing comprehensively, requiring an in-depth and thorough review.

Table 8. CBA estimation of 10% hydrochloric acid and 10% formic acid

Methods	Benefit Equivalent Annual	Annual Equivalent Cost	Ratio B/C
Acidizing Stimulation (10% Chloride)	2170591.816	1253433.996	1.731
Acidizing Stimulation (10% Formate)	1940631.429	1037913.564	1.869

- Annual Equivalent Benefit of Acidizing Stimulation (Chloride 10%) AEB = 2170591.816 US$ and Stimulation Acidizing (Formate 10%) AEB = 1940631.429 US$.

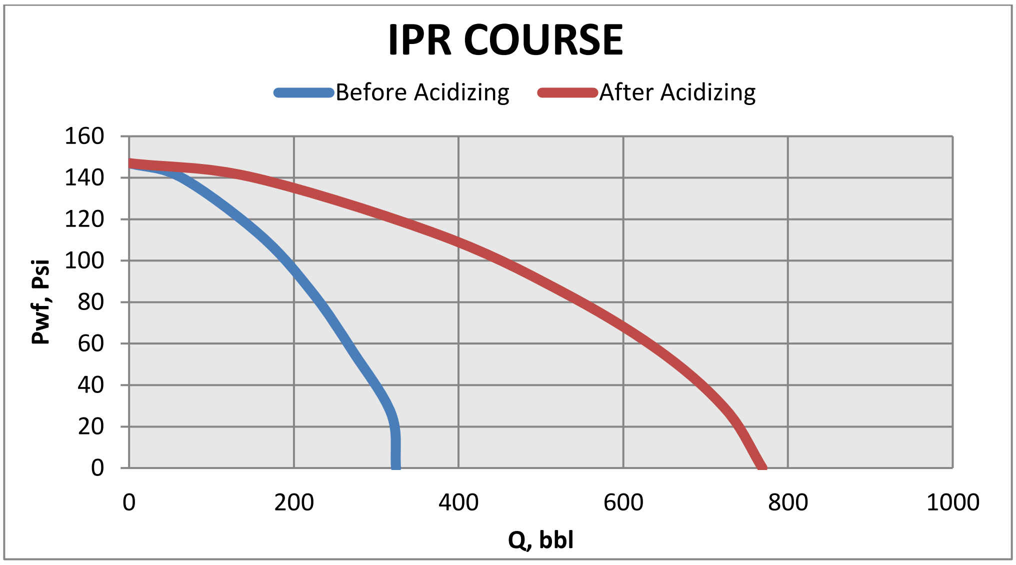

Figure 1. IPR Curves Before and After Acidizing Stimulation

- Annual Equivalent Cost of Acidizing Stimulation (10% Chloride) AEC 1253433.996 US$ and Stimulation Acidizing (Formate 10%) AEC =1037913.564 US$

Comparing the Acidizing Stimulation (Formate 10%) method with the 0 "Do Nothing" method. The increase in benefits from method 0 to the Stimulation Acidizing (Formate 10%) method is 1940631.429 US$ and the increase in costs is 1037913.564 US$. Thus the B/C ratio of the increase is

$$B/C_{B\text{-}0} = \frac{1940631.429}{1037913.564} = 1.9$$

$B/C_{B\text{-}0} > 1$, then the Acidizing Stimulation method (Formiat 10%) is selected, then the Acidizing Stimulation method (Formiat 10%) is compared with the Acidizing Stimulation method (Chloride 10%), so that the B/C ratio is increased as follows

$$B/C_{A\text{-}B} = \frac{\text{Benefit Equivalent } A - \text{Benefit Equivalent } B}{\text{Cost Equivalent } A - \text{Cost Equivalent } B}$$

$$= \frac{2170591.816 - 190631.429}{1253433.996 - 1037913.564} = 1.1$$

From this it can be concluded that the Acidizing Stimulation method (10% formate) is the best than the Acidizing Stimulation method (10% chloride), so Acidizing Stimulation (10% formate), which is chosen, in summary the selection of methods can be seen in **Table 9** below.

Table 9. Summary of Method Selection

Methods	Annual Benefits	Annual Cost	ΔA/ΔB ratio	Decision
B-0	1940631.429	1037913.564	1.9	Formate (10%)
A-B	229960.388	215520.432	1.1	Formate (10%)

IV. CONCLUSION

1. Well Z formed a $CaCO_3$ scale of 8.34 meq/lt and a $CaSO_4$ scale of 0.01 meq/lt which were analyzed based on physical data and chemical content of formation water obtained from the laboratory.
2. To overcome the scale problem, acidizing stimulation was carried out at a depth of 870 ft with 35 liters of mutual solvent, 101 liters of acid + chorotion inhobitor with injected acid volume of 60 bbl.
3. After acidizing stimulation, the average production of well Z has increased, based on the Productivity Index (PI) after acidizing stimulation has increased from 4.748 bbl/psi to 9.036 bbl/psi. The results of the Inflow Performance Relationship (IPR) curve reading, before acidizing the maximum flow rate (Q max) = 324,107 bpd, increased to Qmax = 769,021 bpd.

4. Based on the Cost Benefit Analysis (CBA), the Acidizing Stimulation method (10% formate) was chosen to overcome the scale problem because the B/C ratio >1 or 1.9 means that for every 1 US$ invested in the Acidizing Stimulation method (10% formate), a savings ratio o f 1.9 will be obtained. So it is very reasonable to decide that the Acidizing Stimulation method (10% formate), is feasible and more useful and efficient.

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