ANALYSIS OF THE SUCCESS OF ACID WASHING STIMULATION USING COILED TUBING AS AN EFFORT TO INCREASE PRODUCTION OF WELLS X-1 AND X-2

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ABSTRACT: *Oil production in Indonesia has decreased as wells age, one of which is due to blockages scale which causes a decrease in productivity. This research aims to analyze the success of stimulation acid washing using coiled tubing in increasing production from wells X-1 and X-2 in the Sukowati Field. Evaluation is carried out by comparing production data before and after stimulation based on oil production rate parameters (Qo), skin factor (S), productivity index (PI), and flow efficiency (FE). The research results show that acid washing stimulation is effective in increasing production. In well X-1, production increased from 143 BOPD to 304 BOPD, while well X-2 experienced an increase from 140 BOPD to 322 BOPD. The skin factor experienced a decrease indicating a temporary reduction in resistance to fluid flow productivity index and flow efficiency experienced an increase which reflects the improvement in the well's ability to flow fluids. Factors that influence the success of stimulation include formation conditions, perforation density, well production history, and selection of the type and volume of acid used. This study can be said to be successful because the well can return to its original well performance after stimulation of acid washing by using coiled tubing.*

KEYWORDS: *Acid Washing, Coiled Tubing, Carbonate Formation, Productivity Index, Skin Factor*

1.0 INTRODUCTION

Oil production in Indonesia continues to decline as the age of wells increases and challenges in production operations increase. One of the main causes of such decline is formation damage (formation damage), especially due to blockage scale which is formed in the area around the perforation hole and production tubing. Scale is precipitation that results from the process of crystallization and mineral deposition in the formation of water. Areas that are in direct contact with formation water during the production process, including formation matrices and fractures, well pits, pipes, and production equipment on the surface constitute the formation site scale. Scale can inhibit the flow of fluids from the reservoir to the well, thereby significantly lowering productivity [1].

The Sukowati Field is one of the oil and gas fields operated by PT Pertamina EP Regional 4 Zone 11, with the characteristics of carbonate formations. The two wells that were the focus of this study, namely wells X-1 and X-2, experienced a decrease in production rates even though the reservoir pressure was still sufficient for *natural flow*. This decrease is strongly suspected to be caused by blockages in the perforation zone, as indicated by the results of the evaluation of *the run-in hole gauge cutter* and the *scaling index,* which showed a significant positive value.

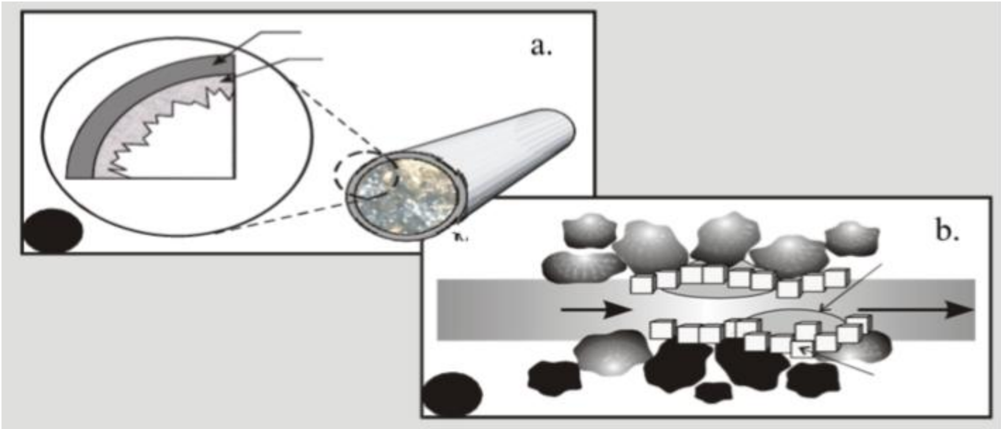

Figure 1. Sediment *Scale* (a. On Pipes; b. On Formations) [2]

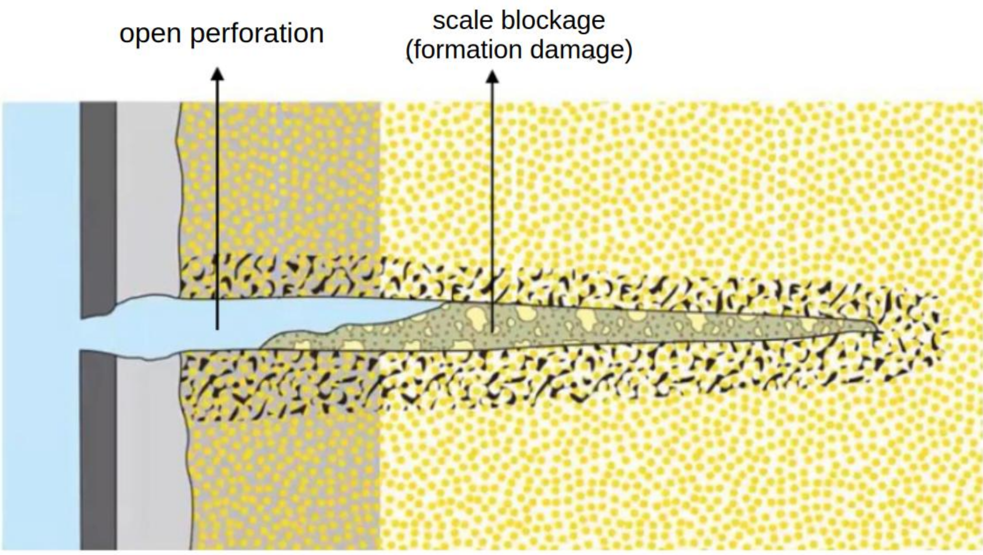

Figure 2. Illustration of Formation Damage in Perforation Due to Perforation Scale [3]

To solve this problem, one of the commonly used methods is acidification stimulation (acidizing), especially stimulation work acid washing Using coiled tubing unit (CTU). Acid washing is a procedure of acidizing which aims to remove deposits scale around the well pit (tubing) and open the perforation hole that is clogged by scale [4]. Coiled tubing (CT) is a rollable tubing made of steel material that is between 0.067 and 0.25 inches thick and between 1-5 inches in diameter [5]. Method coiled tubing This allows acid injection in a directional manner directly into the target zone without contaminating other formations. Different from the bullheads, coiled tubing provides flexibility, operational efficiency, and higher effectiveness in dissolving deposits scale.

This study aims to analyze the effectiveness of acid washing stimulation using *coiled tubing* in improving the production performance of X-1 and X-2 wells. Evaluation was carried out based on technical parameters such as oil flow rate (Qo), *skin factor* (S), *productivity index* (PI), and *flow efficiency* (FE), before and after treatment. In addition, the study also identified factors that affect the success of stimulation work, such as formation characteristics, perforation density, and the type and volume of acid used.

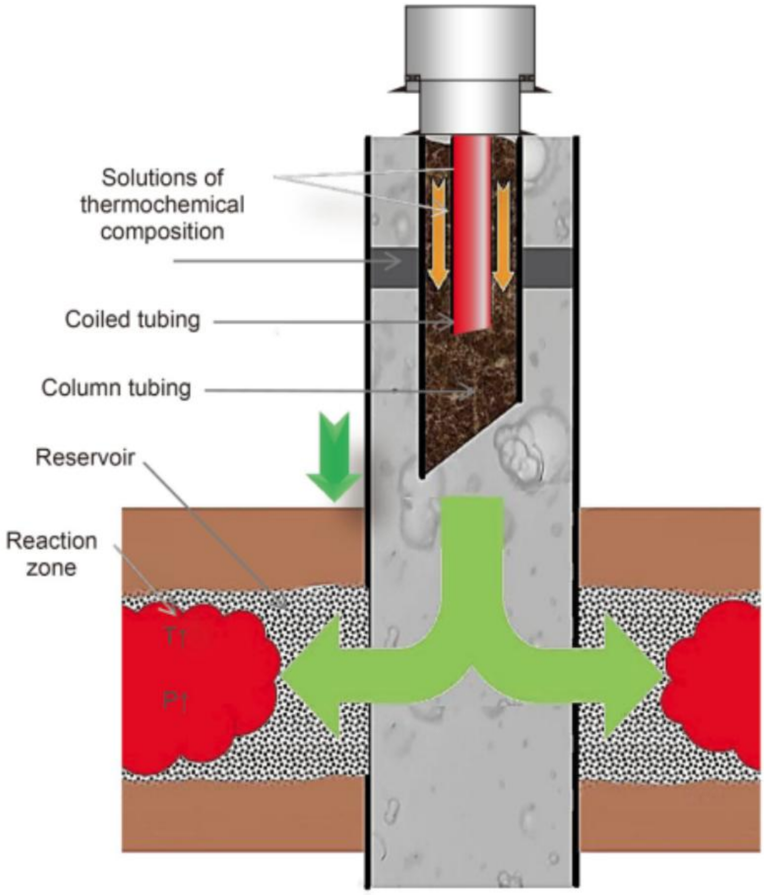

Figure 3. Illustration of the current CT Mechanism *Acidizing* [6]

2.0 RESEARCH METHODOLOGY

2.1 Location and Research Object

This research was conducted in the Sukowati Field managed by PT Pertamina EP Regional 4 Zone 11. The wells that are the object of study are wells X-1 and X-2 which are in carbonate formations (Tuban Formation), with depths of 7610 ftMD and 6727 ftMD respectively. The research was carried out for two months, from January to February 2025.

2.2 Data Types and Sources

The data used in this study consisted of primary and secondary data, namely:

- Well data includes reservoir pressure (Ps), well bottom pressure at flow (Pwf), permeability (k), oil viscosity (μo), porosity, well radius (rw), discharge radius (re), formation thickness (h), and formation temperature.
- Production data, namely oil flow rate (Qo) before and after stimulation.
- Data on acid washing *stimulation operations* include the type of acid, concentration, volume, and stages of work implementation.

Table 1. X-1 and X-2 Well Sump Data

Paramater	X-1	X-2	Unit
Well depth (MD)	7610 MD / 6759 TVD	6727 MD / 6491 TVD	Ft
Reservoir Pressure, Ps	2516	2664	Psi
Well bottom flow pressure, Pwf	2070	2228	Psi
Well Head Pressure, Pwh	145	180	Psi
Temperature, T	265	258.9	degF
Porosity	0.15	0.15	faction
Permeability (k)	167.22	167.40	mD
Well radius (Rw)	0.71	0.71	Ft
Drainage radius (Re)	5,475	2,900	Ft
Oil viscosity	2.32	2.32	cp
Water cut	91.4	93.3	%
Formation thickness/productive zone (h)	10	15	Ft
Formation Pressure gradient	0.41	0.44	Psia/ftTVD
Water fracture gradient	0.433	0.433	Psi/ft
Oil fracture gradient	0.356	0.356	psi/ft
Bo	1.535	1.535	RB/STB
Flow rate before stimulation	143	140	BOPD
Flow rate after stimulation	304	322	BOPD

2.3 Research Procedure

This study uses a quantitative approach by comparing the performance of the well before and after acid washing stimulation. The methodological stages include:

1. Identify problems, based on production decrease and pressure data.
2. The implementation of *acid washing* stimulation, using *coiled tubing* with a 15% HCl solution, accompanied by *pre flush*, *main acid*, and *post flush* stages.
3. Evaluation of the success of stimulation is carried out by calculating the following parameters:
4. Comparative analysis was carried out on Qo, S, PI, and FE values before and after stimulation to determine the effectiveness of the work and what factors affected the results of the two wells, namely X-1 and X-2.

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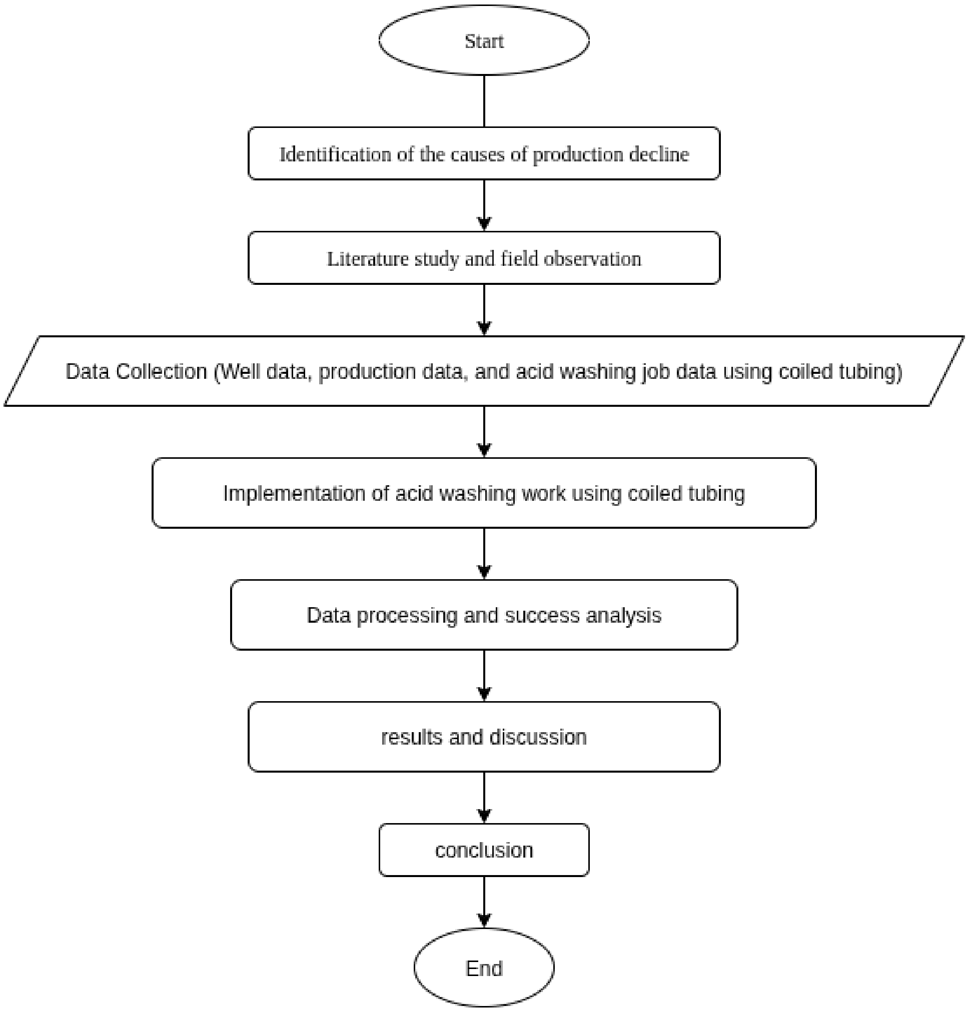

Figure 4. Research Flow Diagram

3.0 RESULTS AND DISCUSSION

3.1 Analysis of Acid Use and Implementation of Stimulation Work Acid Washing

Production history before stimulation, where the last oil production before the well *shut in* in the X-1 well was recorded at 143 BOPD and the X-2 well at 140 BOPD. This decrease in production indicates the existence of *formation damage* Consequences of sediment *scale* on the area of the face of the perforation hole. To overcome this, stimulation is carried out using acid *washing*, which aims to eliminate *scales* that are clogged in the perforation hole. The implementation of acidification stimulation in the two wells uses the *pumping* that is *coiled tubing*. Use *coiled tubing* on stimulation surgery *acid washing* Because it can inject the same directly into the perforation hole area without hitting other areas or zones. Moreover, *coiled tubing* is an operating equipment that does not take up too much space and process *rig up* and *rig down* that does not take up too much time [5].

Injection *acid* in these X-1 & X-2 wells uses 15% HCl as *main treatment* to remove *scale* which clog around the perforation hole. *Acidizing treatment* Using this 15% acid is more successful in limestone than in sandstone, due to the ability of limestone to react with *acid* on the job*matrix* *acidizing* thus forming *wormhole*, as seen in Figure 5. This provides better flow conductivity and increased productivity [7].

The advantage of using HCl acid is that it is a type of acid that is readily available compared to other acids (such as organic acids). However, on the other hand, the use of HCl acid becomes very corrosive at hot temperatures, where the formation temperature in the X-1 and X-2 wells can be said to have a hot temperature of 258.9 ^{o}F and 265 ^{o}F. At hot temperatures, acids react too quickly with rocks, reducing penetration into the formation (*live acid penetration*). These X-1 and X-2 wells that are included in carbonate rocks, if the acid reacts with the reaction formation very quickly, causing face *dissolution (*only dissolved surfaces). Therefore, it is necessary to add additional additive modifications to reduce these problems, namely *non-emulsifier agent* which aims to prevent the formation of emulsification between acids and oils within the formation and *live acid penetration* deeper because of the controlled reaction. Addition of ingredients *chelating agent* It is also necessary to stabilize reactions at hot temperatures, reduce corrosion, and be able to dissolve carbonate minerals. In the X-2 well before stimulation *acid washing*, injected *Low Acid* which aims to condition the hot temperature of the formation and dissolve at the same time *Scale*. In addition, the addition of surfactants aims to slow down the reaction without reducing the dissolving capacity [8].

The use of a concentration of 15% provides high effectiveness at a low cost. A concentration of 15% is considered optimal in the efficient placement of acids into the formation with the target dissolution of carbonate rocks without causing damage to weak boundary zones. Although HCl is corrosive, the use of a concentration of 15% allows the use of effective corrosion inhibitors to protect well and pipeline equipment. Higher acid concentrations will require more expensive and complex corrosion inhibitors and can lead to high corrosion of metal tubing [9].

3.2 Well Productivity Before and After Stimulation Acid Washing

3.2.1 Oil Production Rate (Qo)

Acid washing *stimulation in* the X-1 well began on March 23, 2024, and continued until March 28, 2024. Meanwhile, the X-2 well starts from June 24, 2024, to July 1, 2024. The results obtained before and after *acid washing* stimulation can be seen in the graph below. After acid washing stimulation using coiled tubing, there was a significant increase in the oil production rate from both wells. In the X-1 well, production increased from 143 BOPD to 304 BOPD (an increase of 112.7%), while in the X-2 well it increased from 140 BOPD to 322 BOPD (an increase of 129.8%). This shows that acid washing is effectively able to open the scale blockage in the perforation hole area.

In the results above, there is a significant difference in results because there is one of the different works, namely in the X-2, that scale clean out (SCO) is also carried out. This can be seen from the graph that the X-2 well has quite a lot of problems so that the graph shows a decrease that is every time and there are no significant increase fluctuations. This is inversely proportional to the X-1 well having a history of significant fluctuations in production which can be seen in the graph image.

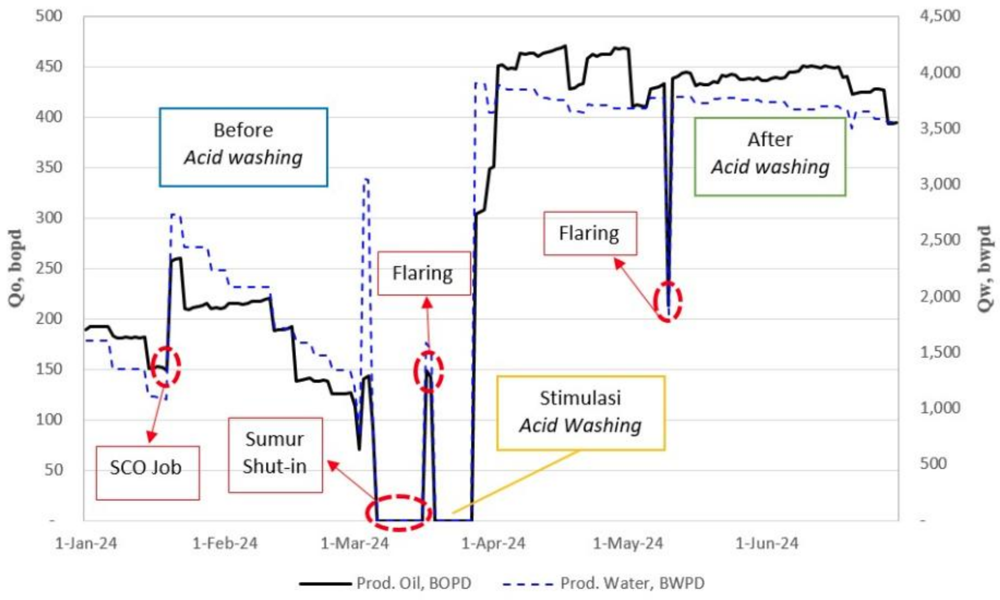

Figure 5. X-1 Well Production Graph Before and After Stimulation

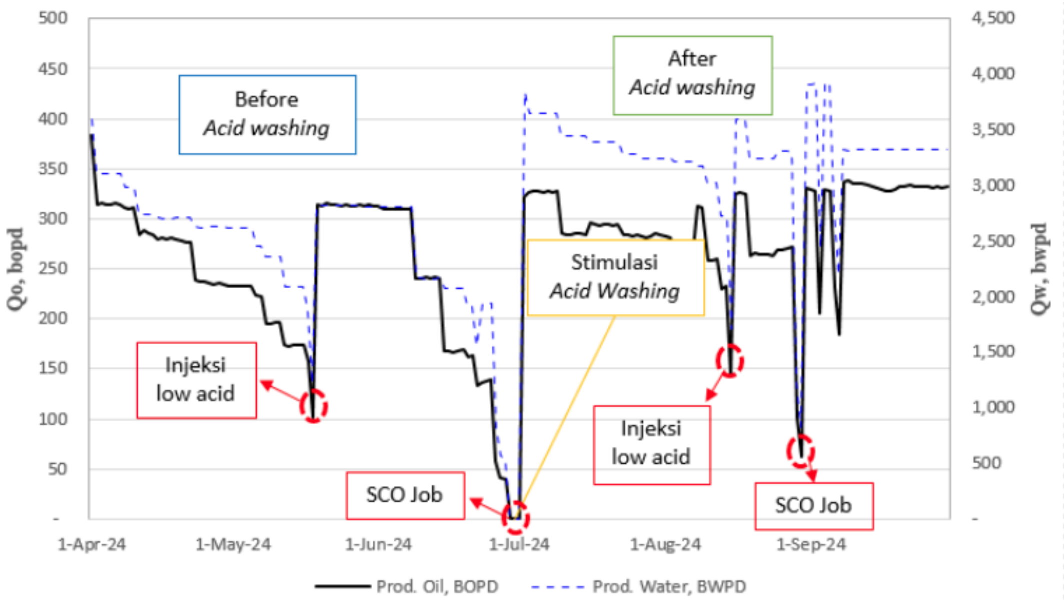

Figure 6. X-1 Well Production Graph Before and After Stimulation

3.2.2 *Skin Factor (S)*

Analysis using the radial flow approach showed that the skin value in the X-1 well dropped from +2,163 to -2,713, indicating an improvement in formation. In the X-2 well, the skin factor decreases from +7,986 to +1,230. This decrease in the value of the skin indicates that resistance to fluid flow has been significantly reduced. This shows that the stimulation carried out is successful so that it can reduce the value of *Skin* where is it *Skin* that is less than zero or negative indicates the condition of the stimulated well [1].

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3.2.3 Productivity Index (PI)

The productivity index is the ability of a well to produce, where the PI value will increase after stimulation is carried out. The productivity index of wells X-1 and X-2 before and after the implementation of *acid washing* stimulation can be calculated have a pressure ratio when static and *Flowing* large enough to have *loss pressure* to lift the fluid to the surface due to blockage by *Scale* in the perforation hole area. Therefore, stimulation is carried out to increase permeability and decrease pressure change (ΔP) so that there is an increase in productivity [2].

3.2.4 Flow Efficiency (FE)

Flow efficiency is a comparison of the *productivity index* that is affected by the skin to *the productivity index* without the influence of the skin. To calculate the productivity index without skin influence, equation (4) is used. *The flow efficiency of* the X-1 and X-2 wells before and after the implementation of *acid washing* stimulation can be calculated. n the results of the calculation above, namely the calculation *flow efficiency* in the X-1 well the FE value before stimulation was 0.843 to 2.046 after stimulation, which increased by 142.6%. In the X-2 well, the FE value before stimulation was 0.521 to 1.554 after stimulation, which increased by 198.2%. In the results of the two wells that have been stimulated, increased results can be obtained. This indicates an increase in the ability to flow fluid. *Flow efficiency,* which is equal to one, indicates that there is no damage to the well. *Flow efficiency,* which is worth more than one, indicates that there is a repair of the well by stimulation. *Flow efficiency* that is worth less than one indicates damage to the well [10]. This indicates an increase in the efficiency of the well flow rate due to the *Skin* which is solved, and the increase in productivity of the well in flowing fluids.

3.3 Factors Affecting the Success of Stimulation Work Acid Washing

3.3.1 Perforation and Formation Thickness

The X-1 well has a perforation density of 5 spf with a formation thickness of 10 ft, while the X-2 well has 12 spf and a thickness of 15 ft. The density of perforation affects the effectiveness of acidizing; Lower perforation allows the acid to work more focused on a limited area, thus more effectively lowering *skin factor*. In contrast, perforations and higher thicknesses require a larger volume of acid to ensure an even and optimal distribution [11]. Both wells also have a high water cut, which is 89% on X-1 and 91% on X-2. This condition increases the risk of scale formation due to a reaction between dissolved ions in the formation of water and carbonate minerals such as calcite and dolomite, which are commonly found in carbonate rock formations [12]. The higher the water cut, the faster the potential for scale to form that clogs the perforation zone.

3.3.2 Production and Work History of Wells X-1 and X-2

The two wells have different production and treatment histories, as shown in Figures 6 and 7. This affects the success of *acid washing stimulation* because when the well has undergone *acidizing treatment*, of course, it will not only increase production but can damage the formation. The X-1 well showed significant production fluctuations due to several technical problems but received only one *acidizing* treatment (*scale clean out*) before *acid washing* stimulation was performed. Meanwhile, the X-2 well has undergone three *acidizing* treatments, including *low acid* injection and *scale clean out* throughout 2024.

The high frequency of treatment in X-2 risks causing formation damage, especially in carbonate rocks that are sensitive to acid dissolution. Repeated use of high-concentration acids can erode rock structures and reduce the strength of formations. Therefore, an evaluation of the use of acid type and concentration needs to be carried out. Use *Low Acid* (7.5–10%) or organic acids such as acetic acid can be an alternative to reduce the risk of over-dissolution and increase the effectiveness of stimulation in already weakened formations [13].

3.3.3 Use and Determination of Acid Volume

There is a slight difference between the actual acid volume and the calculation results in the two wells. In the X-1 well, the volume of 15% HCl solution used was 840 gallons, 23 gallons less than the calculation (863 gallons). Meanwhile, the volume of 32% HCl concentrate in X-1 exceeded the calculation of 26 gallons. This difference was considered insignificant, and stimulation remained effective, indicated by a stable increase in production of post-acid washing.

In the X-2 well, the actual volume of 15% HCl solution was recorded at 1260 gallons, 35 gallons lower than the estimate (1295 gallons). The 32% HCl concentrate is also slightly less, which is 561 gallons compared to the calculation of 547 gallons. This lack of a 15% solution can limit the reach of the acid to the damage zone, which is indicated by the *skin factor* which is still positive (+1,230). Nevertheless, these differences are still within tolerance limits and do not have a major impact on the overall effectiveness of stimulation. In general, stimulation *acid washing* in both wells was considered successful, because HCl acid was proven to be effective in dissolving scale in carbonate formations, even compared to organic acids such as acetate [14].

4.0 CONCLUSION

Based on the results of the study, acid washing stimulation using 15% HCl in X-1 and X-2 wells has been proven to be effective in improving performance. HCl acid was chosen because it has high reactivity to carbonate rocks and is easy to obtain. The evaluation showed a significant increase in the production rate, a decrease in *skin factors*, and an increase in *productivity index* and *flow efficiency*. The X-1 and X-2 wells experienced an increase in production of 112.7% and 129.8%, respectively, with post-stimulation well productivity above 300 BOPD.

The success of stimulation is also influenced by the characteristics of the formation, the density of the perforation, and the history of previous treatments. X-2 wells that are more frequently acidized show a higher risk of formation damage. However, both wells showed a positive response to stimulation, therefore acid washing was declared successful in restoring well production performance.

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