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WELL PRODUCTIVIY ENHANCEMENT USING MATRIX ACIDIZING – A NIGER DELTA CASE STUDY.

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Abstract

As a result of the rapid reduction in productivity of well B14, south west of the Niger Delta region, the need to investigate the cause of the damage was initiated. When it was identified fine migration as the major cause of the production decline, acid stimulation was recommended as the mitigation strategy.

Acid (matrix) stimulation practice involves the pumping of acid into the formation through the wellbore at the rates and pressures below the fracture gradient of the formation. Conventionally, hydrochloric acid (HCL) is used for carbonate formations while hydrofluoric acid (HF)/ mud acid (HCL +HF) is best suited for sandstone formations. Also, in a very high damaged formation and very high temperature environment that requires prolong contact of the HCL acid with the steel pipe, due to the severe corrosion that will occur, organic acids are more suitable.

In stimulating this well, mud acid was used and the well was stimulated using organic mud acid or organic clay acid.

Stimulating this well led to a total incremental production gain of over 485 BOPD (150% gain) however a corresponding reduction in skin was not observed This paper reviews and highlights the operational best practices as utilized in this project as well as the potential cause for an increase in skin even after a stimulation job.

Key words: *Matrix Acidizing; Mud Acid; Skin; HCL; Stimulation; Production; Formation Damage; Permeability*

1. Introduction

The ultimate aim of all the activities taking place in oil and gas industry is to maximize profit and minimize cost. It's now imperative for production engineers to always engage in every act that will guarantee this optimal production and in turn yield a substantial income to the industry.

Practically, due to the major operations associated to field development such as drilling, production, completion, workover etc., this primary aim is being defeated as a result of formation damage. Any unintended impedance to the flow of fluid into or out of the wellbore is referred to as formation damage. The definition of formation damage involves the flow restriction as a result of reduction in permeability in the near wellbore, changes in relative permeability, and flow restrictions in the wellbore. Over the last few decades, serious attention has been paid to formation damage issues for two primary reasons;

- The ability to recover fluid from the reservoir is affected very strongly by the hydrocarbon permeability near the wellbore.
- The ability to control - to some degree the drilling, completion and production operations that could potentially cause damage to the formation.

However, in oil and gas industry today, some operations have been developed to improve the productivity of a well in case of formation damage. This is achieved by simply altering and improving the formation permeability around the wellbore or within the entire reservoir. Any operation which is geared at improving the well productivity by re-opening old channels or opening new channels in the rock for oil and gas to flow through is called reservoir stimulation. In order words, it is the method use to increase the productivity of a well by removing the damage near the vicinity of the wellbore or by superimposing a highly conductive structure into the formation. The major reason for reservoir simulation is to maximize the productivity by removal of near wellbore damage (skin), decreasing the fluid viscosity and increasing the formation permeability or increasing thickness of the perforation region. Stimulation operation can be solely focused on the wellbore or the entire reservoir and can be conducted both on new and old wells. Some stimulation techniques include;

- Use of explosives to break the rock.
- Acid application to partially dissolve the formation.

1.1 Objective of Study

As a result of some major operations prior or during production such as, drilling, completion, water/gas injection, production, workover, improved/enhanced oil recovery (IOR/EOR) etc., which causes formation damage, there arose a drastic decline in the well productivity or in most cases, the well might totally stop production. This damage most times when discovered does not mean that the well has exhausted its economic production but could be as a result of skin damage within the vicinity of the wellbore or total formation damage which hinders the flow of formation fluid to the wellbore and consequently reduces production leading to significant loss to the producing company.

- This paper discusses causes of formation damage which may lead to well stimulation.
- It equally highlights how best matrix acid stimulation could be done in order to achieve a maximum success.
- To ascertain the improvement on the formation after stimulation, the reservoir and wellbore parameters like permeability, skin, etc. will also be reviewed and analyzed.
- This study will also consider the criteria for selecting a candidate well for matrix acid stimulation.
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1.2 Background of study

The acidizing process is used to either stimulate a well to greater than ideal matrix reservoir flow or to remove damage. Basically, there are two types of acid treatments that are related to injection rates and pressures. Matrix acidizing refers to operations were the injection rates results in the pressures below fracture pressure. On the other hand, when injection pressures are above fracture pressure the operation is referred to fracture acidizing. Fracture acidizing is used to enlarge the effective wellbore by increasing an acid – etched fracture deep into the wellbore for relatively low permeability formation to improve well productivity several fold. On the other hand, matrix treatment is applied primarily to remove damage (i.e. restore permeability) caused by drilling, completion, workover fluids and solids precipitated from the produced water or oil (i.e. scale or paraffins). During matrix acidizing, the acid dissolves the sediments and the mud solids within the pore throat that are inhibiting the permeability of the rock. This increases the size of the pores of the reservoir which in turn stimulates the flow of hydrocarbon. Effective acidizing is guided by practical limits in volume and types of acid and procedure so as to achieve an optimum removal of formation damage around the wellbore. This method is applied in both sandstone and carbonate formations. Although the acid system used in sandstone and carbonate differs, the same practice is applied to both. In carbonate rock, hydrochloric acid enlarges the wellbore or tends to bypass the damage by forming wormholes. The permeability increases is much in carbonate than in the sandstone. Removal of several plugging in the carbonate or sandstone can result in very large increase in the well productivity. However, if there is no formation damage, matrix treatment may not natural production more than 45 – 50%. This will however depend on the size of the treatment and penetration depth of live acid. Also, if there is no damage present, improper or poorly executed acid treatment can reduce the natural formation permeability and reduce the well productivity , as in new well with low permeability. Several acids are used in the treatment such as; hydrochloric acid (HCL) or acetic acid, hydrofluoric acid (HF) or formic acid, etc. HF is used mainly for sandstone or silica based problems while HCL is for limestone and carbonate formations.

2.0 Materials and Methods

2.1 Candidate Selection: the decision to stimulate a well is mainly determine by some reservoir productivity indicators. These variables include: increase in skin, increase in pressure drop caused by near wellbore skin effect, rapid reduction in well production before the anticipated economic production limit, increase in gas-oil –ratio and increase in water cut.

For a successful acid stimulation job, care must be taken to ensure that the appropriate damage mechanism, acid compatibility with the formation and effective flow back of spent acid to production facilities after stimulation were determined.

2.2 Data Collection: the data used were collected from producing wells in the Niger Delta marginal fields in the south west region. The stimulated well data was gotten from two operators within the region.

The marginal field under study lies in the south west area. It is a large east-west trending elongated rollover structure with four major culminations separated by three saddles. The Isobar growth fault marks the southern limit of the field.

The field was discovered in the sixties. There are 97 hydrocarbon bearing reservoir blocks in the field. Twenty-seven of these reservoirs are gas bearing while the remaining seventy are oil and gas bearing. These reservoirs have depth from 5500 – 11600 ft. 3-D seismic was acquired in 1994 and interpreted between 1994 and 1995. The first 3-D based study in this field took place between 1995 and1996.

The field came on stream in January 1965 with a peak production rate of ±36 MBOPD in the early 1970s. To date, a total of sixty-six wells have been drilled in the field including 3 multilateral and 9 horizontal wells (7 abandoned). Presently, more than 80% of these wells are on gas lift and the field is producing at an average rate of 32 MBOPD with 34.5% water cut as at end July 2010.

The surface facility was commissioned in 1967.The existing surface facilities include two flow stations and an AGG Compressor plant. Production staffs visit the facilities daily to carry out operational activities. Station warden man the facility on a 24-hr basis.

Well B14: this was completed in three different zones namely. **Zone 01** has 16ft net oil and 57ft net gas with gas oil contact and oil down to at 4956ft and 4972ft subsea respectively. After sand consolidation the tubing was found to be plugged with sand. No production was recorded. **Zone 02**: has net gas oil and water of 8ft, 20ft and 20ft respectively. As at the end of 1999, the zone was making 60% water 720 BOPD on choke 20/64 inches. It was shut- in December 2000 to sand and water production. Zone **03**. encountered 29ft net oil in the upper member and 25ft net oil in the lower member. In July 2000 sand trace was observed on choke 14/64 inches. The well was shut in 2001 due to sand production. When the well was opened for trial test in December 2003 on choke 12/64 inches, it produced only 195 mscf /day of gas. The well was later re-entered for a sand wash job and treated for sand production thereafter.

2.3 Well History: Well B14 is an anticline structure tending North West–South east. The sediments across the well structure are the typical sandstone – shale sequence peculiar to the Niger Delta. It has an average porosity of 30.8% with an average permeability of 1300md with a sand thickness of 31ft net pay zone, initial reservoir pressure was 3,147 psia while the current reservoir pressure is 2162.2 psia. The production started in 1991 at a rate of 1125 BOPD with a basic sediment and water and gas oil rate (GOR) of 0.0% and 881 scf./ stb respectively. It was optimized on bean up (32/64) to a peak of 1706 BOPD in July 1992. The production declined in January 2012 to 453 BOPD on 14/64 inches choke. With the drop in production well was qualified for acidizing job.

Table 3.1 Reservoir/well parameters for well B14

Parameters	Value	Unit
Reservoir	Bode 2	
Well status	Flowing	
Average thickness	31	Ft
Initial Permeability	1300	Md
Current permeability	270	Md
Porosity	30.8	%
Water saturation	35	%
Initial reservoir pressure	3147	Psia
Present reservoir pressure	2126.2	Psia
Bubble point pressure	3050	Psia
Initial solution GOR	881	Scf/stb
BHT	222	°F
Oil gravity	42.1	API
Oil viscosity	0.3230	Cp
Oil formation volume factor	1.479	bbl/stb
Gas gravity	0.73	
Drainage area	964	acres

Table 3.2 Production data of Agbada well B14 before stimulation

Date	Bean	BOPD	BWPD	GOR	BS&W %	THP
14/01/2010	34	1632	0	405	0.06	450
23/06/2010	36	1588	0	369	0	330
24/06/2011	36	1588	0	635	0	330
25/06/2011	36	1888	0	638	0	330
20/09/2011	42	1776	0	426	0	250
21/12/2011	42	1122	10	692	0.9	200
02/01/2011	48	1147	9	482	0.8	170
13/01/2011	48	1200	12	325	1.0	180
03/08/2011	48	754	8	1457	1.1	120
16/09/2012	48	694	8	1316	1.1	120
30/09/2012	48	810	12	1257	1.5	100
07/10/2012	48	737	7	1671	1.0	120
12/11/2012	26	277	131	2939	32	140
13/11/2012	26	313	209	2587	40	120
17/11/2012	32	456	114	918	20	120
24/09/2012	32	313	209	4381	36	110

Table 3.3 Production test data before stimulation for well B14

Initial production from start (BOPD)	Optimized production (BOPD)	Current production before stimulation (BOPD)	Predicted production (BOPD)	Actual production after stimulation (BOPD)
1125	1706	313	900	798

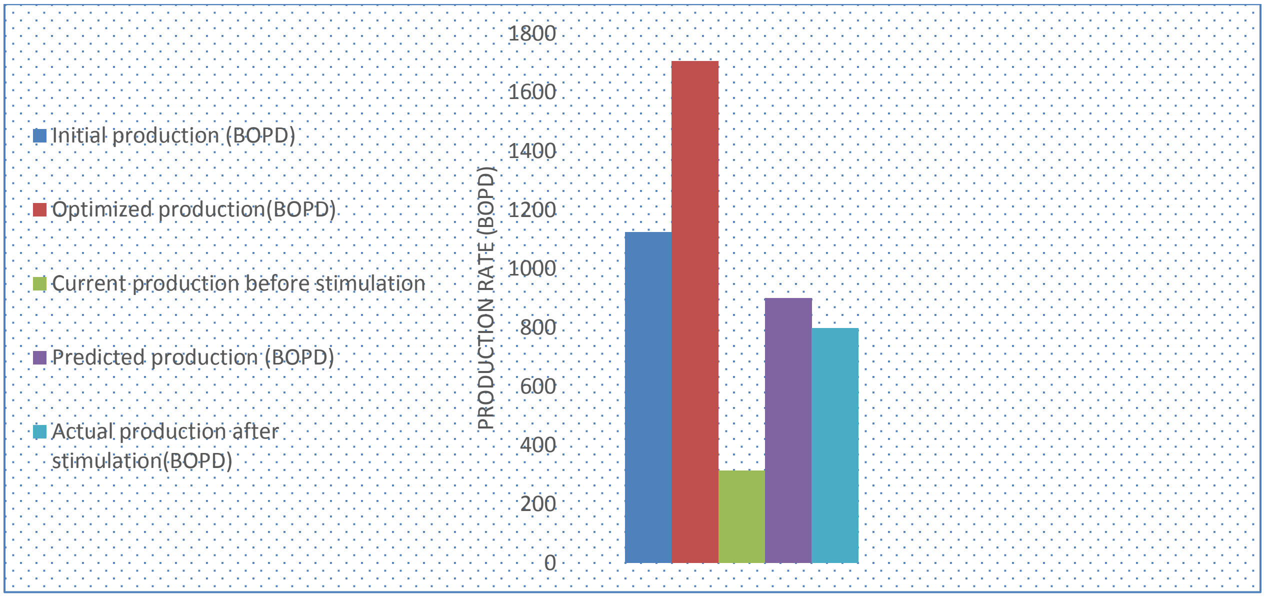

Fig. 3.1 Well B14 production test graph

2.4 Treatment Recipe For Well B14 (Mud Acid Treatment)

The acid treatment for well B14 was mixed and pumped with the following Chemicals into the perforation:

- SPACER:-240 gals 3% NH4 cl + 24 gals solvent.
- PREFOAM:-600 gals 3% NH4cl + 6 gals surfactant.
- FOAM:-200 gals 3% NH4cl + 4 gals surfactant + 1400scf/bbl. N_2.
- PREFLUSH:-750 gals 3% HC+L + 5 gals corrosion inhibitor + 5 gals surfactant + 15 gals Iron control.
- MAINFLUSH: -1200 gals of – 1.5% mud acid (MA) + 8 gals of Inhibitor + 8gals surfactant + 24 gals Iron control.
- SPACER:-100 gals 3% NH4CL + 100 gals solvent.
- OVERFLUSH: 1200 gals, half strength clay acid (HSCA) + 6gals corrosion Inhibitor + 4gals surfactant + 24gals Iron control. 8.3% NH4CL was displaced with one coil tubing volume (care was taken not to over displace the half strength clay acid away from the wellbore.

All surface injection pumps were shut down and shut in pressure on coil tubing and annulus were recorded. Later the well was shut in for 12 hours to enable clay stabilization. Wing value was opened for flow back. Then the rate per choke was slowly brought up (flow was started on choke 16/64"). Since the well did not flow unaided it was Nitrogen lifted via coil tubing until it continued to flow before pulling out of hole. Producing fluid and tubing head pressure were monitored.

3.0 Results

WELL B14: the value for skin after stimulation of the well was approximately 10 with liquid rate of 798 BOPD (485BOPD incremental production). From the sensitivity run before stimulation, at the skin value of 20, the liquid rate is meant to be approximately 900 BOPD (i.e. incremental production of 587 BOPD). As a result of this difference, it could be suggested that, the decline in productivity of well B14 was not only as a result of formation damage. However, the presence of other factors that could lower well productivity should investigated further in this well.

4. Discussions of Results.

Although A was did not produce as predicted by the model after the stimulation but this probably could be as a result of other factors other than formation damage. The resin consolidation and sand face completion design for this well could potentially have reduced the inflow area, thus resulting to high skin values. This sand control method is known to be susceptible to plugging by fines if not evenly applied. Chemical composition of treatment can also be sensitive high reservoir temperatures. Further investigation is therefore required to identify the cause of formation damage.

5. Conclusion and Recommendation

The need for stimulation job (matrix acidizing) only arises if the well is not producing at its full potential as a result of permeability reduction caused by skin damage.

The success recorded in this study was as a result of the proper acid /formation compatibility test prior to the stimulation operation. With the test, a good acid system was selected. Also, the type and volume of acid recommended for the well was dependent on the level of damage since larger volume of acid is required in formation with greater damage.

Although well B14 was not producing as predicted by the model could probably be as a result of other factors other than formation damage which is recommended as a subject for further study.

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