69

New Acid Simulation Era: Matrix Acidizing as Sandstone ad Limestone with Chelating Acid System

NEW ACID STIMULATION ERA: MATRIX ACIDIZING AT SANDSTONE AND LIMESTONE WITH CHELATING ACID SYSTEM

K. Amru, N.F. Prakoso, H. Kusuma, R.G. Afandi, and A.N. Muklas
Medco E&P Indonesia

Abstract

Rimau asset produced oil and gas from Limestone reservoir and Sandstone Reservoir. Acidizing job for mature field hold essential job for production surveillance and optimization. Acidizing on those different reservoir types, have own acid recipe designed for each reservoir uniqueness.

Each Acidizing type, either Carbonate Acidizing with regular Acid HCl or Sandstone Acidizing with HCl-HF recipe, facing its own challenging problems. Likewise face dissolution problem (mainly at HCl Limestone acidizing), Corrosion and iron precipitation, second reaction and precipitation (mainly at HCl-HF Sandstone acidizing), and limited mineralogy reservoir data to assist acidizing design. Those challenging problems, will have no issue by Chelating Acidizing System. And it works either at Sandstone or Limestone without further additional cautions.

Result of Chelating Matrix Acidizing in Rimau, show production increase. In term of job cost, Chelating Acidizing have fairly same cost with regular Acid. Furthermore, Chelating is less hazardous than HCl Acidizing and HCl-HF Acidizing. Chelating is friendly with downhole metal equipment. So it won't create damage in sub surface equipment, due to long exposure contact.

Before used for oil field purpose, chelating especially EDTA used for lab titration purpose, for Calcium (Ca) analysis in water hardness test. Chelating especially EDTA is also well known in medical used. In oil field, chelation is used to enhance stimulation treatments, scale removal, and to clean surface facilities. This Chelating purpose in oilfield, especially EDTA at matrix stimulation. First investigated in 1997 by Fredd and Fogler.

Keywords: Acidizing, Chelating, Sandstone Stimulation, Limestone Stimulation

1. Introduction

Acidizing is the oldest stimulation technique in oil and gas history. Acidizing Carbonate with HCl, patented at 1896 and conducted for the first time at 1897. Meanwhile Acidizing sandstone with HF start 30 years after, at 1933.

Chelating Acidizing itself, began observed by Fredd and Fogler at 1997 by their paper work. In March 1998, this study published at Journal with title "Alternative Stimulation Fluids and Their Impact on Carbonate Acidizing". This study limited for carbonate acidizing. Further development, Chelating Acidizing also applied for sandstone acidizing. In 2011 Mohamed Mahmoud wrote his dissertation experiment, to compare Chelating acidizing at Carbonate formation and Sandstone formation using various Chelating acidizing.

Rimau asset, produced either from Limestone reservoir and Sandstone Reservoir. Found at 1996, regular Acidizing HCl become common job stimulation at limestone reservoir. Following limestone acidizing, sandstone acidizing became common job after that, along with hydraulic fracturing stimulation.

Acidizing at limestone reservoir and sandstone reservoir have different nature and consideration. Especially when we have limited data at rock mineralogy for further consideration of selected acid system. This way we need simple acid system, which able to applied either at Limestone reservoir or sandstone reservoir.

Chelating agent or chelating chemical commonly categorized as Amino Polycarboxylic Acid (APX Acid)[1]. One of chelating chemical which used for Chelating Acidizing is EDTA (Ethylene Diamine Tetra Acetic Acid). There is other Chelating chemical used for acidizing, but in this acidizing we only use EDTA type only. Chelating acidizing by EDTA is the first chelating acidizing type observed and studied by Fredd and Fogler for Carbonate Acidizing. Further study and experiment, it found that EDTA also available for sandstone acidizing.

At Limestone Carbonate reservoir, EDTA mainly focusing at Calcite (Ca) dissolution only. Meanwhile for Sandstone, EDTA and other Chelating Acidizing chemical focusing at Calcite (Ca) dissolution, Ferrous (Fe) dissolution, and Magnesium (Mg)[2].

2. Problem Statement

At Limestone Acidizing, one of the major issue is face dissolution problem. If we use regular Acid HCl 15% (for most common example), due to natural fast reaction rate between HCl and CaCO3 (Carbonate) at Limestone formation. HCl will be react and disappeared only with the face of the near well bore formation. Acidizing won't create long wormhole penetration to overcome Skin depth, unless we add additive. Thus Acidizing will be useless.

At Chelating acidizing, due to natural slow reaction between Chelating and CaCO3 (Carbonate) at Limestone formation, this face dissolution issue can minimize. Thus can create long wormhole to overcome skin thickness of formation damage at Limestone formation.

Regular Acid (HCl) and Sandstone/Mud Acid (HCl-HF) if contacted with metal, Which dominated at wellbore (casing, tubing, artificial lift, etc), will create iron precipitation and corrosion problems. That's why we must add acid additive for iron control and corrosion inhibitors at Acidizing job. And we must count the contact time, so Acidizing won't harm the wellbore itself.

Different with Chelating. Chelating itself is natural corrosion inhibitor and iron control. So it is safe for long contact with metal.

At Sandstone/Mud Acid (HCl-HF), by chemical reaction HF will dissolve Quartz (SiO2) which dominated at sandstone. But HF itself, if we don't aware with the mineralogy contain of sandstone formation, it will create second unwanted reaction and induce precipitation at formation. Thus the Acidizing itself will be useless. That's why Sandstone/Mud Acid is not standalone with HF only, but assisted with HCl, and have complication composition depend on the mineralogy composition of the sand formation.

In general, damaging potential by sandstone acidizing (HCl-HF) created though precipitation of fluorosilicates (Na and K), and precipitation of fluoride (Ca, Al, and Fe)[3]. That's why, mineralogy data input hold essential role for sandstone acidizing. Meanwhile reservoir mineralogy tends to have high heterogeneity and not all of the depth covered by mineralogy data.

In Chelating acidizing, we don't have any concern of it. Because chelating doesn't create precipitation reaction like sandstone does.

For summary, regular acidizing at Limestone or Sandstone will face challenge likewise:

---

[1] See : SPE 185097, Chelating Agents in Production Enhancement : A Review, 2017. SPE 185636, Oilfield Scale Removal by Chelating Agents : An Aminopolycarboxylic Acids Review, 2017.

[2] See : Removing of Formation Damage and Enhancement of Formation Productivity using Environmentally Friendly Chemicals, Mohamed Ahmed Nashr Eldin Mahmoud (Doctoral Dissertation at Texas A&M University, May 2011)

[3] See : SPE 185097, 2017.

1. Face dissolution problem at HCl Acid Limestone formation.
2. Iron precipitation and corrosion acidizing problems.
3. Limited acidizing contact time.
4. Limited mineralogy data
5. Unwanted secondary reaction at sandstone with HF chemical.

3. Methodology

Methodology for this Chelating as new acid system project, based on literature and best practice paper study, laboratory test, and real field implementation. We combine all of those methodology to ensure the success result of this project.

Chelating Acidizing using EDTA is simple to applied. By mixing 200 pptg Na2-EDTA at fresh water with KCl, mutual solvent, and non-emulsifying agent. Chelating acid solution is ready to inject. Na2-EDTA have specific gravity around 0.86 gr/ml.

Total volume needed for matrix acidizing is measured by skin thickness. For rules of thumb, we used 3 to 5 ft matrix acidizing penetration design. For the application, after matrix acidizing penetration 3 to 5 ft, we left residual Chelating Acid to soak well until top perforation interval for 24 to 48 hours or more. After soaking period, we start to produce and monitor the well.

We add soaking step after matrix penetration step, because Chelating have non-corrosive characteristic. This step conduct to clean the near wellbore, as well as to ensure non plug restriction at perforation interval. We conduct this step either at ESP Well or Gas Lift well. And it has no problem with wellbore metal performance. We also conduct this step either at Limestone carbonate formation, or at Sandstone formation.

Best practice of regular HCl acidizing usually need to pass 80% solubility test criteria. This to ensure successful of HCl acidizing. For this Chelating acidizing, we don't need to fulfil those criteria. Because Chelating won't dissolve Carbonate mineralogy only, but also will dissolve other additional mineralogy.

As well as for acidizing at sandstone formation. At best practice, we need to know mineralogy of the well at certain depth which related with producing interval. This step is important to decide best sandstone acid recipe and composition. Without this, if we conduct blind sandstone acidizing, it will increase fear to side precipitation reaction with certain mineralogy composition.

At this Chelating Acidizing, we have no concern for those problem. So if we have lack data for well mineralogy, this Chelating Acidizing could be solution for us.

Chelating material, also considered as non-hazardous chemical. Unlike HCl or HCl-HF which need more cautions to handle, since it considered as hazardous chemical. In Chelating Acidizing, we don't have those high concern to handle.

4. Result and Analysis

We have conduct chelating acidizing at several wells, either at Carbonate limestone formation or Sandstone formation. Either at ESP well or Gas Lift well. And the result is satisfied.

Chelating acidizing works either at limestone formation or sandstone formation. This will help to solve face dissolution problem which may occur at limestone formation, and solve lack of sandstone mineralogy data at target depth. As well will eliminate precipitation of second reaction problem at sandstone formation.

This Chelating acidizing now is considered as new applied acid system, which applicable to conduct as regular acidizing job at Rimau field. The result of the Chelating acidizing, with variation of formation and artificial lift downhole, shown at the table below.

Overall result shows good increase rate and production. For XX-302, we conduct re-chelating acidizing with 5 ft penetration matrix injection. Longer than previous penetration design (3 ft). And with 48 hours more soaking time, longer than previous soaking time (24 hours).

Observing the result of XX-302, it shown that ideal matrix injection penetration design is 5 ft. Followed by minimum 48 hours soaking. The soaking hours also proved that Chelating have no corrosion effect with wellbore metal, and this is an advantage compared to regular HCl limestone carbonate acid or HCl-HF sandstone acid.

Chelating also considered able to solve face dissolution problem. So that success overcome skin thickness and improve production result.

We can see this indication by comparing result of regular HCl 15% acidizing limestone at 2017[4], which increase the production gain by average 46.5%. With Chelating acidizing at same limestone reservoir in 2018, which increase the production gain by 192%.

5. Discussion

Chelating Acidizing have various chemical chelating which can be applied. For this Chelating system, we only applied Na2-EDTA yet. Meanwhile in worldwide application, other chelating than Na2-EDTA had been applied and studied. Likewise, HEDTA, GLDA, HEIDA, and others.

This give us information, that Chelating Acidizing system have other variation which interesting to be applied in the field. Furthermore, in several paper stated that combination between Chelating and regular HCl had been studied and applied[5].

Chelating especially EDTA also have superior advantage as a chemical material which easy to get in regular marketplace. Anyone can have those material and handle it for acidizing, without need further service from service company. Chelating especially EDTA is non-hazardous generic chemical which easy to dissolve in liquid without need any special equipment.

For the design and application, we found that matrix injection with 5 ft penetration and minimum 48 hours soaking until top of perforation is the best practice to conduct Chelating Acidizing.

6. Conclusion and Recommendations

Through this chelating acidizing description and result, we can conclude that:

1. Chelating Acidizing solve face dissolution problem which may occur at regular HCl Limestone acidizing.
2. Chelating has lower reaction rate than HCl at limestone. This low reaction rate will ensure worm hole forming and minimize face dissolution problem due to fast reaction.
3. Chelating acidizing is non-hazardous chemical, easy to applied, easy to get at marketplace, and don't create corrosion and iron precipitation problems in the metal wellbore.
4. Chelating acidizing able to be applied for long time contact with metal wellbore and near well bore reservoir.
5. Chelating acidizing give solution for any field which have limited mineralogy data
6. Chelating Acidizing won't create unwanted secondary reaction at sandstone which may occur with HF chemical for sandstone acidizing.
7. Chelating acidizing works either at limestone formation or sandstone formation

And as for the recommendations, we recommended that:

1. As rule of thumbs, if we have uncertainty of skin formation damage thickness. We can design 3 ft to 5 ft penetration matrix injection for Chelating acidizing

---

[4] See table 3

[5] See : Removing of Formation Damage and Enhancement of Formation Productivity using Environmentally Friendly Chemicals, Mohamed Ahmed Nashr Eldin Mahmoud (Doctoral Dissertation at Texas A&M University, May 2011)

2. If design volume has no concern. Ideally we can design Chelating acidizing for 5 ft penetration matrix injection, and 48 hours minimal soaking time.
3. Chelating Acidizing using EDTA give good result either at limestone or sandstone, and it still have opportunity to improve Chelating Acidizing experience using other Chelating chemical or by mixing it with regular HCl acidizing.

7. Acknowledgement

The author wants to acknowledge Medco E&P Indonesia for the encourage and the permission to applied Chelating Acidizing. As well as the permission to present and publish this paper. Especially for Rimau FPE (Field Petroleum Engineer) who had involved and gave a lot of support for this project.

8. References

1. Almubarak, T., Ng, J.H., and Nasr-El-Din, H.A., 2017. Chelating Agents in Production Enhancement : A Review, SPE paper 185097.
2. Almubarak, T., Ng, J.H., and Nasr-El-Din, H.A., 2017. Oilfield Scale Removal by Chelating Agents : An Aminopolycarboxylic Acids Review, SPE paper 185636.
3. Amru, K, 2018. Interim Report of Chelating Acidizing Project Collaborated with StimPage Project and Production Optimization Opportunity Project, Medco E&P Indonesia.
4. Becker, J.R., 1998. Chelate effect, at Corrosion and Scale Handbook, Penn Well, Corp., Tulsa Oklahoma., pp. 108.
5. Fredd, C.N., and Fogler, H.S., 1997. Chelating Agents as Effective Matrix Stimulation Fluids for Carbonate Formation, SPE paper 37212.
6. Fredd, C.N., and Fogler, H.S.,1998. Alternative Stimulation Fluids and Their Impact on Carbonate Acidizing, SPE Journal (March edition, 1998).
7. Kalfayan, L., 2000. Production Enhancement with Acid Stimulation, Penn Well, Corp., Tulsa Oklahoma.
8. LePage, J.N., De Wolf, C.A., Bemelaar, J.H., and Nasr-El-Din, H.A., 2009. An Environmentally Friendly Stimulation Fluid for High Temperatures Application, SPE paper 121790.
9. Mahmoud, M.A.N.E, 2011. Removing of Formation Damage and Enhancement of Formation Productivity using Environmentally Friendly Chemicals. PhD Dissertation, Texas A&M University, College Station, TX.
10. Prakoso, N.F., and Wicaksana, D., 2009. Jurnal Teknologi Minyak & Gas Bumi IATMI, Acidizing in ESP Wells: An Efficient Production Optimization, (2nd Edition - August 2009) pp. 27.

List of Figures

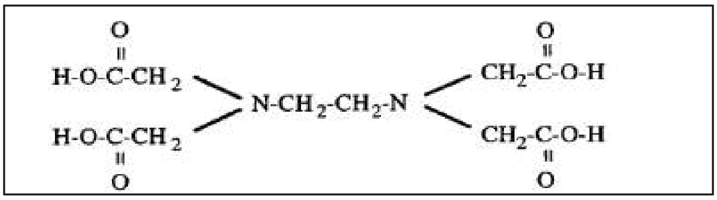

Figure 1. Chemical structure of EDTA

$$EDTA^{4-} + CaCO_3 \leftrightarrow [EDTA - Ca]^{2-} + CO_3^{2-}$$

$$K = \frac{([EDTA\text{-}Ca]^{2-})}{(EDTA^{4-})\,(Ca^{2+})} = \sim 5 \times 10^{10} \quad \text{or } \log K = 10.7$$

Figure 2. Chemical reaction and Constanta reaction between EDTA and Carbonate Calcite dissolution

List of Tables

Table 1. Composition to create Chelating EDTA for 200 pptg

No.	Material	Deskripsi	Conc.
1	Fresh Water		921 gpt
2	KCL	Clay Control	150 pptg
3	NA2 EDTA	Chelating chemical	200 pptg
4	Additive	Mutual Solvent	50 gpt
5	Additive	Non Emulsifying	7 gpt

Table 2. Result of Chelating Acidizing

No	Well	Formation type	Artificial Lift type	Before Chelating Acidizing			After Chelating Acidizing			Remarks
				Last Fluid rate, BPD	%WC	Last oil production, BOPD	Fluid rate, BPD	%WC	Oil production, BOPD	
1	XX-009	Sandstone	Gas Lift	84.4	86%	11.8	186	92%	14.8	Chelating acidizing with 3 ft penetration and 24 hours soaking
2	XX-286	Sandstone	Gas Lift	89	94%	4.9	162	97%	23.49	Chelating acidizing with 3 ft penetration and 24 hours soaking
3	XX-346	Sandstone	Gas Lift	24	4.1%	4.1	61	14.1%	52.39	Chelating acidizing with 3 ft penetration and 24 hours soaking
4	XX-302	Limestone Carbonate	ESP	194	88.2%	22.9	984	93.2%	66.91	Chelating acidizing with 5 ft penetration and 48 hours more soaking

Table 3. Result of Production Gain by Regular HCl at Limestone Formation in 2017

No	Well	Formation	Acid date	Last test before acid				initial test after acid				Increase	
				BFPD	BOPD	MSCFD	%WC	BFPD	BOPD	MSCFD	%WC	Oil gain	percent increase
1	XX-376	BRF	6-Jan-17	180	50.4	566	72	300	84	625	72	33.6	66.67%
2	XX-188	BRF	9-Jan-17	12.8	12.75	445	0.35	920	9.2	2.55	99	-3.55	-27.84%
3	XX-259	BRF	25-May-17	992	29.76	6.96	97	1152	34.56	8.087	97	4.8	16.13%
4	XX-65	BRF	1-Jun-17	616	18.84	7	97	823	24.69	7	97	5.85	31.05%
5	XX-107	BRF	3-Jun-17	536	75.04	183	86	436	74.12	17.34	83	-0.92	-1.23%
6	XX-40	BRF	14-Jun-17	300	84	123	72	876	175.2	98	80	91.2	108.57%
7	XX-27	BRF	6-Aug-17	256	30.72	269	88	595	71.4	271	88	40.68	132.42%