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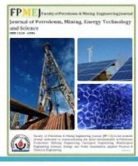

Understanding of Visco-Elastic Surfactant And Acid Stimulation Application

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Abstract

Surfactants are divided into four main categories based on their ionic charge. The most common applications can be summarized as corrosion inhibitor, emulsifying and de-emulsifying agents, foaming agent and improver of solids carrying capacity. Visco-Elastic Surfactant (VES) is one of surfactant groups initially used as a friction reducer and to enhance the solids carrying capacity. In this paper many tests were performed on VES samples of newly produced product to study the work frame and the applicability of that product especially through three important factors 1) Viscosity build-up of the VES at different shear rates, 2) Study different concentrations behavior of the VES and its application especially on acid diversion, 3) Salt effect on the formed mixture of VES and its effect on the viscosity behavior, and finally 4) Temperature effect on the Visco-Elastic behavior was examined to define the work frame of that product (VES) application in the oil field in the acid diversion. VES product shows elasticity to stresses through the change in viscosity of the solution. Also, it was found that temperature affects negatively on the VES behavior, which limits the application of the VES in the high temperature reservoir, unless formation cooling action to be carried out before pumping the VES. On the other hand the salts have a positive effect on the VES behavior through increasing the viscosity buildup of the VES, which supports the application of VES in high saline formation water. The tested VES product shows good behavior as Visco-Elastic and could be used in limited temperature ranges, based on that result a case study was demonstrated in which it has been used as an acid diverter in carbonate reservoir. The well after the acid stimulation resulted in improving the well productivity and producing at 4100 BOPD after stimulation.

Keywords: Surfactant; Visco-Elastic.

1. Introduction

1.1 Surfactants

There are four categories of surfactants a) anionic surfactant, b) cationic surfactant, c) nonionic surfactant & d) amphoteric surfactant. These four categories are classified based on its ionic group[1]. Surfactant is composed of two main parts, head; which is the carrier of the ionic charge and the active part of the surfactant and tail; that represent the hydrocarbon part of the surfactant and differs from surfactant to other on the no. of alkyls on group[2]. Surfactants application usually depends on the ionic charge to support the purpose of application, for example in corrosion inhibitor, the cationic surfactant is used in cession inhibitor in order to be adsorbed on the tubular faces and cover it to form a film that helps preventing the acid attach to the tubular faces[3].

Anionic surfactants are usually used as non-emulsifying agent or as friction reducer. Nonionic surfactant is the widely used surfactant as it doesn't react with the other chemicals or with the formation's mineral, it is used in improve the flow back and reducing the surface tension, and finally the amphoteric surfactant, in which VES is the main member of this group, Amphoteric surfactant is a surfactant that has positive and negative charge at the same time and tends to be positive under certain pH rage[4].

1.2 Acid Diversion

The success of matrix acidizing treatments depends on the placement of acid to remove near-wellbore formation damage efficiently. The acid should be placed so that all potentially productive intervals accept a sufficient quantity of the total acid volume. If significant permeability or formation damage variations are present in the interval to be treated, acid will enter the zones with the highest permeability or least formation damage, leaving little acid to treat what may be the most productive zones[5]. To achieve uniform damage removal, the original flow distribution across the treated interval needs to be altered to provide generally equal acid distribution. The methods used to alter this flow distribution are called diversion methods, since their purpose is to divert the flow of fluid from one portion of the interval being acidized to another[6]. The diversion method best suited for a particular situation depends on many factors, including the type of well completion, perforation density, the type of fluid that is produced or injected after the treatment, casing and cement sheath integrity, bottom hole temperature, and bottom hole pressure[7]. The best way to uniformly treat an interval is with a mechanical isolation device such as a straddle packer. This packer allows acid to be injected into small intervals, one by one, until the entire zone has been treated, however, this method is often not practical or possible without a packer; diverting agents must be used during stimulation to reduce flow into nonproductive or undamaged zones and redirect this flow to zones in greater need of damage removal[8].

1.3 Acid Diverters: Types and Uses

Acid diversion alters the natural flow profile into a formation during injection, causing acid flow to be diverted from undamaged or high permeability intervals to damaged or lower-permeability intervals[9].
The diversion methods used to alter the original flow profile may attempt to achieve complete shutoff of flow into specific intervals or to equalize flow across the entire interval being treated, regardless of permeability or damage severity[10]. The types of diverting methods fall into four general categories:

- Ball sealers
- Degradable particulate-diverting agents
- Viscous fluids
- Foam

2. Experimental Work

A set of experiments were done to emphasize on the VES physical properties to stand on the frame of application, temperature range, viscosity build up, concentrations & range of acid strength.

2.1 Tools and Materials

The following apparatuses and equipments have been employed:-

1- BrokField viscometer to measure the viscosity of the fluid at different shear rates.
2- Acid resistance magnetic Stirrer.
3- Water bath.
4- pH meter.
5- pH caliber (Sulphonate solution with pH 7).
6- Glass ware.

The following materials have been used:-

1- 37.1 % Hydrochloric Acid ACS (American Chemistry Society).
2- $CaCO_3$ 93%.(ACS).
3- VES product with golen color, 0.99 Sp.Gr. & amphoteric ionic charge.

2.2 Study of Different VES Ratios in Acid Diversion

Optimization is always the main target in any work, as optimization seeks the cost control and high performance. Each surfactant has the optimum concentration at which the maximum benefit can be achieved. Determine the optimum ratio of the VES is really important to minimize the cost of the treatment and to avoid any unexpected formation damage could be a result of that extra dosage. The test was run with 13% HCl through applying different VES volume ratios 6, 7, 8 & 10% by volume, the test results shows in fig (1) that with higher VES concentration, higher viscosity build up of the VES gel at the same shear rate is achieved. That result was a guide for more application of the VES based on the target or the purpose of the treatment either diversion or fluid loss control. As it is known in fluid loss control higher viscosity is required to have a complete blockage of the targeted interval.

Also it shows the optimum application based on the formation permeability, as with higher permeable interval, higher viscosity is more desirable than lower viscosity. VES with 400 cp to 600 cp is enough to divert the acid to another interval with low permeability, 6% to 7% by volume concentration of VES solution has the that range of viscosity which is enough in acid diversion application as shown in fig. 1.

2.3 Temperature Effect on the Gelling Action

Reservoir temperature has an important impact on the performance of any injected chemicals into the reservoir, as temperature acts as a reaction rate accelerator. In our study we are trying to understand the behavior of the VES under different temperature ranges to simulate the reservoir temperature effect. VES Solutions with different load concentrations 5, 6, 7, 8& 10% of VES was examined to determine the limitations of VES application at different temperature ranges. In Fig (2) below shows that temperature has a negative impact on the VES gelling action behavior. At high temperature the VES loss its viscosity and break down to low viscosity solution. All curves in fig (2) show a peak value of viscosity at certain temperature, and then viscosity starts to decline with temperature increase which proves that temperature helps to a certain limit as a reaction rate accelerator to build up the viscosity of the VES solution then with higher temperature the viscosity starts to break down.

2.4 Visco-Elastic Behavior at Different Shear Rates

Visco-Elasticity is the ability of a gel to deform under stress and restore normal viscosity once the applied stress is removed. This feature is important in acid diversion mechanism as the pumped fluid exposure to different range of stresses through the formation; the pumping rate, tubing friction; drag force, formation permeability and friction inside the formations are aspects of the stress that gel exposed to. So to examine the Visco-Elastic capability of the selected VES is essential to understand the behavior of the VES within the formation. Different shear rates were applied on two different VES solutions 3%&4% VES and then to observe the change of viscosity behavior at different shear rates. Moderate shear rate and very low shear rate were applied, to fully understand and assure the Visco-Elastic behavior of the subject surfactant VES over a wide range of shear rates. Fig (3) & (4) below show the VES viscosity responses to moderate and very low shear rates respectively.

2.5 Effect of Salts Concentration on VES Behavior

Formation water is full of salts such as NaCl& $CaCl_2$, once the VES solution is pumped to the formation it comes into contact with the formation water. Also, in acid diversion, the VES is carried by hydrochloric acid that reacts with the carbonate formations and release $CaCl_2$ as a reaction result. So, examine different concentrations of salts of on the VES behavior at different temperatures is important to understand the VES performance within the reservoir. Fig (5) shows a viscosity build-up with higher salt consternations, that result in a positive effect of the salts on the VES performance as higher viscosity is required to support the diversion action of the VES. Also fig (6) shows the temperature effect on VES solutions mixed with different concentrations of $CaCl_2$ salt. Temperature has a negative effect on the gel viscosity of the VES mixed with salts but the viscosity decline is not sharp and keeps the viscosity of the VES solution in the application range.

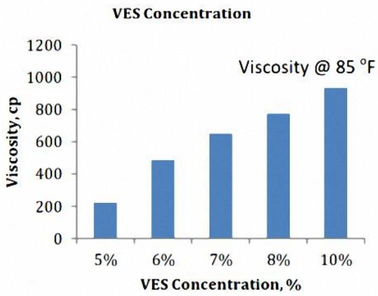


Fig.1. VES Concentration Effect.

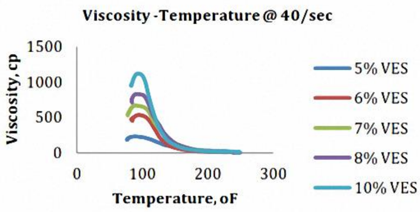


Fig. 2. Temperature Effect on VES.

Fig. 3. Visco-Elastic Behavior of the VES.

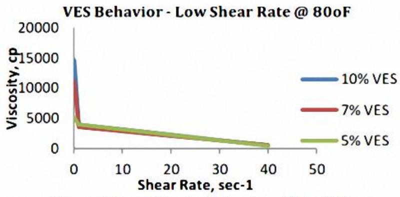


Fig. 4. Visco-Elastic Behavior of the VES.

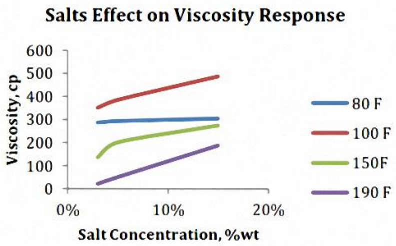


Fig. 5. Viscosity Response with Salts Concentration.

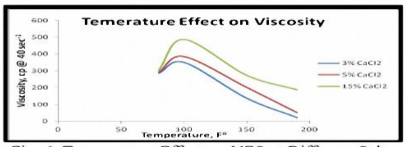


Fig. 6. Temperature Effect on VES at Different Salts Concentration.

3. Case Study

An oil well lies in the southern area of West Qurna field, Basra, Iraq, recently drilled into Mishrif carbonate formation at 2535m with a perforated interval of 100m. The reservoir average temperature is 177°F, and the oil is 32°API, no evidence for H_2S. The pay zone is of three intervals with different permeability and reservoir pressure as shown in fig (7), The well after completion was flowed back, showing very low productivity index, with a total daily production of 320 BOPD, the formation damage was attributed to the mud loss during the drilling of the pay zone, LCM (loss Circulating Material) was used to stop losses to the formation which includes medium calcium carbonate materials.

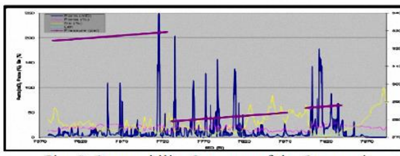


Fig. 7. Permeability Pressure of the Reservoir.

The decision was made to acid stimulate the pay zone to enhance the productivity and to create new channels to overcome the drilling and workover fluid damage. The perforated interval is 328 ft, and has permeability and pressure heterogeneity, so diversion in this case was important to have fair acid distribution. VES with 15% HCl acid diversion technique was selected due to its minimal residual damage compared to other chemical techniques. Table 1 shows the pumping schedule of the 15% HCl acid and the VES acid diversion in stages, where fig (8) shows the pumping pressure changes due to the change in the pumped fluid and the effect of the gelling action. Change in pressure reflects the response of the formation resistance to the VES solution, pressure build-up was a result of the VES gelling action as the formed gels plugged the high permeable intervals and divert the acid the rest of the interval. The well then flowed back through coiled tubing nitrogen lifting, the well started to flow back and cleaning itself, once the spent acid out of the formation, the production has been diverted to the well test separator, the flowing period test showed a production of 2400 bbls/day @ 320psi WHP and 46" chock size.

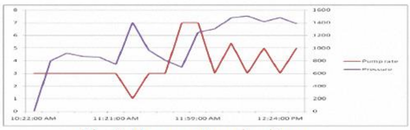
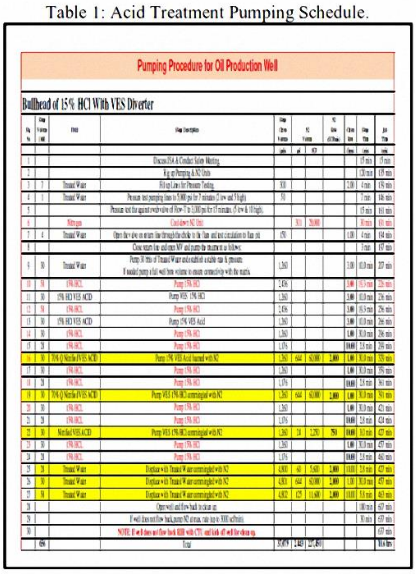


Fig. 8. Pressure Pumping Curve.

Table 1: Acid Treatment Pumping Schedule.



Pumping Procedure for Oil Production Well

Bullhead of 15% HCl With VES Diverter

			Stage Description							
					psi	SCF				
1			Discuss JSA & Conduct Safety Meeting						15 min	15 min
2			Rig up Pumping & N2 Units						120 min	135 min
3	7	Treated Water	Fill up Lines for Pressure Testing	300				2.00	4 min	139 min
4	1	Treated Water	Pressure test pumping lines to 5,000 psi for 7 minutes (2 low and 5 high)	50					7 min	146 min
5			Pressure test the against swab valve of Flow-T to 3,000 psi for 15 minutes (5 low & 10 high)						15 min	161 min
6		Nitrogen	Cool down N2 Unit		301	20,000			30 min	191 min
7	4	Treated Water	Open the valve on return line through the choke to the flare and test circulation to flare pit	150				1.00	4 min	194 min
8			Close return line and open MV and pump the treatment as follows:						3 min	197 min
9	30	Treated Water	Pump 30 bbls of Treated Water and establish a stable rate & pressure. If needed pump a full well bore volume to ensure connectivity with the matrix.	1,260				3.00	10.0 min	207 min
10	58	15% HCL	Pump 15% HCl	2,436				3.00	19.3 min	226 min
11	30	15% HCl VES ACID	Pump VES 15% HCl	1,260				3.00	10.0 min	236 min
12	58	15% HCL	Pump 15% HCl	2,436				3.00	19.3 min	256 min
13	30	15% HCl VES ACID	Pump 15% VES Acid	1,260				3.00	10.0 min	266 min
14	30	15% HCL	Pump 15% HCl	1,260				1.00	30.0 min	296 min
15	28	15% HCL	Pump 15% HCl	1,176				10.00	2.8 min	299 min
16	30	70% Q Nitrified VES ACID	Pump 15% VES Acid foamed with N2	1,260	644	60,000	2,000	1.00	30.0 min	329 min
17	30	15% HCL	Pump 15% HCl	1,260				1.00	30.0 min	359 min
18	28	15% HCL	Pump 15% HCl	1,176				10.00	2.8 min	361 min
19	30	70% Q Nitrified VES ACID	Pump VES 15% HCl commingled with N2	1,260	644	60,000	2,000	1.00	30.0 min	391 min
20	30	15% HCL	Pump 15% HCl	1,260				1.00	30.0 min	421 min
21	28	15% HCL	Pump 15% HCl	1,176				10.00	2.8 min	424 min
22	30	Nitrified VES ACID	Pump VES 15% HCl commingled with N2	1,260	24	2,250	750	10.00	3.0 min	427 min
23	30	15% HCL	Pump 15% HCl	1,260				1.00	30.0 min	457 min
24	28	15% HCL	Pump 15% HCl	1,176				10.00	2.8 min	460 min
25	28	Treated Water	Displace with Treated Water commingled with N2	4,800	60	5,600	2,000	10.00	2.8 min	427 min
26	30	Treated Water	Displace with Treated Water commingled with N2	4,803	644	60,000	2,000	1.00	30.0 min	457 min
27	58	Treated Water	Displace with Treated Water commingled with N2	4,802	125	11,600	2,000	10.00	5.8 min	463 min
28			Open well and flow back to clean up						180 min	637 min
29			If well does not flow back, pump N2 at max. rate (up to 3000 scf/min).						30 min	657 min
30			NOTE: If well does not flow back RIH with CTU and kick off well for clean up.							657 min
	466		Total	30,079	2,143	227,450				10.6 hrs

4. Conclusions

1- The tested VES product is valid for oil field application at limited temperature range.
2- Concentration of the VES will depend on the purpose of the application. Higher concentrations of VES can build-up a solution with a viscosity of 1000 cp which can be used as a fluid loss control treatment.
3- Temperature affects negatively on the VES gelling action.
4- Salts support the viscosity build-up of the VES solution.
5- VES can successfully divert acid and allow fair acid distribution that will support enhancing the well productivity.

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