VISCOELASTIC SURFACTANTS APPLICATION IN HYDRAULIC FRACTURING, IT'S SET BACK AND MITIGATION - AN OVERVIEW

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ABSTRACT

Fracturing fluid is an essential component of hydraulic fracturing stimulation. The oil and gas industry has experienced transformation in fluid technology for hydraulic fracturing. Fracturing fluid should have the reasonable viscosity that can suspend and transport proppants into the fracture. It should also be able to keep the fracture open throughout the life of the well. Sometimes ago polymers were used for this purpose as it's able to withstand high temperature under well condition. However due to formation of filter cake caused by the polymer based fluids, there are formation and conductivity damages to the formation, therefore its application in fracking a bit limited. Viscoelastic surfactant (VES) were then applied in fracturing operation as they exhibit viscous and elastic behavior in brine (increased viscosity) by entanglement of the VES micelles, but its viscosity is drastically reduced at high temperature. Then additions of inorganic or organic nanoparticles have been found to help in stabilizing the viscosity of this VES fluid at very harsh condition of high temperature and pressure. Internal breakers are also added to the VES fluid to help break the fluid into low viscosity fluid after fracturing has been completed so as to enhance easy flow-back (cleanup) of VES to the surface. This paper however highlights the process of VES fluid application in hydraulic fracturing stimulation, its set back and mitigation approach adopted in the industry using nanoparticles to stabilize its viscosity at high temperature.

Keywords: hydraulic fracturing, viscoelastic surfactant, internal-breakers, micelles, leakoff, rheology, nanoparticle.

INTRODUCTION

A fracturing fluid basically is one that has ample viscosity which is able to suspend and transport proppant into the fracture. The fluid should also have ability to break into lesser viscosity for the purpose of fracture cleanup, allowing fast flow back of fluid to the surface [1]. Since fracturing fluid is an essential part of hydraulic fracturing procedure, therefore making a decision of fracturing fluid, design job and well work-time procedure will determine the productivity of the well after stimulation by hydraulic fracturing [2-3].

For decades, high viscosity Polymer fluid were used in fracturing treatments and operations but recently researches have shown that cross linked polymer fluids cause some serious damage to the formation permeability [4-7]. The major cause is that the polymer fluid leaves behind a residue called filter cake which after fracturing causes poor conductivity to the formation's permeability. A study done between low polymer concentration loading and high polymer concentration loading in over 200 hydraulic fractured wells has revealed that fluids with lower polymer concentration yield better productivity than high polymer concentration [8].

VES APPLICATION IN FRACTURING

To put an end to the damage caused by the polymer fracturing fluid, surfactants have being applied in the past few years for fracture stimulation process. Surfactant micellar fluids are of low molecular weight. The major reason why surfactants are adopted is to eliminate formation damage and fracture conductivity damage in hydraulic fracturing operations [9-10]. Figure-1 shows picture of broken surfactant micellar fluid and polymer fluid. The Figure-1(a) shows a broken surfactant micellar fluid using unsaturated fatty acid (UFA). Figure-1(b) shows oxidizer polymer fluid with a lot of insoluble residue capable of generating fracture conductivity and formation damages [11].

(a) (b)

Figure-1. (a) Clean broken surfactant micellar fluid (b) Broken Polymer fluid with lots of residue [11].

The surfactant has viscoelastic (viscous and elastic) properties which helps it to increase its viscosity (in brine) by the entanglement of its very long wormlike micelles (at lower temperature). The viscolelastic surfactant (VES) fluid formed does not form filter cake unlike the viscous polymer fluid. Be that as it may, the VES fluid has a high leak-off control, due to its low viscosity at high temperature and pressure, which further leads to fluid loss into the formation matrix. This seems to pose a set-back in the area hydraulic fracturing application. However, modern studies have shown that application of nanoparticles in VES fluid can help to generate a wall-building leakoff control which is similar as that of polymer fluid. This can be achieved by addition of small amount of inorganic crystals-35 nm zinc oxide [12-13]. These nano-scale particles have very high van der

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waals and electrostatic forces of attraction and also high surface area. The nanoparticles give the VES better viscosity by pseudo crosslinking with the surfactant micelles just like the crosslinked polymer fluid. This interaction does not use particle bridging of particles precipitation [14] for fluid leak-off control. The entangled miscelles are broken after activation of the internal breaker to form rod like micelles and viscosity of the fluid is reduced for easy cleanup [13]. Figure-2 shows micelles structure after breaking.

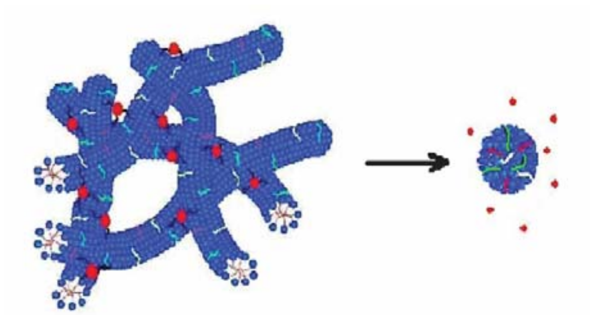


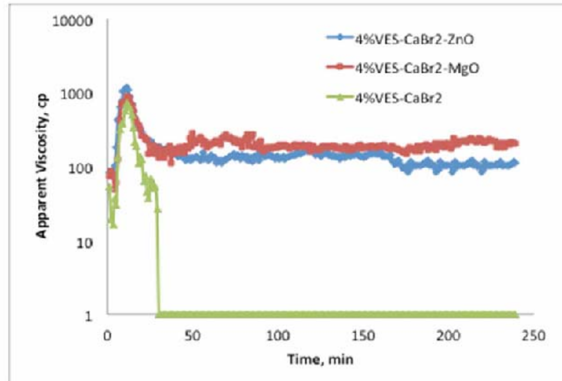
Figure-2. Auto oxidation breaks nanoparticles and VES micelles using internal breakers to degrade the long viscous and entangles micelles to non-viscous spherical shapes, releasing the nanoparticles [13].

VES'S SET BACK AND MITIGATION

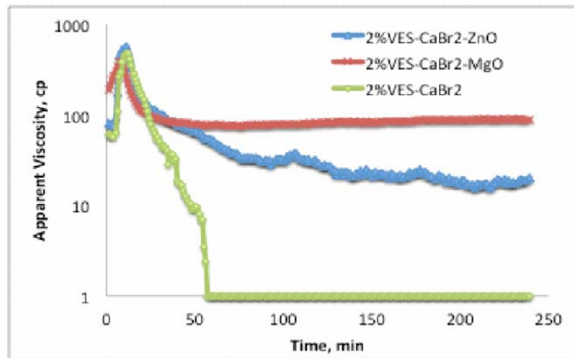
Now we know that the viscoelastic surfactant (VES) fluids has major setback when it comes to its rheology, its leakoff ability and VES proppant pack conductivity at high reservoir temperature. Therefore analyzed below are some of its mitigations.

a) VES Rheology

In a study, amidoamine oxide surfactant in $CaBr_2$ and $CaCl_2$ brine solution were tested with and without nanoparticles [15]. The nanoparticles used were ZnO and MgO. The result of the surfactant micellar fluid was tested using a viscometer. The result showed that VES fluid without nanoparticle turned into low viscosity fluid at high temperature as the micelles breaks into spherical shapes while VES with nanoparticles indicates that addition of nanoparticles enhances the viscosity of the fluid even at high temperature as shown in Figure-3 below.



(a)



(b)

Figure-3. (a) Viscosity result of 4% VES fluid (b) Viscosity result of 2% VES [15].

The above result shows that an increase in VES concentration leads to an increase in amount of micelles-to-micelles entanglement and viscosity of the fluid. This happens as a result of increased micelles that have more opportunity to attach to the surface of the nanoparticles. The result in Figure-4 shows the outcome of increased surfactant concentration from 2% to 4% by volume, which further leads to increased apparent viscosity at temperature as high as 275°F.

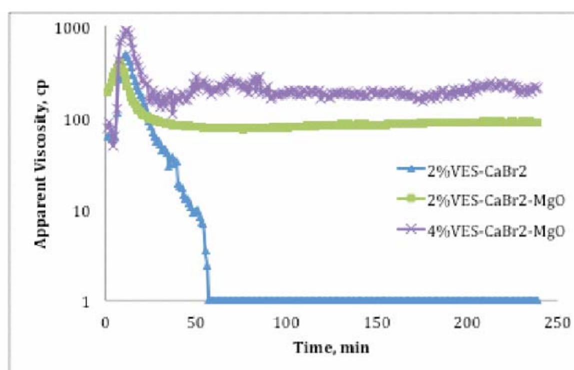


Figure-4. Effect of increase in VES concentration from 2% to 4% [15].

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Addition of microparticles also gives same result as that of nanoparticles when tested [15]. This stabilizes the viscosity of the VES even at temperature as high as 275°F. Therefore these microparticles may be used to replace the nanoparticles to give same result. Figure-5 shows the viscosity stabilization of the VES up to 275°F of MgO microparticles.

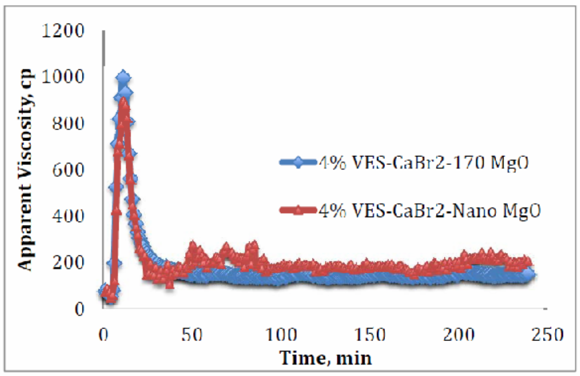

Figure-5. Stability of VES fluid's viscosity using MgO micro particles as compared with MgO nanoparticles [15]

Reduction in Salt concentration at high temperature has been found to help to stabilize the viscosity of the VES fluid. This was proven by reducing the concentration of $CaBr_2$ from 14.2 ppg to 13 ppg, but without nanoparticles the viscosity reduced to 100cp [15]. This shows that reduction in brine concentration helps to stabilize the viscosity at high temperature as shown in Figure-6.

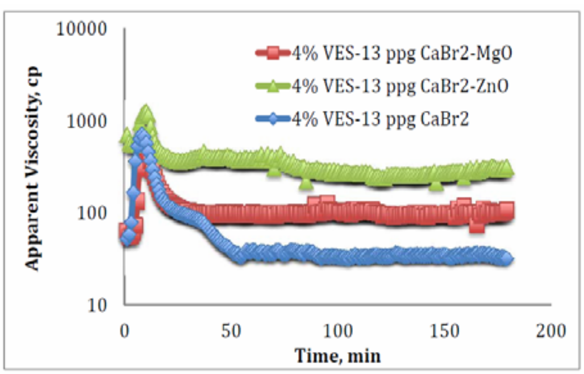

Figure-6. Decrease in salt concentration to from 14.2 ppg to 13 ppg causing stabilization of viscosity at high temperature [15].

It has also been seen that addition of different concentration of nanoparticles (MgO) ranging from 2-8 pounds per thousand gallons (pptg) gives almost same result at a temperature of about 275°F [15]. This shows that lesser amount of nanoparticle can help to stabilize the viscosity of VES at high reservoir temperature and therefore cost can be saved as shown in Figure-7.

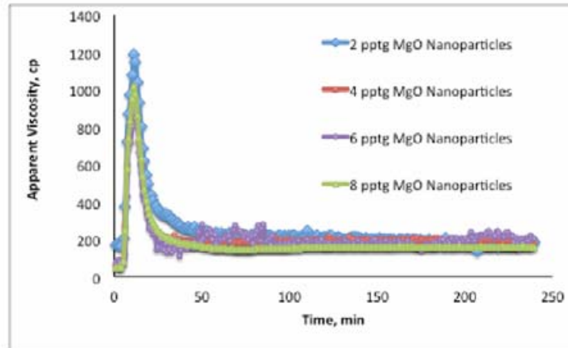

Figure-7. Stability of viscosity of VES for varied nanoparticle concentration [15].

b) VES leakoff control tests and mechanism

Leakoff control is all about the ability of the fluid to maintain a reasonable viscosity until after fracturing occur, then break into lower viscosity fluid in a manner that it does not leak off into the formation matrix. In a study to monitor the fluid leakoff control of VES, a ceramic-filter discs of about 400-md, 2.5-in diameter and 0.25-in thickness was setup with a computer connection to directly measure the weight of fluid loss alongside with specific gravity. The total amount of fluid flowing through the disc was monitored and recorded as a function of time so that fluid leakoff coefficient can be analyzed [14]. The leakoff test was done in two categories. First using fluid with nanoparticles and second without nanoparticles added. Result reveals that the fluid with nanoparticles had a better leakoff control as a pseudo filter cake was formed which helps to control fluid loss. Figure-8 shows that adding nanoparticles enhances the fluid efficiency of the VES.

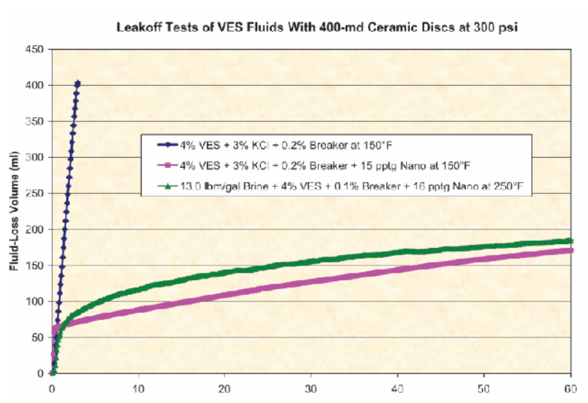

Figure-8. Fluid leakoff test for substantial reduction of fluid loss in a VES with nanoparticle and without nanoparticle [14].

c) VES Proppant pack conductivity

An experiment carried out on an unconsolidated sand packs showed that retained permeabilities of the proppant packs in VES fluids are naturally greater than 90% and extremely higher than those of polymer fluids.

Table-1 shows the significant difference in using a VES compared with polymer. While Figure-9 shows a simulated result of proppant placement in the fracture due to good conductivity of proppant pack in VES fluid as compared to polymer based fluid. [1]. Figure-9a showed a higher fractured length for VES fluid as compared to Figure-9b showing polymers fluid with a lower fracture length.

Table-1. Proppant pack conductivity for VES [1].

Proppant Mesh	Fluid	Pack Permeability (D)	Retained Permeability (%)
20/40	...	560	...
20/40	4% VES	520	93
20/40	Crosslinked guar	250	45
16/20	...	840	...
16/20	4% VES	770	92
16/20	Crosslinked guar	330	39
16/20	Crosslinked low guar	440	52

*Closure stress is 4,400 psi.

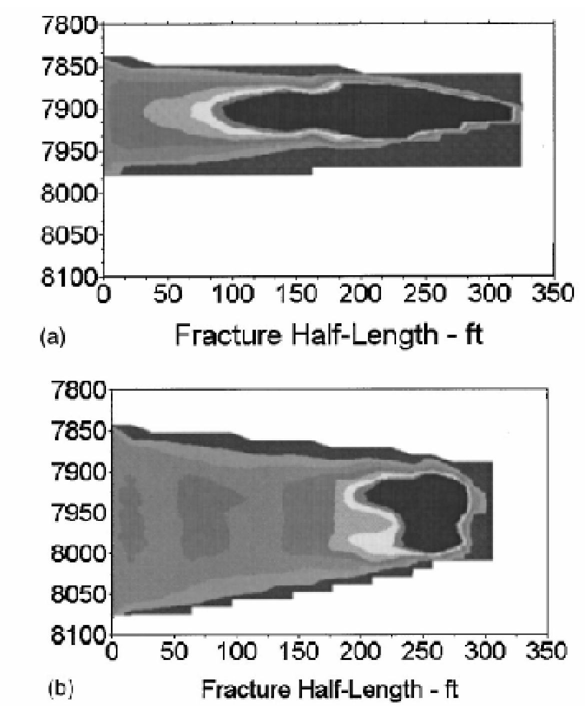

Figure-9. Simulated proppant placement profile within the fracture for (a) VES fluid and (b) Polymer fluid [1].

INTERNAL BREAKERS FOR VES FLUIDS

The major function of the internal breaker system is to help reduce the damage caused to the formation and fracture conductivity [16-17]. Unsaturated fatty acids (UFA) are commonly used which is be activated using auto-oxidation process leading to the collapsing of the elongated micelles, thereby making the viscosity of the VES drop to brine like viscosity. The pseudo filter cake formed is degraded to form nanoparticle plus surfactant fluid. However experiment have confirmed that very minor formation and fracture conductivity damage is experienced in using this nanoparticles' surfactant micellar fluid system [10, 13].

CONCLUSIONS

In conclusion, VES fluids have been found to possess viscoelastic properties which made it suitable for application in hydraulic fracturing. Studies have shown that application of nanoparticles to the VES made it possible for viscosity to stabilize at high temperature as high as 275^{o}F. Furthermore, addition of internal breakers helps to break VES into lower viscosity fluid which aides in effective cleanup and reduction in formation and fracture conductivity damage. VES is has the ability to transport proppants further into the fracture as compared with polymer based fluid.

An area currently looked into is the use of glass fibers to improve proppant suspension and helps to control proppant flowback so as to maximize well productivity. Addition of 10 to 20 microns and lengths of 10 mm or more provides optimum pack stability and ease of handling [18].

However there are still on-going research work regarding the field of VES application in hydraulic fracturing in order to develop and improve its performance and properties.

REFERENCES

[1] Samuel M.M., Card R.J., Nelson E.B., Brown J.E., Vinod P.S., Temple H.L., Qi Qu and Fu D.K. 1999. Polymer free fluid for fracturing Application. Paper SPE 59478 Drilling and Completion Journal. 14: 4.

[2] Alfred R.J. Jr. 1996. Fracturing Fluids- Then and Now. Paper SPE 36166 Journal of Petroleum Technology. 604.

[3] Amstrong K., Roger C, Reinaldo N., Erik N., Ken N., Michael S., Jim C., Gilbert D., Michael P., Neal W. and Gary S. 1996. Advanced Fracturing Fluid Improve Well Economics. Oil Field Review. 7: 43.

[4] Ayoub J.A., Hutchins R.D., Van der Bas F., Cobianco S., Emiliani C.N., Glover M.D., Kohler M., Marino S., Nitters G., Norman W.D. and Turk G.A. 2006. New Findings in Fracture Cleanup Change Common Industry Perceptions. SPE paper 98746, Symposium on Damage Control in Lafeyette LA.

[5] Ayoub J.A., Hutchins R.D., Van der Bas F., Cobianco S., Emiliani C.N., Glover M., Marino S., Nitters G., Norman W.D. and Turk G.A. 2009. New Result Improve Fracture Cleanup Characterization and

Damage Mitigation. Paper SPE 102326, Production and operations Journal.

[6] Rick G., Fulton D. and Shen C. 2009. Fracture-Face - Skin Evolution during Cleanup. Spe paper 101083, SPE Production and Operations Journal.

[7] Berati R., Hutchins R.D., Ayoub J.A., Dessinges M. and Englang K.W. 2009. Fracture Impact of Yield Stress and Fracture Face Damage with a Three-Phase 2D Model. Paper SPE 111457, Production and Operations Journal.

[8] Kostenuk N. and Gagnon P. 2008. Polymer Reduction Leads to Increased Success: Comparative Study SPE 100467 Drilling and Completion Journal.

[9] Brown J.E., King L.R., Nelson E.B. and Ali S.A. 1996. Use of Viscoelastic Carrier Fluid in Frac-Pack Applications. Paper SPE 31114 presented at the SPE Formation damage control Symposium.

[10] Crew J.B., Huang T. and Wood R.W. 2008. The Future of Fracturing-Fluid Technology and Rates of Hydrocarbon Recovery. Paper SPE 115475, Presented at SPE Annual Technical Conference and Exhibition held in Denver Colorado, USA.

[11] Huang T., Crew J.B. and Agrawal G. 2010. Nanoparticle Pseudo cross-linked Micellar Fluids; Optimal Solution for Fluid Loss Control with Internal Breaking. Paper SPE 128067, SPE Symposium and Exhibition Presented in Louisiana, USA.

[12] Huang T. Viscosity Enhancer for Viscoelastic Surfactant Stimulation Fluids. US Patent No. 7, 544, 643.

[13] Huang T. and Crew J. 2008. Nanotechnology Application in Viscoelastic Surfactant Stimulation Fluids. Paper SPE 107728 Productions and Operational Journal.

[14] Sullivan P., Christianti Y., Couillet I., Davies S., Hughes T. and Wilson A. 2006. Methods of Controlling the Fluid Loss Properties of Viscoelastic Surfactant Based Fluids. US Patent. No. 7, 081, 439.

[15] Merve R.G., Hashim A., Nasr-El-Din and Crew J.B. 2013. Enhancing the Performance of Viscoelastic Surfactant Fluids Using Nanoparticles. Paper SPE 164900, SPE Annual Conference held in London, U.K.

[16] Crew J.B. 2005. Internal Phase Breaker Technology for Viscoelastic Surfactant Gelled Fuids. Paper SPE 93449, International Symposium on Oilfield Chemistry held in Houston, Texas, USA.

[17] Crew J.B. and Huang T. 2007. Internal Breakers for Viscoelastic Surfactant Fracturing Fluids. Paper SPE 106216, International Symposium on Oilfield Chemistry, presented at Huston, Texas, USA.

[18] Amstrong K., Roger C, Reinaldo N., Erik N., Ken N., Michael S., Jim C., Gilbert D., Michael P., Neal W. and Gary S. 1996. Advanced Fracturing Fluid Improve Well Economics. Oil Field Review. 7: 48.