Rheology Modification of Viscoelastic Diverting Agents using Ionic Co-Surfactants

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Abstract

Various diversion techniques are used in injection treatments, such as matrix stimulation, to ensure total zonal coverage of the treatment fluid. Viscoelastic surfactants (VES) have been used recently as chemical diverters in stimulation of heterogeneous carbonate formations. VES is added to acid solution as an additive. As diverter stage reaches reservoir rock, acid reacts with formation and pH increases. VES apparent viscosity rapidly increases with increasing pH and finally, it forms an in-situ gel and diverts acid to other untreated layers.
VES based acid can be cleaned up easily and provide higher regained permeability than conventional gelled-acid systems. However, most conventional viscoelastic surfactants lose their viscosity at high temperatures. Co-surfactants can be added to VES to modify its viscosity at high temperatures. In this study, an ionic co-surfactant, named KKJ, is added to VES to improve its rheology. Various experiments are conducted to investigate the effect of KKJ on VES behavior. In addition, effect of NaCl on VES is tested at different conditions. Results of conducted experiments clearly indicate the positive effect of proposed ionic co-surfactant on VES viscosity.

Introduction

The primary purpose of matrix acidizing is to improve flow capacity through a damaged region near the wellbore. Acid treatment in carbonate formations can remove or bypass formation damage. Diversion is a technique used in injection treatments, such as matrix stimulation, to ensure uniform distribution of the treatment fluid across the treatment interval. Injected fluids tend to follow the path of least resistance, and this may lead to inadequate treatment of less permeable areas within the stimulation interval. Therefore, an acid recipe without considering the high contrast in injectivity of the reservoir layers could not lead to acceptable results because the main acid flow would easily penetrate into the high permeable zones and make wormholes within them and other target layers with low permeability remain inert. In order to achieve the main objectives of a uniform stimulation in all layers, an efficient diverting system should be included.

Viscoelastic surfactants (VES) have been used as chemical diverting agents to gain total zonal coverage in stimulation of heterogeneous carbonate formations (Alleman et al. 2003). These surfactants are added to acid solution. VES apparent viscosity rapidly increases as acid reacts with formation, and then forms an in-situ gel. Therefore, it diverts acid to untreated zones. An advantage of VES acid systems is simplicity: they typically require a single-component surfactant additive only. These systems can be used as the main stimulation fluid or included as diverter stages with an untreated acid solution (or other retarded acid system) (Kalfayan, 2008).

VES based acid can be cleaned up easily and provide higher regained permeability than conventional gelled-acid systems (polymer-based). If reservoir fluids (oil, condensate) do not break the formed gel, mutual solvent is typically needed in preflush and overflush to break the formed gel.

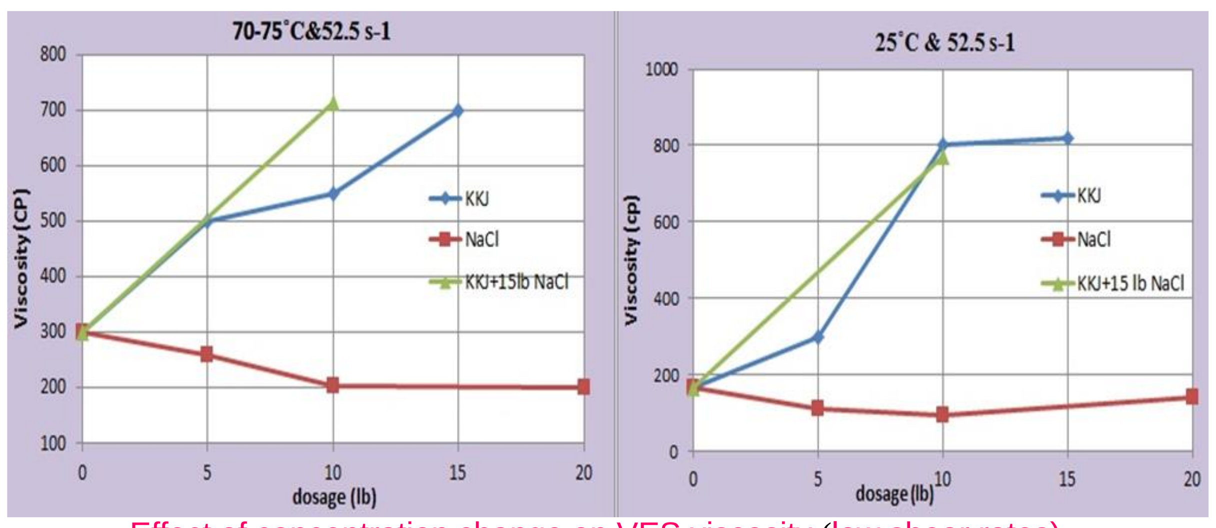
Most conventional VESs do not tolerate high temperatures. VES tends to degrade under long duration of heating and losses its high viscosity (Crews et al. 2008). Many chemical additives are known to improve the rheological behavior. Such materials are typically called co-surfactants, rheology modifiers, or rheology enhancers, etc.

Experimental Studies

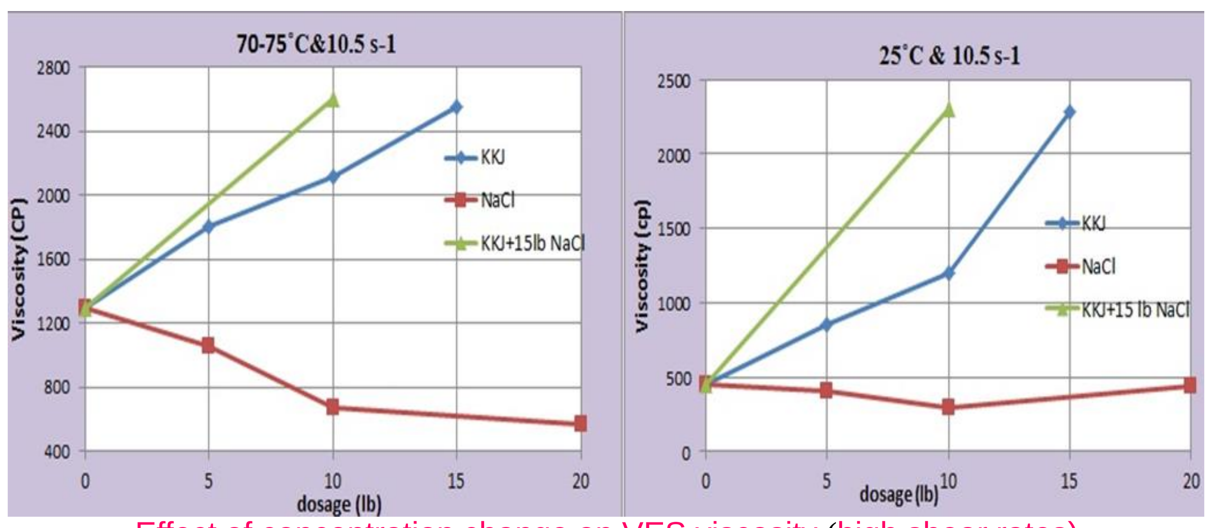
Rheology modification experiments of a commercial VES are conducted in Mehran Acid Lab. Below sections present materials used in experiments and test procedures.
Spent method is used to investigate rheology of various solutions. In this method acid reaction products are present in solution rather than live acid. Water, $CaCl_2$, and carbon dioxide are the reaction products of HCl with calcite. 200cc of solutions with different dosages of co-surfactant (KKJ) and NaCl are prepared. All solutions are prepared to contain 7vol% VES and 44 gr. of $CaCl_2$. Prepared solution are put in oil bath for 45 minutes, and then their viscosity were measured at surface conditions and 70-75˚C. As an example, Table 1 shows the recipe of spent VES solution with 10 lb KKJ. In spent method calculations, it is supposed that live solutions contain 15 wt % HCl.

Recipe of spent VES solution with 10 lb KKJ-01

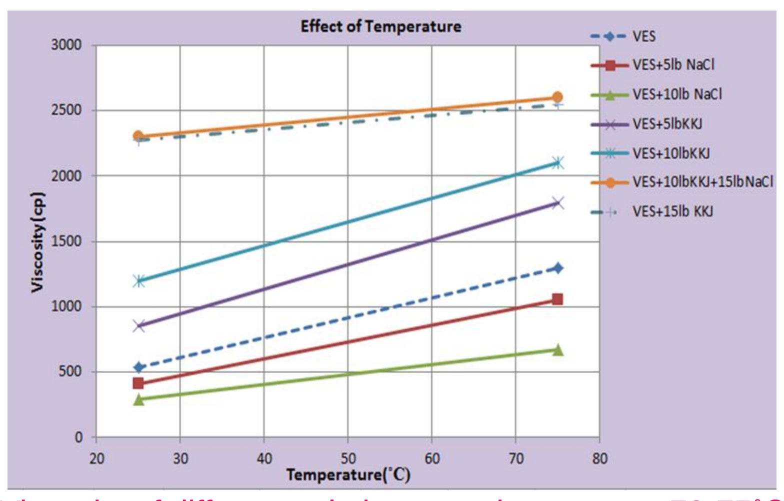
Name	/1000cc	/200 cc	LAB unit
Distill Water	710	142	cc
Co-surfactant	1.2	0.24	gr
$CaCl_2$	220	44	gr
VES	70	14	cc



Effect of concentration change on VES viscosity (low shear rates)



Effect of concentration change on VES viscosity (high shear rates)



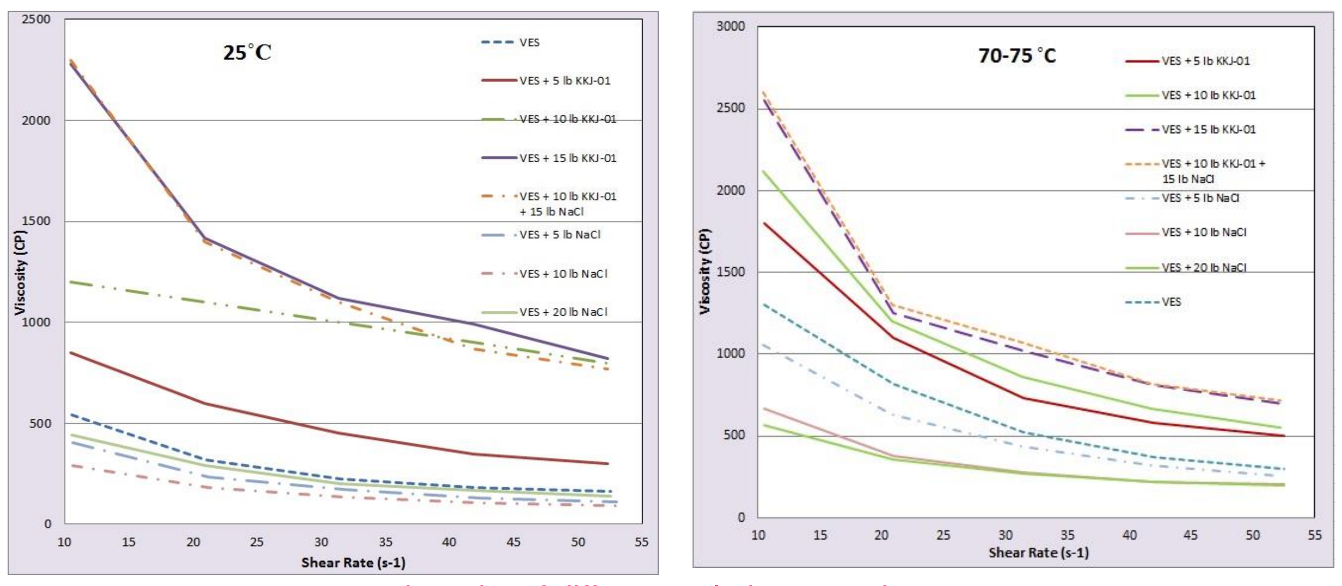
Viscosity of different solutions vs. shear rate at 70-75˚C

Results and discussion

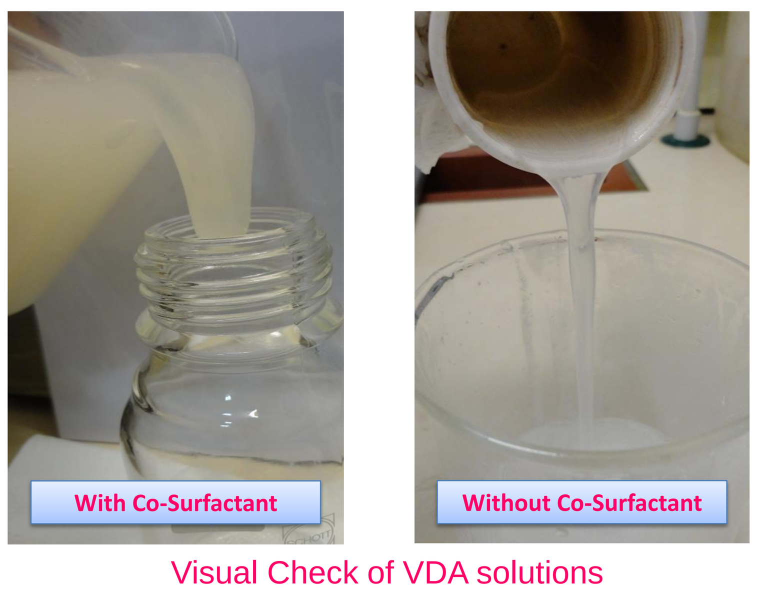
Experimental studies are conducted according to previously mentioned test procedures. Results of these tests are observed visually and with a viscometer. Viscosity of VES are measured under various shear rates.

Viscosity of various fluids vs. shear rate

Shear rate (s-1)	VES	VES+ 5 lb NaCl	VES+ 10 lb NaCl	VES+ 20 lb NaCl	VES+ 5 lb KKJ	VES + 10 lb KKJ	VES + 15 lb KKJ	VES + 10lb KKJ +15lb NaCl
Viscosity of solution at surface condition (cp)								
10.5	540	407	290	443	850	1200	2280	2300
21	320	234	180	290	600	1100	1420	1400
31.5	224	175	135	200	450	1000	1120	1100
42	180	130	108	170	350	900	990	870
52.5	165	110	92	140	300	800	820	770
Viscosity of solution at 75˚C (cp)								
10.5	1300	1056	670	570	1800	2120	2550	2600
21	820	630	380	360	1100	1200	1250	1300
31.5	520	440	280	270	730	860	1020	1070
42	370	320	220	220	580	670	810	820
52.5	300	260	204	200	500	550	700	715



Viscosity of different solutions vs. shear rate



Visual Check of VDA solutions

Conclusions

In this study, an ionic co-surfactant (KKJ) is added to viscoelastic diverting agent to modify its rheology. In addition, effects of NaCl addition is investigated on viscosity of VES solution. Following conclusions can be drawn from the results of conducted experiments:

- KKJ addition increases VES solution viscosity at both surface and high temperature (75˚C) conditions. VES viscosity increases with increasing KKJ concentration.
- NaCl addition decreases VES solution viscosity at both surface and high temperature (75˚C) conditions.
- Addition of both NaCl and KKJ to VES solution can improve rheological behavior of solution more than KKJ itself.
- Increasing temperature from surface to 75˚C, increased all solutions' viscosity. This behavior is in agreement with the literature.

References

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