

Mikhail Aleksandrovich Silin, Liubov Abdulaevna Magadova, Victoria Valerievna Ponomareva
Gubkin Russian State University of Oil and Gas, Moscow

Development and research of cutting fluids for stimulation of oil production on the basis of water-salt and acid solutions containing surfactant compounds and water-soluble polymers

Reorientation in the issue of safety in oil and gas production is a recent feature of oil and gas industry in Russia and CIS countries. It remains at constant level not so much on the account of commissioning more new wells but due to improvement in the operation quality in every specific well to ensure its production capability closest to its potential [3].

The focus of attention of oil and gas industry specialists on the issues of applying modified cutting fluids in the system of oil and gas production results from their key role in production stimulation.

Cutting fluids ensure successful performance of different manufacturing operations which affect the quality of construction, productivity and duration of the well maintenance as a capital facility. Because of this, cutting fluids have to possess the range of specific properties that ensure successful implementation of various technological operations and borehole repair zone permeability [7].

The methods of oil production stimulation in domestic practice are the actual methods of oil field development, but they require further evolution of technologies in the direction of cutting fluids improvement. Such cutting fluids may contain surfactants with predetermined and regulated viscoelastic and thermochemical properties. Also, these cutting fluids must be easily destructible in the borehole zone and must not cause pollution of the reservoir.

The oil and gas industry viscoelastic compositions based on polyacrylamide, polysaccharides and other polymers have been used in a wide range of applications.

Polyacrylamide is applied for various purposes, e.g.:

in drilling as a stabilizer and regulator of mud rheological properties, as rock tunneling accelerator and as soil structure generator for wellbore strengthening. Recently polyacrylamide application has been reduced in connection with difficulties in its removal from the formation as its presence deteriorates the reservoir permeability [1, 2].

The main advantage of the natural vegetable polysaccharides is their low cost. But their technological indices are rather low, which narrows the field of their application. Because of this, chemically modified cellulose derivatives, i.e. starch and guar are used, as they possess a set of technological features [2].

For further effective viscosity increase, polymeric structures are often cross-linked. After pumping polymeric fluids into the formation there is no need to ensure viscosity of the composition. Therefore, the destruction of molecular skeleton of polymeric structures occurs under the influence of a destructing factor. The efficiency of the destructing factor reaches no more than 80% nowadays. Incomplete gel destruction after hydraulic fracturing leads to fracture permeability decrease.

The application of viscoelastic compositions based on polymeric substances has the following disadvantages: the necessity of cross-linking; the necessity of using a destructing factor; high friction pressure loss during pumping; incomplete recovery of un-decomposed gel after destruction.

The application of viscoelastic compositions based on surfactants helps avoid the disadvantages.

Specified surface-active substances (SAS) are able to form viscoelastic fluids in aqueous solutions. Such surfac-

tants are called “viscoelastic surface-active substances”. As distinct from numerous surfactants that usually form Newtonian solutions, they are capable of generating viscoelastic gels, even if low-concentrated. Such specific rheological process can be observed mainly due to presented types of surfactant aggregates. Surfactant types with high enough concentration gather as spherical micelles in low-viscosity fluids, whereas in viscoelastic fluids long cylindrical, worm-like or rod-like micelles are present and can interlace (Figure 1). Interlacing of such micellar structures gives elasticity and viscosity to a fluid. For good liquid rheological properties in distinct conditions appropriate micellar structures must be formed with proper interlacing. For this purpose surfactant structure must meet specific geometrical requirements, while micelles should have enough length or inner bonds for appropriate interlacing [6].

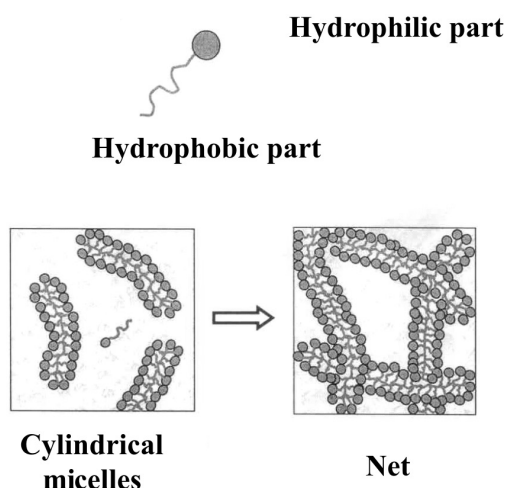


Fig. 1. Formation of viscoelastic surfactant micellar structure

Surface-active substance concentration in aqueous viscoelastic fluid reaches from 1.0 to 10.0 wt. %, preferably from 1.5 to 5.0 wt. % [6].

Compositions based on viscoelastic surfactants have a set of advantages over viscoelastic compositions based on polymeric substances. These advantages are as follows: absence of cross-linking agents, ability of application in high-temperature and high-permeable formations, low rate of leakages, structure destruction at high fluid distribution rate and its repairing at low one, structure destruction after interaction with hydrocarbon phase and complete removal of composition components from a formation. Interaction with hydrocarbons cause micelle transition from cylindrical to spherical form that results in destruction of micellar structure (Figure 2).

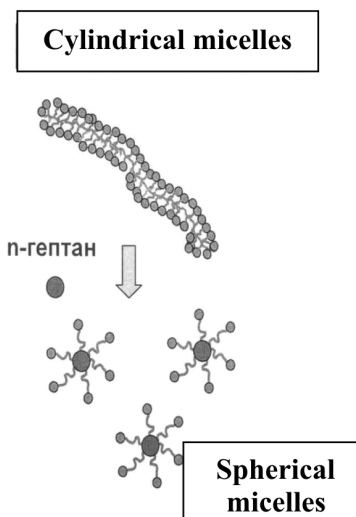


Fig. 2. Destruction of viscoelastic surfactant micellar structure at interaction with hydrocarbon

In the Center of Field Chemistry in Gubkin State University compositions of viscoelastic cutting fluids based on well-known industrial surfactants were developed and studied [6]. Every composition was created on the basis of principle of interaction between cationic and anionic surfactants. As a result, a surfactant molecular complex is formed. Such complexes generate micellar structures in aqueous medium.

Obtained effective viscosity values of developed compositions are not high enough with regard to hydraulic fracturing technology. So polymeric substances (0.1 wt. %) were admixed for their rheological properties improvement. Polymers integrate into micellar structure of viscoelastic surfactants and favour its strengthening (Figure 3). The following polysaccharide reagents were used for research: carboxymethyl cellulose (CMC-600), Hydroxyethyl cellulose, Hydroxypropyl guar and xanthan-type biopolymers of brands Xanthan DRILLUX 1405 and Xanthan Gum E415.

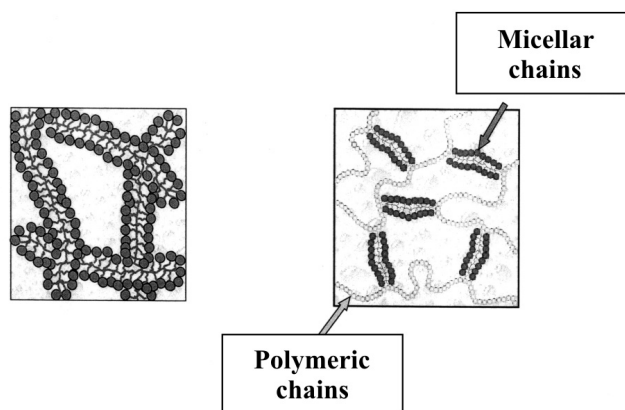


Fig. 3. Strengthening of viscoelastic surfactant structure after polymeric substance addition

of sodium chloride (10 wt. %) solution. Rheological properties were investigated using the case of a study of obtained aqueous part by observation effective viscosity response to fluid distribution rate increase. Results are shown in Figure 4.

As it can be seen from Figure 4, after Composition 1 (9.9 wt. %) and Xanthan Gum E415 (0.1 wt. %) mixture interacts with hydrocarbon phase in the medium of sodium chloride solutions (10 wt. %), its effective viscosity decreases significantly. In this case we can conclude that micellar structure of developed complexes was destroyed.

The hydrocarbon part, obtained after the mixture of Composition 1 (9.9 wt. %) and Xanthan Gum E415 (0.1 wt. %) interacted with kerosene in a medium of sodium chloride (10 wt. %) solution, was examined for its interfacial tension on the boundary with distilled water. The results of these measurements show (Table 2) that after the surfactant composition 1 interacts with kerosene in sodium chloride solution (10 wt. %), the medium interfacial tension is about 10 times less than for kerosene TS-1. Addition of

the polymer substance to surfactant enables the decrease in interfacial tension of studied complex hydrocarbon part by 35 times. Such intense decrease in interfacial tension occurs as the result of synergistic effect of interaction between polymeric substance with micellar structures. It allows to produce the flow stream in the best possible way and to the clean out the formation pay zone to the fullest extent when covered complexes are employed as components of cutting fluids.

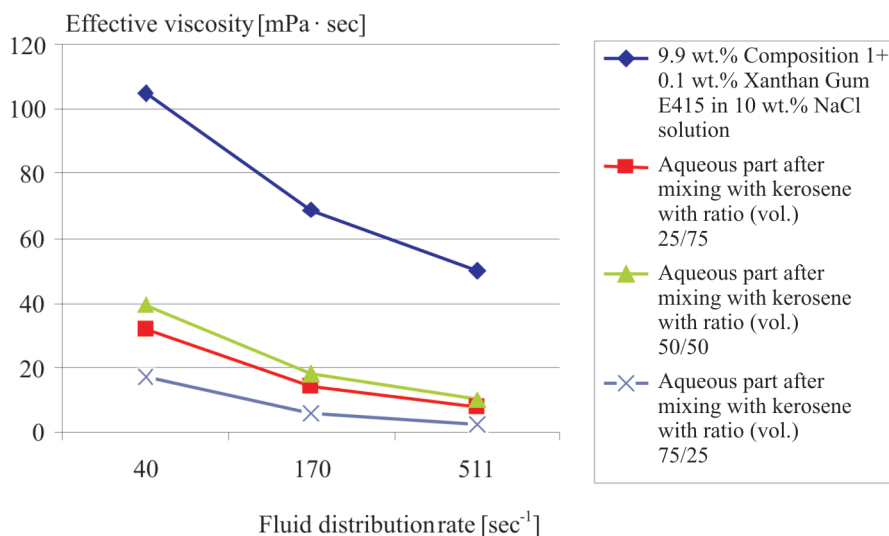


Fig. 4. Dependence of effective viscosity from fluid distribution rate for mixture of Composition 1 (9.9 wt. %) and Xanthan Gum E415 (0.1 wt. %) in sodium chloride solution medium and its aqueous parts after mixing with kerosene

Table 2. Interfacial tension on the boundary hydrocarbon part – distilled water

Examined composition	Interfacial tension [mH/m]
Kerosene TS-1	47.50
Hydrocarbon part obtained after Xanthan Gum E415 (0.1 wt. %) interaction with kerosene in sodium chloride solution (10 wt. %) medium	46.70
Hydrocarbon part obtained after surfactant composition 1 (9.9 wt. %) interaction with kerosene in sodium chloride solution (10 wt. %) medium	4.24
Hydrocarbon part obtained after surfactant composition 1 (9.9 wt. %) and Xanthan Gum E415 (0.1 wt. %) mixture interaction with kerosene in sodium chloride solution (10 wt. %) medium	1.38
Hydrocarbon part obtained after Xanthan Gum E415 (0.1 wt. %) interaction with kerosene in potassium chloride solution (10 wt. %) medium	49.80
Hydrocarbon part obtained after surfactant composition 1 (9.9 wt. %) interaction with kerosene in potassium chloride solution (10 wt. %) medium	4.24
Hydrocarbon part obtained after surfactant composition 1 (9.9 wt. %) and Xanthan Gum E415 (0.1 wt. %) mixture interaction with kerosene in potassium chloride solution (10 wt. %) medium	1.82

Conclusions

1. The effect of water-soluble polymeric substances addition (0.1 wt. %) to the developed viscoelastic surfactant

compounds on their rheological and surfactant properties was studied.

2. It was found that xanthan-type exopolysaccharide and hydroxyethyl cellulose additives favoured effective viscosity increase in developed compounds and decrease in interfacial tension of the boundary hydrocarbon phase – distilled water.
3. Destruction of developed viscoelastic surfactant compounds containing polymer substance was studied in interaction with hydrocarbon phase.
4. Addition of a polymer substance enhances viscosity of developed surfactant compounds significantly and does not influence the phenomena of viscosity decrease in interaction with hydrocarbons for such compounds.

The article was sent to the Editor on 18.11.2010. Accepted for printing on 13.01.2011.

Recenzent: dr hab. inż. Teresa Steliga

References

- [1] Ibragimov L.H., Mistchenko I.T., Cheloyants D.K.: *Stimulation of oil production*. Nauka, 414 p., 2000.
- [2] Magadova L.A.: *Development of fracturing fluids on aqueous and hydrocarbon basis and related technologies for using the fluids for hydraulic formation fracturing improvement*. Ph. Sc. (technical science) dissertation. M., 375 p., 2007.
- [3] Muslimov R.H., Shaposhnikov D.A.: *Colloidal chemistry in processes of oil recovery from formation*. Kazan, FES Academy of Science RT, 156 p., 2006.
- [4] Silin M.A., Magadova L.A., Ponomareva V.V., Davletshina L.F., Mukhin M.M.: *Research of xanthan-type viscosifiers used in technologies of acid hydraulic formation fracturing*. Oil and gas technologies. № 2 (67), p. 25–28, 2010.
- [5] Silin M.A., Magadova L.A., Ponomareva V.V., Davletshina L.F., Mukhin M.M.: *Research of xanthan-type acid viscosifiers for their application in technology of acid hydraulic formation fracturing*. The V All-Russia academic and research conference “Field chemistry” (24–25 June 2010) devoted to Gubkin State University 80th anniversary and Chair of Technology of chemical materials for oil and gas industry 50th anniversary, p. 83–86, Moscow 2010.
- [6] Silin M.A., Magadova L.A., Ponomareva V.V.: *Research and development of formulations of viscoelastic fluids based on surfactants*. Oil and gas well construction onshore and offshore. № 10, p. 30–34, 2010.
- [7] Tokunov V.I., Saushin A.Z.: *Cutting fluids and complexes for oil and gas wells productivity increase*. Nedra, 545 p., 2004.



Silin Mikhail Aleksandrovich – Ph. Sc. (chemistry).



Magadova Liubov Abdulaevna, Ph. Sc. (technical science).



Ponomareva Victoria Valerievna, the post-graduate student.