Laboratory grounding of waterproofing sealant based on acrylic polymers

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Abstract. Modern Russian resource base is characterized by the state of deterioration. Economic indicators urgently need to be kept at the attained level. Enhanced oil recovery, produced water constriction gained by means of innovations are the crucial tasks when planning the events concerning the volume gain of recoverable hydrocarbon reserves in Russia as well as in the whole world. The present paper analyses the modified water shutoff polyacryl nitryl compound. Laboratory and investigative research has been carried out. The compound under study enables to restrict water inflow along the highly porous channels.

1. Relevance

Nowadays Russian resource base is deteriorating; the largest part of oil fields is water-flooded up to 80-90 % and even more. Thus, there is an urgent need to keep the attained level of economic indicators of the oil recovery. Enhanced oil recovery, produced water constriction gained by means of innovations are the crucial tasks when planning the events concerning the volume gain of recoverable hydrocarbon reserves in Russia as well as in the whole world. Consequently, there is an urgent demand at present to apply high performance technologies in all processes of oil fields exploitation.

Normally about 10-15 years elapse before new oil deposits and fields are found and developed. Therefore, enhanced oil recovery, produced water constriction and oil cost reduction gained by means of innovations in technology are practically indispensable in attempt to increase commercially exploitable hydrocarbon reserves in Russia.

At present the majority of oil fields in Russian Federation are produced with the intensive growth of water influx. Oil recovery decreases and the number of hard to recover oil reserves increase. The number of highly watered wells increases with a low oil recovery index. This situation is typical of a considerable amount of LLC “LUKOIL-Western Siberia” oil fields. Key factors of the advanced water flow into a development well are water breakthrough along the highly porous channels (splits and
interlayers) and coning caused by water hoisting, faulty sealing of a capital string and behind-the-casing water flow.

Increase of the oilfield development efficiency under such conditions must be provided with the reliable water shut-off technologies and activities on regulating filter currents in oil strataums [1-10]. It is important to develop new shut-off technologies and adapt the existing ones to the geological and physical conditions of separate oil fields. Modification of the renowned water shutoff and water diverting compounds, their combined application enable to get a synergistic effect of the concurrent oil recovery increase and water shut-off. Herewith, oil recovery index grows [1-7]. One of the promising areas of water shut-off, inflow profile modification/conformance control and the increase of oil recovery index is the development of gelling compounds and agents on the polymer base or modification of the applied gelling compounds and agents, adaptation of technologies and agents to the certain geological and physical conditions. Such compounds/agents are recommended to be applied in the technologies of regulating the porosity of the reservoir watered intervals, coating of channels, through which water flows, and initiating filtration processes in the technologies in the oil stratum zones which are not flooded [1, 2, 12, 13].

2. Objective
The main objective is to describe the adapted and modified gelling agents and waterproofing sealants based on polymers, to study their physical and chemical features and filtration characteristics with regard to the typical geological and physical conditions of the oil field of Kogalym and Langepas.

3. Methods and materials
As it is necessary to study the adapted and modified gelling agents based on polymers, the laboratory methods and modeling water motion limitation in the environments characterized by the presence of pores and splits are used when studying their physical and chemical features as well as filtration characteristics. The experiments apply the data and materials of several West-Siberian oil fields and specimens of acrylic polymers.

4. Outcomes
For instance, water soluble acrylic polymers injection is used to obtain selective coating of stratum water flow into oil-wells [1, 2]. Interaction of water soluble acrylic polymers with salts contained in stratum water or adsorption of polymers on water-saturated formation creates resistance to water motion by means of sedimentation in porous channels. However, this technology can be applied only to provide shut-off to stratum highly mineralized waters of a chlorocalcite type. Such water type is typical for the region under research. In wellsites there is a technology providing a flooded interval of oil stratum with subsequent injection of a buffer composed of fresh water being the hydrolyzed polyacrylonitrile, the second buffer of fresh water and further driving of all the mentioned liquids into a stratum by means of oil-field brines with the density of 1.18 g/sm³ [1]. However, as time goes by, the water soluble polymer is squeezed out of a stratum, which leads to low coating efficiency and precludes the usage of this method ubiquitously. The reason why polymers are squeezed out of the stratum is the mutual repulsion of negatively charged anionic types within the polymer (hydrolyzed polyacrylonitrile) macromolecules and the pore space surface. There is a water shut-off technology which stipulates subsequent injection of aqueous solution bank of partially hydrolyzed polyacrylamide and clay slurry with the further injection of a displacement agent into the wet stratum [1]. The drawback of such technology is rather low efficiency due to the fast prograding of an isolating shield, which is stipulated by rock matrix bond and polyacrylamide breakdown. A set of experimental research including the verification of the existing technologies, selection and adaptation of gelling agents based on polymer agent was carried out for the conditions of the group of fields under research. Laboratory examination of the above mentioned technologies has shown that their application is limited and is impossible in some geological and physical conditions. Thus, the laboratory testing of the existing water shut-off technologies has proved the current problems and low efficiency of water
shut-off stipulated by a high durability of the created gel barriers and shields, which leads to the time-effect cutting concerning the water flow limitation. Application of water shut-off based on waterproofing sealant which contains acrylic polymer solution and a crosslinker being an aluminosilicate component has proved to be rather efficient. The compositions containing partially hydrolyzed polyacrylonitrile and a crosslinker being aluminium chloride having gelling properties held good under the conditions of Kogalym and Langepas oil fields. In case when the cross-linked molecules of partially hydrolyzed polyacrylonitrile together with alumiino chloride gel make up a shield with a high water-shutoff potential, the header porousness decreases by several dozens of times (50 times and more).

Two technologies were developed with the aim to increase the efficiency of applying polymer based water shut-off. The composition of the WBPP technology is made up of water-based polyacrylamide polymers, a crosslinker and a dissolvent and the composition of WBSP, water-based swelling polymer (partially hydrolyzed polyacrylonitrile), a dissolvent and a crosslinker (aluminium chloride).

The composition of a “dissolvable polymer – crosslinker” type are used for treating the stratams having porosity of an average value. Compositions with an indissolvable strongly swelling polymer are intended for treating the stratams having highly porous channels (highly porous interlayer, stratum fractured zones).

It is necessary to select a polymer, a crosslinker, and their compositions with regards to the dissolvent composition for obtaining crosslinked polymers with the required properties. The water-based polyacrylamide for oil recovery is chosen with account of the quantitative information concerning the physiochemical and filtration characteristic of polymers included in the database “Polymeric densifiers” (the database contains information on 360 specimens manufactured by 22 producers), properties of polymers and their dissolvents are also preliminary studied with account of the specified conditions of West Siberian oil fields.

Polymers with the capacity to slow down or block water filtration in highly porous splits and interlayers (WBSP technology) are required for regulating and redistributing filtration flows in highly heterogeneous and permeable stratams. Such polymers as well as a solvable part contain dissolvable, strongly water-swellable polymer with addition of crosslinker.

The time required for jelling in case of polymer compounds based on partially hydrolyzed polyacrylonitrile and aluminium chloride crosslinker depends on polymer molecular properties (molecular mass, degree of hydrolysis), salinity of water used as a dissolvent, temperature, density and type of a crosslinker.

In technologies WBPP and WBSP the polymer’s molecules cross-linking in the solution is followed by the formation of gel being a grid of “crosslinked” polymer chains in a dissolvent. The stage of crosslinking is characterized by a dramatic increase of working solution viscosity. Viscosity grows rather rapidly near the gel point and the system becomes non-flowing with the gel formation (Figure 1).
Figure 1. Typical dependency type of the viscosity of a gelling composition based on the crosslinking polymer system on the time required for gelling. \( T_{gel} \) is time required for gelling.

The stated dependency of the gelling period on the initial agent concentration and the process temperature (Fig. 2) shows that the working composition for obtaining the required parameters (gelling time and temperature) as well as injection technology (a homogenous composition consisting of all the components or partial and separate polymer injection of a polymer and a crosslinker) should be chosen with regards to the application conditions of such compositions. 

The durability and efficiency of the crosslinked polymer composition with regards to blocking or reduction of water filtration are the significant process variables determining the gel strength and consistency. These variables are influenced by the following parameters:

- chemical: the presence of dissolved oxygen, hydrogen sulphide, ferrous iron, polymer type, dissolvent composition;
- physical: temperature, filtration rate (differential pressure) during the injection of a composition into stratum, shear degradation during the process of dissolving.

Figure 2. Dependency of time required for gelling on initial agent concentration and temperature

5. Conclusion
1. A modified water shutoff compound based on polyacryl nitryl has been studied. Laboratory and investigative research enabling to justify polymer application in water shut-off and isolation techniques has been carried out.
2. The use of technology with the modified agent components (partially hydrolyzed polyacrylonitrile) and the complexation of gelling agent and crosslinker properties allow reaching a synergistic effect of the water shut-off and isolation of coating.
3. The technology implying the application of partially hydrolyzed polyacrylonitrile and aluminium chloride injected into the watered intervals as banks separated by fresh water has been developed.

References

[1] Andreev V E, Dubinsky G S, Kotenev Yu A, Kulikov A N and Mukhametshin V Sh 2014 Metotechnology of water influx limitation and enhanced oil recovery (Ufa: USPTU)

[2] Mukhametshin V V, Andreev V E, Dubinsky G S, Sultanov Sh Kh and Akhmetov R T 2016 The usage of principles of system geological-technological forecasting in the justification of the recovery methods SOCAR Proceedings 3 46–51 DOI: 10.5510/OGP20160300288

[3] Chang H L, Zhang Z Q, Wang Q M, Xu Z S, Guo Z D, Sun H Q, Cao X L and Qiao Q 2006 Advances in polymer flooding and alkaline/surfactant/ polymer processes as developed and applied in the people’s Republic of China Journal of Petroleum Technology 58 (2) 84–89 DOI: 10.2118/89175-JPT

[4] Diaz D, Somaruga C, Norman C and Romero J 2008 Colloidal dispersion gels improve oil recovery in a heterogeneous Argentina Waterflood SPE Symposium on Improved Oil Recovery (United States of America: Society of Petroleum Engineers) pp 1–10 DOI: 10.2118/113320-MS

[5] Moritis G 2008 More US EOR projects start but EOR production continues decline Oil & Gas Journal 106 (15) 41–46

[6] Satter A, Iqbal G M and Buchwalter J L 2008 Practical enhanced reservoir engineering: assisted with simulation software (USA: Penwell)

[7] Spildo K, Skauge A, Aarra M G and Tweheyo M T 2009 A new polymer application for North sea reservoirs SPE Reservoir Evaluation & Engineering 12 (3) 427–432 DOI: 10.2118/113460-PA

[8] Khisamov R S, Abdrakhmanov G S, Kadyrov R R and Mukhametshin V V 2017 New technology of bottom water shut-off Oil industry 11 126–128 DOI: 10.24887/0028-2448-2017-11-126-128

[9] Kadyrov R R, Nizaev R Kh, Yartiev A F and Mukhametshin V V 2017 A novel water shut-off technique for horizontal wells at fields with hard-to-recover oil reserves Oil industry 5 44–47 DOI: 10.24887/0028-2448-2017-5-44-47

[10] Yakupov R F, Mukhametshin V Sh, Zeigman Yu V, Chervyakova A N and Valeev M D 2017 Metamorphic aureole development technique in terms of Tuymazinskoye oil field Oil industry 10 36–40 DOI: 10.24887/0028-2448-2017-10-36-40

[11] Thomas S 2008 Enhanced oil recovery: an overview Oil & Gas Science and Technology–Rev. IFP 63 (1) pp 9–19

[12] Turner B 2009 Polymer gel water-shutoff application combined with stimulation increase oil production and life of wells in the monterey formation offshore California SPE Western Regional Meeting (United States of America: Society of Petroleum Engineers) pp. 314–321 DOI: 10.2118/121194-MS

[13] Daneshy A A 2006 Selection and execution criteria for water-control treatments SPE Symposium and Exhibition on Formation Damage Control (United States of America: Society of Petroleum Engineers) DOI: 10.2118/98059-MS