The Development of a Water proofing Polymeric Composition based onCarboxymethylcellulose forCarbonateReservoirs

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Abstract

The article shows the various types of water-shutoff agentsincludingtheadvantagesanddisadvantagesofeachtype.Water-shutoff composition based on carboxymethylcellulosewas developed to limit the water inflow in the fracture-poroustype of the reservoir. Chromium acetate is used as a stitcher,copper sulfate is recommended as a densifier. The laboratorystudies revealed the dependence of the kinetics of gelation andthestrengthcharacteristicsofthedevelopedgel-formingcomposition on the concentration of reagents and temperature.From these data it is possible to quickly determine the optimalconcentrationofreagentsforspecificgeologicalconditions.

Keywords: Watershutofftreatment,carbonatereservoir,carboxymethylcellulose.

INTRODUCTION

In recent decades, most of oil and gas fields of the RussianFederation are characterized by a significant increase in watercut and decrease in rates of hydrocarbon production. For thisreason the problem of maintaining the economic efficiency ofoil production becomes especially relevant. Carrying out ofwaterproofingworkisimportanttoreducethecostofextraction and further use of co-produced water, as well as toregulate the flow of fluids in the reservoir and near-wellborezoneintheprocessofoilandgasfieldsdeveloping[1].

Currently two main areas of limitations of water inflow towellsaredeveloped:mechanicaloverlapofthefloodingintervals andinjectionofvariouschemicalagentsintoformation[2].Thefirst methodinvolvestheuseofslipcouplings, packer or plaster, lowered into the well through thetubes. The main drawback of this method is the reduction oftheusefulcrosssectionoftheproductioncasing.

Chemical methods are divided into nonselective and selectiveaccordingthecloggingmechanismoffractured-porousmedium.Thereagentswhichareappliedinnon-selectiveisolationmethodsusedtoformwaterproofingscreen,regardless of the type of fluid that saturates fromations (oil,gas, water). The main materials for such insulation are cementslurry. The main advantage of cement slurry is low cost andtheeasyavailabilityofthecompositioncomponents.However, because of the low penetrating ability, the use ofsuchcompositionsisgreatlyreduced.

Selective isolation methods are methods based on the use ofmaterialsthatincreasethefiltrationresistanceinwater-saturated partofthe reservoir. There are three selective groups of materials: organic polymermaterials,inorganiccompounds,heteroorganiccompounds[2].Inorganiccompoundsincludesilicates(silin,alkalisilicate)andaluminosilicates(nephelineandceritadewasacomponents). The selective effect of this group is caused bythe ability of silicates and aluminosilicates to heliroute in thepresenceof the polyvalentmetals ions that are containedinthe formation water and acid environment. Such compositionshave a low viscosity, high strength and selectivity. The maindisadvantage is the low efficiency of the plugging of salineformation water.

Heteroorganic compounds are organosilicon (AKOR, GKZH-11),organoaluminumetc.SuchcompoundscontainthechemicalbondofSi-OandSi-C.Itindicatestotheirintermediatepositionbetweentheothertwogroups.Theadvantage of these compositions is caused by the resistance tohigh temperature and low viscosity. However, the scarcity andhighcostofcomponents,andthecorrosivenessrestrictswidespreaduseofthesecompoundsinwaterproductionrestraininginoilwells[3].

Thegroupoforganicpolymericmaterialconsistsofcrosslinked polymeric composition based on polyacrylamide,polymers"Gipan"and"Givpan",oksietilandcarboxymethylcellulose.Gel-forming compositions based on organic reagents shouldhave adjustable gelation time and high strength characteristics[4].Also,theymustbeavailableandhavealowcost. Temperature has a significant influence on the structurizationtimeformostofthepluggingcompositions.

ProducingformationoftheTatarstanRepublicandPermregion, presents with carbonate reservoirs, were selected as anobjectforstudy.Theseformationshavelowreservoirtemperature (T<40 °C), high salinity of formation water (> 50g/l). The characteristic feature is that the productive layers arerepresentedwithdismembered(ratio>3)formations.Theaverageoil-saturatedthicknessintheTulaandVereiskyhorizonsislessthan3m.

MAINPART

To carry out works to water production restraining in terms ofcarbonatereservoirswedevelopedandsuggesttousewater gel-formingcompositionbasedoncarboxymethylcellulose(CMC). In this composition organic salt of chromium (III) isusedasagelationinitiator.Coppersulfatesolutionisusedasa catalyst (densifier). To determine the optimal concentrationsofreagentsfordevelopedwaterproofingcompositionlaboratoryexperimentshavebeenconductedtostudythedependenceofthestrengthandthegelationtimevstemperatureandconcentrationofCMCandcrosslinkingagent.

Experimental studies on the development and testing of thewaterproofing composition were conducted with the use ofmodern equipment in the laboratory of enhanced oil recoveryof the Mining University. Laboratory experiments includedrheologicalstudy.Thefollowingcharacteristicswereevaluated:

1. The gelation time – the period of time from the startofincreasingtheviscosityofthegel-formingcomposition tobecome a gel. The tolerable upperlimit of the gelation time is taken for 24 hours (theaverage duration of technological operational delayafter repair) [2];
2. Plasticstrength–aparameterdescribestheforcevalue exerted on the gel that it is able to withstanduntildestruction;
3. The induction period of gelation is the parameter thatspecifiestheperiodoftimeduringwhichtheeffective viscosityofthecompositiondoesnotchangerelative totheinitial;

Seriesofexperiments,includingdeterminingthetimeofgelation by the visual method were conducted to evaluate theoptimalconcentrationofcomponentsinthewaterproofcomposition. Themethodof determining the gelation timeconsists of the following: the composition were prepared thenpoured in a glass container whicn was covered with aluminumfoil and holded at different temperatures (20, 40, 60, 80, 100ºC). Then, every 15 minutes, the glass was inclined at an angleof 45° to observe the variation of the meniscus angle. Thecomposition was considered as a gelled when the angle of themeniscus with the inclination of the glass container doesn'tchange. As a result of the laboratory studies 4 compositionwith different concentrations of chromium acetate and coppersulfatewereselected.MassfractionofCMCinallcompositions was the same (5,5 %). Composition 1 has themaximumcontentofchromiumacetateandcoppersulfateamong 4 selected compositions. Figure 1 presents a graph ofthe dependence of gelation time vs temperature during theexperiment.

PlasticstrengthofeachgelwasmeasuredattheunitRehbinder(conicalplastometer).Themethodinvolvesmeasuring the depth of immersion in the prepared gel of acone withknownmassunderaconstantloadfor15minutes.

Figures 2 and 3 present graphs of the plastic strength's of thecomposition vs the temperature after 5 days from the time thecomposition wasprepared.

Theinductionperiodofgelationofthewaterproofingcomposition was investigated using a rotational viscometerRheotestRN4.1(MedingerMessgerateGmbH,Germany).

The effective viscosity and shear stress of the compositionshavebeendeterminedataparticularshearrate,which depends on the diameter of tubing strings and pump [5]. Tosimulate the movement of gel in the bottom hole formationzone the study was conducted at a constant shear rate of 5 s-1(figure4) [6].

The dependence of the gelation time of the compositions vstemperature obeys the exponential law with a high degree ofcorrelation. With increasing concentration of copper sulphateand chromium acetate, the gelation time decreases. It shouldalso be noted that the gelation time varies from 200 to 400minutes for the temperature conditions of the Perm region andTatarstan (20 °C-40 °C) and its more than one hour for thetemperatureconditionsofWesternSiberia(T≥75ºC).According to the materials of the article [4] the gelation timemustbe1-24 hours,whichsatisfiesthecondition.

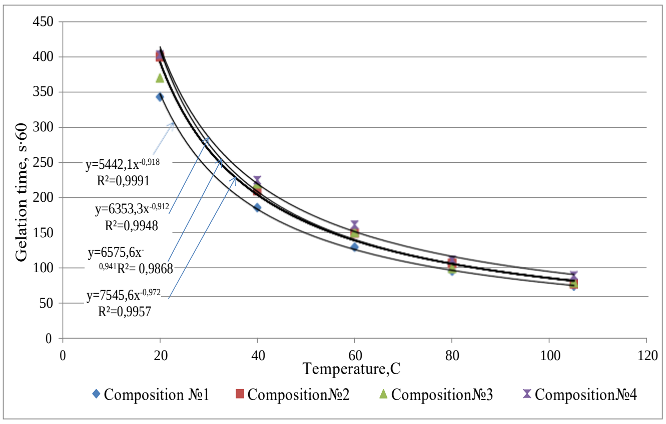

Figure1– Gelationtimeofthecompositionsvsthetemperatureandconcentrationofchromiumacetateandcopper sulfatefor 5.5%carboxymethylcellulose

Plasticstrengthreachesamaximumvalueat60°C.Thiseffect can be explained by blasting action of the temperaturefactorontheaqueoussolutionofCMCwithincreasingtemperatureabove60°C[7].AccordingtoA.V.Blazhevich [2] theminimumallowablestrengthofthegel-formingcomposition is equalto3000Pa. Thevalueof theplasticstrength of the developed composition is above the minimumvaluesforallmeasured temperatures(20°C-60°C).

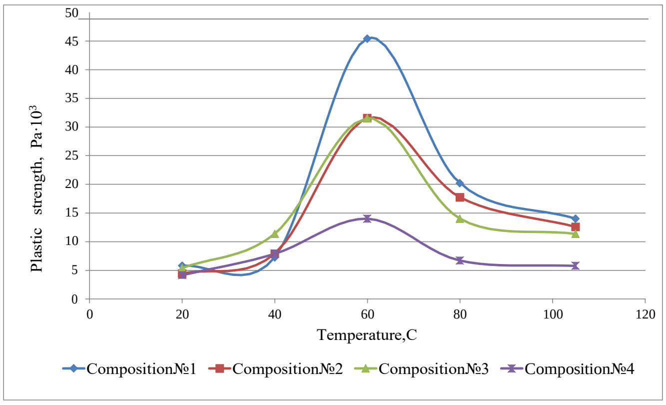

Figure2–Thedependenceoftheplasticcompositionstrength vs the temperature and concentration of chromiumacetateandcoppersulphate

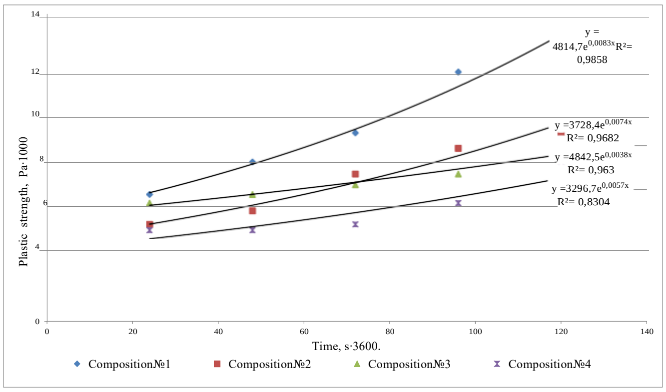

Figure3–
Thedependenceoftheplasticstrengthvstimeat30°C

The change of the plastic strength in five days is happening atanexponentialratewithahighdegreeofcorrelation.Dynamics of changes of plastic strength, as shown in figure 3,shows that the hardening of the composition continues for 5days after the gel was formed. Despite the increase of thisparameter, in the first three days changes in strength are small.Therefore it is recommended to take technological pausingafter theinjectionofthecompositionasequal to 1 day.

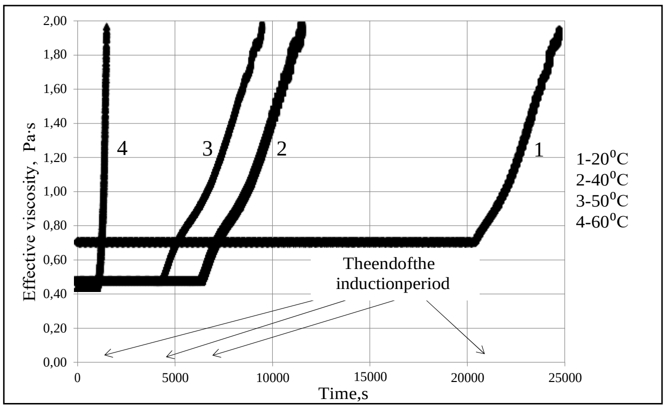

Figure4 –
ThedependenceoftheeffectiveviscosityofthecompositionNo.1 vstime andtemperature(γ=5s^{-1})

As can be seen from figure 4, the induction period (IP) ofgelationdecreaseswithtemperatureincrease.At60°Ctheinductionperiodis1000seconds.

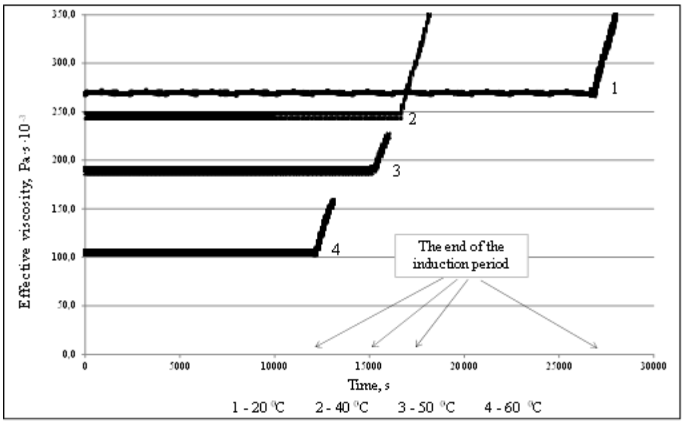

Figure 5 – The dependence of the effective viscosity of thecompositionNo.1 vstimeandtemperature(γ=118s^{-1})

Theinductionperiodofgelationatdifferenttemperatures(20°C-60°C)morethan3hours(figure5).Thisvalueissufficient for injection of the composition into the reservoir ornear-wellborezone.Itisalsoworthnotingthatwithincreasing shear rate from 5 to 118 s^{-1} induction period ofgelation increases not more than 4 % for temperatures below50°C. At t=60°C, the ratio of induction periods is increased upto 12times.

CONCLUSION

To limit the water inflows in fractured-porous reservoirs wedevelopedgel-formingcompositionbasedoncarboxymethylcellulose. In this composition organic salt ofchromium (III) is used as a gelation initiator. Copper sulfatesolution is used as a catalyst (densifier), which increases theplasticstrengthofthe structure.

The gelation time of the composition can be adjustedfromone to 10 hours. Also, this composition has a high plasticstrength(from3000to12000Pa).

The induction period of gelation under shear rates, simulatingmovement in fractured-porous reservoir, is sufficiently highfor injection of the composition to the required depth. It iscalculatedonthebasisofsustainabilityofthegelledcomposition to water breakthrough and to block the processedintervalofthe reservoir.

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