

Abstract

Submitted in partial fulfillment of the requirements for the degree of doctor of philosophy (PhD) in specialty – 6D070800 Petroleum Engineering

Iskander Gussenov

Study of the possibility of gel forming polymers application for the productivity increase of oil wells

Relevance of the study.

Handling of water produced as a byproduct along with oil and gas costs tens of billions of dollars annually. Moreover, high water cuts shorten production life of wells and cause intensive corrosion of equipment. Excess water production indicates poor sweep efficiency of the reservoir due to the large permeability contrasts between different zones. This problem is urgent for mature reservoirs in which super high permeability thief zones were created by long-continued water flooding.

Today, there are a number of technologies that allow the permeability reduction of watered-out channels. Polymer gels got the widest application. In spite of wide choice of permeability reduction materials, the problem of water cut reduction is still urgent for most oil companies.

In Kazakhstan, more than half of produced oil comes from mature oilfields like Uzen, Karazhanbas, Buzachi, Kumkol, Kalamkas, and others. High water cut (up to 90% and more) due to the geological heterogeneity of the reservoirs and several decades long water flooding process is the main reason behind low production rates at mature oilfields. Mainly polyacrylamide and silicate gels have been applied at some of the Kazakhstani oilfields in order to reduce water cut and boost oil production rate. However, practical experience has already proved that despite their effectiveness polyacrylamide and silicate gels possess a number of drawbacks (described in the literature review) and are not recommended to be used under the high salinity conditions. So it is worth to consider the applicability of other plugging materials which may demonstrate better performance at the conditions of Kazakhstani oilfields.

The aim of the research is to examine the applicability of gellan gum for water shut off operations and productivity increase treatments in oil wells.

The object of the study is plugging materials used for permeability reduction treatments in oil reservoirs and their application features.

The subject of the study is the biopolymer gellan gum and its hydrodynamic behavior in brine and oil saturated porous media.

The scientific novelty of this work consists in the following:

- 1) The hydrodynamic behavior of the gellan aqueous solution inside of salt saturated porous space with different permeabilities has been studied for the first time (fig.37).

2) The ability of gellan gel to decrease permeability of the porous media depending on the salinity of saturating water and temperature has been investigated (fig.41, 43, 44).

3) The effect of gellan solution on the reduction of oil permeability has been demonstrated (fig.51).

As a result of the conducted research the following theses are put forth to be defended:

1) A unique feature of gellan gum makes it convenient one-component gelant that can be used for the isolation of watered out thief layers. Exceptional stability of gellan gel in the presence of divalent cations (fig.28) is an advantage of this polymer over its counterparts.

2) Taking into account the properties of aqueous gellan solution, alternating injection of gellan and brine slugs is recommended for the near wellbore treatments (fig.39). It has been demonstrated that the alternated injection regime allows the reduction of the amount of polymer used at least in 2 times. However, for the in-depth treatments, the continuous injection of gellan solution after sufficient pre-flush is the best choice (fig.49).

3) The results provided by JSC “Turgai Petroleum” prove the efficiency of gellan for the treatment of injection wells. According to the report, the injection of 2 tons of dry gellan powder into the injectors 3383 and 3065 allowed the incremental production of 5,890 tons (43108 bbls) of oil during 11 months after the treatment (table 8). At oil price 50 USD per barrel and gellan cost 4.5 USD/kg the net profit turns out to be around 2 million USD excluding the cost of the equipment exploitation.

4) The efficiency of gellan for the treatment of producing wells has been proved by the results presented by LLP “Soth-Oil” (see the Appendix). According to the report, the injection of 120 m³ of 1% concentrated gellan solution into the production well K-34 resulted in the reduction of water cut from 80 down to 40% (fig.60). The comparison of the well performance before and after the treatment proves the high efficiency of gellan gum for the plugging of discrete high permeability channels and fractures.

The practical significance of the work. The conducted laboratory works determined the range of reservoir conditions within which the effective application of polymer gellan is possible. As a result, the recommendations on the application of gellan for the treatment of injectors and producers have been given. The interpretation of the results of the field pilot tests suggests high efficiency of gellan gum for the isolation of discrete high permeability fractures and channels.

This work has been done in the Laboratory of Engineering Profile of KazNRTU n/a K.I. Satpayev and Institute of Polymer Materials and Technology.

The applications and publications. The results of this work were applied at Kumkol (2013) and Karabulak (2015) oilfields. As a result, more than 5,800 tons of oil have been produced incrementally during 11 months. Moreover, water cut of the producer K-34 has been reduced from 80 to 40%.

Dr. Randall Seright (New Mexico Tech), who works more than 30 years in the field of polymer gels application for the productivity increase of oil wells, has written positive review on this PhD thesis.

The results of the work have been published in more than 14 publications, including: 3 articles in Thomson Reuters data base, 3 papers in the journals recommended by the Ministry of Science and Education, 1 innovative patent, 1 paper in Oil&Gas Russia, 6 abstracts at different international conferences, which were held at Slovakia, Russia and Kazakhstan.