Technical and technological justification of repair and insulation works at oil fields of the Republic of Tatarstan using special compositions

Ramsis Kadyrov*, Vyacheslav V Mukhametshin, Ruslan Gilyazetdinov, and Dina Kobishcha

1Institute of Oil and Gas FSBEI of HE "Ufa State Petroleum Technological University", (Branch in the City of Oktyabrsky), 54a, Devonskaya Street, Oktyabrsky, Republic of Bashkortostan, 452607 Russia
2Ufa State Petroleum Technological University, 1, Kosmonavtov St., Ufa, the Republic of Bashkortostan, 450064, Russia

Abstract. In the work, the authors touched upon the problem of implementing effective works to limit water inflow in the conditions of oil field development at the final stage. The analysis of the main technologies used for repair and insulation works was carried out, based on which their insignificant efficiency was established, which is reflected in the coefficient of well operation. Based on laboratory studies, experiments were conducted to find the optimal composition for insulation work in the oil fields of the Republic of Tatarstan. Based on the above, the optimal composition of the working substance for repair and insulation has been obtained, which, at low cost, is highly resistant to various external influences, including high thermobaric parameters.

1 Introduction

It is known that the efficiency of oil field development is largely defined by the state of production and injection well stock, which determines the continuity of their operation and high technical and economic indicators [1-5].

Plugging is important during repair and insulation works (RIW), but, nevertheless, the efficiency and success of such works remains not high enough. Field data show that recently the cases of leaky, low-strength cement plugs or their absence are increasing.

Currently, the main method of plugging during drilling is to pump the cement slurry into the well through a pipe string lowered to the level of the lower elevation of the bridge with subsequent lifting of this string above the cementing zone. The process is controlled according to the volume of displacement fluid calculated based on the condition of equality of levels of cement slurry in a pipe string and the annulus. The analysis of field data shows that this method is not quite efficient, which is associated with diluting the cement slurry
with well fluid during the formation of cement stone. In some cases, the cement slurry moves to the perforation interval, enters the formation, and reduces its productivity. The issue of high-quality plugging during well repair remains relevant.

2 Methods and materials

Sand column washing or visco-elastic separators (VES) covering the perforation interval by 5-10 m [6-8] are widespread to prevent colmatation by the cement slurry of the perforation interval.

Different visco-elastic separators of the cement slurry were analyzed in the presence of various process fluids in a well. Concentrations and ratios of reagents in VES were chosen in laboratory conditions at 20 °C, while taking into account not only the optimal duration of gelling of the composition, but also the strength of the gels formed. Next, the carrying capacity of the cement slurry (W/C=0.5) was determined by the studied visco-elastic separators on the laboratory unit (test unit in the form of a glass pipe 1.5 m long, 0.06 m in diameter is shown in the figure). The tube was set at an angle of 45°.

The carrying capacity of the cement slurry by visco-elastic separators was determined using this model.

In order to simulate the plugging conditions in the inclined boreholes, the glass pipe 1 was fixed in a rotating metal cage 2, by means of which the inclination angle of the pipe is changed. The loss conditions in a well are created by opening the ball valve 3. The procedure for the well model was the following. Initially, the Devonian formation water 4 was poured into the glass pipe, the density of which was controlled by adding tap water, then the test VES 5 and cement slurry 6 with a density of 1800 kg/m³ were poured, after which the test VES 7 was poured.

The behavior of the test VES in the well model was observed visually. The static shear stress of clay slurries was determined according to the standard procedure [9]. VES compositions on various bases were studied: polyacrylamide DP9-8177 (TU 2458-010-70896713-2006), biopolymer by KK Robus (TU 9172-003-35944370-01), Vitam vinyl polymer (TU 2458-028-25690359-2007), Biosin XM – modified biopolymer of xanthan type (TU 2458-002-89193842-2008), PSK-2 polymer-silicate composition (TU 2458-001-89193842-2008), clay powders PBMA, PBMG, PBN (TU 39-0147001-105-93).

Fig.1. Laboratory well model: 1 – glass pipe; 2 – metal cage; 3 – ball valve; 4, 8 – produced Devonian water; 5, 7 – clay suspension made of PBMG clay powder; 6 – cement slurry.
3 Results and Discussion

It was experimentally found that most of the test reagents did not retain the cement slurry. Clay suspension from clay powder of PBMA, PBMG grades and a polymer composition based on the PSK-2 reagent showed the ability to retain the cement slurry. The clay slurry of PBMA clay powder, which retains the cement slurry, turned out to be impenetrable. Besides, PBMA clay powder is not used in the fields of PJSC TATNEFT due to its relatively high cost, therefore, all further studies were carried out on clay suspension from clay particles of PBMG, PBN grade (see Table 1, Figure 1).

The results of the studies are shown in Table 1. The table shows that the clay slurry from PBMG clay powder with a density of about 1100, 1130 kg/m³ and a static shear stress (SSS₁₀₁₀ min = 134…290/215…302 dPa) when the zenith angle of the well model changes to 70°, in the absence of losses (valve is closed) is able to hold the cement slurry. If there is absorption (valve is open) at the zenith angle of 70°, the clay slurry is mixed with the cement slurry. Since the PBMG clay powder suspension has a carrying capacity over a wide range of zenith angles, it can be recommended for VES.

<table>
<thead>
<tr>
<th>VES composition</th>
<th>Carrying capacity of test VES (density, SSS₁₀₁₀)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Composition: polymer-silicate composition PSK-2 (TU 2458-001-89193842-2008) Fresh water (1:3 respectively)</td>
<td>Holds</td>
</tr>
<tr>
<td>PBMA clay suspension</td>
<td>Able to hold density=1140 kg/m³, SSS₁₀₁₀ min=191.52/215.5 dPa</td>
</tr>
<tr>
<td>PBMA clay suspension</td>
<td>Does not hold density=1040 kg/m³, SSS₁₀₁₀ min=57.5/81.4 dPa</td>
</tr>
<tr>
<td>PBMG clay suspension</td>
<td>Does not hold density=1050 kg/m³, SSS₁₀₁₀ min=2.4/9.6 dPa</td>
</tr>
<tr>
<td>PBMG clay suspension</td>
<td>Able to hold density=1100 kg/m³, SSS₁₀₁₀ min=134/215 dPa</td>
</tr>
<tr>
<td>PBMG clay suspension</td>
<td>Able to hold density=1130 kg/m³, SSS₁₀₁₀ min=290/302 dPa</td>
</tr>
<tr>
<td>PBMG clay suspension</td>
<td>Able to hold density=1200 kg/m³, SSS₁₀₁₀ min=1283/1450.8 dPa</td>
</tr>
<tr>
<td>PBN clay suspension</td>
<td>Does not hold density=1150 kg/m³, SSS₁₀₁₀ min=9.52/90.97 dPa</td>
</tr>
<tr>
<td>PBN clay suspension</td>
<td>Does not hold density=1340 kg/m³, SSS₁₀₁₀ min=38.3/119.7 dPa</td>
</tr>
</tbody>
</table>

A plugging technology was developed for RIW using a polymer-silicate composition (PSK-2) and a clay suspension of clay particles of PBMG grade (1).

The technology is based on plugging using two separating plugs with the prevention of cement plug displacement due to temporary blocking of the perforation interval (absorbing interval) of a productive formation by gel and preservation of basic parameters of the cement slurry by exclusion of cement slurry dilution due to its separation from well fluid from above and below by a visco-elastic separator.

To eliminate sliding of the cement plug during its installation, productive formation is blocked with a gel plug based on polymer-silicate composition (PSK-2). Gel is formed at the interaction of polymer-silicate composition with formation water with density of 1180 kg/m³ in the 1:1 ratio of formation water:PSK-2. The volume of polymer-silicate composition for gel is selected taking into account coverage of well interval from sump, and 45-55 m above the perforation interval, then first separating plug is pressed.

For this purpose tubing pipes equipped with a special branch pipe are lowered to the
perforation interval of a well and produced water with the density of 1180 kg/m³ and a gel-forming reagent are pumped into tubing in series. The first separating plug is displaced with the fixing head after the first plug is completed. The fact of pressure increase indicates that produced water and gelling reagent entered the annulus, and the displacement fluid remained in the tubing. The pressure continues to rise and under the excess pressure of 4-5 MPa, the fixing head of the pressure plug passes through a circular narrowing. The pumping of displacement fluid is stopped, at the same time the fixing head is fixed in the circular groove of the circular narrowing, thus sealing the annulus from the tubular space.

Tightness is checked by reducing pressure to hydrostatic pressure and absence of the displacement fluid overflow more than the volume of tubing string compression. Then the branch pipe is lifted to the upper boundary of the formation water with the density of 1180 kg/m. Only after that pumping pressure is increased to 7 MPa and more, which moves the first separating plug through the circular narrowing and ensures its fixation in the seat. Note here that the branch pipe radial holes are opened.

After that, the bridge is installed. For this purpose, the first portion of the visco-elastic separator (water suspension from clay powder of PBMG grade) in volume of 1/4 of the cement slurry volume for plugging is pumped into tubing in series with an open annular valve; cement slurry (field tests revealed that the volume of cement slurry for plugging in a production casing with a diameter of 146 mm or 168 mm is taken considering the cement plug height of 20-30 m using 1 ton of cement (0.8 m³); second portion of visco-elastic separator (PBMG clay powder water slurry), 1/4 of the cement slurry volume for plugging. After that, the second separating plug with a fixed head is installed with further annular narrowing of the second separating plug with a fixed head, and the fixing head should cover the annular narrowing, as indicated by the pumping pressure increase by 1-2 MPa from initial one. The fact of pressure increase indicates that the first portion of the visco-elastic separator, cement slurry, the second portion of the visco-elastic separator went into the annulus, and the displacement fluid remained in the tubing.

The pressure continues to rise and under the influence of an excess pressure of 4-5 MPa, the fixing head of the second separation plug passes through the circular narrowing thus sealing the tubular space from the annulus. Pumping of displacement fluid is stopped, at the same time the fixing head is fixed in the circular groove of the circular narrowing, thus sealing the annulus from the tubular space, tightness of which is checked by pressure decrease to hydrostatic pressure and absence of the displacement fluid overflow more than the volume of the tubing string compression. Only after that the branch pipe is lifted on a tubing string to the upper boundary of the first portion of the visco-elastic separator. Then pumping pressure is increased again to 7 MPa and more, which moves the second separating plug through the circular narrowing, which is opens the radial holes of the branch pipe for well flashing. The well is flashed.

Then tubing is lifted 150-200 m above the upper planned boundary of the second portion of the visco-elastic separator. The well is left for 24 hours for the cement slurry to solidify. After 12 hours, the tubing is lowered and the location of the cement plug is determined.

The process is carried out using standard equipment for well workovers.

4 Conclusion

The studies made it possible to develop a plugging technology for repair and insulation works in oil wells using a polymer silicate composition (PSK-2) and clay suspension made of PBMG clay powder.
References

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