Approbation of the system technology for improving well drilling under difficult mining conditions of Bashkortostan fields

A P Chizhov¹², V E Andreev¹², V V Mukhametshin¹ and L S Kuleshova³

¹ Ufa State Petroleum Technological University, 1, Kosmonavtov st., Ufa, Republic of Bashkortostan, 450062, Russian Federation
² SASI “Institute of strategic research of the Republic of Bashkortostan”, 129/3, October avenue, Ufa, Republic of Bashkortostan, 450075, Russian Federation
³ Ufa State Petroleum Technological University, Branch of the University in the City of Oktyabrsky, 54a, Devonskaya St., Oktyabrsky, Republic of Bashkortostan, 452607, Russian Federation

E-mail: vv@of.ugntu.ru

Abstract. A method for systematic improvement of the drilling technology in difficult mining conditions has been suggested. The study deals with unstable rocks of the sedimentary cover of the eastern edge of the Russian platform and conditions for well construction. Wells are directional with horizontal ends. Field tests have shown that technical and technological solutions can solve scientific and technical problems. It is recommended to test these solutions in the conditions of other Russian regions and abroad.

1. Introduction

Currently, there is an increase in the complexity of mining conditions for well construction. The increasing complexity of conditions is associated with both natural and man-made factors. The increasing complexity of conditions decreases quality indicators for well construction, and deteriorates the efficiency of drilling technologies [1–15]. This is due to the abnormality of changing thermodynamic and geological and technical drilling conditions and oil and gas well completion. In addition, there are no methods for monitoring and controlling well drilling technological processes.

The experience of using traditional construction technologies in existing conditions shows that a decrease in the main indicators of drilling efficiency is due to unsteady hydraulic conditions of drilling, irreversible violations of initial properties of technological solutions in the wellbore, lack of control and regulation of interaction of technological solutions with fluids of the rock mass.

2. Materials and methods

Complex field problems, such as stabilization of the hydraulic state and well behavior, preservation of natural reservoir properties of productive formations and their isolation from fluid-saturated formations of the productive strata, improvement of tightness of the annular space of the support, can be solved based on a systematic approach.

The systematic approach involves the implementation of the following scientific principles: information support, organization and management of drilling technological processes.
Information support provides data about difficulties arising when deepening the well bottom. For example, in order to understand the characteristics of the penetrated loss interval, tightness and strength of the open hole are assessed by pressure testing from the wellhead.

![Graph showing hydromechanical strength of the wellbore](image)

**Figure 1.** Hydromechanical strength of the wellbore: 1 - pressure testing in the absence or unsteady fluid filtration; 2 - pressure testing with established fluid filtration; a, b - possible deviations of the crimping pressure; C\(_p\)\(_1\), C\(_p\)\(_2\) - calculated permissible pressure of crimping

Determined and controlled:
- tightness index — K = \( \frac{Q}{\Delta P} \) (m\(^3\)/s/MPa);
- barrel strength index — \( \nabla P = \frac{\Delta P}{H} \) MPa/m;
- fluid filtration start pressure gradient — \( \nabla P_\text{f} = \frac{\Delta P_1}{H_1} \).

The organization and management of drilling technological processes is impossible without the methods based on hydromechanical strengthening of the wellbore by water jet drilling fluids. The technology is implemented simultaneously with the well drilling process and ensures the formation of a near-wellbore waterproofing screen. The near-wellbore waterproofing screen that is formed under these thermodynamic conditions is characterized by thickness of the adhesive layer on the borehole wall - 2–3 mm; depth of the colmatation zone in the matrix of permeable rocks - 10–30 mm; hydromechanical strength of the well under repression - 0.018-0.025 MPa/m (rock pressure gradient); shaft tightness in case of depression - 0.010-0.015 MPa/m [1].

In order to increase the efficiency of the screen and improve the hydromechanical strength of the walls of wells drilled in unstable and unstable rocks, gel-cement drilling solution that was tested can be used. The development of a new drilling solution was carried out in collaboration with scientists and specialists of NPP "BURINTEH" LLC at the company's laboratory facilities. Gel-cement drilling solution "Gel-Drill" [2, 4] has good thixotropic, waterproofing, inhibiting parameters and carbonic aggression.

### 3. Results and Discussion

In 2016-2017, with the participation of BURINTEH and TEHGEOSERVICE, field tests (FT) of the wellbore hardening technology were carried out using new drilling fluid.

The pilot project was aimed at assessing the compliance of technological parameters and operational characteristics of drilling fluids with their purpose when drilling deep wells in difficult geological and thermodynamic conditions, as well as improving quality, efficiency and environmental
safety of drilling operations and extending the operating time of oil and gas wells at maximum limited volumes of produced formation waters.

Pilot tests were carried out on 17 inclined horizontal wells with a depth of 1430–2050 m. The testing interval was 220–1780 m (pilot, transport and production casing boreholes).

Typical for the drilling depth is the presence of fluid-saturated wells in the section of wells with reservoir pressure differentiated by the section and area of deposits, as well as unstable rocks prone to hydraulic fracturing. They cause violations and complications of the drilling technology and associated negative consequences. With the traditional drilling technology, this happens: when the Kashir horizon is opened in the range of 959–1010 m (integral values); the Verey horizon is opened in the range of 1040–1098 m; the Bashkirian stage - in the range of 1098-1155m; the Serpukhovian stage – in the range of 1155–1350m.

The technological complexity of geological and technical conditions for well drilling is characterized by the following integral indicators: intensity of most (≤80%) losses - 30-50 m³/h, water showings - 0.5 to 1-12 m³/h, gas showings - background or short-term - 0.015–0.6 vol. %, talus and landslides - from weak to intense (landslide) ones.

Drilling of pilot wells was adapted to serial equipment and design technological solutions, providing a synchronous and coordinated mode of hydromechanical strengthening of the wellbore by quantum impact.

The tool consisted of a three-cone chisel 215.9 RDS US 616 I430 with six nozzles with a diameter of 11.1 mm, an above-bit sub - a colmatator with a side nozzle diameter of 12.7 mm, a drill collar. The drilling method is rotary with a rotation frequency of 30–35 rpm, the contact of the jet with the borehole wall is 0.013–0.004 s, the wellhead pressure is 9–13 MPa. Flushing fluid: polymer clay drilling mud (BR) "Gel-DRILL" (patent of LLC NPP "BURINTECH" [4]) with the following parameters: ρ = 1190-1230 kg / m³, SNS 1 min / 10 min, HC + 50-70 s, Ø = 5 ml / 30 min, c ≥ 16% (bentonin + cement).

Analytical assessment of pilot testing results was carried out according to the reports of service support of LLC NPP "BURINTEH" and reports on the services provided for telemetric and technological support of LLC "TECHGEOSERVICE". Well logging methods were also used (cavernous and thermometry, SGDT, cementometry).

Thus, the pilot test based on the hydromechanical strengthening method identified that
1. "Technology" corresponds to its purpose and ensures the achievement of the goals. Wells are drilled without complications and disruption of technological processes in the intervals for technical (pilot, transport) and production strings.
2. Similar results were obtained when using the "technology" instead of "Gel-Drill" polymer clay drilling mud.
3. Of six wells drilled without the use of an over-bit sub-collator, a positive result was obtained for two wells (No. 1200G and No. 13479G). The result is accidental and insufficiently effective since the method does not stabilize the initial properties of the cement slurry-stone, does not improve tightness of the cemented casing annulus and does not protect productive formations from pollution.

The advantages of the "technology" are: a non-linear increase in quality, technical, economic, and environmental indicators of drilling operations, and deterioration of production safety.

**Table 1.** Technical and economic indicators when drilling wells No. 453g and 454g of the Tatyshlinsk field

| Technical and economic indicator | No 453g (experimental) | No 4504g (serial) |
|----------------------------------|------------------------|-------------------|
| Time spent on additional operations (planned), hour: cementing of the Verey horizon | 0.20 | 39.91 (1.7 days) |
| transfer of a well from one type of solution to another one | - | 32.33 (1.3 days) |
| Cost of 1 m³ of solution, s.u. (GEL-DRILL) | 0.88 | 1.00 (clay-emulsion) |
| | | |

3
Reducing the total time spent on drilling wells. 453g (experimental) - 79.4 hours (3.3 days). Total: 3.4 + 3.3 + 7.7 days

Formation of a sealed waterproofing near-wellbore screen isolates the wellbore from the rock mass; possibility of their active interaction during the drilling process.

Generalization and analytical evaluation of the data and results of pilot tests of "Gel-DRILL" and "Polcarb-BIO" during hydraulic hardening of the wellbore allow us to make a well-founded conclusion on improving the quality and efficiency of drilling operations in difficult geological and technogenic conditions.

4. Conclusion
The current level of quality, technical, economic and economic safety achieved by using traditional well drilling technologies excludes the likelihood of their further improvement and development without switching to systemic technological developments that ensure nonlinear growth of the baseline well construction indicators. In general, the results of the pilot study allowed for the following conclusions:
1. The use of "Gel-Drill" in combination with hydromechanical strengthening of the wellbore improved quality and efficiency of drilling of nine experimental wells with horizontal completion at "BASHNEFT" fields.

As a result, the technical and economic indicators of drilling operations increased (for example, well No. 453g Tatyshly):
- ROP - by 13.6%;
- technical drilling speed - by 8.6%;
- commercial drilling speed - by 6.5%

The technological indicators changed in the following way:
- the coefficient of cavernousness of the Verey horizon decreased;
- the time for additional operations (isolation operations, borehole reaming, drilling fluid replacement) decreased by 97.5%.
- the prime cost of 1 m³ of drilling mud decreased by 12%.

To continue the technological stagnation, improve technological processes and efficiency of development of oil and gas deposits, one of the promising scientific and technical directions is a synchronous and coordinated regime of the quantum impact on the formation of a near-wellbore waterproofing screen during well drilling.

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