Geological, technological and technical justification for choosing a design solution for drilling wells under different geological conditions

V G Mukhametshin¹, G S Dubinskiy²,³, V E Andreev²,³, V V Mukhametshin³ and L S Kuleshova⁴

¹SC «NizhnevartovskNIPIneft», 5, Lenina St., Nizhnevartovsk, Nizhnevartovsk region, Khanty-Mani Autonomous Area – Yugra, 628616, Russia
²SASI "Institute for Strategic Research of the Republic of Bashkortostan", 129/3, Oktyabrsky Ave., Ufa, Republic of Bashkortostan, 450075, Russian Federation
³Ufa State Petroleum Technological University, 1, Kosmonavtov St., Ufa, Republic of Bashkortostan, 450062, Russian Federation
⁴Ufa 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: MuhametshinVG@nvni.ru, vv@of.ugntu.ru

Abstract. The oil companies focus on the prevention of leakage of the producing well to ensure the long-term well viability. The article considers the rationale for preventive measures to reduce the risks to the integrity of the strings and ensure the operation of the wells for the duration of their use. The authors propose tools for analyzing the condition of wells as well as technical and technological solutions for extending the operation of the well without damage.

1. Introduction

The well fund that is operable for a long period and preferably throughout all field development process will provide the efficient development of oil and gas fields. It requires preservation of the porosity and permeability properties of the bottom-hole formation zone in a state as close as possible to natural parameters [1-7].

The well design must meet environmental protection conditions and exclude possible formation water pollution and pore fluid flows not only during drilling and operation but also after well completion and abandonment [8-10]. It is, therefore, necessary to ensure conditions for the high-quality and efficient separation of the strata. This is one of the main factors.

Thus, geological factors should first determine the principles of designing well structures. Geological factors such as estimated and actual lithology, stratigraphy and section tectonics, rock thicknesses with different strengths, permeability, porosity, presence of fluid-saturated formations in the section and formation pressures have the greatest influence on well characteristics. When designing wells, the geological structure of the section of the rock is a constant factor.

During the development of hydrocarbon deposits, the initial formation characteristics change because the recovery rate of fluid, the methods of intensifying production and maintaining the formation pressures, the use of different influences on the productive horizons for fuller extraction of...
oil and gas from the subsoil, the duration of exploitation modifies the formation pressure and temperature. Designing well should consider all these factors due to the mentioned processes [8-10].

To ensure the best drilling conditions, the most efficient wiring technology and prevent possible complications, it is necessary to consider the following factors [9-13]:
- description of the rocks exposed by the well in terms of possible landslides, screes, cavity formation;
- rock hardness;
- rock permeability and formation (pore) pressure;
- zones of possible gas, oil and water show and absorption of the washing fluid and the conditions for the occurrence of these complications;
- temperature of rocks along the bore;
- angles of dips and the frequency of their alternation in hardness.

The detailed examination of the first four factors can justify the determination of the length (depth of descent) of the casing strings, i.e. to make a correct design decision.

2. Purpose
The study aims to show the justification of design solutions when choosing the wellbore trajectory and its structure based on the geological features of the field and technological processes for drilling and operating wells.

3. Methods and materials
Since it is necessary to study the influence of geological, technological and technical factors on the choice of the trajectory and design of the well and the justification for the choice, the justification of such recommendations requires methods of geological field analysis and modelling of trip processes during drilling and well operation. Analysis and modelling used information and materials from two oil fields located in Western Siberia and one in Bashkortostan.

4. Results and discussion
The study examined and analysed three objects with different geological and physical conditions: the Kipskoe field located on the territory of Bashkortostan, the Kusvoe field and the Samskoe field in the West Siberian region.

Design lithological-stratigraphic sections of deposits are based on data from prospecting and exploration. The section of the Kusvoe deposit contains permafrost rocks in the range of 180-400 m. Researches examined depths of up to 1833 m: quaternary sediments are soft, and hard rocks are deeper. The researchers examined the section of the Kipskoe deposit to a depth of 2920 m. The main rocks of the Quaternary are sand, sandy loam, clay, loam grey, dark grey soils. Deeper, there are mainly clay rocks, siltstones, less often limestone, sandy rocks (regionally oil-bearing). The lower part of the J3vs formation is represented by grey to black mudstones with rare interbeds of sandstones and siltstones.

The profile of well drilling should address the requirements for drilling cluster wells, the strength characteristics of the rocks that make up the geological section of the field, the methods and technical means used in the well operation. The well profile of the Kusvoe field was calculated by the Temporary technological regulation for the control and design of profiles at the fields of LLC LUKOIL-Western Siberia.

A well with a six-interval profile (Figure 1) has following parts: 1) the vertical section; 2) the first section of the set of zenith angle; 3) the stabilization section of the zenith angle; 4) the second section of the set of zenith angle; 5) the stabilization section of the zenith angle; 6) the section of low-intensity reduction of the zenith angle.
Figure 1. Design profile of the directional well bore of the Kusvoe field

When drilling the Kusvoe field, all work related to the set and adjustment of the zenith and azimuth angles of the directional bore should not extend beyond the interval of the planned depth of descent of the downhole pumping equipment (DPE). The necessity allows performing these tasks below the descent interval of the DPE.

Because in the section of the designed well of the Kusvoe field, there are no horizons with abnormally high reservoir pressures and zones with significant complications, then the geological section represents the area of compatible drilling conditions. The presence of permafrost, water-saturated formations in the context of the designed wells determines the choice of structures considering these features.

The well design solution of the Kusvoe field resulted from the planned tasks and the requirements of the “Safety Regulations in the Oil and Gas Industry”.

The design of the production well should provide:
- maximum possible use of the formation energy of the productive horizons during operation due to the selection of the optimal bottom-hole designs and production string diameter;
- use of effective equipment, optimal methods and modes of operation, maintaining formation pressure, heat exposure and other methods of increasing oil recovery;
- conditions for safe work without accidents and complications at all stages of well construction and operation;
- obtaining the necessary geological information on the opened section;
- conditions for protecting the subsoil and the environment, primarily due to the strength and durability of the lining of the well, the tightness of the production strings and annular spaces, as well as the isolation of fluid-containing horizons from each other, from permeable formation and the daylight surface;
- maximum standardization by casings and wellbore sizes.

The geological features of the section of the Kusvoe field as well as the planned research complex, include the following well design features:

The direction with a diameter of 324 mm descends to a depth of 50 m to ensure reliable overlapping of the bedding interval of unstable deposits prone to screes and landslides and prevent erosion of the wellhead. The cement lifting to a depth of 50 m to the wellhead.
A well conductor with a diameter of 245 mm descends to a depth of 500 (680) m vertically or 505 (694) m along the wellbore to ensure reliable overlapping of the bed interval of permafrost rocks and unstable rocks prone to collapse of the upper part of the Lyulinvor formation. It requires two portions of cementation.

The production string with an external diameter of 146 mm descends to a depth of 2915 m vertically (3036 m along the wellbore). It serves to attach the well walls, separate the production horizons and test them. The height of the cement slurry above the roof of the productive horizon is at least 150 m. The distance from the wellhead to the level of cement slurry rise behind the production string for injection wells is 260 m.

Drilling through a layer of permafrost, loose sandstones and unstable clay sediments requires solving the following main tasks: strengthening of well walls, reducing the thawing effect of the drilling fluid, increasing the drilling mud capacity at a relatively low ascending flow velocity. The solution of these problems needs the clay drilling fluids with a high content of active clay phase, highly effective polymers - structural agents, and the use of flocculating chemicals maintaining a low temperature. For drilling under the conductor, the project envisages drilling solution prepared from bentonite clay powder treated with chemical reagents. To open the productive formation, it is necessary to use a solution with a minimal negative effect. Therefore, in the conditions of the Kusvoe field, the clay solution for the initial opening of the oil formation is the suspension of high-active bentonite clay with the addition of chalk treated with soda ash, lubricants and surfactants to reduce the surface tension of the filtrate and hydrophobize the surface of the pore channels of the reservoir formation.

The geological features of the Samskoe field are similar to those of the Kusvoe field, and therefore the wellbore profile has similar sections of the wellbore (Figure 2). Drilling features are also similar except for the presence of separate absorption zones.

Figure 2. Profile of the directional wellbore of the Samskoe field
The geological features of the Kipskoe field have led to the selection of a three-interval profile (Figure 3): 1) vertical section, 2) set of zenith angle, 3) holed section. The sections of the profile are in a vertical plane passing through the design bottom hole and the wellhead. This orientation creates an optimal profile for the economical and rational operation of wells with sucker rod pumping units.

![Figure 3. Scheme of the three-interval profile of the Kipskoe field](image)

The geological features of the Kipskoe field section, the formation pressure and hydraulic fracturing determined the following well design:

- the direction (50 m) isolates the absorbing horizon and the freshwater complex, fixes the unstable upper rocks and prevents the sticking of the drill string;
- a conductor (200 m) overlaps the freshwater complex in the interval of 50-100 m, isolates the horizons, fixes the areas of scree and landslides and prevents the sticking of the drill string in the interval of 50-190 m;
- intermediate string (to a depth of 400 m) overlaps the saline deposits of the Kungur formation in the interval of 260–290 m;
- production string (to a depth of 1826 m) for fixing zones of scree and landslides in the intervals of 1222–1258 m, 1696–1702 m, overlapping absorbing horizons in the intervals of 467–487 m, 1025–1110 m, 1390–1670 m.

The project of the Kipskoe field provides the production strings with a diameter of 168 mm. Solid and stable limestones composing the production facility, the absence of high-pressure horizons, bottom water and gas caps lead to a lack of fastening and it remains open. This design of the well structure increases the well perfection coefficient.

Even under different geological conditions, the paths of the wellbores have bending zones (changes in azimuth and zenith angles). Of course, the bends of the wellbore predetermine the appearance of leakages in the strings due to the increased load during tripping and lowering operations (TLO) during drilling, especially when drilling below the string shoe, and well repair.

To increase the efficiency of well drilling and improve design methods for designing profiles of directional and horizontal wells, it is necessary to model the wells and operations in them [14]. For the correct design of the trajectory of the barrel and the string, preservation of its stability and reliability
during the entire period of operation, it is necessary to evaluate the possible state of the pipe string during the TLO.

To simulate the stress-strain state of the production string (PS), we used the software in the field of drilling applications of the Landmark Halliburton company: COMPASS, WELLPLAN. The determination of the distribution of lateral forces along the wellbore used the module "Analysis of tension and moments" which allows predicting and analysing the moments and axial loads that occur in the drill string, casing string or in the shanks during the TLO.

The authors used the fixed-ended column model that considers the position of the drill pipes relative to the axis of the well, determined the contact points of the drill pipes with the casing string which permits calculating lateral forces with the position of the contact points (couplings, locks). For our case, the calculated contact points of the drill pipe with the casing will be close to the behaviour of the tubing during tripping operations of the current workover and capital workover operations.

In a virtual well with a minimum deviation from the vertical of 150 m (radius of curvature), we modelled the stress-strain state of drill pipes for a well with the design shown in Figure 4.

An analysis of the results of modelling a virtual well in the conditions of the Samskoe field showed that at depths of 1000–1180 m in the virtual well there will be contact between the drill pipes and the production string, that is, damage in the form of the wiping troughs.

When modelling the stress-strain state at a real well No. 8082 of the Samskoe field, we found that the main loads on the string are on the upper part of the well. In all cases, we also distinguish the lower zone as the second risk zone in the section of the string 1400–1600 m. The position of the string during TLO indicates the possibility of the tool touching the walls of the PS and consequently causing friction and wear.

Geophysical studies in well 8082 revealed two leakage intervals in 1460–1485 m and 1597–1606 m.

![Figure 4. Well design.](image-url)
We performed the same analysis of loads and deformations along the wellbore for other wells. For example, in well 16547 we identified:
- the main loads on PS arise in the upper part of the bore, all loads decrease with depth but at the same time remain significant to a depth of 1600 m;
- the position of the string when the tool lowers and raises indicates the possibility of the tool touching the PS walls in the depth interval of 1560–1680 m;
- according to the geophysical logging results in well 16547, we identified one leakage interval of 1557–1582 m.

Based on the analysis of 180 wells of the Samskoe field, it was revealed that inferiority in PS leakage in 49% of cases occurs due to the influence of the zenith angle of the wellbore (areas with pronounced touches of wellbores and straight paths in the interval of PS leakage), in 6% of the wells, the azimuthal angle, for other reasons - 45%.

It is obvious that at the points of bending of the barrel (changing the angles of the trajectory) there is an increased risk of leakage of the string which requires preventive measures to increase the efficiency of the wells.

The profiles of directional and horizontal wells in these fields must satisfy the following criteria: ensuring normal patency of the various configurations of the drilling tool and casing strings; the possibility of launching devices during the completion of wells and their operation; to ensure that the well and sidetracks get into the given circle and the tolerance corridor (vertically and horizontally); designing the trajectory and construction of the well should minimize the possibility of leakage of PS during further operation.

5. Conclusion
The article reveals the possibility of assessing the impact of a decent tool (drilling pipes, etc.) by touching-friction on the wells PS.

Modelling the stress-strain state of PS using the Landib Halliburton package allows predicting the risks that relate the tool operating in the well. Prediction of stress-strain state of PS allows designing a more stable and reliable design of wells.

Based on research and modelling for the Samskoe field, we propose to prevent the leakage of the PS of the new well stock from drilling wells with gently sloping trajectories, excluding the intersection of straight trajectories and production strings below 1300 m (below the dynamic level intervals of operating submersible electric centrifugal plants and/or increase the strength of the problem sections of the string.

References
[1] Mukhametshin V V and Kuleshova L S 2019 Justification of Low-Productive Oil Deposits Flooding Systems in the Conditions of Limited Information Amount SOCAR Proceedings 2 16–22. DOI: 10.5510/OGP20190200384
[2] Akhmetov R T, Kuleshova L S and Mukhametshin V V 2019 Application of the Brooks-Corey Model in the Conditions of Lower Cretaceous Deposits in Terrigenous Reservoirs of Western Siberia IOP Conf. Ser.: Mater. Sci. Eng. 560(1) 012004. DOI: 10.1088/1757-899X/560/1/012004
[3] Kuleshova L S, Kadyrov R R, Mukhametshin V V and Safiullina A R 2019 Design changes of injection and supply wellhead fittings operating in winter conditions IOP Conf. Ser.: Mater. Sci. Eng. 560(1) 012072. DOI: 10.1088/1757-899X/560/1/012072
[4] Kuleshova L S, Kadyrov R R, Mukhametshin V V and Akhmetov R T 2019 Auxiliary equipment for downhole fittings of injection wells and water supply lines used to improve their performance in winter IOP Conf. Ser.: Mater. Sci. Eng. 560(1) 012071. DOI: 10.1088/1757-899X/560/1/012071
[5] Yakupov R F, Mukhametshin V Sh, Khakimzyanov I N and Trofimov V E 2019 Optimization of Reserve Production From Water Oil Xones of D3ps Horizon of Shkapovsky Oil Field Using Horizontal Wells Georesursy 21(3) 55–61. DOI: 10.18599/grs.2019.3.55-61

[6] Stenkin A V, Kotenev Yu A, Mukhametshin V Sh and Sultanov Sh Kh 2019 Use of Low-Mineralized Water for Displacing Oil from Clay Productive Field Formations IOP Conf. Ser.: Mater. Sci. Eng. 560(1) 012202. DOI: 10.1088/1757-899X/560/1/012202

[7] Valeev A S, Kotenev Yu A, Mukhametshin V Sh and Sultanov Sh Kh 2019 Substantiation of the Recovery of Residual Oil from Low-Productive and Heterogeneous Formations in Western Siberia by Improving the Waterflood System Using Gas and Water-Gas Impacts IOP Conf. Ser.: Mater. Sci. Eng. 560(1) 012204. DOI: 10.1088/1757-899X/560/1/012204

[8] Bulatov A I and Savenok O V 2010 Completion of oil and gas wells. Theory and practice (Krasnodar: Prosveshchenie-Yug) p 542

[9] Kalinin A G, Ganjumyan I R and Messer A G 2005 Reference book of the engineer-technologist on drilling of deep wells (Moscow: Nedra) p 808

[10] Milshtein V M 2003 Cementation of drilling wells (Krasnodar: Prosveshchenie-Yug) p 375

[11] Hossain M E and Al-Mejed A A 2018 Fundamentals of Sustainable Drilling Engineering (New York: John Wiley & Sons Limited (USD)) p 785

[12] Jimenez W C, Pang X, Benge M, Darbe R and Meadows D L 2017 Enhanced Mechanical Integrity Characterization of Oilwell Annular Sealants Under In-Situ Downhole Conditions: A Path to Optimized Wellbore Economics Society of Petroleum Engineers DOI: 10.2118/185341-MS 16 p

[13] Kendall Mcclendon 2014 Drilling Technology (Gardners Books) p 203

[14] Dvoynikov M V 2018 Designing of Well Trajectory for Efficient Drilling FOR by Rotary Controlled Systems J. of Mining Institute 231 254-262. DOI: 10.25515/PMI.2018.3.254