Technical and economic analysis of possibility of aluminium drill pipes use in drilling of ultra-deep wells in Volgograd Transvolga region

N V Krivosheev¹, M V Lyashenko², V V Shekhovtsov²

¹ Branch of “Lukoil-engineering”, LLC “VolgogradNIPlomorneft”, 96, Lenin Ave., Volgograd, 400078, Russia
² Volgograd state technical university, 28, Lenin Ave., Volgograd, Russia

e-mail: shehovtsov@vstu.ru

Abstract. This article presents analytical calculations to confirm possibility of using aluminium drill pipes in drilling of the ultra-deep wells on deposits of Volgograd Transvolga region. Also, analysis of using oil rigs with a smaller load rating than when using traditional (steel) pipes is presented. Use of aluminium drill pipes for drilling the ultra-deep wells allows increasing investment attractiveness for exploration of small fields with difficult geological and technical conditions at a large depth.

1. Introduction

The oil-gas sector plays an important role in country economic development. Fuel-energy companies provide about half of taxes receipts and their portion of production grows in the whole export.

One of the main problems of Russia oil-gas complex within the next few years would be development of ultra-deep drilling of oil and gas deposits. Also, topical question is the profitability of ultra-deep deposits exploration.

Deposits of Volgograd Transvolga region are located in west and north-west part of the near-Caspian oil-gas province (Caspian lowland).

There are several oil deposits: the oil giant Tengiz with initial oil reserves of 3.133 billions of tons located on the territory of Atyrausk region of the Republic of Kazakhstan; oilfield Kashagan with geological oil reserves 4.8 billions of tons located in the basin of North Caspian of the Republic of Kazakhstan.

In undersalt deposits of Astrakhan region, the Astrakhan gas condensate deposit discovered and has been exploring for a long time. Its geological reserves of gas are 2.5 trillion of m³ and reserves of condensate are 400 billions of tons.

Features of all discovered deposits in the Caspian lowland are a level of hydrogen sulphide up to 39% and carbonic acid – up to 11% (data for the Central-Astrakhan gas condensate deposit).

Hydrogen sulphide, on the one hand, negatively affects the metal structure of well and, on the other hand, is valuable chemical raw material for obtaining of cheap sulfur.

Harsh thermobaric conditions at the depth down to 7 km: layer pressure in deposits up to 105 MPa, temperature in deposits up to 120 °C, are observed in undersalt deposits of Near-Caspian province.

The large depth and fluid aggression do not allow using standard steel pipes for drilling and casing
of wells. But the use of the special anticorrosive version of import pipes significantly increases expenses for well construction. Also the drilling equipment with increased reliability and drilling rig with high load rating influence expenses for wells.

It should be noted that many hydrocarbon deposits with low reserves were discovered and exploring of these deposits depends on the profitability of construction which is influenced by the cost of 1 meter of drilling.

To decrease cost of drilling and to solve the problem of exploring profitability of deposits located at the large depth, the use of alloy (aluminium) drill pipes in drilling is proposed. It results in the possibility of using of the drilling rig with the smaller load rating.

Advantages of alloy pipes are:
- low specific weight;
- floatage (lightening in drilling base fluid);
- high specific strength;
- low value of longitudinal elasticity module and shear modulus;
- high vibration damping characteristics;
- corrosion resistance in the aggressive environment;
- non-magnetic features;
- good drilling capacity;

Experience of alloys use in drilling and in wells operation is [2-6]:
- In the end of 50s - mid 60s specialists of All-Soviet Oil and Gas Scientific Research Institute in cooperation with Kuibyshev metallurgists made a whole complex of research, experimental and design works which led to the exploration of production and wide industrial using of aluminium alloy drill pipes.
- In the early 70s, specialized workshops for producing of alloy drill pipes were constructed on Kuybyshev and Kamensk-Uralsk metallurgical plants.
- In the 70s-80s, alloy drill pipes were actively used on Volgograd and Saratov wells.
- In the early 80s, total production of alloy drill pipes was about 20-20.5 thousand tons per year;
- Alloy drill pipes made of alloy AK-4-1T1 were used in drilling of the Kolsk ultra-deep well “SG-3” with depth 12260 m at downhole temperature 180-220 °C.
- Corrosion resistance of aluminium alloy D16T was confirmed by the industrial experience of using LNKT-74x8 (alloy pump-compression pipe) in well №13307 branch 1350 of Samotlor deposit. At that deposit, layer medium has corrosion activity caused by high mineralization and high levels of hydrogen sulphide and carbon acid gas.
- Use efficiency of LBTPN-90x9 P (alloy drill pipe with increased reliability with the protection thickening) in the structure of the drill string was confirmed at drilling of side holes in Priobskiy, Sutorminskii, Tavlino-Russinskiy deposits and other deposits of west Siberia at depth down to 3000 m.
- Alloy casing drill pipes LOT-178x4 and pump-compressor pipes LNKT-90x10.5 made of alloy 1953T1 were used on the well №15 of Bayadynskoe deposit of “Lukoil-Komi”, LLC.
- Alloy drill pipes LBTPN-90x9 and pump-compressor pipes LNKT-90x9 made of alloy AK-4-1T1 were recommended by “Lukoil-engineering”, LLC for using by NSHU “Yareganeft” for drilling of pipehole intervals with a small diameter and overhauls of operational and steam injection wells on Yarega deposit.
- The efficiency of using of LBTPN-103x11 C (with ribbing (in fig. 1)) in the structure of the drill string was confirmed by drilling of horizontal wells on deposits of “Tatneft”, OJSC. One of the advantages is increased mud removal at drilling.

But despite of advantages and positive practice of using of alloys in wells construction alloy pipes are not widespread because of next disadvantages:
- high cost;
- intense wear;
aluminium alloys are high chemically active so it limits drilling base fluid mixture.

Fig. 1. General view of LBTPN: a – LBTPN (base version) with internal end upset; b – LBTPN with external end upset (for solving of technological problems when constant passage internal diameter is required); c – LBTPN -P with protection thickening (for protection of main pipe body from wear and also for increasing of pipe longitudinal stability and better spotting in a hole tube); d – LBTPN -S with screw rigging (for improving of tube cleaning from drilled rock in horizontal wells having great deviation from vertical, and also for decreasing of probability of drill string bottom part differential sticking) [10].

The problem of wear and interaction with drilling base fluid can be solved by the range of engineering methods. And the high price of elements is compensated by decreasing a whole mass of the drill string and by using of the drill rig with lower load rating than at drilling with using of steel pipe.

Lack of mass experience of alloy drill pipes use in drilling of the ultra-deep wells and partiality of information from open sources requires new research.

2. Defining safety factors and operational parameters of aluminium and steel drill pipes work

For example, drilling interval of limestone and dolomite from 5490 to 5950 m was chosen. This interval has the following conditions: the layer pressure gradient is 1.8 kgs/cm² per 10 m, the fracking pressure gradient is 2.15 kgs/cm² per 10 m, downhole temperature is 120-130 °C, hydrogen sulphide level in volume is 6%, carbon acid gas level in volume is 10% (data taken from similar deposit). LBTPN-P 129x11 mm made of alloy D16T with length 4100 m, LBTPN-P 103x11 mm made of alloy D16T with length 1659 m were proposed for drilling instead of the drill string made of steel G-105.

Several methods were chosen for analysis of drill strings.

The first way is presented in “Hand-book for calculation of drill strings for oil and gas wells” [1] by Russian scientists V.M. Valov, G.M. Sarkisov et al. In accordance with this method, strength for drill string weight, transferred torque and bend caused by buckling from rotation is calculated for a drill string. Also, this method takes into account (for choosing of safety factor) loads caused by sticking liquidation process, by acceleration and braking of the drill string during lowering and lifting operation, loads generated by friction on hole walls and vibrations generated by a drilling bit. It should be noted that the specific questions for horizontal wells of creation of necessary load on the drilling bit, buckling (spiral and sinusoidal bend) of the drill string in its compressed part between weighted drill pipes and the drilling bit and also problems of optimal arrangement were not presented in this hand-book. This hand-book can be used for vertical and inclined wells only [1].

Calculated safety factors are compared below:

- on static strength: for aluminium pipe factor is 2 times greater than for steel pipe;
• on normal stresses: for aluminium pipe factor is 2.5 times greater than for steel pipe;
• on shearing stress: for aluminium pipe factor is 2 times greater than for steel pipe;
• on fatigue strength: for aluminium pipe factor is 2.5 times greater than for steel pipe.

The second way is proposed by American scientists Johancsik, Dawson, Paslay, Chen, Cheatham, Wu, Juvkam-Wold, He, Kyllingstad in models of axis loads, torques and buckling, which are base for all known software of various companies. Those models are different from each other in the calculation of the drilling string on the horizontal part of the hole. For vertical parts, different models provide approximately similar results [7,8] because the critical force of buckling is negligible in this case. Despite the fact that in relatively vertical wells buckling is negligible, there are conditions for buckling origin when the bottom part of drill string does not have sufficient length for stiffness and weight for creating of load on the drilling bit. In this case, the neutral section moves to string of drill pipes and the string is compressed. In described case well is vertical. Calculation of the drilling string is made in software DrillNET by Petris Technology, Inc. Calculation results are presented below.

Using of aluminium drill pipes in the structure of the drill string improves operational characteristics in comparison with using of steel pipes:
• weight of drill string in air - 1.87 times smaller;
• axial load during drilling with rotation - 2.5 times smaller;
• load on drilling string hook - 2.1 times smaller;
• friction force during drilling with rotation - 2 times smaller.

Better characteristics of aluminium drilling pipes in operation are caused by the lightening of the drill string and decreasing of friction.

Comparison of obtained calculation parameters with force parameters of supposed drill rig shows that for drilling by steel pipe, drill rig would consume more energy both for load capacity and for rotating of an upper drive mechanism.

3. Selection of the drilling rig

Selection of the drilling rig is made from the condition that the sum of static and dynamic loads during lowering (lifting) of the heaviest drilling and casing strings and also during the liquidation of accidents (sticking) does not exceed values of parameter “Permissible load on the hook” for the selected drilling rig. For analysis, drilling rigs «ZJ 70» (from the project), «ZJ 50», «ZJ 40» were selected.

Initial conditions for load rating selection of the drilling rig - maximal operating mass (data from deposit-analogue):
• steel drilling string in air is 1905 kN (194.4 tons);
• alloy drilling string in air is 1017 kN (103.8 tons);
• maximal weight of the casing string with diameter 244.5/250mm is 3582 kN (365.6 tons);
• the weight of upper power drive on rigs “ZJ” is 196 kN (20 tons).

In accordance with paragraph 135 of “Federal norms and rules in the area of industrial safety “Rules of safety in oil and gas production”” to prove selection of the drilling rig, the following conditions have to be met [9]:

Maximal permissible load from the operational mass of the drilling string (in table 1):

\[ Q_{\text{max drill string}} \leq 0.6 \times Q_{\text{max permissible on hook}} \]

Table 1. Calculation result on mass of the drilling string

| ZJ70/4500 | ZJ70/4500 | ZJ50/3150 | ZJ40/2250 |
|-----------|-----------|-----------|-----------|
| 1905+196 kN < 1017+196 kN < 0,6*4500 kN; | 1017+196 kN < 0,6*3150 kN; | 1017+196 kN < 0,6*2250 kN; |
| 2101 kN < 2700 kN | 1213 kN < 2700 kN | 1213 kN < 1890 kN | 1213 kN < 1350 kN |

Maximal permissible load from operational mass of the casing string (in table 2):
\[ Q_{\text{max casing string}} \leq 0.9 \times Q_{\text{max permissible on hook}} \]

### Table 2. Calculation result on mass of the casing string

| ZJ70/4500 | ZJ50/3150 | ZJ40/2250 |
|-----------|-----------|-----------|
| 3583+196 kN \(< 0.9 \times 4500\) kN | 3583+196 kN \(< 0.9 \times 3150\) kN | 3583+196 kN \(< 0.9 \times 2250\) kN |
| 3779 kN \(< 2835\) kN * | 3779 kN \(< 2025\) kN * | 1890 kN \(< 2025\) kN (lowering in sections) |
| 3779 kN \(< 4050\) kN | 1890 kN \(< 2835\) kN (lowering in sections) | 1890 kN \(< 2025\) kN (lowering in sections) |

Note: *-condition is not satisfied; it is necessary to lower string by sections or change downhole structure.

From presented conditions for selection of drilling rig, it is clear that using of drilling pipe made of aluminium alloy allows using drilling rig with small load rating. But it is necessary to lower the casing string with diameter 244.5/250 mm by sections or to change the hole structure (it is shown above). The possibility of lowering and cementing of aluminum casing pipes should be considered in further works.

### 4. Economic evaluation

Economic evaluation of the well construction with using of ZJ70 with steel drilling pipe G-105 (design), ZJ-70 with alloy drilling pipe D16T, ZJ50 with alloy drilling pipe D16T, ZJ50 with alloy drilling pipe D16T was performed by means of longevity method by calculation of bill of quantities for well construction. Comparison of obtained results was made: for the well construction with using of ZJ70 with steel drilling pipe G-105 (design) expenses are 1.05 billions of rubles; with using of ZJ-70 with alloy drilling pipe D16T expenses are 1.04 billions of rubles; with using of ZJ50 with alloy drilling pipe D16T expenses are 0.89 billions of rubles; with using of ZJ40 with alloy drilling pipe D16T expenses are 0.85 billions of rubles. Analytical calculation shows that using of alloy drilling pipes provides economy about 0.6-19%.

### 5. Conclusions

Obtained results show that using aluminium drilling pipes for drilling of ultra-deep wells could provide increasing of investment attractiveness of exploring of small deposits at large depth with difficult geologic and technical conditions. Also lack of mass experience of using alloy drilling pipes for drilling of ultra-deep holes and partiality of information in open sources lead to new researches.

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