Trunk Pipeline Throughput Enhancement Using the Continuous Additive Dosing Technology

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Abstract. The article covers the peculiar features of using drag-reducing additives to solve the problems of gas condensate transport, namely: reducing energy consumption on current condensate pipelines and reducing capital costs while increasing the pipelines throughput. The authors have developed an optimization method of drag-reducing additive dosing to decrease the energy consumption of pumping in a particular section of a condensate pipeline, justified and proposed a technical solution for the use of continuous drag-reducing additive dosing.

1. Introduction

In 2020, PJSC Gazprom is going to produce about 30 billion m³/year of gas and 10 million tons/year of gas condensate from the Bolshoy Urengoy Achimov Deposit [1, 2]. With an increase in production, energy costs for pumping hydrocarbon and the load on the condensate pipeline increase.

The analysis of practical experience of domestic oil and gas industry enterprises [3-14] and overseas researchers [15-23] gives evidence of drag-reducing additive (DRA) application basically on oil trunk pipelines (OTP). In this case, DRAs in OTPs solve the following tasks:

1. enhancement of the current OTP throughput without construction of additional oil pumping stations (OPS), loops, reconstruction of the OTP, OPS, etc. linear part;
2. reduction of specific energy consumption while maintaining the OTP former performance;
3. reduction of the load on the OTP linear part (LP) and the OPS process equipment by reducing the operating pressures while maintaining the OTP performance and, as a result, enhancement of the OTP reliability;

4. reduction of operating pressures in the pipe sections while maintaining the same pumping performance for recovery operations (installing a repair coupling, etc.) without stopping pumping.

Applying DRAs in OTPs, we have the task of using the same additives in a particular section of a condensate pipeline. Thus, an effective drag-reducing additive supply to a condensate pipeline is currently an urgent technology. This technical solution will allow recovering the Achimov gas condensate pipeline throughput at a constant pressure and other pumping parameters, without affecting physical, chemical and operational parameters.

Currently, the DRAs efficiency is determined in the process of pilot transportation by oil trunk and oil product pipelines. To conduct such tests in condensate pipelines both time and material resource consumption are required. It is much easier to conduct such studies in the laboratory. However, in this case there is a problem of reliable transfer of the laboratory experiment results to industrial conditions.

In the course of the study, the authors set a goal to give a justification and technical solution for the use of continuous drag-reducing additive dosing to recover the trunk pipelines throughput. This goal was to be achieved by solving the following tasks:
1. testing at an experimental facility;
2. evaluation of the proposed technology feasibility in relation to the Bolshoy Urengoy Achimov Deposit conditions;
3. development of the drag-reducing additive dosing optimization method.

The study was carried out using drag-reducing additive prototypes P-1 (a prototype dosage of 20 g/t in the temperature range from 30 °C to 70 °C in the 1st and 2nd test series) and P-2 (a prototype dosage of 20 g/t in the temperature range over 50 °C in the 2nd test series).

Gas condensate (GC) of the Achimov deposit Urengoy oil and gas condensate field (OGCF) was tested (the date of extraction is 24.09.16). These additives were tested in the recommended dosage, numerically equal to 20 g/t. This specific consumption was minimal to meet the criteria for a positive assessment of the DRA efficiency at the experimental facility of the Engineering and Technical Center of the OOO Gazprom Dobycha Urengoy.

In the period from January to December 2016, the pressure at the initial point of the condensate pipeline was in the range from 3.9 to 4.7 MPa, the mean annual pressure was 4.34 MPa. Thus, during the tests, the pressure in the circuit of the laboratory unit was maintained within 4.0-4.5 MPa. Two series of tests were carried out at condensate flow rates of 12 and 24 m³/h in the pipeline of the laboratory unit.

It should be noted that, based on the conditions of the experiment, a drag-reducing additive is recognized as having passed laboratory tests and recommended for pilot testing (PT), if the following parameters are obtained:
- pressure drop reduction by at least 15% (DRp ≤ -15%);
- reduction of energy consumption by at least 10% (DRe ≤ -10%).

2. Results
The analyzed condensate parameters obtained in the course of 2 series of tests are reflected in the summary table 1.

Table 1. Parameters analyzed during the experiment.

| Additive | Temperature, t, °C | Pressure drop | Energy consumption |
|----------|-------------------|--------------|--------------------|
|          | DP0, MPa | DP0, MPa | DR0, % | E0, kW·h/m³ | E0, kW·h/m³ | DRe, % |
|          | 1-st test series. Condensate flow- 12 m³/h |          |          |          |          |        |
| P-1      | 30      | 0,596   | 0,502   | -15,7   | 0,0385   | 0,0340   | -11,6   |
|          | 40      | 0,596   | 0,503   | -15,6   | 0,0385   | 0,0338   | -12,1   |
|          | 50      | 0,596   | 0,500   | -16,1   | 0,0385   | 0,0339   | -11,9   |
|          | 60      | 0,596   | 0,496   | -16,4   | 0,0385   | 0,0335   | -12,9   |
|          | 70      | 0,596   | 0,465   | -16,8   | 0,0385   | 0,0333   | -13,4   |
|          | 30      | 0,539   | 0,453   | -13,7   | 0,0357   | 0,0328   | -8,1    |
|          | 40      | 0,539   | 0,460   | -14,7   | 0,0357   | 0,0325   | -8,9    |
|          | 50      | 0,539   | 0,458   | -15,1   | 0,0357   | 0,0323   | -9,5    |
|          | 60      | 0,539   | 0,457   | -15,3   | 0,0357   | 0,0322   | -9,8    |
|          | 70      | 0,539   | 0,453   | -15,9   | 0,0357   | 0,0318   | -10,9   |
| P-2      | 30      | 0,681   | 0,574   | -15,7   | 0,0401   | 0,0356   | -11,3   |
|          | 40      | 0,681   | 0,573   | -15,9   | 0,0401   | 0,0351   | -12,4   |
|          | 50      | 0,681   | 0,572   | -16,0   | 0,0401   | 0,0349   | -12,9   |
|          | 60      | 0,681   | 0,571   | -16,2   | 0,0401   | 0,0348   | -13,2   |
|          | 70      | 0,681   | 0,567   | -16,7   | 0,0401   | 0,0345   | -13,9   |
|          | 30      | 0,653   | 0,570   | -12,7   | 0,0431   | 0,0394   | -8,7    |
|          | 40      | 0,653   | 0,567   | -13,2   | 0,0431   | 0,0392   | -9,0    |
|          | 50      | 0,653   | 0,553   | -15,3   | 0,0431   | 0,0387   | -10,3   |
|          | 60      | 0,653   | 0,550   | -15,7   | 0,0431   | 0,0384   | -10,9   |
|          | 70      | 0,653   | 0,546   | -16,4   | 0,0431   | 0,0382   | -11,4   |
|          | 2-nd test series. Condensate flow- 24 m³/h |          |          |          |          |        |
For clarity, the curves of variations of the relative pressure drop (Fig. 1 and 2) and relative electricity consumption reduction (Fig. 3 and 4) depending on the condensate temperature in the two series of experiment are given.

Figure 1. Graphs of variance of the relative pressure drop depending on the condensate temperature with specific DRA dosage of 20 g/t at its flow of 12 m$^3$/h.

Figure 2. Graphs of variance of the relative pressure drop depending on the condensate temperature with specific DRA dosage of 20 g/t at its flow of 24 m$^3$/h.
Figure 3. Graphs of variance of relative energy consumption reduction depending on the condensate temperature with specific DRA dosage of 20 g/t at its flow of 12 m³/h.

Figure 4. Graphs of variance of relative energy consumption reduction depending on the condensate temperature with specific DRA dosage of 20 g/t at its flow of 24 m³/h.

As shown by the presented experimental test results visualization, prototype P-1 has demonstrated a relative decrease in the pressure drop by more than 15% and energy consumption by more than 10% at a dosage of 20 g/t in the both series of tests in the temperature range from 30 to 70°C. Prototype P-2 has only met the specified laboratory requirements for evaluating the efficiency in the second series of tests at temperatures above 50°C.

3. Discussion
The drag-reducing additive efficiency is primarily estimated by a relative increase in the condensate pipeline throughput. Also an important indicator is a relative decrease in the pressure difference at the ends of the condensate pipeline linear section (pressure drop). Based on the DRA case record in OTP, it is noted that its use in condensate pipelines [1] allows:
1. increasing the pumping capacity at a constant pressure drop in a pipeline section (maximum recorded – by 60 %);
2. reducing the operating pressure while maintaining constant flow rate (maximum – by 45 %);
3. increasing the loop performance during the trunk pipeline repair (maximum recorded – by 60 %);
4. profiting from a pipeline throughput enhancement (for example, additive Necadd-447 in the trunk oil product pipeline of "Ufa - West Direction" [1] has allowed increasing the economic effect by 336,625 thousand rubles/day as of 2006.).
5. reducing energy consumption, including reducing the load on oil pumping unit electric drives (additive M – FLOWTREAT: has increased the performance of the head oil pumping station by 25% in the pipeline of "Urengoy - Surgut" [1] with a concentration of 10 g/t; has shown a maximum recorded efficiency of 53.1% with its concentration of 30 g/t in the condensate pipeline of "Yurkharovskoe field - Purovsky CPP (condensate processing plant)" of OOO NOVATEK-YURKHAROVNEFTEGAZ).

To identify the minimum operating DRA concentration with sufficient drag-reducing efficiency it is proposed to use the continuous dosing technology. This technology (Fig. 5) provides a drag-reducing additive supply to a condensate pipeline in permanent mode using a hydrodynamic jet module (reactant dosing unit).

**Figure 5.** DRA supply diagram.

DRA in the commodity form is pumped from barrels by a barrel pump (Fig. 6, BP-1) into tank (T-1), then is supplied by means of dosing pumps (N-1,2) for mixing with unstable gas condensate which is transported from the CGTU (Complex Gas Treatment Unit) by the pipeline to the PTGTU (Pre-Transport Gas Treatment Unit).

| No | Denomination       | Designation              | Amount |
|----|--------------------|--------------------------|--------|
| 1  | T-1                | Tank                     | 1      |
| 2  | BR-1               | Barrel with a reactant   | 1      |
| 3  | P1, P2             | Dosing pump              | 2      |
| 4  | BP-1               | Barrel pump              | 1      |
Figure 6. Sketch of the additive dosing unit.

The amount of the dosed drag-reducing additive (P, kg/day.) is calculated by the formula:

\[ P = \frac{c \times Q_k}{1000}, \]

where, \( Q_k \) – condensate flow, t/day;
\( c \) – drag-reducing additive operating dosage, g/t.

The optimum DRA operating dosage is established during pilot tests. It is recommended to start the pilot tests with a DRA dosage equal to 20 g/t and, depending on the obtained data, to increase/decrease the DRA specific consumption with a step of 5 g/t.

Prior to the DRA supply an analysis of the following data is made during the identical period (which shall not be less than 6 months): the condensate flow rate at the receiving point of the pre-transport gas treatment unit (Q, m³/h); electricity consumption by the pump electric drives (kW×h); pressures at the initial (Pᵢ, MPa) and ultimate (Pᵤ, MPa) points of the condensate pipeline; pressure drop (Pᵰ, Pᵰ = Pᵢ - Pᵤ, MPa).

The controlled parameters obtained during the drag-reducing additive application are compared with the above data. It should be noted that the use of DRA, depending on the specific consumption, on average, can achieve a reduction in electricity consumption at pumping up to 40%.

4. Summary

To identify the minimum DRA operating concentration with sufficient drag-reducing efficiency it is proposed to use the continuous dosing technology, which is a continuous DRA supply to a condensate pipeline by means of a hydrodynamic jet module. The optimum DRA operating dosage is established during pilot tests. It is recommended to start the pilot tests with a DRA dosage equal to 20 g/t and, depending on the obtained data on electricity consumption, to optimize the DRA specific consumption with a step of 5 g/t. Thus, in the course of work a scientific novelty of the study which is the use of a drag-reducing additive (DRA) during a "cold transport" of gas condensate (i.e. without preheating) has been substantiated.
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