Regulation of the Operation of Ejector Systems under Unsteady Gas Pipage

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Abstract. During the natural gas trunk transportation, the need for the repair work demanding cutting off the pipeline’s section and gas etching occurs periodically. According to established repair practice on a linear part considerable volumes of natural gas are pitted in the atmosphere. Jet pumps — ejectors can participate in the offered processes of the cut section’s pumping, however because of not stationarity of process it is necessary to save high coefficient of ejection by regulation of the ejector operation. Regulation of the ejector operation by means of the needle with constant pressure of working gas and gas at the exit from the ejector and gas-intaking variable pressure is offered. Operation parameters of the ejector are determined by means of ANSYS Fluent CFD packet. The adjusting diagram of dependence of the ejection coefficient and a consumption of the inhausted gas on pressure of the inhausted gas and the provision of the needle in the snivel is constructed.

1. Introduction

PJSC Gazprom has the world's largest gas transmission system (GTS). Its main part is a part of the Unified Gas Supply System (UGSS) of Russia. There are close economic relations of all UGSS elements that are shown in processes of planning, pricing and management.

Therefore, so far as concerns that scale, questions of reliability, energy saving and power efficiency take on strategic character, and even insignificant cost reduction can result in notable energy saving effect. At high costs of gas transportation for long distances the maximum implementation of the energy saving potential that is available in gas industry is necessary.

Within PJSC Gazprom the main problem solutions for power consumption decrease in the industry are reflected in "The concept of energy saving and increase in power efficiency of PJSC Gazprom for 2011-2020. The public company designated ensuring resource-saving, increase in energy efficiency of production process at all its stages by priorities of the environmental policy and corporate ecological strategy. The problem of development for the technologies increasing efficiency for the gas trunk transportion is included into the List of priority scientific and technical problems of Society for 2011-2020.

Within PJSC Gazprom for the purpose of forming of the uniform database on results of implementation of provisions of Concepts of energy saving and increase in power efficiency of The public company "The directory of effective energy saving technologies in production, transportation and an underground gas storage" providing the systematized list of the energy efficient technologies and the equipment approved on objects of PJSC Gazprom is developed.
The analysis of implementation of the program of energy saving of PJSC Gazprom in gas transportation showed that the following directions are most effective in natural gas economy in % of the total value of economy:

- cost reduction when carrying out repairs and scheduled works at the compressor stations (CS), the linear part (LP), gas distribution stations (GRS) – 38.6%;
- carrying out repairs of GCU for increase in their technical condition – 17.0%;
- upgrade or replacement of the equipment of KS, LP and GDS – 16.4%;
- improvement of supervisory control quality for providing the rational modes of gas trunk transportation by means of estimated and optimization complexes – 13.6%;
- implementation of resource-saving actions when carrying out repairs and elimination of gas leaks on KS, LP and GDS – 11.7%.

We will open the first direction in more detail.

In order to accidents prevention and saving of operating state on line sections of the main gas pipeline periodic repair work which frequency and location on the route is determined by data of in-line inspection and other sources of information are performed.

At established practice of carrying out hot and gas dangerous work on gas transmission systems etching in the atmosphere of gas is carried out from the repaired section of the pipeline with total loss of emissions. In some cases, according to requirements of the security regulation similar operation with emission in the atmosphere and for the next section adjoining to repaired is carried out that increases the general losses of natural gas at execution of repair work.

According to sources the annual average number of repairs is in the range from 12 up to 15 each 1000 km of the route of gas pipelines. Nodes with linear cranes and jumpers (at the multi-strand gas pipeline) are located between gas pipelines through each 25-30 km of the pipeline route. The average amount of the gas which is thrown out only for one repair, depending on the size of the pipeline’s repaired section and gas pressure in it, can reach 3 – 4 million m³.

At the same time, it’s obvious that service life of the majority of the operated gas pipelines grows, maintenance requirements will increase under repair, and losses of gas in the atmosphere because of emissions will continue to grow.

In addition to natural gas losses at emission the gas transmission company pays for emissions of pollutants which IV hazard class methane belongs.

2. Relevance of the problem

The relevance of the problem of reduction of natural gas losses (owing to emissions in the atmosphere) is connected with continuous prices increasing for energy carriers and aging of fixed assets.

For the specified reasons in terms of energy saving there will be correct a pumping, collecting and the subsequent utilization of natural gas at repair of main gas pipelines.

Several main requirements are imposed to the technologies applied to gas pumping:

1) small time of pumping — because of big expenses, connected with the fact that the repaired pipeline is not operated (for the pipeline with a diameter of 1420 mm 30 km long with the initial pressure of 7.5 MPa and final 1.0 MPa, time of pumping should be no more than 100 h);

2) high mobility of the equipment that is connected with need of its application on different sections of pipelines (overall dimensions of the equipment should provide its driving through roads with asphalt and gravel coverings);

3) depth of development or minimum residual pressure;

4) material costs of holding preparatory activities;

5) ensuring industrial safety, reliability of operation of the gas transmission system and gas supply of consumers.

For these purposes some schemes as in case of single-strand, and multi-strand gas pipelines (Figure 1) were offered. One of basic elements in the specified schemes is the jet pump — the ejector.
Figure 1. Schematic diagrams of utilization of gas at repair of the site of the single-strand and multi-strand gas pipeline.

In the scheme for the single-strand gas pipeline the disconnected pipeline section is the source both of ejecting and pumped out gas, and gas pressure will fall on a suction line of both the ejector, and the centrifugal compressor (pulp and paper mill). As a result, it will be required to pumping to use several steps of compression of pulp and paper mill at the final stage. Cases of the main gas pipeline section repair are in one technological corridor with one or more gas pipelines are more widespread. In schemes of pumping of gas at repair in a technological corridor with two and more gas pipelines a source of the ejecting gas is the next gas pipeline in which pressure remains at one level.

There is a domestic development of mobile compressor station of production Energomasheksport. In it the three-stage ejector intended is used to level falling pressure in the disconnected section in the course of pumping. At decrease in coefficient of ejection there is a switching to the following step of the ejector.

In addition to step regulation of the ejector operation there is also the regulation of the ejector operation by means of the needle, basic construction of such ejector is given in figure 2.

Figure 2. An ejector design with a needle.

As a result of the needle movement in the snivel the cross-sectional area changes that affect the nature of a working stream in the snivel. Calculation for the ejector operation in the conditions of existence of various provisions of the ejector is quite labor-consuming when using analytical formulas, for this reason calculation of parameters of the ejector is executed in a package of numerical hydrodynamics Fluent of the program ANSYS complex.

3. Problem definition
Key operation parameters of the ejector are the coefficient of ejection of \( n \), an expense of the operating \( G_{\text{high}} \) and the pumped out \( G_{\text{low}} \) gas. For simplification of calculations we will accept the following assumptions:
— constant pressure on an input of working gas and at the output of the ejector;
— environment – methane;
— one design was investigated.

For carrying out calculations in the environment of KOMPAS-3D the volume occupied with natural gas (Figure 3) is constructed. Due to the axial symmetry and influence of gravity (gas density in the considered conditions about 30-50 kg/m³) from all volume the sector in 180° was left.

![Figure 3. Settlement 3D model.](image)

The purpose of calculation will be determination of operation parameters of the ejector at various provisions of a needle in a snivel (Figure 4).

The set boundary conditions:
— $R_{\text{in(high)}}$ of $=5.6$ MPa — high pressure of working gas on an entrance to the device;
— $R_{\text{out}} =5.4$ MPa — gas pressure at the output of the device.

Change interval of provision of a needle — 10 mm.

Properties of methane are taken from Fluent Database library, density paid off on the equation of real gas of Peng-Robinson. Model of viscosity $k$-epsilon according to recommendations for viscous fluid.

![Figure 4. The scheme of the ejector from the provision of a needle. (position of the tip of the needle)](image)

4. Results of computer modeling
During the carried-out computer modeling the dependence of the ejector operation on the provision of the needle and pressure of the pumped-out gas is defined. Results of calculation at the provision of the needle 1 are given below — the extreme right provision adopted conditionally at some distance from the nozzle. Then ejector operation parameters for 3 more provisions of the needle differing in movement by a step of 10 mm in the direction from the nozzle (Table 1) were consistently determined.

| Situation | $P_{\text{in(low)}}$(MPa) | $G_{\text{(high)}}$(kg/s) | $G_{\text{(low)}}$(kg/s) | $\frac{G_{\text{(low)}}}{n=G_{\text{(high)}}}$ |
|-----------|----------------------|---------------------|---------------------|-------------------------------|
| 1         | 5.400                | 0.752               | 0.728               | 0.970                         |
|           | 5.375                | 0.774               | 0.686               | 0.890                         |
|           | 5.350                | 0.770               | 0.516               | 0.670                         |
|           | 5.325                | 0.782               | 0.378               | 0.480                         |
|           | 5.300                | 0.796               | 0.186               | 0.230                         |
Distribution of pressure in the plane of longitudinal symmetry at the provision of the needle 3 and pressure of the pumped out gas of 5.3 MPa is given for the general evaluation of the ejector work in figure 5.

| 2  | 1.084 | 0.684 | 0.631 |
|----|-------|-------|-------|
| 5.400 | 1.142 | 0.554 | 0.485 |
| 5.350 | 1.196 | 0.372 | 0.311 |
| 5.300 | 1.264 | 0.164 | 0.130 |
| 5.250 | 1.302 | 0.088 | 0.068 |
| 5.225 |

| 3  | 1.210 | 0.712 | 0.588 |
|----|-------|-------|-------|
| 5.400 | 1.258 | 0.544 | 0.432 |
| 5.350 | 1.330 | 0.430 | 0.323 |
| 5.300 | 1.400 | 0.258 | 0.184 |
| 5.250 | 1.440 | 0.162 | 0.113 |
| 5.225 | 1.480 | 0.098 | 0.066 |
| 5.200 |

| 4  | 1.236 | 0.744 | 0.602 |
|----|-------|-------|-------|
| 5.400 | 1.272 | 0.540 | 0.425 |
| 5.350 | 1.340 | 0.400 | 0.299 |
| 5.300 | 1.416 | 0.258 | 0.182 |
| 5.250 | 1.456 | 0.178 | 0.122 |
| 5.225 | 1.496 | 0.108 | 0.072 |
| 5.200 |

Schedules of coefficient of ejection (Figure 6) and a consumption of the pumped out gas (Figure 7) depending on pressure of the last are constructed at 4 provisions of a needle for assessment of overall performance of the ejector at this type of regulation.

The analysis of the received results shows close values of coefficient of ejection with a pressure of 5.31 MPa for the curves corresponding to provisions 1 and 2. On the right from this value the coefficient of ejection is higher for the provision of the needle 1 than for provision the 2 one. The similar situation is noticeable on graphics of a consumption of the pumped out gas, however it is not so strongly expressed.

In terms of minimization of a consumption of working gas it is necessary to provide the maximum value of coefficient of ejection, that is for pumping of identical amount of gas from the disconnected site it will be required smaller expenses of working gas and, as a result, energy on the drive of pulp and paper mill.

In terms of minimization of time of pumping it is necessary to provide the maximum flow of pumped-out gas, therefore movement of the needle from provision 1 to provision 4 at pressure decrease in the disconnected site from 5.4 to 5.2 MPa has to be provided.
Figure 6. Dependence of coefficient of ejection on pressure of the pumped out gas.

Figure 7. Dependence of a consumption of the pumped out gas on its pressure.

5. Conclusions
The dependence of the ejector operation with the needle in the snivel has quite difficult character, and the provision of the needle not linearly influences coefficient of ejection and an expense of the ejecting environment. In general, it is possible to draw the conclusion that regulation of the ejector operation by the needle allows to achieve high efficiency at the narrow range of pressure. As a result, the refusal of step regulation and transition to regulation by the needle will lead to considerable restriction on operating ranges of expenses whereas addition of step regulation of the ejector with regulation with the needle allows to increase efficiency of separate steps.

References
[1] Gadelshina A R, Kitaev S V, Galikeev A R 2015 Current state and prospects for development of resource saving technologies Gazprom Public Company Territorija «NEFTEGAZ» Oil and Gas Territoryvol 12 pp 136–9
[2] GAZPROM PJSC 2011 Gazprom concept of power saving and improvement of energy efficiency in 2011–2020 (Moscow: PJSC Gazprom).
[2] GAZPROM PJSC 2011 Catalog of efficient energy-saving technologies in gas production, transportation and underground storage JSC Gazprom (Moscow: PJSC Gazprom) p 310
[3] Ivanov E S, Kitaev S V 2015 Resource saving technology of the main gas pipeline section shutdown for repair with gas generation by the compressor station for GPU and consumer via gas distribution plantTerritorija «NEFTEGAZ» = Oil and Gas Territoryvol 6 pp 40-6
[4] COMPANY STANDARD Gazprom 3.3-2-024-2011 A technique of rationing of a consumption of natural gas for own technological needs and technological losses of trunk transport of gas
[5] Kozminykh A V, Lyubin EA 2014 Decreasing of gas losses during gas pipeline repair Fundamental and applied research in the modern world (St. Petersburg: Future Strategy) vol 5
[6] Garris N A 2011 Resource-saving technologies at operation of the equipment of pump and compressor stations (Ufa: Ufa State Petroleum Technological University) p 255

[7] Yumagulov R D, Godovsky D A 2018 The use of an ejector for pumping gas from the emptied gas pipeline *Pipeline transport-2018* (Ufa: Ufa state petroleum technological university) pp 424-5

[8] Yumagulov R D, Godovsky D A 2019 Calculation of operating modes of the ejector for pumping gas from the compressor station *Pipeline transport-2019* (Ufa: Ufa state petroleum technological university) pp 423-4

[9] Fedorova N N, Valger S A, Danilov M N and Zakharova Yu V 2017 Basics in ANSYS 17 (Moscow: DMK Press) p 210

[10] Buranshin A P, Godovsky D A and Tokarev A P 2019 Ejector installations in resource-saving at trunk transport of gas *Pipeline transport-2019* (Ufa: Ufa state petroleum technological university) pp 389-390