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Monitoring and identification of operation modes of energy carrier pipeline transportation

Sergey Dudin[1] , *Vasily* Golik[1], *Dmitry* Novitskiy[1], *Rasul* Mamadaliev[1], and *Natalia* Kazakova[1,*]

[1]Tyumen Industrial University, Volodarskogo str., 38, Tyumen, 625000, Russia

Abstract. The authors analyzed the examples of using operation mode monitoring systems for energy carrier pipeline transportation. It is noted that the effectiveness of this class of systems depends on the information and software support. Harnessing the power of satellites equipped with a standard telemetry and optical equipment allows you to monitor and control the operation modes of energy carrier pipeline transportation on a fundamentally new level. The article considers modern operation modes of pipelines transporting energy carriers. It describes operational complications that have a negative impact on the hydraulic pipeline operation modes. Main tendencies and directions of improving the efficiency of energy carrier pipeline transportation are presented. It is noted that at the present stage of science and technology development in order to improve the effectiveness of monitoring it is necessary to use advanced mathematical models to implement continuous monitoring, control and management of the pumping process at different modes of pipeline operation within a single approach.

1 Introduction

Energy carrier pipeline transportation systems are well developed both from the standpoint of the process, and from the standpoint of the hydrocarbon pumping process safety. Increased attention to ecological and safe transportation of hydrocarbons from supervisory organizations dictates the need to improve pumping monitoring and control systems. Activities to ensure the operational reliability and efficiency of pipeline systems are focused on the application of modern technologies for the recovery and repair of pipelines. Development of pumping mode monitoring systems is aimed at solving problems of detection and prediction of the transported product leaks.

At the same time, the Russian Federation has a number of government programs and regulations of federal and regional levels focused on improving the energy efficiency of industrial facilities in the oil and gas sector of the country [1, 2]:

- Russian Energy Strategy for the period up to 2030;
- Decree of the President of the Russian Federation "On approval of the priority directions of development of science, technology and engineering in the Russian

* Corresponding author: srg_work@mail.ru

Federation and the list of critical technologies of the Russian Federation" (As amended by the Decree of the President of the Russian Federationof 16.12.2015 N 623);

- Russian Federal Law N 261-FZ "On energy saving and increasing energy efficiency "of 23.11.2009;
- Decree of the Russian Governmentof 27 August 2005 №1314-ron the "Concept of the federal system of monitoring of critically important objects and (or) potentially dangerous objects of the Russian Federation infrastructure and dangerous goods";
- Federal Target Program "Research and development in priority areas of the Russian scientific and technological complex for 2014-2020" (approved by RF Government Decree of 21 May 2013№ 426) and others.

Therefore, a priority in the development of hydrocarbon pipeline transportation systems is development and improvement of energy-saving technologies for energy companies. Systems of monitoring operation modes of energy carrier pipeline transportation may become one of the most promising tools for the reduction of energy costs for energy resource pipeline transportation.

2 Research object

Currently, a characteristic feature of pipeline operation is substantial under load of hydrocarbon pipeline transportation facilities at pressure modes below design. This is especially important for pipelines transporting gas-saturated and unstable media, as well as for pipeline sections where there are conditions for developing effects of the product multiphase state and unsteady flow regime. Adverse effects of multiphase flows occur during evaporation of gas condensate, a change of concentrations of wax, salts, resins in the flow, a modified bulk share of gas in the flow of gas-saturated oil, etc. Unsteadiness of the pumping process occurs when implementing a start (stop) mode, at transient pipeline operation modes, as well as at emergency modes.

Because of these features of operation there is a need to carry out a timely assessment of the hydrodynamic condition of the product being pumped in a pipeline to optimize the energy costs for its transport.

The solution of this problem is possible using systems of monitoring the hydrodynamic characteristics of the transported medium. All the systems for monitoring, control and parameter control of the test process are based on the principle formulated as "information on the status of the controlled process model is processed to be used as a model of the process in real time". Methods of collection and transmission of information are quite easily implemented by technical means of telemechanics(remote control). Mainly mathematical models are applied as models characterizing the process under investigation that allow the most accurate description of the process under study. Using high-frequency computers and direct participation of the operator allow for continuous monitoring and control of the test process parameters in real time [3].

3 Methods

In the oil and gas industry the implementation of the above-described principle of the formation of energy carrier pumping process monitoring systems for pipelines was achieved through the use of automation and telemechanics and introducing data centers at the offices operating main pipelines, which led to a full dispatching control over pipeline transportation. This made it possible to increase the efficiency of management of individual physical processes in pipelines, support them at the required level, coordinate the progress of individual processes, carry out monitoring of the work of the technical means of measuring the initial information on the processes occurring in the pipeline, and analyze the state of the pipeline system by the dispatch control services and offices[4].

At the present stage of science and technology development in order to improve the effectiveness of pumping mode monitoring it is necessary to solve the following urgent tasks[1, 5]:

- the use of advanced mathematical models to implement continuous monitoring, control and management of the pumping process at different modes of pipeline operation within a single approach;
- the improvement or modernization of methods of collecting and processing information on the status of the pumping process or the development and introduction of new (adaptable) methods of collecting and transmitting information on the basis of modern technology and software products.

A special way of improving information support systems is the use of satellites equipped with a standard telemetry and optical equipment as a general tool of information monitoring technologies for existing and emerging means of communication (Fig. 1). The use of the above noted, according to many experts, will allow monitoring and control of the pumping process parameters on a fundamentally new level, due to timely and efficient pickup and delivery of information from the controlled object (pipeline) in general over its entire length to the central control room for its subsequent use by a hydrodynamic model of the pumping process, imaging of calculation results on computer with their reference to the coordinates of the pipeline in horizontal and vertical directions along its entire length. Integration of the information received into the management decision-making algorithm for regulating pipeline system operation modes will ultimately optimize energy costs for pumping by preventing the formation of operational complications along the pipeline route [6].

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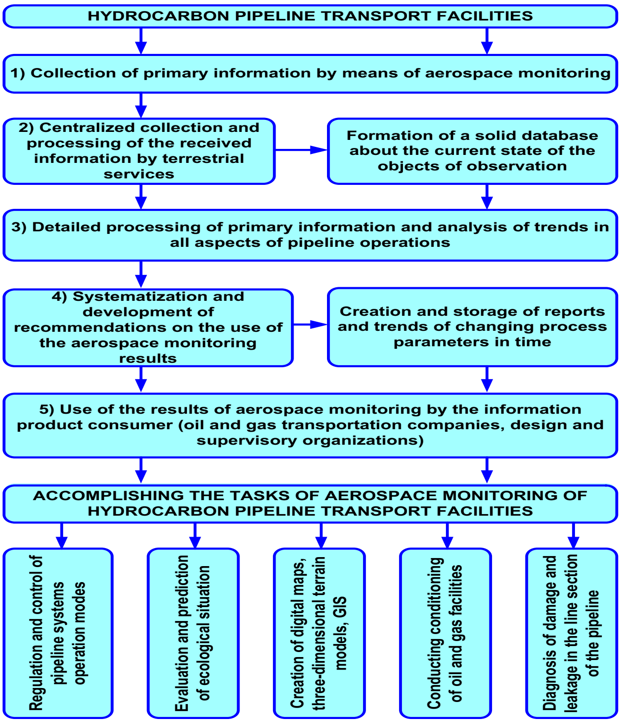

Fig. 1. Stages of implementation of aerospace monitoring of hydrocarbon pipeline transportation facilities [1, 2]

Such systems not only provide the possibility of economic control over the work of existing pipelines while maintaining the required parameters, but also create the possibility of collecting solid data for further processing and analyzing trends in all aspects of pipeline operations[9].

Theissuesofmathematicalmodelingofenergycarrierflowsinpipelinesinvolvedmanyresearchers, including N.A. Slezkin, S.G. Teletov, S.S. Kutateladze, M.A. Styrikovich, H.A. Rahmatullin, A.N. Krayko, L.E. Sternin, A.K. Dyunin, Yu.T. Borshhevskiy, A.I. Guzhov, V.F. Medvedev, R.I. Nigmatulin, N.A. Yakovlev, M.A. Guseinzade, A.B. Shabarov, Yu.S. Danielyan, V.A. Yufin, V.N. Antipiev, V.A. Zysin, E.L. Kitanin, A.K. Gallyamov, Kutukov S.E., G. Wallesandothers.

To date, many authors have developed a number of flow models of hydrocarbon liquids in pipelines using classical assumptions of the theory of continuum mechanics. The differences lie in the quantity and quality of the conditions considered and characteristics of the hydrocarbon pipeline transportation.

In commercial pipelines, according to [10], the most common structural forms of flow are plug and emulsion. There are no clear boundaries between the individual forms of the flow of gas-liquid mixtures, as there are relatively broad transition zones, both in speed and gas content.

A characteristic feature of two-phase hydrocarbon flow regimes is pressure pulsation, for example in the case of pipeline transportation of gas-liquid mixtures. Pipeline pressure pulsation leads to disruption of normal operation of the pumping equipment, instrumentation, etc.[11].

When pumping multiphase mixtures such as gas-oil-water consisting of two mutually insoluble liquid phases - crude oil and water - difficulties arise due to the formation of emulsions during their movement through the pipes. In addition, under real operational conditions of pipelines laid in hilly terrain the gas-liquid flow is acted upon by friction forces and gravitational forces. As a result, the liquid phase is accumulated in the ascending sections, and gas - in the descending sections of the pipeline route. For example, during the operation of pipeline systems there are complications (Fig. 2) associated with a decrease in the flow cross section or a complete blockage of pipes due to the formation of stable gas slugs and accumulations of liquid (water or condensate).

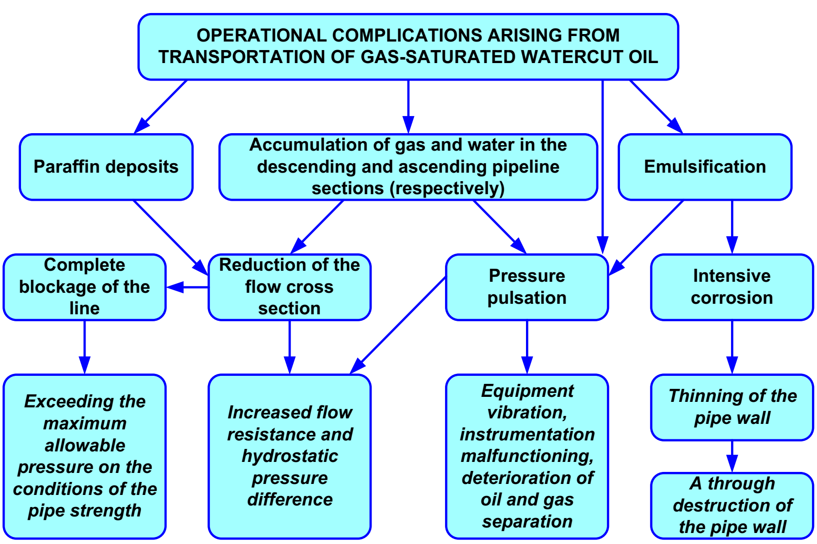

Fig. 2. Operational complications arising during the transportation of heterogeneous media

Oils pumped by main and process pipelines almost always contain dissolved petroleum gases that can accumulate in local accumulations of gas emitted from the liquid at low pressure. In addition, in pipelines water plugs associated with pumping of water cut oil can form. Accumulations of water and gas reduce the operating cross-section of pipes and increase their flow resistance[12]. Similar difficulties arise in the pipeline transportation of unstable liquids (BFLH, unstable condensate, liquefied petroleum gas), especially in the winter or in the starting period.

4 Results and discussion

Given the above, we can state that:

- a special way of improving information support systems is the use of satellites equipped with a standard telemetry and optical equipment as a general tool of information monitoring technologies for existing and emerging means of communication;
- operational complications in pipelines increase the hydraulic resistance, hydrostatic pressure differential and often lead to a complete blockage of the cross section of the pipeline (local formation of gas accumulations, water congestions and crystal hydrates).

Stability of operational complications is primarily caused by thermo baric hydrocarbon flow conditions in the pipe, as well as the component composition of the hydrocarbon system and the geometrical shape of the pipeline[13].

It is known that the power requirement for pumping a mass unit of hydrocarbon raw materials in a gaseous form is by 2 - 3 orders of magnitude greater than the power requirement for pumping hydrocarbons in a liquid form. Therefore, for energy saving during hydrocarbon transportation at the design and operation stages an important task is development and use of the flow and heat and mass transfer calculation method for gas-liquid hydrocarbon media in the process and main pipelines [2, 14].

The Department of "Transport of Hydrocarbon Resources", Industrial University of Tyumen, have recently conducted research in the field of process monitoring in energy resources pipeline transportation systems[5]. To date, a number of physical and mathematical models have been developed describing the process of transportation and storage of energy carriers in the oil and gas industry facilities. The latest development of the authors is a physical and mathematical model of the gas-liquid mixture flow in the condensate line which allows for on-line analysis of the hydrodynamic state of condensate in the pipeline [15, 16].

5 Conclusion

1) Modern pipelines run at pressures below the design, which creates favorable conditions for the formation and existence of operational complications that reduce the hydraulic effectiveness of pipelines.

2) Harnessing the power of satellites equipped with a standard telemetry and optical equipment allows you to monitor and control the operation modes of energy carrier pipeline transportation on a fundamentally new level. Implementation of the above noted will increase the efficiency and expand the scope of the use of existing monitoring systems.

3) The developed method of calculation of the equilibrium gas-liquid mixture flow in the product pipeline enables operational analysis and prediction of the hydrodynamic condition of gas-liquid media in pipelines when changing the component composition of phases, temperature and pressure, and hydraulic conditions.

4) Information obtained by monitoring energy carrier flows in pipelines can be integrated into the management decision-making algorithm to regulate operational modes of pipeline systems, which will ultimately reduce the energy costs for pumping by preventing the formation of operational complications along the pipeline route.

References

1. S. M. Dudin, V.O. Nekrasov, Yu.D. Zemenkov. Oil and gas: a Separate edition of the Mining information and analytical Bulletin, 53-62 (2013)
2. S.M. Dudin, Y. D. Zemenkov, A.B. Shabarov, N.In. Saranchin. Pipeline transport, **5**, 42-45 (2010)
3. S.M. Dudin, Oil and gas, **2**, 65-69 (2011)
4. E.I. Yakovlev, T.V. Zvereva, A.E. Soshhenko et al. *Pipeline transportation of gas condensate products* (Nedra, Moscow, 1990)
5. Yu.D. Zemenkova, *Diagnosis of damage and leakage during pipeline transport multiphase hydrocarbons*. (The Vector The Beech, Tyumen, 2002)
6. S.M. Dudin, Y.D. Zemenkov , Oil and gas, (2007) http://www.ogbus.ru/authors/Dudin/Dudin_1.pdf, 12.09.07 – 15 p.
7. V.G. Akoveckiy, *Aerospace monitoring of oil and gas deposits: Textbook for university* (Nedra -Biznescentr, Moscow, 2008. – 454 p.
8. V.G. Bondur, Issledovanie Zemli iz Kosmosa, **6**, 3–17 (2010)
9. Recent pipeline technologies improve efficiency // Oil and Gas J. – Vol. 98, №38.
10. A.I. Guzhov, V.G. Titov, V.F. Medvedev and V.A. Vasilyev. Collection, transportation and storage of natural hydrocarbons (223p
11. A.I. Guzhov.The joint collection and transport of oil and gas. – M.: Nedra, 1973.
12. Pipeline transportation of liquid and gaseous energy carriers / E.I. Yakovlev, V.A. Ivanov, B.A. Klyuk et al. – M.: VNIIOENG, 1993.
13. S.M. Dudin, Yu.D. Zemenkov, A V Maier, A.B. Shabarov, IOP Conf. Series: Materials Science and Engineering **154** (2016)
14. S.M. Dudin, Yu.D. Zemenkov, A.B. Shabarov, N.In. Saranchin. Oil and gas, 6**,** 63-68 (2010)
15. S.M. Dudin, K.V. Voronin, S.V. Yakubovskaya, S. Mutavaliev, MATEC Web of Conferences, **73**, 11 (2016)
16. S.M.Dudin, Yu.D. Zemenkov, A.B. Shabarov, IOP Conf. Series: Materials Science and Engineering, **154** (2016)