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SYSTEM OF AUTOMATED MONITORING AND FORECASTING OF THE REMAINING RESOURCE OF PIPELINE TRANSPORT

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Abstract: *This article presents a system of automated monitoring and forecasting of the residual resource of pipeline transport, consisting of a developed and manufactured information and diagnostic complex for monitoring the technical condition of pipeline transport and software. Informative frequency ranges for monitoring the technical condition of pipeline transport are determined. Experimental studies have been conducted to confirm the effectiveness of the developed technical solution. The paper considers the problems of reliability of pipeline transport. The analysis of existing methods for assessing the technical condition of pipelines is carried out. A system of automated monitoring and forecasting of the residual resource of pipeline transport has been developed. Experimental studies have been conducted. The methods of circuit and simulation modeling, the theory of automatic control, experimental planning, decision-making, probabilistic and statistical methods of mathematical processing and the method of finite element analysis were used in the performance of the work. Based on the results of the study, a new methodology for assessing the technical condition of pipeline transport has been developed.*

Keywords: *Automated monitoring system; forecasting of residual resource; pipeline transport; monitoring; residual resource; automation; maintenance; diagnostics; safety; efficiency.*

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СИСТЕМА АВТОМАТИЗИРОВАННОГО МОНИТОРИНГА И ПРОГНОЗИРОВАНИЯ ОСТАТОЧНОГО РЕСУРСА ТРУБОПРОВОДНОГО ТРАНСПОРТА

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Резюме: *В статье представлена система автоматизированного мониторинга и прогнозирования остаточного ресурса трубопроводного транспорта, состоящая из разработанного и изготовленного информационно-диагностического комплекса для мониторинга технического состояния трубопроводного транспорта и программного обеспечения. Определены информативные диапазоны частот для мониторинга технического состояния трубопроводного транспорта. Проведены экспериментальные исследования, подтверждающие эффективность разработанного технического решения. Рассмотрены проблемы надежности трубопроводного транспорта. Проведен анализ существующих методов оценки технического состояния трубопроводов. Разработана система автоматизированного мониторинга и прогнозирования остаточного ресурса трубопроводного транспорта. Проведены экспериментальные исследования. При выполнении работы использовались методы схемного и имитационного моделирования, теории автоматического управления, планирования эксперимента, принятия решений, вероятностные и статистические методы математической обработки и метод конечно-элементного анализа. На основе результатов исследования разработана новая методика оценки технического состояния трубопроводного транспорта.*

Ключевые слова: *Система автоматизированного мониторинга; прогнозирование* *остаточного ресурса; трубопроводный транспорт; мониторинг; остаточный ресурс; автоматизация; техническое обслуживание; диагностика; безопасность; эффективность.*

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Introduction

To ensure the efficiency of pipeline transport operation, it is necessary to pay special attention to improving the reliability and quality of their diagnostics [1-2].

A complex method is known for monitoring the location of a buried pipeline transport (RF patent for invention RU No. 2482515, IPC G01V 1/ 00 (2006.01), G01N 29/00 (2006.01), 20.05.2013), which consists in generating sound vibrations with a resonant frequency in the pipeline by means of a dynamic emitter installed directly in the pipeline in place of the shut-off and control valves, and registering the signal of the dynamic emitter by means of a sensitive element [3-7].

This invention is intended for monitoring the location of pipeline transport laid in the ground, while this method does not allow determining the presence of a defect in the pipeline, its localization and dimensions [8].

The task of the proposed technical solution is to create a system for automated monitoring and forecasting of the residual resource of pipeline transport based on entropy parameterization of vibration diagnostic signals, in which the shortcomings of the prototype are eliminated [8].

The scientific and technical result is a new approach to assessing the technical condition of conducting engineering communications, which allows determining not only the presence of a defect, but also the dimensions and localization (positioning) not only in pipelines, but also in any conducting engineering communications for the transportation of liquid and gaseous media (pneumatic and hydraulic pipelines) [8].

Methods

For today, there are two methods of inspection of pipeline transport: from the inside (with the help of in-line inspection shells) and from the outside (with underground laying – by excavating the pipeline). Each of these methods has its advantages and disadvantages. The absolute advantage of an in-line inspection is the possibility of 100% control of the pipeline along its entire length. The disadvantages of this method include the need for special preparation of the pipeline for the passage of in-line inspection shells (VIS), namely, the construction of VIS start-up and reception chambers, cleaning the internal cavity from deposits, eliminating unacceptable narrowing of the passage section and sharp turns that prevent the passage of VIS. In addition, the number of non-destructive testing (NDT) methods used in the in-line inspection method is very limited (ultrasonic and magnetic methods are used on liquid pipelines, and only magnetic methods are used on gas pipelines), their sensitivity and accuracy are lower compared to similar parameters in stationary conditions, and the results of control in some cases (in the presence of welded joints on lining rings and non-metallic liners) are ambiguous. In addition, the cost of an in-line inspection is quite high (several VIS runs are necessary to clarify the coordinates and dimensions of defects), and the degree of danger of detected defects is determined on the basis of complex calculations that require a large amount of data [9-15].

When conducting an inspection of main pipelines from the outside, the range of NC methods used is much wider and, in addition to ultrasonic and magnetic, radiation, capillary, eddy current and a number of other methods can be used. The advantages of this method of inspection of main pipelines include the use of external NC tools with higher sensitivity and accuracy than that of VIS, as well as the possibility of using more methods, which can significantly increase the reliability of control. However, the external method of inspection has serious drawbacks: most of the NC methods used require a significant amount of preparatory work (excavation, insulation removal, cleaning of the controlled surface), have low productivity, and the results of control are strongly influenced by the properties of the pipeline material, the surface condition, orientation and location of the detected defects. At the same time, the key indicator of the danger of a defect is its area or volume, without taking into account the dynamics of further development[9-15].

System of automated monitoring and forecasting of the remaining resource of pipeline transport

System of automated monitoring and forecasting of the residual resource of pipeline transport consists of a developed and manufactured information and diagnostic complex for monitoring the technical condition of pipelines and software based on entropy parameterization of vibration diagnostic signals [16].

The block diagram of the proposed technical solution and a photo of the installation are shown in Fig. 1-2, respectively.

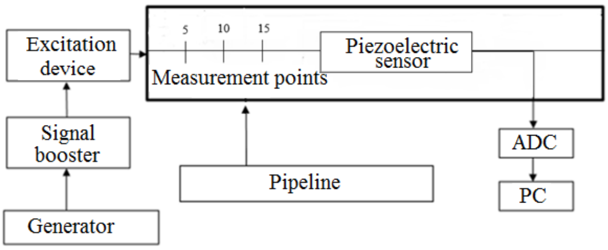

Fig. 1. Flow diagram Рис. 1. Поточная диаграмма

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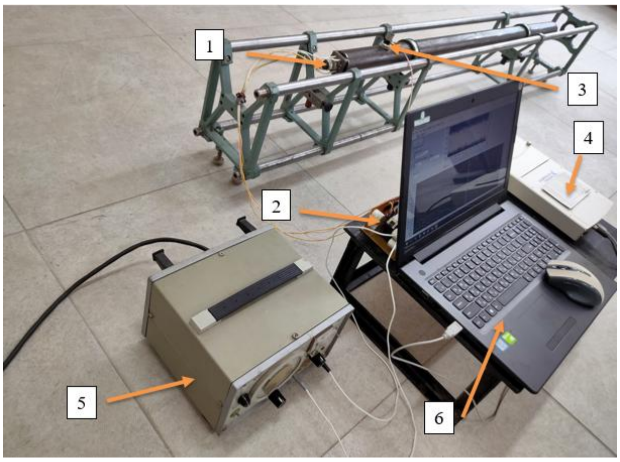

Fig. 2. Installation photo: *1* – excitation device; *2* – amplifier; *3* – sensitive element, *4* – analog-to-digital converter(ADC); *5* – low-frequency signal generator; *6* – personal computer (PC)

Рис. 2. Фотография установки: *1* - возбуждающее устройство; *2* - усилитель; *3* - чувствительный элемент, *4* - аналого-цифровой преобразователь (АЦП); *5* - генератор низкочастотного сигнала; *6* - персональный компьютер (ПК)

**Источник: составлено автором. Source: compiled by the author*

The principle of operation of the system of automated monitoring and forecasting of the residual resource of pipeline transport is as follows.

A sensitive element (piezoelectric sensor) 3 registers sound resonant vibrations that are excited in the pipeline under study using a low-frequency signal generator 5, a signal amplifier 2 and an excitation device 1 [16].

At the same time, the pipeline under study is installed on supports with clamps, with the help of which the ground pressure is created [16].

With the help of a low-frequency signal generator 5 and a signal amplifier 2, a signal is applied to the excitation device 1, which excites resonant vibrations in the pipeline under study. The signal from the sensor element through the ADC 4 is sent to the personal computer 6 for further analysis [16].

The software "Condition monitoring system" (Certificate of state registration of a computer program No. 2019618374) was created in the graphical application development environment "LabVIEW" [17].

The "Condition monitoring system" program is designed to determine the technical condition of pipeline transport in real time with the ability to predict the remaining resource. The data analysis is based on the method of entropy parametrization of vibrodiagnostic signals. By increasing the entropy indicators, it is possible to judge not only the presence of a defect in the object under study, but also to determine its size and localization (positioning) [17].

Figure 3 shows the appearance of the "Condition monitoring system" program panel.

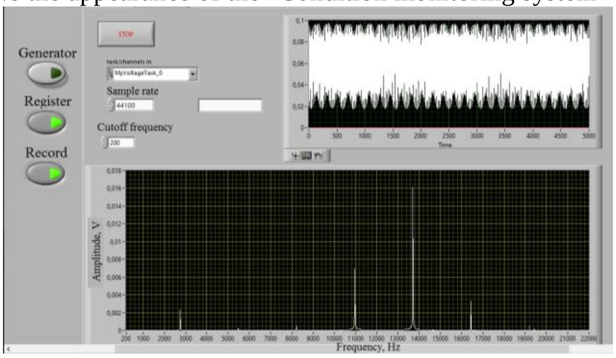

Fig. 3. Program panel

Рис. 3. Панель программы

**Источник: составлено автором. Source: compiled by the author*

A steel pipeline with a diameter of d = 60 mm, a wall thickness of δ = 5 mm, a length of L = 1200 mm was chosen as the object of research.

The following defects in the pipeline were analyzed: a defect of 2 mm (the defect was made in the center of the pipeline under study), a defect of 3 mm, a defect of 5 mm, a defect of 6 mm, a defect of 7 mm, a defect of 8 mm, a defect of 10 mm, defects with a transverse and longitudinal section. The photo of the pipeline with the defect is shown in Fig. 4.

Fig. 4. Photo of a pipeline with a defect of 8 mm

Рис. 4. Фотография трубопровода с дефектом 8 мм

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Figure 5 shows the results of a study of a defect-free pipeline and pipelines with defects of 2 and 8 mm. The analysis of the results shows an unambiguous definition of defective pipelines.

Based on the obtained research results, it can be concluded that the sensitivity of the information and diagnostic complex for monitoring the technical condition of pipelines allows tracking defects in the frequency range of 1000-11000 Hz. The most informative frequencies for detecting even minor defects are the range of 200-4000 Hz and 6000-8000 Hz. In addition to identifying the defect, the system allows you to assess the remaining resource of pipeline transport and build a forecast of its trouble-free operation.

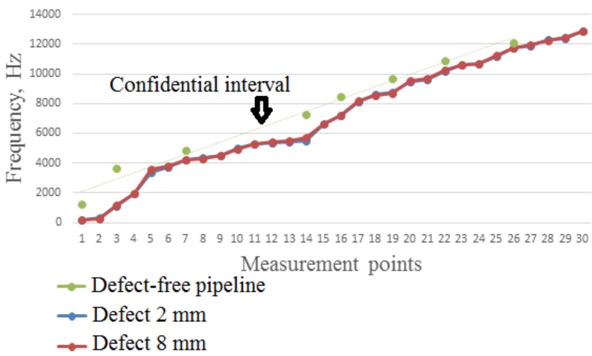

Fig. 5. Results of the study of pipelines with and without defects

Рис. 5. Результаты исследования трубопроводов с дефектами и без них

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Results carried out with the help of the proposed installation and software showed the efficiency and high reliability of the results obtained. Experimental studies were carried out without taking into account the soil.

Conclusion

System of information and diagnostic complex for monitoring the technical condition of pipelines has been developed and manufactured. A method of automated monitoring of heat and power equipment and forecasting of the residual resource of pipeline transport based on entropy parameterization of vibration diagnostic signals is developed and described.

To conduct experimental studies, the "Condition monitoring system" software was developed and created, the purpose of which is to determine the technical condition of pipelines. Experimental studies were conducted. An informative frequency range is defined for monitoring the technical condition of pipeline transport with the possibility of predicting the remaining resource.

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