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The dynamic identification of the technical condition of pipelines on the basis of the analysis of the temporal characteristics of electromagnetic-acoustic signal

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Abstract. To assess the resource of safe operation of process of technological pipelines, it is proposed to control the technical condition of the pipeline metal using the method of dynamic identification. The method is based on the analysis of the coordinates of the roots of the denominator of the transfer function on the complex plane. The transfer function of the system "object of control-electromagnetic-acoustic transducer" is an integral quantitative parameter characterizing the state of the metal.

Introduction

Ensuring the safety of technological processes of the oil and gas industry is determined by the reduction of failures of technological pipelines, which make up a third of all equipment failures at the enterprises of the industry. During the entire period of operation, the process of technological pipelines are under the influence of aggressive conditions and mechanical stresses, which leads to a change in their technical condition [1], [2].

At the moment, the assessment of the technical condition and service life of technological pipelines is made on the basis of the results of mechanical tests of metal samples cut from the existing equipment, or using physical methods of non-destructive testing. The actual problem of evaluation is the ability to identify defects at an early stage of their development. [3-9]. Existing methods for assessing the stress-strain state have their advantages and disadvantages. A promising direction in the assessment of stress-strain state of equipment and structures is the use of electromagnetic-acoustic effect. Currently, the EMA effect is used for thickness measurement and developed detection of defects such as discontinuities. Separate works are devoted to the detection of degradation of metal properties at an early stage and tensometry using the EMA effect [10], [11]. The questions of assessing the resource of safe operation of technological pipelines using the EMA effect are poorly understood and studied, which necessitates further research.

Materials and methods

Experimental studies were conducted in the laboratory. Experimental studies have allowed to study the degradation processes, the impact of operational loading on the change of electrophysical properties of metal elements of technological pipelines. Since the elements of the process pipeline operate under different loading schemes, the experimental studies were made in two directions: under static loading (tension) and under cyclic loading. As the objects of research we used samples of steel grades 10, St3 and 09G2S, the most widely used in the manufacture of process of technological pipelines in the oil and gas industry. To test the samples for low-cycle fatigue at pure bending (figure 2, c), the installation developed by the Professor of the Department "Equipment of petrochemical and oil refining enterprises" of the Ufa State Oil Technical University Gaziev R. R. (patent No. 2262682 of the Russian Federation) was used [12]. The basic parameters of the inductor and the design of the electromagnetic acoustic transducer (EMAP) (figure 1), a General view of the experimental facilities (figure 2). The signals received at the output of the system "control sample-electromagnetic-acoustic transducer" are shown in figure 3. In figure 3a shows the signal at the output of the EMAT, in figure 3, b EMAT signal passed through the filter.

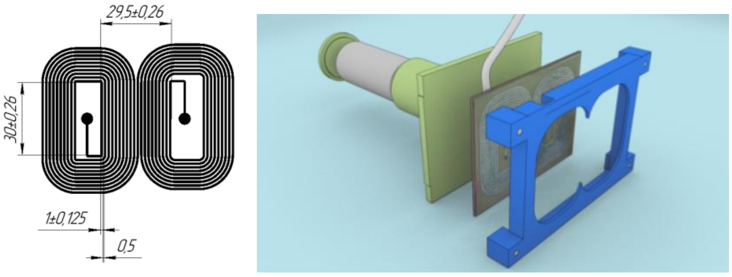
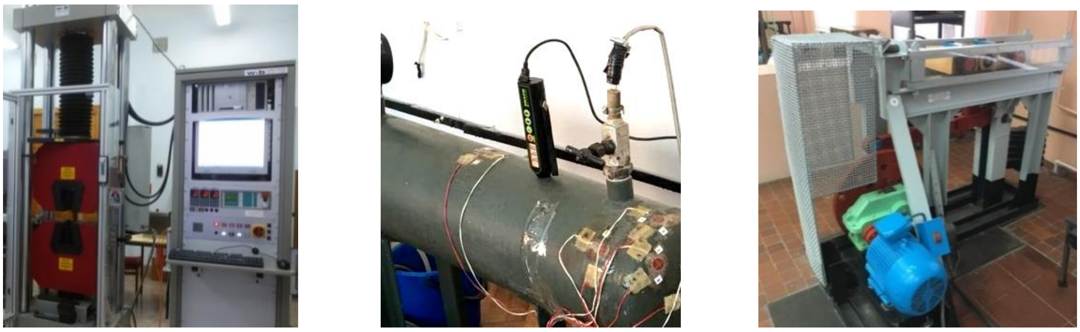


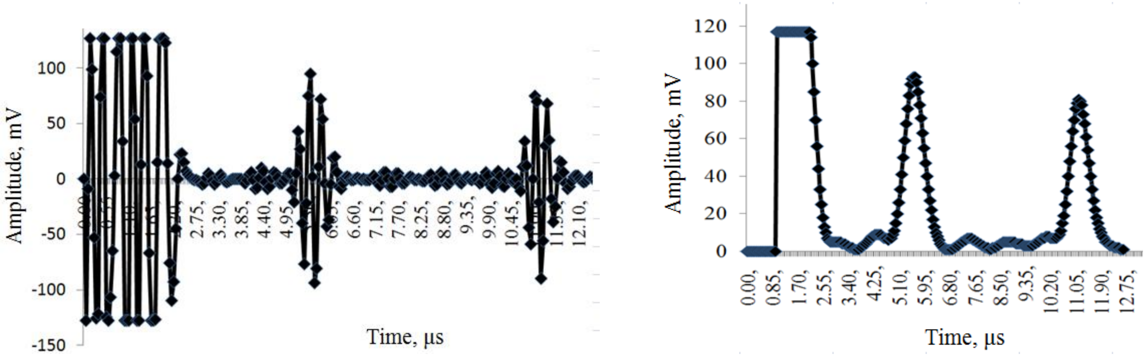
Figure 1. EMA Inductor of the transducer and electromagnetic acoustic transducer (EMAP).



a) b) c)

(a) the static tensile tests using a test machine Walter + Bai; (b) the installation for the study of complex stress-strain state of the pipeline model in the form of a thin-walled cylindrical vessel; (c) the external view of the installation for test of samples for cyclic loads

Figure 2. General view of experimental facilities.



a) b)

(a) sounding and bottom signals at the output of the EMAT; (b) bottom probe and EMAT signals after passing through a coherent filter

Figure 3. Time sweep of EMA signals.

Experimental research

The developed software processes the signal of the electromagnetic-acoustic transducer, using the first reflected (bottom) signal, which is the most informative and easy to detect. The temporary diagram of the electromagnetic acoustic signal of the transducer is shown in figure 4. In figure 4, the first reflected signal is located in the range from 5.55 to 7.25 μs.

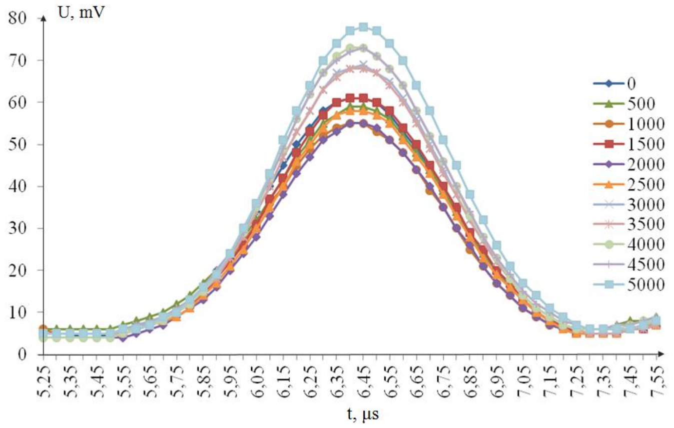


Figure 4. Changing the bottom signal with increasing load on the sample from 0 to 5000 kilogram-force 09G2S grade steel.

The developed program by the method of areas identifies the transfer function of the system "object of control-electromagnetic-acoustic transducer" calculates the roots of the characteristic equation of the system-the polynomial of the denominator of the transfer function [13], [14]. In General, the transfer function W(p) is defined as the ratio of the image of the output signal y(p) to the image of the input signal x (p). For the system" EMAP – object of control " the signal of external action x(P) is a joint action on the object of control of the alternating magnetic field of the current in the inductor and the magnetic field of the permanent magnet, the response signal of the object Y (P) is the EMF induced in the EMAP inductor [14]. To determine the transfer function of the system and search for the roots of the characteristic polynomial, the TAU 2.1 program developed at the Department of "Automation of technological processes and production" of the Ufa State Oil Technical University was previously used. For a more precise definition of the transfer function the calculation was made by the method of moments in the program developed by Professor G. K. Ayasan.

Results

After a series of tests by loading steel samples, the dependence between the applied force and the values of the roots of the characteristic equation was revealed. The obtained dependence is shown in figure 5. The real parts of the roots of the characteristic equation are deposited along the abscissa axis, the imaginary parts of the roots of the characteristic equation are deposited along the ordinate axis. It is possible to estimate the current technical condition and resource of safe operation of the process of technological pipeline of a hazardous production facility by the location of the roots of the characteristic polynomial (denominator) of the transfer function on the complex plane (figure 6). When the state of the metal changes, the coordinates of the roots of the characteristic equation of the transfer function also change.

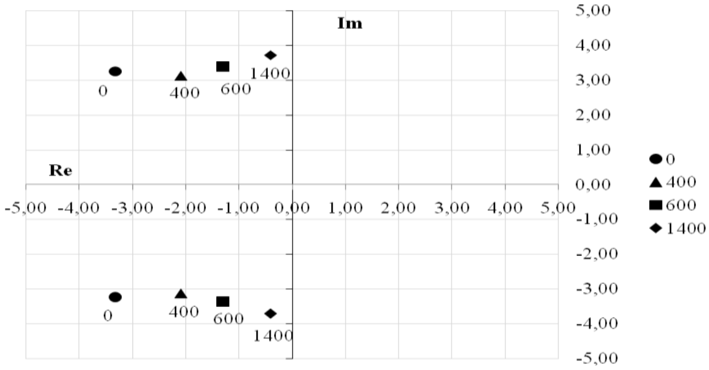
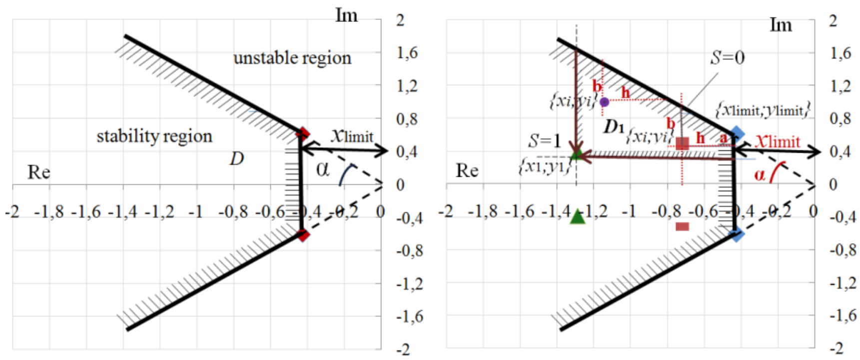


Figure 5. The location of the roots of the characteristic equation under the action of cyclic loading (09G2S, 0-1400 cycles).



a) b)

a-the area of stability of the pipeline D; b-the initial area of the operational state of the pipeline D1

Figure 6. The assessment of the current technical condition and resource of the pipeline by the coordinates of the roots of the characteristic polynomial.

Conclusion

The studies established the relationship between the quantitative values of the roots of the polynomial transfer function of the system "object of control - electromagnetic acoustic transducer" and between the level of the stress-strain state of metal [14]. The results of the research can be used to develop a methodology for assessing the service life of the technological pipelines safe operation to ensure industrial safety.

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