Remote Diagnosis of Dug-in Areas and Bottom Pipe by Main Acoustic Emission Method Using a Self-organizing Wireless Network

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Remote Diagnosis of Dug-in Areas and Bottom Pipe by Main Acoustic Emission Method Using a Self-organizing Wireless Network

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Abstract. This paper discusses methods of nondestructive testing, the main method is method of acoustic flue gas emission. It was found that the use of this method in the diagnosis of bottom pipe and dug-in areas allows to reduce time, does not require surface dressing to a certain value, provides almost instant information about the defect at a great distance to the nearest gas-pumping station and is not inferior to the reliability of the control other existing methods.

1. Introduction

The emergence of modern large-scale facilities - nuclear power stations, LNG terminals with, offshore drilling rigs, large chemical plants, large airliners - led along with economic benefits to large negative consequences in the event of their failure. Humanity can not refuse such facilities, but it can prevent the disaster or reduce their impact through the effective use of methods and means of nondestructive testing and technical diagnostics.

Currently, in accordance with current regulations and guidance documents [1, 2] technical diagnostics of gas mains is carried out mainly by the following methods: visual and measurement control (VIC); Magnetic (MTD) or capillary (CD) inspection; ultrasound (ultrasound) or radiation ; acoustic emission (AE); integrated control with the help of in-flaw-shells; thermal (infrared) control (TC).

There're several disadvantages in each of these methods, almost all of them (except for in-pipe and heat methods) require the immediate presence of employee on the workplace, the release of the pipeline from the insulation stripping metal, characterized by low productivity.

Control of state of the metal of dug-in areas and bottom pipe of pipeline sections are greatly complicated by the inaccessibility of objects. Only in-line flaw-shells are currently used for this purpose, which have more weight (up to 2.5 tonnes), high cost (≈ 4 million. rub.), on the long runs - low productivity (movement in collecting information no faster than0 5 m/s, seizure and analysis of the information only after the passage of the projectile and seizure).

In this paper we propose a method of using acoustic emission method, based on the reception of metal AE [3–6] signals generated by defects, their conversion into electrical signals and transmitted to the wireless receiving and recording module using self-organizing radio network. The sensors provide an autonomous low-voltage power supply, and are mounted on the inner surface of the pipeline during its assembly before going into the pond (the trench), and serve both a power signal transducers and their relays.

The main sources of emissions in metals are the motion of dislocations, plastic deformation or accompanying the emergence and growth of cracks in the structure under the influence of mechanical stresses.

Also, the source of acoustic emission (continuous) is through defects in the walls of pipes that store or transport liquid or gas under pressure, due to the friction of the flowing medium of the defect.

At the same time the surrounding metal are emitted by different types of waves: longitudinal, transverse vertically polarized (TV-waves), transversal horizontally polarized (TH-sloping wave and running parallel to the surfaces of SH-waves) Rayleigh waves, Lamb waves are normal [7].

The symbols of transverse waves: T - Transverse; V- Vertical; H - Horizontal; S - Surface.

Contact of metal with non-gaseous molecular medium (liquid, dirt and sediment, thick dense coating) causes the outflow of the acoustic energy of the metal in the environment for all of these types of waves other than SH-waves. Consequently, this type of wave has the highest "range", and that’s why it would be the most profitable for the purpose of diagnosing of extended objects by the AE method. However, such wave is practically impossible to initiate or take from metal surface with a piezoelectric method.

In ferromagnetic materials it allows to realize electromagnetic acoustic method. But this method, firstly, characterized by low reduction factor of energy (not more than 5%), and secondly? requires the development of special sensors with complicated construction. Therefore, we accept the piezoelectric conversion, based on the fact that the transported medium is satisfactorily clean gas, and the thickness of the insulation coating is significantly less than the length of the sound wave AE signals and therefore do not contribute to their absorption.

Remote search for defects in bottom pipes and dug in areas of pipeline shown in figure 1. The AE signal is received from the closest sensor on the pipeline wall (receiver-transmitter module), this sensor convert it into a radio signal, which is successively relayed to other sensors and this way it delivered to the receiving antenna of registering module fixed on each gas compressor station (GCS). This provides a significant advantage, since the signal is delivered over a distance of tens and even hundreds of kilometers to the nearest GCS in a matter of seconds. Like cell phones, each sensor has its own radio frequency carrier on which is determined by the number and position of the sensor, which adopted the AE signal and sent it to the airwaves. However, even if some of the intermediate sensors are out of control, the signal will still be transmitted: based on the marginal reception range of AE signals from the metal detectors are spaced along the pipeline 20 m, and the radius of the radiation radio each of them 100 m, and therefore this signal will "hear" and transmit at least 10 adjacent sensors. This requires the introduction of broadband in the wiring diagram of the sensor unit of the relay and a second (receiving) antenna, but unlike the cell phone such additive is not particularly difficult, because unlike phones it do not require coding information transmitted in order to protect its confidentiality.

This system has a fundamental difference to the above-ground, bottom and dug-in areas of gas pipelines.

On the above-ground parts of transceivers modules are installed on the outer surface of the pipeline, the transmission of radio signals over the air goes into the surrounding atmosphere, the power - with autonomous battery charging from solar panels.

On the bottom and dug-in areas of the pipeline modules are installed on the inner surface of the pipe during installation, radio transmission is on the transported medium (ie, the pipeline itself plays the role of wave guide), power supply - cable (from the feeder, paved installation inside the pipeline). Structurally, these sensors are fundamentally different from the "above ground", as should not create resistance to movement of gas and at the same time to withstand the pressure of the environment and impact of technological "wind".

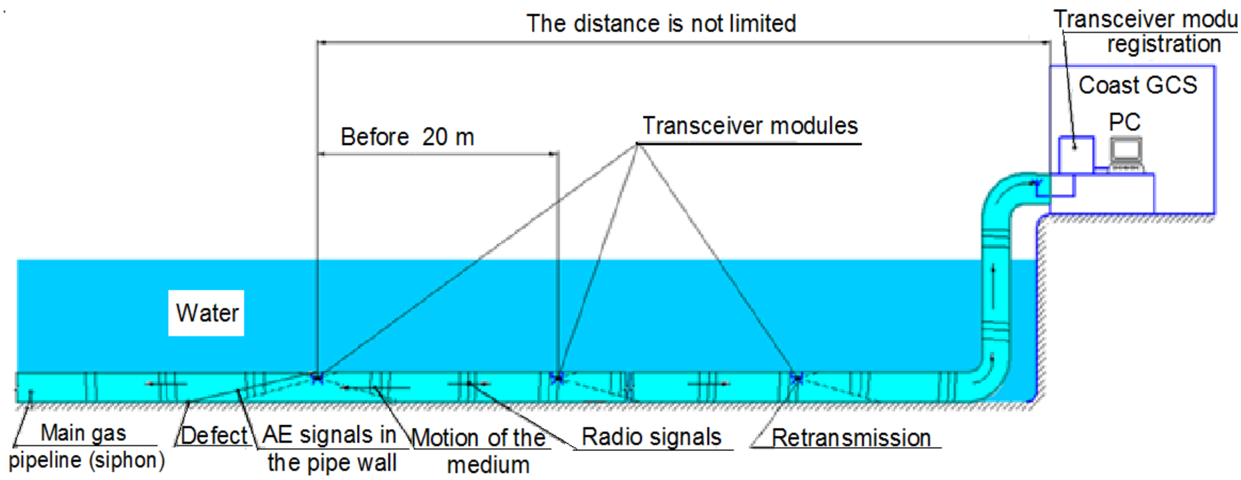

Figure 1. The general scheme of remote detection of defects in dug-in areas gas main AE wirelessly using a self-organizing radio network.

In the gas-pumping station signals are processed by the receiving-recording module and subjected to automatic analysis on computer with a special program. In addition to the basic parameters (amplitude and frequency of the acoustic emission) the following factors must be considered:

- a radio frequency on which the signal is received (the identification numbers for the receiving and transmitting unit, i.e. defective portion of the pipeline);
- a constant gain AE sensors at receiving signals from the metal and the relay (for adjusting the amplitude of the acoustic emission).

2. The principle of the reception, conversion and transmission of AE signals on the air

The generator of radio frequency carrier at its output produces uniform frequency signals for the individual sensor. These signals are sent to the first input of the comparator. If the second comparator input signal is absent then its output voltage is zero. If AE signal gets on the piezoceramic plate of the sensor, it converts into electricity and enhanced pre-amplifier. Then comparator overlays vibrations received at its inputs. As a result of lower audio frequency modulates a higher radio frequency, and the output of the comparator formed by a radio frequency signal, the contours of which are defined frequency and amplitude of the audio signal. This signal is amplified and intermediate broadband power amplifiers and a transmit antenna gets into the air (figure 2).

3. Retransmission of signals from other modules

A radio signal received from a neighboring module by the receiving antenna connected between the intermediate and output amplifier stages, amplifies the output amplifier and also via the transmitting antenna gets into the air.

4. Signal processing by receiving and registering module

The signal received by antenna amplified and gets to the input of the modulator and the first digital frequency. Frequency defines the value of the radio frequency carrier signal and delivers that information to a computer for identification numbers of the transmitting-receiving module, which received the signal.

The modulator builds envelope of a radio signal that is reshapes the AE signal. This signal gets into an analog-digital converter and a second digital amplitude frequency. ADC and a second frequency supplied to the computer data on the parameters of AE signal. As a result, computer generates information block comprising:

- the frequency of the individual modules, which adopted the AE signal;

- signal amplitude AE;
- the frequency of the AE signal.

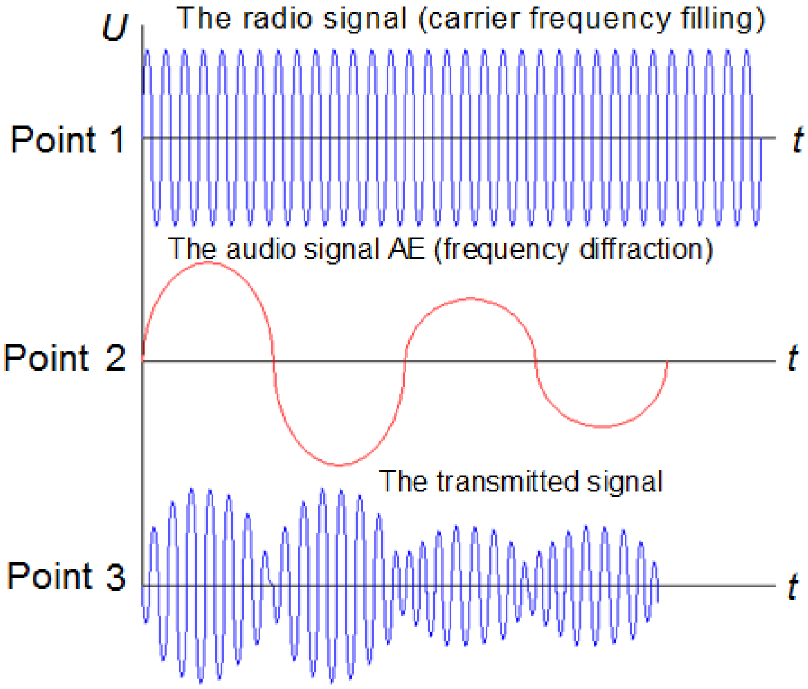

Figure 2. The principle of the reception, conversion and transmission of broadcast signal AE.

The amplitude of the signal shows the activity of the AE source (by comparison with the amplitude of the test signal, simulating a defect), and the frequency and intensity following the AE signals - about the nature of power: a continuous signal is low (less than 20 kHz) frequency - Through-flow; individual clicks on a frequency of 200 ÷ 500 kHz - structural transformation of the metal, accompanying the development of fatigue defect.

The location of AE source is determined by the number and position of receiving and transmitting unit, which accounts for the extreme value of the amplitude of the AE signals. The number and position of the unit is also automatically determined by the value of the radio frequency carrier, for which the computer must be clearly card is loaded pipeline, as well as a table of individual values of RF modules.

5. Transceiver modules and their installation

Purpose of the transceiver module is receiving AE signals from the metal of the pipe, converting them into VHF signals and sending into the air to transfer to the shore via GPS hoc network.

Requirements:

- Each of the modules should have its own radio frequency carrier indicated in the passport, as well as an individual serial number. Approximate position (geographic coordinates), number and frequency of each module during installation and downhill area in the waters have to be applied to the scheme of the pipeline;
- Distance of the effective action of typical piezoelectric RT metal excluding waveguide effect considered no more than 5 m;
- The range of the effective action of the transmitting device must be at least 100 m basing on the fact that the failure of any module would not let self-organizing of radio network (sending GPS signals to other modules);
- The power supply module should be self-contained;

- Construction of receiving and transmitting modules should not create obstacles to the passage in the places of their installation of flaw detection and cleaning projectiles.

The basis (basic instrument) is a standard module "RealEstate 4040R", presented in Figure 8; it has the following main characteristics:

- Pre-amplification factor of AE signals before transmission to air 40 dB;
- The range of the carrier radio frequencies from 30 MHz to 3 GHz;
- Distance of the effective operation of the transmitting apparatus 100 m;
- Stand-alone power supply 3V (two AA alkaline household batteries voltage 1.5 V).

The fully assembled modules go to the installation site.

Installing modules on the dug-in areas made directly before docking pipes in the trench with the installation of APM on the top of the forming inner surface of the pipe wall. Installing modules on the bottom pipe made before docking the ship-handler also preferred setting APM on top of the forming inner surface of the pipe wall.

Case of the MRP sets along the tube axis with the orientation of the front grille of the wind power generator towards to the gas flow. The side edges of the case attached to the metal tube near the corners of welding case cathetus length of 5 mm to 30 ÷ 40 mm. Tips and antennas grab the pipe. Burn-through housing, antenna tips and the pipe wall aren't allowed.

The disadvantage of the system is that the installation of the sensors can be realized only at the stage of construction of the facility, and to exclude the possibility of subsequent prevention.

This limitation does not diminish the relevance of the topic: for example, such a system could equip the Russian section of the bottom pipeline "Turkish Stream", whose length is 910 km from Anapa's Black Sea coast. If the AE signal occurs at this site, tower coastal gas-pumping station (station "Russian") will be informed about it in less than a second.

Thus, a new method of diagnosis gas pipeline by the method of acoustic emission is created. Using a self-organizing wireless network that significantly reduces the time spent on extended scan of the object, does not require stripping of metal and will not yield on the reliability of the existing control of other existing methods, also is one of the most promising Diagnostics of pipelines, which can prevent accidents and reduce their consequences.

References

[1] VSN 012-88 2007 *Construction of Main and Field Pipelines. Quality Control and Acceptance of Work* (Moscow)
[2] STO Gazprom 2-2.4-083-2006 2006 *Instructions nondestructive quality control of welded joints in the construction and repair of commercial and main gas pipelines* (Moscow: LTD "IRC Gazprom")
[3] Kondo K *and* Takada J 1991 *Proc. of Int. Conf. on Motion and Powertransmissions* (Hiroshima: JSME) **2E2** 763–768
[4] Scruby C B 1987 *J. Phys.E: Sci.Instrum.* **20** 946–953
[5] Scruby C B 1985 *Nondestructive Testing* **8**
[6] William B *and* Jolly D 1970 *Materials evaluation* **28 (6)** 135–144
[7] Guo D *and* Mai A 1998 *Review of Progress in Quantitative Nondestructive Evaluation* **17** 485–492