Acoustic Emission Leak Detection on a Technological Pipeline

Otkrivanje propuštanja na tehnološkom cjevovodu uz pomoć akustične emisije

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Summary

Leak detection is one of the main tasks of pipeline inspection, as the extension of pipelines usually requires a pipeline repair capability. Reliable and fast detection of fluid leaks in pipelines is extremely important for seaports, where their branched system is located. The most frequent locations of pipeline leakages are seam weldings and flanged joints, which are most exposed to plastic deformation. The aim of this study was to detect leaks in a technological pipeline connecting two vertical bitumen storage tanks. Based on the spectral analysis of acoustic emission signals (AE), a characteristic picture of the pipeline micro-damage process course (leakage, delamination, cracking, rupture, etc.) was obtained.

KEY WORDS

acoustic emission (AE)
acoustic signal
technological pipeline
defect existence
control method and control process

Sažetak

Otkrivanje propuštanja jedno je od osnovnih zadaća pregleda cjevovoda, jer duljina cjevovoda obično zahtijeva mogućnost popravka istoga. Pouzdano i brzo otkrivanje propuštanja tekućine u cjevovodima iznimno je značajno za morske luke gdje se nalaze njihovi razgranati sustavi. Najčešće lokacije propuštanja cjevovoda su zavareni rubovi i spojevi s prirubnicama. Cilj ovoga rada bio je otkriti propuštanja na tehnološkom cjevovodu koji spaja dva okomita spremnika za bitumen. Na temelju spektralne analize signala akustične emisije (AE), dobivena je karakteristična slika tijeka nastanaka mikro oštećenja na cjevovodu (propuštanje, delaminacija, pukotine, puknuća, i sl.).

KLJUČNE RIJEČI

akustična emisija (AE)
akustični signal
tehnološki cjevovod
postojanje oštećenja
metoda kontrole i proces kontrole

1. INTRODUCTION / *Uvod*

The pipeline is one of the potential objects for which the acoustic emission method can best be used to detect the existence or probability of a defect emergency [4]. Pipelines are distinguished according to the type of transported substance (liquids, gases, mixtures), diameter, coatings, location (underground (open), underground, under water). The application of this method is especially relevant for quickly searching for defects in hidden pipelines located in the territory of ports, in the immediate vicinity of the sea coast. The mentioned pipelines are intended for the transportation of goods (oil products and other liquid substances) to the place of loading or unloading, and leaks should not threaten the pollution of the port area and the environment.

The most effective application of the acoustic emission (AE) method is possible in the inspection of metal pipelines with a low specific attenuation coefficient of acoustic signals [4, 2]. If the pipeline has insulation, acoustic waveguides are used for the application of AE, which extend to the surface of the insulation and have continuous acoustic contact with the surface of the pipeline [5, 8]. When inspecting open, relatively short pipelines, it is most advantageous to use portable (displaceable) equipment. This can be explained by the fact that if the overall probability of leakage in small sections of the pipeline is high, the probability of a defect in several places is low, which makes the installation of a large number of piezoelectric transducers (PT) economically impractical. In this case, it is best to direct the measurement point of the acoustic signal in the direction of the leak, which leads to a quick detection of the leak location [3, 6, 7].

The investigations according to the method of acoustic emission (AE) were carried out with portable devices "IKU-1" and "PAC Pocket AE -2". The detection and localization of leaks with these devices was carried out as follows:

- The piezoelectric transducer (remote block) is installed on the free insulation pipeline section;
- a change in the parameters of the signal from the installed PP indicates a defect existence or a source of acoustic interference in the frequency range of the device;
- the leak location is determined manually by recording the power of the acoustic signal during the sequential discrete transmission of the PP. fleeting through a leak or defect, the acoustic signal power increases. A diagram of the bitumen storage installation with measurement indicator, showing the acoustic signal on the technological pipeline, is shown in Fig. 1

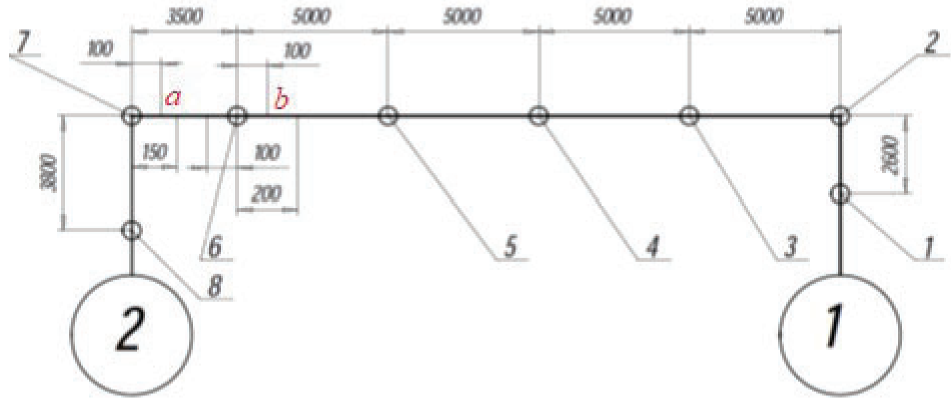

Figure 1 Diagram of the cross location of the main and additional points of AE control (top view)
Slika 1. Dijagram s poprečnim presjekom lokacije glavne i dodatnih točaka AE kontrole (pogled odozgo)

When locating a leak with a single or dual channel device, the attenuation of the acoustic signal from the pipeline is used. The X_T coordinate of the leak can be determined by the following formula (1):

$$X_T = \frac{1}{2}\left(1 - \frac{\upsilon}{V}\right) l_{ab} - \frac{1}{2\alpha} l_g \left(\frac{Ua}{U_b}\right) \quad (1)$$

where a,b – are points on the diagram (see Fig. 1) where PP are installed on the pipeline (the leakage is found between them);
lab – is the distance between PP installation points, m;
α – is the attenuation coefficient of acoustic signals in the pipeline material;
Ua, Ub – average rectified values of the signal voltages at the output of the PP, placed respectively at points a, b,;
V – acoustic signals propagation velocity in the pipeline material, m / s;
υ – fluid flow velocity in pipeline, m / s;

Location errors and leakage sensitivity are significantly affected by such structural elements as stopcocks, flanged connectors, embranchments, baffles, diaphragms, etc. This is because these constructive components cause the following influencing factors:

- locally weaken the signal;
- connections are the most likely locations for leakage;
- internal inhomogeneities are sources of acoustic noise in the process of the operating substance flow around them.

According to [5, 9], in order to find the leakage of the pipeline with the help of the PP, which makes a reciprocal acoustic contact with the pipeline, it is necessary to supply liquid or gas under excessive pressure. It is recommended at preselected and prepared points of the pipeline, successively measure the level of the acoustic signal and compare their value. The higher the power of the recorded acoustic signal, the closer the PCB installation point is located to the defect (leak).

2. OBJECT ORIENTED TESTING / *Objektno orijentirano testiranje*

The purpose of the investigation was to determine the presence of a defect in the technological pipeline connecting two vertical bitumen storage tanks. The test object represents a system consisting of two steel pipelines coaxial with each other and connecting two cylindrical tanks, the total length of which is 30 m. (see Fig. 1)

Hot oil 1 is supplied through the outer pipeline 2, which heats the outside of the inner pipeline 4, heating the liquid bitumen 5 to reduce its viscosity. Inside the outer pipeline, the inner pipeline with spacers (stiffeners) 3 is centred (see Fig. 2).

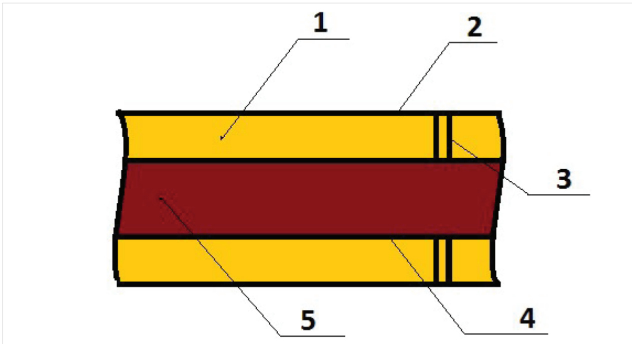

Figure 2 A fragment of the pipeline: 1 - hot oil, 2 - external pipeline, 3 - centring devices, 4 - internal pipeline, 5 - liquid bitumen
Slika 2. Dio cjevovoda: 1 – vruće ulje, 2- vanjski cjevovod, 2 – uređaji za centriranje, 4 – unutrašnji cjevovod, 5 – tekući bitumen

3. AE METHOD INVESTIGATION AND DETECTION PROCEDURE / *Postupak istraživanja i otkrivanja ae metodom*

During operation, a thermo fluid leak of hot oil into bitumen was discovered due to a defect in the internal pipeline. Since the leakage is in the internal pipeline, it is not possible to detect it by the use of all available methods. Therefore, the method of acoustic emission (AE) was the best option used to detect and locate the inspected defect. To solve this problem, instead of hot oil, compressed air at a pressure of 6 atm was supplied to the outer pipe with the help of a compressor. On the external pipeline, the locations of the sensors were cleaned for carrying out the AE study. In the course of the study, the AE activity was measured with the devices "IKU-1" and "PAC Pocket AE -2", using the method of sequential analysis of AE information from each point where the PP sensors were installed.

4. AE METHOD RESEARCH RESULTS / *Rezultati istraživanja AE metode*

With the help of the "IKU-1" device, the AE activity was measured in sequence at each of the pre-designated eight main control points when the pressure in the external pipeline reached 6 atm. (see fig. 1) Using the "IKU-1" device, the activity of AE was measured sequentially at each of the eight pre-determined main control points when the pressure in the external pipeline reached 6 atm. (see Fig. 1)

For an approximate determination of the defect location zone, the activity values of AE are divided into two groups (points 1,2,3,4) and (points 5,6,7,8). In this case, the AE activity values for each group are summed up separately for each group. A diagram is presented in which the length of the controlled pipeline is placed on the X-axis and the sum of the AE activities of the group of points excluding that point is positioned from the extreme points on the Y-axis, with one of the values located with the opposite sign. The intersection of the graph with the OX axis indicates the approximate location of the defect zone. Then the process is repeated for the intercepts from point 2 to point 7. The results of processing the activity values are shown in Figure 3.

To determine the expected location of the defect more precisely, additional control points were cleared and measurements were taken after preliminary calculations (points a and b, see Fig.1).

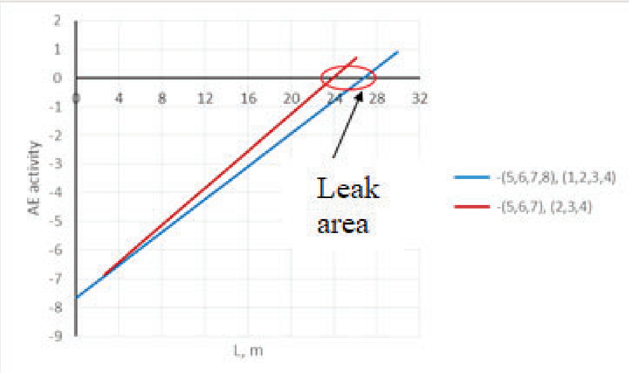

Figure 3 Diagram for determining the defect location

Slika 3. Dijagram određivanja lokacije oštećenja

AE activity was monitored by using simultaneously two devices (IKU-1; PAC Pocket AE -2). According to the AE signals data (device IKU-1), the spectral analysis and the maximum values of the amplitude AE (PAC device Pocket AE -2) the signal spectrum corresponds to the leakage spectrum (see Fig. 4, 5).

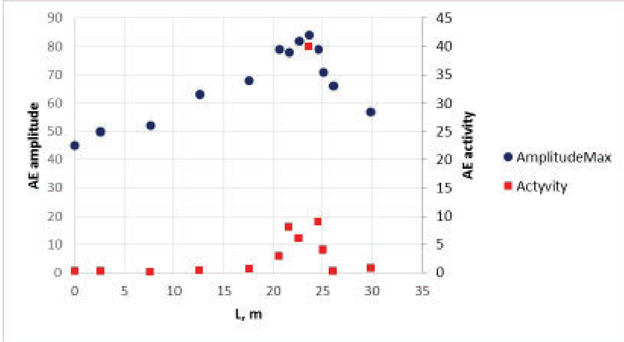

Figure 4 Diagram of the distribution of the maximum values of the amplitude of AE signals and AE activity along the length of the pipeline

Slika 4. Dijagram distribucije maksimalnih vrijednosti amplitude AE signala i AE aktivnosti cijelom dužinom cjevovoda

The results of the investigation indicated that within the permissible pressures such flow regimes are formed where the generation of acoustic side signals (noise due to turbulence) is likely to take place. The section of the pipeline where the defect is located generates a high acoustic resistance. After analysing the circuit and measurement results, it was supposed that the most suitable points between which the pipeline defect and leakage are located are points between 5, 6, 7.

The test pressure in the pipeline was generated with an additional pump; the measurements were performed with an ICU-1 device. The level of acoustic noise (background) measured at point 5 was 0.56 mV. The results of the measurements of the levels of acoustic signals at points 5, 6, 7 with alternate pressurization of the pipeline showed that the highest level is observed at point 6 and ... The location of the defect and leakage is closer to point 6 than to points 5 and 7. The distance from point 6 to the pipeline defect and leakage was approximately determined by formula (2) with the following parameter values:

$$l_T = 0{,}5 l_{6-7} - \frac{1}{2_\alpha} l_n \left(\frac{U_6}{U_7} \right) \qquad (2)$$

where: lT=0,5 м

l6–7 = 3,5 м – length of the pipeline between points 6 and 7;

α = – acoustic signals coefficient of attenuation;

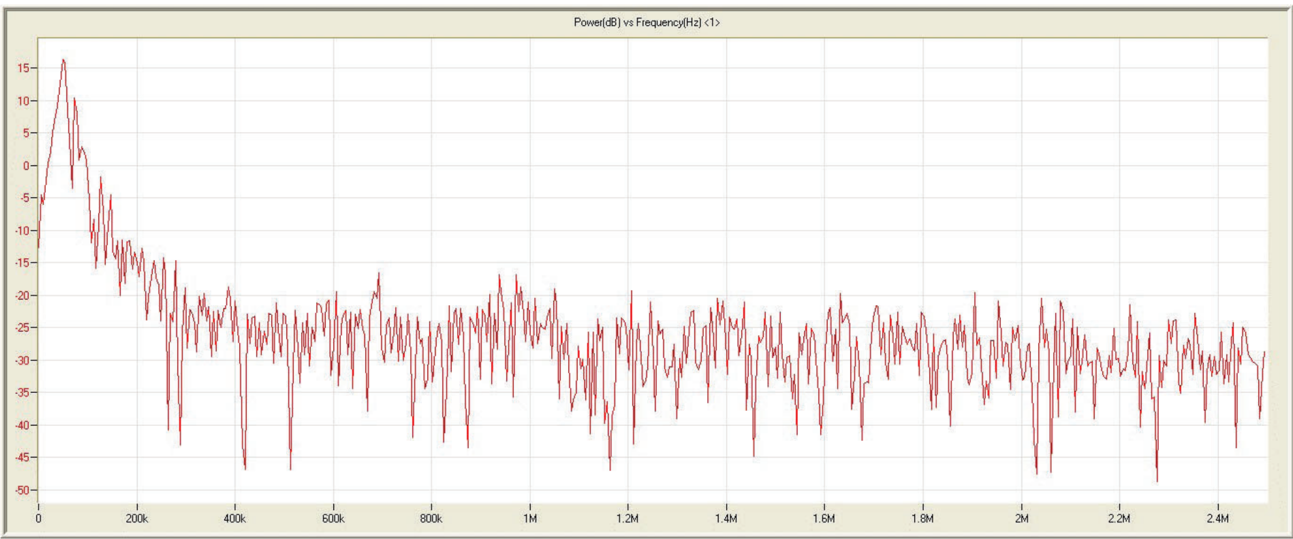

Figure 5 AE signal spectrum sample

Slika 5. Uzorak spektra AE signala

U6 = , U7 = – are the rectified average values of the acoustic signal voltages at points 6, 7, respectively.

After the pipeline dismantling, it was found that the actual distance was lT 1 m. Thus, the relative errors in determining the linear coordinate were 19% for the first dimension and 26% for the second. The low location accuracy is due to the complex dependence of the attenuation coefficient of ultrasound on the length of the pipeline.

5. CONCLUSIONS / *Zaključci*

1. Based on preliminary measurements, the pipeline section of the probable location of the defect was determined.
2. According to the AE control data, a more precise area of the defect location was determined: at a distance of one metre from point 6 in the direction of point 7.
3. According to the spectral analysis data, the defect corresponds to the leakage spectrum; according to the results of the outer pipe opening; it represents the type of a crack (see Fig. 6).
4. The AE method application led to the identification of a defective pipeline and the approximate location of the leakage in 5 hours instead of 14 ... 20 days.

Figure 6 Photo of a fragment of the inner pipe in the defect zone, the location of which was determined by the AE method
Slika 6. Fotografija dijela unutrašnje cijevi u oštećenoj zoni, čija lokacija je otkrivena AE metodom

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