New areas of application of acoustic emission method

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Abstract
Acoustic emission laboratory at the Institute of Machine and Industrial Design of Brno University of Technology is long focused on the use of acoustic emission testing (AT) for diagnostics of damage development in cyclically loaded materials and machine parts. In addition to these relatively traditional applications already however this laboratory workers devote other non-traditional possibilities of using acoustic emission method. In this paper there are presented the first interim results of the project, which is focused on applications of AT in function diagnostic of pneumatic devices. There are compared the signals obtained from the fully functional pneumatic cylinders with signals from cylinders with various types of artificially created damage. The second part briefly presents the first results of the acoustic emission application in other very non-traditional areas. The attention is paid to the usability of AT for identification and localisation of undesirable discharges in gas-insulated conductors for high-voltage substations and for increasing of accuracy and objectivity of the tests for sensitiveness determination of explosives to friction.

Keywords: Acoustic emission, non-destructive testing, pneumatic cylinder, gas-insulated conductors, explosives

1. Introduction

Acoustic emission method (AE) passes through the very rapid development especially in the field of instrumentation. Modern analysers enable highly sophisticated scanning of signals on the surface of the tested bodies. Somewhat worse situation is in the exact identification of sources of acoustic emission signal. Nevertheless, the AT method has been routinely used for the diagnosis of pressure vessels, storage tanks, pipelines and power equipment. Reasons are of course quite specific characteristics of AE method that is able to identify and locate the presence of active defects which can be relatively easily found and verified by other NDT methods in this case.

2. Pneumatic cylinders

The first research of use of AE as a method for defects detection in pneumatic circuits starts by research of Dickey, Dimmick and Moore [1]. In their paper is described relation between amplitude of AE signal and rate of gas leak in valve. Research in the paper [2] is focused on noise measurement of gas valve. Results of this research describe correlation between signal of acoustic emission and leakage rate in frequency domain. In those papers was just performed potential of acoustic emission as a non-destructive method for pneumatic industry with no particular results connected to development of specific methodology of measurement.

AE as a method of NDT for pneumatic industry have been developed during last decades. Main purpose of this method is to analyse and gas leakage on a specific parts of the system such is pneumatic pistons and cylinders. In the paper [3] is described utilization of AE for diagnostic pneumatic systems of power plants. In this study measurement of leakage defects in pneumatic systems was undertaken by three methods like AE, noise measurement and vibro-diagnostic. Comparison of signals from each measurement proofed that results obtained by AE fully describe defect on testing specimen. In other studies like the papers [4] or [5] was measured by AE used for detection of leakage in valves with aim of development a universal method for description of leakage defects. In the paper [4] was performed research of influence of leakage rate (from a defect) on RMS value of the AE signal. This measurement was provided by sensors of AE. An effect of various internal pressures on a signal of AE was tested as well. The results of the research proof that RMS of AE signal rise with higher leaking rate as well as with higher internal pressure.

In the study [5] was aim to analyse the signal of internal leaking of valves so that their rate could be calculated by analytical method. Effect of different sizes of valves on a signal of AE was tested and the amplitude of the signal was determined from the signal. Analysis of the obtained signal was performed by Fourier transformation. Moreover, in this study was suggested procedure for creation of methodology of determining leakage rate from the signal of AE. This procedure contains parameters as size and type of valve and internal pressure. By applying those parameters on analytical processing of the AE signal the leakage rate should be obtained.

However experiments in papers were undertaken in laboratories and under specific conditions. Therefore, particular tool for detection of leakage of pneumatic circuits have not been developed.

The AE laboratory at the Institute of Machine and Industrial Design of Brno University of Technology has long focused on the use of AE for diagnostics of damage development in cyclically loaded materials and machine parts (standard fatigue, contact fatigue, bearings etc.). In addition to these relatively traditional applications already however this laboratory specialists devote other non-traditional possibilities of using acoustic emission method [6, 7, and 8].

2.1 Experimental procedure

The research of AE as a method of non-destructive testing for parts of pneumatic circuit is undertaken at Brno University of Technology, Institute of Machine and Industrial Design. This research is focused concretely on pneumatic cylinders as a project in cooperation with company Policske strojirny a.s. The aim of this research is to develop system for non-destructive damage detection of specific types of pneumatic cylinders by use of AE.

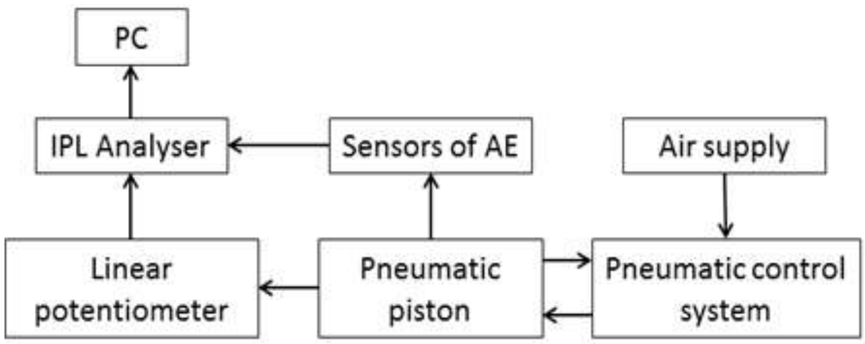


Figure 1. Schema of the experimental stand for testing of pneumatic cylinders

An experimental stand was created for simulation of pistons behaviour in operation. For analysis of cylinder's damage during operation a measuring chain was created. This chain usually comprises three or four sensors of AE, linear potentiometer and 4-chanel IPL analyser. A system DAKEL was used for signal processing and post-processing. During the experiment pneumatic cylinders were operated by pneumatic control system. A schema of the experimental stand is shown in Fig. 1.

Firstly cylinders without damage were used for experimental measurement to obtain signal of AE which correspond to proper operation of cylinders. After that, defects on each cylinder were created. There were 14 cylinders, each with different kind of a defect. During operating cylinders were measured also by sensors of AE in aim to analyse which defect is possible detect by signal AE. Sensors were placed into three positions on the piston's body to find the best position for signal detection. Linear potentiometer was used for measuring of the position of the cylinders (Fig. 2).

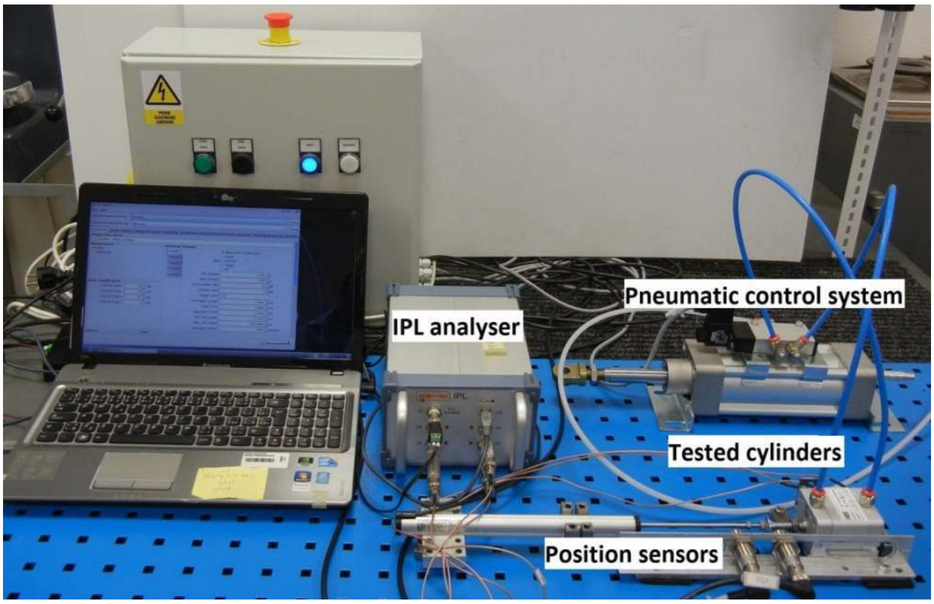


Figure 2. Assembly of experimental equipment

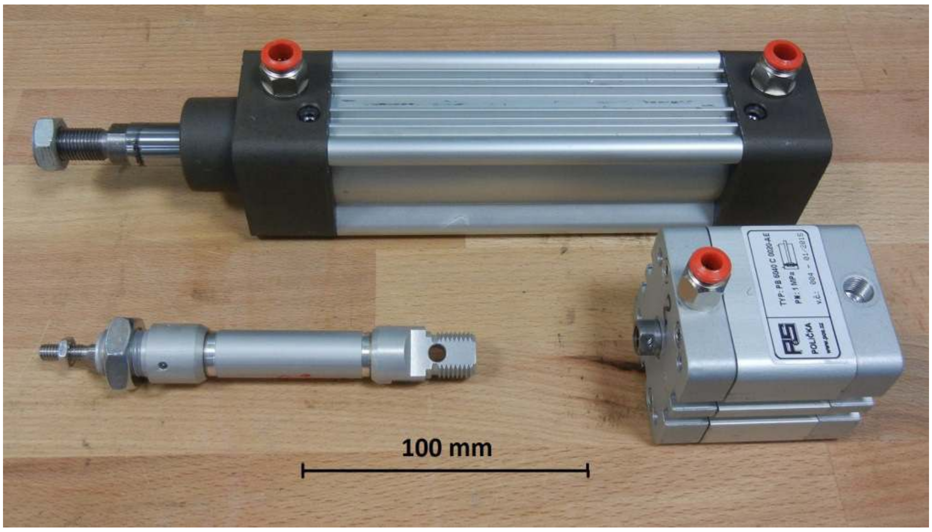
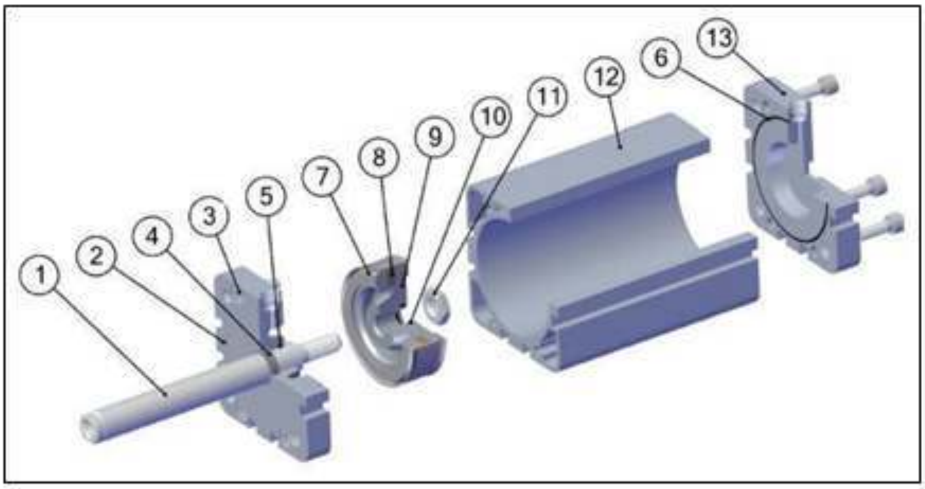


Figure 3. Types of tested pneumatic cylinders

2.2 Experimental results

For data analysis was the most effective method spectral analysis. By this method was possible to identify particular frequencies and distinguish signals from cylinders with damage and without. Envelope method was also used for signal analysis but this method was not as accurate as spectral analysis. Further presented results were obtained on the cylinders PB 6040C (producer Policske strojirny). Structure of cylinders is shown in Fig. 4.



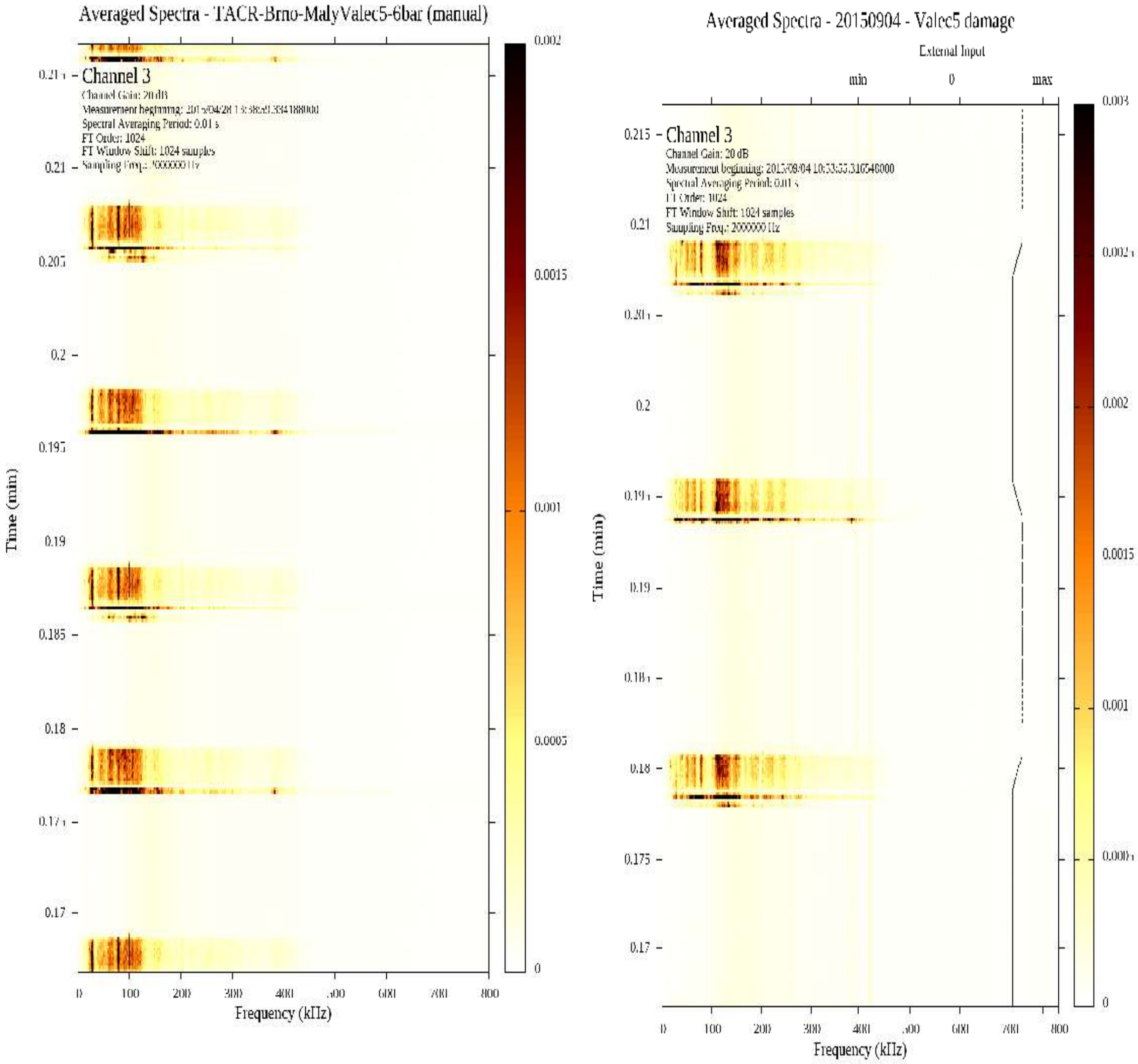
1	Piston rod	6	O-ring	11	Nut
2	Front cover	7	Piston sealing	12	Cylinder body – tube
3	Bolt	8	Magnet	13	Back cover
4	Sealing of the piston rod	9	Piston		
5	Rod conductor	10	O-ring		

Figure 4. Scheme of the pneumatic cylinder PB 6040C

The range of measuring frequencies of the signal is naturally set by AE sensors and its size is approximately from 50 kHz to 400 kHz. According to damage of cylinders some dominant frequencies were lost or some were gained in the AE signal.

Figure 5 shows the record of one AE sensor placed in the middle of cylinder's body which has no defect. From the graph is visible that AE sensor detects signal only if the position is in ejected mode. Cylinders were operated with frequency 1Hz. Each event is characteristic by it's dominant frequencies which are repeatable in range from 20 to 150 kHz. This measurement was repeated for other 14 pistons of the same type and results of AE signals were same.

As following, measurement for cylinder with defect was undertaken. For this measurement was used same cylinder as before but with created defect. In particular O-ring on position 10 had been cracked (Fig. 4). Moreover linear potentiometer was used to measure position of the piston rod during operating. Results plotted in Fig. 5 show that signal events occur when piston goes from one position to another. Signal from potentiometer is plotted on the right side of the graph in Fig. 5 and symbolize movement of the cylinder. Defect created on piston cause move of range of dominant frequencies to higher magnitudes. Those frequencies have also repeatable characteristic for each movement of the piston like in Fig. 5 where are pictured 3 operational circles of the piston.



a) b)

Figure 5. Spectral analysis in particular time - differences between signal spectrums obtained from signals of pistons without defect (a) and with defect (b).

In order to highlight differences between signals spectrums obtained from signals of pistons without defect and with defect (Fig. 5) the spectral analysis in particular time were plotted. From results on graphs in Fig. 6 and Fig. 7 is visible the difference caused by defect created on the cylinder. Domain frequencies were moved from area under 100 kHz to area above 100 kHz.

2.3 Conclusion

In this part of our paper were presented results of testing pneumatic cylinders by acoustic emission. By this method was verified that cylinder of same type have same characteristic of AE signal during operating and this can be used as a pattern for a comparison of signals from defected cylinders. The evaluation of the influence of different types of cylinders disturbances on the nature of signal changes is currently underway.

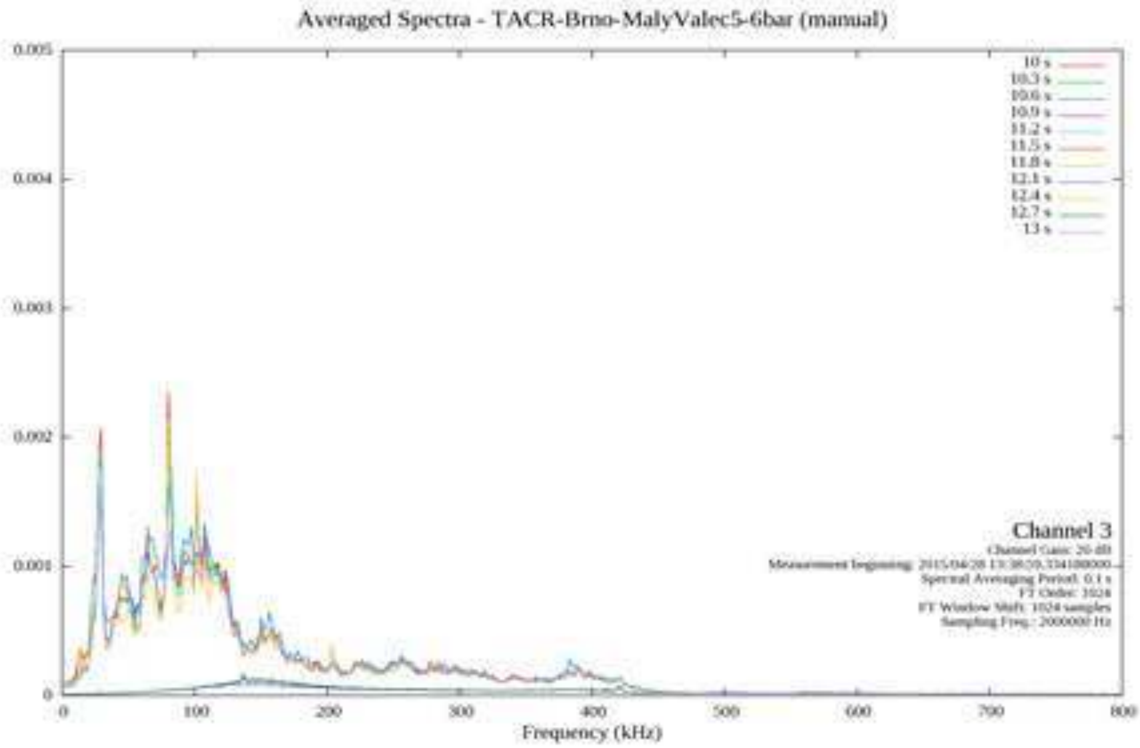


Figure 6. Signal spectrums from piston without defect

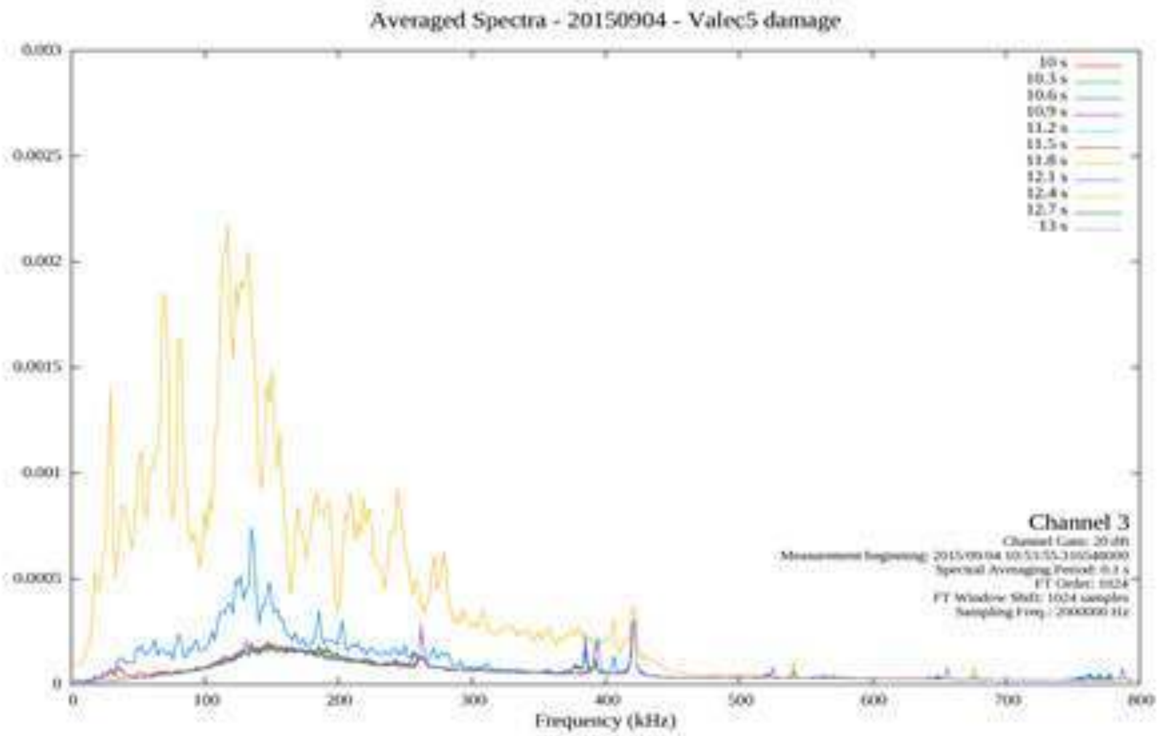


Figure 7 Signal spectrums from piston with defect

3. Breakdown of gas insulated lines of very high voltage

The main objective of this new area of researches in our laboratory was the measurement of the output during the tests to determine whether it is possible to use AE for detection of the partial discharges occurring in increasing voltages up to 650 kV in the entire system of gas insulated lines. Undesirable electrical discharges occur within the conduits on various impurities or bumps on the surface in this case. The output control is done on the assembly of several connected parts. In the event of a discharge it is necessary to disassemble the entire unit and all parts must be inspected. To accelerate repairs would be very useful to identify the faulty component and locate the place of discharge.

3.1 Experimental results

Several sensors were placed onto surface of power line and signal during operating was obtained. The measurement was provided by system DAKEL-XEDO, which is used for analysis of signal AE and digital record of signals.

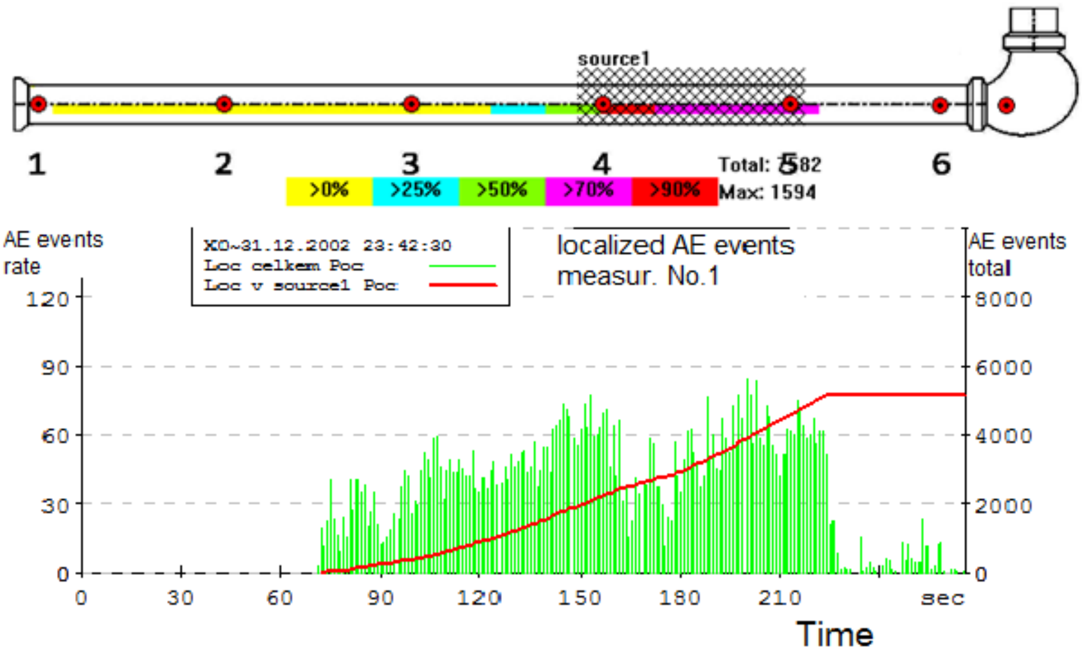


Figure 8. Demo of location map (top) and time curves of AE localized events (bottom) at output test no.1.

Measurements showed that by using more AE sensors fitted to the surface of power line is possible accurately localize position of breakdown. Due to the testing of a long pipe (about 10 m) in which the AE registered discharge was carried out localization of discharge. Repeated measurements showed formation of discharge between the transducers Nos. 4 and 5. Measurements were not successful between parts mutually insulated. This result, however, is useful for reliable determination of defective parts in the whole assembly.

3. 2 Conclusions

a) Acoustic emission method can be used for basic identification of metal parts of EHV lines in which occurs partial discharges,
b) When using multiple sensors on components it is possible to locate the place of the discharge,

c) Eventual discharges into supporting insulators were not been registered at the current setup of the AE system. The cause is probably an effective damping material of these insulators. On the other side this feature increases the reliability of discharges identification in other parts.

4. Tests of resistance of explosives to friction

We also received a very specific requirement to verify the possibility of evaluating the resistance to friction of explosives. These tests are carried out according to EN 13631-3 - Explosives for civil uses - Part 3: Determination of sensitiveness to friction of explosives. The test is conducted on a simple device in which the explosive is placed on the ceramic plate (Fig. 9). Tested explosive is placed into a porcelain plate with a roughened surface with grooves. Standard evaluation is done only sensually and is largely dependent on the experience of the test engineer. The aim of the project was to verify the possibility of an objective evaluation of these tests using AE method.

4.1 Experimental results

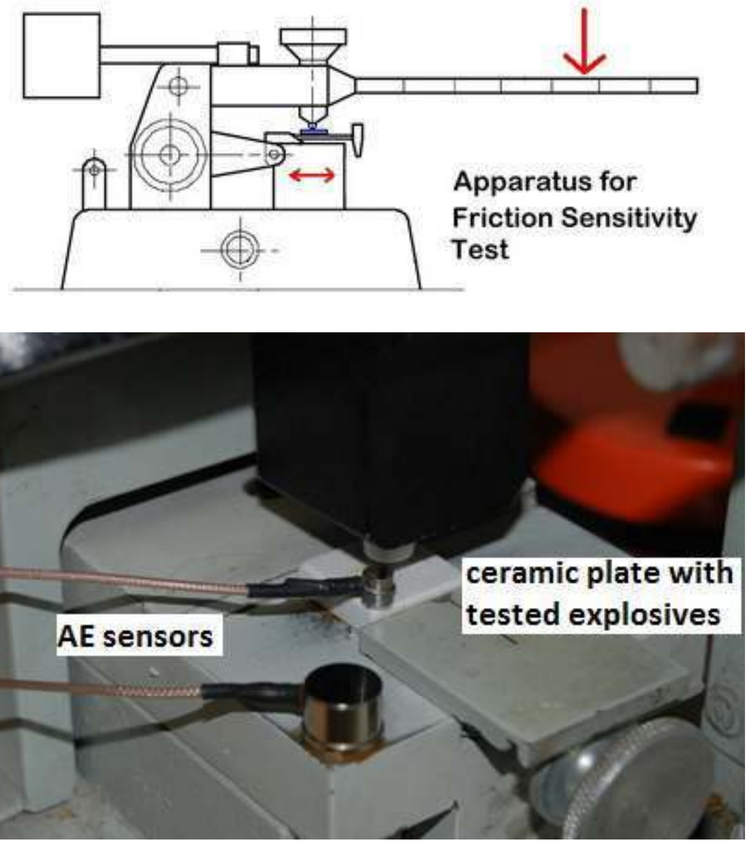


Figure 9. Scheme of the test equipment and detail of the location of AE sensors

AE sensors were placed directly on a porcelain plate and on the clamping plate of the testing machine. By comparing the individual emission events were observed differences in the nature of the signal, when an explosive responded compared to a negative result. During successful tests were detected oscillations of high amplitude and high frequency in the second part of the hit represents the retraction and higher signal amplitude at the beginning of the hit (see Fig. 10).

It was conducted only a limited number of tests and therefore it is necessary to validate that findings of experiments with an optimal setting of apparatus based on preliminary measurements and make a deeper analysis of the signal in the frequency and time-frequency domain. Overshoots will also be evaluated via the detection thresholds and distribution of signal energy. For practical use, it is necessary to find the optimal placement of sensors and resolve the problem with their fastening on the surface the test ceramic plate.

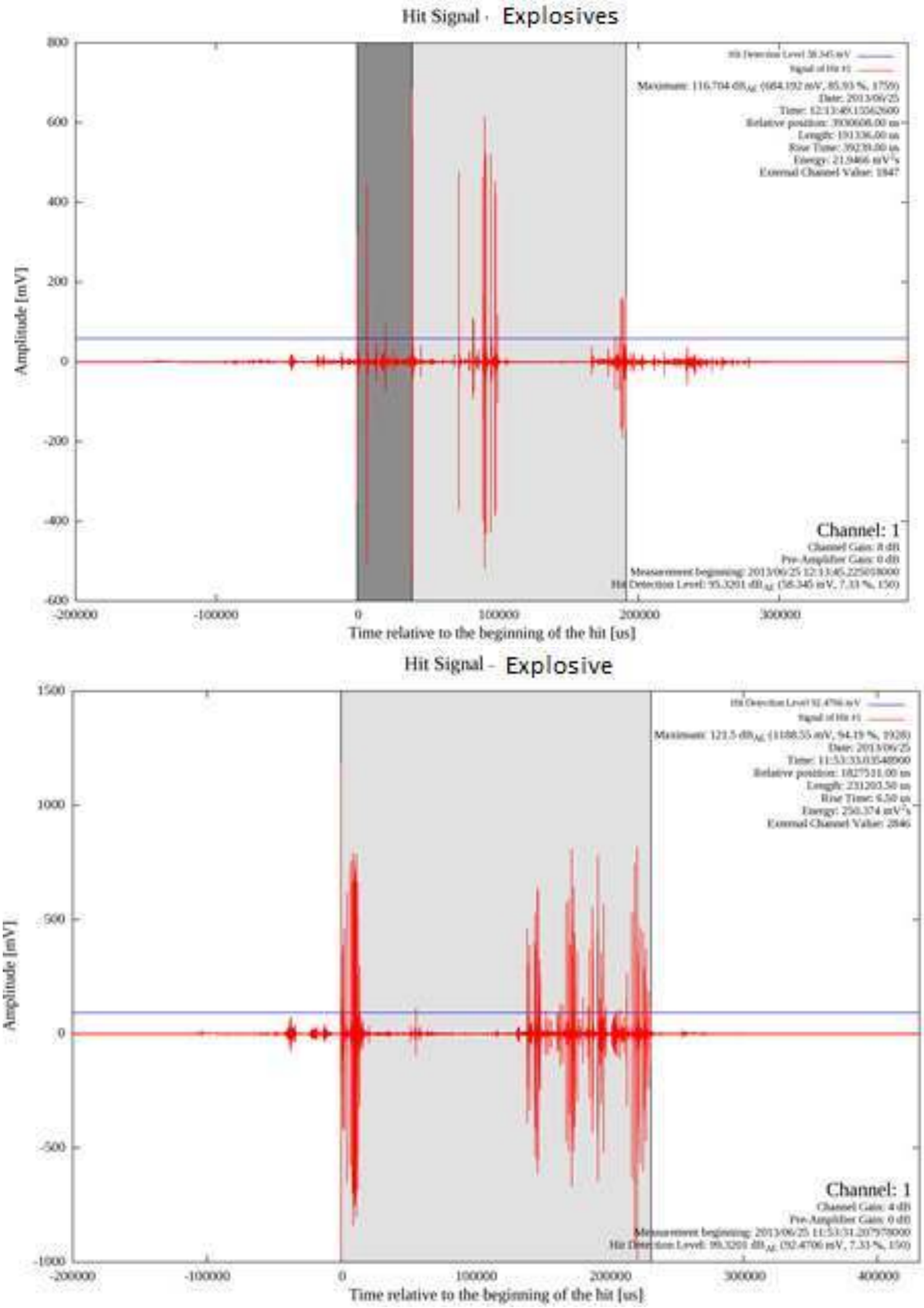


Figure10. Comparison of AE signal hits for not responding (above) and reacting explosives (below).

5. Conclusions

Acoustic emission method was used in three areas of non-standard technical diagnostics, which were made in the Laboratory of AE at FME BUT recently: a) applications of AE for function diagnostic of pneumatic devices, b) usability of AE for identification and localisation of undesirable discharges in gas-insulated conductors for high-voltage substations, c) tests for determination of sensitivity of explosives to friction. In connection with the actual solution of the project of TA CR, we will focus on identifying the area of development of damage of pneumatic cylinders. In collaboration with other workplaces will be developed the professional apparatus, which will be included in the final inspection at the manufacturer. Other developed instruments will be used for external diagnostics among users of pneumatic cylinders in the production lines and transportation facilities.

The presented results confirm the wide range of new industrial applications acoustic emission method. For the application in routine practice, the basic problem is the high sensitivity of the method and the need for suppression of disturbing signals. Certain problem is then also a need to ensure the long-term repeatability of the measurement conditions.

Acknowledgements

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