USING OF NON-DESTRUCTIVE TEST OF ACCOUSTIC EMISSION FOR PROLONGING THE OPERATION LIFE OF COMPOSITE PRESSURE CYLINDERS

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Review article

Abstract: Financial crisis in the years 2008 to 2013 had a negative effects also in a state administration, and as well in a purchase, renewing and services of technical means of fire protection. Under the terms of School educational and vocational establishment of the Fire and Rescue Service of the Czech republic (FRS CR), center in Frydek - Mistek, this condition was fully displayed at the FRS CR at the state of composite pressure cylinders (PCs), that are from the point of view of operation of the breathing apparatuses, and other technical means such as bags, sealing means, means for works on water, that are inevitable for their operability. In this article prolongation of an operation life of PCs is described, on the basis of supplementary nondestructive acoustic emission testing (AT), that is a part of hydraulic pressure test. In conclusion it is written the state of PCs after the operation life having been prolonged and before their final decommissioning.

Keywords: Non-destructive test, operation life, accoustic emission, elastic waves, pressure cylinder.

Introduction

28 PCs of various volumes were in operation for training in the field of chemical service up to July, 1st 2011, 23 were out of order due to the end of their operation life and only five of them were ready for use. There were not financial resources for the purchase of new PCs, but there was a possibility to prolong the operation life of PCs by a method of non-destructive test of acoustic emission at the Drager Safety company, Ostrava-Vitkovice Division. The company Dräger Safety carries out this type of tests on the basis of Certificate given by Technical Inspection of the Czech Republic and producers of PCs types of Luxfer and EFIC. Acoustic emission testing (AT) is one of the method of non-destructive tests and it can appropriately supplement the hydraulic pressure test by information about the condition of the PC material under load is and how it behaves during the test. Until the test was carried out the FRS of the Czech republic did not have any significant experience with the procedures of prolonging the operation life of these PCs.

Acoustic Emission

What is Acoustic Emission (AE) really? Process of cracking branches, stones or bones can be considered as the first touch of a man with the AE. Phenomenon of so called "cry of tin" (the first who noticed this phenomena was Joseph Kaiser and called it as "Zinngeschrei") is the first observation of AE in metal. It is an audible sound produced by a tin bar during a plastic deformation process such as bending. There are a lot of definitions of AE and I would like to use one of them that says that it is a phenomenon when there are generated transition elastic waves, for example during plastic deformation, spreading of a crack, erosion, corrosion, impacts or leak (*CSN EN 1330-9, 2009*).

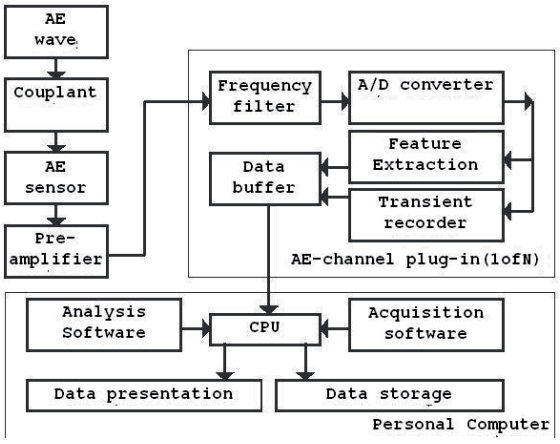

Fig. 1 Block chart of measuring device of AE (Mareš, 2010)

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The highest concentration of the acoustic emission is at the characteristic stress of the given material. It is a phenomenon when any material emits elastic stress waves when it is stressed and so it is in a certain way called noisy. This sound is mostly not audible for a human ear, it is put at a high frequency range. The waves are spreading in an object from the place of a source to the surface of the object. This perception is detected, most frequently with piezoelectric sensors, pre-strengthened, filtered off any noise, strengthened again and transformed into electric signal called emission signal. Then the signal is transformed into a graphic record by software, ***as it is shown in Fig. 1***.

According to the character of the recorded signal there are two recognized emissions: the continuous emission and the burst emission ***as it is shown in Fig. 2***. The signal of the continuous emission is such a time duration, that is not decreasing in a long period of time kunder the threshold, it is not possible to divide in time. Typical example for that is a leakage of medium under pressure. The burst emission shows the signal in particular, distinctively divided in time, packages of waves. The example of such a signal can be a formation of micro-cracks, their increase, initial point of the material tension or its reduction; and such a signal has a direct employment for the test of PF. (*Preditest s.r.o., 2011*)

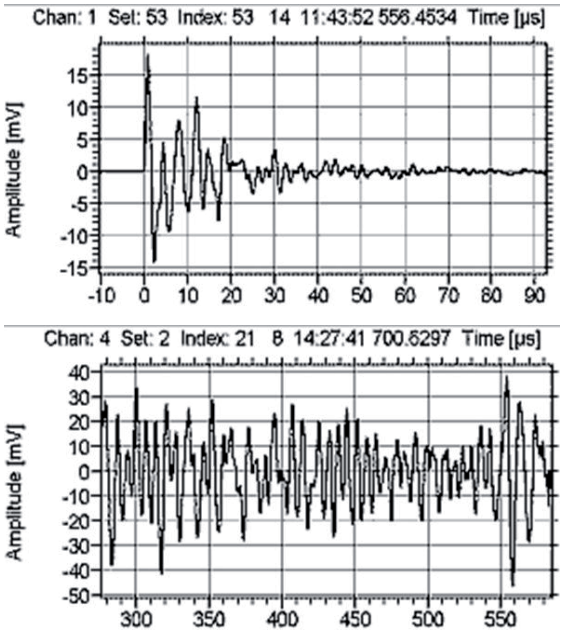

Fig. 2 Burst (left) and continuous (right) signals of AE (Hejný, 2007)

Characteristics and evaluation of burst AE

While processing of burst signal it is evaluated (*Mareš, 2010*), ***as it is shown in Fig. 3:***

- ***threshold*** - the level of where the initial point and ending point of each emission event is defined,
- ***frequency of burst signal*** - amount of AE events for the period of time,
- ***ring down count*** - amount of signals exceeding the trehshold,
- ***first threshold crossing***,
- ***peak amplitude*** (amplitude),
- ***signal duration*** - time difference between exceeding the first and the last signal,
- ***rise counts - number of counts needed to achieve peak amplitude***,
- ***rise time*** - is defined as a period of time from exceeding the treshold and peaking the amplitude,
- ***amplitude spectrum of the signal***,
- ***signal shape, energy of impulse***.

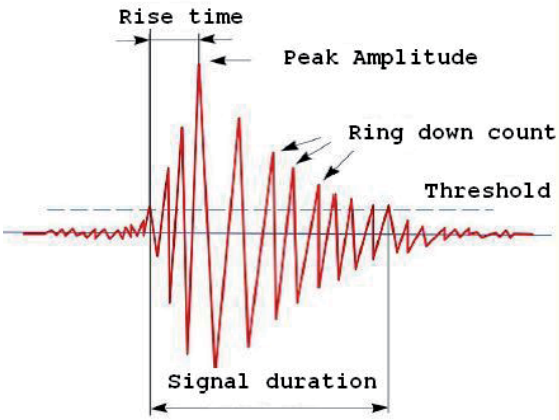

Fig. 3 Burst signal parameters AE (Preditest s.r.o., 2011)

Materials and methods

AE test procedure

The body of the PC consists of liner (metal - Al, or plastic - polyethylene), compact covering (carbon fibre) and outer covering (glass or carbon fibre). Resistance fibre unlike to liner, that is almost without any tension, brings most of the strength effecting to the liner from inside or outside. Therefore, the state and quality of resistance fibre is examining by each periodical pressure test of the body of the cylinder.

The test was carried out according to the Czech standards (*CSN EN ISO 11623, 2003*), (*CSN EN ISO 16148, 2007*).

Description of the test

- after the assessment of the condition of the PC (on the basis of mechanical a heat failure), disassembling of the cylinder valve and its checking, inside revision of the PC was carried out and a screw thread connection of the valve revision was carried out as well by a screw gauger.
- PC was put into the pressure box, ***as it is shown in Fig. 4***,

Fig. 4 Pressure box by Dräger Safety company

- two piezo electric sensors were put in cross by plasticine onto a cylindrical, cleaned surface of PC, ***as it shown in Fig. 5***,
- check of the signal transmission of the system and its interconnection with software was carried out,
- initial pen-test was carried out (source Hsu-Nielsen) - mne, ø 0,5 mm, 2H between the sensors, for the calibration both of seven-level sensors,
- PC was attached to pressurizing device and then it was pressurized up to test pressure,
- the final pen-test was carried out after depressurizing and then the calibration was carried out again,
- duration of pressurizing and frequency of ring down counts per second (P/s) were graphically recorded and the data was recorded to the testing protocol to its assessment and later printing.

Fig. 5 Position of the PC at the testing device of Dräger Safety company.

Evaluation of the test

Now it is important to evaluate the test. It is required not to change the burst signal into the continuous signal (the frequency of ring downs AE are not decreasing at higher amplitudes). If so, it would mean, with high probability, that there is any leakage of either the pressurized medium or spreading and forming a crack, and therefore it is leading to the catastrophic mechanism of damaging the PC.

The test and data provided ***as it shown in Fig. 6*** that at the beginning and ending of both pen-tests and at the beginning of pressurizing and then after the depressurizing the PC, the burst signal was formed. However, the intensity of the signal was completely decreasing during the pressurizing process, and therefore the material mechanically reacted to the pressure forces by its tension and this way it reacted by its sound phenomenon.

The next phenomenon, that is measured, is the number of ring down counts of the signal (amplitudes) per second, and its strength (peak the amplitude). In the measured test we work at seven levels of each sensor, when there is a particular colour for each level and the ring down is transformed by electric unit of voltage in mV into a graphic figure. According to the number of the ring downs and the peak of amplitude it can be considered how active

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the material is from the point of view AE. The scale of colours is evaluated there (from the weakest to the strongest one): green 150 mV, light blue 300 mV, yellow 600 mV, white 1200 mV, red 2400 mV and dark blue 9600 mV.

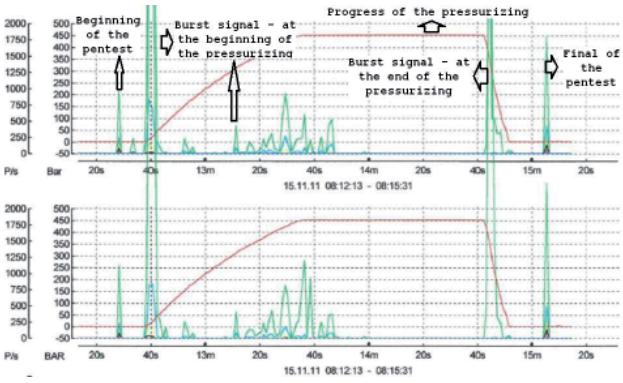

Fig. 6 Graphic course of the test

In practice, it is watched each signal that exceeds the graphic volume of testing pressure, it is 450 bars, or if the threshold of AE exceeds 1500 ring downs per second, or if there is abundance of graphic course from the red colour up to the dark blue colour as it shown in Fig. 6. That was not approved in our testing case. The operation life of PCs was prolonged for three more years according to the data as it is said on the labels placed on the PC.

Results

After expiring the prolonged operation life of PCs, there was a unique possibility to carry out the final revision of these cylinders in cooperation with the Repair plant division of FRS CR in Olomouc, see Fig. 7, before their definite putting out of operation or another prolongation of their operation life. The intention of that was to carry out a periodical revision of PCs in order to find out their real state and to have a sample and data for same cases in future. The conclusions of this assessment are dated in table.

Tab. 1 Evaluation of technical state of PC after prolonging their life operation, before putting out of operation

No:	Number of manufacture	Volume [l]	Year of made	Volume expansion	Body of PC	Screw thread connection	Inner verification	Number of bottling before/after
353	IC 06090	6,8	03/1996	5 %	mech. wear	unsuitable	suitable	27/51
354	RAG125764	6,8	04/1996	over 5 %	mech. wear	unsuitable	suitable	31/50
355	IC 04844	6,8	07/1995	up to 4,5 %	mech. wear	unsuitable	slight corros.	16/35
358	RAG119068	6,8	03/1996	over 5 %	mech. wear	suitable	suitable	25/48
359	RAG166625	6,8	11/1996	5 %	mech. wear	unsuitable	suitable	32/40
360	RAG125802	6,8	04/1996	up to 5 %	mech. wear	unsuitable	slight corros.	38/26
362	RAG166766	6,8	11/1996	over 5 %	mech. wear	unsuitable	suitable	32/33
363	RAG166809	6,8	11/1996	suitable	mech. wear	unsuitable	suitable	32/47
365	RAG125833	6,8	04/1996	up to 5 %	mech. wear	unsuitable	slight corros.	19/26
366	DDJ110745	6,8	02/1996	up to 5 %	mech. wear	unsuitable	slight corros.	34/46
367	RAG166658	6,8	11/1996	suitable	mech. wear	unsuitable	suitable	31/30
368	RAG166815	6,8	11/1996	5 %	mech. wear	unsuitable	suitable	26/40
369	RAG166623	6,8	11/1996	over 5 %	mech. wear	unsuitable	slight corros.	27/34
370	RAG166647	6,8	11/1996	suitable	mech. wear	suitable	suitable	41/28
371	RAG166702	6,8	11/1996	suitable	mech. wear	unsuitable	suitable	51/29
372	RAG166782	6,8	11/1996	5 %	mech. wear	unsuitable	suitable	51/42
373	IC 05045	6,8	07/1995	up to 4,5 %	mech. wear	unsuitable	slight corros.	20/23
375	DDJ 6831	6,8	11/1995	up to 4,5 %	mech. wear	suitable	slight corr.	28/28
376	ID 01310	6	07/1995	up to 4,5 %	mech. wear	suitable	good	15/15
380	RBG104398	9	01/1996	up to 5 %	mech. wear	unsuitable	corrosion	15/4
381	RBG104416	9	01/1996	up to 5 %	mech. wear	unsuitable	good	15/4
382	RBG104397	9	01/1996	up to 5 %	mech. wear	unsuitable	corrosion	17/4
383	RBG104400	9	01/1996	up to5 %	mech. wear	unsuitable	corrosion	15/4

Each PC successfully underwent a hydraulic pressure test according to the valid test rules (*CSN EN ISO 11623, 2003*). The most serious failure is given in table, the number of bottling by filling medium is given in the last column, before and after the AE test. Revision shows that 82,65% of PCs are not suitable for calibration test of screw thread connection and 17,4% of PCs are unsuitable from the point of view of volume expansion, which is higher than 5%.

Only for 3 pieces of PCs (13,5%) could be hypothetically prolonged in their operation life by AE test.

Fig. 7 Test device for hydraulic pressure test and for the test of volume expansion of PCs at Repair plant of FRS CR in Olomouc

Conclusion

From the above mentioned data it can be concluded, that it would be very risky to recommend any prolongation of the operation life of PCs where the operation life had already been prolonged by AE test before or even to recommend further use in operation. Nevertheless, prolongation of the operation life of PCs by the method of AE was the only way, and as it was proved as a right option, for that difficult period of time. It is also needed to emphasize the fact that during the use in operation, after the PCs having been prolonged in their operation life, there was only one failure and it was the failure of packing under the bottle valve during bottling by medium. The lesson what can be learned from the situation of that time is, that purchase and renewing of these technical means of fire protection in bulk is not a proper solution. It is also needed to take into consideration the fact in future that during the periodical revisions of these technical means some problems might occur in case the revisions will be carried out on a large scale.

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