Developpement and Use of Nde Methods on Pressure Equipement: Industrial Experience in Applying Acoustic Emission

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Abstract. The European regulation regarding pressure equipment (i.e. Pressure Equipment Directive PED 97/23/CE) is applicable since May 2002.
The member states have since adopted regulations enabling the use of innovative NDE methods such as acoustic emission as a global method associated to a local method such as TOFD technique which permits an accurate characterization and precise sizing of flaw indications.
These NDE methods have been studied, tested and assessed by CETIM since several years.
Their development leans on various R & D studies that CETIM conducts along with industrial partners whose main preoccupations are to guaranty the safety and the fitness for service of their pressure equipment.

Introduction

The bearing European lawful field on pressure equipment is in force since May 2002. Among the various directives which cover PE, most significant are:

- The directive 97/23/CE “pressure equipment” of May 29, 1997
- The directive 99/36/CE “transportable pressure equipment” of April 29, 1999.

For this reason the directive 97/23/CE “equipment pressure” was transposed in the French Decree 99-1046 of December 13, 1999 related to the new equipment. The requirements related to the in-service equipment are specified in the Decree of March 15, 2000.

The application of this directive, which is founded on the principle of the new approach, induced the need for a harmonization of the practices in the fields of manufacturing, testing, certification and the accreditation. This harmonization being today with its first stammering, the actors intervening in the field of the pressure equipment witness difficulties in following the new requirements which require an accompaniment with their implementation.
The lawful evolution allows the introduction of innovating non-destructive testing methods such as the acoustic emission associated with the ultrasonic imagery method (TOFD); these methods are not only used as quality assessment tools for initial workshop inspection, but also as methods enabling to guarantee the in service safety, availability and reliability of pressure equipment.

They are studied, implemented and are validated by CETIM since many years.

The continuation of the document highlights the technical challenges imposed by the implementation of acoustic emission on pressure equipment and the way CETIM articulates it's R&D activity in order to raise them. These developments have been tested and confirmed through on site practical cases presented here below.

Technical Challenges of the Acoustic Emission and Approach Lead by Cetim to Raise Them

1. How to ensure the safety of the tests under pressure?

In France, as in other countries, each pressure equipment must undergo a performance test at the workshop, and periodically during its life in service.

According to the regulation, this performance test is carried out by a hydraulic proof test which enables to check that the equipment is able to resist the maximum service pressure.

Within the framework of the new regulation and for stage with the various disadvantages of this test for certain vessels, the industrials wish to replace the hydraulic proof test by pneumatic tests monitored by an NDE method such as acoustic emission. To be acceptable, this step must answer two questions: guaranteeing the safety of the test itself and bringing reliable information on the integrity of the whole equipment.

CIAPES R&D Programs:

The aim is the development of real time monitoring protocol for hydraulic and pneumatic tests, collecting data obtained by acoustic emission (EA) in order to ensure the safety of these pressure loading cycles.

The tests carried out in these programs were divided into two parts: development of the criteria in laboratory and validation on operation site.

For the tests laboratory, "simulated" defects representative of real defects (lack of penetration, cracks, blisters,…) were introduced into mini structures built for this purpose. [Figure 1]

Thereafter, the capacities were pressurized according to a cycle loading test followed by burst test, both tests being monitored by acoustic emission. [Figure 2]

Figure 1: mini structures including artificial defects that were tested

Figure 2: Opening of a week area during the burst test of a mini structure

The acoustic emission data recorded during these tests were analyzed in order to determine new evaluation criteria based on the recommendations of European standards and taking into account the following acoustic emission data:

1. The total emission: first reached sensor
2. Localization of acoustic emission sources
3. Emission during the holds
4. Kaiser effect verification
5. Characteristics such as burst amplitude, energy, duration, etc…

The development and the improvement of these criteria through new techniques of analysis of data made it possible to obtain more precise and more reliable diagnoses for the detection and the localization of the sources and the discrimination of the hazardous sources.

LOTERE project:

LOTERE (French name for “Real Time Software”) is a decision-helping tool intended to be used for the control of pressure equipment. The principle is based on the capture of ultrasonic waves generated by weak points when the equipment is loaded by a pressure cycle. These waves are collected by several sensors judiciously placed on the equipment in order to be able to recover by triangulation the exact position of the suspected point. The determination of the co-ordinates of these points as certain parameters of acoustic emission is ensured by a dedicated system.

2. How to improve the defect localization?

COSEP Program:

CIAPES Programs continued within the framework of project COSEP (Control and Monitoring of Pressure Equipment). COSEP is a multi-partner project conducted by CETIM which gathers both pressure equipment manufacturers and users wishing to get the benefit from a global method which is able to detect the evolving defects and avoid the realization of hydraulic proof tests on certain types of equipment. [Figure 3]

Figure 3: Acoustic emission monitoring of the workshop final testing of pressure vessel

The program which relied on laboratory tests of mini-structures and on site testing of operating equipment, made it possible to validate the methodology CETIM-CST ® which is based on the localization of indications using a triangular grid on the surface of the equipment. The developed methodology offers the advantage of introducing a space vs time criteria making it possible to identify the exact origin of the acoustic activity and its severity, thus limiting the area where the complementary non destructive testing must be conducted. In this way, a potential evolving defect will be detected and located by acoustic emission (used

as a global method) and then identified and measured by complementary investigations (used as a local method) targeted on the emissive zone.

3. How to guarantee the detection of the propagation of the defects?

The characteristic of the acoustic emission is to reveal during a test under pressure and in real time the defects which are propagated and which are likely to lead to a premature rupture of the equipment during the test or in service.

This propagation of the defects is acceptable only in the condition of a sufficient ductility of materials. A preliminary study of the acoustic emission of materials used made it possible to show that the detection of the defects with propagation was at pressures having a sufficient margin compared to the pressure of bursting.

In this objective a bank of data was made up; it was integrated as a module of the data base CETIM-BDF 3.0 ® described in the continuation of the document.

4. How to ensure the access to the wall of the pressure equipment?

The wave guide technology: The exploitation of storage tanks implies a reinforced safety of the installation under pressure.

This safety is obtained by the application of a fireproof protection coating which is generally of a slope type that makes it difficult to reach the external wall of the equipment for in-service inspections.

The use of acoustic emission implies, to preserve its global characteristic, the need of a direct access to the wall of the equipment in order to mount and verify the sensors.

The technical solution suggested by CETIM consists in indirectly reaching the wall of the equipment by means of “wave guides” (one per sensor) crossing the slope and directed towards the surface of the installation. [Figure 4]

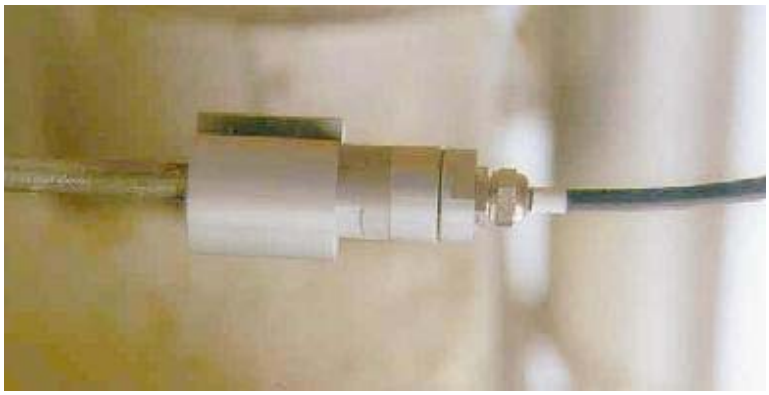

Figure 4: view of a sensor assembled at the end of a wave guide (technological solution developed by CETIM)

During in-service inspections, the sensors are placed at the end of the wave guide; they then receive the acoustic waves propagated from the surface of the equipment rather than being condemned with the tank in the slope and thus to be exposed to possible damage risks. [Figure 5]

Figure 5: Substitution of the hydraulic proof test of a spherical storage tank by a pneumatic test monitored by acoustic emission

5. How to consolidate the good practices by their introduction into tools and adapted references?

CETIM-BDF 3.0 ®: The results obtained made it possible to consolidate CETIM-CST ® methodology and pack the French acoustic emission Data base CETIM-BDF 3.0 ® which capitalizes CETIM's know-how and experience in the field of the control of pressure equipment by acoustic emission. The data base is continuously growing as new tests are conducted on industrial applications.

AFIAP/GEA Workgroup: A working group on acoustic emission was created in 1999, under the supervision of the French Association of Pressure Vessel Engineers (AFIAP), in order to work on a good practices guide related to the use of acoustic emission on pressure equipment: This guide which is available since 2002 covers different aspects of the conduction of acoustic emission on this particular application such as:
- General technical rules in the control and processing of acoustic emission data,
- Specific procedures to conduct such a test on different types of pressure equipment.

CODAP® 2000: CETIM took an active part in a study conducted for the French Mechanical profession of boiler and piping manufacturers whose objective was to introduce in December 2002 into the famous CODAP® 2000 code a specific appendix related to acoustic emission when this method is to be used for the workshop hydrotesting of pressure vessels.

Thanks to this specification, the pressure vessel manufacturers, whose clients wish to use acoustic emission as a method for the monitoring of in-service inspections, can obtain an initial acoustic signature of the equipment (also called step “0” signature) in order to use it as a reference for future inspections.

Conclusion and Outlines

• This work shows that acoustic emission used as a real time monitoring method is able to define and locate potential weak areas in pressure vessels in order to conduct local investigations

• The work undertaken by CETIM and its industrial partners has made it possible to consider acoustic emission as a global method in order to be used on simple pressure vessels such as storage tanks (above and underground cylindrical or spherical tanks)

• R&D programs conducted by CETIM such as CIAPES and COSEP brought technical answers to the development of this non destructive method on other “more complicated” pressure equipment, in compliance with the European and international standards as well as the AFIAP Good Practices Guide

• The strong regulation associated to the results of these studies should be able to set a new approach in the ways of qualification pressure equipment, even if the acoustic emission still requires a very strong expertise for those who apply it.

Bibliographical References

[1] Essais non destructifs : l'émission acoustique, J. ROGET AFNOR - CETIM - 1988
[2] Applications actuelles et certification en émission acoustique, M. CHERFAOUI - J. ROGET, Congrès COFREND - Nice - Octobre 1990
[3] Nouvelles avancées dans le contrôle par émission acoustique des appareils à pression, CETIM – CEA – CNRS – CERN – ELF – SEP – SOLVAY – ICI – L'AIR LIQUIDE – BSL INDUSTRIES (journées AFIAP – PARIS 1995)
[4] Quality testing of gaseous helium pressure vessels by acoustic emission, M. BARRANCO - M. LUQUE, V. SERGO, C. MARGAROLI, CERN, M. CHERFAOUI, C. HERVE – CETIM - ICEC 17, International Cryogenic Engineering Conference 1998
[5] Acoustic emission monitoring of pressure vessels during proof test : examples of application on a nitric acid absorption column and a HP urea vessel, E. SOUTIF, BSL INDUSTRIES – C. HERVE, F. ZHANG, CETIM, AICHE Ammonia Safety Symposium 1998
[6] Le contrôle par émission acoustique de tubes en composites, C. HERVE – M. CHERFAOUI – J. ROGET, CETIM Informations n°116 – juin 1990
[7] Contrôle et surveillance des équipements sous pression par émission acoustique, C. HERVE – M. CHERFAOUI – J. ROGET, Journées d’études européennes sur les équipements sous pression – 2001