Wednesday 12 September 2018

Welcome-Registration

Time: 8:30 - 9:30
Date: 12th September 2018

Conference Opening

Auditorium
Time: 9:30 - 10:00
Date: 12th September 2018

Keynotes

Auditorium
Time: 10:00 - 11:00
Date: 12th September 2018

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42 - Acoustic emission method at the integrated structural health monitoring systems - the past, the present, the future

Igor Razuvaev

Alcor Corp., Dzerzhinsk, Russian Federation

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86 - Acoustic emission work over the last 10 years and relationship with Industry 4.0

Mohammed CHERFAOUI

CETIM, Senlis, France

Acoustic Emission method at the Integrated Structural Health Monitoring Systems - the past, the present, the future.

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Keywords: acoustic emission, Integrated Structural Health Monitoring Systems, high temperature, waveguides, explosion safety, noise, high resonant sensors, wireless systems, optical sensors, big data, intellectual maintenance systems

Abstract

In the report the review of application of method AE for monitoring of technical condition dangerous plants in nuclear power, chemical and a petroleum-refining industry is made. The basic directions of development the AE method in monitoring - sensors on another then piezoelectical physical principles, wireless systems, application of the Big Data are considered.

1. Introduction

Integrated Structural Health Monitoring (ISHM) systems with acoustic emission (AE) are actively used for monitoring the structural integrity of various units at nuclear power plants, refinery, chemistry and at many other industries. The purposes of application - safe operation of the equipment and optimization of maintenance based upon proactive strategy. In some cases use ISHM changes the basic approaches to a safety of technological installations and objects.

Basic operative target of the ISHM - detection of dangerous defects at early stages. As the ISHM systems are applied to the control of the unit's in-service, rather than AE diagnostic during shutdowns there is a number of the problems. ALCOR Corp. Is leading Russian company at the AE ISHM system design and application. Since 1993 our company designed and produced a large number of the AE ISHM systems with more than 3800 AE sensors totally.

In the report some results of scientific researches and the design development executed by our company are stated.

Future direction of AE method in monitoring - sensors on another then piezoelectical physical principles, wireless systems, application of the Big Data are considered.

2. Brief historical overview.

Apparently, the first application of the AE method in ISHM was system of monitoring of the nuclear reactor, developed by Westinghouse in 1976 (Fig 1). This unique development has been executed in CAMAC system. Data processing was carried out by minicomputer PDP-11 which computing power was approximately a million times less, than at modern smartphone. The special attention and respect is deserved with that fact, that developers of this system could create the AE sensor for work in conditions of the high temperature and high radiation. Thus transfer of a signal to a line in length more than 150 m without amplifier has been provided.

Fig 1. Westinghouse AE monitoring System, 1976

Other example of application AE in ISHM were works of Finnish company ACUTEST on creation and introduction of the AE ISHM on Porvoo Refinery, Finland. Have been created ISHM systems for the control of a technical condition more than 150 objects on 8 technological Units. Application of these systems has allowed considerably increase the safety and profitability of the Refinery (Fig 2).

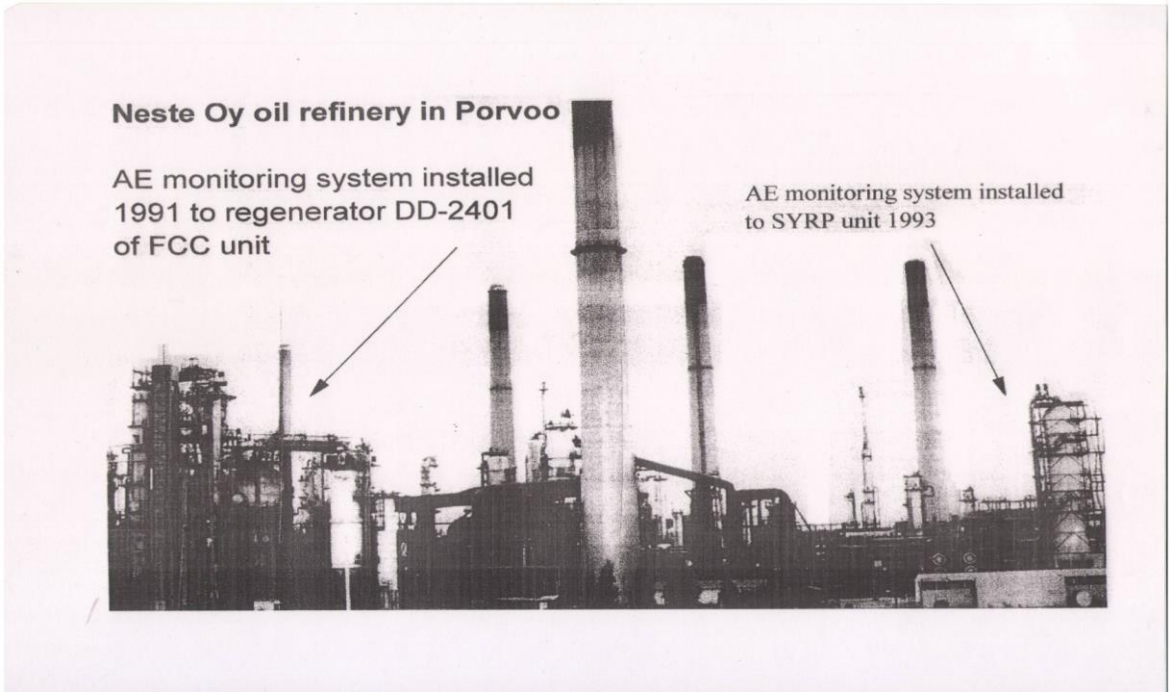

Fig 2 AE monitoring Systems at Neste Oy Refinery

Are described both other examples and the governmental programs on introduction of the AE ISHM systems.

In Russia the first AE ISHM systems has created in 1993 by our company. There were systems for the continuous control of a technical condition of very dangerous objects – large isothermal reservoirs for the liquefied hydrocarbon gases (Fig 3).

Fig. 3. Large LPG Storage vessel with AE ISHM System “Recourse-M” 1993.

By present time we have produced AE ISHM Systems “Resource-2000” for more than 370 objects (Fig 4). Application of our systems on some dangerous industrial objects has allowed to find out developing defects and to prevent possible accidents.

Fig. 4. Some units to be monitored by AE ISHM system “Resource-2000”

Moreover, on the basis of application of ours AE ISHM systems in Russia the Government normative acts and standards of Oil&Gas Companies concerning industrial safety are now changing. There is a transferring from the periodic inspections to continuous monitoring a technical condition of especially dangerous objects.

3. Problems and current solutions.

3.1. Extreme temperatures of the monitored objects.

At monitoring the temperature of controllable devices can be in a range from-198 °C for objects of the chemical industry up to +700 °C and above for the equipment of oil refining and power plants. AE sensors applied at diagnostics, as a rule, are not designed for the long-term work in such conditions. Therefore for application of the AE at monitoring are necessary either special sensors, or the special devices protecting sensors from adverse influences, or both and another together.

For monitoring low-temperature objects we had been developed special AE sensors which provides long-term reliable work at cryogenic temperatures. Thus it was possible to provide high enough sensitivity - nearby 200 dB ref. 1V/m.

Usage of usual piezoelectric sensors in conditions high (more than 200 °C) temperatures is limited by Curie point at which the sensor loses sensitivity. By development of ISHM systems “Resousre-2000” for the high-temperature objects we considered following possibilities:

Creation of sensors with piezo elements with Curie point more than +700 °C on the basis of titanium-scandium-bismuth-lead (TSBL)

Creation of sensors on the other physical principles

Usage of wave guides for distancing the sensor from hot surfaces.

We have refused high-temperature piezo elements because of their low sensitivity.

Sensors on other physical principles will be discussed later.

As a result we have concentrated efforts to development of special wave guides. We managed to create wave guides which not only do not weaken an AE signal, but even a little bit strengthens.

3.2. Explosion safety.

One of important for ISHM systems functions is the self-test by the sensor and AE channels. For check of the sensors installed on large industrial units, is necessary to put on them test signals with amplitude about 100V. It makes application of the simplest Ex type – IS - practically impossible. For the ISHM systems “Resousre-2000” we develop sensors with Ex type "m".

3.3. The problem of noise.

One of main problems in application of AE in ISHM and at AE on-stream diagnostics (OSD) are natural noise of objects of monitoring.

The basic sources of noise in these appendices are:

- The moving of technological liquids, gases, etc.
- Operation of rotating equipment (compressors, pumps, valves, etc.).
- Meteo factors.
- Artefacts of a various types and an origin.

In difference to the usual АЭ testing, at monitoring and at OSD to eliminate action of these factors is impossible.

Hence, the opportunity of successful of the AE method depends on that, is how much effective sensors, the equipment and software of the ISHM are capable to separate the useful signals from background noise.

On a level of background noise objects of monitoring in oil refining and in petro chemistry can be parted on 2 classes - "silent" and "noisy".

Large-capacity tanks concern to the first class – LPG, LNG and liquefied ammonia storage vessels.

On these objects band-pass AE sensors with high sensitivity a frequency band from 70 up to 300 kHz are necessary. In this case application built-in programmed digital LP and HP filters with the rejection outside of a transmission band more than 50 dD/octave, and also the built in expert systems allows to gain good results [5].

Another situation is at application of the ISHM and OSD of equipment of oil refining units (reactors, heat exchangers, separators, columns, pipelines, etc.). Processes occurring in them and working equipment generate ultrasonic signals in a frequency band up to 120 kHz at amplitudes up to 90 dB and more.

In these requirements using “dear old” resonant sensors is very difficult, as these sensors have too high sensitivity a frequency band of noise. Use of the frequency filtration also does not guarantee the positive effect as at an overload of these sensors noise on frequencies nearby 100 kHz they are capable to generate signals of high amplitude on their natural resonant frequency, together with on following harmonics. That is there is the full suppression by noise of the useful signals. Simultaneously the quantity of "false alarms" considerably grows. All this not only reduces efficiency ISHM and OSD, but also renders negative influence on reputation of AE method.

The trivial solution of the above-stated problem is application in ISHM and in OSD high-frequency AE sensors. For what distance between sensors have to be reduced. It causes the multiple growth of number of AE channels and leads to corresponding magnification of cost of the system and expenses for its service.

Thus, application of the ISHM and OSD for the oil refining unit’s usual resonant sensors is inefficient technically, and application high-frequency sensors is inefficient economically.

For the solution of this problem our company have been developed AE Monitoring Sensors (AEMS) sensors with new architecture.

Their frequency response, shown on fig. 5.

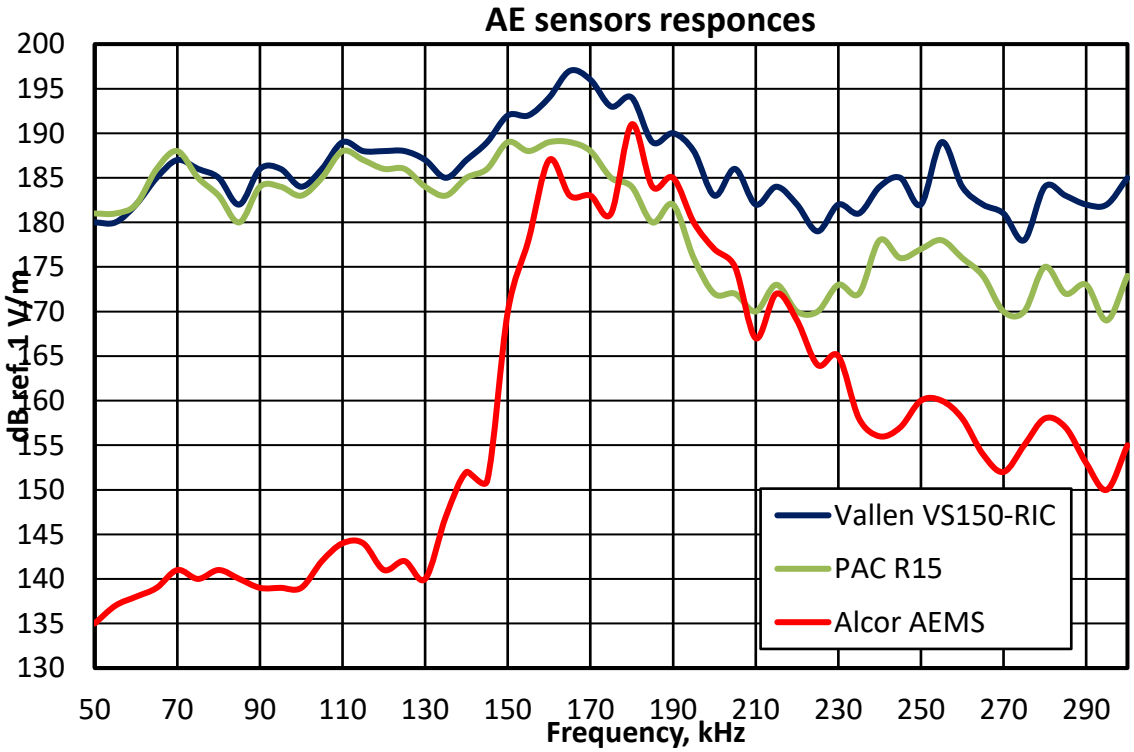

Fig.5. Frequency responses of the AEMS (red) and industry standard resonant sensors.

AEMS are steady against action of noise of working refinery units in a range up to 130 kHz at provides enough high sensitivity a range 160-190 kHz.

Inside frequency range of the background noise of the refinery units (approx. 10 – 100 kHz, fig. 3) sensitivity of the AEMS is on 40-45 dB less, than at classical resonant sensors.

Therefore action of noise with high amplitudes on AEMS does not lead to a full “flare” in a working frequency range. Peak sensitivity of the AEMS below similar at classical resonant sensors on 5-10 dB at all. In view of that the threshold in AE channels of the monitoring systems usually is at a level from 40 up to 50 dB, such decreases of peak sensitivity it is possible to consider, from our point of view, as reasonable cost for qualitative the best stability to action of noise of the working equipment.

On these sensors the patent is obtained.

4. Future direction of AE method in monitoring systems

4.1. Optical AE sensors.

As shown above, application of method АЭ in monitoring shows very high, and thus often mutually exclusive, requirements to sensors. In our opinion, the piezoelectric technology has approached to the limit, and will "squeeze out" from it something else is extremely difficultly. Besides the most important lack of piezoelectric transducers is that they do not allow to register AE signals itself, but give out the reaction to these signals.

Electronics for the AE systems develops much more quickly, than sensors. Already exist, for example, high-speed 20-bit ADC. Their application capably to expand dynamic range of the systems approximately up to 120 dB. But application of these ADC with piezo sensors and preamplifiers has no practical sense.

The decision of these problems, in our opinion, is on a path of application of optical AE sensors on the basis of laser interferometers (Fig. 6).

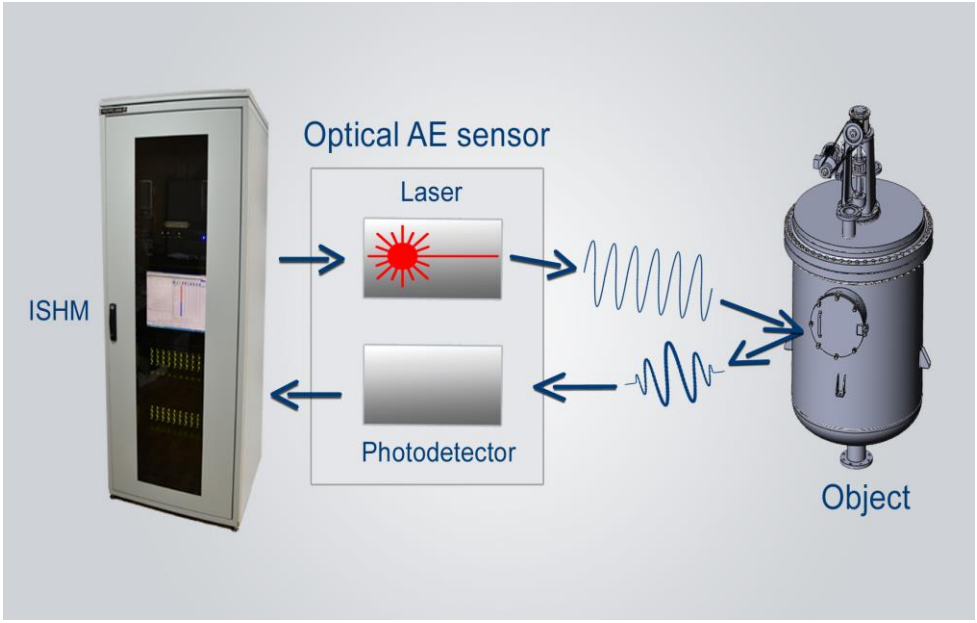

Fig. 6. Simplified scheme of the optical AE sensor at the AE ISHM system

Optical sensors allow operatively and in the broadest ranges change frequencies and to register oscillations of AE signals directly.

The dynamic range of interferometers is 180-190 дБ.

All this will allow not only to solve the problems of extraction of useful signals from noise cardinally, but also will create conditions for use of data AE monitoring in quantitative calculation of a resource.

4.2. Wireless systems.

This is another perspective direction of development of the AE ISHM systems. Wireless systems allow to change their configuration flexibly and to be fine-tuned under object operatively, in view of localization of potential defects. And, of course, will get out kilometers of a cables.

It is necessary to solve only 2 problems - synchronization and long (years!) power supplies without changing batteries.

4.3. Big data.

AE ISHM systems generate Mbytes of data daily. It's not only AE data, but also parameters of technological processes and signals from additional sensors (Fig. 7).

Fig. 7. Big Data approach.

These files of the information are necessary for analyzing practically in real time and together with data of the periodic NDT inspections, information from operators, etc. Nowadays applied in AE post processing technologies for such modes are not conformed. It becomes a hurdle for increase of efficiency of monitoring systems.

Yield - use of Big Data technologies and creation of interfaces with EAM systems. It will allow not only to raise functional of the AE ISHM systems as the tool for safety, but also to transform them into the basic source of data for intellectual maintenance systems.

5. Conclusion

Development of the new sensors, new electronics and new technologies of the analysis of AE monitoring data of in real time considerably expands opportunities of the AE ISHM systems. It actually creates the new market. The main thing now - competently use of the collected by large work experience.