New Generation of AE Sensors for the Integrated Structural Health Monitoring and On-Stream Diagnostic Systems

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Abstract. In the report the purposes and the results of creation of the new generation of the acoustic emission sensors are described. The sensors were designed for the AE testing at very noisy environment, first of all for the SHM systems and for the AE testing of the dangerous industrial objects while in service (on-stream diagnostic). Comparative characteristics of the new and traditional sensors are discussed.
Keywords : acoustic emission sensors, integrated structural health monitoring systems, on-stream diagnostic.

1. Introduction.

The method of an acoustic emission (AE) is the most effective method of monitoring of a technical state of the process equipment of oil refining and petrochemical manufactures [1,2,3,4]. For monitoring formation and development of flaws of type as cracks method AE mostly effective, and only for the monitoring of the corrosion other NDT methods HK are more successfully applied. Therefore AE takes leading place in integrated structural health monitoring (ISHM) systems for the monitoring a technical state of oil refining and petrochemical equipments. By present time Alcor Corp. developed and produce the ISHM systems “Resource-2000” on more than 300 objects. It is applied more than 3700 AE channels.

2. The Problem of noise.

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

The basic sources of the background noise are:

1. The motion of technological mediums in checked equipment.
2. Operation of equipment (compressors, pumps, valves, etc.).
3. Meteorological factors.
4. 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.

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Hence, the opportunity of successful of the AE method depends on that, 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 petrochemistry can be parted on 2 classes - "silent" and "noisy".

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

Fig. 1. LPG vessel with ISHM system“Resource-2000”

On these objects can successfully be applied classical resonant AE sensors created on the basis of SE150-M by Hal Dunegan, and also band-pass AE sensors with high sensitivity a frequency band from 70 up to 300 kHz. 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 gives good results [5].

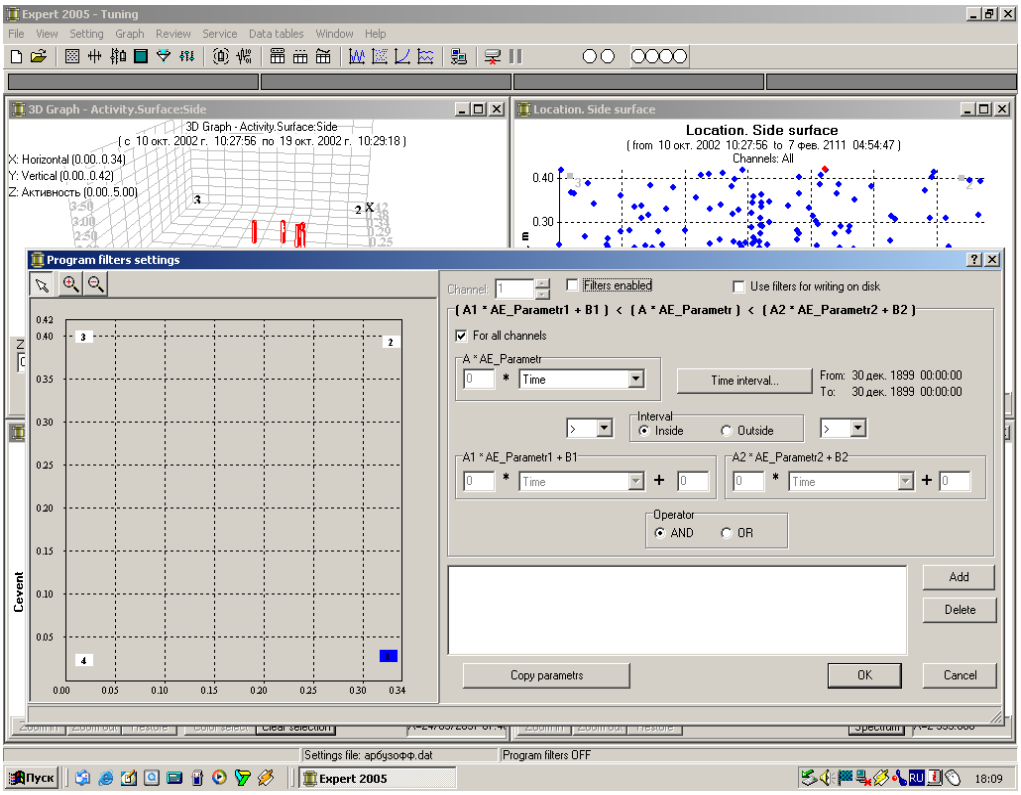

Fig.2. The screen of expert system.

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

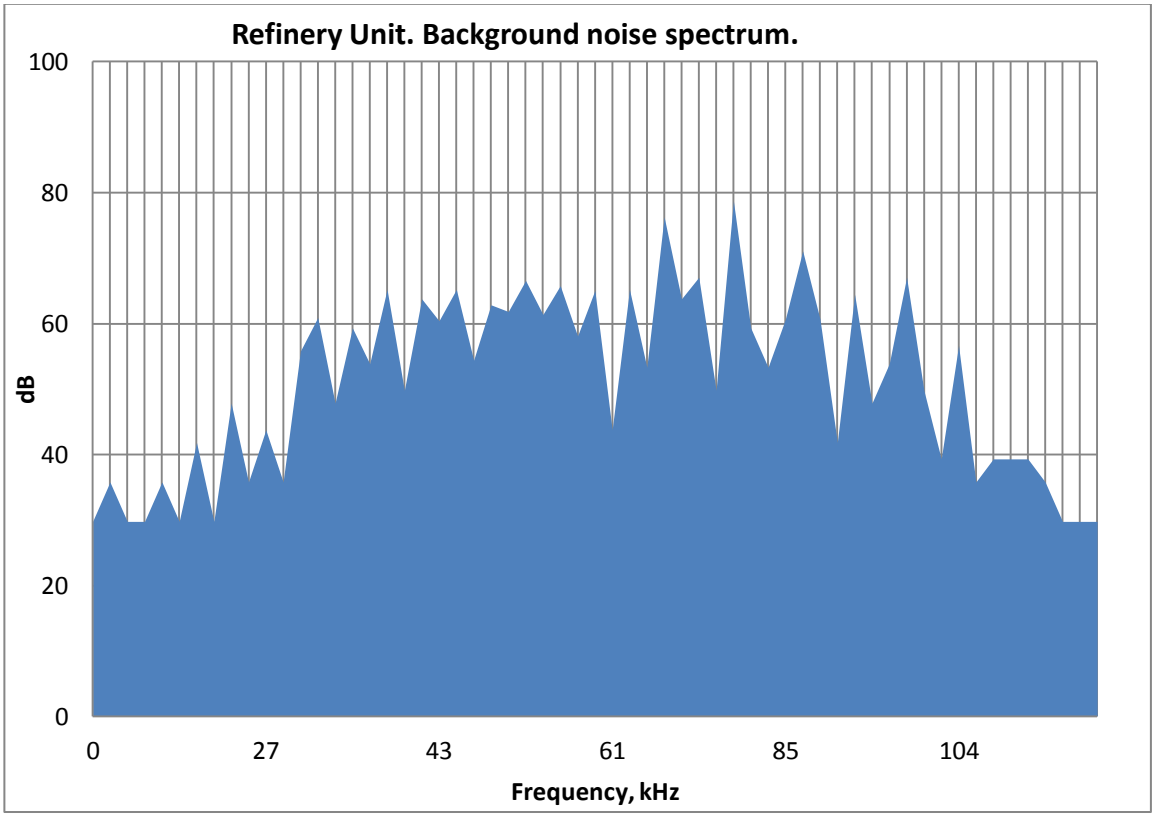

Fig. 3. Routine spectrum of background noise at refinery pipeline.

In these requirements using “dear old” classical resonant sensors is very difficult, as these sensors have too high sensitivity a frequency band of noise. Use of the frequency filtration does not guarantee the positive effect also, as at the 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 units classical resonant sensors is inefficient technically, and application high-frequency sensors is inefficient economically.

3. New generation sensors – AE Monitoring Sensors for ISHM and OSD.

For the solution of this problem we have been developed AE sensors with new architecture.

The primary goal at their development was to lower sensitivity a frequency band up to 120 kHz approximately on 40 dB ref. 1 V/m in comparison with the sensors as SE150-M and to maintain high sensitivity a frequency band from 150 kHz up to 200 kHz.

This problem has been solved by creation multiplicated piezoelectric transducer.

It consists of the basic sensing element (SE) of the special geometry to which one or several additional piezoelectric transformers (PT) are connected.

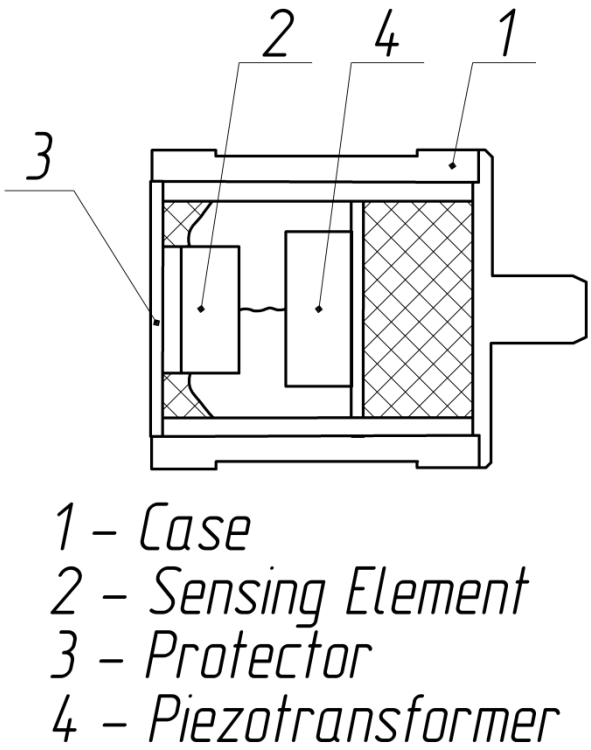

Fig.4. The Block diagram of the AE Monitoring Sensors.

Configurations and electrical performances of the system SE-PT are calculated so that to gain high quality factor of contours with a resonance in a frequency range from 160 up to 190 kHz.

As a result it was possible to create Monitoring Sensors (AEMS) with response, shown on fig. 5.

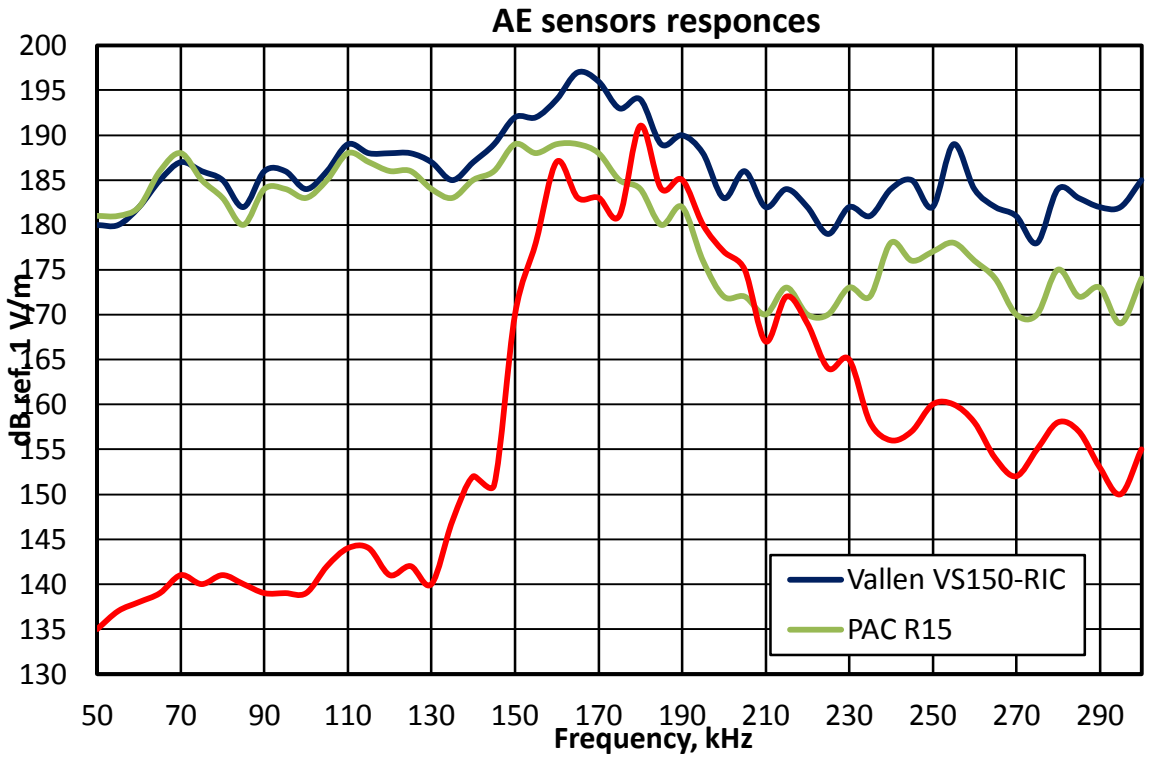

Fig. 5. AFC of the AEMS and industry standard resonant sensors.

Apparently, 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 is near or slightly below of the classical resonant sensors. 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 may be 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. Conclusion.

Created by Alkor Corp. new generation of the AE sensors – AE Monitoring Sensors -is intended mainly for application in ISHM and at OSD.

Their application for monitoring and diagnostics of refinery and petrochemical plants allows to find out under operating conditions such flaws, as fatigue cracks (fig. 5) at simultaneous significant reduction in amount of "false alarms".

Fig. 5. The fatigue crack which has been found out ISHM «Ресурс-2000» in a welded seam of the refinery pipeline.

It opens new possibilities of application of the AE method for the testing of dangerous objects while in service.

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