Integrated monitoring of the refinery and chemical plants as the tool for proactive maintenance

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Abstract

The methods and results of the long-term integrated condition monitoring of refinery and chemical plants equipment (reactors, heat exchangers, separators, refinery columns, pipelines) and bulk isothermal vessels in-service are discussed. Primary monitoring method is acoustic emission. Addition methods used are infrared thermography, gas concentration analysis and process parameters analysis. Techniques for the ensuring long-term reliability of the monitoring system are discussed. One of the most serious problems for the continuous monitoring in-service is a noise of a technology nature. To avoid AE signal suppression and “false alarms” multilevel hardware and software filters systems were developed. Real time and periodic in-service integrated condition monitoring provide root defect identification and forms the actual knowledge database for proactive maintenance strategy.

1. Introduction

Refineries and chemical plants work continuously. Their shutdowns are caused by scheduled inspections and repairs, or by failures. In any case the shutdown brings not only financial losses, but also increases environmental pollution and sharply intensifies process of wear of the equipment because of negative influence of transients at a stop and start-up.

The primary goals of maintenance of the refinery and chemical plants are the increase in the uptime and raise of safety of factories.

The most effective method of the solution of the first problem is proactive maintenance directed on revealing and elimination of the reasons of origination of defects. Identification of these reasons a post factum, after shut down equipment is not always possible.

For the solution of the second problem for such dangerous objects as oil refining and chemicals plants, the operative control of a technical condition of the equipment is necessary.

The most effective way of the solution of both problems is integrated monitoring a technical condition of the equipment, which is eye end ears of the proactive maintenance strategy.
We have created modern strategy of the integrated continuous control of the equipment condition - IC^3E. Optimal for each technology unit combination of the NDT method in real-time continuous condition monitoring and periodic on-stream inspection, diagnostic or indication tools are the base of the strategy.

2. The Strategy

Strategy of the integrated continuous control by the equipment condition (IC^3E) represents the set of technologies and the actions providing :
Real-time processing of the instrumental data about an equipment condition;
Periodic on-stream inspections;
Interpretation and analysis of these data;
Operative formation and performance of compensating actions;
Conducting uniform for the enterprise a database about a equipment condition and the executed actions;
Optimal, according to the set criteria, management of an equipment condition, including optimization of loadings, maintenance, repair and updating.
This strategy is based on processing of the instrumental data about an equipment condition.
For the refineries and chemical plants equipment (reactors, refinery columns, vessels, pipelines) the basic sources of these data are integrated monitoring systems. In these systems acoustic emission monitoring allows real-time continuous or on-stream periodic inspection of the mechanical integrity of the equipment. In order to determine the nature of potential defect is analysed parameters of process. Leak detection, ultrasonic and thermography testing are used periodically. At low pressure units corrosion monitoring used.
Detection by monitoring systems of potential defects occurs at early stages of their development that allows executing the program of compensating actions for prevention of possible failure.
Thus, the IC^3E strategy provides:
Significant additional profit due to increase of the plant uptime.
Increase of a level of safety by the continuous operative control of an equipment condition. Detection of potential defects at early stages of their development allows avoiding failure.
Reduction of expenses for performance of technical diagnostics and estimation of a residual resource.
Exception of the charges caused by losses of “dead volume” of a products, expenses for removal/restoration of a heat insulation, etc.
The savings of the equipment lifetime by exception regular hydro- and pneumotests, elimination of harmful influence of transients at a stop and start-up and by optimization of a technological process according to monitoring data.
Significant depreciation of compensating actions.
Opportunity at the stationary control of operation of the equipment having defects.

3. INTEGRATED CONDITION MONITORING OF THE BULK VESSELS

At the end of 1993 we have created the two AE systems “Resource-M” for the continuous monitoring of the two bulk isothermal vessels in JSC “SIBUR-NEFTEKHIM”, Russia.
Number of AE channels in them 40 for propylene vessel in capacity 5000 м3 and 60 for ethylene vessel in capacity 10000 м3. This quantity of channels allows completely inspect an internal wall of each vessel. The sensors are located in 5 lines on ethylene vessel and in 4 on propylene vessel. The scheme of arrangement of sensors on the ethylene vessel is adduced on fig.1.

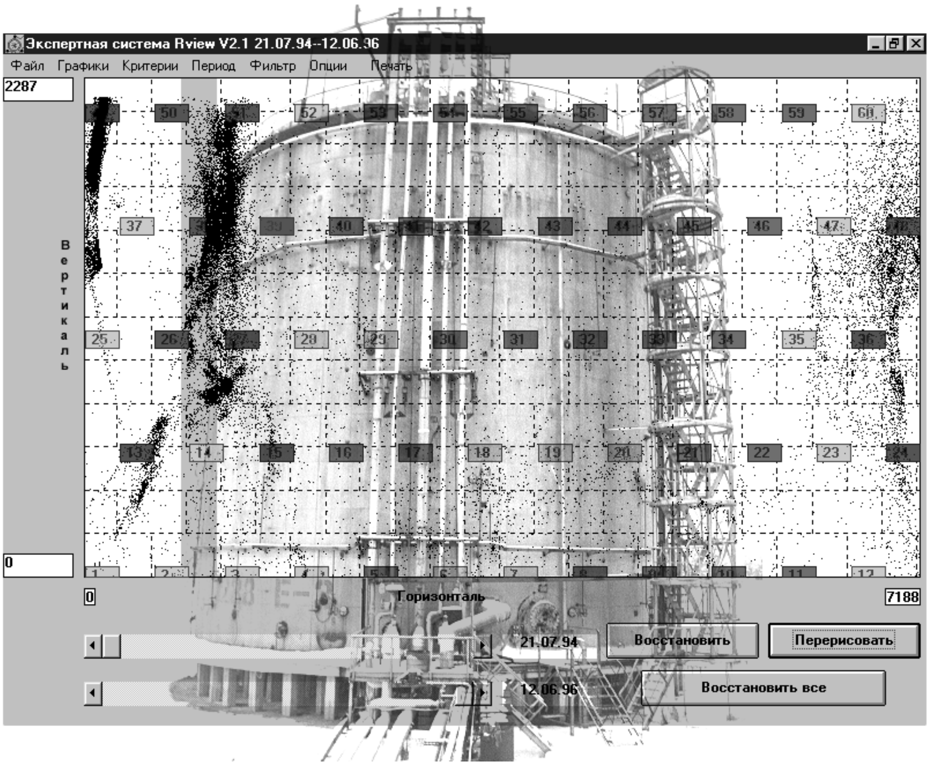

Figure 1 : Sensors displacement and located AE sources.

On this figure the internal wall of a vessel is displayed. The rectangles with numbers designate sensors. The dotted line designates welded seams. The grey vertical band is a zone of external pipelines. On a background the photo of the vessel is adduced. Except parameters of AE signals, both systems continuously register parameters of technological process - level of a product, temperature and pressure in a gas phase.
At system designing the special attention was given to maintenance of their reliability by long continuous activity in conditions of the operational chemical plant. Before the installation on object the systems were subjected to various tests, including tests for effect of the climatic factors and electrothermotraining.
Sensors and preamplifiers were developed for long continuous activity in conditions of low temperatures (up to mines 125 °C). At production of sensors the special welding

technology instead of pasting was used. All sensors were tested by thermal impact at immersing in a vessel with liquid nitrogen. The special thermo compensation unit, ensuring stable activity at change of temperature of an environment was entered into the scheme of the preamplifier. The sensors and the preamplifiers are made explosion-proof.

In systems there self-checking subsystems ensuring check of all elements of systems on a command of the operator. All sensors and preamplifiers can generate self-check pulses. It provides a series check of all channels with the purpose of localisation of a faulty module for the consequent replacement.

The special problem was installation of sensors. Both vessels have two walls, between which the layers of a thermal insulation are located. The sensors are installed on an exterior of an internal wall. For their mounting without vessels shutdown were developed special technology. An external and internal wall can move rather each other under effect of change of temperature of an environment and under influence of solar radiation. For reliable long-term acoustic contact of the sensor with an internal wall the sensor holders have two degrees of freedom. The sensors flatten to a wall by springs with a normalised effort and installed on special lubrication, not freezing up to temperature -125 º C and lower.

The systems provide location of AE sources with a method of triangulation. In the software of each system there are interactive criteria subsystem with five various criterions. The evaluation of a degree of danger is executed on a three-level scale. Each level of danger is coded by the colour by a principle of a traffic light. For each level of danger in the rules the necessary operations of the attendants are adduced.

In a monitoring system there is also program complex of assessment worked out and forecast of residual resource of object, but its discussion leaves for frameworks of the given report.

The conditions of the real technological process are characterised by presence of large number of sources of noise signals that is not characteristic of use of an AE method at testing. These sources of noise have a various nature. The parameters some from them coincide parameters "classical" AE. Therefore correct determination of a nature of signals represents for systems of monitoring a serious problem. A classification of sources of occurrence of noise first of all was carried out. They can be divided into the following basic groups:

1. Electromagnetic interference.
2. Noise of technological equipment.
3. Noise of technological process.

The problem of protection from electromagnetic interference has been solved relatively easy. When the electromagnetic interference effect at a system, the signals come on some channels almost simultaneously. Such a signals are rejected.

For assessment of parameters of noise of technological equipment the special tests directly on the vessels were carried out. The technological equipment (pumps, compressors, valves) was actuated and was switched off under the special program. Thus the parameters of arising signals were analysed. The frequency of signals from basic technological equipment does not exceed 30 kHz. Besides the frequent spectrum of noise of technological equipment has uniform character. These data were used for construction of hardware and software filters.

The greatest difficulty is represented by noise of technological process. Such effects, as hit of drops of a product on a wall at filling of the vessel form signals, which are not

distinguished on parameters from true AE. For elimination of influence of this kind of noise it was required to set up systems on a feature of a design of each vessel individually, and execute the correlation analysis of AE signals parameters and parameters of technological process.
At the end of 1992, before fulfilment of scheduled inspection of the ethylene vessel was executed thermography inspection. It the results have shown presence on an external wall of two zones with reduced temperature (fig. 2, dark zones in a top).
It's clear, that the thermography data in themselves do not allow determining the reason of such phenomenon. The reduction of temperature can be called both leakage of a product or defect of a thermal insulation. During planned inspection was carried out internal ultrasonic testing (UT But any defects in these zones were not detected. The conclusion was made that the reason of lowering of temperature was subsidence of perlit in interwall space. Perlit was added in interwall space and vessel was handed in maintenance.
At the end of 1993 on the vessel was installed AE monitoring system. The system was detected increased AE activity (dark zones at the left above fig.1). The zones of AE activity on the internal wall in a top have coincided with zones with reduced temperature on an outside surface.

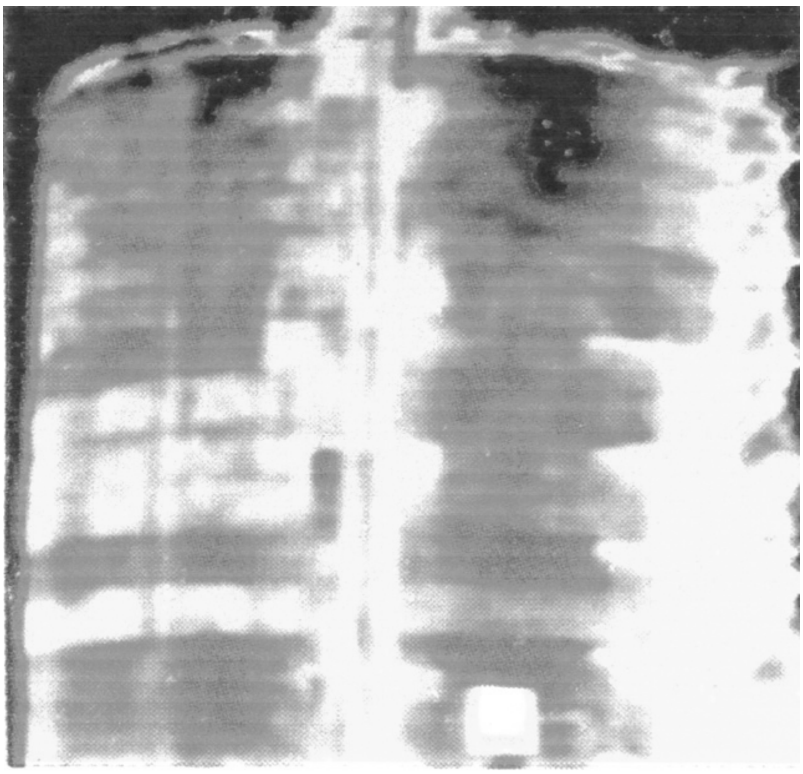

Figure 2. Thermogram of the ethylene vessel.

Pursuant to the rules of activity of AE monitoring system the staff of a plant has increased frequency of the analysis of concentration of a product in interwall space and has conducted the analysis of concentration with sampling of tests on forming of the internal tank. These data have shown, that the maximum of concentration is necessary above zones with the raised AE activity. Changes of concentration in time have coincided with changes of AE activity and with change of a level of filling (Fig. 3).

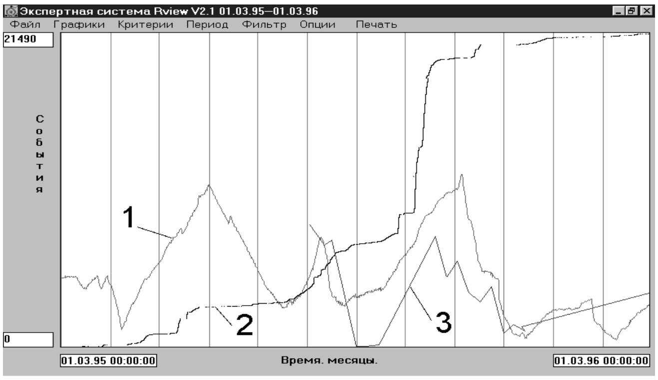

Figure 3. Trends

1 – Product level, 2 – AE activity, 3 – Product concentration in interwall space.

Criteria analysis of AE signals from suspicious zones attributes these signals to a category critically active. Pursuant to the operational rules a level of filling of the vessel immediately have begun to reduce. At lowering of a level is less than 30 % AE events do not register practically and concentration values also drop. It is offered to the owner of the vessel to limit a level of filling.

The most probably reason of the missing of a defect at ultrasonic testing is that UT was executed on the empty vessel. The absence of a load could result in "closing" the defects and they become invisible for UT. It proves higher efficiency of AE monitoring in comparison with traditional scanning NDT methods.

Installation of monitoring system has enabled not to shut down the vessels from 1992. As a result the significant additional profit is gained and the resource of the vessels is saved up. Besides safety of its functioning is essentially raised.

Now integrated condition monitoring system “Resource-2000” is installed on the 12 isothermal vessels with ethylene, propylene and ammonia. Number of AE sensors on each system from 40 to 90.

3. INTEGRATED CONDITION MONITORING OF THE REFINERY PLANT

At the end of 2003 we install integrated condition monitoring system “Resource-2000” on the catalytic reforming plant at JSK “LUKOIL-Permnefteorgsintez”.

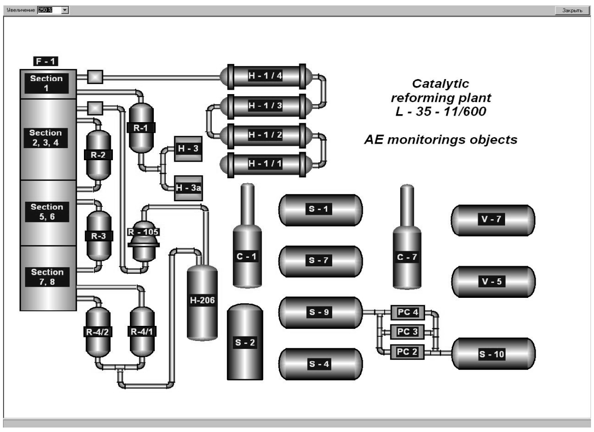

Figure 4. The schema of the controllable equipment of the reforming plant

This system supervises a condition of the 21 devices (reactors, heat exchangers, separators, refinery columns, etc.) and more than 900 m of technological pipelines (fig. 4). Total number of sensors – 411.
The choice of the equipment for the monitoring has been carried out on the basis of the analysis of risks on model Risk-Based Decision Matrix (RBDM).
The main equipment of reforming plant works at the temperature more than 500 degrees of Celsius. Therefore, for the long-term reliable work of sensors without decrease in their sensitivity they have been positioned on wave guides (fig. 5).

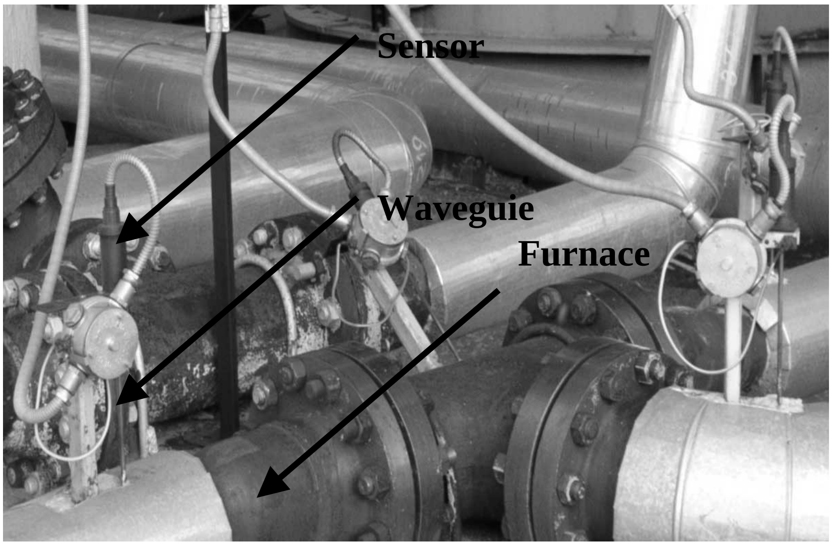

Figure 5. Sensors and waveguides

The design of wave guides has been calculated so that to provide effective transfer of an AE signal from object to the sensor. As a result we have amplification of a signal in a wave guide on 10-12 dB (fig. 6).

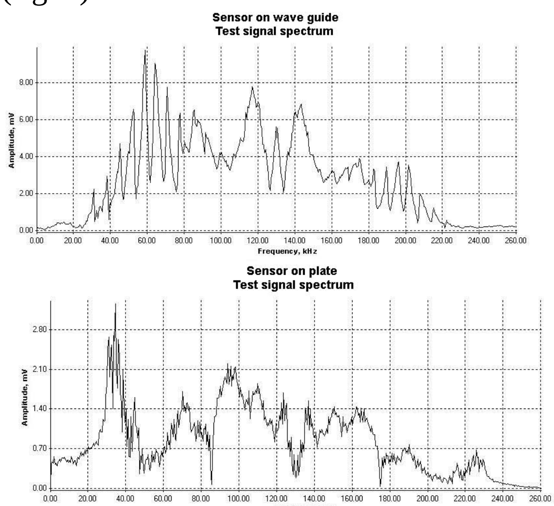

Figure 6. Signal propagation via wave guide

The refinery equipment contains a significant amount of sources of noise. It is not only compressors and pumps. There are a lot of another sources

For the effective separation of AE signals from high-level background noise we have developed programmed digital strip filters and have created a technique of their tuning up.
In each installation site of the sensor frequency characteristics of noise have been registered. Then programmed digital strip filters have been adjusted to suppress noise. As coefficient of the rejection of filters outside band pass is more than 50 dB per octave, we managed to achieve a comprehensible level of discrimination (fig. 7).

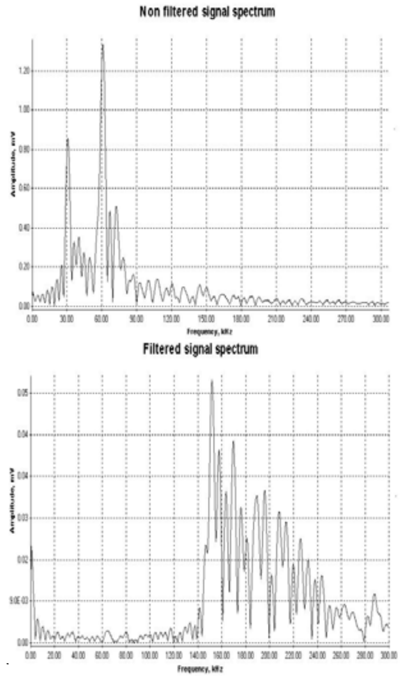

Figure 7: Noise filtering

At the analysis of data of monitoring in real time parameters of technological process of reforming are used. There are 90 parameters and they enter in the monitoring system from the control system via LAN. At excess by criterion of integrity of setpoint values the object on fig. 4 is highlighted by green, yellow or red color by a principle of a traffic light, and also the voice warning and an audible signal sounds. The signal system works until while the on duty operator will not enter the personal password and will not confirm reception of the information on a critical state of the equipment. The further actions of the operator are certain in rules of monitoring. It can be, for example, reduction in loading, switching to a reserve or shutdown.
For the analysis of data of monitoring by NDT experts they are daily transferred via FTP to the Alcor Corp. research laboratory which is located on distance more than 1200 km from the reforming plant. In this laboratory the detailed analysis of data is carried out, the reasons of occurrence of flaws are defined and the official conclusions are formed. These conclusions also contain recommendations to the personnel and management of a factory on performance of corresponding compensating actions.
The additional profit obtained because of increase of the reforming plant uptime, already practically has paid back expenses for installation of the monitoring system. Besides on one of heat exchangers the system had been found out internal defect (fig. 8) which development could cause serious failure. The defect and the reason of its occurrence can not be detected by usial NDT (ultrasonic or radiography) methods. It become possible only during continuous monitoring.

Figure 8.Internal defect on the heat exchanger cover

This example demonstrate a possibilities of the condition monitoring as the tool for proactive maintenance.

4. CONCLUSION

In the report are summed up more than 16 year successful experience of creation and use systems of integrated condition monitoring of the refinery and chemical equipment.
Long term continuous monitoring of bulk isothermal vessels has shown, that it is profitable way of boosting safety of such objects. For the fulfillment of examination of isothermal vessels by conventional NDT methods we have to release them from a product and to heat up from operation temperatures to temperature of an environment, and after examination to cool up to operation temperature. The effect of a thermal cycle from - 104 ºC up to + 20 ºC and back itself provokes occurrence and development of defects at this thin-walled tanks. While using monitoring system isothermal vessel works accordingly their actual technical condition. The resource of the equipment is increased, prolonging lifetime.
Integrated continuous monitoring of the equipment condition of large plants has even more advantages. Except for even more substantial growth of profit, it reduces requirement for additional natural resources (water, air, ground). Safety and resource of the equipment are increased. At decrease in energy consumptions for the unit of production the cost price drops. Environmental pollutions decreases. We consider, that this list of advantages will be added at the further expansion of application of strategy and the role of the condition monitoring as the tool for proactive maintenance will raise.

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