Acoustic Emission Monitoring of high risk installation in industrial environment

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Abstract

Acoustic Emission (AE) technology is widely used to control in service pressure vessel in a wide range of industry. Acoustic emission monitoring and its benefits have long been known and utilized by many industries to optimize the use of structures, increase operational safety, and to save money through effective condition assessment and maintenance. The application and acceptance of AE monitoring within the civil engineering industry has greatly expanded in the past few years [1].

Among the technological progress of AE it is possible to apply the technology in Atex environment with industrial process giving some genuine information on propagating defects even in refining and petrochemical plants. The monitoring of critical equipment allows an early detection of significant defects and the ability of following their severity in service to give an alarm to improve the safety of equipments and particularly piping systems.

Some industrial examples are given in this paper to shed into the light the return of experience on AE long term monitoring.

AE technology is used: to give an in situ diagnostic, to prevent catastrophic ruptures, to help to reduce maintenance costs, and to avoid shutdown with assessing risk based inspection.

Keywords— Acoustic Emission; Monitoring

I. INTRODUCTION

Cracks or significant defects are detected during periodic inspection by traditional techniques like ultrasonic or radiography or other NDT technics. Then raise the problem of decision to take with only the size of the defect and a lack of information about the kinetic and the raison its origin. Furthermore a repair could be difficult to achieve due to production constrain or metallurgical problems. In some case, a specific study has to be made before repair to collect information about metallurgical local process conditions. When a monitoring of the defect kinetic propagation can be made, it gives genuine indications and increases repair efficiency. We have implemented acoustic emission into a Total refinery in this perspective [2, 3, 4].

II. PRINCIPE OF THE MEASUREMENT

Acoustic Emission (AE) is the result of sudden energy release within a material, which appears as elastic wave. This technique is widely used as a non-destructive testing technique for fitness for service evaluation in industrial field. AE is also a powerful tool to identify, localize and understand damage initiation and propagation. Most of all microscopic mechanisms has been studied and correlated with AE signals.

Many developments in AE technology, mainly developments in AE instrumentation, have occurred in the past ten years. Analytical calculations, in some cases, result in the combination of theoretical solutions with signal analysis. However, this technique is mainly experimental based, the best tool for signal analysis is still source recognition and database files.

That is why, tools based on signal pattern recognition have been use to allow complex problem analysis (multi source and different propagation patterns). Traditional analysis based on location can be performed by discarding AE signals or noise from outside the monitored area. A multi parametric analysis using pattern recognition and neural network via Noesis software was performed to isolate signals such as delamination and define a real-time criterion based on AE features [5]. Nevertheless, in order to feed any pattern recognition analysis different experimental measurements have been made on samples and small structure to feed the data base which used in real time.

III. INSTRUMENTATION

Two different parts of piping were monitored with almost the same difficulty from AE point of view. High rate of vibration and turbulence coming from steam flow and a leak in case 1, and from process flow and unit in case2. Both cases were located in a refinery environment.

To overcome difficulty of industrial environment, a specific instrumentation has been defined after a preliminary background process and environment noises measurements.
Atex sensors are glued on steel waveguides (fig.1) which are surface welded on the pipes (wall pipe temperature above 250°C for both cases). The MISTRAS ISR50 sensors where used based on several research and development programs. It was already proven that stress corrosion cracking can be detected by AE in steam flow environment [6, 7]. Then the signal is preamplified with Atex preamplifier and driven by a specific cable outside the Atex area. Figure 2 is showing the acquisition system a MISTRAS PCI2 eight channels AE system.

Systems are powered by an uninterruptible power supplies system to prevent loss of powering and insure a better parasitic noise rejection.

Figure 1: case 1 AE instrumentation on a high pressure steam T shape piping.

Figure 2: Case 1 AE instrumentation outside hazardous area: AE system/UPS and Zener barriers.

The sensor coupling is checked with Hsu Nielsen source. Neighbor’s sensors receive the transmitted elastic waves and allow verifying the good transmission and the ability to process localization of AE events.

Preliminary monitoring is first conducted to define an appropriate procedure, to choose and adapt AE instrumentation and appropriate signal processing to eliminate as much as possible process noise in real time. The size of the files in term of megabits and times are computer controlled in order to secure data files and facilitate the periodic transfer to Mistras monitoring department.

Post processing is computed with pattern recognition analysis to eliminate remaining noise. In addition to traditional frequency filters (analog + digital), multiparametric front end filters have been used in real time to reduce the noise activity and by the way the amount of AE data.

IV. RESULTS

A. History case 1: high pressure steam line.

A leak has been detected in a high pressure steam line and a reinforcement system has been set to tie up the leak (fig1) until the next maintenance turnaround. The thermal fatigue crack has been sized and fracture mechanic processing has been performed. The reinforcement induced by this reinforcement system and specific stiffener has been added to insure the resistance of the T shape piping in case of crack opening.

The high pressure steam line is crucial for the plant operation and the piping could not be repaired without a long duration shutdown, this should be place during a general turnaround of the refinery Nevertheless to continue to operate in safe conditions, a crack assessment should be made. The reinforcement system do not allowed to perform any traditional NDT, and only AE can be carried out to insure a follow up of the crack and its eventual propagation.

The monitoring starts in September 2014 and still is ongoing. First, the AE signals related to crack propagation is limited. Two periods of AE high activity trigger alarms. Both periods have been correlated with specific conditions of operation. Numerous pressure trips correlate with alarms on AE monitoring.

Then a slight modification of the piping system have been found to equilibrate the pics of pressure. Since, the AE signals have been greatly reduced, given an evidence that the equilibration bypass solution is an effective solution. This EA monitoring delivered a strong follow-up of the crack evolution during the time, and bring elements in linked to the process which help the team to mitigate the damage.
B. History case number 2: T shape process line on hydrodesulfuration unit

During unit operation some thermal fatigue cracks have been found in the circumferential welds on a high temperature T shape piping. In thus T piece, blending of a hot and a cold hydrocarbon fluids is made. This part of the pipe give raise of high vibration regime. The vibration level in this area is measured punctually with accelerometers. To reduce the amplitude of vibrations some supports have been modified giving a significant reduction of the vibration amplitude.

At this point team decided that welds of this zone has to be to be monitored by AE (fig 4) to ensure the unit was operated in safe conditions.

The level of the turbulence noise is very high in this area due to the mixture of the two different flow. Nevertheless we were able to detected by AE significant events and confirm that there is still crack propagation in some welds areas. The position of some located event are shifting along the time of monitoring. That's indicates not only circumferential welds are affected, but also the weld on the vertical part of the T is cracking too. This result was not attempted by the team.

Figure 5 give an example of a location map of the data collected during 10 days. A parametric study of signal crack propagation indicates that process temperature variations influence more crack propagation than process pressure trips.

According results, the team decided to stop unit and implement design modifications of the T shape piping to mitigate the turbulence flow. Further metallurgical expertises of this T-shape pipe confirm the cracks propagation, and especially in the vertical part where crack has been never seen before (figures 7).

After modification of the line, the diameter of the pipe has been significantly increase (figure 6).

The AE monitoring system was installed again. The first AE results show a significant reduction of measured process noise (~ 6 dB).

At the beginning of this new monitoring, residual AE event are still detected and located in the welded areas showing some stress releases in the new welds. As we get some
suspicious signal at the extremity of the sensor array, near channel 1 and 2. After that, two complementary sensors 7 and 8 have been added in order to characterize the suspicious acoustic emission sources. The monitoring continue until AE decrease is considered as non-significant some weeks after.

The monitoring of the new configuration (AE showing the absence of crack propagation) and NDT controls have both used to validate the new design.

The Acoustic Emission technology has proven to be a very valuable tool in the damaged piece assessment. Long duration monitoring periods have been conducted with success in very difficult environment i.e. high temperature, high level of process and environmental noises and Atex areas. It has provided invaluable information regarding how process conditions could impact damaged piece. This information were used both to adapt process conditions and to understand better influence parameters on the damage.

EA technology was successfully used for crack detection and for monitoring the kinetic of propagation of a crack into industrial unit pipe system. After pipe system modifications, AE has also confirmed the efficiency of the new design regards to fatigue crack susceptibility.

The acoustic emission on-line system has tremendous potential in monitoring integrity of high pressure industrial equipments and provided data are properly analyzed. EA should be considered as an advanced technology to give an assessment, when other NDT are ineffective.

Figure 6: case 2 new design and new installation of AE sensors.

Figure 7a: position cracks in the welds

Figure 7b: Die penetrant testing of the root pass of the weld of vertical section and weld cross section with a crack position cracks in the welds

V. CONCLUSION:

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