Acoustic Emission Monitoring during Cool down of Refinery Processing Reactors

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Motivation - Necessity

REACTORS: High Temperature Process vessels that use catalyst for reaction. Cost of catalyst is the key parameter for not opening the vessels for internal inspection. Size, Insulation and temperature makes On Stream inspection challenging...

Acoustic Emission Testing can be applied very efficiently in order to detect active flaws in the structure, by taking advantage of the thermal stresses during cool down.
According to ASTM, the term Acoustic Emission refers to “the class of phenomena whereby transient elastic waves are generated by the rapid release of energy from localized sources within a material, or the transient waves so generated”.

DEFINITION AND BASIC PRINCIPLES
BURST TYPE ACOUSTIC EMISSION

Shock wave detected by sensor

Crack initiation
LINEAR LOCATION OF SOURCES

Source Close to sensor 1:
Note the difference in arrival times

Source in the middle:
Time difference equals zero

\[ X = \frac{1}{2}(L - V\Delta T) \]
COOL DOWN MONITORING

- Cool down monitoring is typically performed on THICK WALL high energy piping (EPRI recommendation) or reactors (ASME V) as they are taken out of service and cooled down for turn-around maintenance and inspection.

- As the internal temperature drops (the internal pressure is held at the operating level), a thermal gradient is established through the vessel wall.

- The higher the cooling rate, the higher the gradient. The thermal gradient gives rise to thermal strains that add to the existing hoop and longitudinal strains.

- The ideal cool down test is one where, for a given internal pressure, the thermal gradient stays within limits that correspond to 110% and 150% of normal operating load.
Advantages & Limitations of AE

Minor Disturbance of Insulation

First results and condition information are available just before the maintenance.

Positions of active sources can be located for follow up or for further continuous AE monitoring.

*Flaws in unstressed areas and passive flaws (structurally insignificant under the applied load) will not generate Acoustic Emission.*
TEST PREPARATION AND SETUP

- Operation and Design Review (Especially Seam Location)
- Review Case History
- Design Sensor and Cable Layout
- Install Waveguides, Sensors, Cable and Instrumentation
- System Verification
- Background Steady-State Monitoring
Vessel Setup

Acoustic Emission Sensors are placed evenly on the vessel shell in order to have full coverage.

Special waveguides are used to reach the shell through the insulation.
Data Acquisition

AE data are acquired before cooling to record any environmental noise.
Actual AE test starts with the cooling process.

Reactors Vessel Internal Temperature vs Time.
Red mark indicates the actual AE Cool Down monitoring start.

Vessel Activity and Internal Temperature VS Time.
### SOURCES OF ACOUSTIC EMISSION

- Mechanical Discord
- Steam Flow
- Crack Growth
- Crack Face Rubbing
- Oxide Crushing at Metal Interface
  - Sources Discriminated by Amplitude & Signature
  - Correlation with known location (hangers, elbows, wye blocks and reducers)
  - Source location of AE signals
AE SIGNATURE & SOURCE CHARACTERIZATION

- 1 to 400
- 0
- >400

- Amplitude
- Energy

- A
  - Crack like
- B
  - EMI
- C
  - Mechanical rubbing
- D
  - Leak Noise

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Analysis

Noise (strong wind, electromagnetic interference, nearby operations etc.) can affect the acquired data. Special filters can distinguish irrelevant noise and clear the actual AE data.
Results

AE sources are located and graded based on a scale between “A” (good condition) to “E” (bad condition).
## Recommendations

<table>
<thead>
<tr>
<th>GRADE</th>
<th>COLOUR</th>
<th>INTERPRETATION</th>
<th>RECOMMENDATIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Green</td>
<td>Very Minor Source</td>
<td>No action&lt;br&gt;Results recorded for further test</td>
</tr>
<tr>
<td>B</td>
<td>Cyan</td>
<td>Minor Source</td>
<td>Visual inspection&lt;br&gt;Surface defect such as corrosion, pitting, gouges and cracked attachment welds etc.</td>
</tr>
<tr>
<td>C</td>
<td>Magenta</td>
<td>Source</td>
<td>Defects requiring immediate or short term follow-up evaluation. Evaluation may be based on further AE data analysis, retest, or complimentary NDE by other NDT methods or AE re-examination.</td>
</tr>
<tr>
<td>D</td>
<td>Yellow</td>
<td>Intensive Source</td>
<td>Significant defects requiring immediate follow-up inspection using complimentary NDE methods.</td>
</tr>
<tr>
<td>E</td>
<td>Red</td>
<td>Critical Source</td>
<td>Major defects requiring immediate shut-down and follow-up NDE.</td>
</tr>
</tbody>
</table>
Reactor Cool Down - Case Study 1

- Tested 4 reactors simultaneously
- Operating at 500°C
- Works and other problems hampering BGN
- 2 preparation visits. Everything planned and prepared in advance.
- Sensor mounting on 30-50cm waveguides
- Setup in 3 days.
 Various sources on all reactors.
• Analysis difficult.
• Relied on located sources and source grading
• One zone graded D and another source graded C.
• Follow-up (UT) found 150mm under-surface crack (2mm deep).
• Other indications partial follow-up. No further findings.
Case Study 1

Re-test after repairing.

Monitoring of the specific area in order to verify that the repair was successful and no active indication is present.

In addition the whole structure is monitored in order to locate any active source that might be present to the rest of the vessel.
Case Study 1

Overall, the closely monitored areas of the top head did not have any significant activity, thus we can conclude that the specific area had been successfully repaired since no active sources (older or newer one) are present.

The North side area of the vessel that appears to have a multiple clusters of located AE events was reported to the vessel owner and, at the moment of authoring, was pending follow-up inspection, with insulation removal and internal inspection.
Case Study 2

During a past routine inspection of the welds of the quenches/nozzles to the shell of a large reactor using the PA method, a large volumetric indication was discovered.

No repairs were performed at that time and it was decided to re-inspect in a future shut-down.

16element 2.25MHz PA probe used originally did not permit accurate sizing and discontinuity characterization (cladding details unknown at the time)

Two years after, AE monitoring was performed in the nozzle area during cool down of the reactor, in order to monitor the flaw and assess its criticality, as well as to correlate with the pending UT follow-up and to obtain an AE “signature”.

Case Study 2

The monitored area was covered by nine (9) AE sensors attached on waveguides, surrounding the area with the volumetric indication.

The AE monitoring didn’t reveal any significant activity.

Immediately after, a PA UT re-inspection was performed, in order to compare with the findings of the initial test and to assess any growth of the discontinuity.

UT re-inspection also did not reveal any growth in the dimensions of the flaw, and also didn’t show any problem on the cladding.
Case Study 2

Sources located in the monitored area were graded with a low ("A") MONPAC grade.

Some activity was also recorded and located on a nearby area (about 30cm clockwise) possibly caused by the existence of internal attachments.

This activity also produced located sources that were also graded with a low ("A") grade. This activity does not necessarily indicate discontinuities.
Conclusions

- Unique opportunity to inspect globally and with minimum interference the high temperature thick-walled vessels with guaranteed minimum or even no downtime at all.
- Results of the test can be given almost immediately, within a few hours after test, thus providing a great assistance to the general operations regarding the vessel.
- Follow-up local inspection in the areas indicated by AE may be, immediately performed after the test, and any repairs may be scheduled within the shut-down period.
- Identification of the critical areas, result in major cost savings with respect to maintenance/repairs and minimizes the risk of not identifying areas that can result in failure in the long run.
- All advantages can be further expanded and enhanced with the option of installing a permanent AE monitoring system with remote access functionality, in order to monitor the vessel during in-service operation and/or prolonged time periods.