ADVANCED REAL TIME SOURCE LOCATION APPLICATIONS

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Abstract

New location algorithms have become available to make use of the full waveform as it is now often recorded during AT testing. A process known as Timing Strategies can lead to more accurate and reliable location.

In addition to that, tools for attenuation correction and for an efficient analyses of the located events are discussed.

1 Introduction

Waveforms are ever more becoming part of the standard acoustic emission data-set as it is collected during an AT test. Simultaneously with this, there are new location algorithms becoming available that make use of this rich new data source. These methods are based on a simulation of different wave modes. The location results from these modes compete with each other for maximum location accuracy.

Location becomes very powerful if it is combined with attenuation corrections and a set of tools for data analyses. These tools show the hits and waveforms behind the events and enable an efficient evaluation of the results.

2 Advanced technology for real time location

Before entering into modern location techniques, there must be some understanding about the different modes that are possible in a test piece. Also the different velocities that belong to these modes must be known. Classical wave theory and dispersion curves can help in many practical cases in order to make an estimate.

A second step is then to put these estimates into a location program. Many combinations of different wave modes and velocities are possible so a very flexible algorithm is required.

Then as a third step the delta-t's from waveforms are extracted and a best fit location can be calculated.

2.1 Dispersion curve simulation and use in acoustic emission location

In 1917 Horace Lamb described what later became known as Lamb waves; these are waves in thin plate that are dispersive. For practical cases at plate thickness below approximate 2x the wavelength the group velocity becomes very much dependent on the frequency at a given thickness so most acoustic emission applications are affected.

The dispersion curve gives a description of the velocity vs the frequency x thickness. These curves can be simulated with dedicated software. For practical applications it

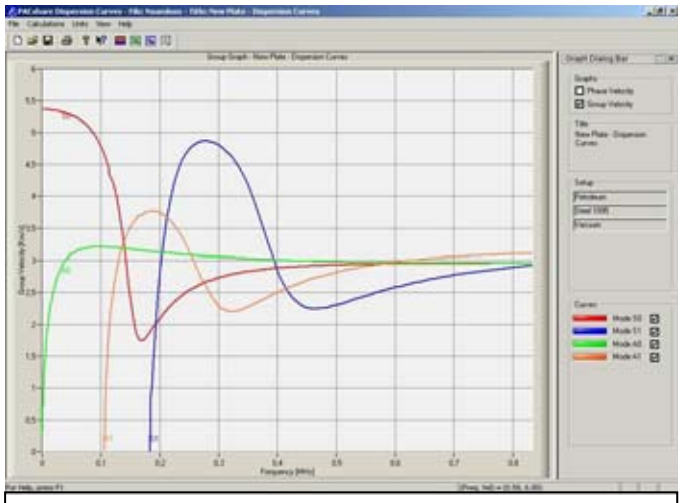

Figure 1 Dispersion curve for a wall of a storage tank

is important that the software supports multiple layers, including fluids on the end layers. Real structures many times have a fixed wall thickness so a velocity vs frequency plot is a preferred presentation.

As an example of the use of a dispersion curve we can consider figure 1, the curve for a steel shell of a storage tank.
From the dispersion curve in figure 1 we read that for there are at least 3 interesting area's:
a) At low frequencies, say up to 100kHz, the fastest mode is So at roughly 5400m/s, this will be the first wave that comes at the sensor after what is left of the longitudinal wave.
b) At high frequencies, say from 700kHz upward, all the modes go to roughly 3000m/s or just below the shear velocity.
c) At a triple point 3 modes have the same velocity: say 130-150kHz at roughly 3200m/s.

There are more velocities involved and not all modes have the same energy. For example the Ao is known to be very strong at very low frequency however with the low velocity that part will only turn up near the end of the hit. However as an example of how to use waveform location techniques, these three area's will serve the purpose in the next part.

2.2 Timing strategies, use of waveforms for location

Delta-t values are defined as the time from the first hit of an location event to the time of the hit where the delta-t belongs to. During the location process, a list of hits is considered for an event and the delta-t values are used to calculate a source location.

Sensors can belong to one or more location groups (each of them having the possibility to use different location types) and events can be shown for one or more groups.

All new multidimensional location methods use a NLR (non-linear regression) method to calculate a "best fit" least square value between observed and calculated delta-t values. As a search method, standard methods are used that are specially adapted to acoustic emission.

Timing strategies describe how to derive specific delta-t values from waveforms and what velocity to use for the location.
Each strategy tells how to handle the waveform, there are options for using

- digital filtering
- threshold setting that differs from the test threshold
- first threshold crossing or peak timing
- different velocities
- real-time or post processing

Several strategies at the same time are possible, so it is for instance possible to use different velocities within one location scheme.
The results of all the strategies are put into the location process and they compete to get the best fit for the final location. It is possible to

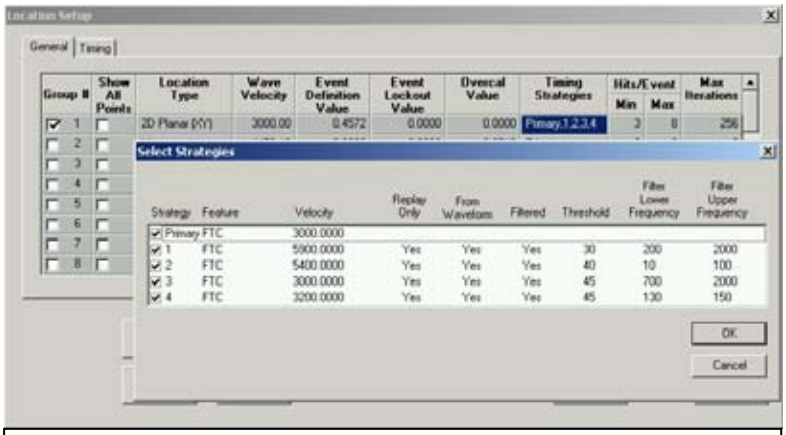

Figure 2 Timing strategies

show the results of different strategies side by side in order to be able to interpret what is happening in the test structure.

In figure 2 the example from 2.1 is implemented: on the first line we have a primary strategy for general use at 3000m/s (like normally used in the old style location), the second line shows a strategy for detecting the longitudinal wave, the following 3 strategies are for the So, for the “all modes at high frequency” and for the triple point.
Working with these strategies provides a means to get different modes located and evaluated so the most accurate location is achieved at the end. The program allows seeing the original waveforms for each located event and it also can show the filtered waveforms.

All this can be done in real time or post test and if needed with different settings.

3 Attenuation

In order to evaluate located acoustic emission results it is in many cases very useful to know how much the signal has been attenuated. One example is prEN14584 (in progress) where an amplitude correction is required for evaluating planar location results.

3.1 The attenuation curve

A first step is always to generate a representative attenuation curve. In the curve the Hsu-Nielsen source amplitude at different distances from a sensor are shown. Modern localization programs allow to enter these values and to visualize the curve and the maximum distance where the signals are still detected at a given threshold.
Also an attenuation over a weld that is crossed can be entered and accounted for.

3.2 Mapping attenuation

Once the attenuation curve is known it can be used to see how well the sensors on a structure cover the structure. An example is shown in figure 3, the sensor positions are shown, the colors show how much the attenuation will be. It is also possible to map a given source and see how the signal attenuates through the test structure.

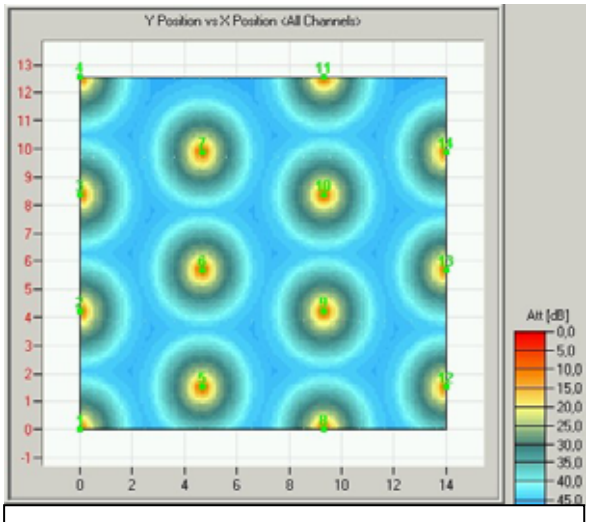

Figure 3 Attenuation map

3.3 Source amplitude correction

With the attenuation curve data it is possible to perform real time source amplitude correction. This allows evaluating the data during a test according to new standards without getting into complicated calculations, this will leave more time for assessing the data in real-time.

4 Location analyses tools

Location is not finished once the dot with the position is put on the computer screen. In most cases this is where it all begins: how does one evaluate the events that are indicated?
Two tools are described below that have proven in the field to be very efficient; in many cases they have more than decimated the time used for evaluation compared to the previously available methods.

4.1 Hit - Event linking

Hit – Event linking allows graphically selecting a group of points in a plot and seeing the raw data. Available are: a listing of the ae characteristics combined with the delta-t values, the corrected source amplitude, the waveforms of the hits that constituted the event, the influence of the strategies etc..
An example is given in figure 4, the points in the green rectangle are shown in the listing, the waveform of the point with the crosshair is shown. In location the waveforms of all hits are shown together.
Hit - Event linking gives a quick link for each single event between the presented location and the underlying data. This makes it very useful; in an evaluation of the events that have shown up during a test one wants to be able to differentiate between for instance crack growth and noise.
The user can go step by step though the data and also there is a graphical link so it is possible to see where the event is plotted in correlation plots.

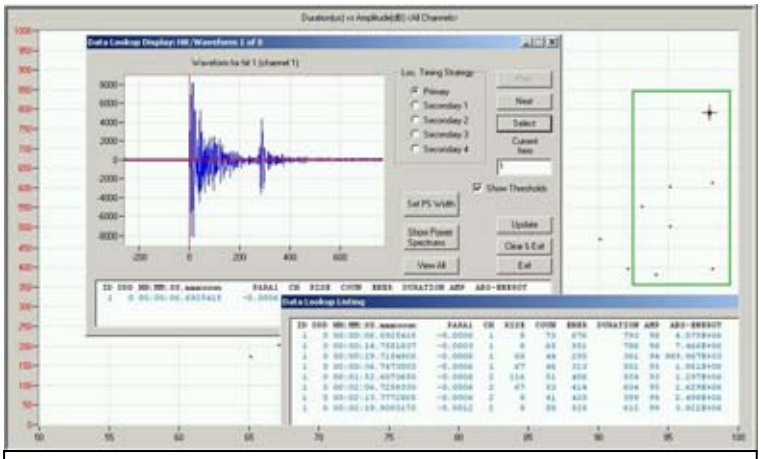

Figure 4 Hit – Event linking

4.2 Cluster and Area History filtering

Cluster and Area History filtering makes it possible to evaluate a group of events as a whole. It works similar to the usual clusters where it was possible to look at an activity plot for a certain cluster. The difference is that this can be done now also by manually clustering and the plot can be any user defined type of plot. This enables the test engineer to quickly look if a concentration of located points in an area on a vessel is only very low amplitude or if it for example originates from opening a pressurization valve.

5 Conclusions

More than ever there are features available to the location software user. These can improve the location accuracy and make the evaluation of the results more reliable and efficient.
Real time waveform extraction combined with flexible threshold and other settings makes it possible to deal with the different modes that are many times present in a structure.
Attenuation corrections help in a more accurate evaluation of sources. Hit-Event linking and Cluster/Area filtering are two tools for looking at the raw data that is behind the event.
Analyzing data with these tools have made data evaluation very efficient.

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