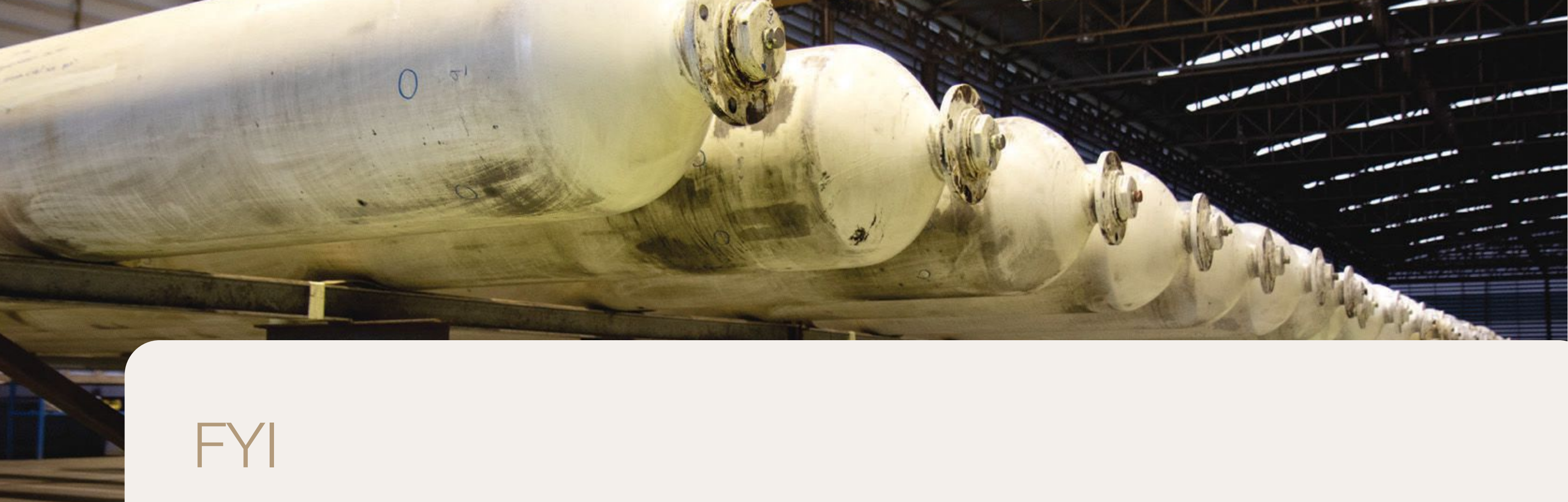


FYI

Basics of AE Analysis for Field Testing: Part 2

by Stanley F. Botten

Editor's Note: *This article has been divided into two parts. Part 1, published in April 2021, included a basic description of the acoustic emission testing (AE) method and other important factors. Part 2 will discuss the various materials used in construction, including both metals and composites, and the influence they have on the AE data.*

Metal Materials

Discontinuities (such as cracks, inclusions, and other defects) in metals can be revealed by the detection of plastic deformation development around them. At the crack tip, stresses can exceed the yield stress level, causing plastic deformation (Figures 1 and 2).

The size of the plastic zone can be evaluated using the stress intensity factor *K*, which is the measure of stress magnitude at the crack tip:

$$r_y = \frac{1}{2\pi}\left(\frac{K_I}{\sigma_{ys}}\right)^2$$

where
r_y is the plastic zone size in elastic material.

The critical value of the stress intensity factor, KIC, is the material property called fracture toughness (Figure 3). The behavior of the discontinuity and its corresponding acoustic emission hit signature is also influenced by other conditions, both in service and within the metallurgical structure itself.

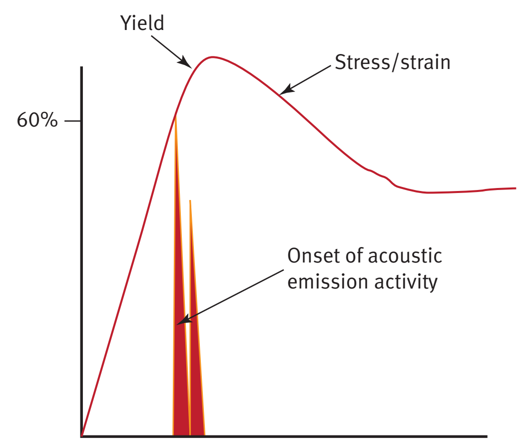


Figure 1. Stress/strain versus acoustic emission activity.

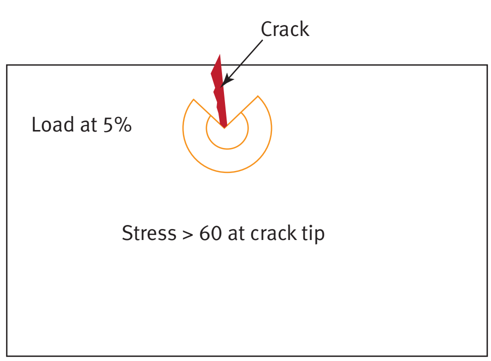


Figure 2. Crack tip stress.

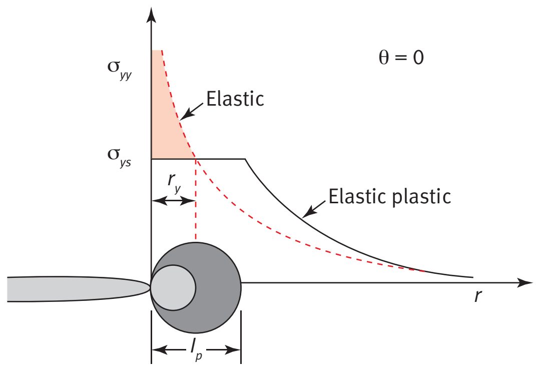


Figure 3. Fracture toughness.

Figures 4 through 8 show some examples and the typical signatures from these cases. To evaluate the acoustic emission data that is recorded in a tabular format, real-time plots called "correlation plots" are used to show the relationship between the amplitude versus the energy and duration of the hit. Figure 9 shows a typical correlation plot of the acoustic emission hits recorded during an AE test. It is noted that several types of acoustic emission sources can be identified from these graphs.

Composite Materials

These materials are regarded as nonhomogeneous and typically contain two or more components in their makeup. For example, fiber-reinforced plastics (FRP) contain both the fiber and the bonding resin, and concrete will have sandstone and cement along with possible steel reinforcing it. Therefore, the sources of acoustic

(a)

(b)

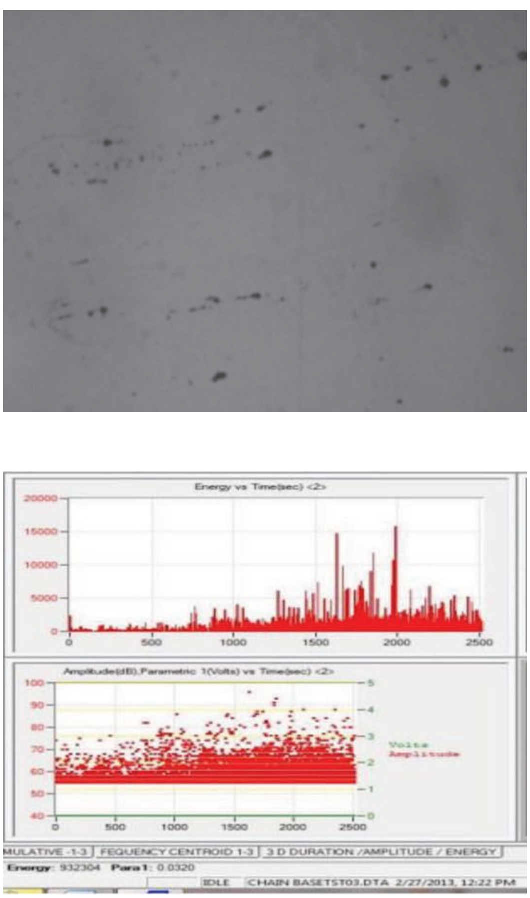


Figure 4. Nonmetallic inclusions: (a) in carbon steel; (b) acoustic emission activity.

(a)

(b)

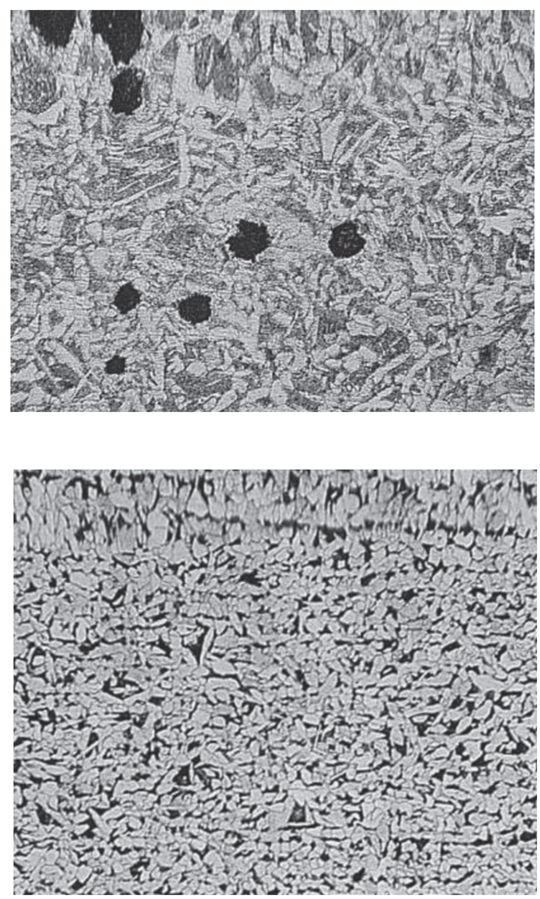
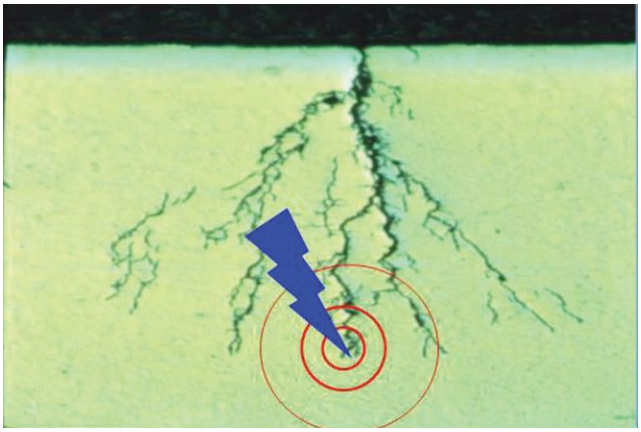


Figure 5. Microstructure of (a) 35-year-old steel; (b) nonaged steel.

(a)



(b)

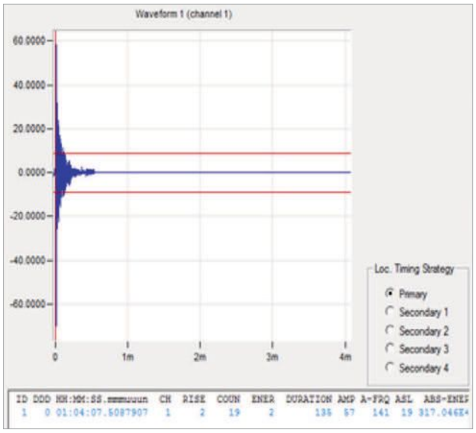


Figure 6. Stress corrosion cracking: (a) in stainless steel; (b) typical acoustic emission waveform.

emission activity may be complex. In addition to this, FRP tends to be viscoelastic and does not exhibit the same elastic behavior as steel.

The following is a short discussion of some of the types of acoustic emission activity that will be encountered during the AE of structures that use this type of material (Figure 10).

It is important to understand that each failure mechanism has its own acoustic emission signature, and it is strongly advised to follow ASME Section V, Article 11 (ASME 2019a) or CARP (Committee for Acoustic Emission in Reinforced Plastics) (CARP 1987) procedures when conducting an AE test of this type. Numerous studies and research have gone into the setting of the accept/reject criteria and recommendations in these procedures.

Types of Acoustic Emission Activity

The amplitude of the AE sensor response to the stress wave received is very much dependent on the following factors:

- Distance: the distance from the source to the AE sensor.
- Attenuation: the attenuation of the stress wave is a function of the absorption of the hit energy by the material carrying the hit. Coarse grain = high attenuation; fine grain = low attenuation.
- Frequency: the acoustic emission stress wave at the source is broadband in frequency. Therefore, in order to detect and measure the acoustic emission hit, special-frequency bandwidths are used during data collection to avoid background noise

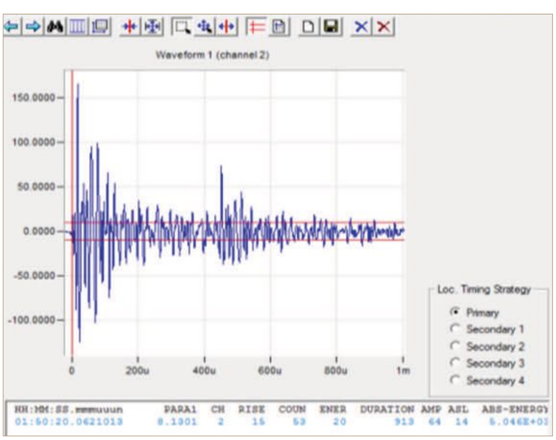


Figure 7. Corrosion activity on steel wire rope.

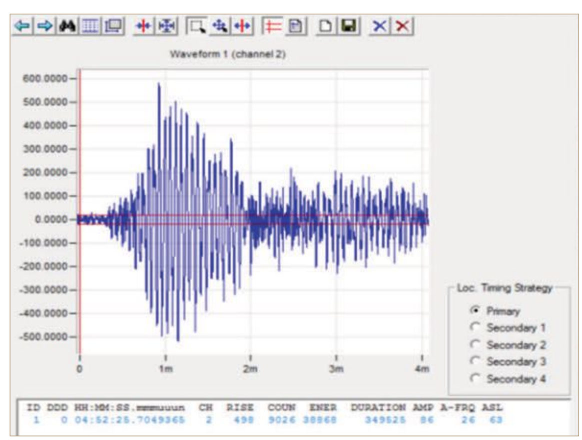


Figure 8. Failure of strands in steel wire rope.

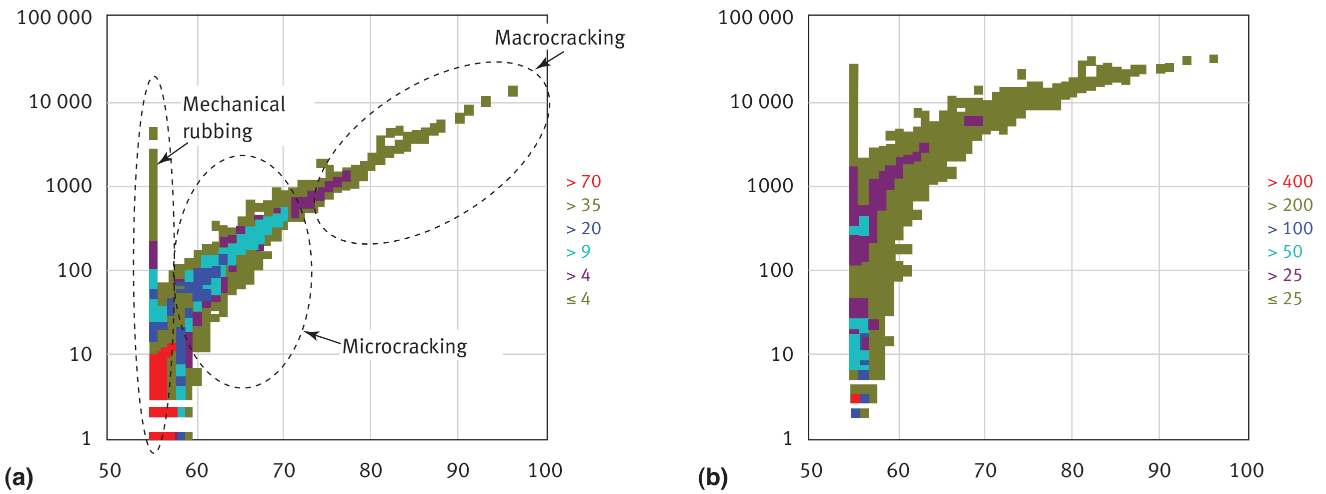


Figure 9. Correlation plots of the acoustic emission hit data showing mechanical rubbing, microcracking, and macrocracking: (a) energy versus amplitude versus hits; (b) duration versus amplitude versus hits.

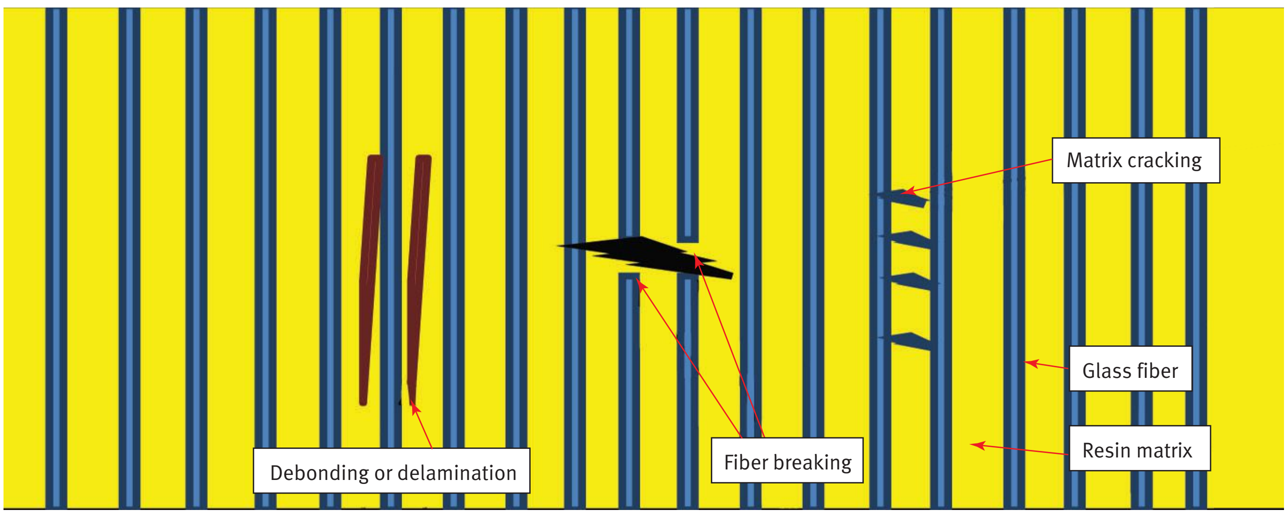


Figure 10. Typical discontinuities in fiber-reinforced plastic material.

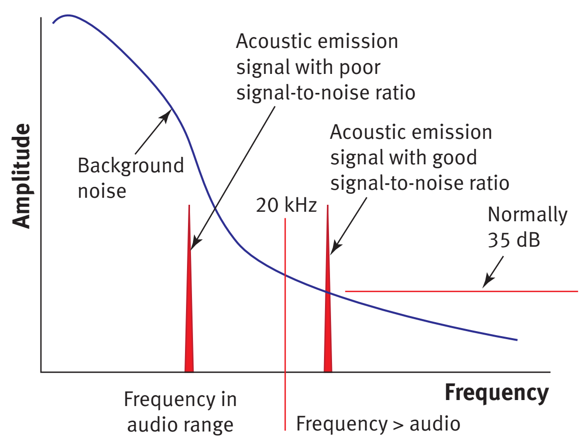


Figure 11. Noise frequency in field operations.

sources. The choice of the bandwidth used in the data collection should consider the effect of the frequency on the attenuation, thus reducing the effective sensor-to-source distance. The higher the frequency of the bandwidth that is used, the greater the reduction on the sensor-to-source distance.

Most common background noise sources are in the audio range of below 20 kHz. For normal field testing, the range is typically 100 to 300 kHz, where a typical 150 kHz resonant transducer is used. This restricts the source-to-sensor distance to approximately 20 ft (6 m) in steel. In special cases and where the environmental noises allow lower frequencies, bandwidths of 20 to 100 kHz can be used with a 60 kHz resonant transducer. On average, this will increase the source-to-sensor distance to 40 ft (12 m) in steel under the same conditions. Under extreme conditions, AE monitoring can be done with bandwidths as low as the 10 to 20 kHz range by using 30 kHz resonant transducers with the knowledge that low-frequency background noise levels are likely to make interpretation of the AE data difficult.

Crack Sizing Using AE

It is particularly important to understand that without very extensive study of the acoustic emission signature from a specific material and crack size, it is impossible to estimate the size of the crack from the hit data. However, when using a controlled stimulus (such as load or pressure), the acoustic emission activity and signature is a reliable tool to determine if the discontinuity detected is critical to the operation of the structure. For this reason, the structure being tested is always loaded in stages. For example, in ASME Section V, Article 12 (for new and in-service structures) the typical load schedules are recommended as shown in Figure 11 (ASME 2019b). More details about the loading procedure are available in Article 12 (ASME 2019b) and MONPAC procedures (Fowler et al. 1989).

Conclusions

Many papers have been published concerning the advantages and disadvantages of the use of AE as an NDT tool. However, many of these papers fail to reference the material factors and their influence on the results recorded and the interpretation of the recorded results. AE practitioners who have many years of experience in conducting AE tests in most cases realize this, but nothing to date has been published concerning the factors that determine the success of the use of this method. This paper is an attempt to clarify the data analysis process and lead to better results.

AE has now come of age, and it is important to note that the success or failure of a test is in the hands of the user, and not the instrumentation or the software. ●

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