High-precision source location of AE event using automatic error correction of signal rising time

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ABSTRACT: Correspondence between the signal arrival time and ultrasonic wave mode is often unclear under noisy environment. In this study, a novel signal analysis method for high-precision source location of AE event is developed. Multiple arrival times are detected by AIC picker. Correspondence between the detected arrival time and ultrasonic wave modes is established in the consideration of experimental conditions. Contribution ratio of each data of signal arrival time to the total error is checked. Low quality data including large error is eliminated and miss correspondence between the signal arrival time and ultrasonic wave mode is corrected.

1 INTRODUCTION

Determination of arrival times of AE wave to each sensor is essential for source location of AE events. In the simplest method, trigger time of AE hit, *i.e.* the time when AE waveform crosses a preset threshold voltage can be regarded as the arrival time. However, this method is not so precise in many cases. Meanwhile, manual determination enables better precision than the threshold crossing method. However, automatization is impossible in this method because the diagnostic criterion of the arrival times is obscure. Here, Akaike's Information Criterion (AIC) picker is one of solutions of this problem, *i.e.* realization of precise and automatic arrival detection. Maeda *et al.* developed a direct computation method of AIC value from seismic waveform [1]. Kurz *et al.* applied Maeda's method to AE waveform [2]. Sedlak developed two-steps AIC picker for better precision [3]. In Sedlak's method, AIC picker is applied twice around the trigger time. In the first step, AIC picker is applied to AE waveform before and after several tens of microseconds of the trigger time. Then, in the second step, AIC picker is applied again to a smaller range of waveform around the detected arrival time in the first step. Current version of our in-house developed AE measurement system "Continuous Wave Memory" (CWM) includes the Maeda's and Sedlak's algorithms.

AE wave is an elastic wave which propagates in solid materials. Therefore, multiple modes of waves with different velocities are included in AE waveform. For example, longitudinal wave, transversal wave and some types of surface waves are observed in bulk specimen. Lamb wave is dominant in thin plate. Lamb wave includes symmetric (S) and asymmetric (A) modes where the top and bottom surfaces vibrate symmetrically and asymmetrically, respectively. Therefore, discrimination of these modes is important for precise AE source location. When the signal-to-noise ratio (SNR) is sufficiently high, a sharp rising edge can be observed in waveform and the earliest signal arrival can be detected easily. However, often SNR is low in practical AE measurement and precise detection of arrival times becomes difficult. Therefore in this study, a novel arrival detection method with automatic error detection and correction was developed for high-precision source location of AE events.

2 SIGNAL PROCESSING METHODS

2.1 *Detection of multiple arrival times of AE wave with AIC picker*

Waveforms from AE sensors via amplifiers were continuously sampled and recorded to hard disk drives by previously mentioned CWM system. A noise reduction filter was applied in frequency domain, *i.e.* spectrum subtraction method. At first, the filtered continuous waveforms were scanned to detect AE hits and events by cross-trigger method. Then, an arrival time t_0 was decided by two-steps AIC picker. The first AIC picker detected a tentative arrival time t_0^* between -60 μs and +40 μs of the trigger time. After that, t_0^* was revised by the second AIC picker between -30 μs and +20 μs of t_0^*. Furthermore, two more arrival times t_- and t_+ were detected by two-steps AIC pickers before and after 100 μs of t_0, respectively. These default values may be appropriate for the most cases, but they can be changed as needed. In conclusion, three arrival times, *i.e.* t_-, t_0 and t_+ were automatically detected around the trigger time for one AE hit. An example of this result is shown in figure 1. Figure 1(a) showed a waveform after applying of noise filter. Figure 1(b) and (c) showed the first and second picking of arrival times, respectively.

After that, some connection between three arrival times and modes of AE wave is needed. In some cases, different modes of AE wave have different frequency characteristics and the arrival times can be easily assigned to certain modes. However, this becomes difficult when a resonant type of sensor is used. In such case, modes of AE wave and area of AE source were limited by reasonable estimation. Then, minimum and maximum time differences of arrival times of two modes can be calculated by each sensor.