THE DECI REPORT

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AN ALTERNATIVE TO PENCIL LEAD BREAKS FOR SIMULATION OF ACOUSTIC EMISSION SIGNAL SOURCES.

INTRODUCTION

Over 25 years ago Nelson Hsu while working with Cliff Bailey at Lockheed Georgia discovered that breaking of a pentel pencil lead on the surface of an aircraft panel would act as a simulated source of acoustic emission signals. Since that time the pentel pencil lead break has been in common use all over the world for simulating sources of acoustic emission for calibration purposes. We have found in our research that the pencil lead break on the surface of a plate replicates the type of source one encounters from noise sources such as impact and friction and pencil lead breaks on the edge of a plate replicates the type of source produced by a growing crack in a plate. One of the main problems encountered when using the pencil lead break is the difficulty in reproducing the same amplitude and phase of the signal. Another drawback is the difficulty in producing this type of simulated signal on a large structure. Another method used for simulating acoustic emission sources for many years is the use of a resonant transducer (usually in the 150Khz range of frequencies) used as a pulser. As will be shown the use of the 150Khz transducer as a transmitter on the surface of the plate is not a good simulation of the type of signal produced by the pencil lead break or crack growth in the plate, due to the large aperture of the 150Khz transducer.

It was our desire to design a repeatable source of crack like signals that could be placed anywhere on a large structure. Since the pencil lead break has been shown to adequately replicate the growth of a crack, it was our desire to design a pulser-transducer combination that would simulate the type of signals produced by the pencil lead break. After many design changes and tests on many types of transducers used as transmitters we produced the Model 600 pulser working into the SE25-P miniature small aperture transducer as a transmitter as the best combination for simulating pencil lead breaks on plates.

This report shows some of the experimental results from our study.

EXPERIMENTAL PROCEDURE

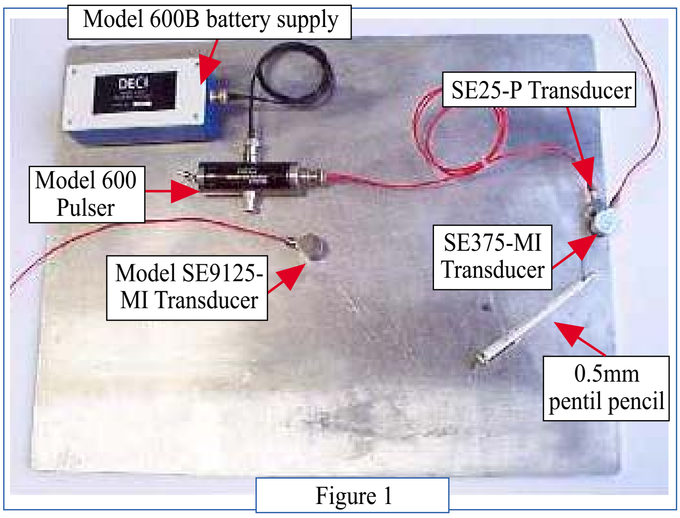


Figure 1

A 500mm X 500mm aluminum plate 4.6mm thick (figure 1) was utilized for the experimental work. A trigger transducer (SE375-MI) was placed at one edge of the plate, and a data transducer (SE9125-MI) was placed at approximately 250mm from the trigger transducer. Signals from the data transducer were input to the AESMART 2000 instrument where they were split into a 20 to 60Khz band pass (LF) and a 100-500Khz bandpass (HF). After 40dB of amplification, signals in both frequency ranges were captured for display on a digital oscilloscope. Signals from the trigger transducer were also input into the AESMART 2000 and amplified by 40dB. The SYNC output of the trigger channel was used to externally trigger the sweep of the digital oscilloscope. Both the SE9125-MI and SE375-MI transducers contain internal preamplifiers with 20dB of fixed gain.

0.5mm pentel pencil lead breaks were made adjacent to the trigger transducer on top of the plate (out-of-plane (OOP) source representing noise sources) and on the edge of the plate (in-plane IP source representing crack growth sources). These signals were captured and used as a reference source for experiments utilizing the pulser and different transmitting transducers to find the best match.

EXPERIMENTAL RESULTS

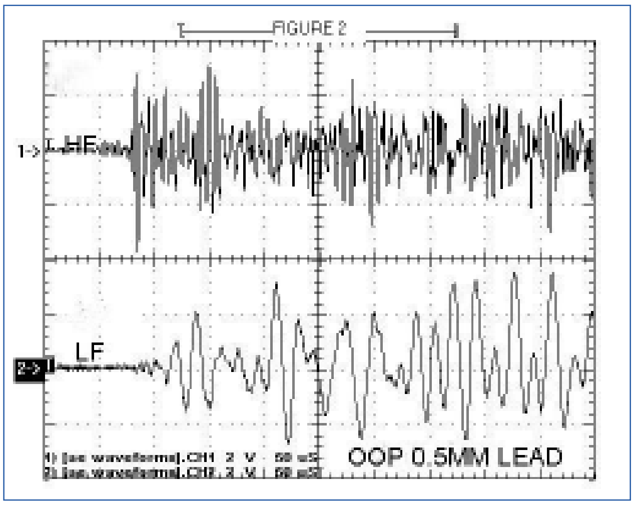
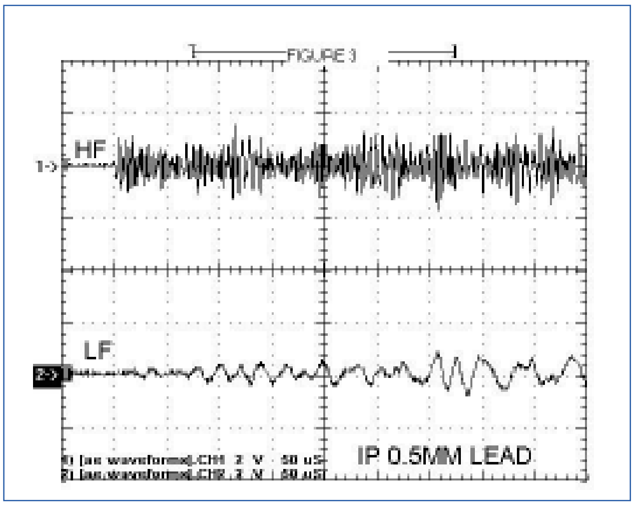
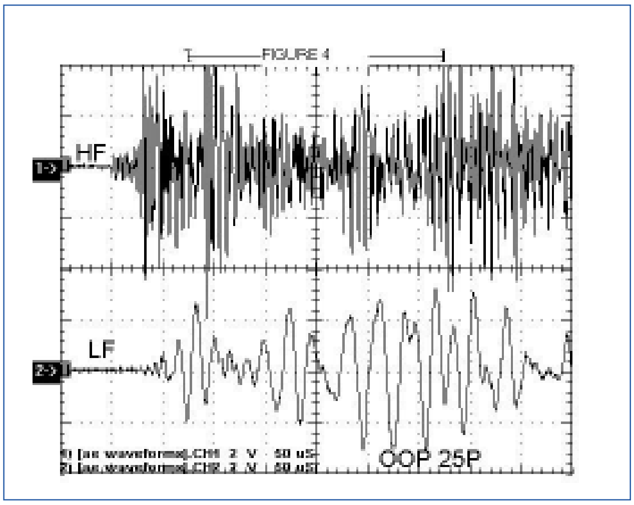


Figure 2 shows the results of breaking a 0.5mm pencil lead on the top surface of the plate adjacent to the trigger transducer. Note in the HF (high frequency) channel the small signal at approximately 50 microseconds. This is the arrival of a very low level extensional wave created by the OOP source. The large signal arriving at approximately 80 microseconds is a high frequency shear wave with a calculated velocity of 3,200M/sec. The LF (low frequency) channel shows a large low frequency signal arriving at approximately 100 microseconds. This is the flexure wave created by the OOP pencil lead break. Note that the peak amplitude of the HF signal divided by the peak amplitude of the LF signal (HF/LF) is approximately one.





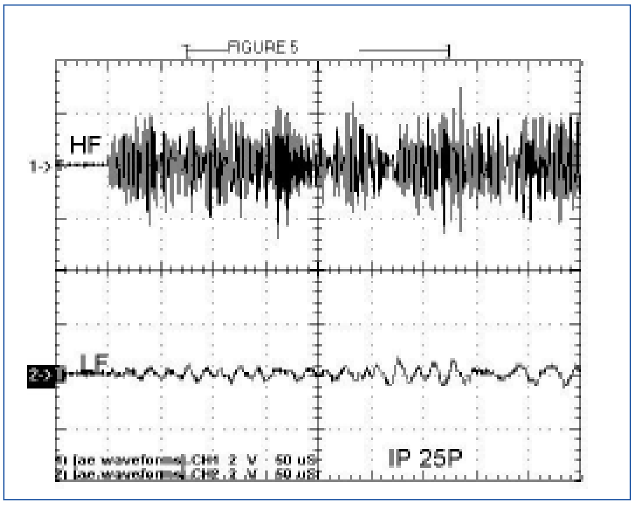


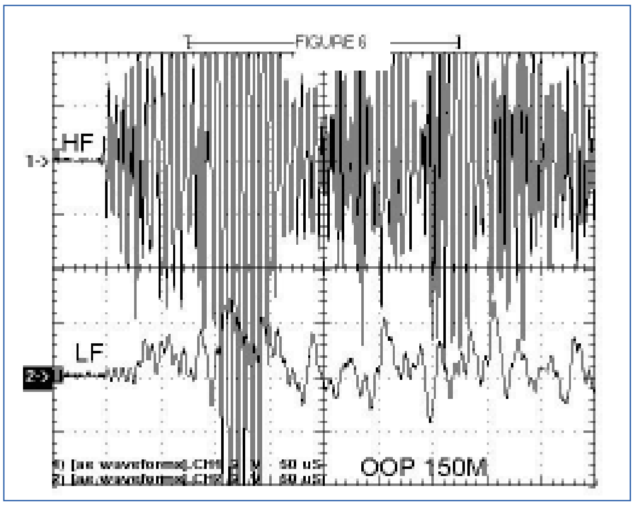
Figure 3 shows the results obtained when the pencil lead is broken on the edge of the plate (IP source). Note that the first arrival in the HF channel occurs at approximately 50 microseconds. This is the arrival of the extensional wave (crack like source) at the data transducer. A value of 5,000M/sec is observed for this extensional wave.

Note that the signal received in the LF channel is much lower than observed in figure 2 for an OOP source. The amplitude of this LF signal is proportional to the depth in the plate where the pencil lead is broken. This feature allows one to estimate the depth of a growing crack by observing the value of the HF/LF ratio. If broken exactly in the center of the plate, no flexure wave component is observed and the ratio of the peak amplitudes-HF/LF is infinity. The software in the AESMART 2000 gives a default value of 60 for these cases. Note that the peak amplitude ratio (HF/LF) is greater than one for this IP source.

Figure 4 shows the results for the SE25-P miniature transducer being used as a transmitter and driven by a 150 volt pulse from the model 600 pulser. For this data the transducer was placed on top of the plate OOP source (simulated noise source). Instrumentation gain was kept constant throughout these tests. We see from figure 3 in comparison to figure 2 that a higher amplitude signal is produced by the pulser as opposed to the 0.5mm pencil lead break, but similar HF/LF ratios are observed.

Figure 5 shows the results for the SE25-P transducer for identical conditions for figure 4 with the exception that the transducer was placed on the edge of the plate adjacent to the trigger transducer to produce an IP (crack like) source. Note the similarity between figure 3 and figure 5. Again we observe a higher amplitude signal from the pulsed SE25-P as opposed to the 0.5mm pencil lead break.

Many researchers for years have used a 150Khz resonant transducer as a pulser for calibration of multiple channel AE systems. We decided to compare the SE150-M transducer with the results achieved from the pencil lead breaks and the SE25-P. Therefore a SE150-M transducer was placed on top of the plate adjacent to the trigger transducer and pulsed with the 150 volt pulse from the model 600 pulser to act as an OOP source. All other instrumentation settings were identical to those used for the data in figures 2 through 5.



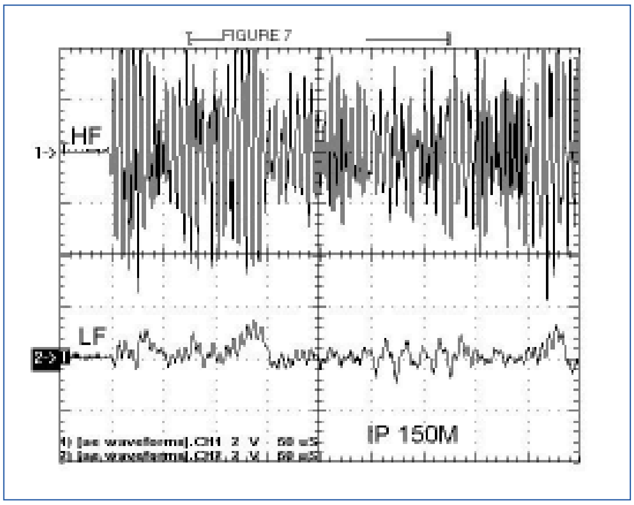


Figure 6 shows the results of this experiment. An extensional wave arrival is shown at 50 microseconds in the HF channel. Due to the high amplitude of this signal, no separation is shown between the extensional wave and shear wave. The 15 volt peak signal seen at 150 microseconds is a reflection from the back surface of the plate. The signal in the LF channel is very low level in comparison to the HF channel and shows very incoherent wave properties. This is due to the large aperture of the SE150-M in comparison to the SE25-P transducer and pencil lead breaks used in the previous figures. **Figure 7** shows the results of placing the SE150-M on the edge of the plate to produce an IP (crack like) source. For this situation there is a large amplitude signal arriving at the extensional wave velocity and a small separation between the extensional and shear wave. The signals produced in the LF channel have similar properties to those produced by this sensor used as an OOP source. It is obvious that the 150 Khz resonance transducer is a poor choice to use as a transmitter for ratio analysis to identify the type of source producing an AE signal.

The next experiment performed was designed to determine the difference between the pencil lead break and the pulser performance of the SE25-P. This was accomplished by first breaking a 0.5mm pencil lead break directly on the 3.1mm aperture of the SE25-P. The signal produced was large enough that the output of the transducer could be input directly into the digital oscilloscope without any amplification.

Another SE25-P transducer used as a pulser was coupled with petroleum jelly face to face with the transducer used in the pencil lead break above. Again the 150 volt selection was made on the model 600 pulser.

Figure 8

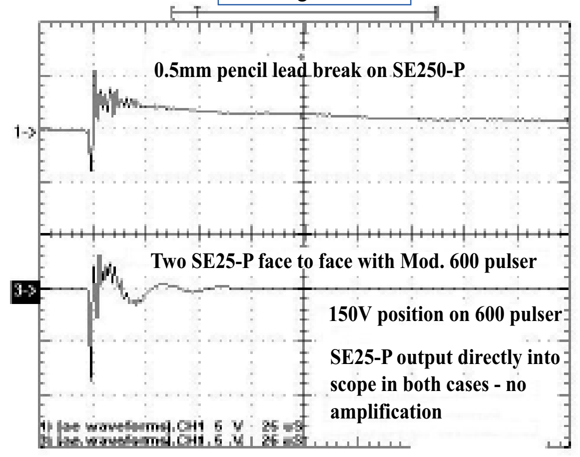


Figure 8 shows the results of this experiment. The upper trace in figure 8 is the signal produced by breaking the pencil lead directly on the face plate of the 3.1mm diameter aperture of the transducer. The lower trace shows the results produced by face to face coupling with one transducer used as a transmitter. Both traces show a very fast rise time to peak amplitude and some high frequency ringing of the transducer with the peak response of the pulsed transducer reaching a higher level than the pencil lead break. This higher amplitude signal from the pulser was also observed from the plate waves generated in the previous figures.

CONCLUSIONS

These results show that the model 600 pulser with its switch in the 150 volt position in combination with a SE25-P miniature small aperture transducer produces signals in plates that are very similar to those produced by 0.5mm pencil lead breaks. It is further shown that the traditional use of a 150Khz transducer as a transmitter does not have similar characteristics to pencil lead breaks, and the distortion produced by the large aperture of this transducer in the low frequency range makes it unsuitable for modal ratio analysis to determine the source of an AE signal. The pulser-transducer combination described in this report will be used by DECI clients in the field on large structures such as bridges and roller-coasters. The SE25-P coupled to the edge of a plate on a structure will give a repeatable crack-like AE signal to assure that ratio filtering of noise sources will still allow detection of a growing crack.

NOTICE

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