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A METHOD OF CALIBRATION FOR ACOUSTIC EMISSION MEASUREMENTS

M.N. Bentley and G. Green

ADMIRALTY MATERIALS LABORATORY POOLE DORSET

ABSTRACT

Studies of the intrinsic noise of an acoustic emission system, and studies of its response to a particular impulsive stimulus, have been shown to enable comparison to be made with similar data obtained with a system having different response, so that each system can be calibrated. In this way, data obtained from differing systems can be compared, and it is suggested that it may be possible to establish whether any acoustic emission (AE) system is capable of determining particular components in a signal.

INTRODUCTION

A problem exists in calibrating AE transducers and their associated signal conditioning equipment in order to both determine the nature of the source event, and facilitate the comparison or exchange of data between observers.

Methods of calibration may be divided into four groups:-
(a) Use of a standard source (1); (b) Reciprocity techniques (2,3); (c) Strain field measurements (4); (d) Measurement of electrical parameters - such as series resonant impedance (5).

The helium gas jet has been proposed (6) as a known, reproducible source of broad band noise, independent of the use of an acoustic couplant; we have therefore investigated this technique with the results reported below.

EXPERIMENTAL

One of the purposes of calibration is to enable an absolute measure of the spectral distribution of energy to be obtained for an AE event. The capture and manipulation of spectra is a prime requirement of the technique to be described; the equipment used to perform this task both rapidly and with good resolution is shown in Fig. 1. Amplitude/frequency data from a spectrum analyser (at 10 kHz bandwidth) is encoded by a Tektronix digital processing oscilloscope coupled to a PDP 11 computer.

RESULTS AND DISCUSSION

The jet operating conditions were first investigated to determine the range of operation over which a subjectively reproducible output would be obtained, with the results shown in Table 1.

These tests were performed with a 5 MHz X cut quartz transducer mounted at the centre of one end of an aluminium alloy cylinder (BS1476 type NE6) 100 mm long and 115 mm diameter, upon which this and all subsequent tests were conducted.

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TABLE 1
OPTIMISATION OF HELIUM JET OPERATING CONDITIONS

Jet Parameter	Optimum	Effect of Parameter
Bore dia. (.5–1.5 mm)*	0.8 mm ± 0.02	Larger bore uses much gas with little increase in energy
Stand-off (.5–10 mm)*	3 mm + 0.1	>3.5 mm energy input decreases
Pressure (0–30 psi)*	21 psi ± 1	Above and below 21 psi input energy decreases
Angle (90°–60°)*	90° ± 1°	Energy decreases below 89° to surface
Length of bore	>10 x dia.	<10 x dia. may give non-uniform flow
Angle of jet tip	45° ± 5°	Minimises turbulence around the jet
Surface finish of block	Fine machined	Not critical

* Range studied

In order to establish any technique of calibration it is necessary to show that two or more dissimilar systems can be corrected to produce the same output for any given input stimulus. Accordingly, a wideband transducer (A) and a resonant (140 kHz) transducer (B) were used, each being connected to an otherwise similar AE system. The response of each system to the helium jet is shown in Figs 2 and 3 together with the intrinsic noise of the system; from which it is evident that by subtracting the noise from the response to the jet one may obtain directly comparable signal/noise plots for the two systems, as shown in Fig. 4. Examination of Fig. 4 reveals that at the resonant frequency of B (140 kHz) the detection capability is equivalent to that of A, thereafter system A is superior.

McBride and Hutchison (6) suggested that the response of the quartz transducer to the helium jet could be defined independent of the couplant, however, Fig. 5 shows that this response is influenced by the couplant, (as it may also be by the choice of primary signal conditioning technique).

We suggest that it is possible to analyse the response of any system in the following way, noting that each component is expressed as a logarithmic function.

Hence, for the response of systems A and B to the helium jet, where their response is given by R,

R_1 = Jet (J) + Block (B) + Couplant A (C_A) + Transducer A (T_A) + System S_A (1)

where T_A = Transducer gain + Spectral response,

Similarly, $R_2 = J + B + C_B + T_B + S_B$ (2)

Similarly, the response of systems A and B to any stimulus (in this particular case a simple step function introduced into the block via an acoustically coupled wide band transducer) may be written as:-

R_3 = Pulser (P) + Couplant P (C_P) + $B + C_A + T_A + S_A$ (3)

and $R_4 = P + C_P + B + C_B + T_B + S_B$ (4)

Then for system A:- $R_5 = R_3 - R_1 = P + C_P - J$ (5)

and for system B, $R_6 = R_4 - R_2 = P + C_P - J = R_5$ (6)

In a similar way the above calibration can be applied to an actual unknown acoustic event, resulting in the equation:- $R_{AE} = AE - J$ (7)

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Fig. 6 shows the response of system A and B to the pulser, (i.e. R_3 and R_4, and Fig. 7 shows the P + Cp − J function for each system, indicating good agreement over the bandwidth 100–730 kHz. The lower frequency limit is set by the spectrum analyser, the reason for the upper limit is considered to be due to the resonant transducer being relatively insensitive to a particular mode of vibration induced in the block by the pulser above 730 kHz.

Performing the same operations upon the results obtained with an X cut quartz transducer (as used by McBride and Hutchison (6)), and the wideband transducer A, the traces of P + Cp − J were found to be in good agreement, at least to 1 MHz.

If the two systems are stimulated by a known input, in this case the simple step function, the spectral responses (eqn 6) may be compared with the appropriate Fourier transform (of form sin x/x) and hence it should be possible to deduce J. Examination of Fig. 7 shows sufficient small scale variability in the results to make such calculations difficult, although the overall response is clearly indicative of the input stimulus, and would further suggest that J obeys a simple power law.

Although this calibration technique has been shown to hold for the simulated source, it has yet to be applied to real acoustic emissions, and it could be that such emissions would generate modes of transducer response not stimulated by either the gas jet or the pulser.

Further, it has been suggested elsewhere (7) that remotely sited pulsed laser (8) excitation may simplify the problem of defining the J term (in eqn 7) by providing a known and reproducible source, which will also enable "line of flight" and "attenuation" maps to be determined on complex structures.

CONCLUSIONS

1. When operated within the optimum conditions specified the helium gas jet is a reproducible source of noise over the range examined (100 kHz–1 MHz).
2. The technique as proposed by McBride et al is sensitive to the acoustic coupling employed for the quartz reference transducer, therefore J cannot be defined in this manner, a severe limitation in the proposed method of calibration.
3. The calibration technique as described and detailed in eqns 1–6 is capable of calibrating two dissimilar transducing systems, with respect to a particular standard source over a limited bandwidth.
4. Using the calibration technique detailed in eqns 1–7 two dissimilar transducing systems must be used in order to establish the frequency limit of either.
5. The technique of calibration we have proposed is capable of defining the spectral distribution of a simple known impulse, from which the energy distribution enables the input function to be determined.
6. Using any known reproducible input stimulus (e.g. a pulsed layer) deconvolution of results obtained for any two differing systems can be used to both define the spectral response of each system and compare results obtained with either.
7. The detection capability of any AE System is defined by measuring the system signal/noise ratio for a standard stimulus i.e. the helium jet.
8. It is recommended that workers report experimental data in the form AE–J until such time that it is possible to define the J term.

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Any views expressed are those of the authors and do not necessarilv represent those of the Department/HM Government.

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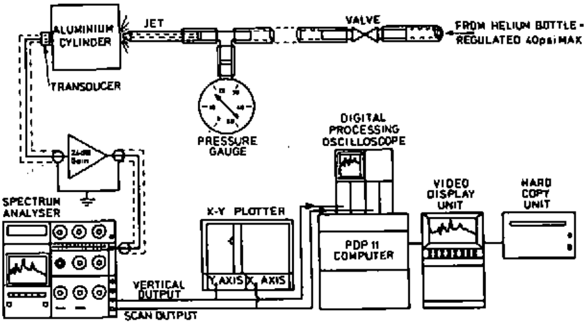

FIG.1 SCHEMATIC OF EXPERIMENTAL 'SET-UP'

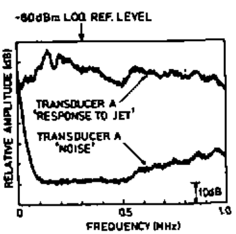

FIG.2 TRANSDUCER A INTRINSIC SYSTEM NOISE AND RESPONSE TO JET

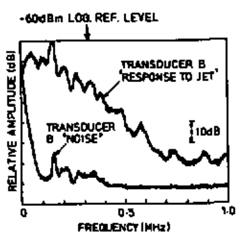

FIG.3 TRANSDUCER B INTRINSIC SYSTEM NOISE AND RESPONSE TO JET

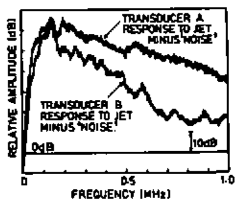

FIG.4 TRANSDUCER A AND TRANSDUCER B CORRECTED RESPONSES

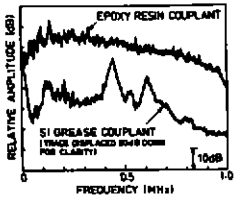

FIG.5 EFFECT OF COUPLANT ON THE RESPONSE OF THE QUARTZ TRANSDUCER

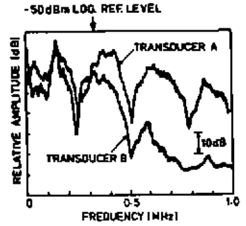

FIG.6 RESPONSE OF TRANSDUCER A AND TRANSDUCER B TO A WIDE BAND PULSER EXCITED BY A REPETITIVE 4μs PULSE

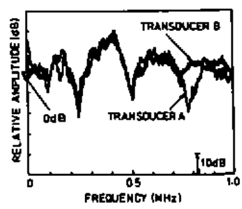

FIG.7 P+c-J FOR BOTH TRANSDUCER A AND TRANSDUCER B