inter-noise 83

ACOUSTIC INTENSITY TECHNIQUES APPLIED TO TRANSIENT NOISE SOURCES

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1. INTRODUCTION

The two-microphone method of sound intensity measurement has found many applications in the evaluation and control of noise radiation from continuous sources. The technique has also been applied to measurements on transient noise sources [1,2], offering advantages of in-situ and near-field performance over the method based upon far and near field single microphone pressure measurements together with associated surface acceleration measurements.

This paper offers a discussion of the application of the two-microphone method to measurements on transient noise sources, and presents some practical results by which near field intensity measurements are compared with surface acceleration as means of estimating total radiated sound energy.

2. INSTRUMENTATION

In its simplest form, instrumentation may take the form of a simple analogue intensity meter with a true integration facility in addition to the usual (short time) time average. This would yield measures of total energy flux passing the microphones during the integration time. More information could be produced by a digital system, where the microphone signals are sampled, converted into digital form and processed by computer. Performance requirements of such a system are discussed in reference [3]. Two approaches can be made to assembling a digital intensity system:

(i) For use with any arbitrary pair of microphones the system can be calibrated via a common pressure signal driving the microphones, resulting in an inter-channel transfer function. This transfer function can be used in the frequency domain to compensate for transducer and instrumentation mis-match. Time domain intensity results can be compensated by transforming one pressure signal to the frequency domain, multiplying (or dividing, depending upon channel chosen) by the transfer function, and then inverse transforming.

(ii) Transducers and equipment selected to give the best possible inter-channel matching.

The I.S.V.R. system is of the latter type, employing a matched pair of microphones, a high performance transient capture device linked to a desktop computer for data storage and use of the I.S.V.R. Data Analysis Centre computer for subsequent analysis.

3. ANALYSIS

Time domain analysis is performed using the well known two-microphone equation for instantaneous intensity [2]. Finite approximation errors for pressure and particle velocity estimations in the time domain are discussed in reference [3]. One particular source of error in this form of analysis is due to quantisation during the recorded "quiet" period preceding a transient event. After removing the D.C. offsets from the microphone signals by subtracting the mean value, quantisation usually results in a finite linearly increasing or decreasing velocity estimate which is clearly in error.

Frequency domain analysis may be performed by the two-microphone cross-spectral formulation for intensity [2,4]. For this to be meaningful the whole transient event must be captured and must start and finish with zero acoustic pressure [2]. Ideally, no windowing should be used; if the above conditions obtain, no windowing will be necessary. Finite approximation errors in the frequency domain are the same as those for the continuous source case.

4. PRACTICAL MEASUREMENTS

Measurements have been made on a 1:3 scale model hydraulic punch press (built under contract from C.E.T.I.M., Senlis, France).

In an anechoic environment, intensity measurements were made at about 1.5 m from the centre of the press. The narrow band energy flux spectra derived using the cross-spectral intensity formulation were compared to energy flux spectra derived from pressure alone, assuming plane wave propagation, and were found to be in very good agreement. This is a good test of the calibration of the measurement system.

To assess the utility of the intensity technique a direct comparison was made with the surface velocity technique of predicting total sound energy radiated by the machine. A good discussion of the validity of the surface velocity technique can be found in reference [5].

The surface velocity was calculated from accelerometer measurements and radiation efficiencies calculated from standard mathematical and empirical models. For each accelerometer position an intensity measurement was also made, giving 70 positions over the whole machine surface. For the intensity measurement, each microphone signal was sampled at a rate of 20,000 samples per second, a total of 4096 samples per channel being captured. For the accelerometer, the sampling rate was the same but only 1024 samples captured because of the limitations of the F.F.T. instrument used.

The estimates of total radiated sound energy given by the two methods were in very good agreement: 0.046 Joules from the intensity method and 0.045 Joules from the surface velocity method. The agreement is, however, less good when analysed into frequency bands. Fig. 1 shows a comparison for the total radiated energy divided into octave bands. Which result is the more correct is not known and requires further investigation and validation.

Other information from the intensity technique includes differentiation between acceleration and ringing noise by inspection of the energy flux-time graphs, and the ability to distinguish between absorption and radiation. The surface velocity method always assumes radiation whereas in many instances elements of the machine were found to be absorbing sound energy at certain frequencies.

5. CONCLUSIONS

The intensity technique can be applied to measurements on transient noise sources. Far field measurements can be made in-situ to determine total sound energy radiated from a machine, and near field measurements made to determine contributions to radiated sound energy from machine elements. Intensity measurements have advantages over surface velocity measurements in that no radiation efficiency need be assumed, and absorption can be detected in addition to radiation.

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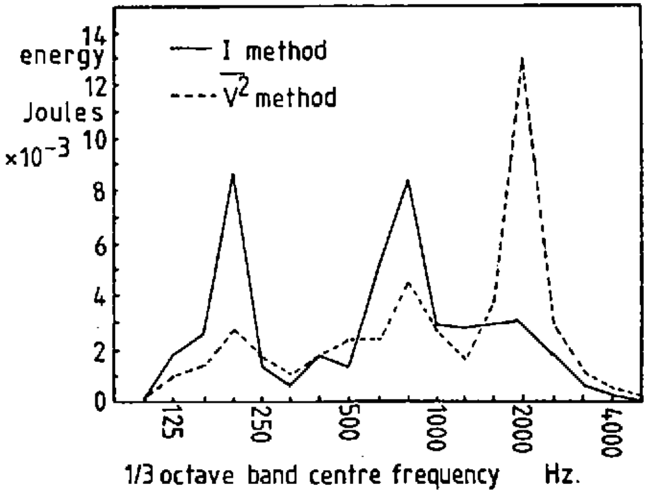

Figure 1. Sound energy radiated by a 1/3 scale model hydraulic punch press.