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BARRIER ATTENUATION OF ACOUSTIC IMPULSES

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INTRODUCTION

Because acoustic impulses have a wide spectral content, typically 500Hz to over 10kHz, experiments involving them are a demanding test of theoretical predictions. One advantage of impulse experiments is that the finite duration of the pulse permits the relative energy flowing along different paths to be deduced by time isolation techniques. This idea has been used to determine the effect of cracks in a barrier, where a readily detectable pre-pulse occurs before the main diffracted impulse. This work on barriers is part of a longer term project to investigate the effect of wind and temperature gradients on barrier attenuation.

THE EXPERIMENTAL SYSTEM

The source consists of shotshell primers discharged through a tube, creating a 0.5ms duration, 140dB acoustic pulse at 1m, radiating from a point source at the mouth of the tube. A two microphone system, pictured in Fig.1, allows a comparison of the diffracted and direct waveforms of two, originally identical, impulses which have travelled the same distance. Thus the ratio of the two peak amplitudes leads directly to the excess attenuation caused by the barrier and ignores attenuation due to geometric spreading.

By having the diffracting edge vertical and the source and microphones midway between the floor and the ceiling, unwanted reflections were sufficiently delayed to be unimportant, providing the distances from the edge to the source and receiver were less than 2m. Distance z in Fig 1, was set to zero for these measurements. Two 1/4" microphones were used, the signal being connected directly to a dual-trace digital storage oscilloscope, permitting both the direct and diffracted waveforms to be captured simultaneously and stored on a floppy disk.

A direct impulse waveform was separated into its individual frequency components by using an FFT algorithm. After multiplying each component by a theoretical diffraction factor, an inverse FFT permits the predicted diffracted waveform to be reconstituted. Alternatively, division of the measured diffracted waveform frequency components by the direct ones gives the appropriate experimental diffraction factors.

MODELLING SIMPLE BARRIERS

There are a variety of techniques for predicting the diffraction factors of a straight edge. Simple design curves, such as that of Maekawa[1], and the equations of Kirchhoff-Fresnel give only the magnitude and make no allowance for any phase shift between frequency components. A more exact approach, due to Oberhettinger[2], used by Ambaud[3] and recently re-presented by Pierce[4], permits complex diffraction factors to be calculated, although it can require half-an-hour of computing time to determine all the factors required to predict a pulse waveform. A reformulation by Hadden[5] permits the same calculation to be completed in a minute with essentially identical results. These approaches calculate the diffraction factors in the frequency domain. An alternative method[6] generates the waveform of a delta function which has been diffracted by the edge and then Fourier analyses this to estimate the diffraction factors. Figure 2(a) compares various theoretical predictions as a function of frequency for a single geometry, while Fig.2(b) compares experimental factors with those using Hadden's formulation at a number of receiver angles.

Complex diffraction factors are required to predict impulse waveforms. Incorrect phase causes a rounded leading edge, wrong duration and amplitude, especially at larger diffraction angles. The Oberhettinger/Hadden approach also correctly predicts the effects of wedged barriers.

WIDE BARRIERS AND CRACKS

Rectangular flat topped barriers constructed from 1cm thick chip-board sheathing a rigid wood frame were also investigated experimentally. As none of the theoretical treatments are exact, a comparison was made with predictions based on Maekawa's suggestion of replacing a wide barrier with an effective thin barrier, a double application of Maekawa's technique[7] and a more rigorous theory by Pierce[8]. The latter gives the best fit to both the frequency behaviour and the waveform.

When the back of the flat topped barrier was removed, leaving an L section barrier with the supporting framework exposed, the received level was actually reduced, as a comparison of the peak heights in Fig.3(a)(i) and (ii) indicates. The energy at the receiver fell to about 75% of that recorded with the full barrier for the geometry shown in Fig.3(b).

If a crack is introduced into the L shaped barrier, portion of the incident energy will pass through it and produce a pulse preceding the main diffraction, Fig.3(a)(iii) and (iv). With a small crack the main diffraction peak is almost unaltered, however, with a large crack the amplitude of the main peak is reduced. Two effects contribute to this. The rarefaction of the leading pulse lies under the main excess pressure peak and also energy may go through the crack rather than around the barrier. As it is difficult to isolate these effects, the data was first analysed by stripping the measured sealed L barrier pulse from the resultant one to obtain the crack pulse with rarefaction. Then its energy content was expressed as a percentage of the diffracted pulse energy for the sealed L barrier. This approach assumes none of the main diffracted energy goes through the slit and so gives an over-estimate of the leaked energy. Alternatively, providing the two peaks are reasonably separated in time, the energies of the two individual peaks can be measured, neglecting the rarefaction of the crack peak. This underestimates the true crack pulse energy but gives an estimate of the fraction of energy diverted through the crack. The following results are for a crack extending along the length of the barrier but of different widths. The geometry is shown in Fig.3(b) along with the effect in the frequency domain. Depending on the path difference, some frequencies are highly attenuated.

Crackwidth	Technique 1		Technique 2	
	Crack	Around	Crack	Around
0.9mm	11 ± 2%	100%	9 ± 2%	105 ± 5%
1.3	23 ± 2%	100%	17 ± 2%	95 ± 3%
2.4	35 ± 3%	100%	30 ± 3%	89 ± 2%
5.3	140 ± 4%	100%	130 ± 4%	93 ± 5%

CONCLUSION

Acoustic impulses provide a rigorous test of the theoretical diffraction models of real barriers and can quantify effects such as having a crack in the barrier.

ACKNOWLEDGEMENT

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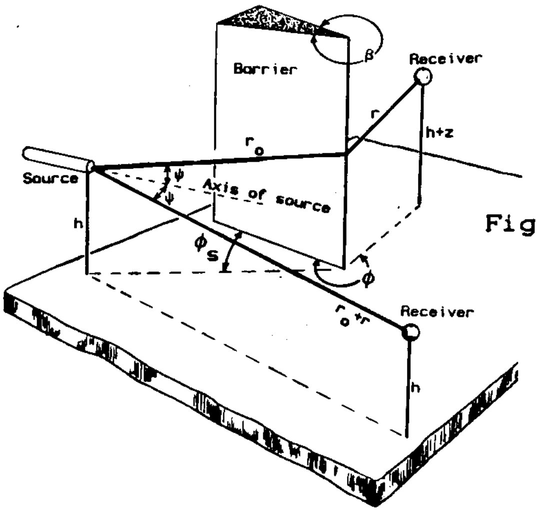

Fig.1 Experimental arrangement for diffraction experiments.

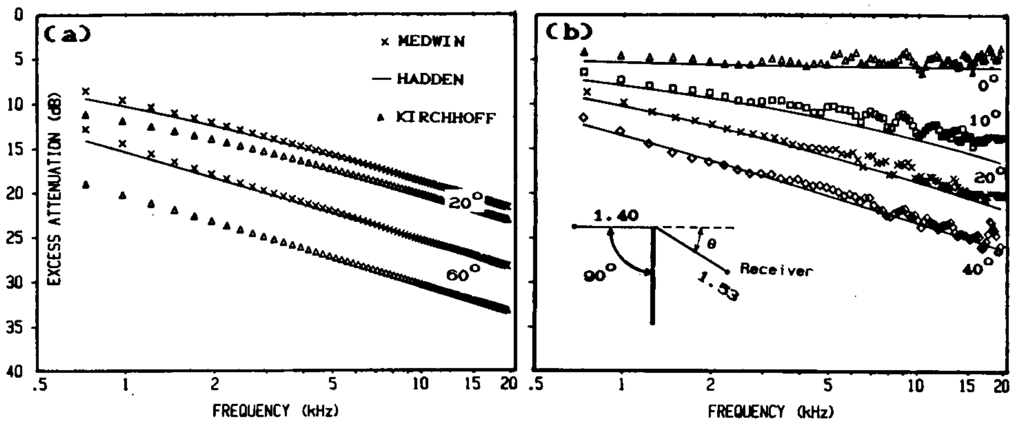

Fig.2 Single edge diffraction: (a) comparison of thoretical predictions (b) experimental data compared with prediction of Hadden theory.

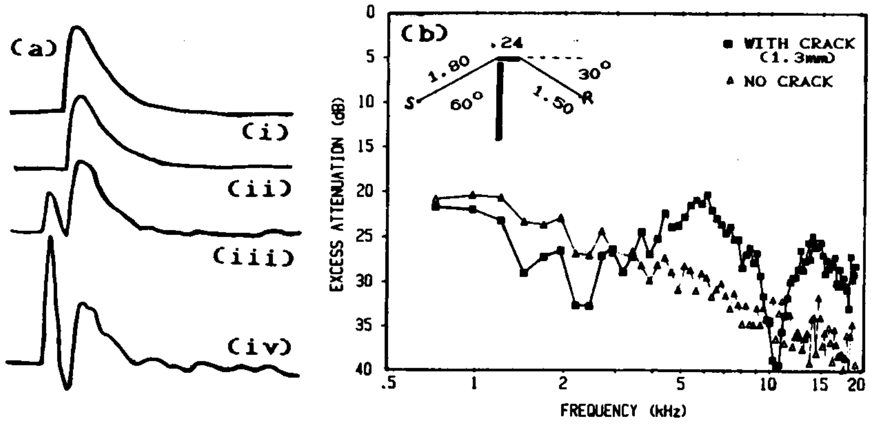

Fig.3 (a) Impulses recorded with (i) full barrier (ii) L-barrier (iii) 0.9mm crack (iv) 5.3mm crack (b) geometry and effect of crack with frequency.