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AN EXPERIMENTAL TECHNIQUE OF DETERMINING ACOUSTIC MODE SHAPES

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Experimental modal analysis techniques are now being used widely in the discipline of mechanical vibrations/structural dynamics [1-3]. In engineering acoustics such techniques are yet to be developed. In this paper we propose a modal analysis technique with potential applications to acoustic ducts, mufflers and resonators. Here, our interest is mainly focused on the global properties such as natural frequencies and modes of gas oscillation over the plane wave frequency regime.

Figure 1 shows schematically experimental setup and instrumentation. Acoustic impedance (Z) at the i^{th} location is

$$Z_i(f) = C_i(f) + jQ_i(f)$$
$$= (j2\pi f/S_1)[p_i(f)a_1^*(f)]/[a_1(f)a_1^*(f)],$$
$$i = 2, 3, \ldots\ldots, n$$

Where f is the frequency (Hz), S_1 is the cross-sectional area at input (#1) and j is the imaginary unit. At each location (i) we measure coincidence $(C_i(f))$ and quadrature $(Q_i(f))$ responses of acoustic impedance. From these we extract natural frequencies (f_r) and modes (ψ_r).

In order to establish the validity of our proposed method, we compare experimental and theoretical results for two example cases with air medium at room temperature.

Example Case: Closed-Open Tube

Natural frequencies (f_r) are compared in Table I and pressure mode shapes (ψ_r) in Figure 2. Note the excellent correlation between theory and experiment.

Example Case: Composite System

Now we consider an unsymmetrical lumped parameter acoustic system as shown in Figure 3(a). Table II lists f_1, and f_2, and corresponding modes ψ_1 and ψ_2 are shown in Figure 3(b and c). Again, note the excellent correlation between theory and experiment.

For more information on the theory, experiment and other example cases, see Reference [4].

References

1. R. Potter, "A General Theory of Modal Analysis for Linear Systems," Hewlett-Packard, 1975.

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3. D. L. Brown and R. J. Allemang, INTER-NOISE '78, 909-914.

4. J. J. Nieter and R. Singh, "Acoustic Modal Analysis Experiment," Submitted to J. Acoust. Soc. Am., 1982.

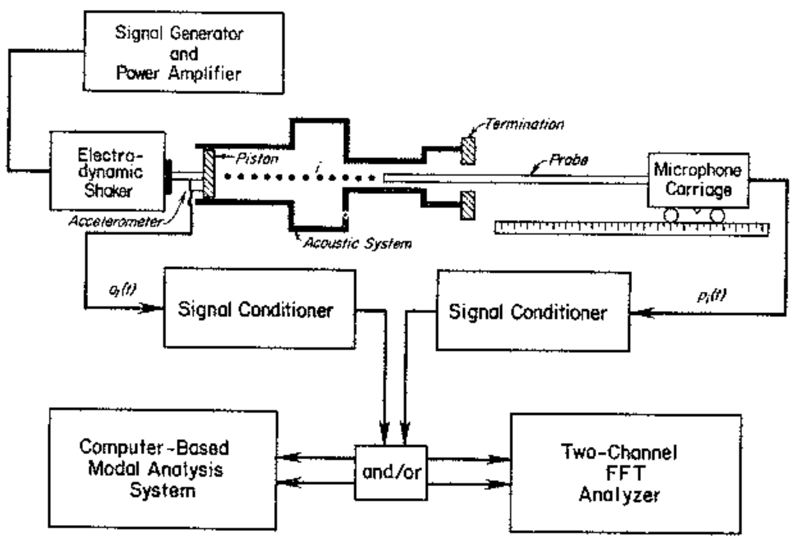

Figure 1. Schematic Representative of the Acoustic Modal Analysis Experiment

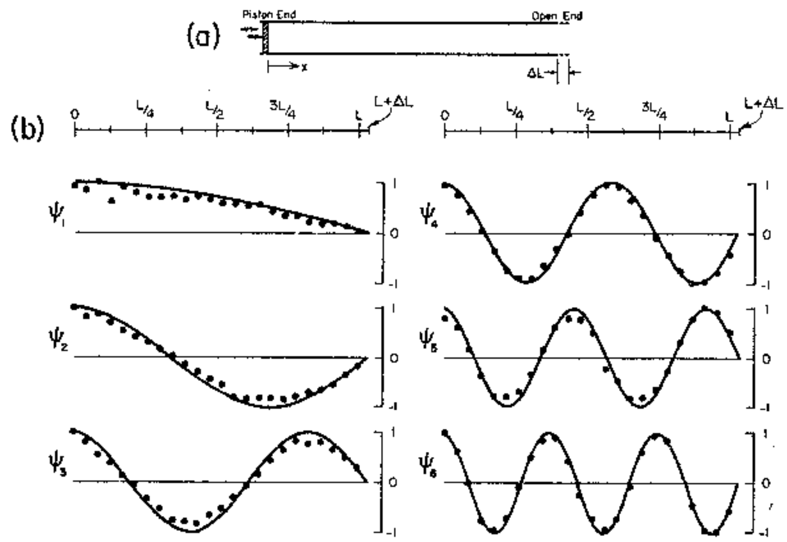

Figure 2. (a) Closed-open tube. (b) Pressure mode shpaes.
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Table I. Closed-open tube

f_r, Hz	f_1	f_2	f_3	f_4	f_5	f_6
Experiment	140.9	422.6	704.5	986.3	1268.1	1549.9
Theory	140.0	421.2	703.7	985.0	1267.5	1550.0

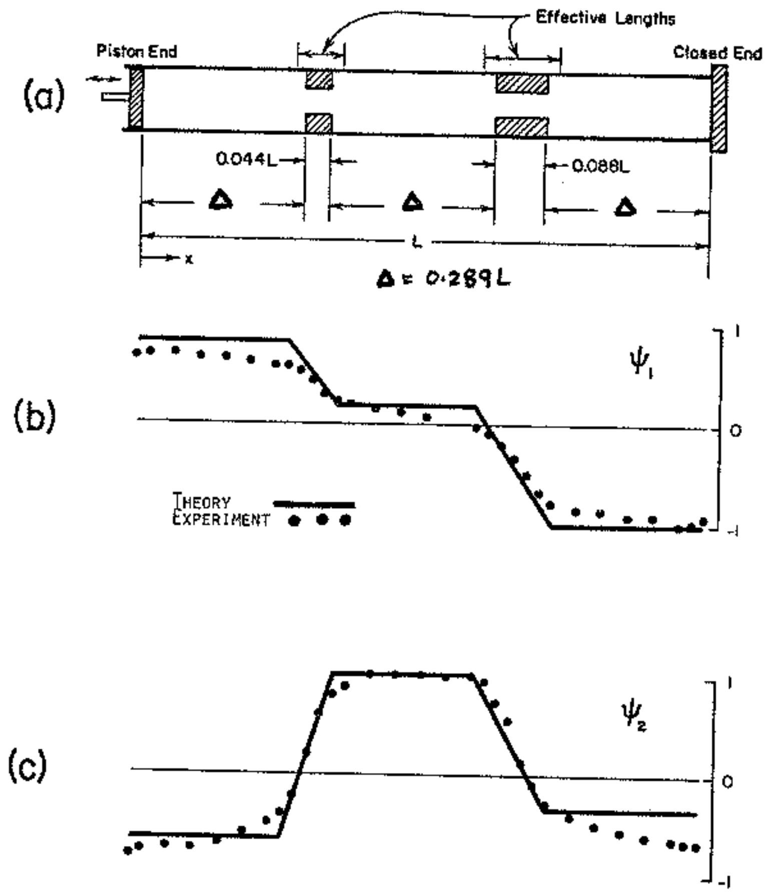

Figure 3. (a) Composite System. (b) and (c) Pressure Mode Shapes.

Table II. Composite System

f_r, Hz	f_1	f_2
Experiment	206.2	385.6
Theory*	218.8	396.5

*Using lumped parameter approach