inter-noise 90

SOUND SOURCE STRENGTH SENSITIVITY TO LOAD IMPEDANCES IN AN AIR-DUCT SYSTEM

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INTRODUCTION

In order to predict the sound field in an air duct system, it is necessary to know not only the passive acoustical properties of the duct but also all of the active properties of each duct component which generates sound. At Inter-Noise 89, Terao and Sekine [1] presented a method for determining such acoustic properties (i.e., acoustic driving force, and characteristic reflection and transmission coefficient) for each duct connected to a fan using two closely spaced microphones per duct and two additional microphones, as appropriate, to cancel the turbulent flow pressures. The method can be used in ducts with flow and does not require anechoic terminations. In this investigation, basic experimental tests were conducted to confirm the active source strength insensitivity to the duct termination characteristics. Tests are made under no flow conditions and using a single duct with a dynamic loudspeaker as a noise source. The source strength of the loudspeaker was measured for five terminations.

RELATIONSHIPS BETWEEN SOURCE PROPERTIES AND TRAVELING WAVES

For a single port source case as shown in Fig.1, the expressions which relate the source characteristics and traveling wave variables at an interface in the traveling plane wave section are

$$p_d = z_p u + p \quad \text{(1a)} \quad \text{, or} \quad p = p_d / \{1 + (z_p/z_L)\} \quad \text{(1b)}$$

where p_d denotes source strength in terms of the driving pressure acting on the interface, z_p is the passive source impedance, u is the particle velocity, p is the sound pressure and $z_L = p/u$ is the load impedance.

The equivalent circuit for eq.(1) is shown in Fig.2. If both p_d and z_p are independent of the load impedance z_L

and are known, p (and also u) can be calculated for a given z_L by using eq.(1b).

EXPERIMENTAL SETUP AND METHOD

Experiments were conducted using the test arrangement shown in Fig.1. A dynamic loudspeaker system with honeycomb diaphragm and back cavity was used as the primary sound source. The voltage e_s for this loudspeaker was fixed at approximately 25mV for all tests. The interface between the sound source and load-side region was set at the loudspeaker diaphragm position to permit easy comparison of the results. The pressure p and velocity u at the interface position are evaluated using loss-free plane wave relations [2] and microphone pressures p_1 and p_2.

The relationships between the loudspeaker diaphragm velocity and plane wave velocity were also studied. The diaphragm velocity was measured directly by employing a laser Doppler meter at four radial positions, as shown in Fig.3, and was also determined from measuring the back cavity pressure.

The passive impedance z_p was measured first by superposing a test signal from an additional loud-speaker as shown in Fig.4. This secondary source signal e_L was supplied with approximately 5.8V, which is far larger than e_s, in order that the driving pressure term in eq.(1a) could be neglected. The driving pressure p_d was determined by observing p and u for each of the 5 load cases as shown in Fig.5 and applying eq.(1a), using z_p from above.

TEST RESULTS AND DISCUSSIONS

Passive Impedance, Load Conditions, and Sound Pressures

Figs.6 and 7 show the acoustic load in terms of reflection factor ($R_L=[z_L-z_a]/[z_L+z_a]$, where z_a denotes the characteristic impedance of air) and sound pressure for each of the 5 loads, respectively. Fig.8 shows the passive impedance z_p of the source region, compared to one of the load impedances, z_{L5}.

Diaphragm Velocity and Plane Wave Velocity

Typical results for the diaphragm and plane wave velocities are given in Fig.9. The agreement between the diaphragm velocities, u_B, measured by the back cavity pressure method, and u_{D1} through u_{D4}, measured by the laser Doppler meter, is good. However large discrepancies appeared between the plane wave velocity u and the diaphragm velocities (u_B and u_D) above 500Hz.

The loudspeaker diaphragm data is not expected to be exactly the same as the interface data due to near field effects. To account for near field effects, a two port modulator was developed using the experimental data (p as shown in Fig.7, and u and u_D as typically shown in Fig.9; u_B was used for u_D). One of the relations can be expressed as;

$$p = z_{21} u_D + z_{22} u \qquad (2)$$

where z_{21} and z_{22} are the necessary four terminal constants of the modulator, and u_D is the diaphragm velocity.

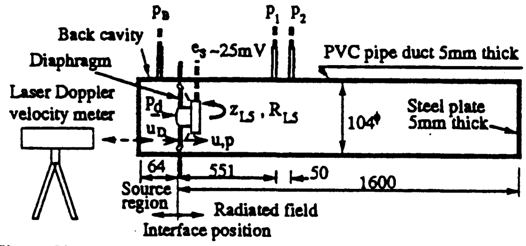

Fig.1 Single port source and test arrangement for load case z_{L5}.

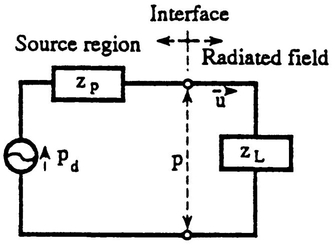

Fig.2 Equivalent circuit for a single port source model.

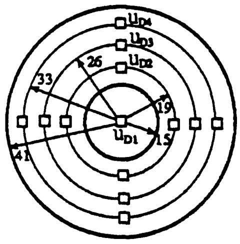

Fig.3 Diaphragm surface positions in measurement by laser Doppler velocity meter.

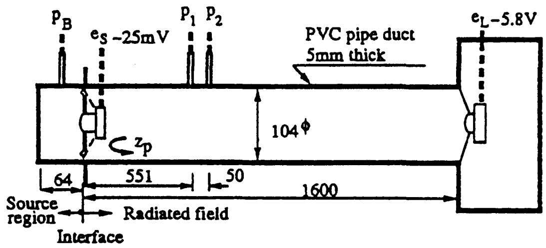

Fig.4 Test arrangement in passive impedance measurement

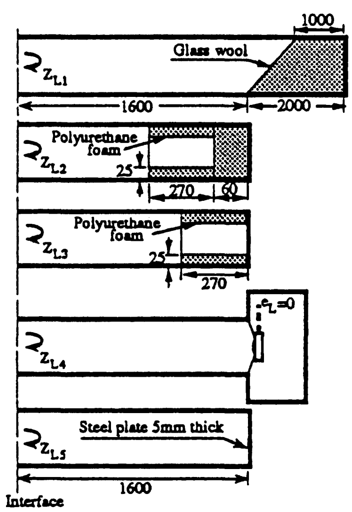

Fig.5 Variations of terminations tested.

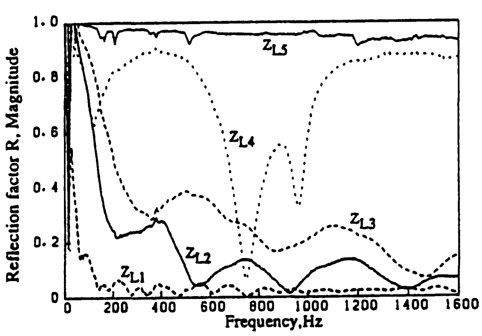

Fig.6 Reflection factor at the interface for each of the terminations.

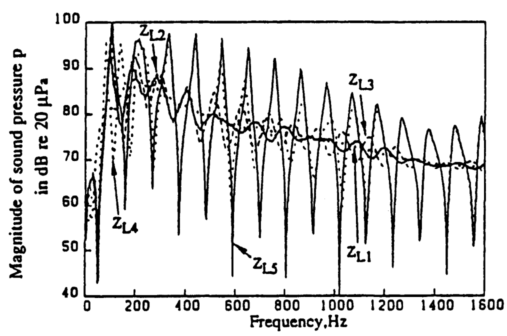

Fig.7 Sound pressure p at the interface for each of the terminations.

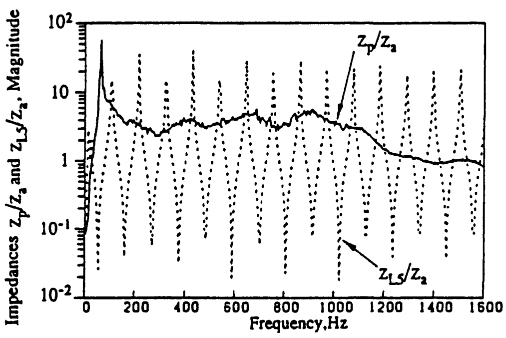

Fig.8 Source passive impedance z_p, with one of the load impedances z_{L5} for comparison.

Fig.10 shows the agreement between measured u and its estimate, u^E, for the case z_{L5}. The estimated u^E was obtained from eq.(2) using u, u_D, and p for z_{L2} and z_{L3}. This result is typical. Fortunately, the modulator is included in the passive property z_p and the diaphragm velocity does not need to be known when the variables are evaluated in the plane wave region for such complicated near field effects.

Source Strength p_d

Sound driving pressure p_d is shown in Fig.11 for each of the terminations. Although the source used is of low impedance and the terminations vary significantly, the driving pressure dependence on the radiated field is negligibly small.

SUMMARY

The sound source strength has been confirmed to be insensitive to duct termination even for a dynamic loudspeaker with low passive impedance.

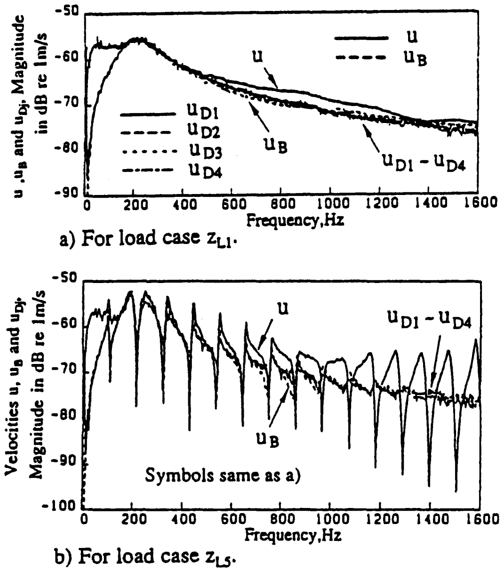

Fig.9 Plane wave velocity u, diaphragm velocities, u_{D1} thro' u_{D4}, by a laser Doppler velocity meter, and u_B, measured from back cavity pressure.

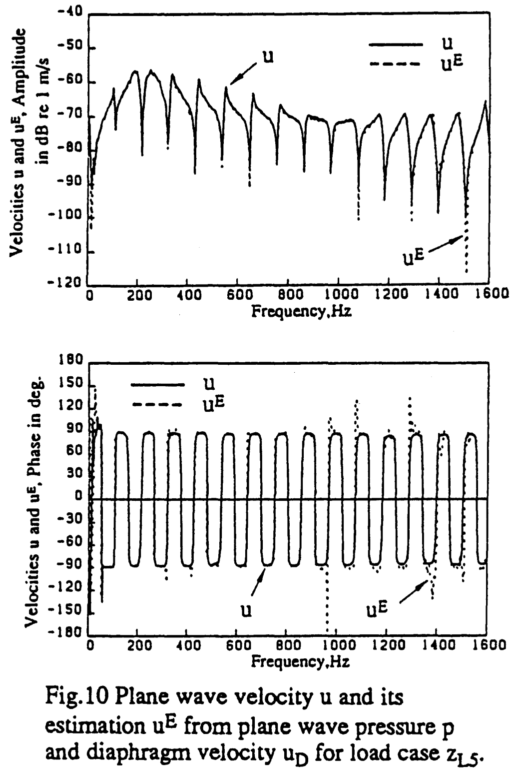

Fig.10 Plane wave velocity u and its estimation u^E from plane wave pressure p and diaphragm velocity u_D for load case z_{L5}.

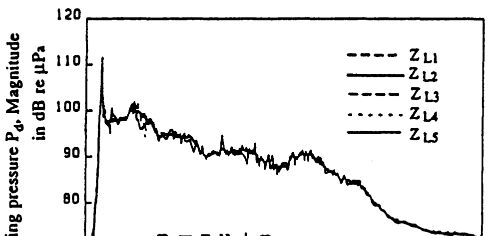

Fig.11 Sensitivity of source driving pressure p_d to acoustic loads.

REFERENCES

[1] M.Terao and H.Sekine:Inter-noise 89 proc.,vol.1.

[2] ASTM Standard,E1050,1985.