Experiments on the Transmission of Sound Through Jets

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Abstract

EXPERIMENTS on the superposition of a turbulent jet flow ($0<M<0.7$) and pure tone sound coming from inside the nozzle are reported. A comparison between the transmitted sound power from the nozzle and the radiated sound power in the far field reveals a substantial attenuation at low frequencies. Therefore, a jet can be considered as a low-frequency muffler. It has been verified that this effect is independent of the broadband jet noise amplification previously reported by Bechert and Pfizenmaier.[1,2]

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The experiments were carried out with a tube and a conical nozzle (Fig. 1) installed in an anechoic chamber. Plane sound waves were produced upstream by a set of four loudspeakers. The transmitted sound power from the tube W_T was calculated in two ways: 1) from measurements of the sound pressure amplitude and phase at different locations of the movable microphone probe and 2) from measurements of the maximum and minimum sound pressure levels. The pressure reflection coefficient r_p in the tube could also be calculated from these measurements.

Figure 2 shows $r_p\ (1-M_T)/(1+M_T)$, which is the square root of the energy reflection coefficient (M_T being the tube Mach number), as a function of the dimensionless frequency or Helmholtz number kR (k = acoustic wave number, R = nozzle radius) at various jet Mach numbers. These results

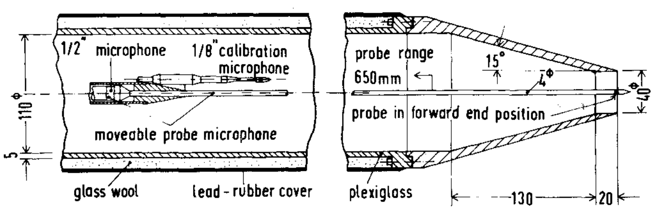

Fig. 1 Conical nozzle with air supply tube and movable microphone probe.

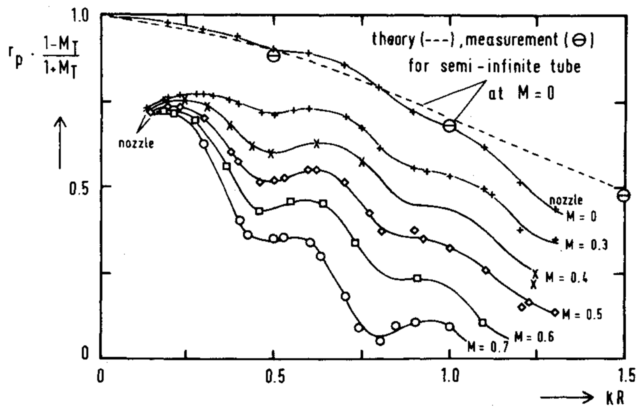

Fig. 2 Nozzle reflection coefficient vs dimensionless frequency kR at various nozzle Mach numbers (M_T = Mach number in the air supply tube, e.g., $M_T = 0.07$ for $M = 0.7$).

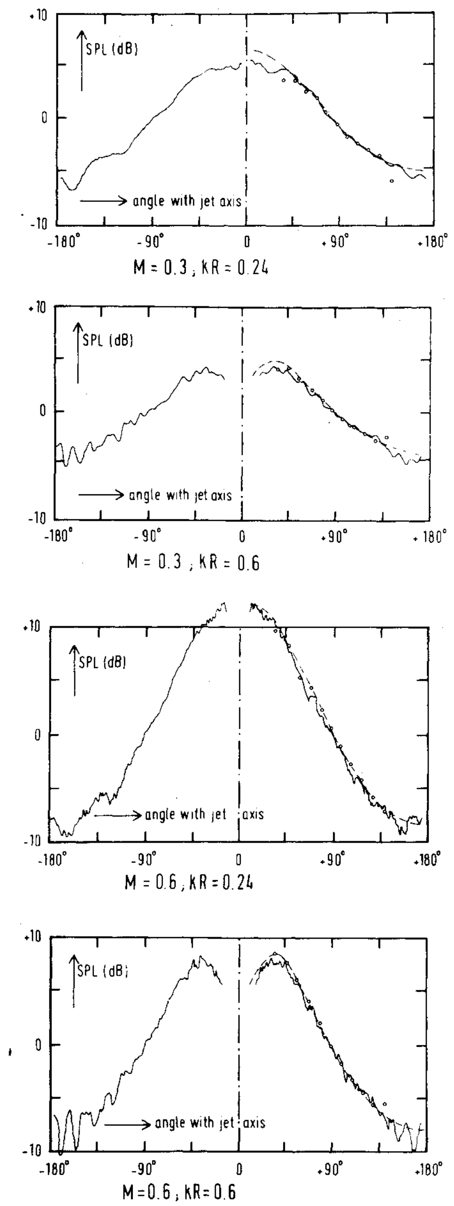

Fig. 3 Far-field directivity patterns (solid line) in comparison with Munt's[5] theoretical results (---) and previous measurements of Pinker and Bryce[4] (o).

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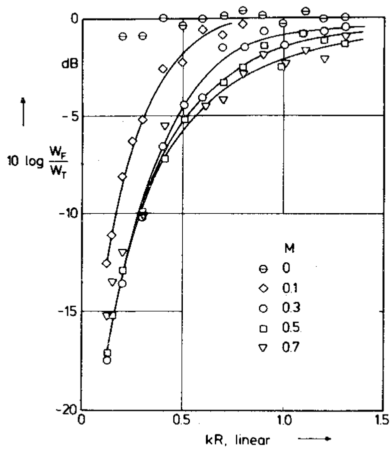

Fig. 4 Ratio of far-field radiation power W_F and transmitted power from the tube W_T vs the dimensionless frequency kR at various Mach numbers M.

compare qualitatively to measurements by Mechel et al.,[3] (see Fig. 3 of Ref. 3) with a flanged pipe at Mach numbers up to $M=0.3$. The waviness of our curves is not yet completely understood, but is possibly due to weak acoustical reflections in the nozzle. The reflection coefficient has a peak which becomes more pronounced in a narrow band of Helmholtz number around $kR=0.2$ as the Mach number increases. Resonances within a nozzle exhaust system should most likely occur within this frequency band.

The acoustic power W_F in the far field was calculated from the directivity pattern of the far-field sound pressure (Fig. 3). The higher the Helmholtz number kR and the higher the Mach number M, the more energy is radiated in the downstream direction, although a valley appears near the nozzle axis, which becomes more pronounced with increasing frequency, and which is caused by the flow. The measurements of the directivity patterns compare very well to recent measurements of Pinker and Bryce[4] and to computations of Munt.[5]

The far-field power W_F has been compared to the transmitted power W_T. The ratio W_F/W_T is plotted in Fig. 4 as a function of the Helmholtz number kR for different jet Mach numbers M. The figure includes some recent measurements at $M=0.1$ and at lower values of kR. The acoustic power is conserved for $M=0$. With flow, however, the power is attenuated at low kR. The results so far indicate an increasing power loss with increasing velocity. Only for Mach numbers $M \geqq 0.3$ does it appear to be practically independent of the velocity.

Additional measurements with different pure tone sound power levels in the nozzle verified that the attenuation is independent of the sound power level at the reported Mach numbers. It is due neither to a shift of sound power to other frequency bands nor to the broadband jet noise amplification. In aircraft engines, this sound transmission loss due to the jet occurs at the lower end of the audio regime, i.e., below 50-100 Hz. Nevertheless, the sound absorption capability of a jet certainly offers an unexploited potential for sound absorber design in fluid machinery. The low-frequency regime of this jet sound absorption effect may complement the conventional absorbers which fail below a certain frequency.

References

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