Use of Sound Absorbing Walls to Reduce Dynamic Interference in Wind Tunnels

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Abstract

A SCHEME for reducing dynamic interference at subsonic and transonic speeds was tested in two wind tunnels. Two types of dynamic interference were considered: excitation of unwanted acoustic resonances within the working section and flow unsteadiness. The tests show that both types of interference could be substantially reduced by replacing the conventional hard walls of a closed or a slotted working section by appropriate sound absorbing walls.

The models used to establish the resonances in the working sections with hard walls were circular cylinders operating in the subcritical Reynolds number range ($R_d < 2 \times 10^5$) and thus generating discrete pressure fluctuations at the vortex shedding frequency. When the resonances were suppressed by the wall material the pressure fluctuations agreed well with previous measurements made in a much larger, low-speed wind tunnel and with predictions. The investigation in the larger tunnel also showed the superiority of sound absorbing walls for buffeting measurements.

Contents

Choice of Wall Material

The acoustic characteristics of the wall material required are not critical, as long as a reasonable degree of attenuation is provided over the frequency range within which resonance is expected, as in the present tests (Fig. 1) in tunnels of height $H = 100$ and 570 mm. Indeed, the final choice of wall material for a transonic working section which is to suppress resonances might be decided as the result of a compromise between acoustic properties, cost, durability, and any additional boundary-layer growth relative to a hard wall. This last factor might be particularly important in a continuously operated fan-driven tunnel, where a small increase in pressure ratio implies a large increase in the fan power.

Pressure Fluctuations Induced by Vortrex Shedding From Circular Cylinders

Measurements are given with the alternative hard and laminate walls forming the top and bottom of the working sections. We consider first the pressure fluctuations measured in the preliminary tests,[1] when the vortex shedding frequency f^* coincides with the predicted tunnel resonance frequency f_r for two-dimensional transverse waves (Fig. 2).

Figure 3 shows the nondimensional 6% bandwidth pressure fluctuations, $\bar{p}/q$, induced by the 18 mm-diam cylinder in the closed working sections. As the tunnel speed is varied, we find for the design condtion of the experiment at $M = 0.4$ a severe resonance with hard walls. Here the vortex shedding frequency, $f^* = 1530$ Hz, is close to the calculated transverse resonance frequency for a two-dimensional working section $f_r = 1490$ Hz. Figure 3 also shows that with hard walls the pressure fluctuations adjacent to the cylinder at $x/H = 2.5$ become extremely large, and vary widely (from $\bar{p}/q = 40$-80%) from day to day. (The external noise level outside the tunnel also became excessive as this resonance condtion was approached.) The streamwise variation of the pressure fluctuations is interesting but must be considered fully elsewhere.[1]

In marked contrast to these results for the hard wall, with the laminate walls there is no obvious resonance. The pressure fluctuations adjacent to the cylinder are only about $\bar{p}/q = 20\%$, and the pressure fluctuations attenuate monotonically moving upsteam so that there is no streamwise mode. Thus, for this condition the closed working section with hard walls gives grossly inaccurate measurements relative to the unconstrained flow.

The measurements in Fig. 3, and those in the larger tunnel,[2] confirm that in a closed working section with hard walls, any phenomenon in which a vortex shedding frequency approaches or coincides with a transverse resonance frequency could be subject to serious interference effects. If interference of this type occurs, the vortex shedding could be altered and no simple corrections could be applicable to the measurements. The laminate walls plainly offer an effective means of drastically reducing such interference effects in a closed working section. Similar phenomena and improvements were also observed in slotted tunnels.[1,2]

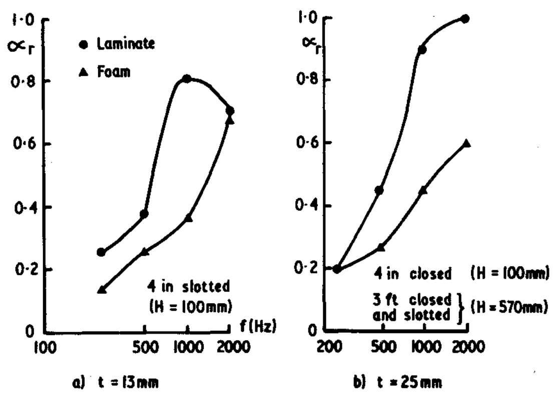

Fig. 1 Random incidence sound absorption coefficients.

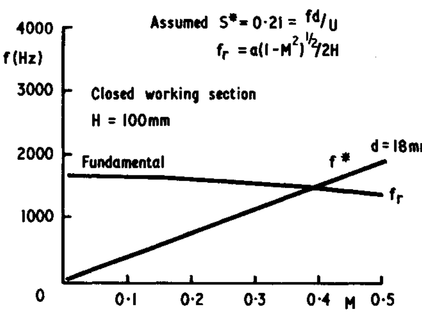

Fig. 2 Predicted shedding (f^*) and resonance frequencies (f_r).

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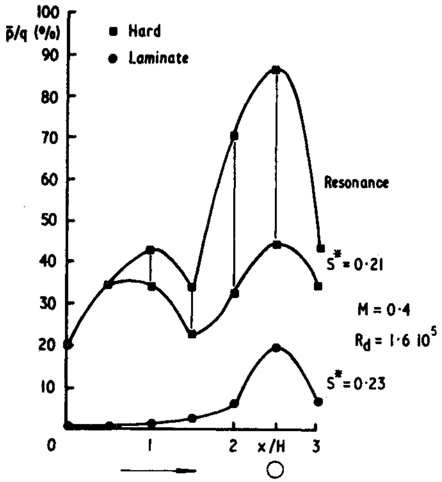

Fig. 3 Interference in closed working sections: $H = 100$mm $d = 18$ mm.

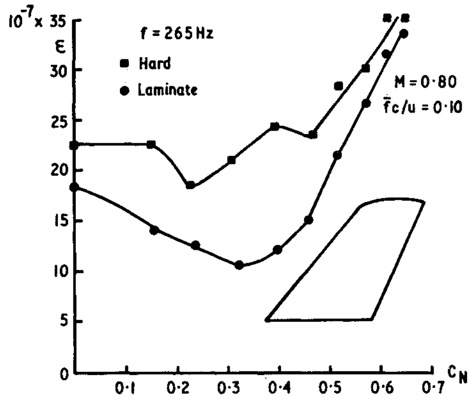

Fig. 4 Slotted working section, $H = 570$ mm—unsteady wing root strain (rms) vs normal force coefficient.

Improvement in Buffeting Measurements

Figure 4 shows the rms unsteady wing-root strain ϵ as a function of the steady normal force coefficient C_N measured on a fighter aircraft model in the large slotted working section. When the flow is attached at low values of C_N, the wing response is appreciably smaller with the laminate liners than with the hard liners, consistent with the greatly reduced level of aerodynamic excitation found over a wide range of frequencies. Hence, buffet onset is more sharply defined with the laminate liners than with the hard liners. In addition, the buffeting measurements with flow separations are less scattered with the laminate liners than with the hard liners. The latter effect is difficult to quantify, but it is most obvious at $M = 0.80$.

Performance at Supersonic Speeds

The present tests[1,2] have not included any formal assessment of the performance of sound absorbing walls for wind tunnels at supersonic speeds. This is not a serious limitation because resonances, the main concern at subsonic and low transonic speeds, cannot be maintained in the working section at supersonic speeds and because the flow unsteadiness is generally much lower at supersonic speeds. However, dynamic interference can still occur whenever unsteady shock or expansion waves from the model are reflected by the tunnel walls back onto the model. Such reflection will occur from transonic working sections with hard walls at high transonic speeds, say from $M = 1.0$ to 1.3. In this speed range the sound absorbing walls should still offer significant reductions in dynamic interference, and this hypothesis has been confirmed by some tests made by firing rifle bullets between the top and bottom liners removed from the pilot tunnel. Schlieren photographs (see Ref. 1) show that the foam wall almost completely cancels the moving shock waves of widely varying strength which emanate from the bluff nose, the rifling, and the recompression fan from the closure of the wake downstream of the base bubble. The laminate wall has the same general tendency, but is less effective.

References

[1]Mabey, D.G., "The Use of Sound Absorbing Walls to Reduce Dynamic Interference in Wind Tunnels," R & M 3831, 1978.

[2]Mabey, D.G., "The Reduction of Dynamic Interference By Sound Absorbing Walls in the RAE 3 Ft Wind Tunnel," Royal Aircraft Establishment, Bedford, England, RAE TR 77-120,