Effect of Stiffening on Sound Transmission into a Cylindrical Shell in Flight

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Theme

IN the context of airborne-noise transmission through an aircraft fuselage, a mathematical model is presented for sound transmission into a stiffened cylindrical shell. The stiffening effect of the ring frames and stringers is approximated by a "smeared" stiffener theory[1] which includes the eccentricity of the stiffeners. Numerical results are presented for a typical narrow-bodied jet in cruising flight.

Contents

The work reported herein is an extension of an earlier study[2] of the transmission of airborne noise through a monococque shell structure under "flight conditions," i.e., under conditions of external airflow and internal pressurization. The specific problem studied was that of an incident oblique plane wave impinging on a flexible cylindrical shell. As a point of reference, Fig. 1 shows the cylinder transmission loss (TL) for a monocoque shell at "standard conditions" (no external airflow or internal pressurization). TL was defined as 10 $\log_{10}$ of ratio of incident to absorbed acoustic energy, as proposed by Smith.[3] The exciting frequency is plotted nondimensionally relative to the critical frequency for a flat plate. Numerical results have been generated for a typical narrow-bodied jet fuselage made of aluminum, with radius $\alpha = 1.83$ m (6 ft) and wall thickness $h = 0.159$ cm (1/16 in.). Inspection of Fig. 1 shows that under no-flow conditions, the monocoque cylinder TL has two major "dips." The lower occurs at the "ring frequency," which is $f_R = 455$ Hz for the cylinder in question. The second dip occurs at the critical frequency, which is $f_C = 7552$ Hz in the numerical example. Referenced to f_C, the dip at the ring frequency occurs at $f_R/f_C = 445/7552 = 0.059$. Manning and Maidanik[4] and White[5] previously have reported on its importance. Between f_R and f_C, the TL follows a mass law. Below f_R, the TL tends to be stiffness governed, except where cylinder resonances occur.

Figure 2 shows the effects of external airflow and "ρc-mismatch" [due to internal pressurization with flight at 10,660 m (35,000 ft), and internal cabin pressurized to 2440 m (8000 ft)] for a 45 deg incidence angle. For purposes of comparison, the dotted curve shows the no-flow TL curve at standard conditions. The solid curves shows the flow TL at various flow Mach numbers, M. In the "mass-law" region, flow contributes a modest increase in TL. Below f_R, external flow interacts strongly with the cylinder resonances and can produce significant changes in TL.

Figures 3 and 4 show the effect on cylinder TL of adding stiffeners to a monocoque shell. Incidence angles are 45 and 60 deg. The ring frames are z-sections 2 in. high, with legs 1 in. wide. The stringer was a hat section 1-in. wide, 1.25-in. high, with feet 0.70-in wide. Both stiffeners are 0.071-in thick. Inspection of Figs. 3 and 4 shows that the TL of a stiffened shell is seen to be considerably higher than for a monocoque structure. The same sort of pattern exists for angles less than 45 deg. Comparison of numbers in Figs. 3 and 4 indicates that stiffeners appear effectively to reduce the size of the "transmission window" for airborne sound so that transmission tends to be restricted to the neighborhood of $\theta = 90$ deg. Calculations for $M = 0.75$ indicated that external flow did not affect the TL curves significantly for a stiffened cylinder.

Figure 5 shows results for $\theta = 75$ deg. Curve A is the TL of a monocoque cylinder, and curve B is that for a stiffened cylinder. It is evident that the stiffeners raise the TL dip at the ring frequency. They also modify the structural resonances of the cylinder. Curve C shows the corresponding TL curve for $\theta = 75$ deg at flight conditions. Comparison of curve C with curve B shows that flow and ρc-mismatch tend slightly to increase the TL of a stiffened cylinder. Curve D shows the TL under flight conditions for $\theta = 105$ deg. Comparing curves C and D shows the difference in noise propagation with and against the flow. External airflow destroys the symmetry about $\theta = 90$ deg that is present under no-flow conditions. For

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Index categories: Noise; Aerodynamics; Vibration.

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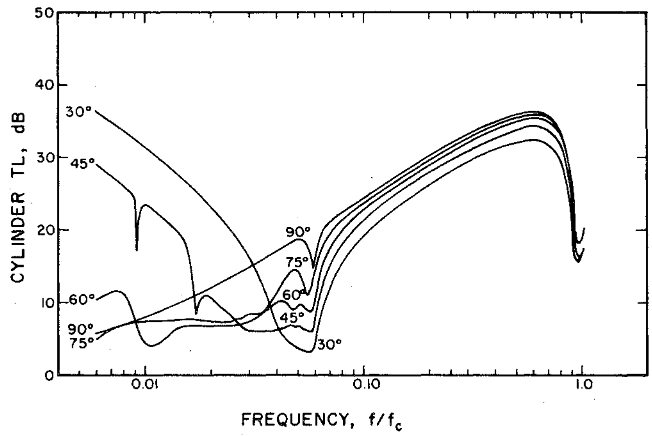

Fig. 1 Cylinder TL for various incidence angles for $M = 0$ and standard conditions, monococque shell.

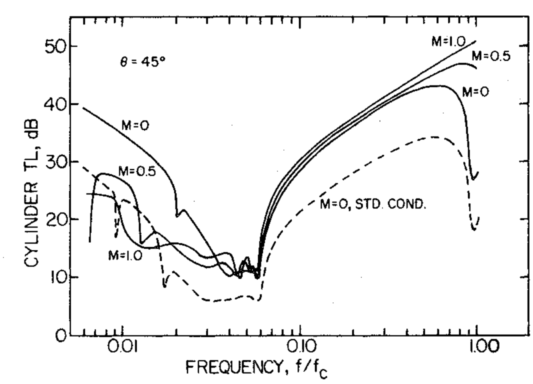

Fig. 2 Cylinder TL at flight conditions, $\theta = 45$ deg, for monococque shell.

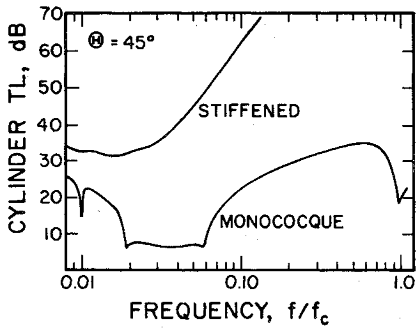

Fig. 3 TL of stiffened cylinder, $\theta = 45$ deg, no-flow at standard conditions.

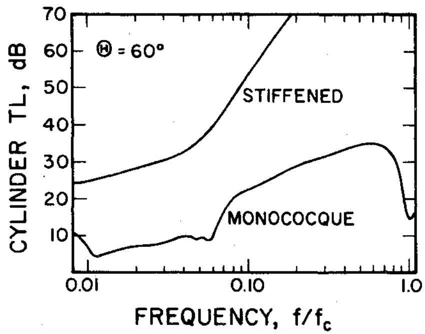

Fig. 4 TL of stiffened cylinder, $\theta = 60$ deg, no-flow at standard conditions.

a stiffened cylinder, flow appears to enhance the TL for sound waves propagating upstream.

There are some limitations that must be placed on the foregoing results for a stiffened cylinder. The "smearing-out" of the stiffeners is valid at low frequencies,[1] but breaks down at high frequencies when the stiffeners begin to act like supports and the shell begins to respond like individual cylindrical panels. This probably explains why the TL for a stiffened cylinder reaches such large values at the higher

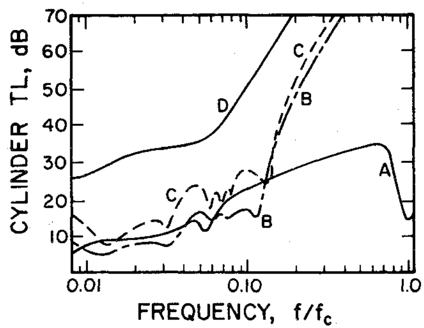

Fig. 5 Cylinder TL for A) monocoque shell, B) stiffened cylinder, C) stiffened cylinder at flight conditions, $\theta = 75$ deg, and D) stiffened cylinder at flight conditions, $\theta = 105$ deg.

frequencies in Figs. 3-5. This reduces confidence in the quantitative numbers, but the resulting trends just discussed are felt to be valid.

Acknowledgment

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