MODELLING OF SOUND TRANSMISSION THROUGH LIGHTWEIGHT ELEMENTS WITH STIFFENERS

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Systems Description

Single Panel System

- Diffuse Acoustic Field
- Lightweight panel
- Periodically Spaced Stiffeners

Double Panel System

- Diffuse Acoustic Field
- Lightweight panels
- Periodically Spaced Stiffeners
- Absorbing cavity
Analytical Model - Panel with Stiffeners

- 3-dimensional model based on the wave approach for infinite thin plate in flexure
- Stiffeners modeled as beams periodically distributed and line connected to panel
Analytical Model - Vibrational Flanking Path

- SEA approach for structural flanking path at panels boundaries

**Vibrational Energy**

Lightweight panels

Panels boundaries (Test room aperture / receiving structure)
Analytical Model - Equation of Motion

\[ Z_p(k_y, k_z, \omega) \tilde{v}(k_y, k_z) = 2P_{inc} \delta(k_0 \sin \theta \sin \phi - k_y) \delta(k_0 \sin \theta \cos \phi - k_z) \]

\[ -Z_{fB}(k_y, \omega) \frac{1}{L} \sum_{n=-\infty}^{n=+\infty} \tilde{v}(k_y, k_z - 2\pi n/L) \]

\[ + Z_{tB}(k_y, \omega) \frac{1}{L} \sum_{n=-\infty}^{n=+\infty} (k_z - 2\pi n/L)^2 \tilde{v}(k_y, k_z - 2\pi n/L) \]

- Plate total wave impedance
- Incident wave projection on plate
- Beam flexural line impedance
- Beam torsional line impedance

Wavenumber Spectrum
Analytical Model - Finite Size

- Finite size of system taken into account using spatial windowing technique applied to infinite panel


Diffraction through finite aperture without any modal consideration
Analytical Results - Single panel system

- Panel: 4 mm thick aluminum plate of size 3.43 x 2.73 m²
- Stiffeners: aluminum, periodically spaced with L=40 cm
Analytical Model - SEA approach for Flanking Path

• Structural coupling 2-3

\[ 10 \log_{10} \eta_{23} = 10 \log_{10} \eta - D_{23} \]

• Structure/volume coupling
  - panel critical frequency
  - panel mass per unit area
  - radiation factor \( \sigma \) (Leppington)
  - modal density (volume and panel)

• Flanking path transmission loss

\[ TL_{fl} = D_{23} + 10 \log_{10} \left[ \frac{2 \pi m^2 f^3 \eta}{\rho_0 c_0^2 f_c \sigma^2} \right] \]

Measured vibration level difference
Measured damping factor (structural time reverberation)
Analytical Results - Double panel system

- Panels: gypsum boards, (18+13) mm thick

- Absorbing cavity: 20 cm thick filled with glass wool (σ=5 kPa s/m²)

- Stiffeners: two U-shaped steel beams screwed together, periodically spaced with L=60 cm

- Damping factor $\eta$ and vibrational level difference between panels $D_{23}$ obtained from measurements on tested system
Analytical Results - Double panel system

- Measured - With Stiffeners
- Calculated - Without Stiffeners - Without Flanking path
- Calculated - With Stiffeners - Without Flanking path
- Calculated - With Stiffeners - With Flanking path
- Evaluated TLfl - Flanking path
Analytical Results - Double panel system