Acoustic black hole project

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PROBLEM: OPTIMISE DAMPING IN STRUCTURAL PLATES

- Need for novel and efficient vibration damping
- Application for mass sensitive structural plates

- Incorporation of damped tapered indentations into structural plates

- Traditional damping of structural plates is covering whole plate surface with viscoelastic material, which is inefficient

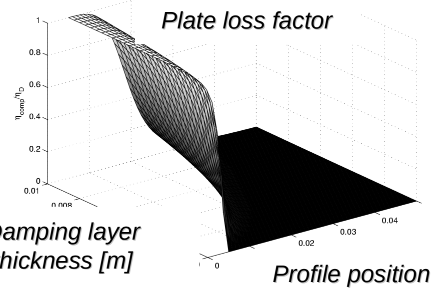
- Instead incorporate a damped tapered profile for around 10% of the added mass

- Circular and rectangular geometries considered
- Quadratically tapered thickness
- Numerical and experimental measurements

DAMPING A TO TAPERED SURFACE IS MORE EFFICIENT

- Apply damping tape to a plate surface, vary the thickness of the plate and the damping layer and note how the overall loss factor varies
- Quadratic power-law variation in thickness

$$h = \varepsilon r^2$$



- As the plate thins, the overall loss factor rises significantly

- In the thinner plate section, flexural wave amplitude increases, wavenumbers decrease, enhancing the shearing effect in the damping layer

- Kinetic energy is converted more efficiently to heat

NUMERICAL MODEL OF A CIRCULAR PLATE WITH RADIAL DAMPED INDENTATION

- Classical equation of motion in circular coordinates, Fourier series solution

$$w(r,\theta,t) = w(r)e^{in\theta}e^{-i\omega t}$$

$$\rho h \frac{\partial^2 w(r,\theta,t)}{\partial t^2} = (1-\upsilon)\Diamond^4\{D, w(r,\theta,t)\} - \nabla^2\left[D\nabla^2 w(r,\theta,t)\right]$$

- Solution for constant thickness section, Harris [1967]

$$w(r,n,\omega) = \begin{pmatrix} c_1 J_n(\beta r) + c_2 Y_n(\beta r) + \\ c_3 I_n(\beta r) + c_4 K_n(\beta r) \end{pmatrix} e^{in\theta}e^{-i\omega t}$$

- Solution for variable thickness section, Conway [1958]

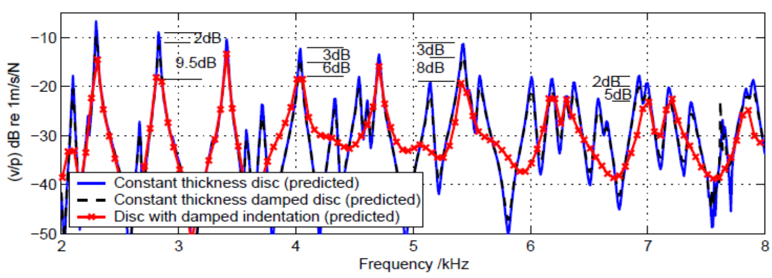
$$w(r,n,\omega) = \left(c_5 r^{\lambda_1} + c_6 r^{\lambda_2} + c_7 r^{\lambda_3} + c_8 r^{\lambda_4}\right) e^{in\theta}e^{-i\omega t}$$

- As radius decreases to zero, slope becomes infinite. No convergence, therefore a truncation radius must be included (a central hole) to avoid this singularity

- Traditional finite element methods and boundary element methods unsuitable for these problems due to the rapid change in wavenumber scale, need for fast simple models provided by bending plates and shell theory
- Constant thickness and damped tapered sections are joined by common displacement, slope, bending moment and shear force
- Point mobility a key indicator of vibration damping performance
- *O'Boy et al. Journal of the Acoustical Society of America, 129(6), 2011*

CONCLUSIONS

- Damped indentations show double the vibration reduction compared to covering all plate with viscoelastic damping material
- Highly effective vibration damper
- Low reflection coefficient from free edges
- Low damping mass ~10% mass of traditional damping methods



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