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

- Study of convergence in classical bending plate theory (flexural waves)

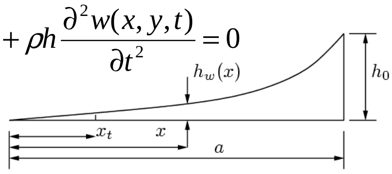
- Damping of flexural waves by localised plate indentations causing zero reflection coefficient from free edges

FLEXURAL WAVES IN IDEALLY TAPERED PROFILES

- A flexural wave travelling into a power-law profile (variable thickness) has a decreasing group speed and grows in amplitude
- Conservation of energy applies

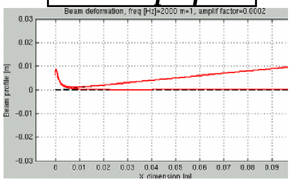
$$\left(\nabla^2\right)\left(D\nabla^2\right)w(x,y,t)+\rho h\frac{\partial^2 w(x,y,t)}{\partial t^2}=0$$

$$h(x)=\varepsilon x^m$$

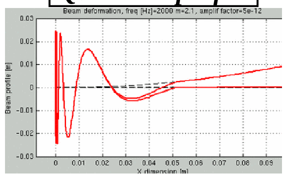


- Apply geometric acoustics approximation – Mironov [1988]
- Linear wedge (m=1), the wave reaches the end and reflects back (unity reflection coefficient)

Linear profile



Quadratic profile



$$x\to 0,\quad c\to 0$$

- For the quadratic case, the equation of motion does not converge, the group speed asymptotically decreases to zero at the wedge end
- As it does not reach the end of the ideal profile, it cannot reflect and a zero reflection coefficient is achieved
- As the plate thins, the waves increase in amplitude, the group speed and the wavenumber decreases dramatically

PRACTICAL PROBLEMS

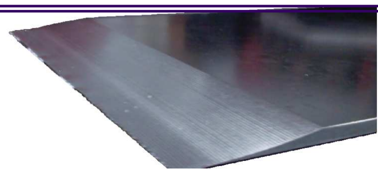
- The classical equations provide a physical insight into wave propagation
- A wave travelling into a quadratic power-law profile would increase in amplitude into non-linear regions, classical equations do not apply
- Any attempt to manufacture an ideal profile, leads to a tearing of the material, deviating from the profile and creating a free edge
- This free edge leads to reflection coefficients of 50-70 percent for flexural waves

PRACTICAL SOLUTION

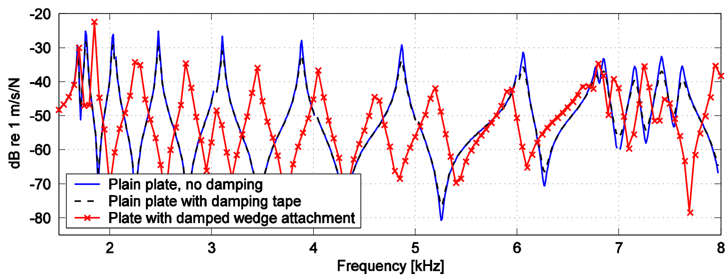
- Krylov [2004, 2006]
- Application of viscoelastic damping to power-law profiles
- Elevated amplitudes and decreased wavenumber causes more efficient conversion of kinetic energy to heat in the damping layer
- As the plate thickness decreases, the composite damping (plate plus damping layer) rises significantly
- Numerical models produced of rectangular plates with damped quadratic profiles attached
- Experimental measurements of point mobility

EXPERIMENTAL AND NUMERICAL POINT MOBILITY

- *O'Boy et al. Journal of Sound and Vibration, 329(11), 2010.*



Plain plate	Plain plate with damping	Plain plate with damped wedge attachment
Frequency /kHz	*Reduction in peak mobility amplitude /dB*	*Reduction in peak mobility amplitude /dB*
2-4	-4.2	-8.5
4-6	-4.0	-11.0
6-8	-4.2	-6.0



CONCLUSIONS

- Damped indentations show approximately double the vibration reduction compared to covering all plate with viscoelastic material

- Highly effective vibration damper
- Low reflection coefficient from free edges

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EPSRC Engineering and Physical Sciences Research Council