Acoustic black hole project

V. V. Krylov and D. J. O'Boy

PROBLEM: OPTIMISE DAMPING IN STRUCTURAL PLATES

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

- Highly efficient damping method for structural plates with low vibration amplitude characteristics uses damped indentations of quadratic power-law profile

- Double quadratic power-law profile is machined into a rectangular plate

- Viscoelastic damping is applied to the profile

- Plate retains significant structural stiffness in both longitudinal and torsional directions

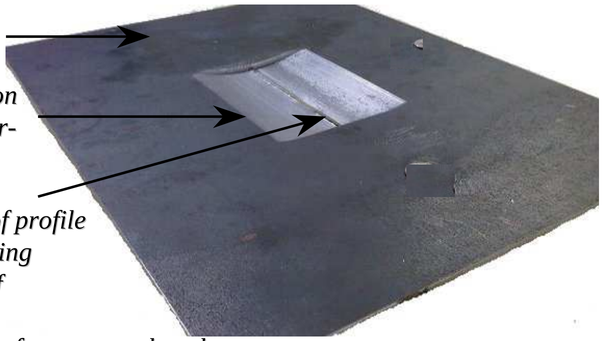
EXPERIMENTAL PLATE WITH LOW VIBRATION POINT MOBILITY CHARACTERISTICS, ENERGY METHOD

Rectangular plate

Profiled indentation of quadratic power-law design

Truncation point of profile

Viscoelastic damping applied to tip of profile



i) Calculate energy for rectangular plate

ii) Subtract energy due to a smaller rectangular plate being removed from the centre

iii) Analytically add the energy due to a power-law profile

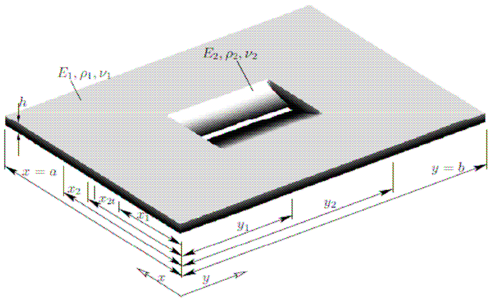
NUMERICAL REPRESENTATION OF A MULTI-SECTION PLATE

- Standard finite element and boundary element methods not suitable due to significant change of scale of the wavenumber

- Fourier series solution unsuitable due to not being able to perfectly match the boundary conditions at all plate corners

- Energy method is chosen – the contribution of kinetic and potential energy in each section of the plate is added separately
- Variational Rayleigh-Ritz: Minimisation of the difference in energy with respect to amplitudes of a suitable shape function

$$0 = \frac{\partial U_{\mathrm{Max}}}{\partial b_{ij}} - \frac{\partial T_{\mathrm{Max}}}{\partial b_{ij}} \qquad w(x,y,t) = \sum_{m=1}^{M} \sum_{n=1}^{N} X_m(x) Y_n(y) b_{mn} e^{i\omega t}$$



- The energy in the profile can be calculated analytically, taking into account the integration of a suitable shape function over the area of the profile, leading to a fast and effective method to determine natural frequencies and mode shapes

- Eigenvalue equation leads to natural frequencies of the composite plate, eigenvectors yield the mode shapes

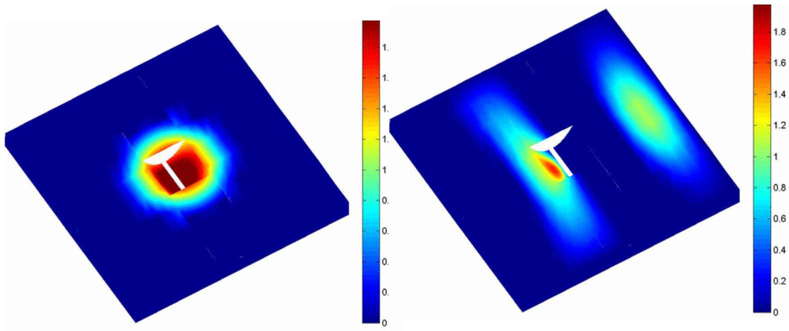
$$\sum_{m=1}^{M} \sum_{n=1}^{N} \left[C_{mn}^{(ij)} - \lambda \delta_{mn} \right] b_{mn} = 0$$

CONCLUSIONS

- The damped profiled indentation in the rectangular plate offers double the overall loss factor compared with a plate entirely covered with viscoelastic material

- The method is highly effective at high frequencies, where addition of mass is a serious problem (contains ~10% of damping mass of traditionally damped plates)
- Loss of structural stiffness is minimised

- Sixth and ninth response modes show significant amplitude increases in the profile, damping applied here yields enhanced vibration damping



Loughborough University

d.j.oboy@lboro.ac.uk

www.lboro.ac.uk/departments/tt/staff/oboy.html

EPSRC
Engineering and Physical Sciences Research Council