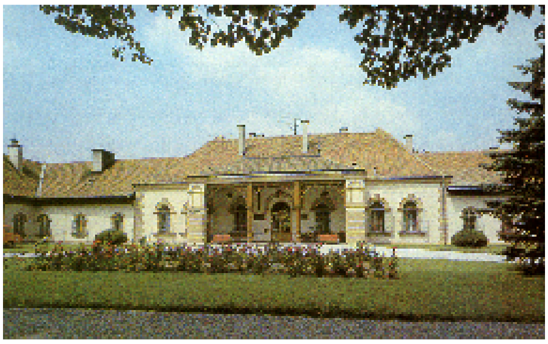


14th INTERNATIONAL ACOUSTIC CONFERENCE

XIV. MEDZINÁRODNÝ AKUSTICKÝ SEMINÁR

Kočovce, 1.– 2. jún 2009

Experimental study on damping of flexural waves in rectangular plates by means of one-dimensional acoustic 'black holes'

V. Kralovic, E.P. Bowyer, V.V. Krylov, D. O'Boy
Department of Aeronautical and Automotive Engineering
Loughborough University, Loughborough, Leicestershire, UK

Introduction

In this paper we present some recent experimental results on new lightweight and broad-band damping treatment for rectangular plates based on the so-called acoustic ‘black hole’ effect [1-5], which represents one of the most efficient ways of creating graded impedance interfaces [6] to reduce edge reflections of flexural waves. These acoustic black holes, or vibration 'traps', use elastic wedges of variable thickness defined by a power-law relationship $h(x) = \varepsilon \cdot x^m$ (with m ≥ 2) to reduce edge reflections. In the ideal case of no edge truncations, bending wave velocities decrease to zero in such a way that the waves never reach the end and hence do not reflect back. They thus represent one-dimensional acoustic ‘black holes’ for flexural waves. It was predicted [2,3] that very low values of reflection coefficient can be achieved even in the presence of truncations and imperfections when a narrow layer of absorbing material is attached to its surface in order to dissipate the remaining energy (note that direct application of thin layers of absorbing materials to the surfaces of rectangular plates has a negligible influence on damping, which has also been demonstrated during the tests).

Naturally, one can implement this approach, i.e. attach wedges of power-law profile, to different structures that have to be damped, for example rectangular plates (Figure 1). Wedge edges can be easily manufactured in the design stage together with a basic rectangular plate. In our experimental study we’re investigating the damping effect of various wedge profiles and materials, types of damping layer, effect of manufacturing (tapered, welded-on, glued-on wedges) for such a case.

Manufactured samples and experimental set-up

In order to examine the damping effect of this treatment, a number of 350 mm x 200 mm rectangular steel plates (Figure 1) were manufactured out of a 5 mm thick steel sheet. Plates were fixed to a support board to ensure stability during the machining process while the exponential profiles ($\varepsilon_{quad} = 2 \cdot 10^{-3}$, $\varepsilon_{cubic} = 4 \cdot 10^{-5}$) were milled off one end with a step of 1 mm / cut.

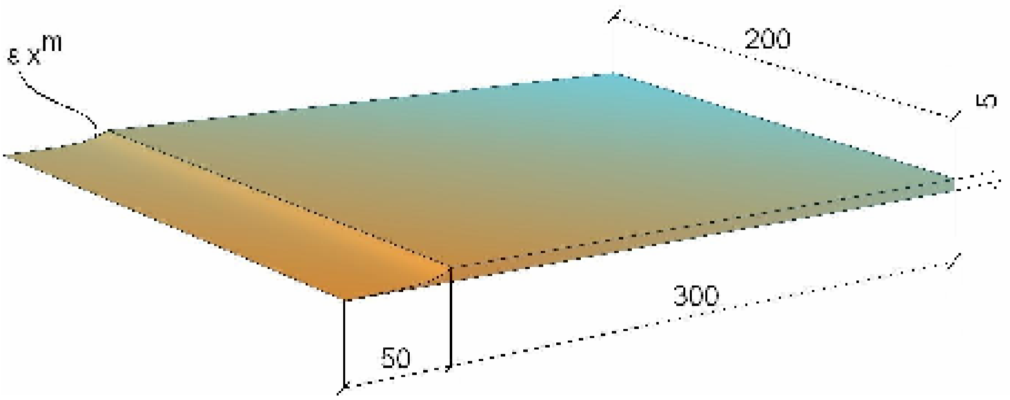


Fig 1 - Sample plate with a wedge-like end of a power-law cross-section on one side utilizing the acoustic black hole effect

Experiments were carried out within the Noise and Vibration Laboratory of the Aeronautical and Automotive Engineering Department at Loughborough University. An electromagnetic shaker LDS 200 series provided excitation to the centre of the uniform part of the plate. The B&K 8200 force transducer was attached to the surface of the plate via wax. Elastic bands, on which the steel plate was resting, were connected to a steel frame. This set-up (Figure 2) provided nearly free boundary conditions. A broad band accelerometer B&K 4371 was attached to the upper surface also via wax. White noise signal was generated by the B&K 2035 signal analyzer and B&K 2816 multichannel data acquisition unit.

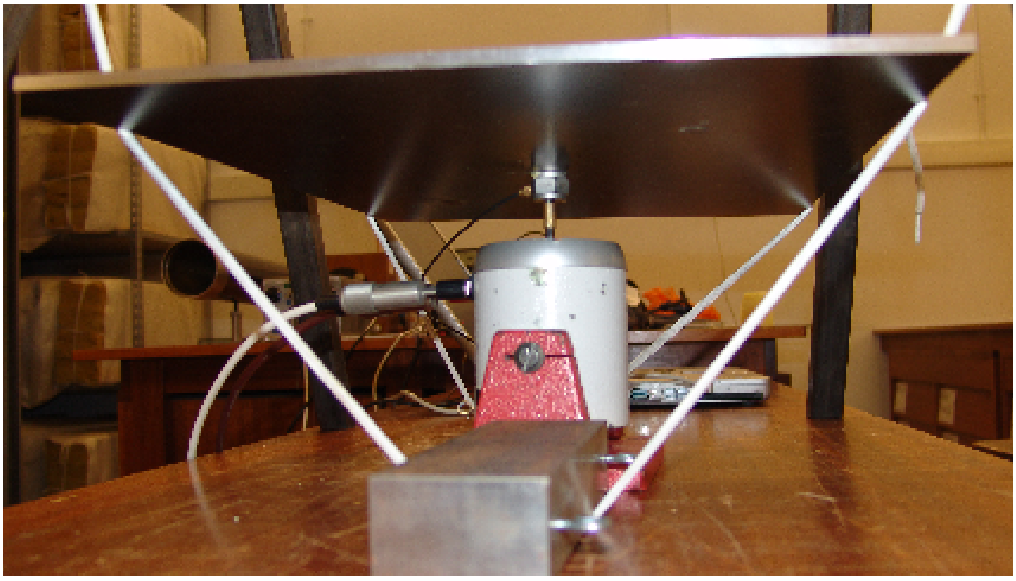
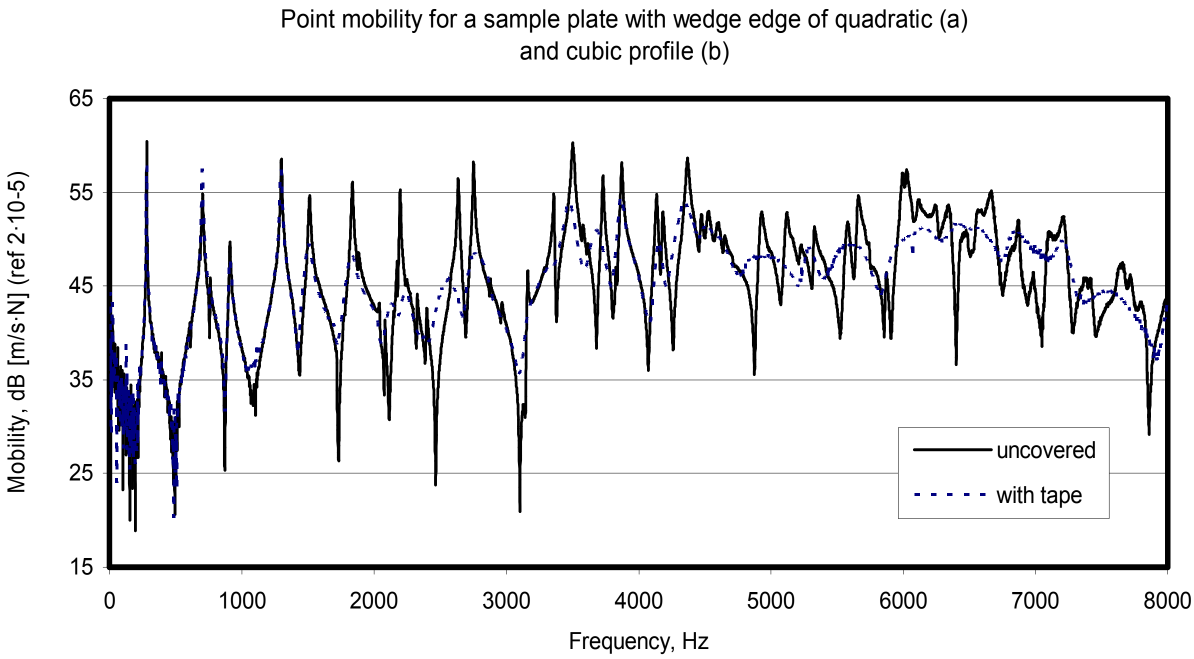


Fig 2 - Measurement set-up: sample plate resting on elastic bands providing nearly free boundary conditions

Several types of absorbing materials such as a duct tape, electro-isolating tapes and a bitumen-like absorbing material were used. For this paper we restrict the results to the case of duct tape.

Point mobility of rectangular plates with wedge-like edges

Point mobility measurements were carried out for rectangular steel plates and plates with wedge-like edges. It was studied how a partial coverage by films of absorbing layers affects the damping properties. Figures 3(a,b) and 4 display the responses of the plates with quadratic and cubic wedge profiles and that of a reference plate, respectively. Solid lines show the responses of uncovered plates, and dotted lines - the cases when a 40 mm strip is attached to bottoms of wedge tips.



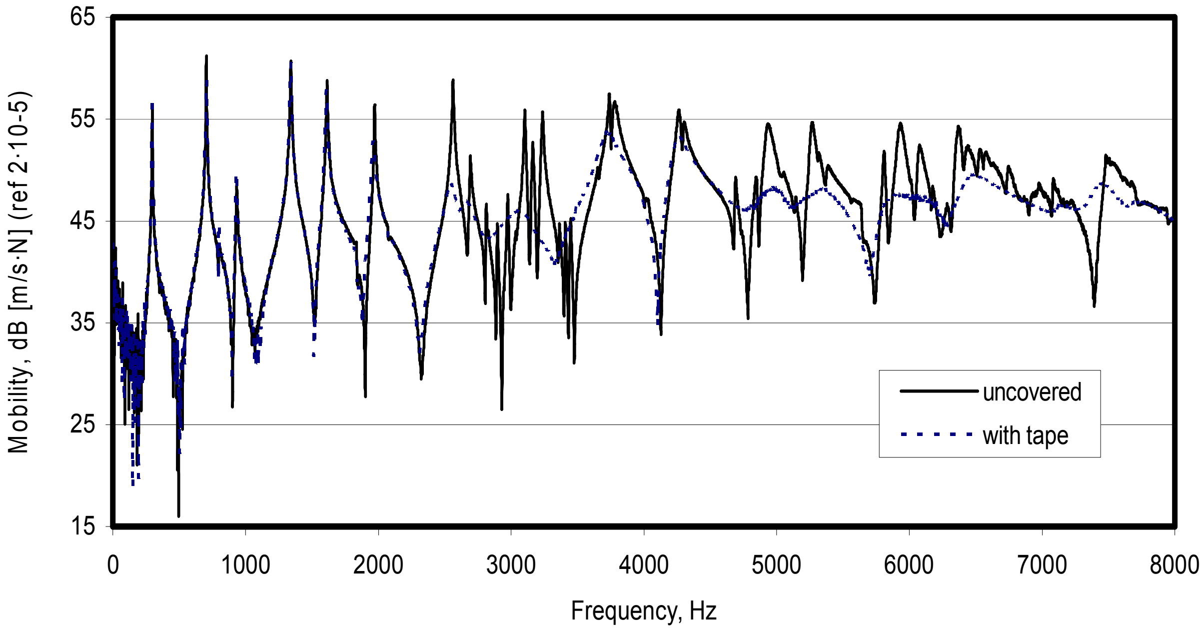


Fig 3 – Point mobility plots: plate with a quadratic (a) and cubic (b) wedge profiles, respectively. Note a significant suppression in the case of covered wedge tips

Note, that there were some difficulties associated with the production of higher order power-law wedges. A more significant damping effect can be expected when reducing imperfections in the production process.

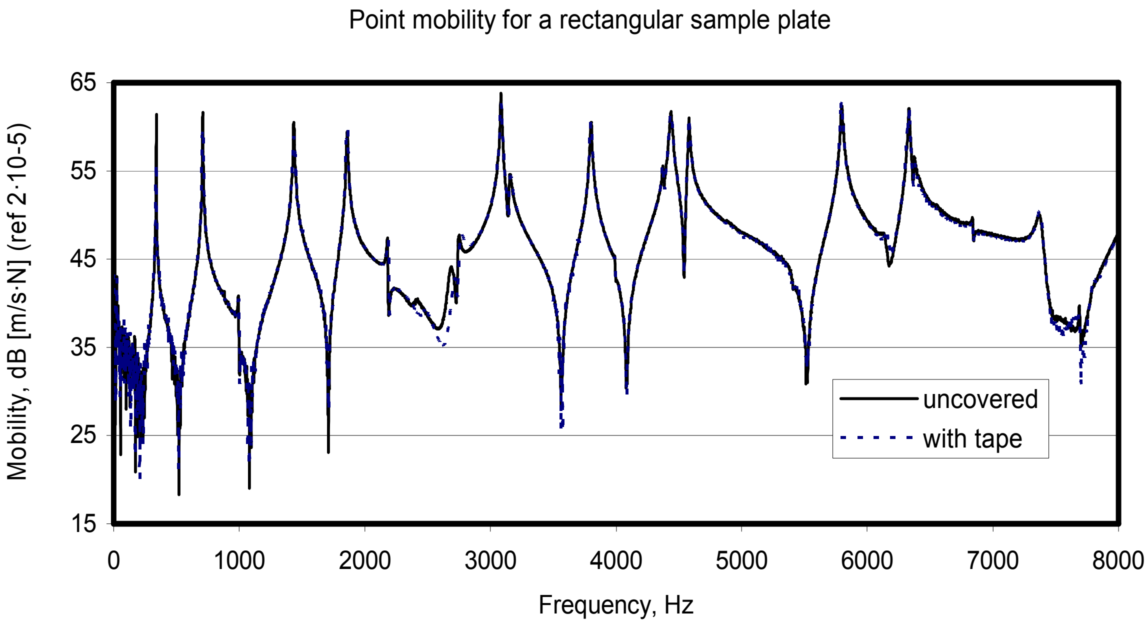


Fig 4 – Point mobility plot of a uniform rectangular (reference) plate. Note a negligible reduction of resonant peaks in the presence of absorbing material.

References

[1] V.V. Krylov, On the velocities of localised vibration modes in immersed solid wedges, Journal of Acoustical Society of America, 103 (1998), pp 767–770, (1998)

[2] V.V. Krylov and F.J.B.S Tilman, Acoustic 'Black Holes' for Flexural Waves as Effective Vibration Dampers, Journal of Sound and Vibration, 274, 2004, pp 605-619, (2004)

[3] V.V. Krylov, New type of vibration dampers utilising the effect of acoustic ‘black holes’, *Acta Acustica united with Acustica* 90(5), 830–837 (2004)

[4] V.V. Krylov and R.E.T.B. Winward, Experimental Investigation of the Acoustic Black Hose Effect for Flexural Waves in Tapered Plates, Journal of Sound and Vibration, 300, 2007, pp 43-39, (2007)

[5] V. Kralovic and V.V. Krylov, Damping of flexural waves in tapered rods of power-law profile: Experimental studies, Proceedings of the Institute of Acoustics, 29, Pt 5, 66-73 (2007)

[6] C. Vemula and A.N. Norris, Attenuation of waves in plates and bars using a graded impedance interface at edges, Journal of Sound and Vibration 196, 107–127 (1996)

Resumé

Tlmenie ohyboveho kmitania obdlznikovych dosiek pomocou jednorozmernych akustickych ciernych dier (experimentalna studia). Dosky s hranami kvadratického alebo vyššieho exponenciálneho tvaru predstavujú nový a efektívny spôsob tlmenia ohybového kmitania [1-4]. Počas testu sme touto metódou dosiahli útlm okolo 10 dB. Exponenciálna časť dosiek predstavuje tzv. akustické čierne diery. Podobný efekt bol dokázaný pre tyče [5].

Acknowledgements

The research reported here has been partly supported by EPSRC grant EP/F009232/1.