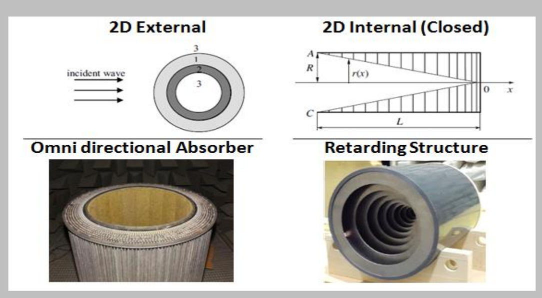
Acoustic metamaterial absorber shielding structures for control of waves in realistic harsh environments

Introduction



The project is based on investigating acoustic black holes and dead end pore absorbers for weak shock waves. The development is to lead to an effective metamaterial absorber being thin, robust and broadband. The absorber built and tested is based on "acoustic black hole" (ABH) and dead-end pore (DEP) effects.

Black hole absorbers comprised of rings and cavities have been first suggested by Mironov and Pislyakov (1). It has been shown also that a structure having multiple rods of varying size and space which acts as a graded index matching layer (2) is able to impedance match air to the absorbing core made of porous material. Dead end pores prove to be effective for designing low frequency absorbers.

In this project both ideas are combined to a single design.

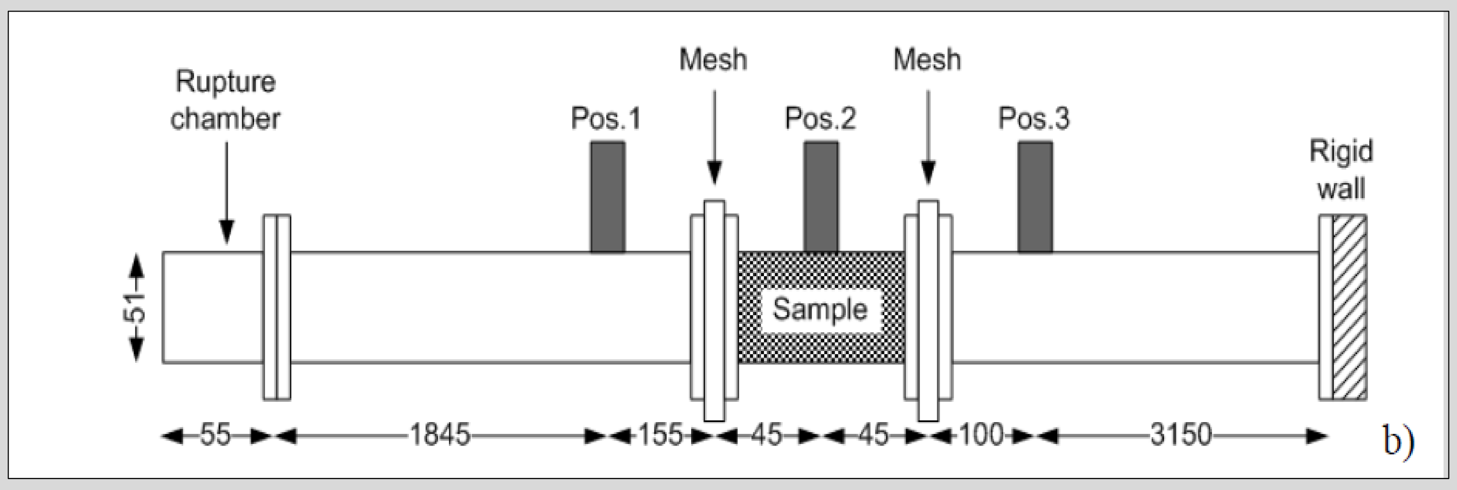
The gradual impedance matching is achieved by varying the size of the central pore. The absorber is tested in shock tube for various levels of acoustic excitation.

Aims and objectives

- **To develop a method for testing absorbers in a shock tube using signals with variable amplitudes**
- **Build and test acoustic absorber based on ABH and DEP effects**
- **Compare absorber performance with that of the cone without DEP for pulses with various amplitudes**

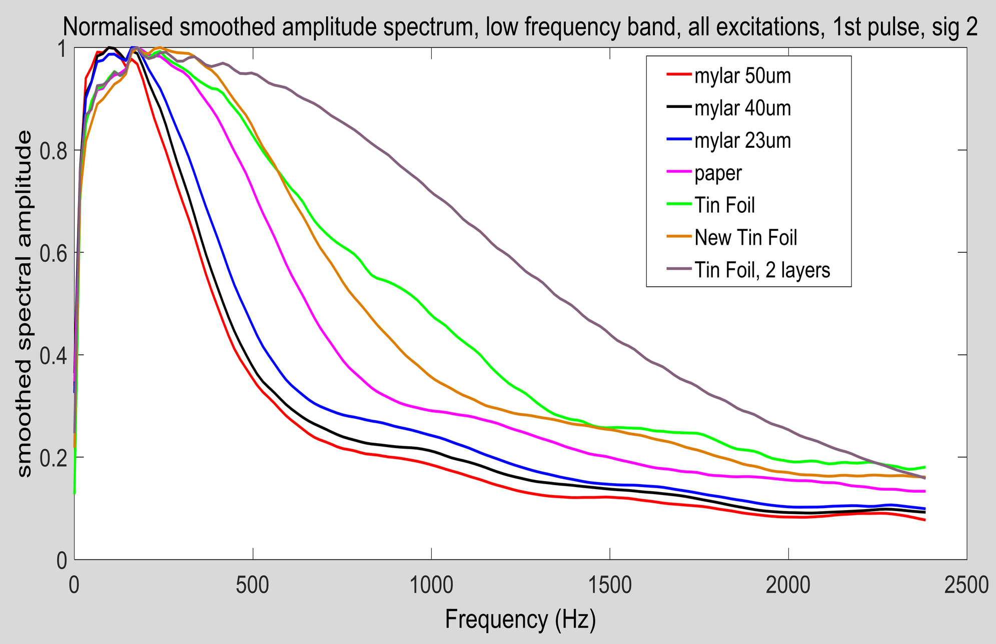
Experimental methods and Results

• Measurements in empty tube

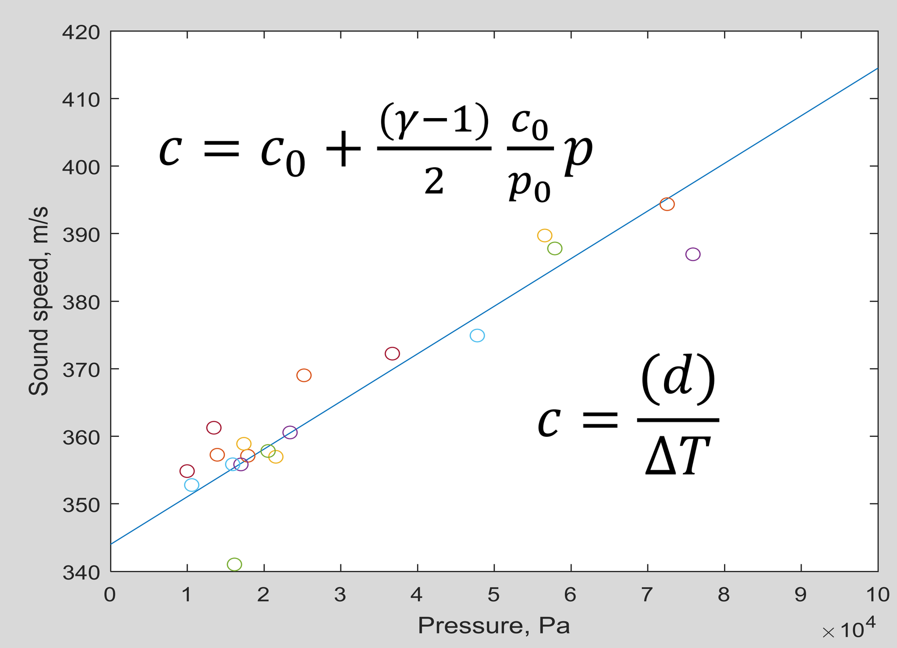


Shock tube in transmission mode. Dimensions in (mm)
The extension of the shock tube in transmission set up (approx. 3.25 m) allows no intended interaction between the transmission pulses to that of the reflected pulse coming from the rigid end location at the end of the shock tube. Because the time of pulse flight is at least twice the duration of the pulses then no superposition is achieved thus reflection and transmitted pulse amplitudes can be treated as separate occurrences.

Pulse amplitudes up to 100KPa
Durations of pulse up to 10ms



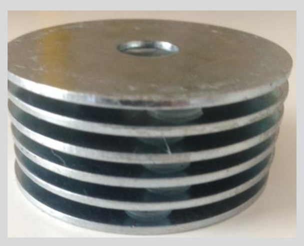
Sound speed in empty tube versus pulse amplitude

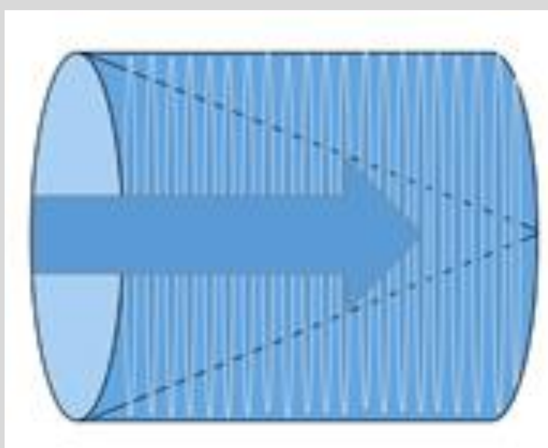


Signal 3 first pulse
Mylar 23 36830 Pa, 372.12 m/s
Mylar 40 58000 Pa, 386.83 m/s
Mylar 50 56690 Pa, 389.61 m/s

Signal 2 first pulse
Mylar 23 47900 Pa, 374.81 m/s
Mylar 40 76000 Pa, 387.69 m/s
Mylar 50 72640 Pa, 394.25 m/s

• Absorber design

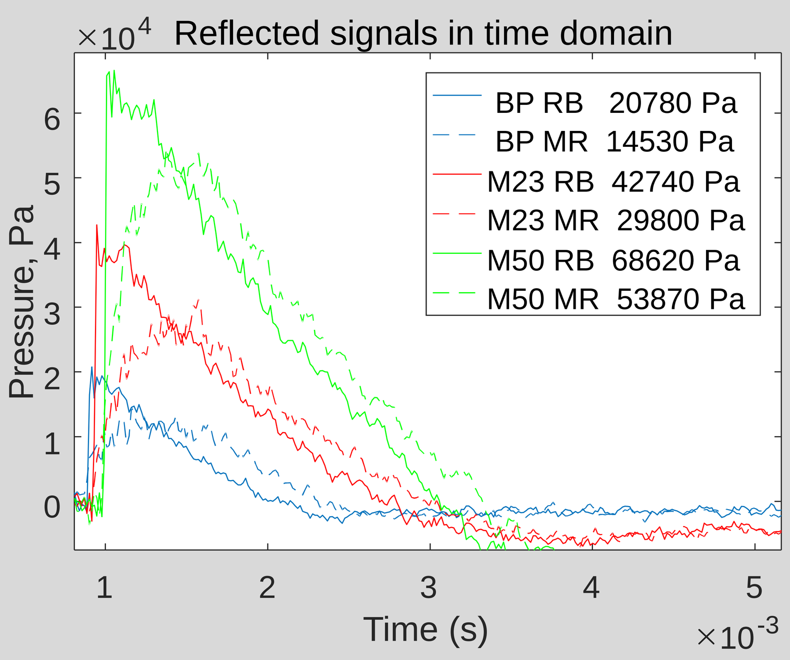




Ring thickness: 2mm
Cavities size: 2.5mm
Absorber thickness: 9.45 cm (21 sections)
Central pore decreases with increasing structure length from 5cm to zero diameter.

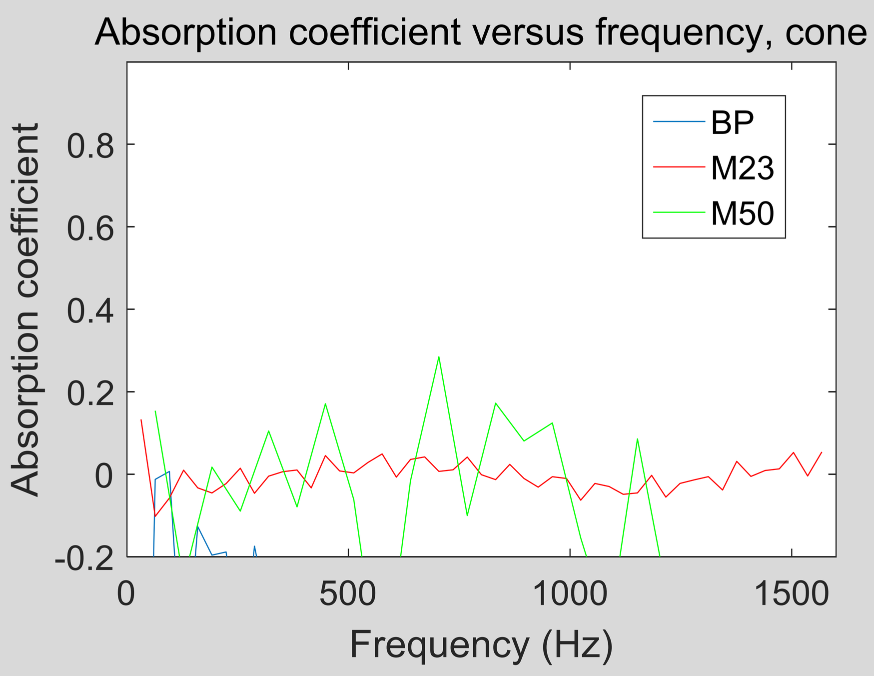
.10 cm hollow cone for comparison

• Results

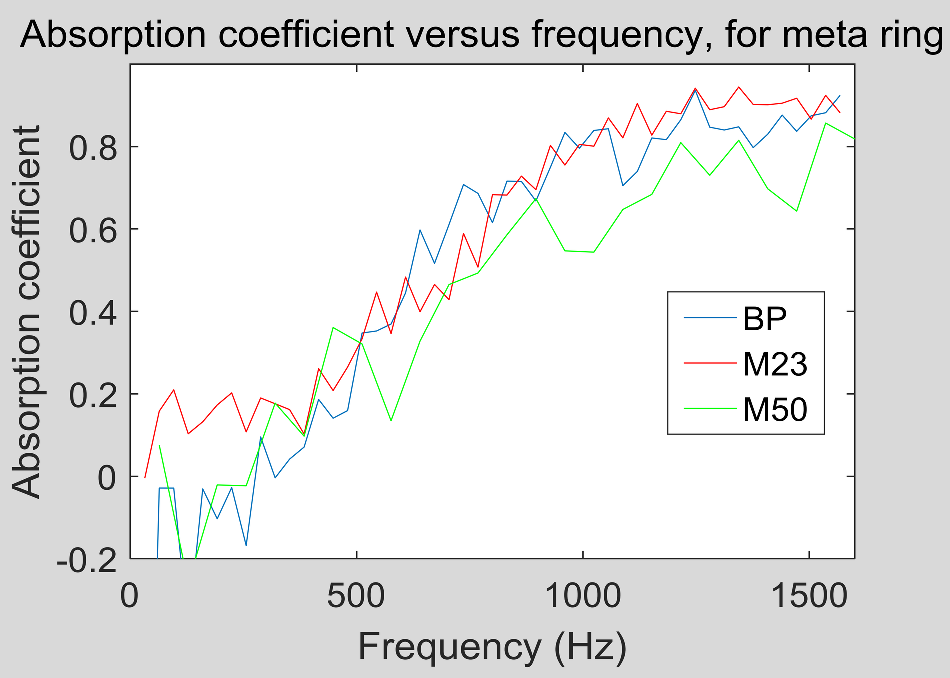


RB – rigid backing, MR – meta ring absorber

Peak reduction coefficient is calculated as the ratio of the peak pressure of the pulse reflected from the absorber to that of the pulse reflected from rigid termination

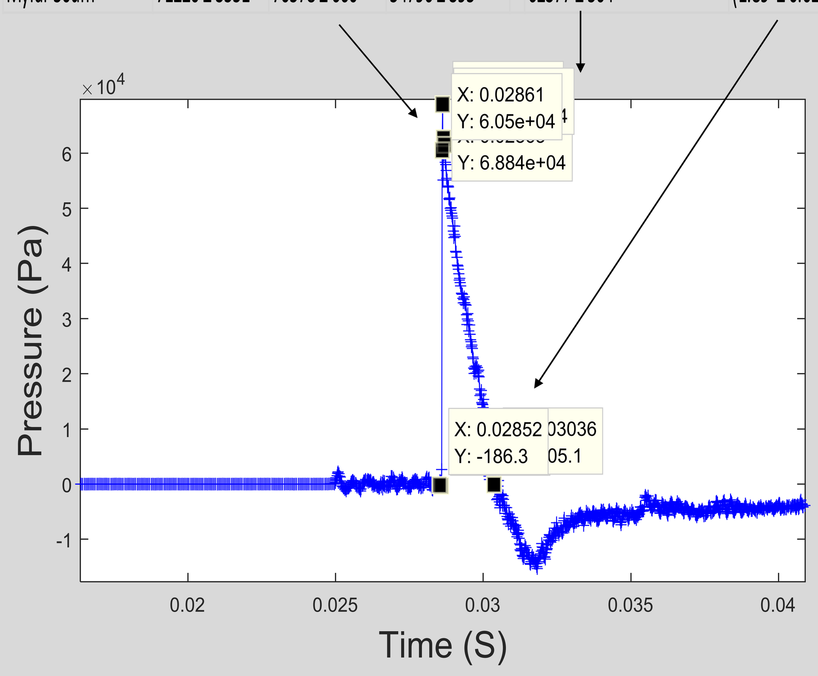


Material	Incident pulse peak, kPa	Peak reduction coefficient	Energy absorption coefficient
BP	23	0.79	0.14
Mylar 23	41	0.73	0.22
Mylar 50	69	0.82	0.07



Energy absorption coefficient is calculated as one minus the ratio of the energy in pulse reflected from the absorber to that in pulse reflected from rigid termination

Membrane	Signal 1 (Pa)	Signal 2 (Pa)	Signal 3 (Pa)	Signal 2 peak average (Pa)	Signal 2 duration (S)
Tin Foil (D)	16422 ± 495	15498 ± 542	13342 ± 290		
Tin Foil x2 (A)	19600 ± 680	18584 ± 746	14698 ± 343	16442 ± 536	$(1.08 \pm 0.04) \times 10^{-3}$
Paper	39384 ± 265	29770 ± 610	24704 ± 311	27013 ± 482	$(1.23 \pm 0.04) \times 10^{-3}$
Mylar 23um	48784 ± 1406	46976 ± 759	36310 ± 227	41647 ± 287	$(1.60 \pm 0.03) \times 10^{-3}$
Mylar 40um	76330 ± 8738	65510 ± 3888	48214 ± 1504	57746 ± 2990	$(1.79 \pm 0.02) \times 10^{-3}$
Mylar 50um	71220 ± 3551	70578 ± 660	54796 ± 395	62377 ± 504	$(1.89 \pm 0.02) \times 10^{-3}$



Future work

The near future work is to develop a model and to optimise design for high amplitude acoustic excitations. Samples of omnidirectional sound absorber structures to be developed aimed at producing effective sound absorption. Prototype structures to be tested by means of 3D printing. The ultimate aim is to validate the combination of DEP and ABH for an effective metamaterial absorber with future blast trials.

A new computational model for high amplitudes – weaker membranes to be exploded – different techniques of shock pulse creation – construction of new prototypes

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References:
(1) M.A Mironov, V.V. Pislyakov,Acoust. Phys.48, 347, (2002)
(2) A.S.Elliott, O.Umnova, R.Venegas, Appl Phys.115,204902 (2014)