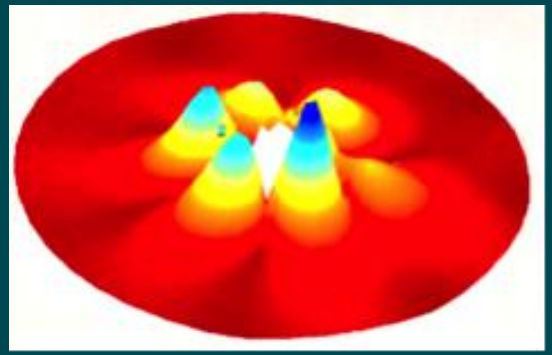

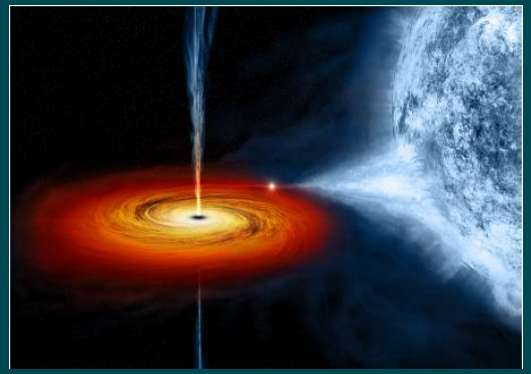

Passive Structural Damping with Acoustic Black Hole (ABH) an Innovative Design Tool

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E-LASS - January 2021

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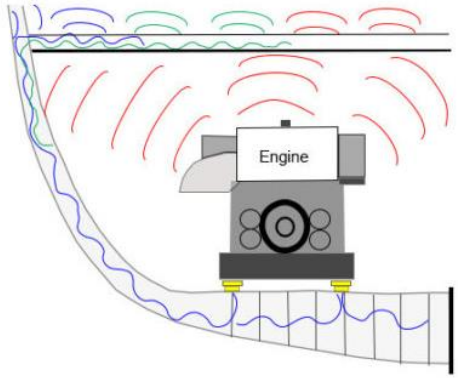
Presentation Summary

1. Maritime Transport Acoustic Comfort
2. What is an Acoustic Black Hole (ABH)
3. ABH Examples for Vibration damping
4. ABH Selected Applications
5. Conclusions

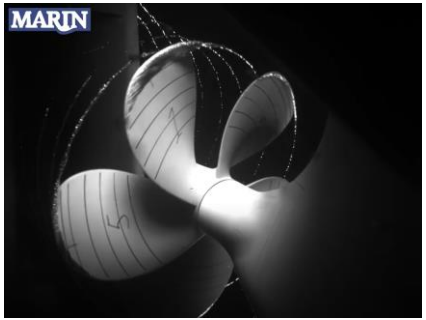
Maritime Transport
Acoustic Comfort

Noise and Vibration onboard

- Main sources of **noise and vibration** on board of a vessel:
  - Main engine
  - Propeller
  - Exhaust system
  - Auxiliary engines, pumps and other equipment
  - Hydraulic system
  - Ventilation and air conditioning system



https://dosits.org/decision-makers/tutorials/sound-source/commercial-vessel/



➔ Cause **discomfort** and **damage** to crews, passengers, equipment and structure.

Regulations and standards

- COMF-NOISE and COMF-VIB
  - Vessel size
  - Areas: Passenger or crew
  - Yachts

Table 3 : Noise level requirements for ships greater than 10000 GT

Locations	LAeq,T in dB (A)		
	grade = 1	grade = 2	grade = 3
Wheelhouse	60	63	65
Radio room **(1)**	55	57	60
Cabins	50	52	55
Offices	55	57	60
Public spaces, mess rooms	55	57	60
Hospital	53	54	55
Engine control room or switchboard room (if continuously manned at sea) **(2)**	70	73	75
Open recreation areas **(3)** **(4)**	70	73	75
Galleys **(2)**	72	72	75
Workshops other than those forming part of machinery spaces **(2)**	85	85	85
Staircases and passages in crew areas	70	73	75

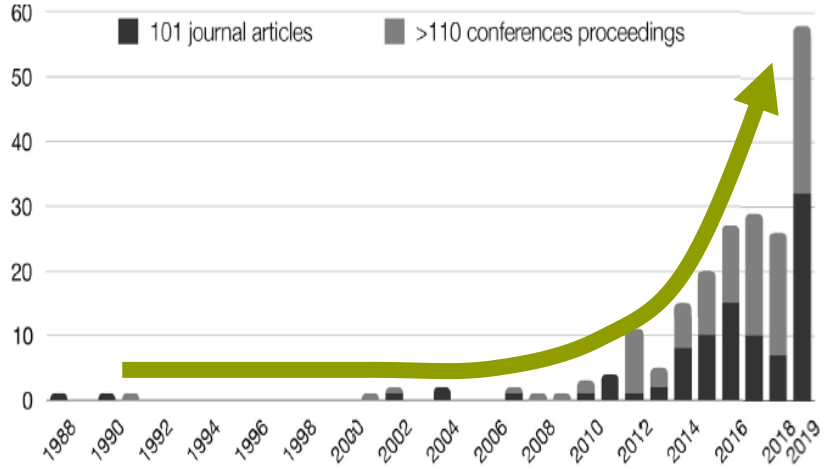
(1) Equipment switched on but not emitting.
(2) Equipment switched on but not processing.
(3) Measurement carried out with a windscreen microphone protection.
(4) A tolerance of 5 dB (A) may be accepted for measurements at less than 3 m from ventilation inlet/outlet.

Table 4 : Overall frequency weighted r.m.s vibration levels

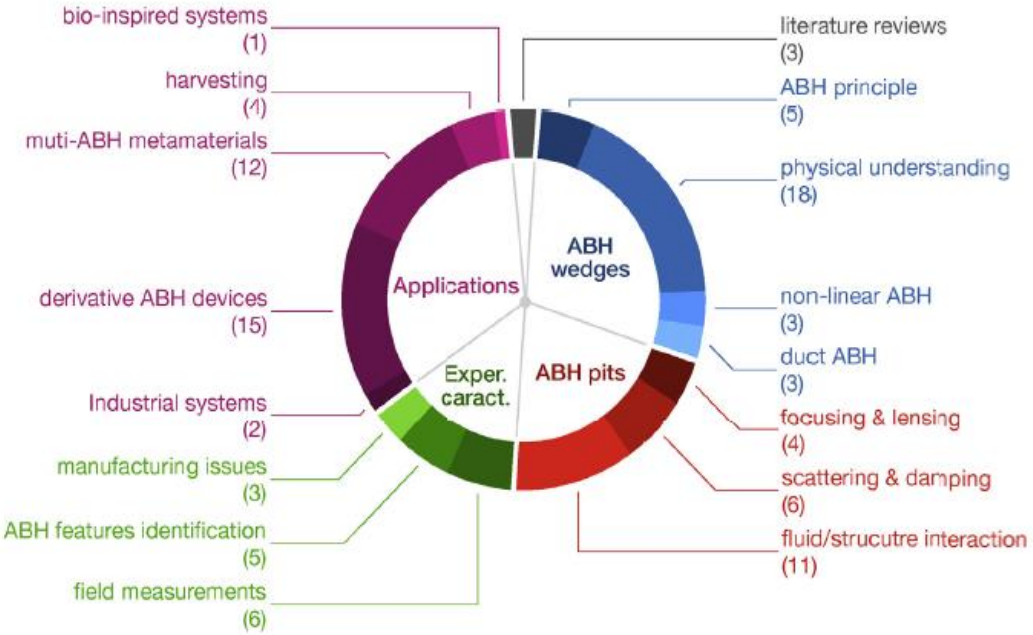
Locations	Vibration velocity (mm/s) values from 1 Hz to 80 Hz		
	grade = 1	grade = 2	grade = 3
Wheelhouse	2,8	3,0	3,2
Radio room			
Cabins	2,8	3,0	3,2
Offices	3,0	3,5	4,0
Public spaces, mess rooms	3,0	3,2	3,5
Hospital	2,8	3,0	3,2
Engine control room or switchboard room (if continuously manned at sea)	4,0	4,5	5,0
Open recreation areas	–	–	–
Galleys	5,0	5,5	6,0
Workspaces			
Staircases and passages in crew areas	5,0	5,5	6,0

What is an Acoustic Black Hole (ABH) ?

Evolution of ABH (Publications, applications, ...)



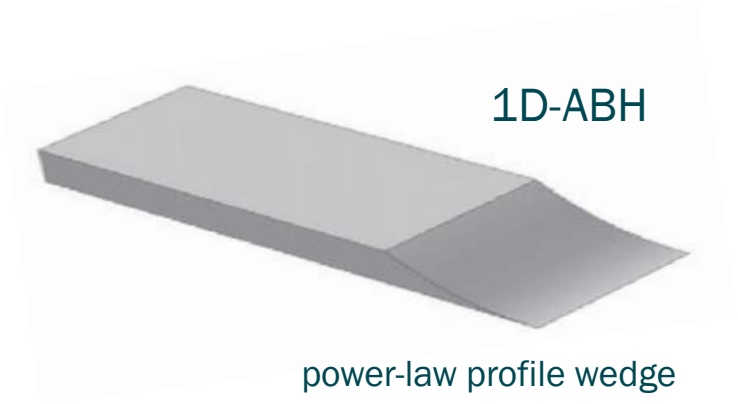
Publications evolution



- **ABH effect was first discovered by Pekeris in 1946**
- **In 1988 Mironov determined the effect of ABH in flexural waves damping in a tapered plate**
- **Number of publications and Patents increased a lot since 2010**
- **Number of applications is increasing as well in many different fields**

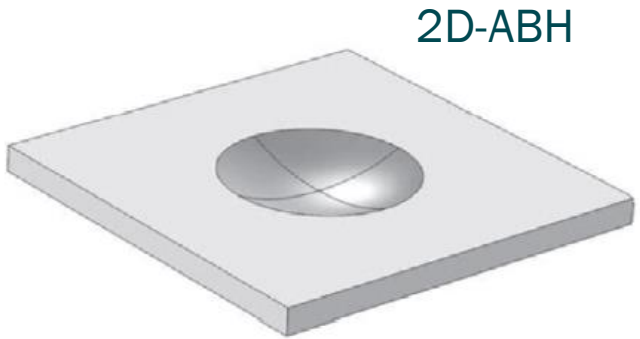
What is an ABH?

Wedges of power-law profile act as one-dimensional ABH (1D-ABH) and increases flexural vibration waves damping.



power-law profile wedge

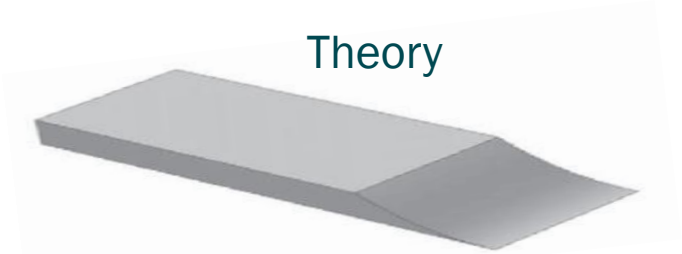
Tapered circular indentations of power-law profile act as two-dimensional acoustic black holes (2D-ABH) increasing vibration waves damping.

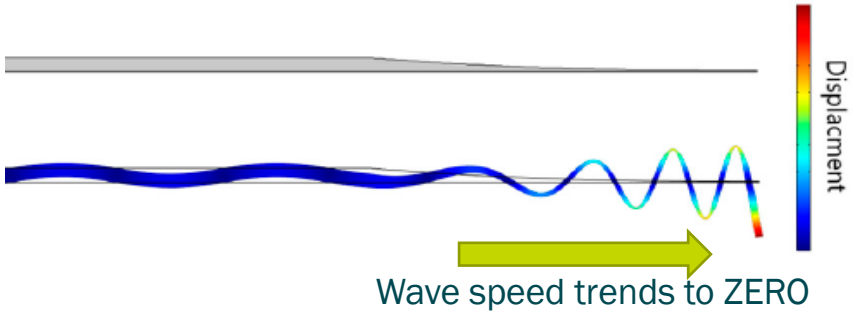


tapered power-law profile

How ABH damps flexural vibrations

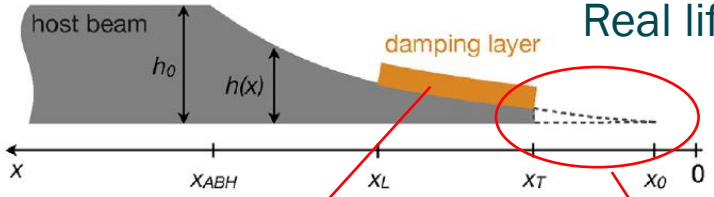
Theory





Wave speed trends to ZERO

Real life



Damps high amplitude disp.

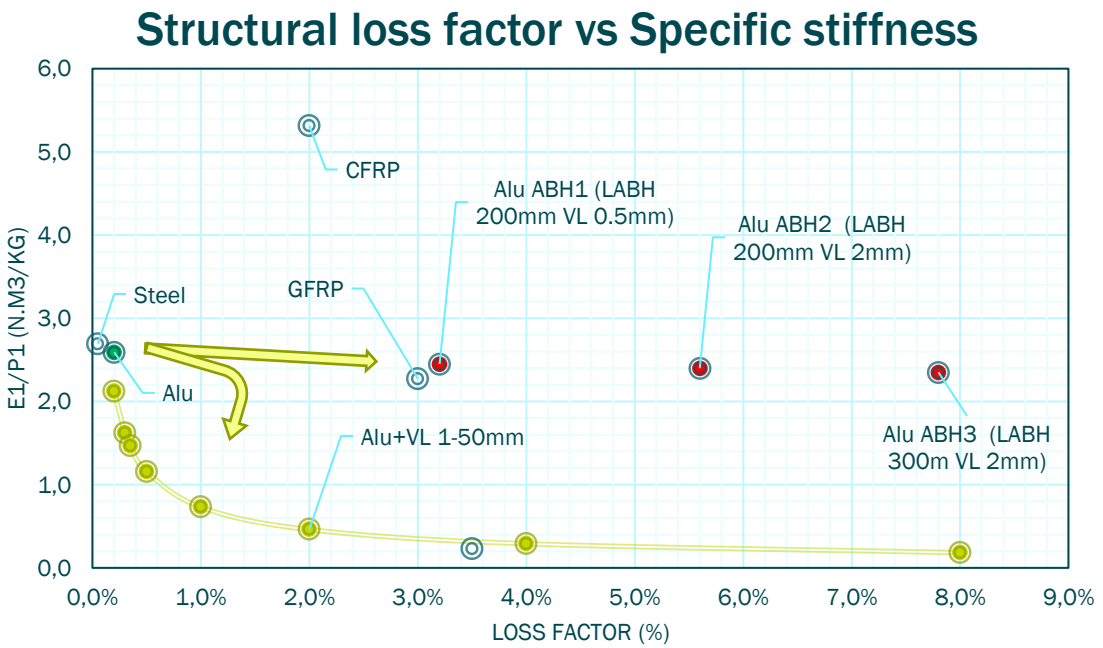
Not realistic zero thickness

Once a flexural wave gets into a tapered (power-law profile), the flexural wave propagation speed tends to zero and there is no way back, therefore damping out vibration!

Typical Structural loss factors vs specific stiffness and ABH

Specific stiffness or ***Specific modulus*** is a materials property consisting of the elastic modulus (E) per mass density of a material (ρ)

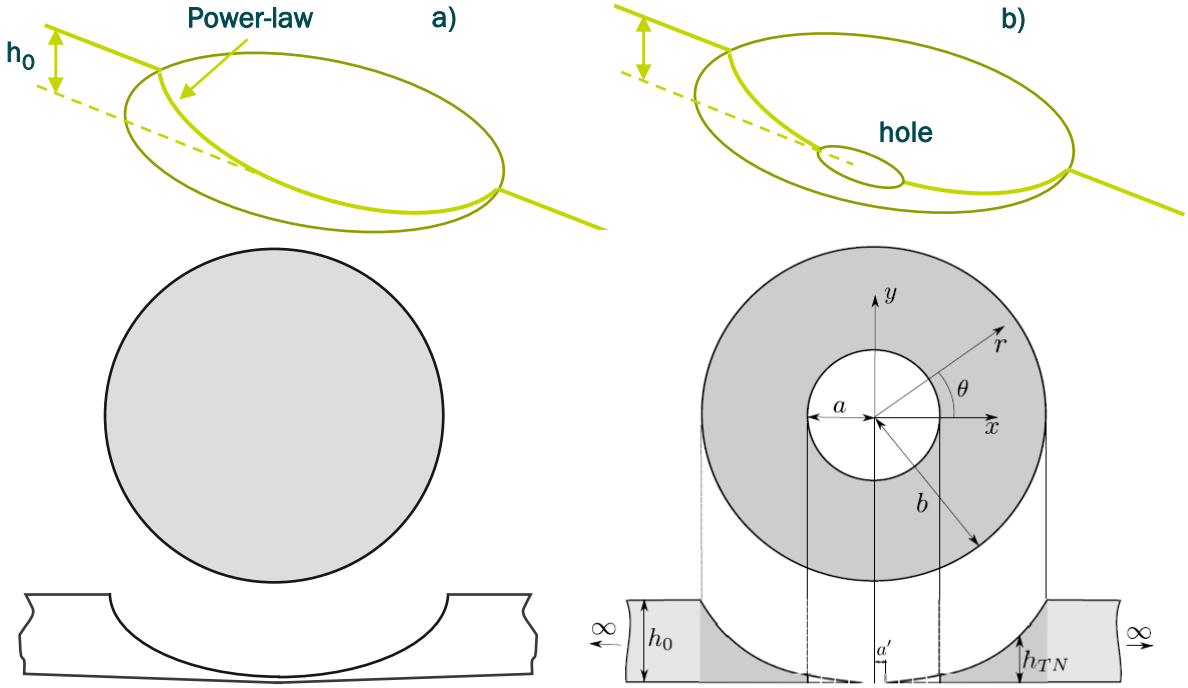
$$specific\ modulus = E/\rho$$



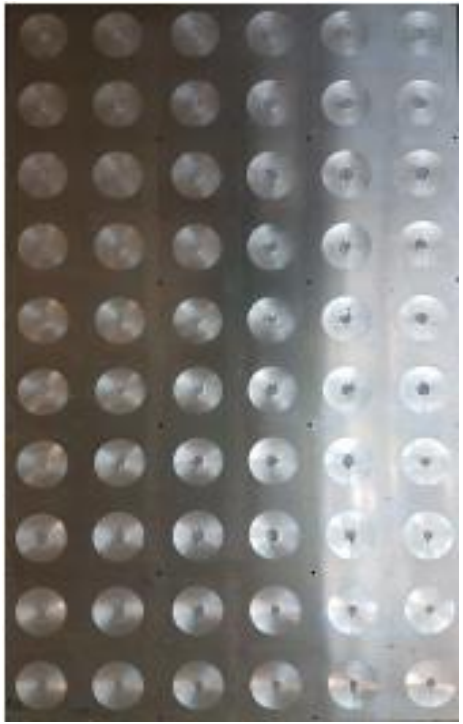
Impact of ABH on loss factor (passive damping)

ABH Examples and Vibration damping in panels

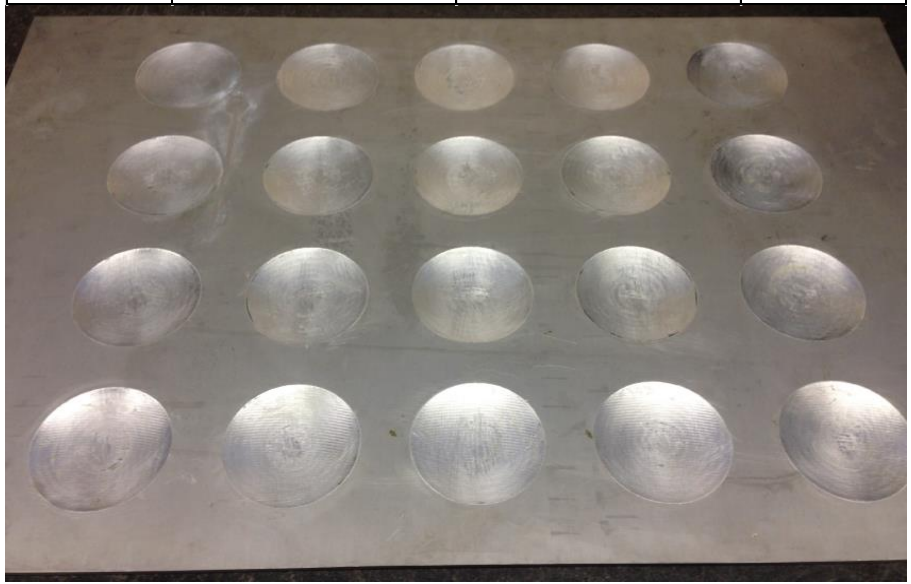
Typical 2D ABH designs (1/3)



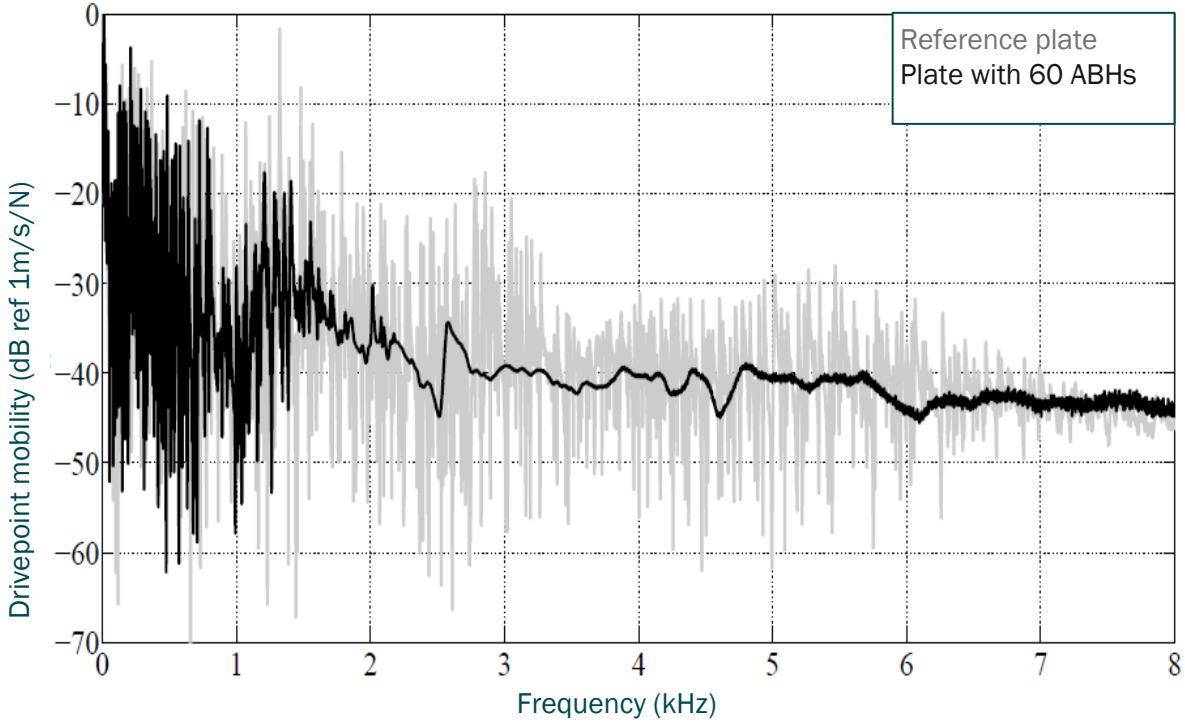
Typical ABH machinig – designs (2/3)

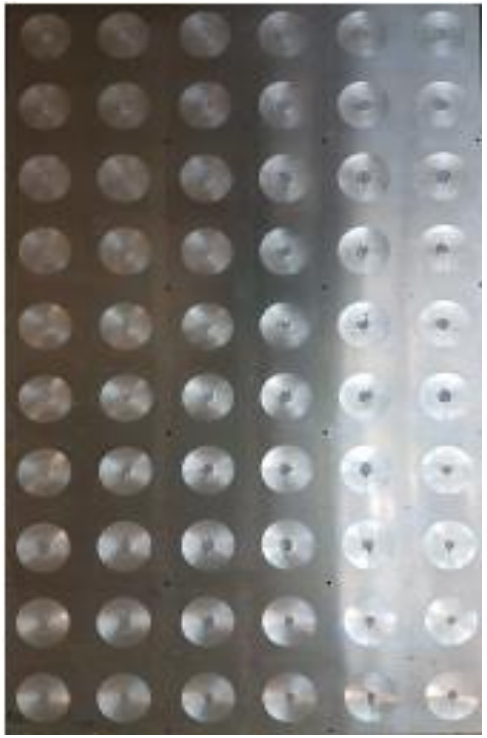


ABH Dimensions			
Power-law	Plate thickness	Termination thickness	Diameter
2.2	6.6 mm	0.86 mm	100mm



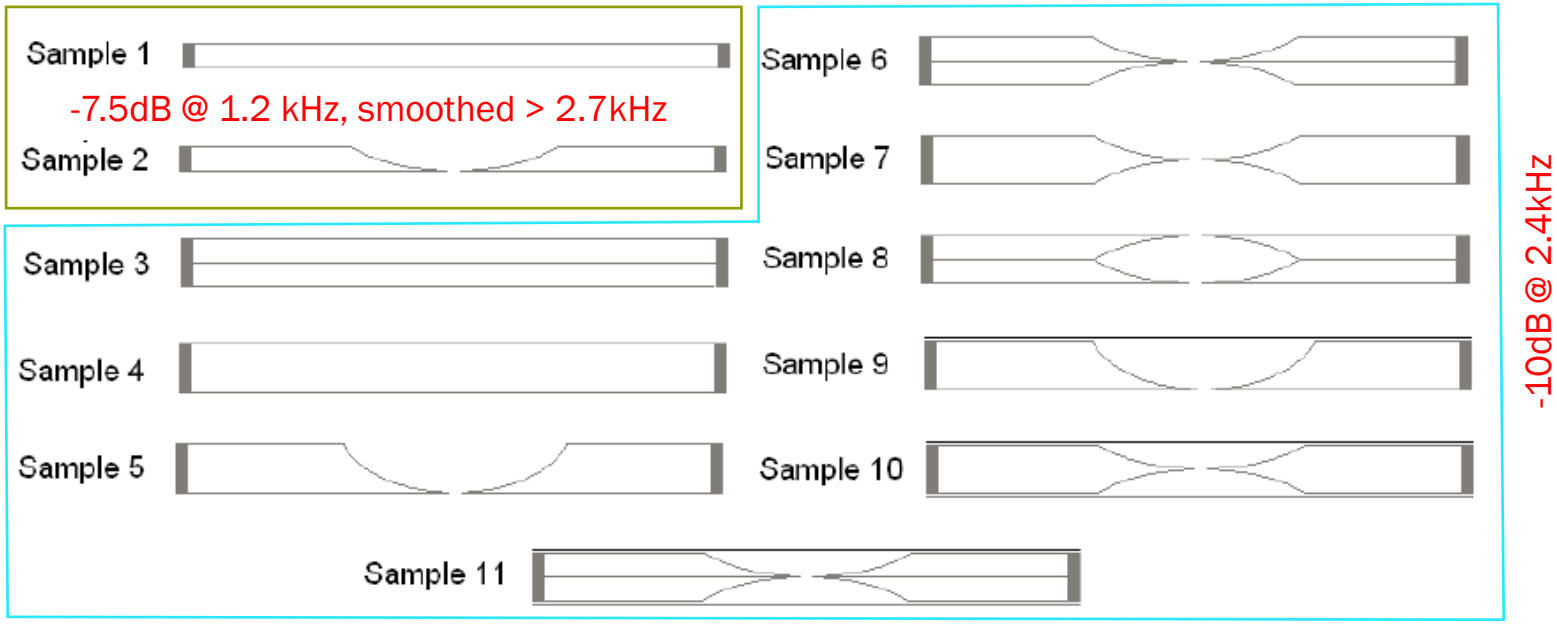
60-ABH array in a Aluminium plate – results (3/3)





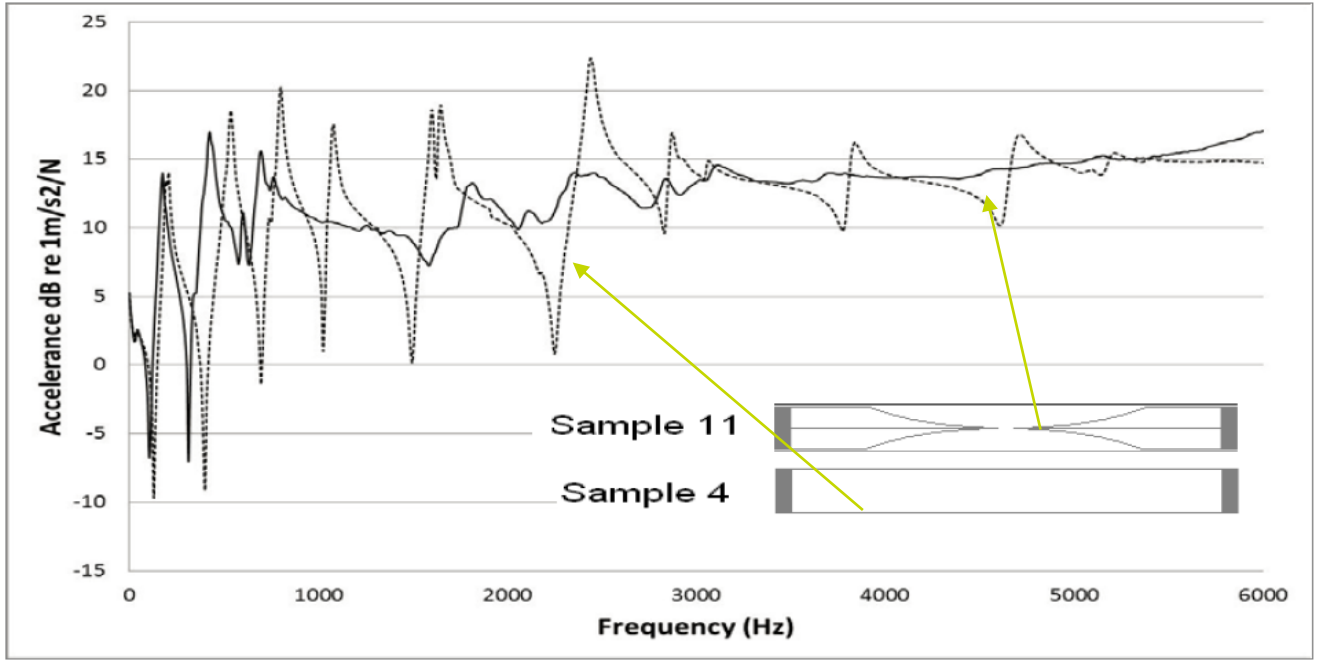
ABH Selected Applications

ABH Design of Experiments on Composite Panels (1/3)



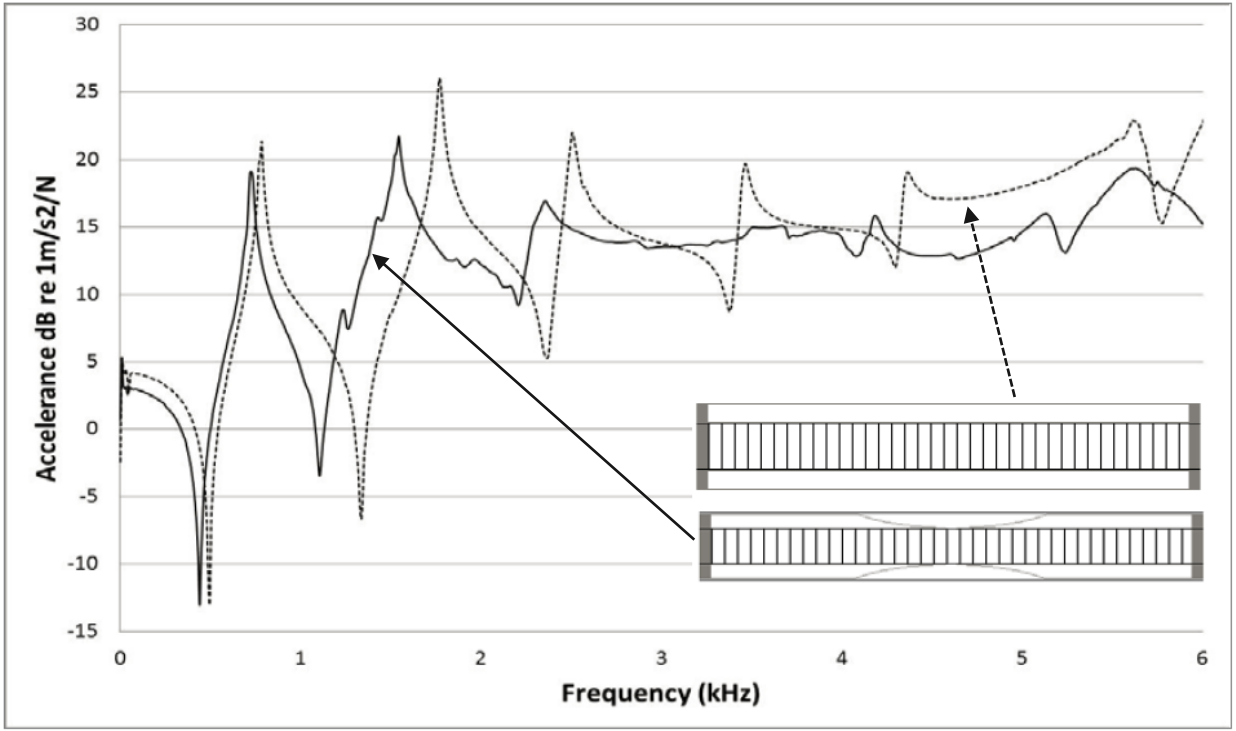
- Different type of configurations of ABH tested on single and double walled composite pannels
- Vibration reduction is very good at frequencies higher than 500Hz, reaching as much as -10dB
- Source Internoise 2015

ABH application on Composite Pannels (2/3)

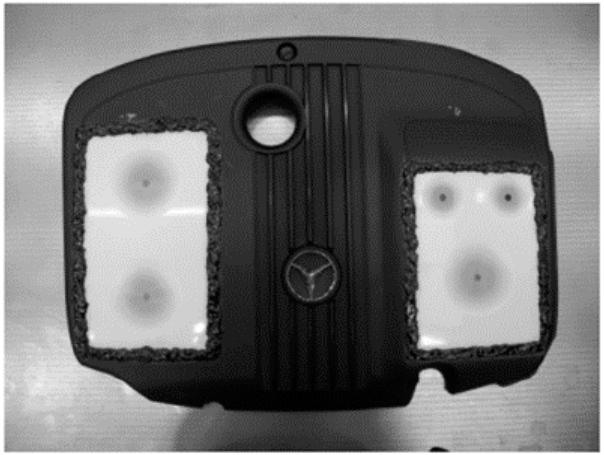


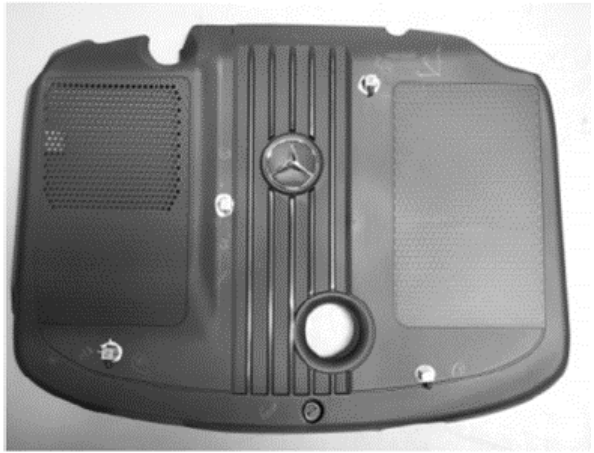
- Some accelerance measurement results between 2 pannels (with and without ABH)
- After 450 Hz the vibration levels decreases up to 10 dB from the reference plate
- Source Internoise 2015

Typical Vibration damping in a Composite Sandwich (3/3)



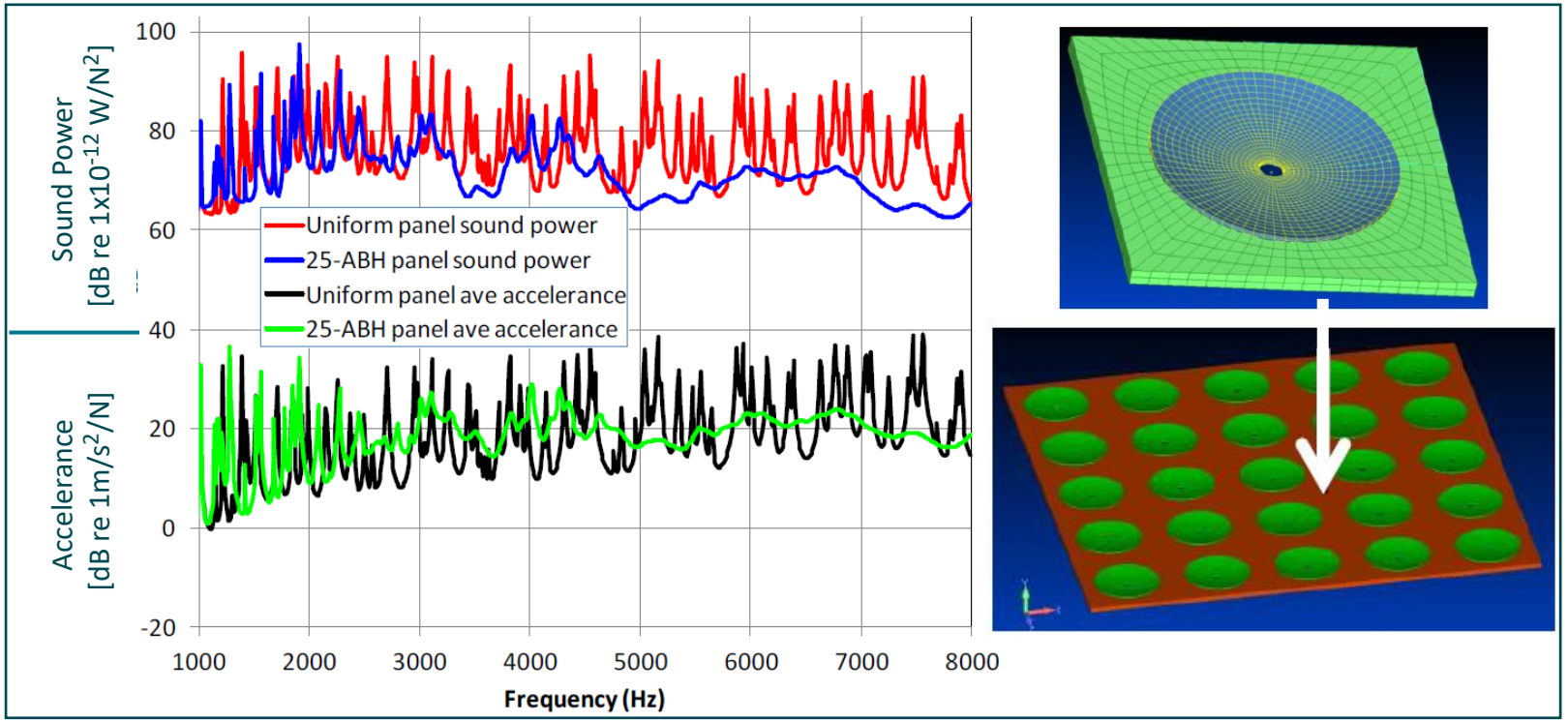
ABH Application on Automotive Part





- **Engine cover with array of ABH (Internoise 2015) – Daimler tests**
- **Measured Acoustic gains at engine 2100rpm:**
- main reduction in the resonant peak amplitudes was in the range 70-1400Hz
- -10 dB was obseved at 369Hz and 442Hz
- total average reduction from the reference sample of 6.5dB

ABH Simulation Example



Sugested ABH Application Methodology

Design study & assessment for NV comfort

- The ABH is an interesting design tool that allow to add damping to a panel-like structure, such as cabine walls, especially made in composite (high specific stiffness)
- The design approach should start with a benchmark of current applications in pannels, and the ABH added at non-bearing walls or part of the structure that do not see loading
- Simulations would support the design process, by estimating the sizes and number of ABH necessary, which will depend on the frequency range to be tackled and pannel design
- A simple plate-like prototype can be produced for assessment & validation using simple accelerance measurements for fast track to product
- Once the solution validated in the prototype, a real size part can be produced and NVH analysed for damping and noise radiation in a better equipped setup

CONCLUSIONS

- ABH is a real trend for passive flexural vibration damping, the scientific production has been growing exponentially since 2010
- The Number of Patents has also been growing these last years, with China heading it
- ABH's is reaching good scientific maturity (TRL level is currently estimated at 4) since Mironov's publications back in 1988
- ABH can be used in metal and composite structures by adding tapered forms with power law decay towards *quasi-zero* thickness
- ABH is a structural functionalization, smart structure and inteligent engineering and can become a **new tool box for engineers** seeking for **passive vibro-acoustic control**
- The Automotive (Daimler) has been trying the ABH in panel-like structures (engine cover)
- No publication was found on applying ABH for Naval structures to improve NV comfort

Thank you

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Rejoignez-nous sur :

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