SIMULATION TO SUPPORT DESIGN OF COMPOSITE METAPLATE FUNCTIONALIZED WITH ACOUSTIC BLACK HOLES FOR ACOUSTIC COMFORT IN SHIP CABINS (H2020 FIBRE4YARDS PROJECT)

Julio Cesar DE-LUCA* and Ramzi
[1] Institut de Recherche Technologique Jules Verne, Bouguenais, France

* Julio-Cesar DE-LUCA (julio-cesar.de-luca@irt-jules-verne.fr)

1. Abstract

Composite materials have been more and more used in transport, to lighting it and reduce fuel consumption and pollution. Composites have high specific stiffness (Elastic modulus/specific mass) and reducing mass and increasing stiffness of a structure is likely to lead to vibro-acoustic issues and potential discomfort to transport users. This issue is commonly tackled using acoustic treatments, which in turn will add weight and make the structure more costly.

The functionalisation of a structure with metamaterials is a smart approach to tackle vibro-acoustic problems. In this matter, the use of acoustic black holes (ABH) has been studied since late 80s and has been gaining momentum with an exponential increase in publications and patents for the last 10 years.

This development used ABH glass fiber functionalized structure by producing 4x 1m² plates, with 3 of them using ABHs to prove that Naval composite structures can be vibro-acoustically treated without adding mass. A simulation modelling helped to design the plates with the best ABH parameters.

A comprehensive state of the art was done with more than 50 high level references (including journals, thesis, congresses, etc.), and the 3 functionalized plates (metaplates) were vibro-acoustically characterized, and the results confirmed that the damping added by the ABH could reduce noise by about 4.5dB and weight by more than 15%.

2. Results

To further assess the metamaterial or structure functionalised with ABH, 4 GFRP demonstrator plates sized 780x1250mm² and thickness of 4.1mm were designed, manufactured, and vibro-acoustically assessed. Three of these plates were functionalised with different ABH designs previously simulated, and the fourth made without ABH functionalisation. Abaqus/CAE and Standard are used in this project to simulate the vibro-acoustic behaviour of the composite plate with ABH. 4-nodes shell elements with full integration (S4) are retained to mesh the part as shown in the figure 1, which also presents a simulation result for a plate functionalized with one ABH.

Figure 2 shows the configurations of the design of experiment (DoE) and the results of an experience of modeling with 12 configurations of a plate functionalized with 6 ABH of different dimensions.

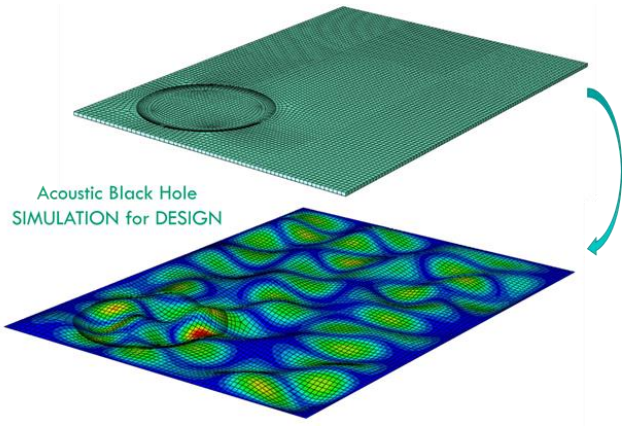

Figure 1 - Mesh of a composite plate with 1 ABH

These demonstrators were vibro-acoustically tested, and the results showed a potential noise reduction up to about 4.5dB and velocity of vibration reduction up to 80% depending on the frequency.

The plate with 6x ABHs was manufactured second the configuration number 8 (C8) see in the figure 2. The experimental results showed a noise reduction of the order of 4.5dB (-40%) compared to the reference

plate, and the simulations previewed a reduction of the order of 3.6dB on the radiated sound, which enough is close to the measured results.

A weight reduction of about 16% was measured in the plate with 6x ABHs compared with the reference plate.

Power-law

Configuration	m	Diameter (mm) D1-D3-D5 [mm]	Diameter (mm) D2-D4-D6 [mm]
C1	2	200	200
C2	2	200	300
C3	2	300	200
C4	2	300	300
C5	3	200	200
C6	3	200	300
C7	3	300	200
C8	3	300	300
C9	4	200	200
C10	4	200	300
C11	4	300	200
C12	4	300	300

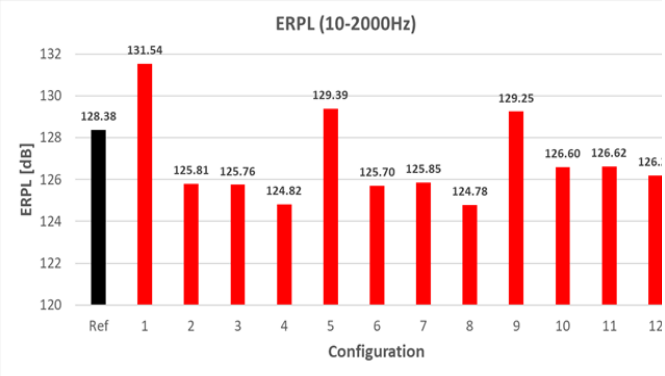

Figure 2 : top – configurations used in the DoE, bottom - Comparison of the averaged velocity of vibration squared value for 12 simulations configuration of a plate with 6x ABHs and comparison to the reference plate (without ABH)

3. Conclusions

A comprehensive study proved the potential gains of functionalizing plate-wise structures with ABH. The simulations showed an enough good correlation with the experimental vibro-acoustic results.

The simulation of ABH for implementation on structures can be an asset for optimization that can reduce noise (transport comfort) and weight of Naval structures at the same time.

The metaplate functionalized with 6x ABHs presented a noise reduction of about 4.5dB (-40%) with weight reduction of about 16%. This will be in time a tool for Naval designers.

3. Acknowledgment

"This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101006860"