ACOUSTIC CHARACTERISATION OF UNDERWATER MULTILAYER PANELS

- CARACTERIZACIÓN ACÚSTICA DE PANELES MULTICAPA SUBMARINOS -

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WHY?

Currently, the international community is recognizing that **the radiation of commercial ship's underwater noise has a negative impact in large and short period of time on marine life**. Underwater noise could affect to communication between individuals, their behavior, and to their own biology.

HOW?

- **This work examines the use of acoustic insulation materials for ships**.
- Study the existing algorithms for predicting acoustic transmission loss.
- The theoretical expressions were compared with empirical results
- The models have been validated through experimental measurements.
- These materials were provided by the company ***SRG of Cartagena*** and tested in the indoor acoustic calibration tank of the ***Naval and Maritime Technology Centre (CTN).***

THEORETICAL PREDICTIVE MODELS

Acoustic mode coupling

Diffuse field method:

- **IPM - Impedance Progressive Method**
- **MRM - Multiple Reflection Method**
- **PWM - Progressive Wave Model**

Acoustic transmission coefficient of a panel, depending on the frequency and angle of incidence, $\tau(\theta, f)$.
With this you can obtain the acoustic transmission loss, TL,

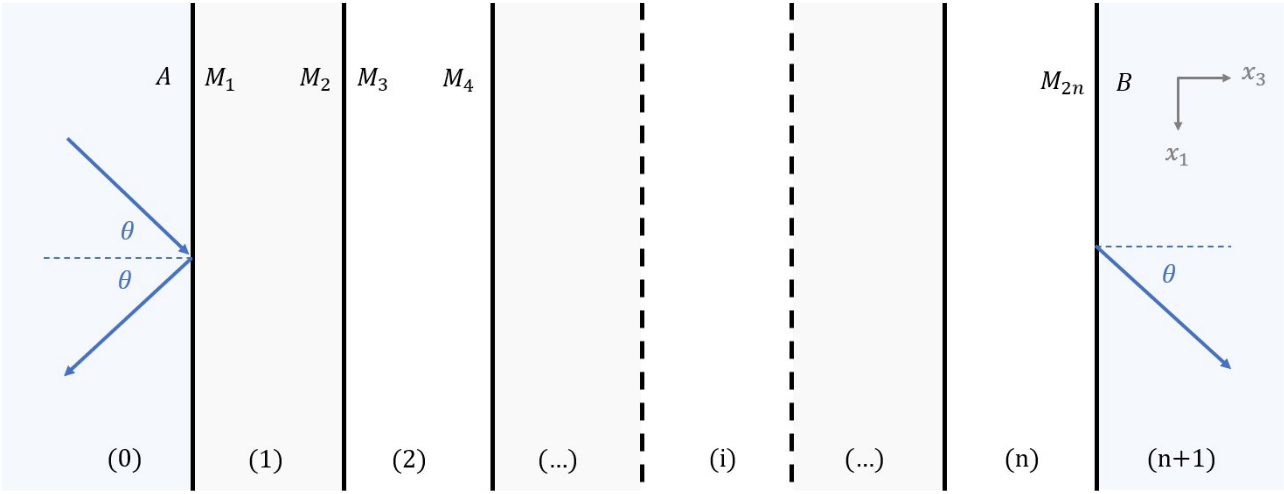
$$TL(f) = 10\log_{10}(|\tau(f)|^2)$$

THEORETICAL PREDICTIVE MODELS

Multi-layer model:

Using transfer matrices, it allows arbitrary coupling of different layers, thus allowing a relatively simple implementation of the algorithm for a wide variety of multilayer material designs.

The starting point is a two-dimensional sound wave that hits a layer with an angle of incidence θ on the left side of the layer. This layer is in contact with the aqueous medium, which causes the acoustic field to progressively reduce.



Scheme to explain the matrix transfer model

EXPERIMENTAL APPROACH

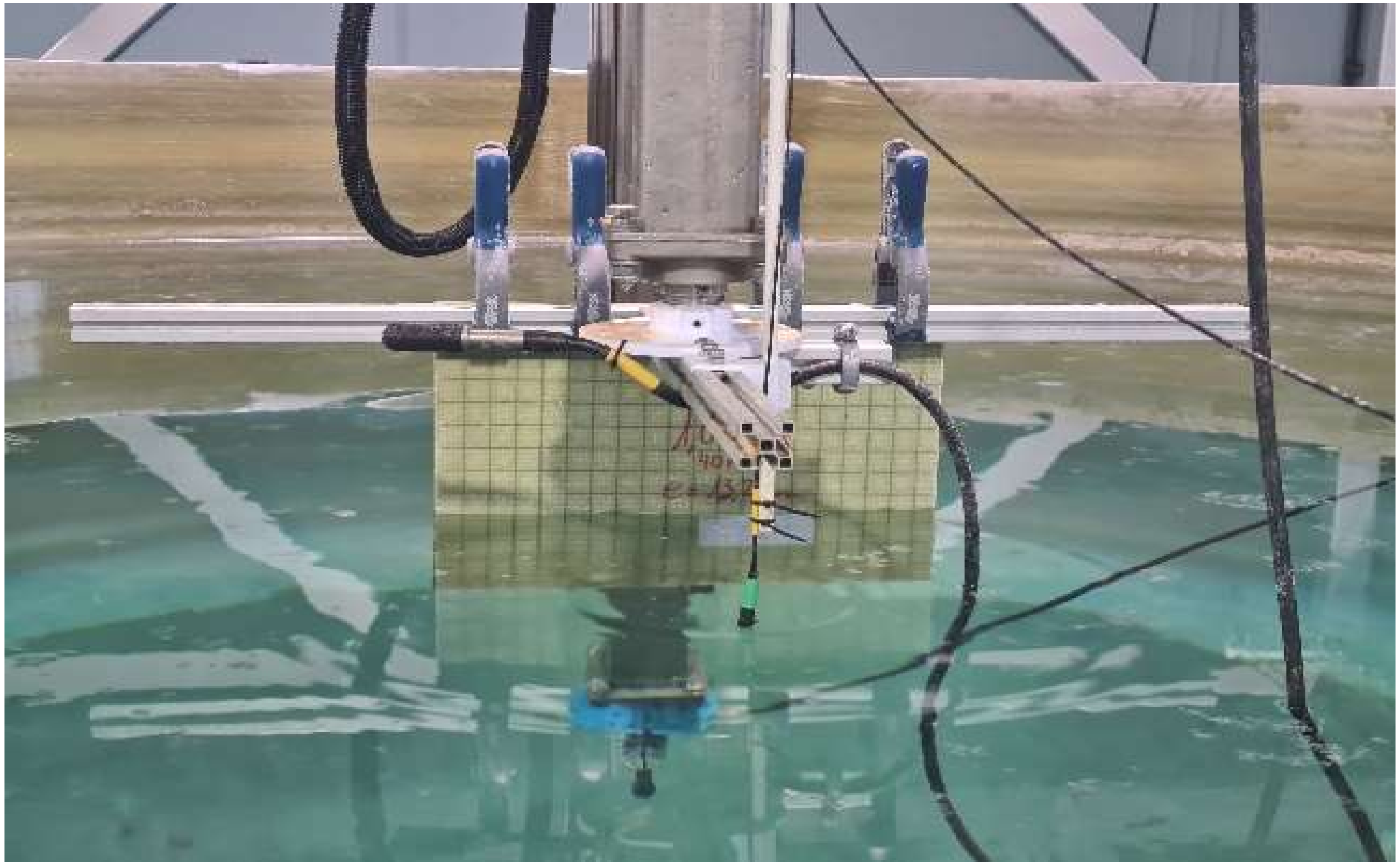
Samples to be characterised:

The tested panels were supplied by SRG.

They consist of a resin core with a single side of polymeric material forming a single-sided sandwich panel.

Detail of the core of the multi-layer panel (left), overview of the sandwich panel (right).

EXPERIMENTAL APPROACH



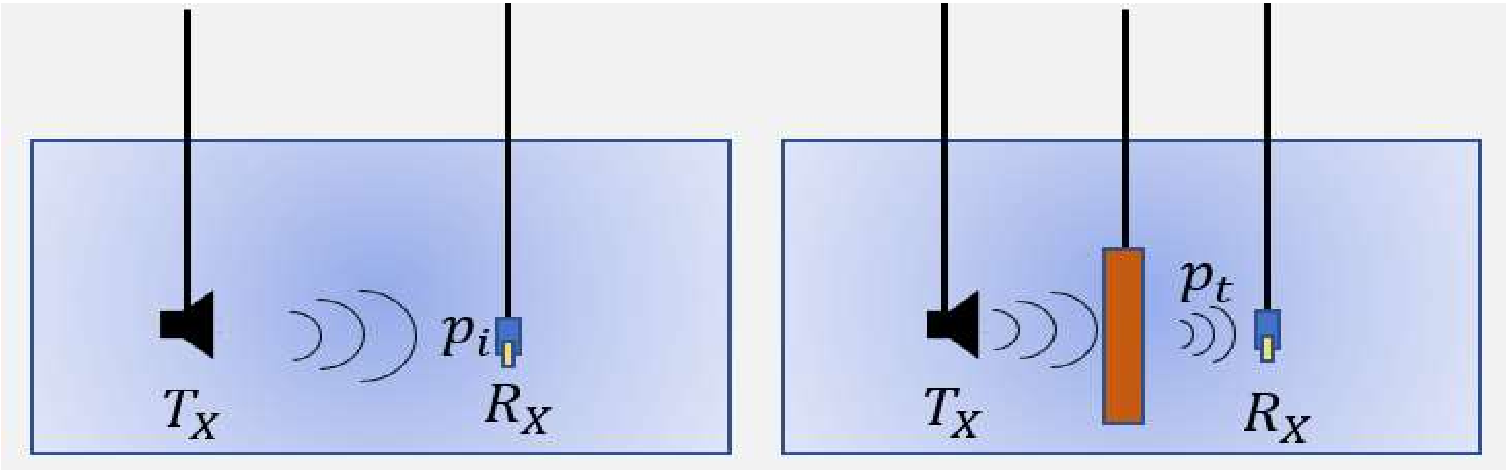
Detail of the multilayer panel prior to measurement

EXPERIMENTAL APPROACH

Acoustic characterization of panels:

We focus on experimentally obtaining the transmission loss (TL) parameter.

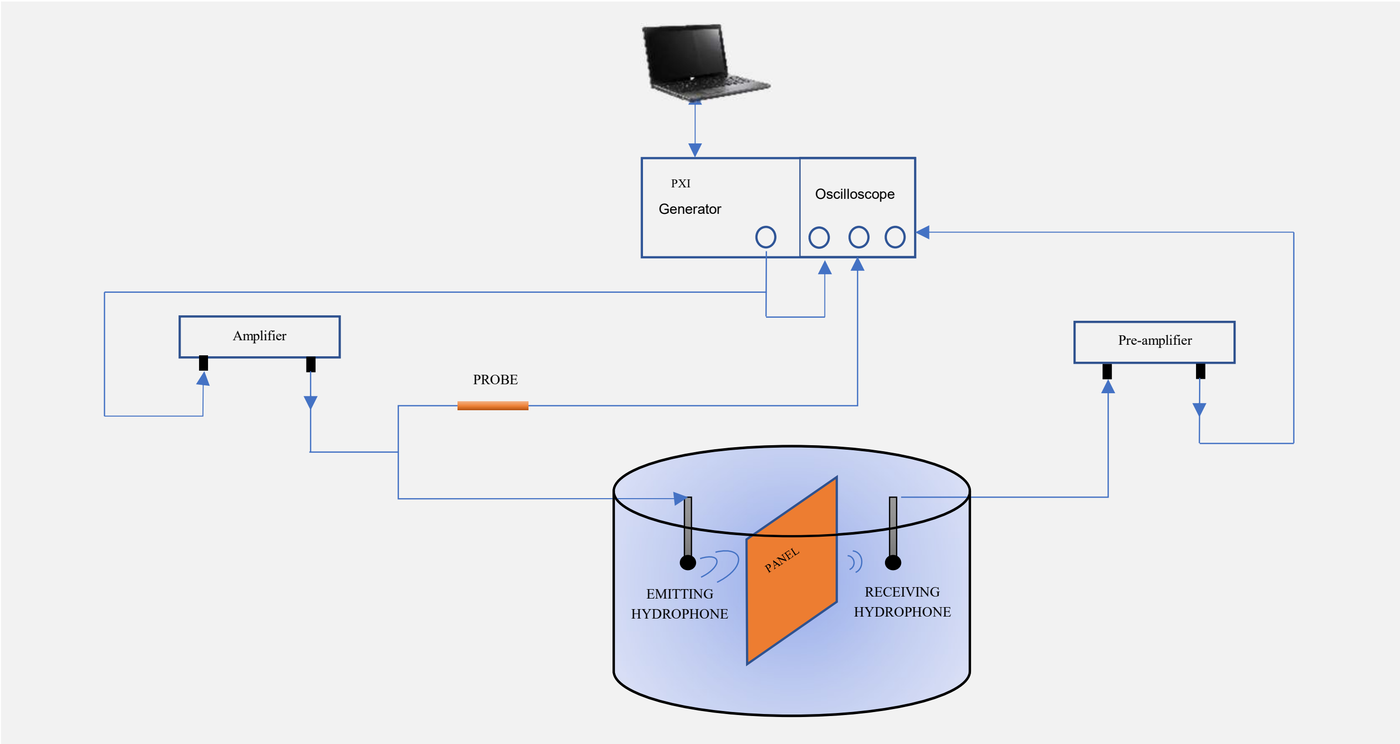
The parameter TL is obtained by comparing the amplitude of a wave received by a hydrophone when a sample of material is placed between the emitter and the receiver, p_t, with respect to the amplitude of a similar wave received when the material is not between them, p_i:



$$TL = 20\, log_{10}\left(\frac{p_t}{p_i}\right)\ [dB]$$

EXPERIMENTAL APPROACH

For the characterisation of the panels used, measurements were carried out in the calibration tank of the CTN hydroacoustics laboratory, equipped with positioners that guarantee a correct arrangement of the experiment.



Schematic of the layout and connection between equipment involved in the test.

EXPERIMENTAL APPROACH

Pictures of the experimental area. On the left, control point for positioners and measuring equipment. On the right, measuring basin with positioners.

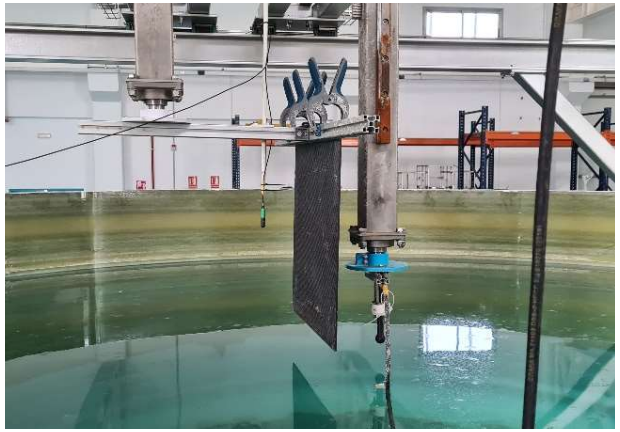
EXPERIMENTAL APPROACH

The measurement protocol is the same for all panels, regardless of their size:

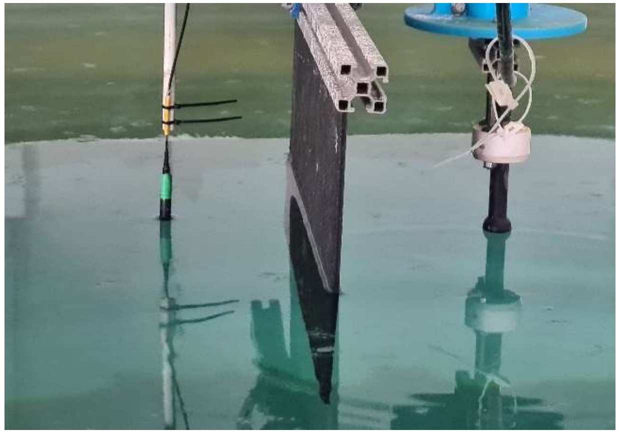
- 1º. Assembly of the tooling for the transmitter hydrophone in Positioner 2 in the work area.
- 2º. Aim Positioner 2 at the centre of the tank on the X and Y axes, and point coordinates.
- 3º. Assembly of the panel tooling and the receiving hydrophone on Positioner 1 in the work area, placed at a distance of 150 mm to avoid possible reflections.
- 4º. Aim Positioner 1 at the centre of the tank on the X and Y axes, and point coordinates.
- 5º. Align vertically and horizontally the acoustic centre of the hydrophone and the emitter transducer with the centre of the panel, both at a horizontal distance of 150 mm.
- 6º. Position, in the direction of the Z axis, so that the centre of the hydrophones and the panel are on the free surface of the water in the tank.
- 7º. Lower both positioners 1100 millimetres in the direction of the Z axis.
- 8º. Take measurements with the panel.
- 9º. Return Positioner 1 to its working position.
- 10º. Uncoupling the panel to the Positioner 1 tooling.
- 11º. Insertion of Positioner 1 to the coordinates defined in point 7.
- 12º. Taking measurements without the panel.
- 13º. Bringing Positioner 1 to the work area.
- 14º. Repeat points 3 to 12 for the characterisation of each of the panels.

EXPERIMENTAL APPROACH

Step 1. Positioners in the working area



Step 5. Positioners in the pool

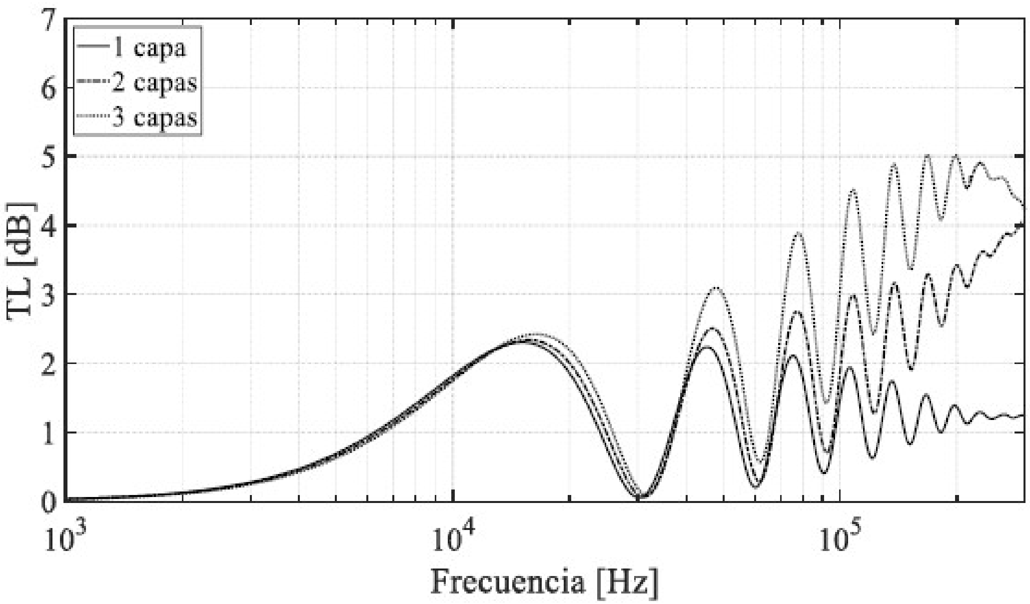


Step 6. Alignment with respect to the acoustic centre

Step 8. Positioners in the measuring position

RESULTS

Theoretical result of multilayer panels



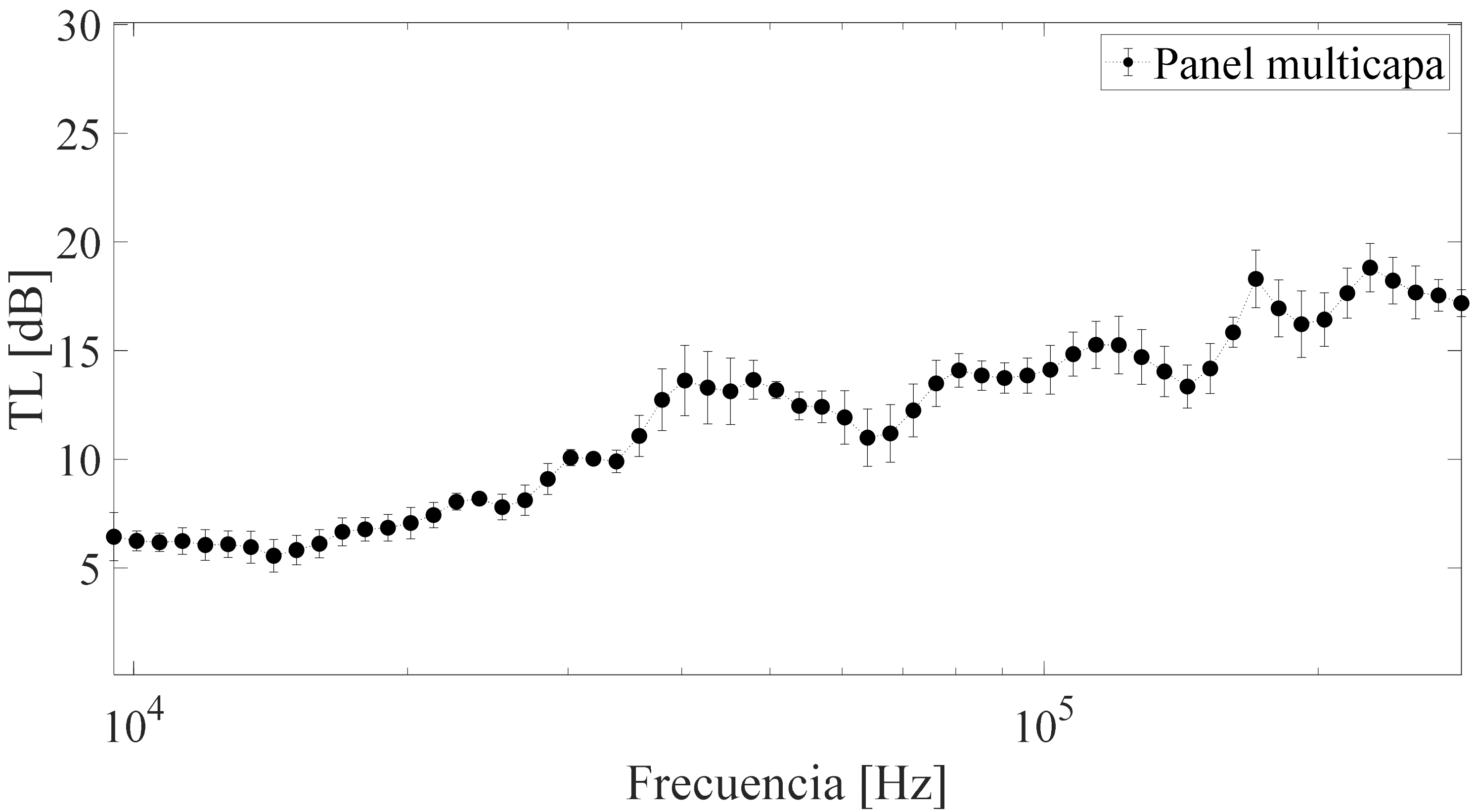
Results of the matrix model considering different configurations:

1. Only the main and thickest layer of the panel (layer 1, the core of the panel).
2. The main layer plus the surface layer of one of the faces (2 layers)
3. The main layer plus a surface finish layer on each side (3 layers).

It can be seen that layer 1 infers a behaviour to the panel that predominates over the other layers but that these add greater losses at higher frequencies.

RESULTS

Experimental result of the multilayer panels

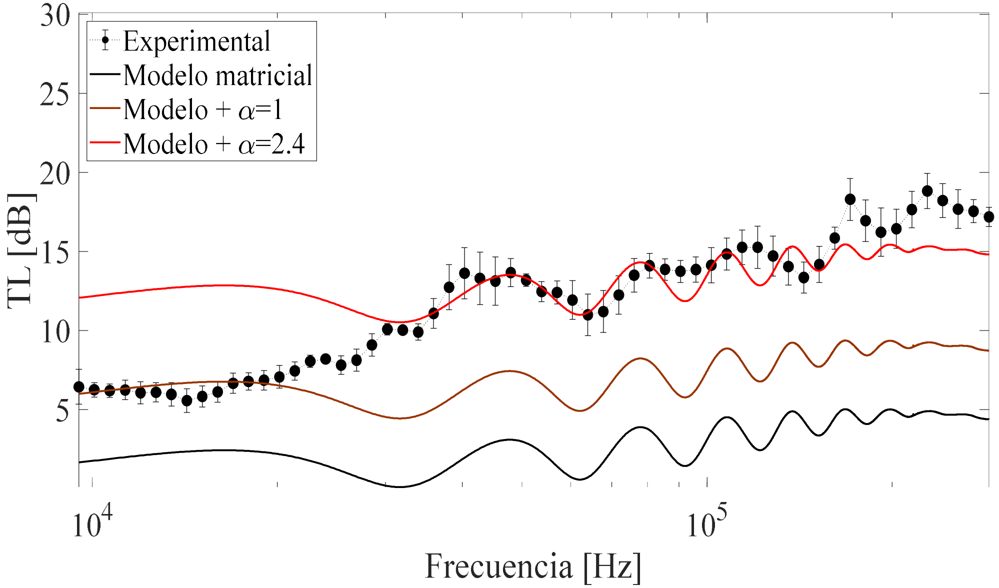


Measured transmission losses with the multilayer panel

RESULTS

Analysis of results

Comparison of experimental and theoretical results for the multilayer panel



The measurements give higher values than the theoretical values (black line) which may be due to additional absorption in the panel either because it is not a strictly homogeneous solid panel as modelled or even because of the presence of (highly reflective) air micro-cavities inside the panel.

Therefore, the transmission losses of the same model have been added, but considering additional absorptions.

Some similarities are found in the experimental profile with respect to the theoretical one, with similar oscillations between 40 and 150 kHz.

For frequencies below 40 kHz, the transmission losses increase slightly with frequency and remain between 5 and 7 dB.

APPLICABILITY TO THE NAVAL INDUSTRY

Sound transmission in surface vessels

Ships built with composite materials are usually vessels with lengths of less than 50 metres. However, given the possible advantages that this type of materials could bring to the civil shipbuilding industry, economic efforts are being made to use them in larger vessels. In this sense, the present work advances in both theoretical and experimental knowledge of the degree of sound insulation that different types of composite materials can have.

Sound transmission in submarines

Composite materials have a wider scope within the military industry, as the properties they offer in terms of mitigating radiated noise, thermal signature or reducing thread weight (reducing consumption and therefore increasing autonomy) are very interesting advantages for this industry. Both in manned and unmanned vehicles.

The characterisation of the superstructure panels is of interest as they have water both on the outside and in the space between the superstructure panels and the strong hull of the submarines.

Thank you very much for your attention

- Muchas gracias por su atención -

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