NUMERICAL APPROACH AND EXPERIMENTAL VALIDATION OF COMPOSITE SOUNDPROOFING PANELS FOR AERONAUTICAL APPLICATIONS

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ABSTRACT

The main advantage offered by composite structures used in the aeronautical field is the high strength to weight ratio. Usually it becomes less important when we analyse its behaviour into the acoustic field, when we analyse the interior noise levels. The insertion of sound proofing materials - porous foams - inside these structural panels contributes to considerably diminish the sound pressure levels in the aircraft’s interior, allowing to reach the maximum levels imposed.
With the target of improving these contributions, actually different combinations in order to minimize the assembly time and flow, material and fabrication costs, interiors weight and internal noise level are proposed. The choice of an appropriate multilayer configuration must also consider the processing technologies and production methodologies that integrate the linings and sound proofing panels in a single fabrication cycle.
The searching for complex combination that could satisfy the structural aspects as well as the acoustics ones is realized by computational numeric predictions. In this paper we present the numeric predictions for the transmission loss of different multilayer material panels used in the aeronautic industry as well as the results obtained from the new configurations proposed. The transmission loss predictions are validated by comparisons with experimental measurements.
As result we expose a brief comparison between the advantages and disadvantages of the model in use and the models we propose.

Keywords: composite soundproofing panel, numeric simulation, acoustic response, multilayered configuration.

1. Introduction

The incorporation of composite materials in modern design of aeronautical structures has continued and increased with its great expansion in last years, at the same time that its use, based on the high ratio between resistance and weight , has overgrown time ago the aeronautical area being used nowadays in various areas of engineering.
In the design of aeronautical structures, the use of these new materials in fuselages and other structural parts, comes together with different kinds of analyses thanks to the constant development of computational simulation techniques and methodologies.
The use of numeric methods, mainly of Finite Element codes (FE) to study the response of these materials carries out an essential part in any process of design and calculation.

The continuous improvement of calculation capacity and the lending of these codes allows nowadays to model faithfully any kind of structure, including the complex configurations and properties that are characteristic of these modern composite materials.
However, when we start studying the vibro-acoustic properties of these type of constructions we find that the use of computational techniques is in a stage of complete development and that it still had not reached the levels of use achieved by other kind of analyses.
Inside the acoustic field, the experimental techniques of measurements in anechoic and reverberance rooms are still the main source of information for engineers and technicians in this area. The use of numeric techniques for acoustic analyse, gradually, is not any more and activity dedicated only to big investigation centres, to become in a new and open tool dedicated to complement the expensive experimental techniques, reaching high levels in prediction and response analyses for composite panels.
The aim of this report is to show the results obtained with the different number simulation techniques used, available in the acoustic engineering field with the different commercial codes, and the use of these values as elements of pre-design in order to conform a soundproofing panel of superior lending.
Focusing on the election of the composite materials and their different combinations made in order to get a series of configurations that carry out the main objectives of the investigation program: minimize the internal noise level, the materials and fabrication costs and reducing the total soundproofing weight.
The acoustical properties of the panel with respect to both acoustical and mechanical excitation were investigated for various core and skin densities.
These series of new chosen configurations proposed according to the computationally obtained values come experimentally tested in anechoic rooms, achieving the validation of these numeric simulations previously done.
Leaving as a final conclusion the comparison between the new designs and the ones in use.

2. Materials & Geometry

The panels geometry is the same for all the configurations used in this work. It's about flat panels of square geometry dimensions of 70 centimetres side and with constant thickness in all the layers that conform it, whatever the material and function (skin or core).
The use and selection of the materials, as it was described before, takes an very important part in the investigation.
Depending on the function inside the panel structure we can enumerate different groups of materials used in this work:

- Thermoplastic Ultem sheet
- Thermoplastic composite laminate (PMMA with both carbon and fibreglass)
- Thermoplastic composite sandwich
- Thermosetting composite solid laminate (Epoxy with both carbon and fibreglass fabrics)
- Thermosetting composite

- Melamine Foam
- Polyester Foam
- Polyurethane Foam

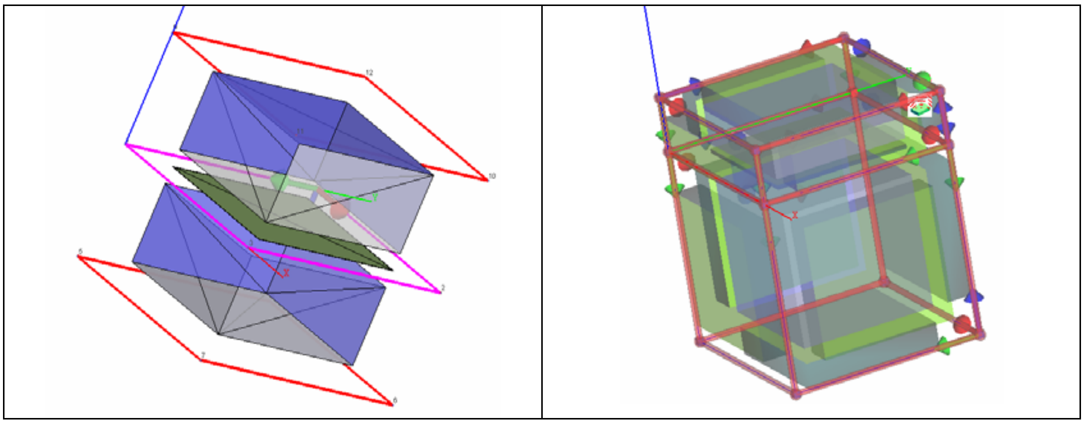
3. Numerical modelling

The study was not limited to the use of only one theoretical formulation of analyses or an only one code of computational simulation. Neither was the aim of this work to come into details of these techniques or its development and its possible improvement. The different commercial programs that exist nowadays were used directly, without modifying its internal architecture of calculation methods. Analysing and evaluating the lending of these codes only with the values obtained for each kind of configuration and frequency range studied.
In order, to the excitement source, a diffuse incident field is also a common situation. In this way, it was adopted for all the tests this kind of source a value of 110 (dB) in White Noise. This can be as a combination of uncorrelated plane waves. A large number of plane waves having random angles of incident, random magnitudes and random temporal phase angles were summed together to simulate a diffuse field excitation.

3.1 Simulation using: Statistical Energy Analysis (S.E.A.)

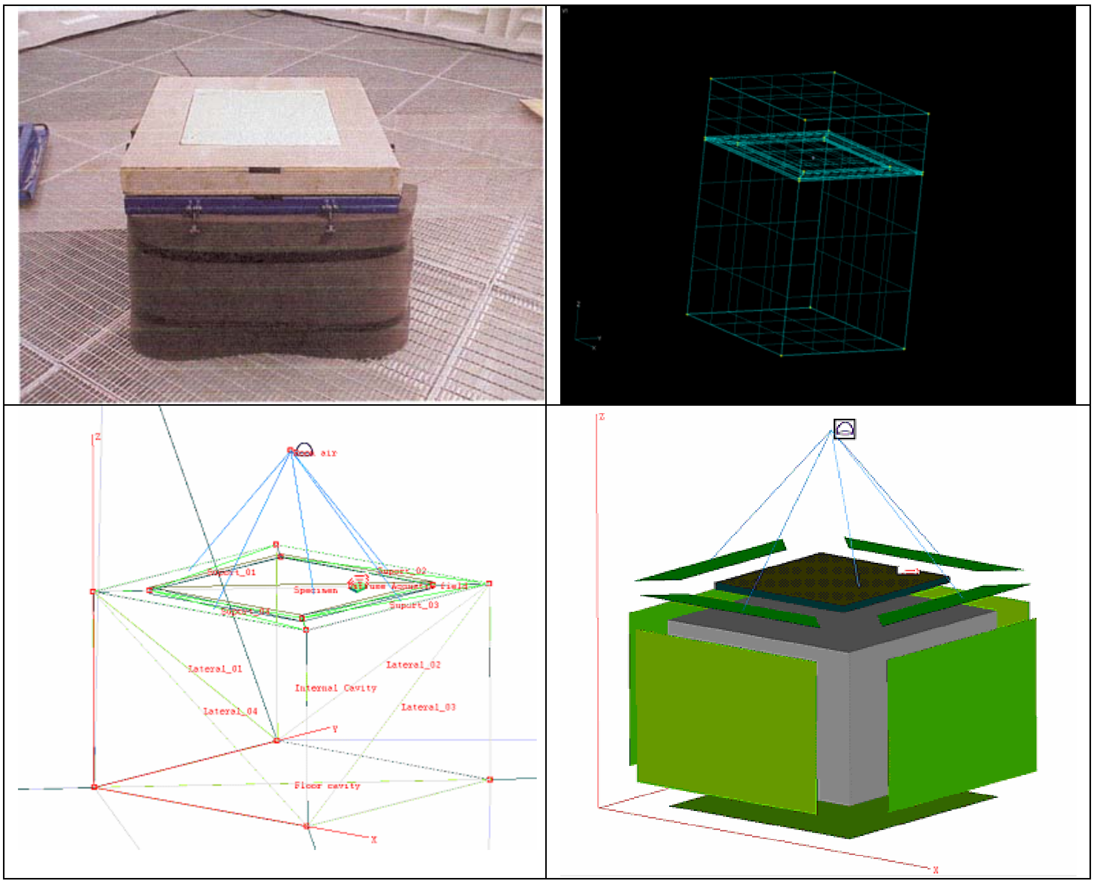
This method, is particularly attractive in high frequency regions where a deterministic analysis of all the resonant modes of vibration is not practical. This is because at these frequencies are numerous resonant modes, and numerical computational technique such as the finite element method have a delimited applicability.
In the SEA analysis with the commercial code AUTOSEA® the model to use was compound by two cavities, a transmitter and a receiver, separated by the specimen under analyse. Using as a solver the internal module VTL. As it is indicated in Figure 1 and 2 below:

Figures 1 and 2



It was also used other model, in order of the geometric characteristics of the validation proves in the experimental tests. This is based in a rectangular cavity inside an anechoic room, as it is describe in the ASTM 423-C90 norm. This is represented in Figures 3, 4, 5 and 6:

Figures 3,4,5 and 6



3.2 Simulation using: FEM\BEM

Related to the Fem-Bem analysis, its study was done with the NOVA® code, this code's characteristic is its simplicity and use easiness and, but as a disadvantage it's limited to the flat panels study. The main task corresponded to the study varying the number of elements with different densities and type of meshes, and the internal programming of the data sheets of all the materials under analyses

3.3 Simulation using: Transfer Matrix Method

The code used for this case was also the NOVA®, with its TMM module. The considerations are the same that were described for the previous study (3.2)

4. Results and Discussions

As it is a study proposed and financed by the private sector, we find limitations in the publishing and information of the whole results, as well as with the composition of the different configurations chosen. In the same way it was not possible to show more information in section 2 about the materials and their characteristics.
However, we will see and discuss the results of the most representative cases in order to not loose the aim of this publication.

The values obtained for all the made tests, correspond to the sound transmission lost (STL). Sound transmission loss, of partition, in specified frequency band, ten times the common logarithm of the ratio of the airbone sound power incident on the partition to the sound power transmitted by the partition and radiated on the other side. The quantity so obtained is expressed in decibels (ASTM 423-C90).

4.1 SEA analysis: Configuration 01 PHS

The discrepancy at low frequencies is seen only in the first value analysed. We see that the major disparity happens once again for the low-medium frequencies, being appreciated the major difference for the range of 1K, to pass immediately to an area of excellent results in the region of "Mass Controlled" (2KHz - 4KHz) and ending with acceptable results for the final region of high frequencies.

4.2 SEA analysis: Configuration 02 PFS

We can observe a discrepancy between both models until arriving to the area of medium frequencies (1600 Hz). From that point onwards, excellent results are reached in the whole rest of the spectrum, also noting a total coincidence with the falling area of "Coincident controlled"(5 KHz).

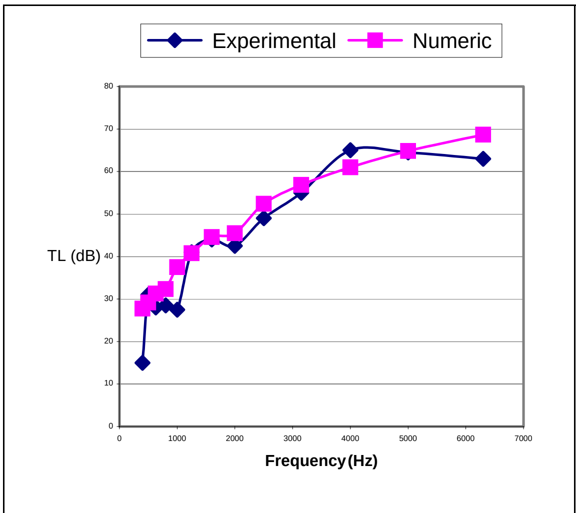
4.3 FEM\BEM and TMM analysis: Configuration 03 SPHS

As it can be appreciated, the theory curve follows the experimental form, but without suffering any punctual changes. In the low and medium frequencies area (400 Hz – 2000 Hz) there is total coincidence, growing the difference from the 5000 Hz onwards. The major difference is seen in the high frequency area where the concordance area for the numeric case is useless.

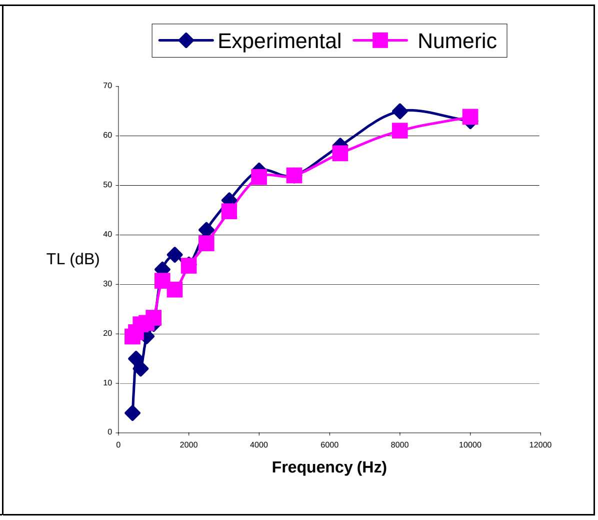
4.4 FEM\BEM and TMM analysis: Configuration 04 SPFS

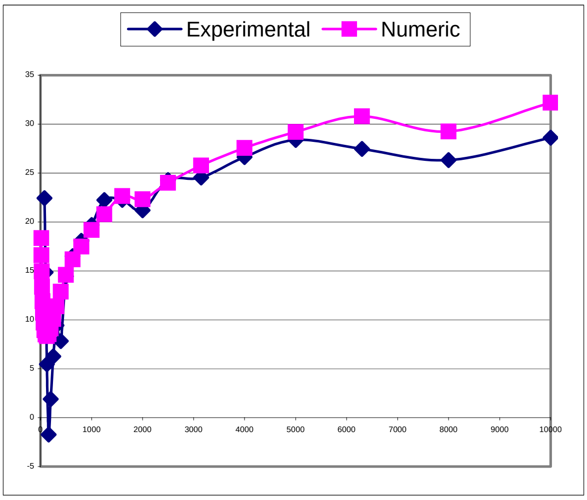
For this case, we can observe an identical answer from the curves, but with a shift of one octave, for the diminishing, due to the media concordance area as well as to the low frequencies.

Configuration 01 PHS

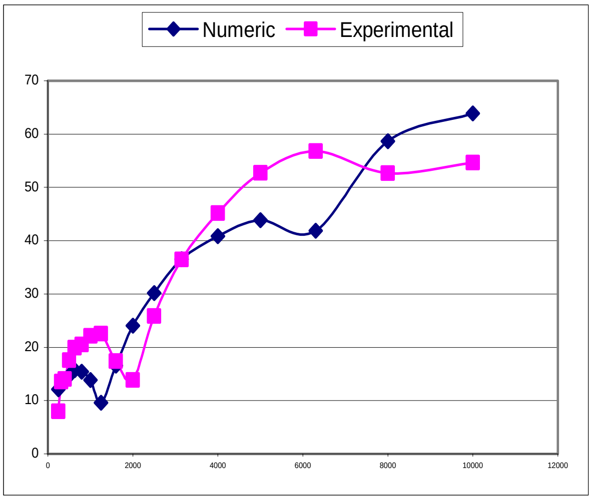


Configuration 02 PFS





Configuration 03 SPHS



Configuration 04 SPFS

5. Concluding Remarks

When designing composite structures for use in aircraft, it is necessary to incorporate acoustic benchmarks into a design cycle. Thus to predict and interpret the vibro-acoustic properties of these types of structures are needed.

The use of diverse techniques lets us to count with sources of information to obtain more precise values in order to the frequency range that interests and the kind of material. An integrated study for both techniques allows to maximize the lending for each method, making it a powerful diagnostic tool.

For the SEA method, is proven a very good answer of this formulation for the analysis of the medium and high frequencies, and a high capacity to simulate the most complex and representative cases (cases with porous materials), with different characteristics, modelling and behaviour are concerned in response to an excitement of a sound source.

The FEM\BEM & Transfer Matrix Method solves acceptably the whole range of frequencies, describing satisfactorily the behavior of the material expressed in the kind of curve an its attenuations, as well as also highly respecting the maximum values experimentally obtained.

In consequence, it becomes an effective method in order to get a numeric approximation that allows to decide between the convenience or not of using certain configurations, specially for those multilayer where it allows to analyze the different responses considering the variations and possible combinations of materials and their respective thick nesses.

6. References

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