CHARACTERIZATION AND OPTIMIZATION OF THE SOUNDPROOFING OF A TRAMWAY DRIVER'S CABIN

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Abstract: Interior and external noise performances are currently crucial parts of the invitations to tender from each city's public transport equipment market. Manufacturers also integrate more characterization methods and vibroacoustic performance evaluations to satisfy customer requirements, beat competitors and ensure vehicle development. This article presents an experimental methodology of sound insulation performances characterization per cartography for a tramway driver's cabin. It also includes the results obtained with the soundproofing treatment. Measurements were carried out in joined reverberating rooms. The polyester driver's cabin was fitted on the two room interface wall without frame and engine. First of all, the parts not to be treated were masked and their insulation potential was validated. The initial global insulation performances, without treatment, were measured by a traditional measurement of noise level attenuation. Then a complete acoustic cartography of the cabin was carried out in order to determine the areas to treat. This allowed the vibroacoustic weakness areas to be characterized and classified. Based on these results and on customer requirements, soundproofing solutions were then developed. These solutions were prototyped and assembled on the cab. For each area, an acoustic cartography was performed to assess the insulation potential of each solution. The best solutions were the all fixed and the global acoustic insulation measurement of the treated cab was realized : results proved the good performances of the soundproofing solutions and the validity of the vibro-acoustic methodology.

1. Introduction

Soundproofing measurements of a LOHR INDUSTRIE tramway driver's cab prototype, were taken between adjacent reverberating rooms. The purpose was to optimize the real acoustic performance of the driver's cab, by ensuring sufficient sound-proofing of the engine compartment, and in this way improve the driver's acoustic comfort. This optimization was performed on the polyester cab, without frame and engine. Items excluded from the study perimeter (windshield, roof panel, front stringcourse, etc), as well technical passages were masked and blocked before the study was started (initial state). A first series of measurements (insulation and acoustic cartography) made it possible to analyze and validate the efficiency of the cab installation on the test wall, as well as acoustic insulation performance in this initial state. As you will see later in this article, a complete cartography of the cab was carried out beforehand depending on the different designated areas. All the areas to be optimized were characterized by acoustic cartography, and then studied in order prioritize them in terms of vibro-acoustic performance. It is on the base of this information that several soundproofing solutions were developed while respecting technical restraints and customer specifications. Then the soundproofing prototypes were made for the previously defined engine compartment areas. For each prototyped solution, an analysis of the acoustic cartographies made it possible to evaluate insulation potential of the soundproofing laminates in place. Lastly, the best solutions were validated and fitted on the cab. A global insulation measurement of the upgraded cabin was carried out.

2. Testing Facilities

All measurements took place in the horizontal adjacent reverberating rooms at the CETRAM. These rooms, where the total background noise level is 20db (A), are completely dissociated from a vibro-acoustic point of view and so meet ISO STANDARD 140-3 (measurement of building soundproofing and its structural components) and ISO STANDARD 717-1 (transmission of the airborne noises) requirements. The largest room, called "emission room", has a volume of approximately 242m³ (10.1m X 6m X 4m). The room called "reception room" has a volume of 200m³. The test window between the rooms represents a surface area of 6.25m ² (cf. figures 1 and 2).

Figure 1. Emission room with tram cabin.

A three-dimensional displacement system had to be designed for the precise positioning of the antenna (cf. figures 2 and 3).

Figure 2. 3D displacement system.

The acoustic antenna (14 microphones) and the analysis software are from MicrodB. Insulation measurements were carried out and analyzed using PAK software from Müller BBM Gmbh.

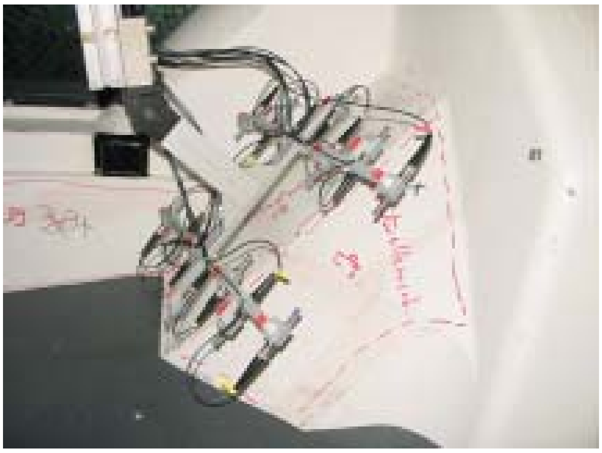


Figure 3. Microphone measurement antenna on support.

Fitting the tram cab in the test window required some care because we needed to be able to move in the cockpit normally (cf. figure 4), and ensure perfect insulation in the coupling area.

Figure 4. Tram cabin fitted between the two rooms. The areas not studied are masked with heavy load.

3. Methodology

Apart from the test facility installation conditions, we concentrated on simpler hypothesis permitting cost reduction through time gain. For example, after verification of the first measurements, it proved extremely interesting to only study half of the cab since it is totally symmetrical. (cf. figure 5).

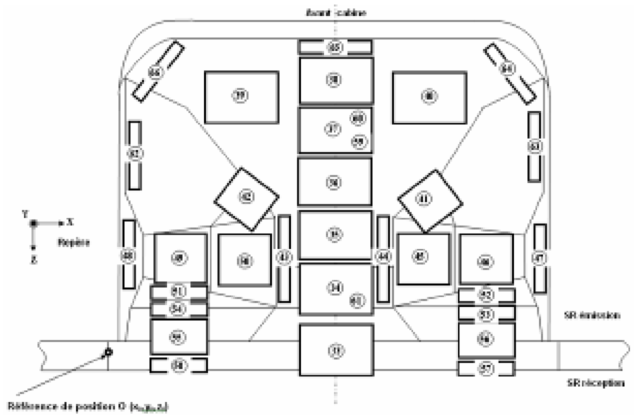


Figure 5. Symmetrical areas to be measured.

The simplified choice of measurements by aerial array and insulation finally proved to be judicious in light of results obtained. The small MicrodB antenna (localization of sources in near field), of compactness (450x450mm ²) and adapted on the 3D displacement module, finally made it possible to scan in a relatively precise way all the areas to be treated. With the installation of a reference microphone (in phase with the excitation signal) under the driving compartment of the tram cab (cf. figure 6), the rebuilding of important areas, such as the sealing plane (cf. figure 7) could easily be done.

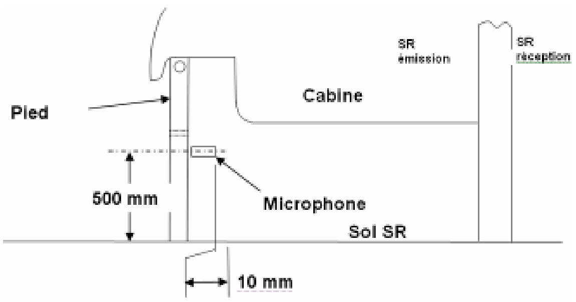


Figure 6. Diagram of the positioning of the reference microphone under the tram cab driving compartment.

To validate aerial array measurements, large polyurethane foam blocks were laid out all around the test area. This made it possible to simulate the anechoicity of a closed environment correctly, or at least have very little reverberation. In the same way, and in order to reduce the back and lateral field effects on antenna measurements, sound-proofing were laid out on unmeasured cab areas. Lastly, in order to look at cab acoustic material behaviour from a transparent and non vibratory point of view, the driving spectrum recorded beforehand on site was replayed. After masking areas which were not to be studied (panes, ceiling, mating plane of the assembly) using heavy loads, a check of their effectiveness was carried using a cartography of the masked areas.

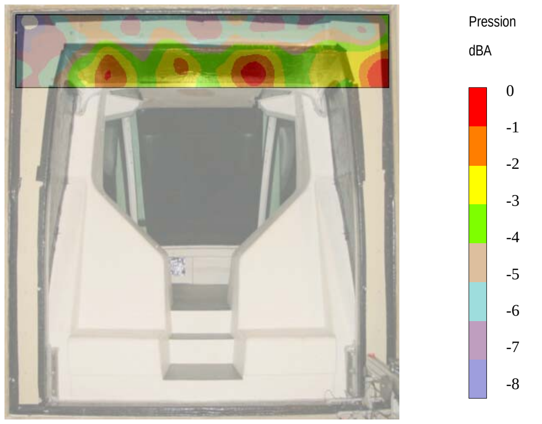


Figure 7. Study of leaks and localization of the acoustic pressure levels on the cab sealing planes.

A measurement of cab soundproofing performance was then carried out. Then all the preset areas were charted, without acoustic treatment.

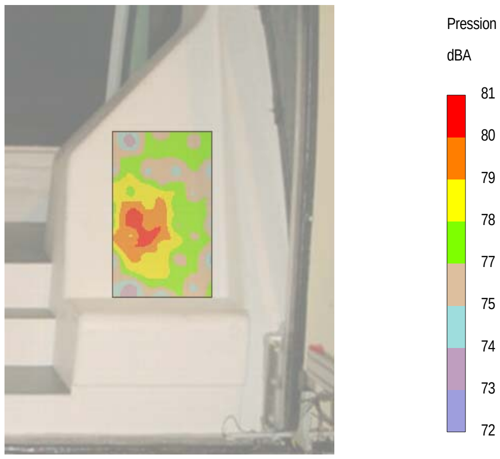


Figure 8. Acoustic cartography allowing the localization of the s pressure fields in a preset area

At the same time a microphone, placed in the cab where the driver's ear is located (point 0), made it possible to measure the resulting acoustic pressure and thus to calculate the influence of the treatment on the soundproofing compared to the reference under the cab. This phase made it possible to prioritize the areas of cab insulation performance.

On each area, by order of priority, various prototype soundproofing solutions were assembled to the driving compartment in order to be evaluated. Specific solutions installed in the cabin were also evaluated during this phase.

Figure 9. Prototype solution on lateral driving compartment.

A new cartography as well as insulation measurements at point 0 were carried out. This made it possible to evaluate the performance of each prototyped solution. The best solution was then assembled on the cab, and then the next areas were studied.

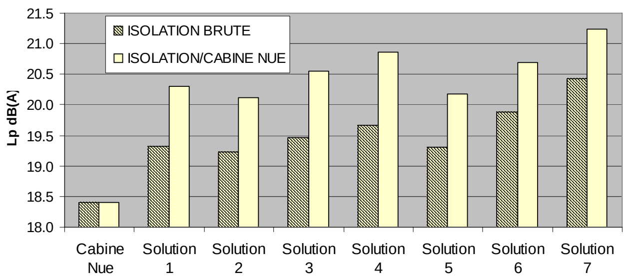
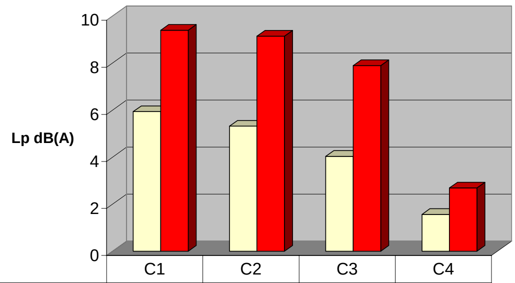


Figure 10. Insulation measured between 160 Hz and 1250 Hz using the reference microphone and microphone located in the cabin for an area equipped with prototype solutions

The best solutions were fitted in each area and an insulation test identical to the preliminary test was carried out. This provided us with the insulation improvement made using these best solutions.



	C1	C2	C3	C4
INSULATION	5.9	5.3	4.0	1.6
INSULATION / cabin without soundproofing	9.4	9.1	7.9	2.7

Figure 11. Final increase of insulation (versus cabin without soundproofing) measured between 160 Hz and 1250 Hz in accordance with the ISO standard 140-3: 1995 for different treatment configurations (C).

This gain, measured with a signal simulating the spectrum and the acoustic energy levels in the engine compartment, was 9.4 dB for the most powerful soundproofing solution. This solution meets the requirements of the customer initial schedule of conditions.

4. Conclusion

Despite the importance and the relatively little time devoted to this study, the chosen methodology was easy to use, without putting aside the rigour required in this type of study. At each stage, the choices resulted from long examination, systematically validated by detailed analyses. The results showed that even if we had been able to examine this problem differently, this methodology allowed us to meet the necessary technical requirements and specifications in the most relevant way.

References

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