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DEVELOPMENT OF NOISE CONTROL DEVICE ACOUSTIC EDGE TYPE BASED ON POLYMERS

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***Abstract*— The following is the development of an INNOVA CORFO project, which explores from the theoretical basis through FEM modeling, the development of scale prototypes in anechoic chamber and field tests through acoustic measurements, the sound insertion loss of a noise reduction device (noise reducing edge).**

1. PHYSICAL PRINCIPLES OF BRR

The acoustic theory used in the development of the noise reducing edge (BRR) is widely known and has been studied by several specialists in the field [1]. However, the challenge lies in achieving a prototype that incorporates all physical, structural and chemical conditions, so that the physical phenomenon occurs, demonstrates stability in the results before various sound stimuli, and fulfills the function for which it has been designed: noise. The fundamental physical principle related to acoustic barriers is the diffraction of a sound wave, see Figure N ° 1, a phenomenon that basically consists of a sound wave being bent around an obstacle. Figure No. 2 shows the distribution of movement of the air particles when a sound wave hits a barrier. It is known that diffraction depends on the shape and size of a body or obstacle. In the specific case of acoustic barriers, the diffraction process that modifies the propagation of sound is determined fundamentally by the conditions of the edge or edge of said barrier. By varying the shape, the acoustic impedance or the absorption coefficient of the edge or edge of the barrier, the intensity of the sound that reaches a receiver behind it varies. The research work on acoustic barriers developed in recent years has shown that a possibility to obtain higher insertion loss values consists of adding a device to the edge of the barrier, whose surface has, at least for some frequencies, a value of No acoustic impedance or very close to zero. A device with this characteristic prevents the acoustic energy from propagating in its vicinity, forcing the acoustic wave to follow a longer diffraction path, thus increasing the acoustic height of the barrier. To build a BRR with zero impedance is not an easy task, there lies the complexity of the design.

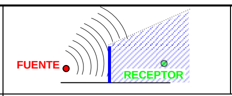
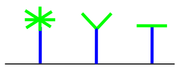
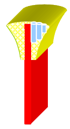
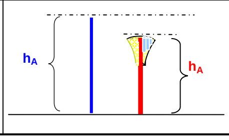
Pantalla Acústica ó Barrera Acústica		Consiste en un elemento sólido diseñado con el objetivo de interferir en la propagación del sonido entre una fuente y un receptor.
Pérdida por Inserción	La Pérdida por inserción de una barrera para una banda de octava, en un punto determinado, es la diferencia entre los niveles de presión sonora (Lp) de la banda, medidos antes y después de la construcción de la barrera. IL barrera = Lp (antes) - Lp (después) dB	
Cumbrera Acústica		Dispositivo que se agrega al borde de una barrera para mejorar su eficiencia acústica, o pérdida por inserción IL.
BRR: Borde Reductor de Ruido		Es un tipo de cumbrera acústica, que se instala en la parte superior de una barrera, con el objetivo de aumentar su "altura acústica" y eficiencia (medido en pérdida por inserción).
Altura Acústica: h_A		Es el equivalente, en metros, a la altura de una barrera simple, con una IL tal, que es equivalente a una barrera de altura menor con BRR.

Figure 1. Sound diffraction of an acoustic barrier and its edge.

There are some designs based on Helmholtz resonators, however it is known that this type of devices have very high resistive values, which means that sufficiently low impedance values at the corresponding resonance frequency are not achieved. The best way to obtain a zero acoustic impedance is to use so-called quarter-wavelength resonators. These resonators consist of straight tubes, of small diameter with respect to the wavelength involved.

The incident sound wave will produce a flat wave inside the tubes, which will be reflected in the background generating for some frequencies a destructive interference that cancels the sound pressure in the mouth (open end) of the tubes. In this way it is possible to generate the impedance value sufficiently low that is needed. A necessary condition for the proper functioning of the device is that there is no dissipation of energy inside the tubes, therefore the inner surface should be as smooth as possible, free of pores or roughness. In summary, the BRR uses the principle of deviation of the propagation of a sound wave through a surface with zero impedance using quarter-wavelength resonators.

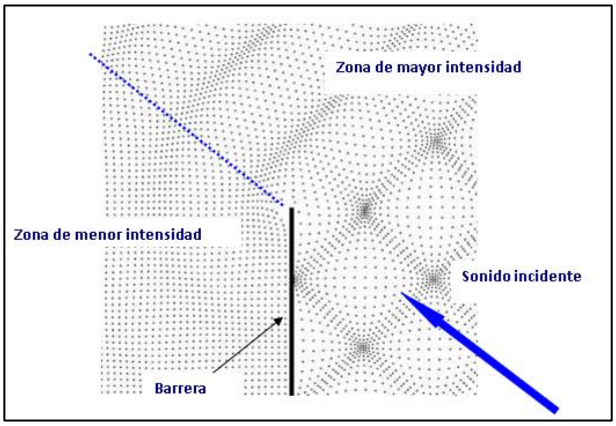


Figure No. 2 Distribution of movement of the particles

2. MATHEMATICAL MODELING DEVELOPMENT.

The objective of this paper is to verify the effectiveness of finite element models by contrasting it with an analytical model. The most complete work regarding the use of ridge with zero impedance is that of Rudi Volz (Schallabweisende Aufsätze zur Verbesserung der Dämmwirkung von Schallschirmen) [2], In his work he discusses the problem of a barrier (semi-infinite plane) with a cylindrical ridge and the influence of the impedance of the surface of said cylinder,

The most important results to analyze are the Loss of Insertion (1) the comparison between the level at the point of reception to vary the impedance of the cylinder (rigid cylinder) and known as Improvement (2).

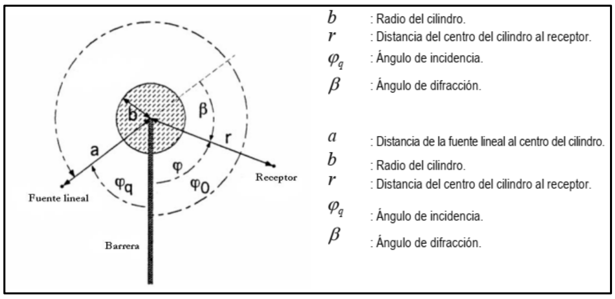


Figure N ° 3.

$$IL = L_{P\ NoBarrier} - L_{P\ Barrier} \tag{1}$$

$$M = 10\log\left(\frac{\left|p_{Z=\infty}\right|^2}{\left|p_{Z=0}\right|^2}\right) \tag{2}$$

IL	: Insertion loss.
$L_{P\ NoBarrier}$	: Sound pressure level without barrier.
$L_{P\ Barrier}$	: Sound pressure level with barrier.
M	: Improvement
$p_{Z=\infty}$	: Sound pressure infinite acoustic impedance.
$p_{Z=0}$	: Sound pressure zero acoustic impedance

That is, the comparison between the pressure amplitude squared at the reception point with and without zero impedance. This comparison allows to establish the real effect of the impedance change without changing the geometry of the problem (3). The theoretical analysis shows that the improvement M is independent of the distance as long as it is large with respect to the wavelength λ. The following graphs show the results for different angles of incidence (30º, 60º and 90º) and where the relation between the radius of the cylinder and the wavelength is:

$$\frac{b}{\lambda} = 0.25 \qquad (3)$$

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$$\frac{r}{\lambda} = \frac{a}{\lambda} = 10.17 \qquad (4)$$

The improvements (5) are further defined:

$$M1 = 10\log\left(\frac{|p_{NoBRR}|^2}{|p_{Z=\infty}|^2}\right) \qquad (5)$$

$$M2 = 10\log\left(\frac{|p_{NoBRR}|^2}{|p_{Z=0}|^2}\right) \qquad (6)$$

That correspond to (5) improvement of the barrier without noise reducing edge compared to BRR and (5) improvement of the barrier without noise reducing edge compared to BRR.

3. TECHNICAL OBJECTIVES OF THE PROJECT.

- Build a BRR capable of increasing the attenuation of existing acoustic barriers by at least 3 dB.
- Allow the useful life of installed acoustic barriers to be increased by at least 10 years.
- Reduce by 50% the final cost of the BBR (ridge) compared to those that are marketed in Europe from the use of polymeric materials at a lower cost than the aluminum used in Europe.
- Develop a BRR family, modular type that can use in combination the different noise control principles, to adapt and modify according to the noise source to control results or specific solutions that are expected to achieve with the implementation of the innovation project technological

4. BRR CONCEPTUAL ENGINEERING

At the beginning, the different physical principles that provoke the noise reducing effect on the edge of a barrier were analyzed, among which the main ones are: the reduction by reactive principle and dissipative principle of the sound energy. The stage of mathematical modeling was defined through FEM, as the first set of tests to which the created prototypes would be submitted. If the models meet the requirements to be validated, they would move on to the materiality analysis stage and then the selection of the models that would be built as prototypes 1: 5, to be tested in the Laboratory of the Universidad Austral de Chile, in Valdivia During a month, we worked in parallel in Valdivia and Santiago, compiling the technical information that allowed us to analyze the "State of Art" of Acoustic Ridge, and later the definition of the first models of BRR to analyze. In the third month, the different BRR configurations to be tested were selected, both in the first phase (FEM modeling) and in the laboratory tests.

5. BRR ACCEPTANCE TEST

An acceptance test was defined for FEM and for Laboratory, which consists basically of analyzing the results obtained in terms of IL (Insertion Loss), for each tested configuration: with wide, short tubes, absorbent edge, filled tubes, rigid cover, plastic mesh cover, etc. At this stage the research team visited the test facilities at the Austral University Laboratory in Valdivia. This visit was very profitable, since it allowed to analyze in situ the results obtained and to observe the different configurations tested in this first stage. The results of this analysis and summary of the technical visit are included later in the point corresponding to Results.

6. ALTERNATIVES DESIGNS BRR

During the following months and compiling the results obtained to date, various models are developed, which must also comply with the requirements of materiality, modularity, and quality that have been defined as an objective goal.

7. VALIDATION OF BRR DESIGNS VIA MATHEMATICAL MODELING.

This work was developed in 3 months, in order to determine if there is a feedback between the tests carried out, since as modifications are being incorporated a new model of BRR is being created, and this must be modeled through FEMLab and SoundpLan before entering the final selection.

8. STAGE 2: DESIGN OF BRR

In this stage, the models are constructed at a scale of 1: 5, to be evaluated in the laboratory. Originally this activity was scheduled for January, but tests of some preliminary designs and configurations, carried out during December, were advanced.

9. MANUFACTURE OF BRR ESCALE 1: 5

The construction of these models began. Some were built in Valdivia, and others were built in Santiago, and the final assembly was made in Valdivia. Since the availability of suppliers and raw material is higher in the capital.

10. TEST IN LAB BRR ESCALE 1: 5

Many times in parallel to the manufacturing activity, the test set was carried out in the laboratory, which was permanently monitored by the Project Manager, and the Acoustic Team Coordinator. This Set-up of tests was very flexible, since as new ideas arose, the installation in the laboratory was modified and the required tests were carried out.

11. BRR DETAIL DESIGN

The design of the BRR has undergone permanent modifications until this stage, since acoustic tests have determined its shape and dimensions. After carrying out the tests with different geometries (high, long, wide) a modularity has been defined that meets the BRR development objectives. This is how the support of the Industrial Designers team, TALLER ZERO, is incorporated during the month of February, those who contribute their experience in the construction of plastic objects and the aesthetic component required for the development of an integral product.

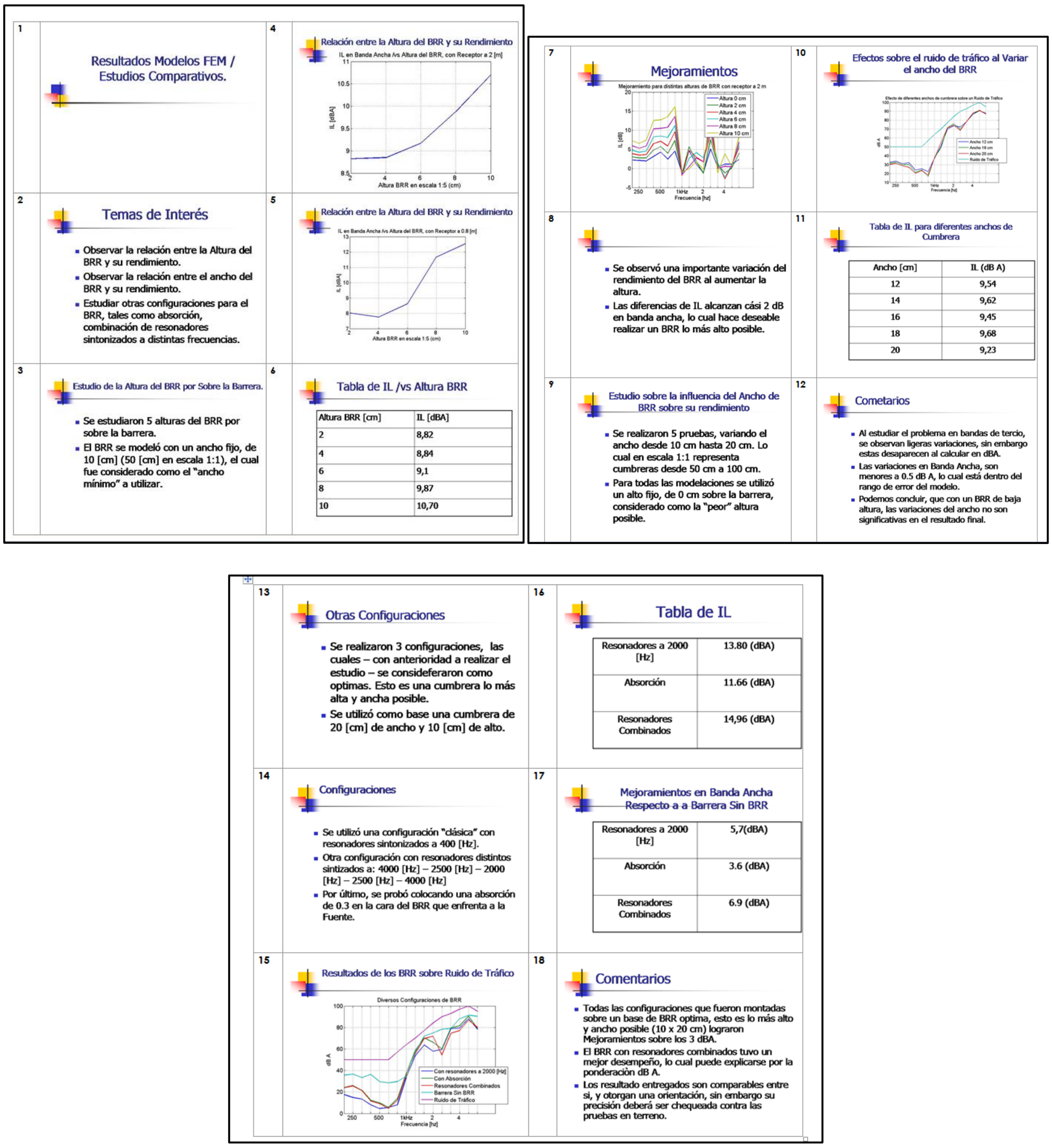

Figure No. 4

12. MATERIALITY OF BRR

The requirements on the materiality of the Noise Reducing Edge were studied by the chemical research team. The Bibliographic compilation on the nature of the polymers and the types of existing plastics can be found in the respective Annexes. Then, in the selection of the polymeric materials suitable for the manufacture of the noise-reducing edge, the following topics were considered:

- Environmental conditions.
- Transportation, installation and assembly.
- Design and construction in series.

13. TEST ON SITE

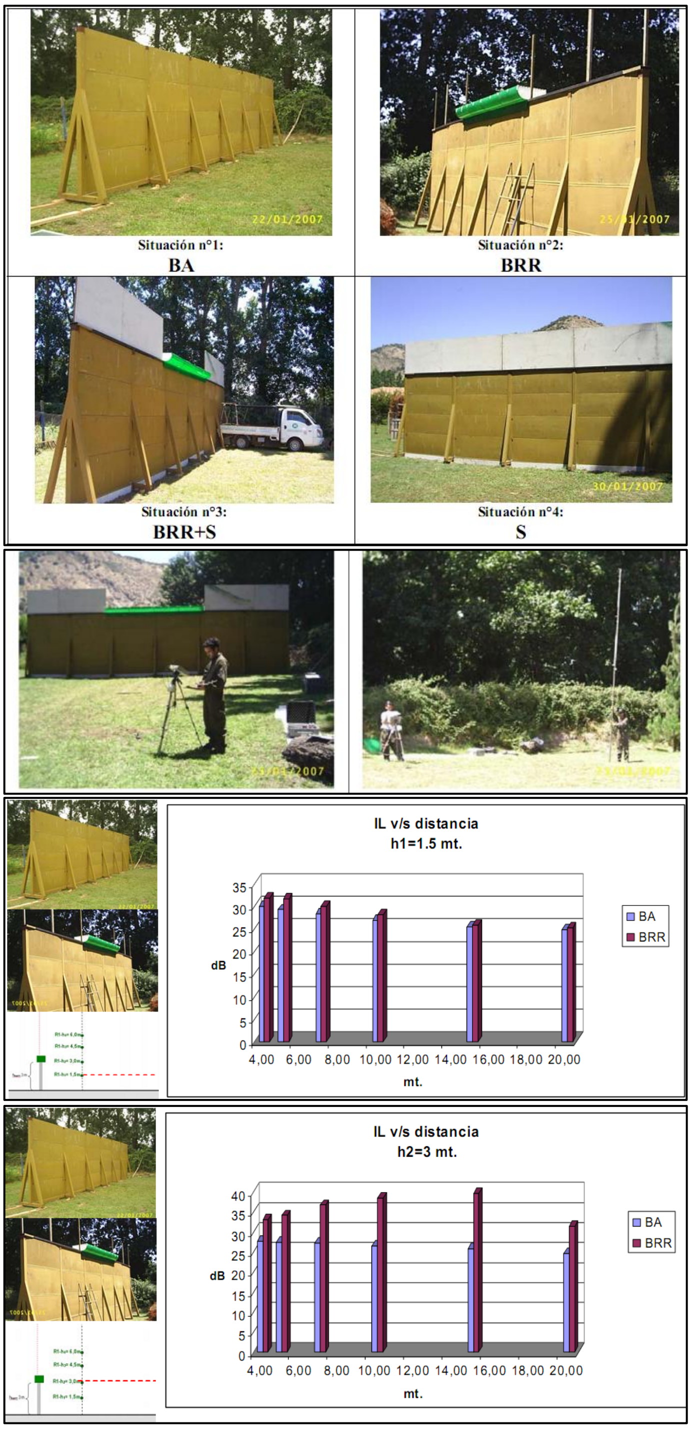

Figure No. 5 Setup and results

14. FINAL CONCLUSIONS OF THE PROJECT

The Project "Development of noise control device acoustic ridge type based on polymers", began on November 9, 2005, and concluded on March 2, 2007 [3].

During the 16 months of duration, it was worked systematically, forming a diverse work team, which underwent changes along the way, but which helped to bring the development of the research project to a successful conclusion.

Finally, we can say that each of the technical objectives initially proposed was fulfilled when the project was formulated, these are:

- Build a BRR capable of increasing the attenuation of existing acoustic barriers by at least 3 dB.
- Allow the useful life of installed acoustic barriers to be increased by at least 10 years.
- Reduce by 50% the final cost of the BBR (ridge) compared to those that are marketed in Europe from the use of polymeric materials at a lower cost than the aluminum used in Europe.
- Develop a BRR family, modular type that can use in combination the different noise control principles, to adapt and modify according to the noise source to control results or specific solutions that are expected to achieve with the implementation of the innovation project technological Therefore, it is an achievement for our company to present the acoustic results achieved, which are much higher than originally proposed, since at the optimum height reached, 3 meters, the BRR Noise Reducing Edge manages to increase the acoustic height of a barrier between 5.4 dB and13.9 dB.

15. BRR DESIGNS

Considering only these results, it is possible to project an increase in the useful life of a barrier already installed in more than 10 years, with the consequent economic benefit that this implies. On the other hand, developing a modular acoustic product, light, excellent presentation, based on polymers, nonexistent in the world market, with an effective acoustic performance, is a success achieved.

It is also important to highlight that the technology used in this research is at the level of the research carried out in Europe and Asia, since we were able to share experiences with various professionals who perform similar work in other areas. The assistance of two professionals from our research team, Víctor Romeo and Mariette Almarza, to the Technological Mission funded also by INNOVA CHILE of CORFO [4] had a decisive impact on the course that followed the research during the second half of the development period . Finally, we can conclude that a new product, the BRR, fruit of the innovation of Chilean minds, will be able to continue its course, until reaching the status of "commercial and exportable product" that we want to give it.

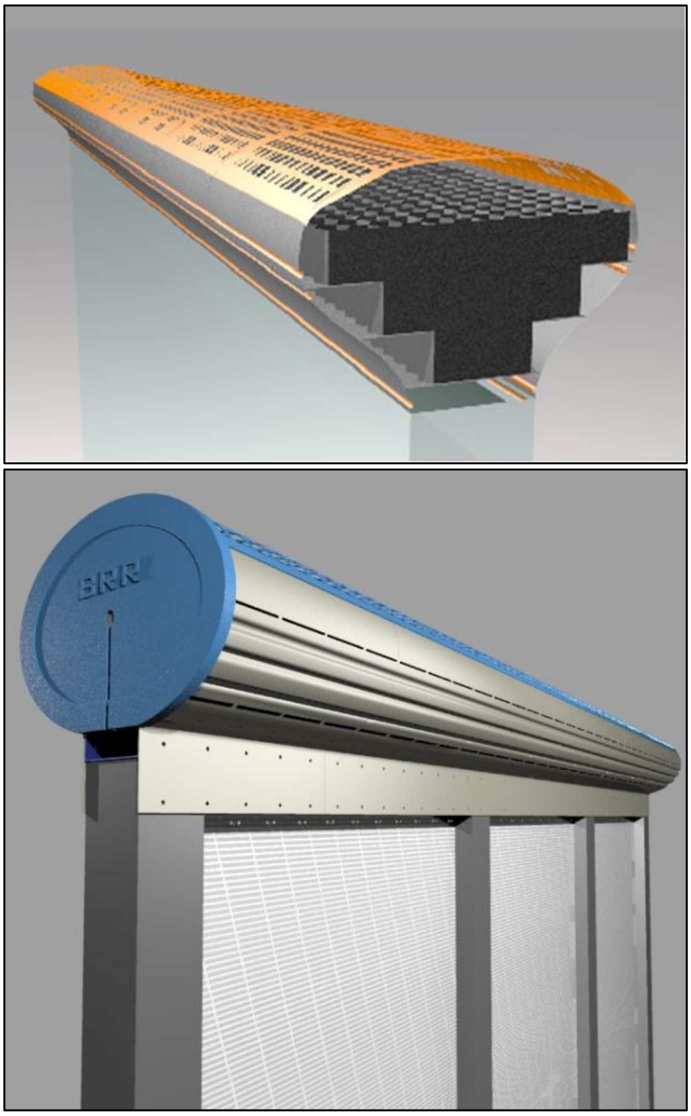

Figure N°6 Model3D of BRR

16. REFERENCES.

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