VIBRO-ACOUSTICS

ICA

Ingeniería para el **Control** del **Ruido**

"An approximate answer to the correct question is preferable, often imprecise than an exact answer to an incorrect question, which can always be as precise as we want."

John W. Tukey

Right questions lead to right answers

"I do not have to swear allegiance to the words of any teacher."

Horacio

The positive thing about a problem with no apparent solution is the pleasure of finding it.

"I defend that symbiogenesis is the result of long-term coexistence and that it is the maing source of evolutionary innovation in all lineages of higher nonbacterial organisms."

Lynn Margulis

A fluid communication is the basis for a further progress


01
OUR HISTORY

HISTORY

Ingeniería para el Control del Ruido (ICR) is a company located in Barcelona dedicated to solving noise and vibrations problems. Founded in 1995 by professionals with more than 20 year of experience in the field of vibro-acoustics, ICR offers recent analysis methods for railways, automotive, wind power, industry and civil engineering sectors.

The company's goal has always been to offer the right and most efficient solution for each vibro-acoustic problem. To do so, most of ICR efforts have been focused on R+D, with the objective to develop new predictive and analysis methods.This company innovative profile has allowed ICR to take part in numerous highly technological projects, both national and international. In some cases, these projects were focused on a technology transfer from ICR to the main European rolling stock manufacturers.

The company staff is formed by PhD, physicistsand engineers. This combined knowledge and experience allows the company to analyze any vibro-acoustic problem from a global and specialized point of view. The result is always a good diagnostic of the noise and vibration problem and the proposal of the best solution.

OPTIMAL COMBINATION THEORY AND ESSAYS

Over many years of developing and applying its own methods, ICR has always stressed the importance of including real-world essays in its studies. The reason for this is that experimentation makes it possible to grasp reality by getting to know the problems addressed, while the theory makes it possible to understand the reality captured and thus establish modifications that are effective. It is for this reason that the most important investments of the company are made, on the one hand, in technology to always have the most advanced methodology, and on the other hand, in continuous training of its personnel.

SOLUTIONS TO NOISE AND VIBRATIONS PROBLEM

At ICR, talking about noise is talking about vibrations and vice versa, since the vibration of an element generates noise, and the noise, by making contact about a particular generates vibrations. Only one simultaneous study of both phenomena makes it understandable the problem, and makes it possible to find the solution.

32 Channel FFT Analyzer

MESUREMENTS IN REAL TIME

ICR has up to 112 channels to measure noise and vibrations simultaneously, with the required accelerometers and microphones.

All these elements analyse the signal according to the frequency and in real time — they can analyse spectra, transfer functions, coherence...

The simultaneous control of a large number of measuring points makes it possible to carry out the necessary essays efficiently to diagnose the solutions of real vibroacoustic problems.

On the other hand, the company's daily work involves having a large number of technical instruments such as sound level meters, microphones, accelerometers, spectrum analyzers, etc., in order to be able to carry out all projects, whether large or small.

02

SECTORS

RAILWAY

ICR has achieved an important position in the railway acoustic engineering sector in the last decade, thanks to its prediction techniques, based on real measurements and the application of the company's own theoretical methods.

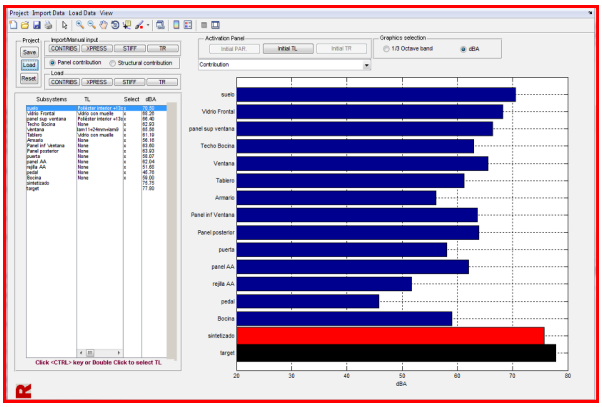
The company is able to measure air-borne noise and structural noise, including the contribution of forces (Transfer Path Analysis) and the quantification of the paths followed by noise and vibrations (Advanced Transfer Path Analysis).

ICR's clients will be able to know exactly how much noise is made by each element of the train, for example, the noise received from each point of attachment, the air conditioning, the auxiliary systems, etc.

This way, the manufacturer can decide, with the information available, whether to change the anchoring methods and establish priorities for future modifications. For this, the company uses exact numerical criteria from the results that can be obtained from each modification.

The knowledge of these contributions does not only establish priorities for modifications—in some cases it can reduce costs because after each test, ICR evaluates improvements with its own software for a new design and defines the necessary changes to fulfil the required objectives.

The full acoustic model of a train enables clients to see the effect produced by any modifications on the design.



Contribution Graphic

As a result of the accumulated experience, ICR has the latest knowledge and resources for this sector.

Based on these studies, ICR carries out other types of jobs in the railway sector—some of them are specific to the sector, like the treatment of "squeal noise". Others, however, have a more generic application, like the environmental impact analysis, modal analysis, theoretical numerical models of the train, etc.

Thanks to the company's wide experience in this market, it is able to solve any vibroacoustic problems.

Experimental setup

WIND POWER

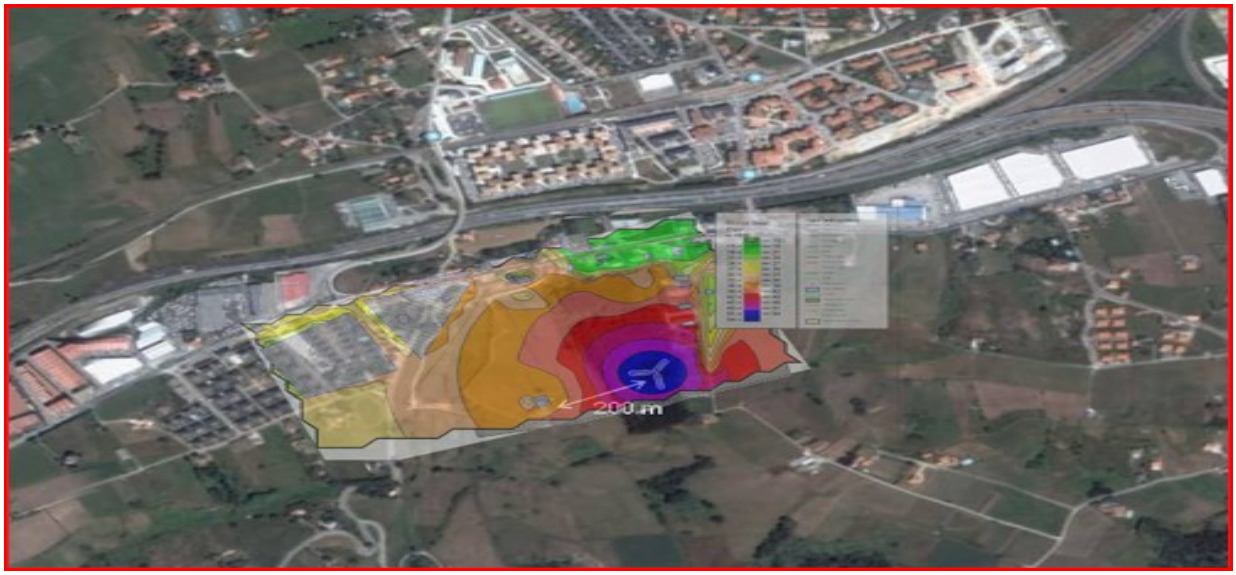
Wind farm are gradually being built closer to built-up areas and the noise they produce is starting to be an essential factor in their feasibility. In order to establish this feasibility in terms of acoustic impact on the environment, ICR carries out a comprehensive study to make sure that regulations are complied with.

It also develops more specific and larger projects in the design stage of wind turbines, with the aim of obtaining real predictions for the future vibroacoustic performance or the mechanism.

Training is so another very important service in the wind power sector. ICR gives very specific courses to companies that manufacture wind-driven turbines, with a syllabus that is adapted to the sector and introduced concepts on acoustics and its relation with current legislation.

ICR works on the acoustic viability from the design phase of the aerogen-router to the environmental control of the park.

Sound power measurement according to IEC 61400 part 11



Environmental impact study of the wind farm

BUILDING

People's peace and quiet is often disturb by different problems — entertainment, fairs, bars, discos, etc. To avoid this problem, current legislation establishes the maximum immission level allowed for every activity depending on the area, as well as the insulation values for each type of activity.

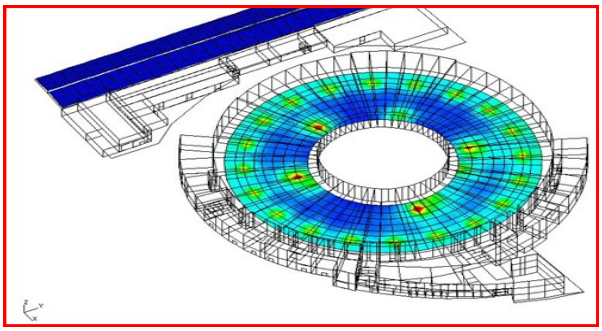
Taking this into account, ICR mainly develops two types of studies:

- The objective of the first study is to assess and prevent the noise level generated by the activities outside. This type of analysis is carried out especially at discos, fairs, ecreational centres, etc.

- The second one studies the transmission paths of noise and vibrations inside a building. The aim of these projects is to assess the sound insulation between the affected buildings.

The company also carries out comprehensive interior acoustics projects (geometry, absorption, diffusion) in the field of audiovisuals—installing a sound system, mixing and recording systems, and control or design of new and quieter recreational centres.

Improving the insulation of a discotheque



Noise prediction radiated by equipments

ICR offers a wide range of engineering services and vibroacoustic consultancy service focused on the sector of architecture and building, namely:

- Functional building solutions
- Insulation calculation
- Acoustic and vibration measurements
- Control and monitoring works
- Acoustic conditioning and insulation design
- Acoustic and vibratory impact study

Finally, we have to mention that ICR has developed new systems to identify the source of noise and vibrations in buildings, using model inversion and other methods like TPA.

SPECIAL BUILDINGS

In the building sector, the company takes part in special and very complex projects, in which it evaluates the future influence of environmental vibrations in buildings where the maximum vibration level is very restricted.

This study is carried out firstly by calculating the environmental vibrations that may affect the installations, and secondly, by characterising the terrain with the SASW method (Spectral Analysis of Surface Waves). The data obtained is used to create a finite element model of the terrain and the building.

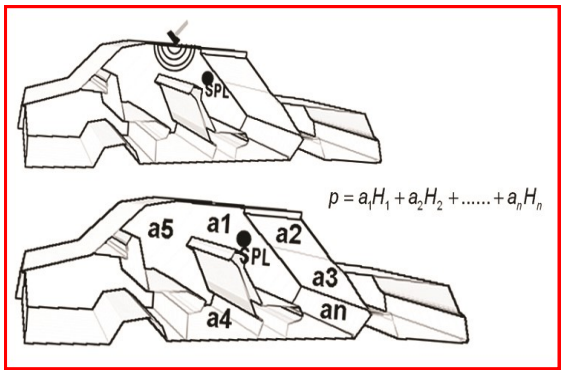
ENVIRONMENTAL IMPACT

The concern for noise impact created by the new high-speed train tracks is no longer a secondary factor when planning infrastructures.

ICR carries out environmental projects to predict noise and vibrations with a methodology based generally on the combination of the calculation of noise prediction with acoustic measurements. ICR believes that measuring properly will lead to a good vibroacoustic characterisation of the terrain, and therefore, to a good numerical model.

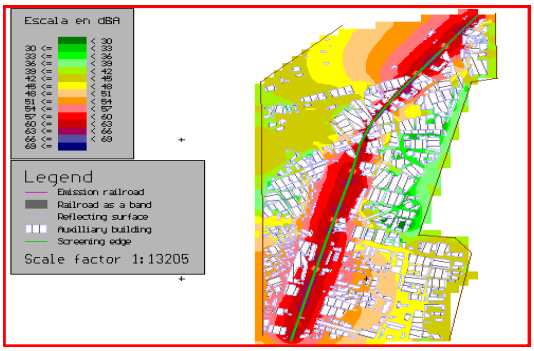
The company also has the best calculation tools, such as CADNA A and SOUNDPLAN, which enables us to obtain highly reliable results for our most demanding clients.

Noise predictions for trains and road traffic are currently regulated by European standards, which are integrated into the company's calculation procedures.

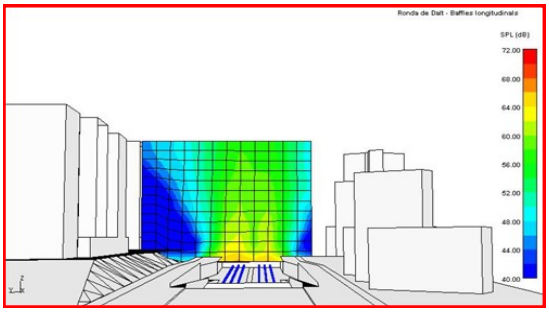


To determine the noise transmission paths of each of the interior panels of vehicle

Most acoustics laboratories of car industries apply theoretical approach of TPA/ATPA developed by ICR



Acoustic impact caused by the train circulation in Girona



Acoustic impact by road traffic in Ronda de Dalt (Barcelona)

ICR carries out daily projects and impact assessment measures in new routes of reel-rails and railway lines

AUTOMOTIVE

Our work in the car industry ranges from experimental studies on the transmission paths of noise and vibrations, to the creation of theoretical models to predict the noise of traffic.

We must not forget the development of new testing methods that optimise time and costs in the current methodology to characterise a vehicle.

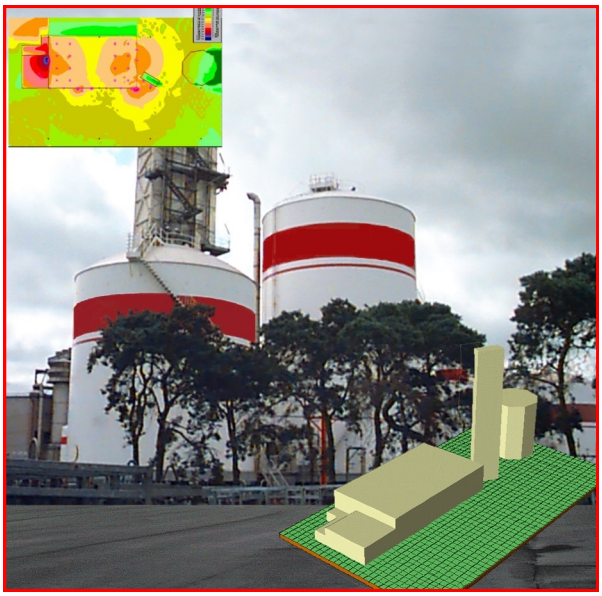
The transparency of the methods used has allowed ICR's customers to deepen the vibro-acoustic knowledge of their products and thus reduce the costs necessary to solve their noise and vibration problems.

INDUSTRY

Deciding on the appropriate solutions to reduce the noise that an industrial plant generates in its environmental is often a difficult job. To decide, the first step is to quantify the influence of each source of noise on the total noise in the affected points.

ICR uses model inversion methods to obtain the acoustic power (SWL) of all the sources of noise an vibrations belonging to a factory, without having to interrupt its operation. Then, we can decide in which order to silence them and calculate how the situation improves with the proposed modifications.

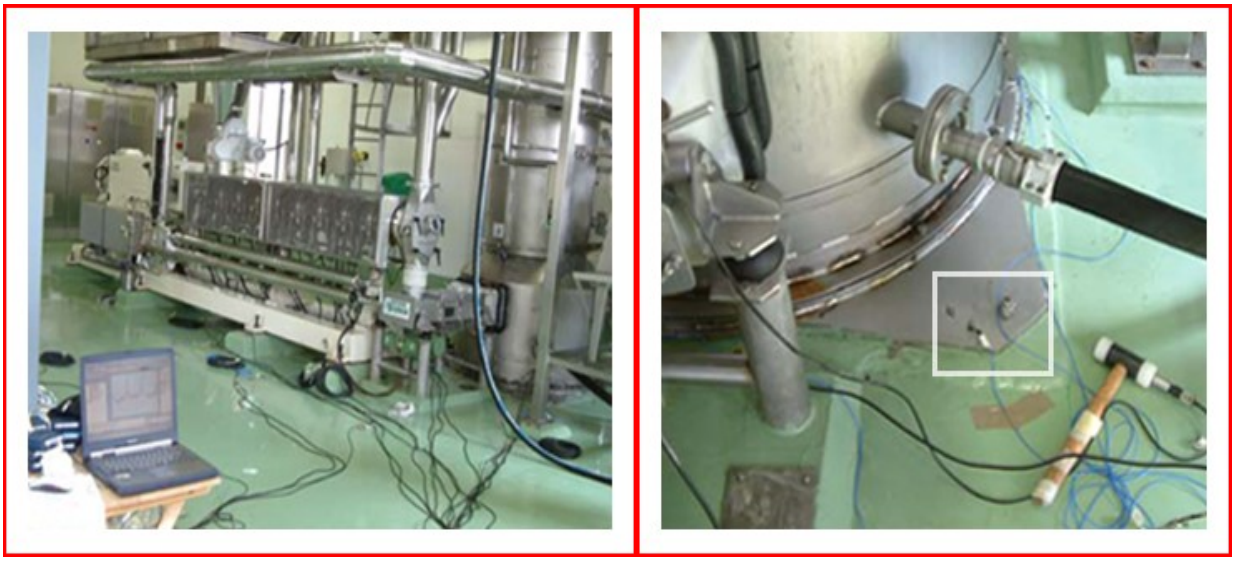
ICR also uses this methodology to measure the noise from outside and achieve the required reduction of the noise made by a machine (blower, shotblaster, etc.), in order to comply with the regulations and prevent the problem-machine from getting closed down.



Acoustic impact study in the chemical plant in Toulouse

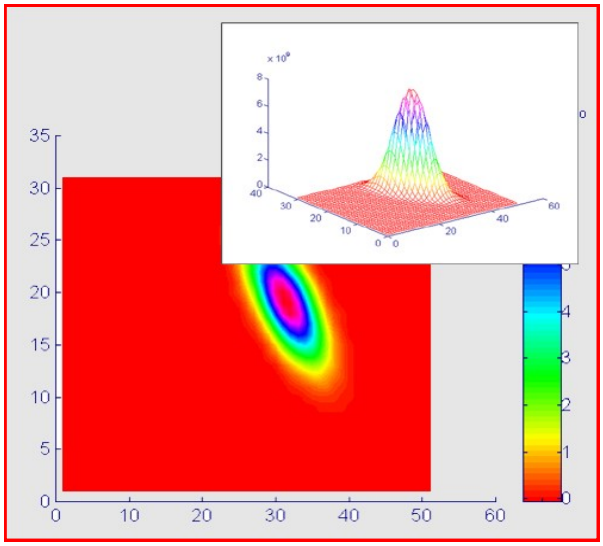
The treatment is feasible because the problem-machine is divided into a group of sources of noise that can be treated separately, in order to design an intelligent noise treatment for each one of them.

In the 21st century, uncontrolled noise and vibration in a machine mean low quality.



Measurements of modal behaviour in a industrial factory

TECHNIQUES AND METHODOLOGY



Acoustic power of the panels of a car

MODEL INVERSION METHOD

The core idea of the application of model inversion is to achieve the calculation of the causes based on the effects, using a cause-effect relation.

Model Inversion method is a mathematical technique developed in geophysics, which ICR has applied to vibroacoustics.

In this case, inversion is applicable to the establishment of the acoustic power of a collection of sources, which we know produce certain noise in a group of measured points. This involves using mathematical methods linked with statistics and uncertainty.

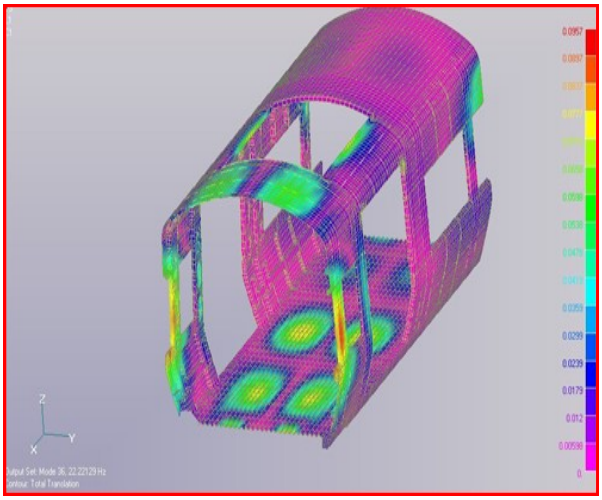
The scarce analytical resources of the market have motivated ICR to adapt various methods in the science of vibroacoustics

NUMERICAL METHODS

FEM (Finite Element Method) and BEM (Boundary Element Method) are powerful prediction methods for low frequencies. Both of them are used to resolve vibroacoustic problems straight from the design and can establish the exact validity of any solutions proposed by clients.

With these numerical methods, ICR evaluates the dynamic performance of structures with the introduction of forces—mechanical, acoustic or aerodynamic. For example, they can determinate the vibration response of a train carriage in the excitation that the engines, the auxiliary systems, etc. Introduce, taking into account the different middle structures.

So, FEM and BEM can provide prediction of noise and vibrations in the design stage, thus avoiding problems in the final product.



Car-engine coupling by FEM

Other numerical methods such as the wave equation or WEM (Wave Expansion Method) are among the many numerical methods used at ICR, according to the requirements of each study.

ICR integrates vibroacoustics into the design stage

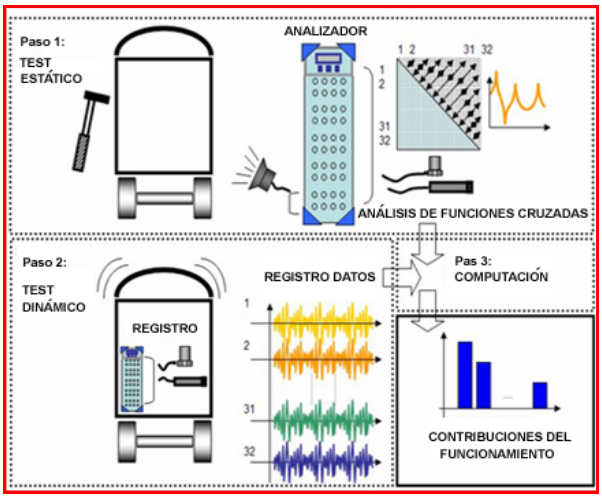
TPA / ATPA

Transmission Path Analysis is a technique invented in the 1980s and developed extensively by ICR, especially in the treatment of paths and the application of the vibroacoustics energy theory.

This system quantifies the contributions of each one of the sources of noise that causes a problem and can be applied in general, that is, it is valid for all fields. For example, on a train, each one of the parts of the vehicle that makes a certain noise can be analysed. And this can also be done in heavy machinery, small mechanisms, etc.

The main idea of this analysis is that the object to be studied is divided into parts and the contribution of each part to the overall noise is defined. This is the only way to find the best solutions to the problem.

ICR gives ongoing training in all the disciplines that gradually improve prediction.

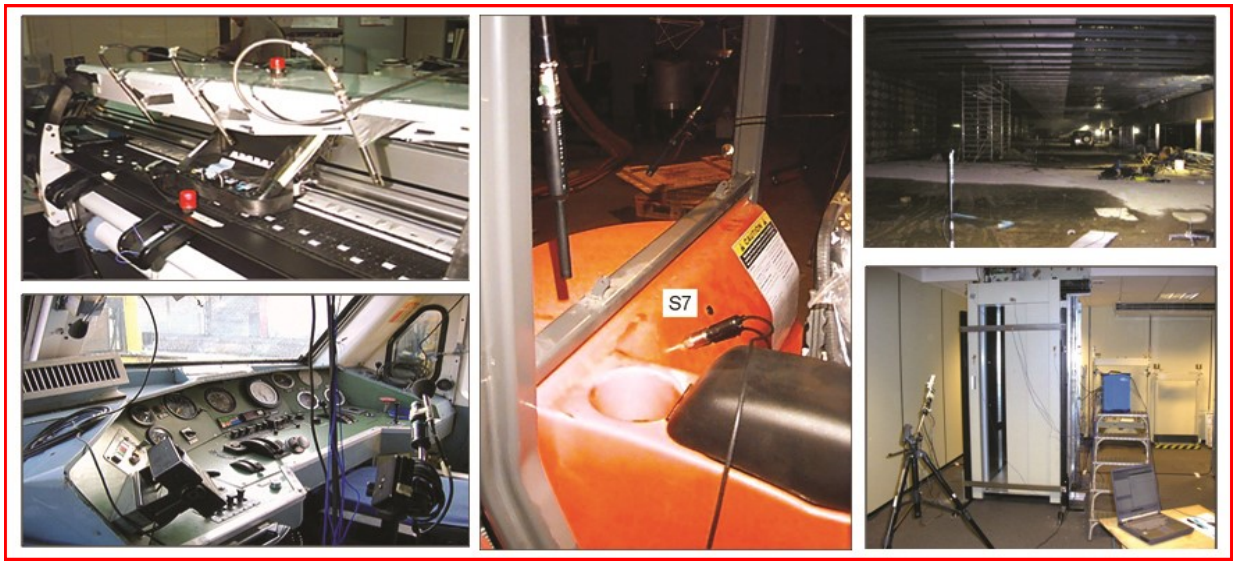


Process of Transmission Path Analysis

With this method we can also evaluate the forces that operate on a mechanical system, for example, dynamic forces that an engine can introduce into the bodywork of a vehicle.

This provides solutions that reduce forces — changing the points of support or the use of appropriate elastic support devices.

So, with this test method and a theoretical development, we can obtain the necessary data to define the necessary improvements to resolve the problem.



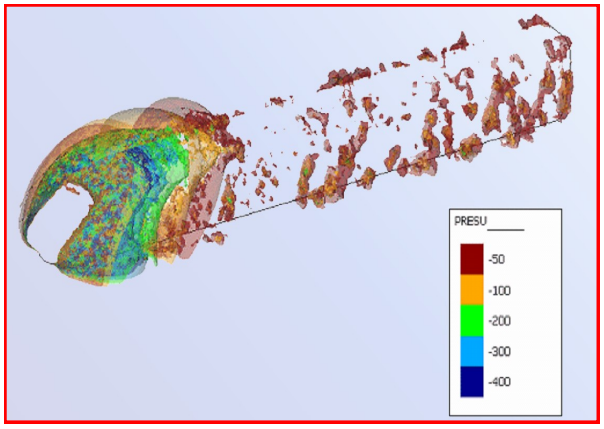
Examples of TPA/ATPA application in diferents sectors

AEROACOUSTICS CALCULATIONS

A problem with vibrations can have different origins and natures. For example, it can come from a source of noise, of electromagnetic forces, or dynamic unbalance.

Fluid motion around a body (a train, a car, a blower, etc.) at great speed is an important source of noise and vibrations. The science that studies this phenomenon is Aeroacoustics.

ICR is currently working on the prediction of interior noise caused by aerodynamic effects, either in a train running at high speed, or in a wind-driven generator.



Aeroacoustic study of a train

Until recently, it was inconceivable that any prediction could be made in the field of aeroacoustics. However, computing has advanced so much that very complex calculations can be carried out now.

ICR has its own calculation methods in the latest **CFD** (Computational Fluid Dynamics) and **CAA** (Computational Aeroacoustics), which, combined with the classic FEM and BEMs, enable the company to quantify the contribution of the aerodynamic load in the vibration of a structure or the noise inside a vehicle.

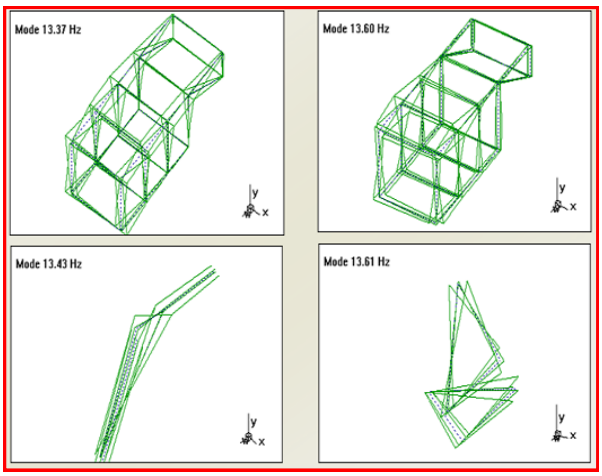
MODAL ANALYSIS

The modal or experimental analysis, or with numerical methods, involves establishing the parameters of each one of vibration modes of a structure, which are the natural vibration frequency, mode shepes and damping.

Vibration in the low frequency range in any structure can be obtained as the superimposition of the contribution of each of the modes. For the calculation of the contribution of each mode you only need the vibrational excitation force and modal parameters mentioned above, so the analysis results of a structure enable the calculation of the vibrational response when it is subject to any excitation.

Because we are able to know the contribution of each mode, the corrective measurements to be taken to reduce the level of global vibrations effectively can be focused on the preponderant vibration modes. ICR has successfully applied these techniques in many different fields of industry.

Vibrations control is a current work of ICR

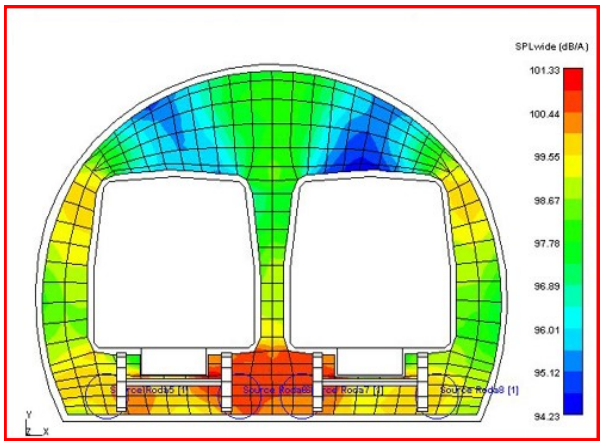


Modal analysis of the structure of a gondola structure of a wind turbine

RAY-TRACING

Whether it happens because of the buildings' acoustics or propagation outside, this technique is based on step-by-step calculations that provide results in the case of homogeneous environments.

In the high frequency limit, the wave equation turns into an eikonal equation that enables the interpretation of the noise propagation with rays.



Ray-Tracing prediction

For medium and high frequencies,
ICR has wide experience in the field of energy theories.

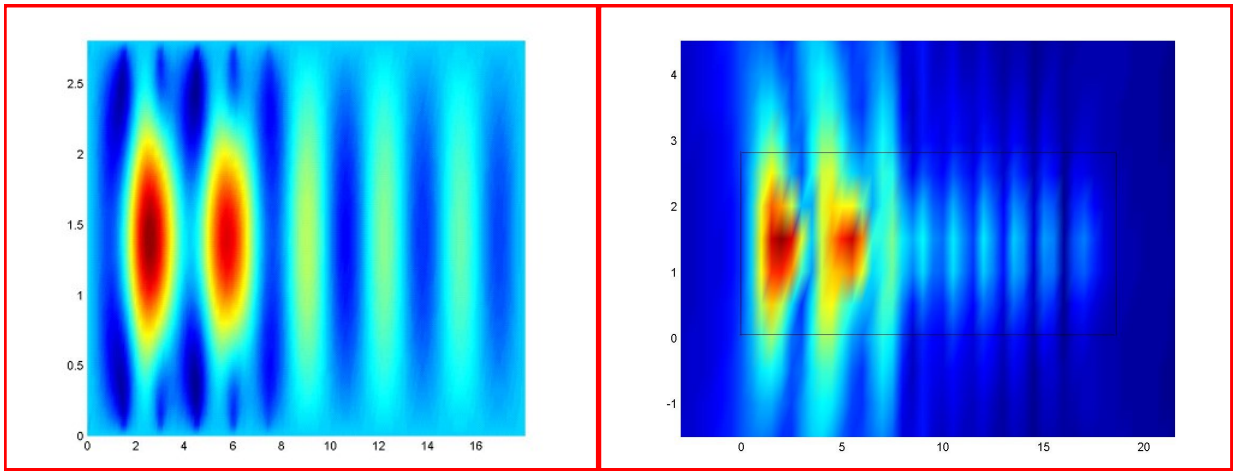
ICR applies its knowledge to any field, when it is required.
The final result is a *Know-How*
for the manufacturing company that,
entered into the production cycle,
forms a true knowledge base
future useable

STATISTICAL ENERGY ANALYSIS (SEA)

The high frequency study in complex systems cannot be studied with wave equations.

The methodology that is normally used is SEA (Statistical Energy Analysis), a vibroacoustic calculation method based on energy transfer between the parts of the system. These transfers are characterised with coupling factors that depend on the modal density.

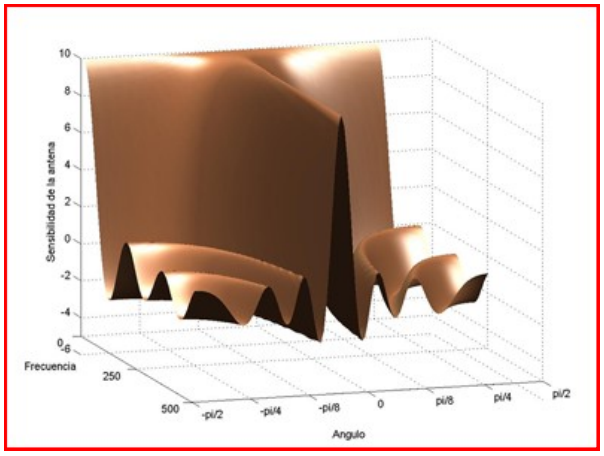
Complex systems with medium to high frequencies can be studied with the SEA, in order to make more realistic diagnoses, which is unfeasible and impossible with other techniques.



Ratiation Acoustic calculation (right) from the velocity distribution (left)

SOURCES LOCALISATION

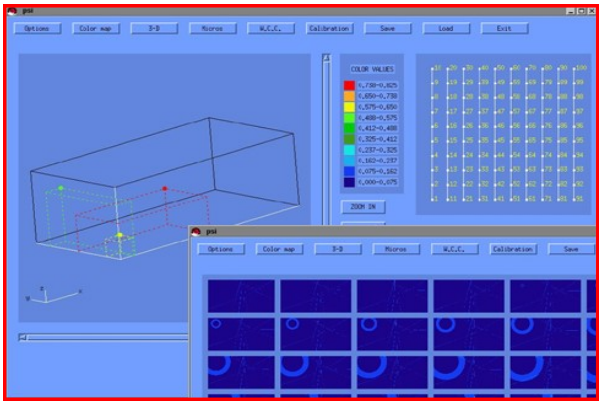
One of ICR's main objectives is to quantify and locate the sources of noise and vibrations, in order to optimise the solution to a vibroacoustic problem. For this, there are methods like holography and acoustic antennas.



Graphic of acoustic antenna sensivity

Acoustic Holographic is a specific inversion technique which calculates the vibrations in a vibrating body, based on the pressures measured in the sound field of the body.

This is carried out with Green's integral equation, which applies both variables—pressure on space and speed on a closed surface.



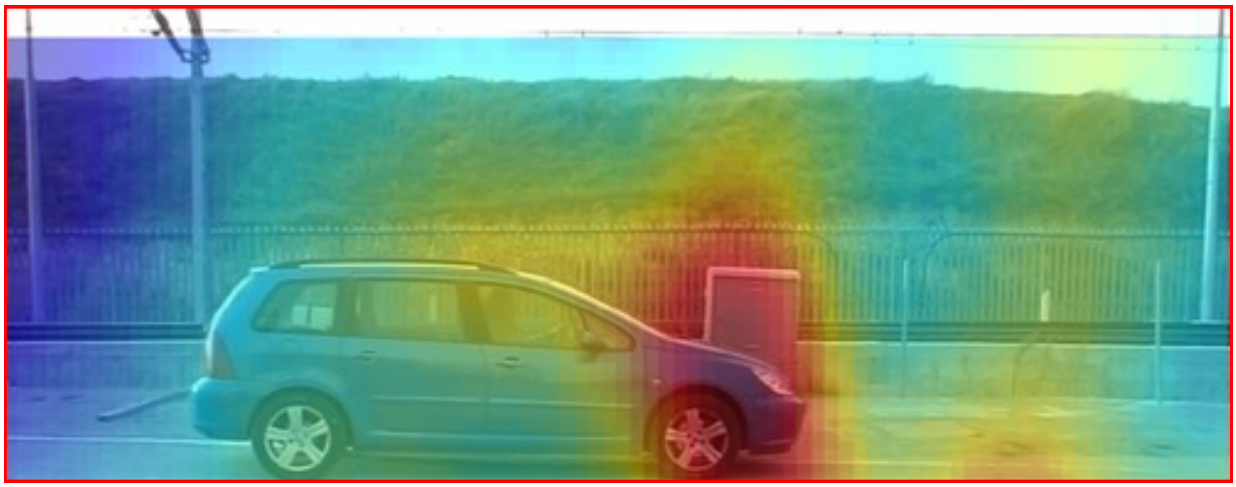
Software to obtain the acoustic photography

Source localisation technology can be the first step to approach a vibroacoustic problem.

Acoustic Antennas are microphone networks that show the direction from which the noise comes from, by processing the signals received.

Acoustic antennas are generally based on a hypothesis of the emitted sound field, like, for example, flat waves, spherical waves, etc.

ICR also has correlation antennas that even locate noise in reverberating fields.



Noise sources localisation on a movement car

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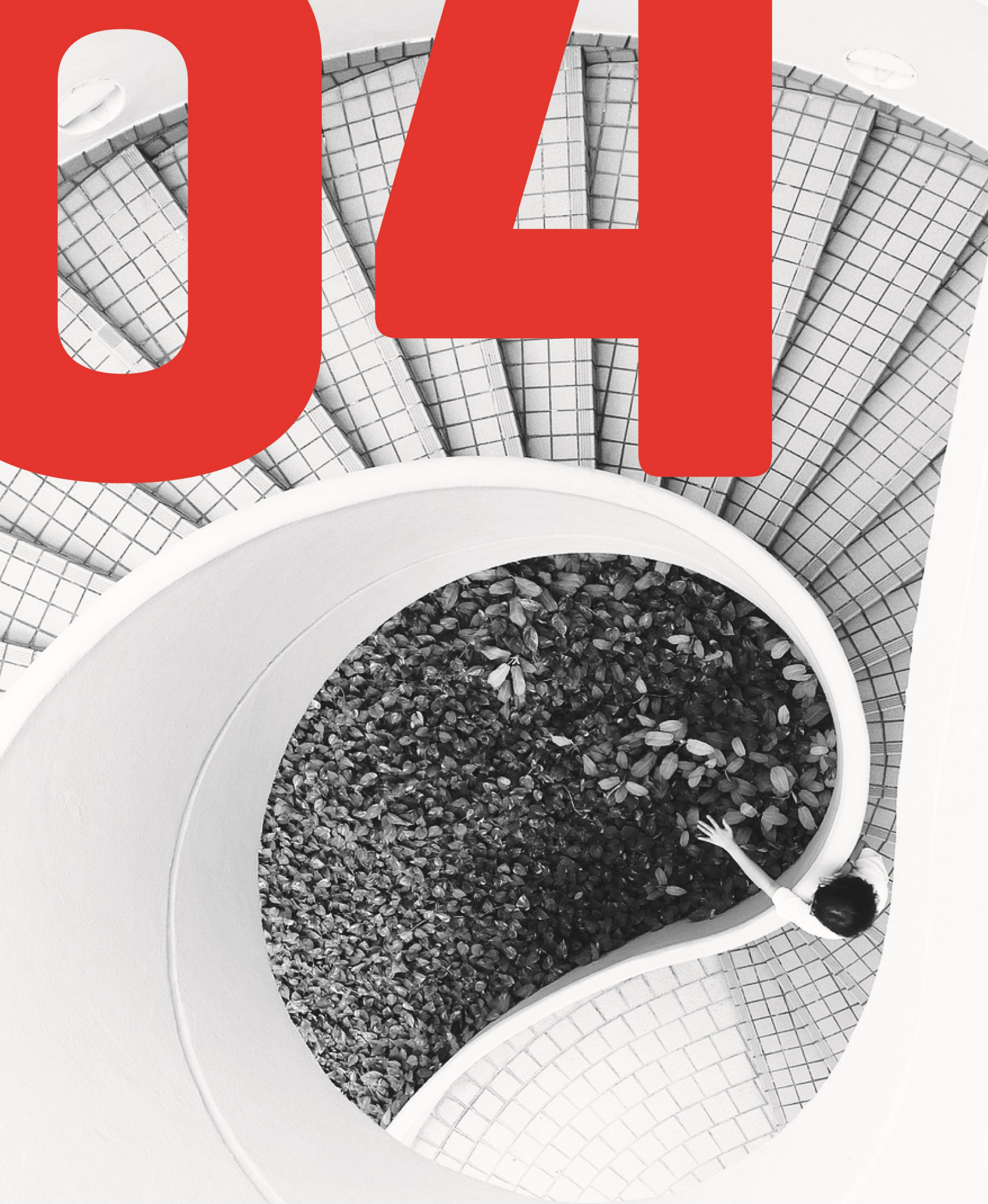


TRAINING

TRAINING

ICR counts on highly qualified professionals, the level of which allows us to offer courses on different fields of acoustics and vibrations.

The training provided is characterized by being fully adaptable to the needs of the client, who always has an temary divided into two parts: one with a generic introduction of vibroacoustics, and a second part of specialization, based on content much more tailored and specific to the sector concerned.

These tailor-made courses guarantee a good theoretical knowledge, and if required, also practical, since the limit is set by the client's interest.

Vibrations course

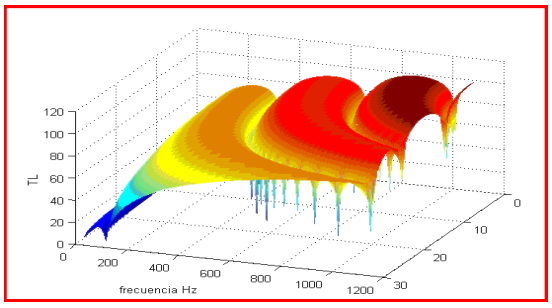
ICR has always used time and resources to provide vibroacoustic training at different levels.

Following this line, it has courses of:

- **Basic Acoustics:** ICR's basic acoustics and vibrations course is aimed at engineers and architects who wish to acquire basic knowledge in acoustics.

Technical and specific training that does not require previous knowledge

- **Advanced Acoustics:** The Advanced Acoustics course aims to make a deepening from the most theoretical side to the most used methods in the field of Acoustics and Vibrations.
- **Isolation:** The isolation course proposes a temary based on basic concepts, various cases and practices through a software of acoustic insulation calculation developed by ICR (dBKAisla)
- **Vibration:** The ICR Vibration course is aimed at engineers and professionals in the sector who wish to acquire basic knowledge in vibration.
- **Environmental acoustic impact course in wind farms:** ICR has captured its experience in acoustics and vibrations by developing training courses with a very specific temary for the wind energy sector.
- **Aeroacoustics:** For this course it is necessary that the student has previous knowledge of acoustics.
- **Acoustics courses for custom-made companies:** Although many of the ICR courses are based on a generic syllabus, the success of their training has always been tailored courses, as they allow companies to go one step further despite the complexity of vibroacoustics. In a clear and affordable way, students are introduced into the subject matter by applying it directly to their products or services, taking into account the regulations that concern them. These courses have been given for companies such as: Alstom Wind, Gamesa, Suzlon, VESTAS, Mercedes, Doga motores, MB-92, STA, Technip, Hyundai Rotem, CAF among others.



Advanced Acoustic Course

05

SOFTWARE

CUSTOM SOFTWARE

Experience in the world of acoustic engineering and vibration has led ICR to raise problems without an optimal and efficient solution from the point of view of existing software. The need to remedy these problems has led ICR to develop its own calculation tools. This has been the starting point for the development of various proprietary software that has sometimes been marketed on the market. This is the case with dBKaisla acoustic insulation software.

On the other hand, ICR has also contributed to the development of Finite Element Codes (FEM) for computational fluid dynamics (CFD) and computational aeroacoustics (CAA) that have been successfully applied in the prediction of noise levels in high-speed trains.

WORKING PROCEDURE

ICR has focused its work in this field on several lines of action:

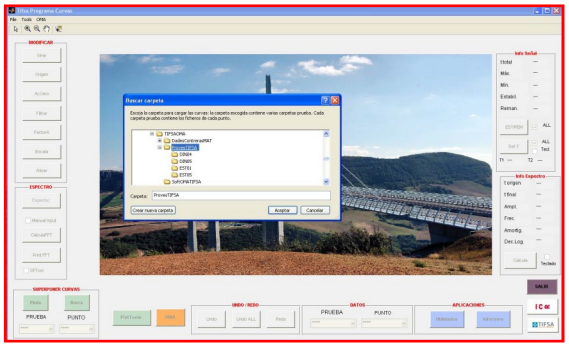
1. Tailor-made software including applications with specific development programmed on the following platforms:
   - OROS: PC-Pack OR24, PC-Pack OR25, PC-Pack OR38.
   - National Instruments: LabView DAQ 4451, DAQ 4472.
   - LMS: programming on UPA and UPP.
   - Matlab.
2. Commercial software: software applications that are on sale
   - dBKAisla, simple and multiple insulation calculations.
   - ICR-Puentes.
3. Software development for the application of calculation methods resulting from R&D projects:
   - FOTACU (Acoustic Photography)
   - InVent (OMA adapted to wind turbines)
   - ATPALAB (Tranfer Path Analysis).

ICR-PUENTES

ICR-Puentes is a program of treatment, frequency analysis and visualization of bridge vibration signals developed and designed by ICR. It is designed to meet the needs of one of its customers and, at a later stage, other companies have acquired the programme in order to optimise their working procedures.

ICR-Puentes is essentially a programme for the management and analysis of bridge vibration measurements. The software design stands out for incorporating a clear interface to facilitate its use.

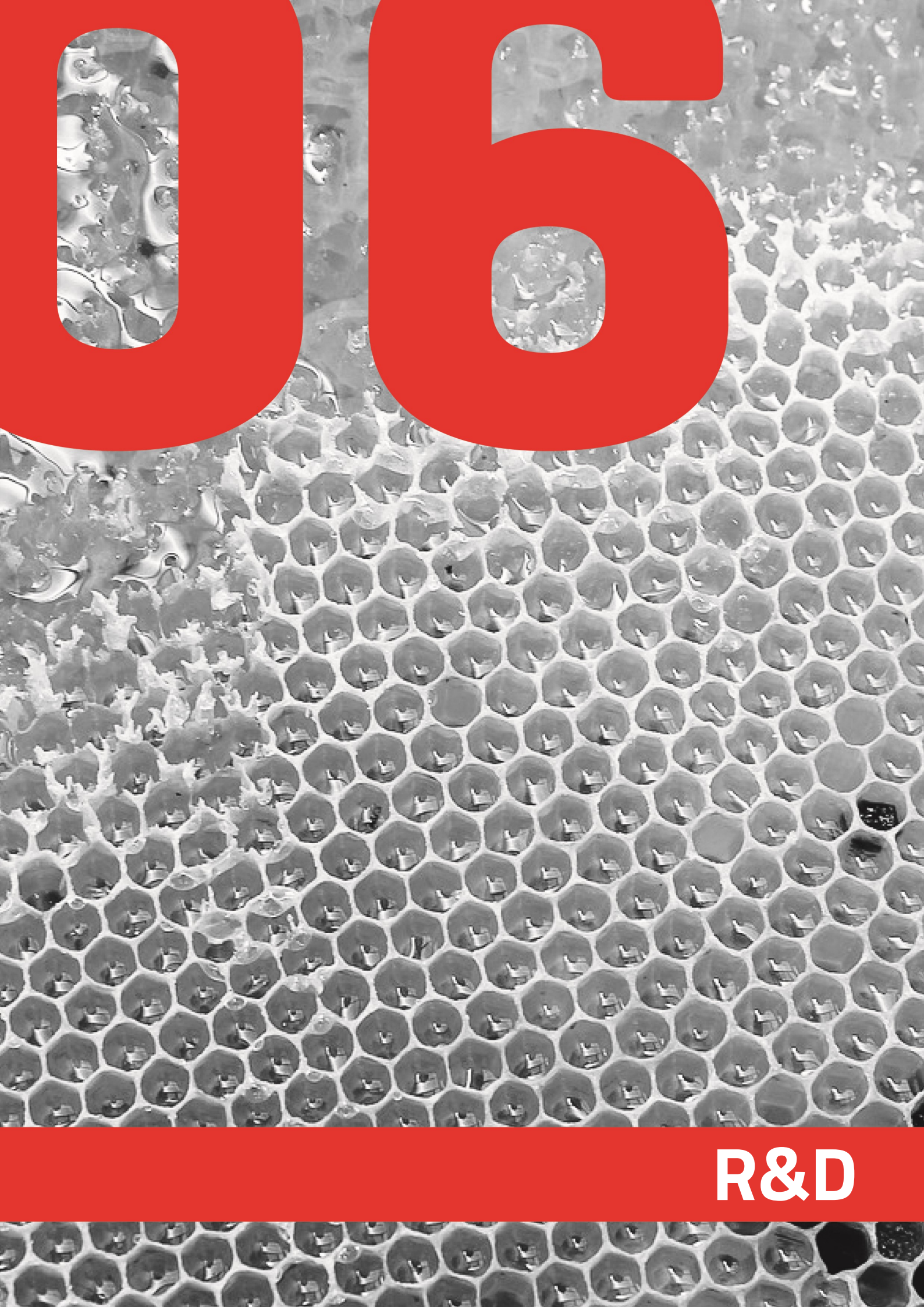
The program integrates several functionalities such as signal visualization, signal modification/ treatment, frequency analysis, reporting and massive data processing.



dBKAisla

dBKAisla is a sound insulation prediction program, dBKAisla. Designed to calculate the insulation of single, multiple and mixed panels, providing the user with the possibility to calculate a set of specific solutions for each type of wall.

In addition, dBKAisla also allows the development of calculation of airborne and impact noise isolation between two premises, taking into account the lateral transmission routes according to the de-fitting method of UNE-EN 12354 (Standard established and recommended by the DB-HR of the Technical Building Code).



06

R&D

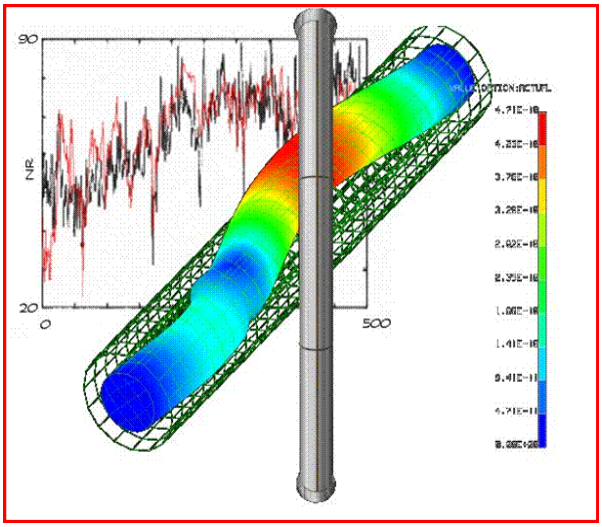
RESEARCH & DEVELOPMENT

ICR has always tried to be up to the technological standard that is required, so it has invested time and money in its resources in order to provide its clients with the most detailed and specific solutions in every case. Thanks to this it has achieved significant advantages in the market, providing theoretical solutions as well as designing new experimental technologies within the vibroacoustic field. .

Some of ICR's most important research fields are: aeroacoustics, TPA, software development, model inversion, dynamic characterisation of the terrain, design of materials, silencers, acoustic photography, etc.

The R+D projects in which the company has taken part have received public and private funding.

Certain innovations achieved by the company have been exhibited at conferences or published in science articles and technical reports and national and European magazines. For example, the mathematical bases of the TPA method have been published in the most important international magazines and they have even been transferred to large multinational corporations.



Structural transmission of vibratory signals in pipelines

A well-defined problem,
tends to be a problem solved

Thanks to the company's ongoing Research & Development, most of the methods that ICR uses every day have been designed in-house. The company has also adapted commercial methods.

Then, some of these methods are briefly outlined.

Model Inversion Method applied to carry out soundproofing treatment without making a complete enclosure.

07

SCIENTIFIC PAPERS

SCIENTIFIC PAPERS

MODEL INVERSION METHOD

TRANSMISSION PATH ANALYSIS

CONTROL APPLICATIONS

AERODYNAMIC NOISE

Then, you will find some scientific articles and technical papers about R+D by ICR, which had been published in prestigious journals.

Abstracts

INVERSIÓN DE MODELOS / INVERSION MODELING METHOD

- *An inversion modelling method to obtain the acoustic power of the noise sources in a large factory.*

  O. Guasch, F.X. Magrans & P.V. Rodríguez. Applied Acoustics 63, pp. 401-417 (2002).

Abstract

A common problem for large factories that wish to decrease their environmental acoustic impact on neighbouring locations is to find out the acoustic power of every noise source. As these factories cannot stop their activity in order to measure each source individually, a procedure is needed to obtain the acoustic powers with the factory under normal operating conditions. Their contribution to the overall sound pressure level at each neighbouring location can then be obtained and it is possible to calculate the improvements obtained after any modification of the sources. In this paper an inversion modelling method is used to do so. Acoustic powers are obtained by means of field sound pressure level measurements and with the use of a sound propagation software. A careful analysis of the solution has been carried out by simulating errors on the measured data in order to detect possible correlations between the acoustic power of different sources and avoid misleading interpretations of the results. The whole methodology has been applied to a liquid-gas production factory.

- *An inversion modelling method to obtain the acoustic power of a car cabin panels in the mid-high frequency range.*

  O. Guasch, F.X. Magrans & P.V. Rodríguez. Proceedings of the 14 Jornada Técnica de Automoción, UPNA-STA. Pamplona, (2002).

Abstract

The Inverse Problem Theory is a quite complete mathematical theory that integrates methods for extracting as much information as possible from measured data, in order to find the most probable values for an a priori unknown physical model. It is based on probability calculus and brings a natural extension of the minimax, least absolute and least squares optimisation criteria. The theory has found several applications in a wide variety of fields such as mathematics, astrophysics, geophysics, engineering or economy.

In this paper, the theory is applied to reconstruct the medium-high frequency acoustic field in the cabin of a Ferrari 456. The acoustic powers of the car cabin panels are obtained by means of sound pressure spectra measurements and with the use of a diffuse model of radiation following Lambert's law. Once all the acoustic powers are known, their influence to the acoustic pressure at any point inside the car cabin can be calculated. A careful analysis of the solution has been performed by simulating errors on the measured data in order to obtain correlations among the acoustic powers and avoid a misleading interpretation of the results. The method has proved encouraging and saves a large amount of time when compared with more classical approaches.

- *An innovative approach for the noise reconstruction and analysis at the medium-high frequencies.*

  O. Guasch, F.X. Magrans, P.V. Rodriguez & G. Manacorda, Proceedings of Euro-Noise, Munich, Germany, October, Vol. I, pp.503-509 (1998).

Abstract

In the last 30 years the Inverse Problem Theory has been mainly developed by geophysicians trying to model the Earth's interior from data collected at the Earth´s surface. As the Earth's interior is unaccessible, methods for extracting as much information as possible from data had been carried out. These methods turned out to be really efficient and have been applied to many other fields of applied physics and mathematics, engineering and economy. A quite complete mathematic theory has been built for them.

In our study we used some of these methods to reconstruct the medium-high frequencies noise field in the cabin of the new Ferrari 456. Our purpose was to know in what ways each of the panels in the total interior surface contribute to the measured noise at different points in the cabin. The results we obtained are very hopeful and we think that will improve in the future as we will have more information and a priori data to manage.

TRANSMISSION PATH ANALYSIS

- *Path Analysis*

  F.X.Magrans, Proceedings Nag Daga (2009)

Abstract

The title of this paper is Path Analysis, and not Transfer Path Analysis, because the latter name has been assigned to the Forces method which, as it is used, is a contribution analysis method, more than a path method.

The origins of the method lie in the need to solve two different problems. The first problem consists in quantifying the contribution of each part of a vibrating system to the total noise measured at a given location. This problem will be called problem A. The second one, called problem B, consists in determining the noise produced by each one of the forces acting on a mechanical system.

In the 60's the method used to solve the problem A was called the "Strip" method. In this method the noisy object was totally covered with insulating blankets in order to attain a very reduced noise. Then the surfaces were uncovered one by one and the contributions of each surface deduced from measurements. The "Strip" method has been applied to motors, whole cars or even to whole train coachs, and it is still being applied today.

A typical case of problem B was to estimate the contributions to interior noise of each one of the engine supports on a car. In order to solve this problem, the practical method was to unlink the engine from the car and then to attach the supports one by one.

- *Low and mid-high frequency advanced transmission path analysis.*

  F.X. Magrans, P.V. Rodriguez & G. Cousin, Proceedings of the 12 International Congress on Sound and Vibration, Lisboa, Portugal (2005).

Abstract

Advanced Transfer Path Analysis (ATPA) is a test-based numerical technique allowing the diagnosis necessary to solve vibro-acoustic problems. For vehicle applications, the main purpose consists in ranking the contributions of potential sources or potential transmitting points, distributed around a cabin, and creating noise at a receiving passenger location. The classic Transfer Path Analysis (TPA), as commonly known, has one objective: giving the contributions

of the sources at the receiver points, independently of their transmission path. Using the ATPA technique, the transmission paths are quantified and ranked. This technique complements the possibilities of the classical TPA method by allowing the determination of the relative contributions of the selected structure and airborne transmission paths. Using the information extracted from the application of this theory, the mechanical component to be modified can be identified. From that point, the decision can be taken to act directly on the source or on the structural elements. This paper starts by giving a short theoretical description of the method. Then, the steps of the experimental procedure applied, the tools used, and the exploitation of the data are described based on an experimental case realized in controlled conditions. Finally, the range of application of the method and of the tools used is described based on a real case.

- *Method of measuring transmission paths.*

  F.X. Magrans, Journal of Sound and Vibration 74 (3), pp. 321-330 (1981)

Abstract

A theoretical explanation and experimental proof are presented of a method for localizing and evaluating the transmission paths of any signal in a "black box" among a set of points previously defined in it. The signal should behave linearly and the system should be able to receive external excitations separately at each of its points. Such excitations need not be the signal under study but they should be linearly related to it. Also presented are the equations that, once the transmission paths have been determined, allow the evaluation of the excitations which act on the system.

- *Definition and calculation of transmission paths within a SEA framework.*

  F.X. Magrans, *Journal of Sound and Vibration* 165 (2), pp. 277-283 (1993).

Abstract

Generally, the problem of soundproofing buildings has employed the concept that energy is transmitted along different paths from the source to the receiver. The S.E.A. systematizes the existence of acoustic and mechanical coupling in mechanical complexes. This study intends to systematize the concept of transmission paths, its numerical treatment and its classification, taking the equations of S.E.A as a reference framework.

- *Direct transference applied to the study of room acoustics.*

  F.X. Magrans, *Journal of Sound and Vibration* 96 (1), pp. 13-21 (1984).

Abstract

In a recent article Kruzins and Fricke [1] applied the method of Markov chains to represent the "random walk" of phonons inside an enclosed space and to predict stationary state acoustic pressure levels, at sufficiently high frequencies, in geometrically complex spaces. In this paper it is demonstrated that with the same initial hypothesis the exact solution can be obtained directly by using the method of direct transference. Explicit expressions for the coefficients of the solution matrix are found, their physical significance is made evident, and a simple method for calculating the solution is presented.

- *The Global Transfer Direct Transfer method applied to a finite simply supported elastic beam.*
  O. Guasch & F.X. Magrans, Journal of Sound and Vibration 276 (1-2), pp. 335-359 (2004).

Abstract

The Global Transfer Direct Transfer (GTDT) method is a two-step transmission path analysis method. It is used to analyse the signal transmission among subsystems from a general N-dimensional linear network, representing a physical model under study. In the first step, the Global Transfer Functions (GTFs) are measured and the Direct Transfer Functions (DTFs) are calculated from them. In the second step, the signal vector is measured for the network running under the desired operational conditions. It is then possible to reconstruct the signal at any subsystem from the contributions of all other subsystems plus its own external excitation. This is done by means of the previously calculated DTFs.

This paper is intended to clarify how the GTDT method works. This is done by means of an analytic study of the bending wave transmission between three points in a simply supported finite elastic beam. This problem constitutes a particular 4-dimensional example of the general N-dimensional network. Concerning the first step of the method, special emphasis is given to the relationship among the DTFs and the GTFs, as well as to elucidate the role of the DTF matrix as a connectivity matrix. As for the second step of the method, the particular case of a correlated force vector acting on the beam is addressed. It is shown how the signal at any subsystem can be reconstructed from the signals at all the other subsystems. In practical implementations this allows to identify problematic subsystems in order to perform appropriate design modifications and avoids the necessity of having to measure operational forces.

- *The role of the direct transfer function matrix as a connectivity matrix and application to the Helmholtz equation in 2D: relation to numerical methods and free field radiation example.*
  F.X. Magrans & O. Guasch, Journal of Computational Acoustics 13(2), pp.341-363 (2005).

Abstract

The Direct Transfer Function (DTF) matrix was developed in the framework of the Global Transfer Direct Transfer (GTDT) method of transmission path analysis. This method aims at solving the problem of transmission paths among subsystems from a general N-dimensional linear network, representing a vibro-acoustical model under study. The DTF matrix can be calculated from the Global Transfer Functions (GTFs), which are measurable quantities, and it is built from all the Direct Transfer Functions (DTFs) between subsystem pairs. The DTFs allow to define transmission paths by relating the signals between two network subsystems when the remaining ones become somehow blocked. In this paper, the role of the DTF matrix as a connectivity matrix is first shown by solving the Helmholtz equation in a two-dimensional grid. The results are compared with those arising from the analysis of the stencils of various numerical methods. Some finite difference and finite element methods have been considered. The connectivity role of the DTF matrix is also elucidated by means of a free field radiation example.

- *A compact formulation for conditioned spectral density function analysis by means of the LDL^H matrix factorization.*
  O. Guasch & F.X. Magrans, Journal of Sound and Vibration 277 (4-5), pp. 1082-1092 (2004).

Abstract

Several methods have been developed in the last decades to deal with the subject of TPA (Transmission Path Analysis) in noise and vibration problems. A distinction can be made between the so called one-step methods and two-step methods. The MISO method is a one-step TPA method because it only requires operational measurements among subsystems in a linear N-dimensional network. That is to say, the method allows to factorise the signal (usually acceleration, velocity or displacement in a given direction, or the acoustic pressure at a given location) at one network subsystem in terms of the signals or forces at the remaining ones, with the only use of operational measured data. This is to be compared with two-step TPA methods like the GTDT method (Global Transfer Direct Transfer) or the FTF method (Force Transfer Functions), which require to measure transfer functions in a first step, with the network stationary. Operational measurements are carried out in a second step and the previously measured transfer functions are then used to obtain the desired signal factorisations.

The basis of most TPA methods were developed in the mid 70's. Since then much work has been done in order to solve some of their numerical problems, as well as to enlarge their range of applicability. In this paper attention will be paid to the MISO method. It will be shown that the conditioned spectral density functions analysis developed to deal with partially correlated signals on a linear network corresponds in fact, to the LDL^H factorisation of the network signal cross-spectra matrix. Although this may be a known result because the MISO method dates from the 70's, the authors have not found any published proof of it. A proof is derived in this paper that might be found interesting by itself and serve as a compendium to obtain the MISO factorisations in a compact and straightforward way.

CONTROL APPLICATIONS

- *Application for measuring material acoustic properties in an impedance tube.*

  D. Castro. Customer Solution, National Instruments site. (2005).

Abstract

The two-microphone transfer function method has been implemented to find the acoustic properties of materials using an impedance tube. The application generates a broadband noise inside the tube, while it acquires the acoustic pressure at two microphones located at the tube shell. Then, the Frequency Response Function (FRF) between the two channels is computed. A mathematical procedure allows obtaining the following acoustic parameters:

1. Reflection coefficient.
2. Absorption coefficient.
3. Acoustic impedance.
4. Acoustic admittance.

Finally, all interesting process data is transferred to an Excel worksheet (via ActiveX) to be stored and to let the user generate a report.

- *Automated noise test bank for the quality control of isolation pulleys.*

  D. Castro, "Worldwide Conference on Virtual Instrumentation. National Instruments Days Fall 2002 - Spring 2003" , pp. 22-23.

Abstract

Isolation pulleys are submitted to noise tests in order to detect any manufacturing fault. The pulley real operational conditions are simulated inside an insulated cabin and the overall sound

pressure level (SPL) in dBA is measured for a one second period. A comparison with a previously selected threshold value decides whether the pulley is acceptable or not. Three parameters depending on the pulley type are fixed before carrying out each noise test:

1. Maximum allowed SPL in dBA (threshold value).
2. Pulley strap tension.
3. Pulley revolutions per minute (r.p.m.).

This paper presents an application that automatically manages the whole pulley validation process. The application controls the noise measurement equipment, the testing conditions (parameter values), the PLC (Logical Programmable Controller) communication and the data post process. The results are automatically stored in an Excel data sheet by means of ActiveX. An additional storage in a main computer is also performed using a serial port communication.

AERODYNAMIC NOISE

- *Cálculo del ruido aerodinámico generado por el flujo de aire alrededor de un cuerpo. Simulación mediante métodos estabilizados de elementos finitos.*

  O. Guasch & R. Codina, Proceedings of Métodos Computacionais em Engenharia, incorporant VIII Congresso Nacional de Mecánica Aplicada e Computacional i VI Congreso de Métodos Numéricos en Ingeniería APMTAC_SEMNI, Lisboa, Portugal (2004).

Abstract

En este artículo se presenta una metodología para realizar cálculos subsónicos de aeroacústica computacional. El método se basa en la denominada analogía acústica de Lighthill y conceptualmente consta de tres fases. En la primera se resuelven las ecuaciones de Navier-Stokes para un flujo incompresible, con el objetivo de obtener el término que actúa como fuente acústica (se usa el tensor de Reynolds como aproximación al tensor de Lighthill). En la segunda fase se transforma dicho término fuente al dominio frecuencial y, finalmente, en la tercera fase se resuelve la correspondiente ecuación inhomogénea de Helmholtz con el fin de obtener el campo de presión acústica. Todas las ecuaciones se resuelven mediante métodos estabilizados de elementos finitos. Como aplicación numérica se presenta el caso del flujo de aire alrededor de un cilindro para distintos números de Reynolds. En los casos de formación de la estela de vórtices de von Kármán se observa que las simulaciones reconstruyen sin problema el carácter dipolar del campo acústico generado.

- *Time depend subscales in the stabilized finite element approximation of incompressible flow problems*.

  Ramon Codina, Javier Principe, Oriol Guasch and Santiago Badia, Computer Methods in Applied Mechanics and Engineering. (2007)

Abstract

In this paper we analyze a stabilized finite element approximation for the incompressible Navier–Stokes equations based on the subgrid-scale concept. The essential point is that we explore the properties of the discrete formulation that results allowing the subgrid-scales to depen

depend on time. This apparently ''natural'' idea avoids several inconsistencies of previous formulations and also opens the door to generalizations.

- *An algebraic subgrid scale finite element method for the convected Helmholtz equation in two dimensions with application in aeroacoustics.*
  Oriol Guasch, Ramon Codina, CMAME_196 (45_48) pp 4672-4689,(2007)

Abstract
An algebraic subgrid scale finite element method formally equivalent to the Galerkin Least-Squares method is presented to improve the accuracy of the Galerkin finite element solution to the two-dimensional convected Helmholtz equation. A stabilizing term has been added to the discrete weak formulation containing a stabilization parameter whose value turns to be the key for the good performance of the method. An appropriate value for this parameter has been obtained by means of a dispersion analysis. As an application, we have considered the case of aerodynamic sound radiated by incompressible flow past a two-dimensional cylinder. Following Lighthill's acoustic analogy, we have used the time Fourier transform of the double divergence of the Reynolds stress tensor as a source term for the Helmholtz and convected Helmholtz equations and showed the benefits of using the subgrid scale stabilization.

- *A heuristic argument for the sole use of numerical stabilization with no physical LES modelling in the simulation of incompressible turbulent flows.*
  O. Guasch & R. Codina, Journal of Computational Physics (2007).

Abstract
We aim at giving support to the idea that no physical LES model should be used in the simulation of turbulent flows. It is heuristically shown that the rate of transfer of subgrid kinetic energy provided by the stabilization terms of the Orthogonal Subgrid Scale (OSS) finite element method is already proportional to the molecular physical dissipation rate (for an appropriate choice of the stabilization parameter). This precludes the necessity of including an extra LES physical model to achieve this behaviour and somehow justifies the purely numerical approach to solve turbulent flows. The argumentation is valid for a fine enough mesh with characteristic element size, h, so that h lies in the inertial subrange of a turbulent flow.

08

PROJECTS

ENGINEERING PROJECTS

RAILWAY

WIND POWER

CONSTRUCTION

ENVIRONMENTAL IMPACT

INDUSTRY

AUTOMOTIVE

A continuación, encontrarán algunos de los proyectos realizados por ICR en cada uno de los sectores donde trabaja.

RAILWAYS

- *Advanced Transfer Path Analysis (ATPA) of the different compontents which form the coach prototype of the new AVE OARIS model. CAF, Construcciones y Auxiliar de Ferrocarriles.*
- *Consultancy engineering services for acoustic study based on noise level reduction produced by impulsion nozzle of air conditioning units of trains. Merak.*

- *Acoustic study and protocol measurements of 4.000 (C4K) train units for NIR, North Ireland Railways. CAF, Construcciones y Auxiliar de Ferrocarriles.*

Development of a numerical model of airborne noise and acoustic prediction in order to determine future compliance with current legislations as TSI Rolling Stock-Noise 2006/66/EC, British standard and customer requirements. Protocol measurements and post-process: measurement of RASTI according to IEC60268-16 and measurements of airborne and structure-borne noise.

- *Vibrations Operational Modal Analysis (OMA) of railway bridge in Contreras. Ineco Tifsa.*

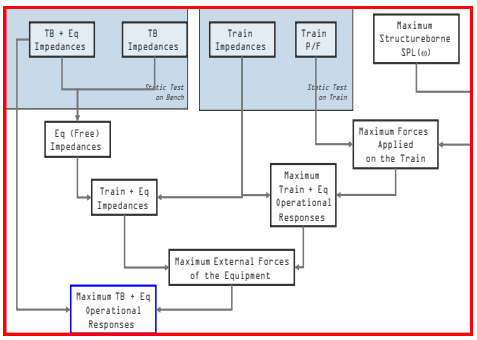
Based on the measurements made by the customer, ICR analyses the vibrations of the bridge in real operating conditions by techniques of Operation Modal Analysis, and thus get a model more valuable.

- *Consultancy engineering services ICR+ in Alstom Transport Savigliano, Italy from december 2011 to present. Alstom Transport.*

- *Consultancy engineering services in Alstom Transport Belford, France, for a 18 month period. Alstom Transport.*

- *Research project "EVS (Equipments Vibration Specification)"; design and development a new tool that specify maximum noise and vibration levels to railway equipment which are installed in the trains. Alstom Transport.*

Prediction of the structural-borne noise pressure levels within a realistic range of uncertainty. For a given maximum SPL, specify the maximum vibration levels measured under certain conditions. Based on experimental measurement (results coming from numerical models would be considered as well).



- *Acoustic study and Advanced Transfer Path Analysis (ATPA) of RENFE 251 electric locomotive for Atenasa.*

- *Advanced Transfer Path Analysis (ATPA) of the cabin of two diesel units series 333 and 334 of Vossloh. Atenasa.*

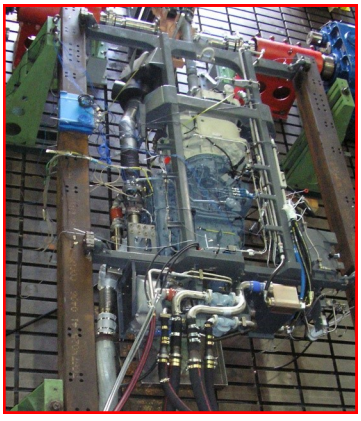
- *Complete acoustic study in the Xin Min Line train in China including ATPA (Advanced Transfer Path Analysis) of the Varsaw subway. Alstom Transport.*

- *Noise and vibration Transfer Path Analysis in a prototype high speed train (AGV). Alstom Transport.*

Static and dynamic vibro-acoustic measurements on the high-speed train, following the TPA method in order to know the contribution to the overall noise of each one of the noise sources of every element of train.

- *Experimental tests of vibration in the power motor system of diesel units carried out in the laboratory of Voith in Hamburg, Germany. CAF, Construcciones y Auxiliar de Ferrocarriles.*

Characterization of diesel power unit system vibrations for the RENFE-TDMD project units. Acceleration measurements, by measuring the operation of the tensile modulus in several conditions (in the test bench, with different configurations).



- *Definition of the acoustic and vibration specifications for the equipments from external suppliers. Project: Chennai Metro. Consultancy engineering services in Alstom Transport Sao Paulo, Brazil. Alstom Transport.*

- *Sound pressure level measurements AVR 121 train in order to fulfil noise regulationsaccording to technical specifications as defined by Renfe and European regulations (TSI). CAF, Construcciones y Auxiliar de Ferrocarriles*

- *Advanced Transfer Path Analysis (ATPA) of one unit of the suburban train CIVIA model. CAF, Construcciones y Auxiliar de Ferrocarriles.*

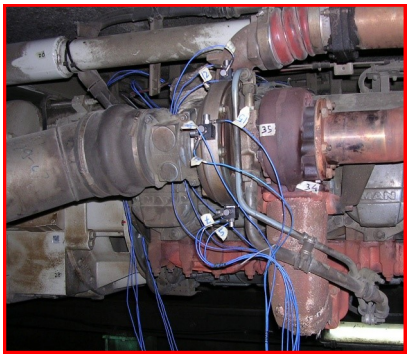
- *Complete aerodynamic acoustic study of the mid-high speed train TAV – S104 . Study of the influence of the non-stationary aerodynamic load on the noise levels inside the high speed train TAV – S104. Lanzaderas project. Alstom Transport.*

- *Study of the flow influence separation and pressure fluctuations beneath the turbulent boundary layer of the new generation high speed trains AGV (Automotrice à Grande Vitesse), France. Alstom Transport.*

Acoustic study of the aerodynamics generated by the noise and excitation of the mechanisms of the new high-speed train.
The study has three main parts: noise located in the cabin by the aerodynamic excitation of glass, noise located in the cabin caused by the ventilation system, and noise located in the passenger area behind the cabin.

- *Experimental Modal Analysis (EMA) in the power motor system of diesel units ADR. CAF, Construcciones y Auxiliar de Ferrocarriles.*

Experimental Modal Analysis in order to know the different real modes existing and take part in the movement of the assembly, which includes the support frame joined elastically with the car, the propulsion unit and the turbo-compressor unit on the engine.



Vibro-acoustic advanced design tools for the noise characterization of the train. Alstom Transport.

Development of testing techniques that define the vibro-acoustic features of the different train subsystems —interior and exterior noise when the train is non-operating.
Evaluation of the contributions to the interior noise of the different subsystem of a train in normal operating conditions.
Evaluation of the contributions to the exterior noise of the subsystems of a train in static operating conditions.

- *Noise and vibration Transfer Path Analysis of the driver's cab of the 250 -028 - 8 Renfe electric locomotive 250 -028 - 8. Atenasa.*

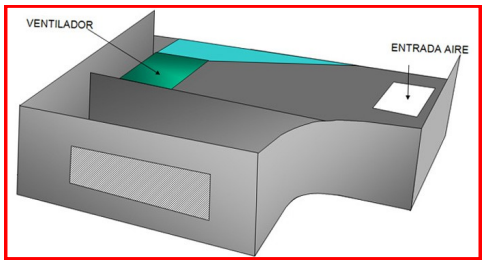
- *Noise and vibrations Advanced Transfer Path Analysis of a diesel train in South of Ireland. CAF, Construcciones y Auxiliar de Ferrocarriles.*

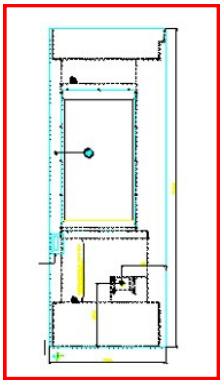
- *Complete acoustic study of the CIVIA 2.000 Train. CAF, Construcciones y Auxiliar de Ferrocarriles.*

- *Advanced Transfer Path Analysis (ATPA) and vibro-acoustic study for the West Coast Main Line Train in Asfordby, United Kingdom. Alstom Transport.*

- *Muffler design for the exit of foul air in the Rome subway and comparison of the sound insulation between two types of doors for the underground train provided by the client. CAF, Construcciones y Auxiliar de Ferrocarriles.*

Design of the elements required to reduce the noise level generated by the extraction of foul air system in a box under the base of the Rome subway.
Acoustic study of three different door designs carried out with dBKAisla ICR software to calculate multiple insulations and to compare the sound insulation of each door.





- *ATPA Technology transfer project for Alstom Transport. The following tasks were carried out for this project:*

1. Development of the testing procedures to obtain the vibro-acoustics specifications of the different subsystems of any train (for internal noise contributions).
2. Evaluation of the interior noise contributions of all train different subsystems under normal operating conditions.
3. Training: ICR trained Alstom Transport employees in the application of the ATPA procedures.

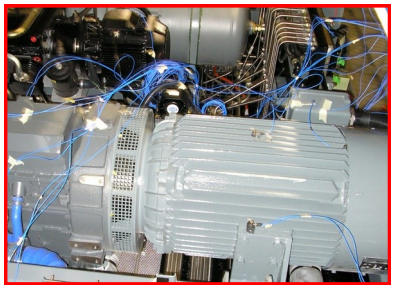
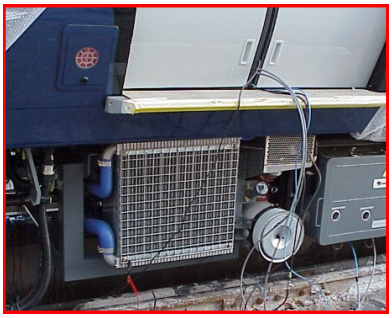
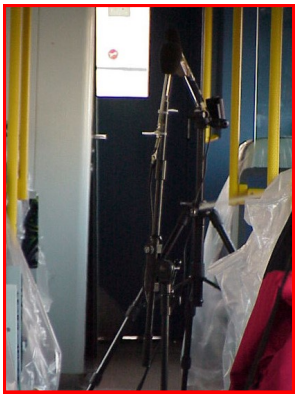
During this project, the following trains were tested:

- ATPA of the Weast Coast Main Line train in Asforby, GB.
- ATPA of the Vectus train in Salzgitter Depot, Germany.
- ATPA of the Coradia train in Salzgitter Depot, Germany.

- *Estudio de las vías de transmisión de ruido y vibraciones del motor de un tren diesel en Irlanda del Sur. CAF, Construcciones y Auxiliar de Ferrocarriles.*
- *Estudio acústico completo en una unidad del Tren CIVIA 2.000. CAF, Construcciones y Auxiliar de Ferrocarriles.*
- *Estudio acústico completo basado en un análisis de las vías de transmisión del Metro de Varsovia, Polonia. Alstom Transport.*

- *Complete acoustic study of a diesel train of Northern Ireland Railways, Ireland. Model and study of the engine coupling by experimental and theoretical methods. CAF, Construcciones y Auxiliar de Ferrocarriles.*

Acoustic study of the diesel units for N.I.R. Based on the calculation of rolling noise, the levels of noise and establishment of solutions to reduce the vibrations caused in the train by the auxiliary engine. Description of the results of the model carried out in order to evaluate the predictions of the noise pressure level inside the N.I.R. diesel trains.

- *Complete acoustic study of the Xin Min Line train. Alstom Transport.*

Vibro-acoustic tests on a similar train, including an analysis of the ways noise and the vibrations of the train are transmitted, and measurement of the equipment and components. Development of a numerical model in order to predict noise and vibrations of the new Xin Mine Line train model.
Monitoring of the first model unit manufacturing and vibro-acoustic test to check the estimated prediction and re-design of the cabin doors and intercommunicating doors of the train.

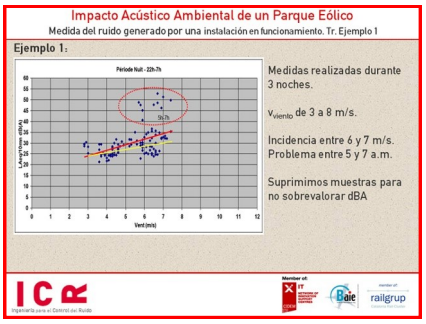


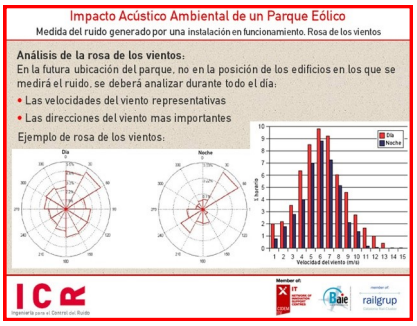
- *Determination of the rail roughness affection to the train inside noise with the train in operation. Ireland. Alstom Transport.*
- *Identification of noise and vibrations origin in the Barcelona subway. CAF, Construcciones y Auxiliar de Ferrocarriles.*
- *Acoustic study of the "floating floors" of the 8.000 Madrid subway series. CAF, Construcciones y Auxiliar de Ferrocarriles.*
- *Complete acoustic study of the new 6.000 Madrid subway series. CAF, Construcciones y Auxiliar de Ferrocarriles.*
- *Study of the contributions of every subsystems to the overall noise perceived in the driver's cab for Line 2 Barcelona subway units with the Advanced Transmission Path Analysis (Direct transference approach) method. CAF, Construcciones y Auxiliar de Ferrocarriles.*

WIND POWER

- *Full specialised course to study the environmental noise impact of a wind farm. Vestas.*

Course specially designed to client needs. The course syllabus, prepared by ICR, is based on the prediction of the acoustic impact calculation of a wind farm. It has three parts: an introduction to acoustics, an environmental noise impact study of the installation of a wind farm, and practical examples.

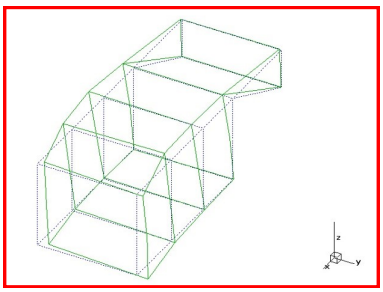


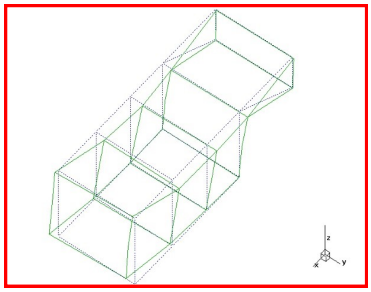


- *Engineering consultancy services to assess noise impact generated by wind turbines installed at Les Forques I wind farm. Noise measurements, noise levels estimation through acoustic software CadnaA based on ISO 9613 and proposal of acoustic barriers solutions. Gamesa Corporación Tecnológica S.A.*
- *Environmental noise impact prediction for the future operation of a wind farm in Gomera (18 MW) located in Sevilla. Gamesa, Corporación Tecnológica S.A.*
- *Experimental tests and study of the acoustic resonances present in the elastic coupling disc located between the generator and the multiplier of the ECO100 wind turbine prototype (Jaure). Alstom Ecotecnia.*
- *Experimental Modal Analysis (EMA) of the interior equipments of the ECO80 wind turbine, generator, drive train and electric cabinets. Measurements in Buñuel. Alstom Ecotecnia.*
- *Sound power measurements in ECO100 wind turbine prototype according to IEC61400 standard. Alstom Ecotecnia.*
- *Operational deflection shape (ODS) of the drive train of the prototype of the ECO 100 wind turbine. Alstom Ecotecnia.*

- *Experimental Modal Analysis (EMA) in rear frame in a wind turbine prototype. Alstom Wind.*

Determination of the frame structure vibration modes of a wind turbine and local modes of some components, using Experimental Modal Analysis (EMA) in order to compare with the modes which have been calculated and to know the frame's dynamic behaviour.





PROJECTS

- *Environmental noise impact prediction and acoustic solutions for three wind farms in operation. Gamesa, Corporación Tecnológica S.A.*

- *Noise measurement carried out in a wind turbine prototype through Modal Analysis Method (OMA) to assess the influence on overall noise of its ventilation systems. Alstom Wind.*

- *Experimental Modal Analysis (EMA) of the drive train of the prototype of the ECO100 wind turbine inside the mounted wind turbine. Measurements in the prototype in el Perelló. Alstom Wind.*

- *Sound power measurements in the ventilation system of the ECO100 wind turbine according to UNE-EN ISO 3745:2004 standard. Alstom Wind.*

- *Experimental Modal Analysis (EMA) of the ECO 80 wind turbine nacelle structure. Buñuel (Spain). Alstom Ecotecnia.*

- *ATPA (Advanced Transmission Path Analysis) of noise and vibration in a wind turbine ECO100 prototype in order to evaluate the contribution of the ventilation system to the total noise. Alstom Ecotecnia.*

- *Aeroacoustics course based on an environmental study of a wind farm. Alstom Wind.*

- *Sound power measurements in a wind turbine prototype ECO100 according to IEC 61400/11 standard. Development of an acoustic model by numerical simulation and determination of the acoustic characteristics of the wind turbine. Villavaliente (Albacete). Ecotecnia.*

- *Custom made course based on environmental acoustic impact due to the installation of a new wind farm. Gamesa Corporación Tecnológica S.A.*

- *Sound power measurements and environmental acoustic impact to a wind farm in Central America. Confidential Client.*

CONSTRUCTION

- *Control measurements in order to evaluate the vibrations produced by the insertion of containment plates to channel water in the buildings next to the works. Acsa Sorigué.*

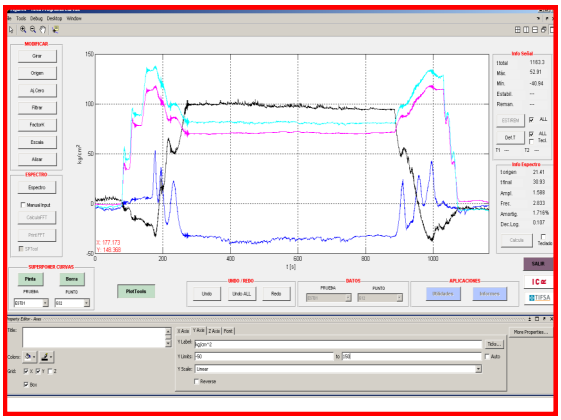
- *Vibration control mesures in the new solar termal plant located in Lebrija, for Sacyr Vallehermoso. Sacyr Vallehermoso.*

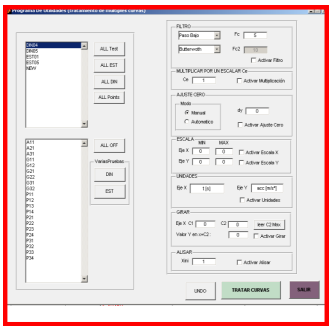
- *Monitoring and technical supervision in the Light Laboratory Synchrotron ALBA in order to control the vibrations over a slab, and the vibrations caused by a crane bridge. Master de Ingeniería S.A.*

  Evaluation of the vibrations in the construction works. Measurements with and without activity on site, vibrations analysis caused by the operation of a crane bridge and vibration levels characterization.

- *Signal processing and reporting custome made software. Ineco Tifsa.*

Frequency analysis and visualisation of bridge vibration signals software development. Main functions: synthesis and application of all kinds of digital filters, polynomial interpolations or with splines, re-randomisation of signals, conversion of data formats, management of the group of signals as a project, establishment of the main frequencies and associated damping, calculation of remaining and stabilised values, etc.
The software includes sub-programmes for mass data treatment and generation of personalised summary reports.





- *Noise and vibration measurements in the facilities of the Microelectronics Institute of Madrid in order to determine whether background levels comply the specifications of the equipment to be installed in a room. Instituto de Microelectrónica de Madrid.*

- *Vibration control for the construction of the white chamber in Nano-manufacturing unit. Contratas y Obras, Empresa Constructora S.A.*

- *Noise measurements in a parking area ventilation equipment in order to assess compliance with the environmental regulations of Barcelona (OGMAUB). And propose solutions for reduce it. Subcomunidad Propietarios Parking.*

- *Diagnosis and prediction of noise and vibrations transmission path in building - VITRASO. FCC Construcción S.A. (Development project)*

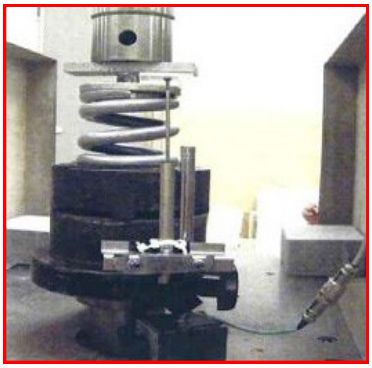
The aim of Vitraso project is the detection of the path transmission of harmful noise and vibration in a building, as well as a new design and its implementation in order to void these paths. From the method of Transmission Paths Analysis (TPA) it is possible to detect the paths with to better contribution and so it be facilitated localized intervention in the elements that conform them. The results obtained by these methods it will be compared with experimental tests and numerical simulations carried out. Furthermore, the contribution of different transmission paths will allow to evaluate the prediction limits according to the standard UNE EN ISO 12354.

- *Vibration study on the ground of the Borges Solar Thermal Plant, property of Abantia and Comsa Emte. Comsa Emte.*

Elaboration of vibrational predictive model through finit elements (FEM) for determining the vibrational level on the turbine of the plant caused by the rail circulation.

- *Vibration and noise prediction study for the project of the Light Laboratory Synchrotron ALBA in Cerdanyola del Vallès, Barcelona. Master de Ingeniería S.A.*

Vibration measurements, vibration prediction on critical area, vibrations insulation calculations of this critical area, acoustic analysis of machinery and the facilities, noise and vibration control of auxiliary equipments, vibrations predictions caused by a crane bridge and insulation calculation of slab.



- *Soil vibration characterisation for the future installation of a nano-manufacturing centre for the Centro Nacional de Microelectrónica in the UAB-Bellaterra Campus. Design consultancy to fulfil vibration criteria. CSIC-CNM y Master de Ingeniería, S.A.*

Assessment of the current charges to quantify the insulators methods necessaries and quantify the limits allowable of exterior disturbance. Execution floating slab monitorization built in the works.

- *Environmental noise impact study for INITEC ENERGIA. Consultancy services for the design of a 450 MW combined cycle thermal plant for Endesa in Ireland. Initec Energia.*

- *Acoustic study for the construction of the Thermal Centre Prestige Jafre in Jafre del Ter, Girona. Bovis Lend Lease - Grupo Prestige.*

- *Acoustic study of Cetoss — Querétaro. Building in México. Rheinold & Mahla S.A.*

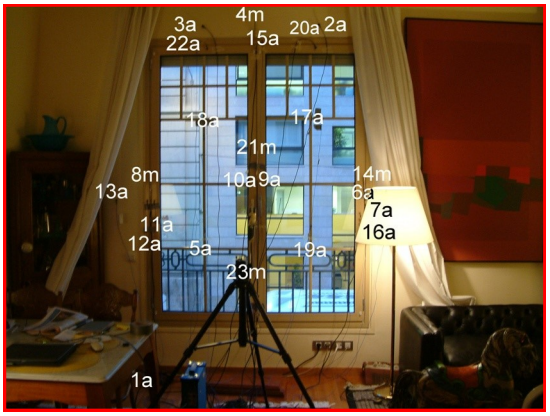
- *Acoustic conditioning project of Centre d'Art Santa Mònica in Barcelona. Generalitat de Catalunya.*

- *Vibration impact preliminary report of works in Gas Natural Headquarter in Barcelona. Gas Natural S.A.*

- *Sound pressure level measurements in Bikini discotheque in Barcelona. Sala bikini.*

- *Transmission paths analysis from exterior to interior through windows in a Hotel of Barcelona. Hotels Rosincs.*

Measurements in two windows of the building to determine the noise transmission from outside the building inside through the windows.



- *Acoustic behaviour assessment for the new office building of CIBA GEIGY in Barcelona. Master Ingeniería y Arquitectura S.A.*

- *Acoustic behaviour assessment for the water treatment plant PEMBROKE R.O. in Malta. Bureau-Veritas, Touluse.*

- *Vibro-acoustic consultancy services for Diagonal Mar shopping center in Barcelona (89.000 m^2). Diagonal Mar S.A.*

- *Vibration levels prediction at the IBM Data Processing Center in San Fernando due to the partial demolition and amplification works. Master de Ingeniería y Arquitectura S.A.*

Determination of the vibration levels that will produce the future extension work of the IBM Data Processing Centre San Fernando—Madrid. Acceleration measurements to obtain the direct vibration transfer between different subsystems of one specific sector of the centre.
Development of building model through Finite Elements (FEM) for the calculation of vibration transfer between sectors that are further away from the building and development of study for the low frequency range analysis. Vibration measurements caused by a hammer-robot to calculate the vibration level predictable in two areas of the building.

- *Vibration analysis of unknown origin in a building in Bordeaux, France. Aplplication of self-developed vibrography method: graphical localization of vibration sources. Bureau-Veritas in Toulouse, France.*

Development of a prior treatment of the temporary signal in order to obtain a cross-correlation between the pairs of accelerometers with enough information. Determination of noise sources position in order of importance from a visual image.

ENVIRONMENTAL IMPACT

- *Custom made course on basic acoustics at MB'92 shipyard repair and maintenance of yachts Marina Barcelona 92.*

- *Noise impact study of the shipyard repair and maintenance of yachts MB92, located in the port of Barcelona.*

Noise measurements at different noise sources and different work situations for power acoustic characterization. Afterwards, definition of a numerical model able to adapt at the variability of the different work situations identified at MB92 and to define solutions according to client's necessities in every moment.

- *Nocturnal vibration measurements of the activity produced by a tunnel drilling boring machine in section 4 of the new line 9 of subway of Barcelona. Entorn S.A.*

- *Vibration measurements in two sections located in section 2 of new line 9 Barcelona subway works subway according local, regional and statal standards. Ute Gorg.*

- *Acoustic measurement of external environment on works of the Line 9 Train of Barcelona Subway according to regulation . UTE Arquitectura.*

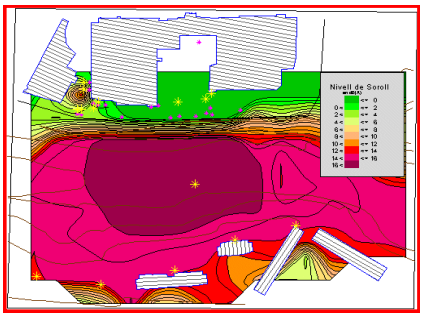
- *Development of the noise map of the council of Bezana, Asturias. Insotec.*

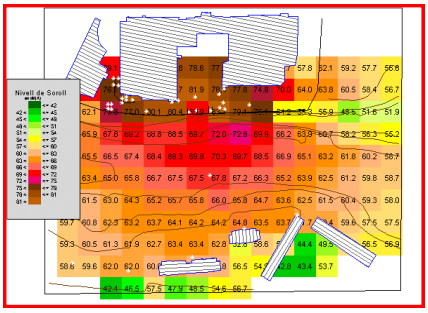
- *Control and monitoring of vibrations produced by the AVE works in the section between Sagrera and Nus Trinitat in Barcelona. Acciona infraestructuras.*

Vibration levels control in the works of the high-speed train AVE for 36 months according to current standards and weekly and quarterly report of problems during the control period. .

- *Environmental impact study of the Funosa foundry in Odena and proposal of aocoustic solutions. Funosa.*

Noise impact study in the factory surrounding area according to Department of environment regulations for the future practical application by Igualada town hall.
Sound power evaluation of each noise source in order to design optimal acoustic solutions to reduce the level of sound pressure on the reception points.





- *Sound pressure level measurements according with current regulations in new residential zone located in Villalba Saserra - between Barcelona and Granollers. Barcelona Granollers Edificis S.L.*

- *Noise impact produced by the operation of the C-31 near Mas Mortera house in Mont-Ras (Girona) and modeling with Cadna. Auding Intraesa.*

- *External noise measurements in the air conditioning unit of a hospital in Barcelona. Clinica IVI.*

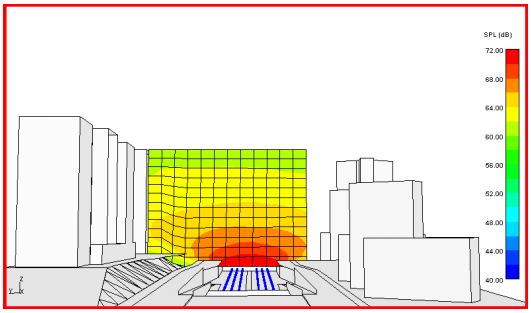
- *Environmental acoustic impact study produced by the Levante AVE rail and proposal of solutions. Ineco Tifsa.*

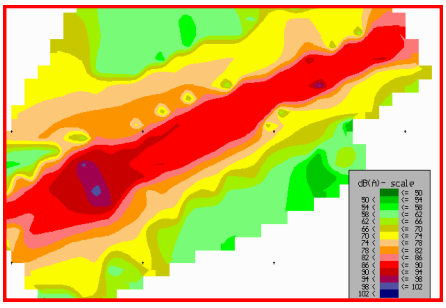
- *Environmental acoustic impact study of the discotheque "Café Mambo" in Eivissa. Café Mambo.*

- *ZIMA-041189-ES project with Adjudication nº 041190. Vibration measurements of the subsoil and prediction of environmental impact though model of vibration propagation in terms of distance (calculations to predict the environmental impact of vibrations caused by the construction of airport Montflorite). Ineco Tifsa.*

- *Environmental noise impact study caused by road traffic in a stretch (Canyelles industrial estate) of Ronda de Dalt in Barcelona. Optimisation of new solutions. Europroject.*

Study to reduce noise levels caused by traffic in a stretch of Ronda de Dalt, approximately 300 metres long. Stages of the study: noise diagnosis, creation of an acoustic model and proposal of solutions for sound barriers.

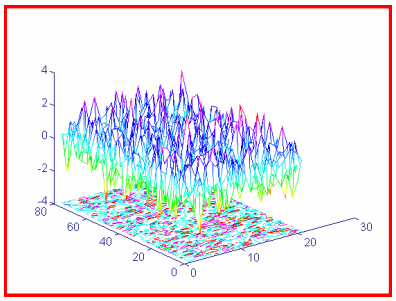


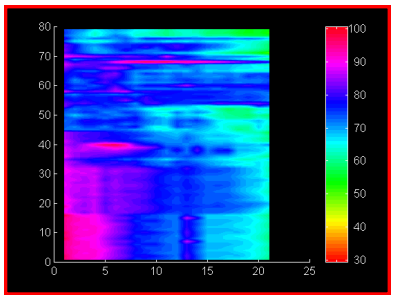


- *Consultancy engineering services ICR+ in Alstom Transport Savigliano, Italy from december 2011 to present. Alstom Transport.*
- *Consultancy engineering services in Alstom Transport Belford, France, for a 18 month period. Alstom Transport.*
- *Advanced Transfer Path Analysis (ATPA) of the cabin of two diesel units series 333 and 334 of Vossloh. Atenasa.*
- *Acoustic study and Advanced Transfer Path Analysis (ATPA) of RENFE 251 electric locomotive for Atenasa.*
- *Complete acoustic study in the Xin Min Line train in China including ATPA (Advanced Transfer Path Analysis) of the Varsaw subway. Alstom Transport.*
- *Definition of the acoustic and vibration specifications for the equipments from external suppliers. Project: Chennai Metro. Consultancy engineering services in Alstom Transport Sao Paulo, Brazil. Alstom Transport.*
- *Sound pressure level measurements AVR 121 train in order to fulfil noise regulationsaccording to technical specifications as defined by Renfe and European regulations (TSI). CAF, Construcciones y Auxiliar de Ferrocarriles.*

- *Model inversion method to the AGA factory-Toulouse (Portet sur Garonne) , France, in order to determine the contributions of acoustic sources to various external control points and neighbours. The study was performed while the factory was in full operation. Bureau Veritas.*

Measurements of the sound pressure level in the factory surrounding area and in the most affected areas. Model inversion method to determine the sound power of the exterior noise emitters in the AGA production plant in Toulouse.





INDUSTRY

- *Acoustic consultancy for the project design of new audiovisual security control centres . LOOP Business Innovation.*

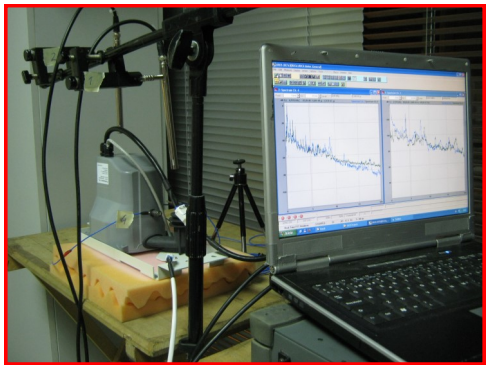
Acoustic study to define a sound emitter system that guarantees optimal listening conditions that do not bother people in the surrounding area. ICR analysed the current system by characterising the system's emission features in terms of directivity: frequency response, and consequently, defining and evaluating intelligibility indicators adapted to the application

- *Study and categorization of noise potential sources in the client's facilities. Confidential client.*

Acoustic measurements while the factory is running, separation of sources through own theoretical methods, development of computerized acoustic model in order to be able repeat the real situation and the modified situation. Proposing solutions, specification of materials and testing for final installation.

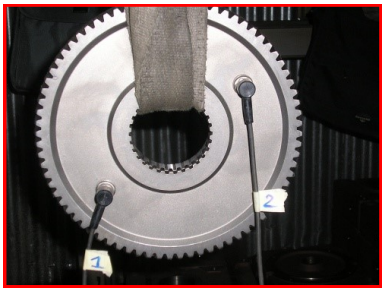
- *Study and acoustic assesment in the desing stage of a new blower of Roca, manufacturer of toilets. Roca.*

ICR has asseset the client during all the desing stage with the proposal of acoustic improvements and alternative prototypes. The goal has been conditioning the motor in order to reduce the noise emitted and the anonying sounds.



- *Vibration characterization of a crane. Industrias Electromecánicas GH.*

Transmission Path Analysis in one of the pulley equipments made by Industrias Electromecánicas GH in order to quantify each one of the noise and vibration sources that compose it. So that, it is possible to determine optimal processing to reduce of noise level generated by the whole assembly. A posteriori, proposing modifications to reduce noise.



- *Absorption coefficient (alpha energy) measurements of different materials with Kundt tube. Texa.*

Noise characterisation (acoustic impedance and absorption ratio) of different materials from the company Texsa S.A., based on the UNE-EN ISO 10534–2 specifications for measurements with a Kundt tube according to the transfer function method.

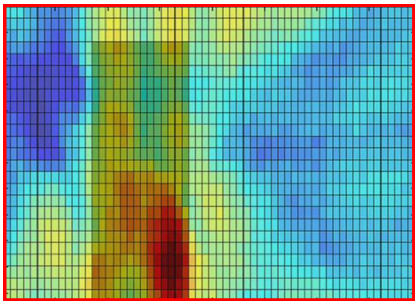
- *Assessment of potential noise impact, both internal and external facilities in Ashland. Ashland Chemical Hispania S.I.*

- *Study of the vibratory behaviour of a machine-tool for Recman. Applus.*

- *Study of the dynamic behaviour of the production plant floor, PURAC Bioquímica, induced by the product elevator machinery. Proposal and calculations of the necessary modifications to correct this behaviour. Technip Coflexip & Purac Bioquímica.*

- *Noise emission study of elevator automatic doors. Selcom Aragón.*

Acoustic measurements and study of noise and vibration transmission paths with TPA method on an automatic door of elevator in order to determine the origin of noise. Propose of solutions to reduce overall noise.



AUTOMOTIVE

- *Interior noise reduction for an hybrid bus . Castrosua.*

Vibration levels measurements above the pump and its supports on the vehicle exterior as well as acoustic pressure measurements at various points in both interior and exterior. This allowed diagnosing the causes of the noise transmission from its origin to its final receiver point. Proposal of the optimal solutions for improving the bus acoustic quality.

- *Acoustic study in order to characterize a reverberation chamber. Ficosa.*

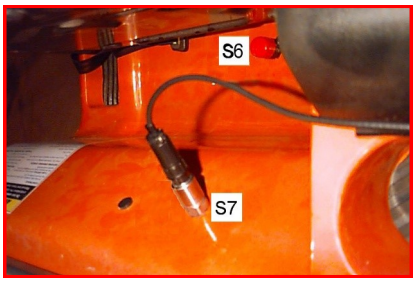
- *Study of the contribution of each one of the noise sources in the external points of CH-350 vehicle AUSA to overall noise and proposal of solutions. AUSA, Automóviles Utilitarios S.A.*

- *Reduction of the noise levels generated by one of trailers carrying freight containers in Sant Boi de Llobregat, Barcelona. Llinás e Hijos S.I.*

Measurements of noise emitted by the trailer carrying both the empty container and full container and operating at different appropriate distances. Propose solutions for reduce this noise level.

- *Advanced Transmission Path analysis of noise and vibration sources in the driver's cab and in external control point. AUSA, Automóviles Utilitarios, S.A.*

Evaluation of the contributions of the different subsystems of the model CH-150 to the noise received in the driver's position and in an exterior spot, with the aim of establishing the modifications that the vehicle needs in order to reduce the sound pressure level received in both points.
Measurements with the vehicle stopped, following the TPA methodology, in order to know how much noise comes directly from the holes and how much comes from the structure vibration.



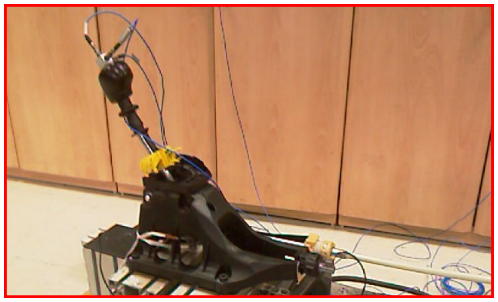
- *Characterisation of the engine following the mobility method and source descriptor. Vibration power injected in the bodywork. AUSA, Automóviles Utilitarios S.A.*

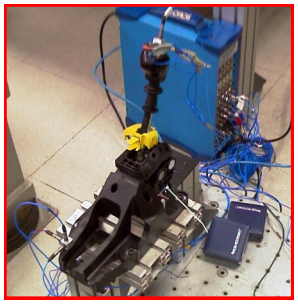
Determination of the vibration power transmitted from the engine to the bodywork of the vehicle CH-150 by AUSA, through the different points of attachment.
Evaluation of the power transmitted by the main engine-bodywork points of attachment, using the Mobility and Source Descriptor Method, which enables us to find a solution to reduce the current vibration level.

- *Acoustic solutions design for the final check cabins at the VW factory in Pamplona, Iruña. Volskwagen.*

- *Complete vibro-acoustic study of car gear changes (characterization, numerical modelling and design solutions). Ficosa.*

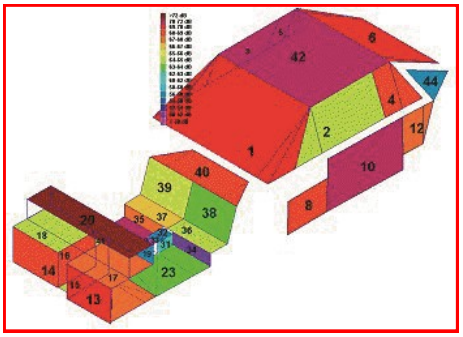
Development of a computer application in Matlab language to calculate for the characterisation of the gear changes and representation of the results obtained.
Full characterisation of a gear changing system that establishes the required modifications to achieve the vibroacoustic requirements that the client establishes for these mechanisms.

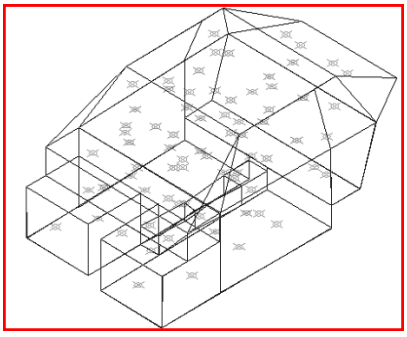




- *Development of an Inversion Modelling Method to determine the panel contributions to the Ferrari 456 cabin noise at the mid-high frequency range. Ferrari.*

Sound pressure measurements of the Ferrari 456 model. Application of the model inversion methodology with the aim of obteining the noise level of each of the interior surfaces and proposal of acoustical solutions.





R&D PROJECTS

PUBLIC FUNDED PROJECTS

PRIVATE FUNDED PROJECTS

- *Public funded projects*

1-"ECO-PLAK: Phase 1"
Project CIDEM of the Generalitat de Catalunya
Duration: 1996-1997

2-"Portable Sound Imaging"
Project ESPRIT of the European Community
Ref: ESPRIT 21 040
Duration: 1995-1998

3-"STBM: Tunnel Boring Machines"
Project BRITE of the European Community
Ref: BRITE BE95-1735
Duration: 1995-1998

4-"ECO-PLAK: Phase 2"
Project CIDEM of the Generalitat de Catalunya
Duration: 1999-2000

5-"PAASC: Transmission Loss software for complex enclosures"
Project CIDEM of the Generalitat de Catalunya
Duration: 2000-2001

6- "Noise reduction in railways using advanced experimental methods. Phase 1."
Project PROFIT of the Ministerio de Ciencia y Tecnología
Ref: FIT-020300-2002-24
Duration: 2001-2002

7- "Noise reduction in railways using advanced experimental methods. Phase 2."
Project PROFIT of the Ministerio de Ciencia y Tecnología
Ref: FIT-020300-2002-24
Duration: 2002-2003

8- "MACIM: computational aeroacoustics models to reduce the environmental noise generated by vehicles aerodynamic noise."
Project P4 of the Ministerio de Ciencia y Tecnología
Ref: DPI2000-0431-P4-03
Duration: 2001-2004

9- "AEROSIVE: interior noise prediction due to unsteady aerodynamic loading on vehicles: airplanes and high-speed trains."
Project CIDEM of the Generalitat de Catalunya
Ref: RDITCRD04-0074
Duration: 2004

10- "Metallic Acoustic Materials."
Project CIDEM of the Generalitat de Catalunya
Ref: RDITCRD05-1-0010
Duration: 2005

– "FOTACU: Development of acoustic photography technology"
Project CIDEM of the Generalitat de Catalunya"
Ref: RDITSIND06-1-0211
Duration: 2006-2007

- *Private funded projects*

1-"Cabin noise reconstruction at the mid-high frequency range"
Company: Ferrari Auto (Italy)
Duration: 1998

2-"META X: Advanced vibro-acoustic analysis in railways. The GTDT method"
Company: Alstom Transport (France)
Duration: 2001-2004

3-"ORNVS-ATPA: OROS NVGate Solution-Advanced Transfer Path Analysis"
Company: OROS (France)
Duration: 2003-2005

4-"Acoustic Blockage Detection Project"
Company: ENI Tecnologie (Italy)
Duration: 2003-2004

5-"META W: Advanced vibro-acoustic analysis in railways. New technologies and computing methods."
Company: Alstom Transport (France)
Duration: 2004-2005

6- "META W: Advanced vibro-acoustic analysis in railways. New technologies and computing methods. Fase I."
Company: Alstom Transport (France)
Duration: 2005-2006

7-"EVS: Equipments Vibration Specification": design and development a new tool that specify maximum noise and vibration levels to railway equipment which are installed in the train.
Company: Alstom Transport (France)
Duration: 2010-2012

8- "Research project Vitraso: Prediction of noise and vibration transmission path in buildings."
Company: Fomento de Construcciones y Contratas (Spain)
Duration: 2010-2012

9- Research project "Invent for the Operational Modal Analysis (OMA)": determination of the own wind turbine modes automatically from noise measurements with the wind turbine in operation. Tailored made software.

ICR

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