C-Valor – A Vibro-Acoustic Software Validation Tool

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In the early 1990s, a commission known as C-Valor was formed by the French Society of Acoustics (SFA) and the French Society of Mechanics (SFM), whose task was to establish a benchmarking tool that would allow the users of vibro-acoustic software to validate the results of their computations. But why would such a tool be necessary? Today, one can observe that, in addition to many "home-made" vibro-acoustic codes developed in universities, scientific institutes, etc., a variety of such software is available in the market. These codes feature complex methods requiring highly sophisticated numerical algorithms. But often the application domains of these methods do not overlap and their degree of accuracy is unclear. In many cases the implemented methods are not properly referenced.

The specifics of a method, regarding the meshing style, convergence criteria, mechanical or acoustic boundary conditions modelling, sound source modelling, etc., are usually obvious to the developer. However, it is extremely difficult for an engineer, who must undertake vibro-acoustic computations, to make a proper choice of software and to validate the initial results. For years, no reference has been available to vibro-acoustic software users, as it is the case for finite element codes for the analysis of mechanical structures or for experimental modal analysis software. This is the main reason that C-Valor was established.

Thirteen scientific centers (universities, institutes, companies) participated in the realization of the tasks defined by the commission. From 2000 to 2005, the Machinery Noise Reduction Laboratory of the INRS (French National Research Institute for Occupational Safety and Health) coordinated the commission's activities. As the facilitator, the INRS had to define and distribute tasks among the partners, generate strong motivation for their voluntarily based engagement, pursue permanent organizational contacts, organize periodic meetings to refine the lines of activity, fine tune the definitions of input parameters and generate coherent results.

The results of the these scientific efforts have been compiled in an interactive CD-ROM available to all institutions involved in vibro-acoustic computations.

Test Structures and Input/Output Parameters. The reference data to be used in the benchmarking tool were to be obtained through various computation approaches as well as experiments. The commission put a particular emphasis on the choice of test cases that could pinpoint eventual pitfalls in the computation methods and on the defining, without ambiguity, all calculation parameters. For future users of the reference tool, it was necessary to select structures that would be easy to model and analyze. Furthermore, all the material, physical and geometrical parameters were to be meticulously specified so that the user could build identical models.

The following structures were defined to satisfy the above criteria and were adopted for reference computations and/or measurements (see Figure 1):

- Simple steel plates, simply supported at all the edges (computation only)
- Simple steel plates, simply supported at all the edges, coupled to one or two cavities with slightly absorbing walls (computation only)
- Multilayer plates clamped at all the edges (computation and test)
- Enclosure with an opening (computation and test),
- Simple vehicle cabin model (computation and test)

Furthermore, three types of excitations were chosen: mechanical (point force), acoustic monopole and diffuse sound field. All the physical and geometrical characteristics of the sources were carefully specified.

Also, to achieve the utmost homogeneity in the computations carried out by various partners, particular care was taken to define the output data in the most precise manner. The selected entities were: mechanical and acoustical energy (in case of structures excited by point force), radiated sound power, sound reduction index, mean square velocity, sound pressure at defined reference points and radiation coefficient.

Computational Methods. A large number of methods and codes were implemented. For simple plate models, apart from the classical finite-element (FEM) and boundary-element (BEM) methods used by the majority of the contributors, a novel analytical method[1] developed by the CSTB as well as source image and ray tracing approaches were implemented. Free-field technologies (FFT) employed an IEM (infinite-element method) rather than BEM.

In the case of multilayer plates, computations by the ENTPE were based on the method suggested by Attala *et al.*,[2] while LISMMAs referred to the Biot and Allard theory.[3]

Modelling and computations of the simple enclosure with an opening were undertaken by the INRS, adopting two different approaches. One modelled the enclosure with coupled fluid and structure, for which the integral equation method was implemented.[4] The other approach considered the enclosure as an uncoupled structure. For such a model, a different tool developed by the INRS and based on the Helmholtz-equation solution was used.[5]

Regarding the raw vehicle cabin computations, a method devised by the INRS and based on monopole distribution modelling was applied.[6] This is not an exact solution but is precise enough for comparison purposes.

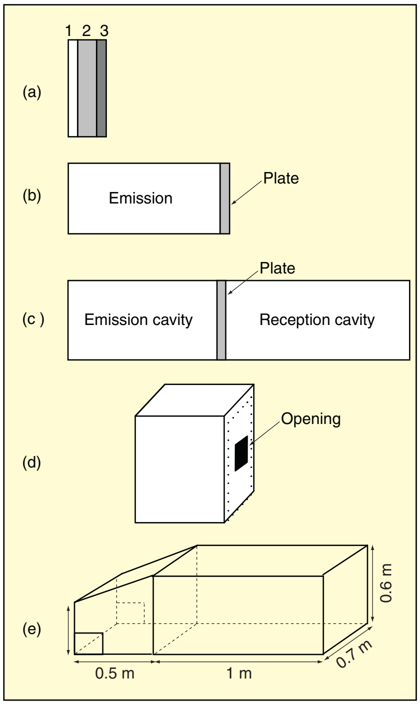

Figure 1. (a) Multilayer plate (first layer, steel; second, felt; third: visco-elastic); (b) Steel plate and single cavity for emission; (c) Steel plate and double cavities for emission and reception; (d) Enclosure with opening; (e) Simple vehicle cabin model.

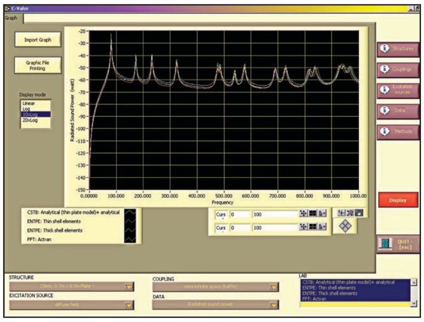

Figure 2: Typical CD-Valor display.

CD-Valor CD-ROM. All the measurement results were compiled in a database to be used by an interface called CD-Valor. It enables the vibro-acoustic software users to consult the benchmarking data, export the graphics and import their own data for comparison (see Figure 2) As its name suggests, CD-Valor and the associated database are presented as an interactive, bilingual (English/French) single CD-ROM that can be obtained from the INRS.

CD-Valor is a valuable aide to both users and developers. The data compiled help to qualify the result of vibro-acoustic codes by computing the same elementary structures defined in this tool. In certain cases, the data calculated through various codes do not strictly match (mainly at high frequencies, and due to incoherent acoustic mode computations among various solvers, nonidentical analysis of the sound fields inside cavities, nonidentical modelling of the excitation sources, etc.). These data can nevertheless, pinpoint computational and even modelling errors by the average user of vibro-acoustics software. Generally we assume that the provided data prescribe limits within which an acceptable result would lie.

Future of C-Valor. The list of the test cases defined by the C-Valor commission is obviously nonexhaustive, and other cases are to be considered. The designers and users of vibro-acoustic software have a common interest to avail themselves of the richest possible repertoire of test cases. While designers will be able to assess the validity of their software in a variety of reference cases, users can acquire a better understanding of the model setup and good assurance of measured results.

After several years of leading the C-Valor program, INRS has now reached the term of its mandate. However, it's important for industrial and scientific communities that this program continue and explore new horizons – to define new structures to analyze, to gather results already available from other organizations, to attract more partners and to expand its activities to an international scale. Therefore, this article is not only a call for new contributors, but also a message to the scientific and industrial communities and personalities to volunteer for leadership tasks within C-Valor. Those interested should contact the author, who will convey the requests to the EAA (European Acoustical Association). The author would also be pleased to provide more information on CD-Valor or related topics.

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For additional information or to purchase a copy of the CD-ROM, please contact the author at: armand.nejade@inrs.fr.