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CAE METHODS IN AUTOMOTIVE INDUSTRY: OVERVIEW OF THE STAKES AND PROSPECTS

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ABSTRACT
The reduction of time-to-market and number of prototypes has increased the integration of CAE methodologies in the automotive industry. But, the environment is still moving and new progresses are to be made. In particular there is a need for fully predictive methodologies in the next future, which is a severe challenge to meet. This paper presents the state of the art for the main acoustic performances, pointing out hard points and most promising perspectives. Then, we briefly present the organization that Renault has settled to meet these challenges.

1 - CONTEXT AND STAKES

Computer aided engineering methods (CAE) are now widely used for acoustics by car manufacturers. They were introduced in a context of:

- improvement of acoustic performance inside the car
- reduction of acoustic emissions during by-pass noise procedure
- reduction of the weight of the car
- reduction of the engineering costs and the number of prototypes
- reduction of the time to market, from about 5 years to about 3 years.

This lead to a development process based on a combination of CAE and CAT (Computer aided testing) methods. CAT methods mean numerical processing of experimental data. This process is well described in reference [1], the 2 figures hereafter are extracted from:
The softwares, either internal or commercial, are to be fully compatible with a structure dynamics code (usually NASTRAN) and a CAD code (mainly CATIA for car manufacturers) in order to be effectively included in the general design process of a car. Updating the models thanks to experimental data still plays a major role.
But now the environment is still moving. Time to market is to be reduced to 2 years, all prototypes before the industrial phase are canceled. The main points of acoustic comfort are no more only the levels, but also the variability and the quality of the sound. The application of fast optimization and updating techniques are not enough. Therefore, there is a strong need for fully predictive methodologies in order to build, as soon as possible in the project, a virtual prototype. In this context, the question is not only the development of further new methods or sophisticated softwares but also their integration in the process (in particular, available results in time and not after the battle). Otherwise, the risk is a separation between the Research Divisions with highly sophisticated methodologies and the Design and Development Divisions with little time and asking for "ready-made" methodologies. Computing methodologies can be split into 3 categories:

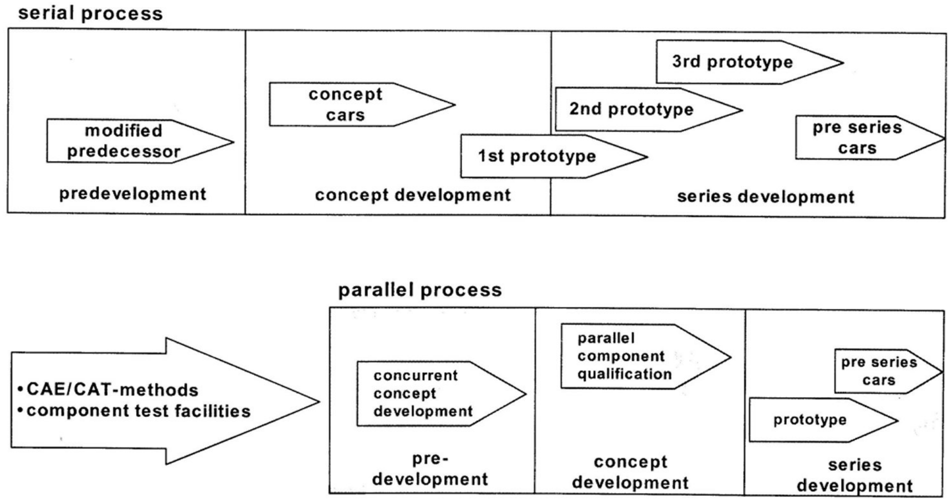

Figure 1: Example of acoustic development process (ref. [1]).

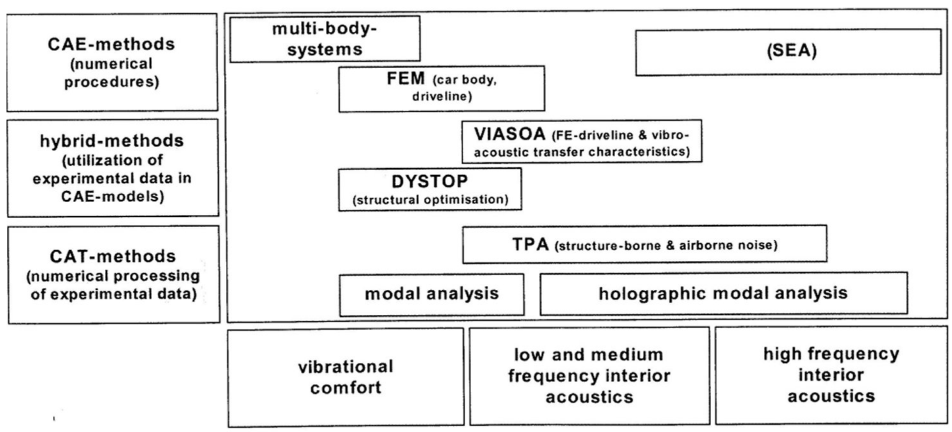

Figure 2: Example of tools used at BMW (ref. [2]).

- updated and hybrids models, which are currently used for new development projects as seen before. They allow a better understanding of the physic phenomena and a better efficiency of the testing and the refinement,
- fully predictive methodologies, for the whole car or for a component (powertrain, suspension, body in white or trim body, ...). The discussion hereafter will point out the difficulties to be overcome in order to reach the objective,
- concept modeling tools, to be used in the very early phase of a development project. The objective is to compare very quickly 2 or more concepts of solutions or to cascade the acoustic targets between all the components of the car. These tools need very few technology (sometimes a simple pocket calculator) but very much knowledge. They are developed directly by car manufacturers and will not be discussed here.

2 - STATE OF THE ART

We put the emphasis on the transfer path as sources can be experimentally evaluated on mule, bench tests or through inverse methodologies independently on the development of the new car. By sources, we mean powertrain, tires, inlet mouth, exhaust line, ...

2.1 - Booming noise

The main point is to predict the noise transfer function of the body in white. One first question concerns the accuracy of the result, taking into account the variability of the experimental results: about 5 % on the eigen values, global or local MAC (Modal Assurance Criterion) of about 0.7 between 2 cars.

The main difficulties are the modelisation of welding points, damping materials (damping layers, windshield, seals, ...), doors, internal fittings. Sub-structuring is a major point: first to reduce the number of degree of freedom and the size of the model, but also to allow parallel processing with the suppliers. The key of success relies on the division of the car into elementary components, a predictive model for each of them can be validated. The level of updating reveals usually our level of ignorance of the physical phenomena.

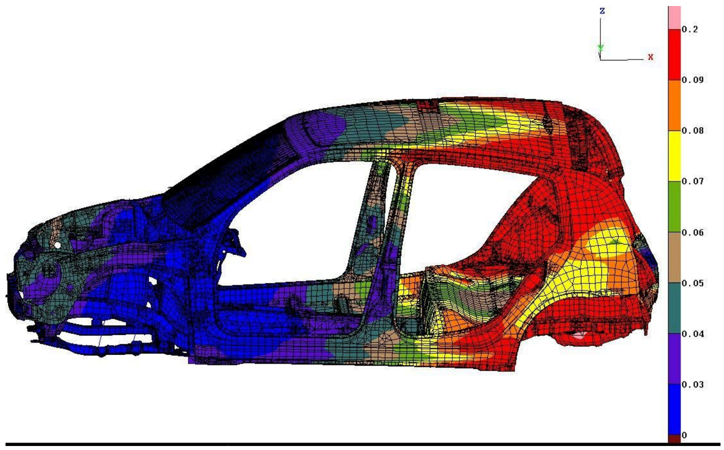

Figure 3: Torsional mode of the Renault Clio II.

2.2 - Middle and high frequencies powertrain noise

Predictive models are difficult, not only because of modal density, size of finite element models, non linearities, frequency dependent parameters, ... but also because of the lack of correct experimental procedures. Two methodologies are investigated by car manufacturers:

- ray-tracing methods are very promising but rely on the appropriate modelisation of sources
- so far, **SEA** (Statistical Energy Analysis) has always been a tricky tool, dedicated to specialists and offered rather poor and restrictive modeling procedures. But now, the last generation of predictive SEA softwares provides a wide range of analytical models, and much more user-friendly modeling procedures. These tools are mature enough to be used for transparency calculation of local car subsets and panels, and avoid transparency tests. However, no model is still available for complex assemblies such as weld points and these tools can still not be used for the calculation of structure borne noise. But work is on progress on a procedure of calculation of Structural Coupling Loss factors from local FE models.

2.3 - Road noise

The main problems concern the modelisation of the strut, the joints (non linearities) and the coupling between the suspensions and the body. Moreover, solid-borne noise can be present up to 600 Hz, which implies the modelisation of the body in white in this frequency range.

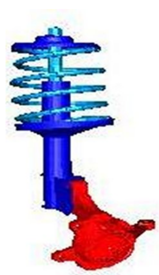

Figure 4: Strut of the Renault Clio II.

2.4 - Aerodynamic noise

The transfer function is the same as for middle and high frequency powertrain noise, with a special attention to doors and glasses. Concerning the excitation, CAA (Computational AeroAcoustics) is much dependent on CFD (Computational Fluid Dynamics). What should be predicted is the wall pressure fluctuations. Car manufacturers are spending much time on collecting appropriate experimental data and use semi-empirical models (like Corcos) adapted to the specific flow around a car. LES (Large Eddy Simulation) techniques are still considered as research techniques.

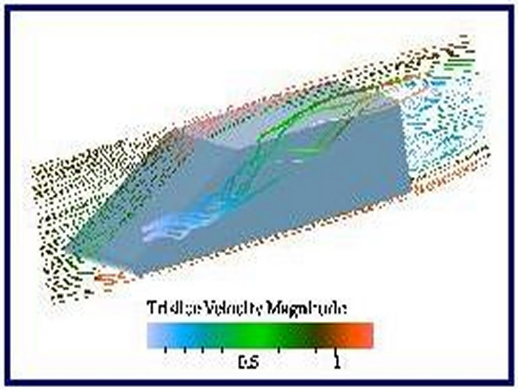

Figure 5: CFD simulation on simplified geometry.

3 - FUTURE METHODOLOGIES

This part of the paper tries to point out the most promising methodologies in a short future, which will be included in the development process of car manufacturers.

3.1 - Low frequencies

- modal based or FRF based sub-structuring, including the coupling between fluid and structure
- adaptive meshes
- time domain BEM (Boundary Element Method), using delayed potential as for electromagnetism
- stochastic FEM (Finite Element Method) and more precisely perturbative methods which are a post-processing of classical FEM

3.2 - Middle and high frequencies

- mix-methodology combining ray-tracing (for the computation of the Green function) and BEM
- spectral FEM
- energetic models less restrictive than SEA, based on condensed FEM models for each subsystem

4 - THE VENUS PROJECT

To accelerate the diffusion of CAE methodologies and to meet the challenge described above, Renault has settled the VENUS ("Vehicule Numerique Silencieux") project in order:

- to provide fully predictive methodologies of modelisation to experts working on acoustical tuning
- to integrate in real time these methodologies in the vehicle development process
- to provide pre and post-processing tools (optimization, database, variability estimation, target cascading ...)

The project has a leader, a steering committee, working groups for the different topics, quality, time limit and financial objectives and indicators. Some suppliers are fully integrated. People of different businesses (research, design and engineering, software, acoustic refinement, ...) are located in the same place during the project.
Even if numerical techniques and virtual car will become a reality within 2 to 5 years, it shall be noticed that there is no improvement without high quality testing, without a perfect understanding of physical

phenomena. Numerical topics, CPU time and storage size are of second order. There is no efficient software without efficient engineers.
As a conclusion, the introduction of acoustic computational methodologies in the design process is not a purely computational or numerical problem but one has also to tackle with physics, modelisation, organization and trainings. All these topics are strongly linked together.

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