



HAL
open science

ProSPADD: a guiding tool to optimise and attenuate the vibro-acoustic response of structures

Vincent Manet

► **To cite this version:**

Vincent Manet. ProSPADD: a guiding tool to optimise and attenuate the vibro-acoustic response of structures. 6th international scientific conference Saterra 2004, Nov 2004, Mitweida, Germany. pp.30-33. hal-00659221

HAL Id: hal-00659221

<https://hal.science/hal-00659221>

Submitted on 12 Jan 2012

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

ProSPADD : A GUIDING TOOL TO OPTIMISE AND ATTENUATE THE VIBRO-ACOUSTIC RESPONSE OF STRUCTURES

Vincent Manet

Marmonier S.A.S/ 81-85, avenue Lacassagne / 69003 Lyon / France

The main issues induced by the propagation of vibrations and acoustic waves along a structure, such as a car, are the increase in unscrewing and debonding risks, in fatigue stress and in noise level.

These amplifications, real signature of the structures resonant modes, appear enhanced at their resonance frequency on the vibration transfer diagram. But the basic strategy of separation between excitation and resonance frequencies is rapidly limited from the only parameters mass and stiffness, whilst damping is arbitrary sustained.

The damping technology SPADD[®] and its methodology offer new perspectives by adding damping without mass nor stiffness leading to highly competitive solutions with regard to the excitation spectrum and the technical-economic constraints of (weight / performances / cost), and easily integrate the design process of the car industry either at a curing or at a preventive stage.

This paper presents the technology and methodology through the application on a real case of the automotive industry.

1 Introduction

As Artec aerospace first used his SPADD[®] technology in the field of satellites, it clearly proved that the concept was mature enough for application. Marmonier, a specialised supplier in thermic and vibro-acoustic solutions for the automotive industry, had the gamble of introducing this technology into cars.

Even if many things can be and are simulated, we must admit that in most of engineering projects of complex structures (such as vehicles), vibro-acoustic issues generally only appear on real structures, it means at the last stages of design, when most of the design parameters cannot be changed drastically, and when it has become anyway too late to do major changes.

At such design stages, one generally has to completely change the modal contents of a part, or at least cancel one or two modes, but:

- With very few space (because of the interaction of the part with a high number of parts belonging to the same sub-system and to other vehicle sub-systems),
- Without adding weight (which is directly related to the energy consumption of the vehicle and to environmental standards),
- Sometimes even without adding stiffness (which is related to the overall behaviour of the vehicle: changing the stiffness of one single part changes the stiffness of the sub-system it belongs to, and hence can impact the whole vehicle, especially in term of durability),
- With few time to find a solution (because the time to market cannot be changed for marketing purposes and due to the fact that vehicle development planning are always more compressed),
- And of course, without any additional cost (since at this stage, all development budgets have already been consumed).

The purpose of the SPADD[®] technology is to add damping “without” mass or stiffness.

2 Principle

The underlying principle used in the SPADD[®] technology is very simple: the purpose is to redirect the energy contents of cumbersome modes in parallel of the structure, where it will be dissipated. This mechanical energy is converted into heat in small “patches structures” called SPADD[®].

A SPADD[®] device consists of viscoelastic damping materials constrained or unconstrained and embedded in a mechanical structure. The geometry of a SPADD[®] device has to be optimised for each problem, but can be found as patches (2D), small 3D structures or struts.

Considering the equation of dynamics, the damping is generally not considered as a dimensioning parameter of this equation, which is a mistake, because it introduces at strong limitation of possibilities.

The addition of SPADD[®] devices to a system changes its mass, stiffness and damping. Thus efforts are made to avoid re-solution to determine an optimum design. This is achieved by using a perturbation method. In this case, as in all structural dynamic perturbation methods, changes in modal properties like eigenvalues and eigenvectors due to modification can be expressed directly in terms of eigenproperties of the original unmodified system and changes in mass and stiffness matrices...

Comparisons of results obtained by the perturbation method with results obtained by re-solution (updating the modal basis) show that the perturbation method is accurate and computationally efficient.

It is important to use complex values since the dynamic properties of viscoelastic systems are represented under harmonic vibration conditions by complex moduli, which is due to the phase difference between stress σ and strain ε (we do not

indicate stress or strain direction, it is true for any direction, hence for principal or shear direction):

$$\sigma/\varepsilon = E_1 + i E_2 \text{ (with } i \text{ the complex unit),}$$

and $E_1/E_2 = \eta$ is referred to as the loss factor of the material.

Viscoelastic material properties can be determined experimentally using an Oberst apparatus for example, and generally depend on both temperature and frequency.

Hence, a standard eigensolver can be used for finding the complex eigenvalues which give the natural frequencies and modal loss factors. Modal summation is then used to compute the response to excitation.

3 Presentation of the tool and methodology

ProSPADD is a software developed on the theoretical considerations recalled in the previous section.

The software is based on Matlab and related finite elements tools, and the interface is already done with Nastran, while universal files will soon be included in the input file formats.

The aim of this software is to offer designers a very simple tool to find, without discretizing any device, the best damping which can be added to the structure.

The geometrical modelling of the SPADD® device is replaced by updating the matrix system: the designer only has to indicate the area where the optimisation can be performed, and eventually the kind of technology to be used (unconstrained material, constrained material, strut...).

The methodology is as follows:

0. start from an existing model in Nastran
1. perform a modal analysis of the system in Nastran: at this stage, the designer generally face a problem, because one of the modal frequency is in a high energy range of the excitation. In this case, launch ProSPADD
2. import the FEM model
3. define the type of treatment among available SPADD® technology
4. define the area of treatment, and eventually some parameters (maximal dimension, geometry, materials...),
5. define the mode(s) to be damped or the vibration level to be attenuate (FRF)
6. launch the analysis
7. analyse the results:

ProSPADD will propose the designer the following results:

- the best positioning of SPADD® devices within the chosen area (topological optimisation)
- the maximum reachable damping according to the entered constraints (technology,

dimensions...), the others parameters remaining design parameters

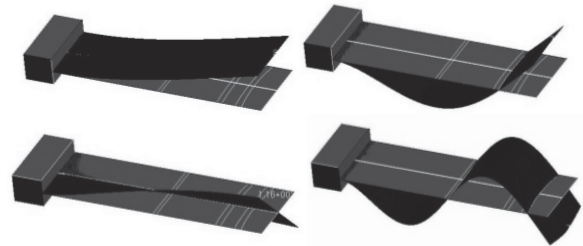
- the damping added to all modal base
- the attenuation of frequency response level
- the export of the FEM of the treated structure (which can be used for re-resolution, for example, in Nastran)

It is important to understand that this methodology allows the designer to *really consider the damping as a dimensioning parameter*. Until then, it has generally been applied at the end of the design, when a problem is encountered (for example a cumbersome mode), in a curative way. But, as soon as designers understand the potential of having a new design parameter, they can start using it in a predictive way, at the very first stage of the design. In this case, damping can really be added even through mass and stiffness can be spared.

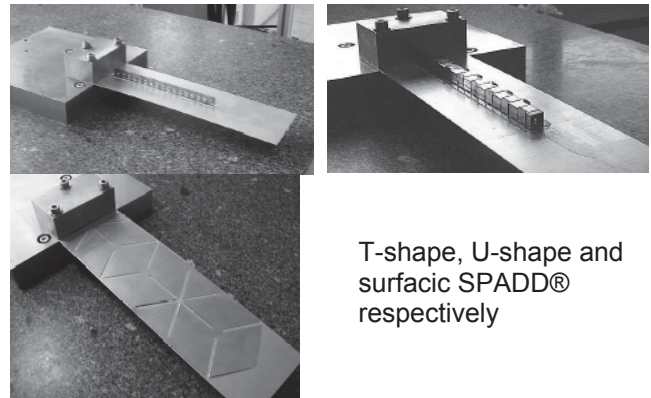
4 Academic study of a cantilever beam

In this section, we propose to add damping to the bending modes (1, 2 and 4, mode 3 being a torsional mode) of a cantilever beam using different kind of SPADD® shapes.

We recall the modes 1 to 4 of a cantilever beam:



Experimental validation and presentation of SPADD® devices:

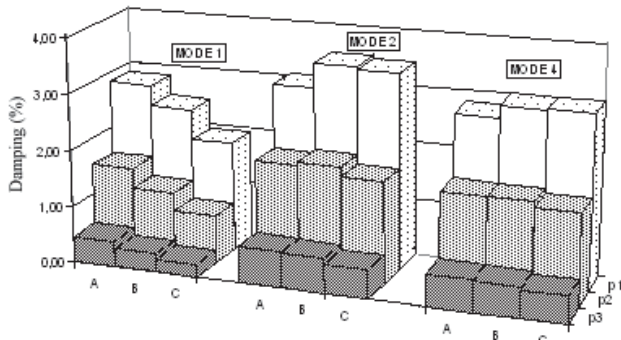


T-shape, U-shape and surfacic SPADD® respectively

Many configurations have been simulated and tested (different shapes, different geometrical constraints...), they all have been compared in terms of FRF and added damping

Results:

The flow charts below shows the results for modes 1 to 3 in term of damping for 3 different materials (A, B and C), and 3 geometries (P1, P2 and P3) :



The following table illustrate correlation between simulation and experimentation.

Mode	Freq (Hz)	Damping (%)	
		ProSPADD	Experimental bench
1	7	4,26	4,92
2	40	3,24	3,16
4	112	4,15	4,87

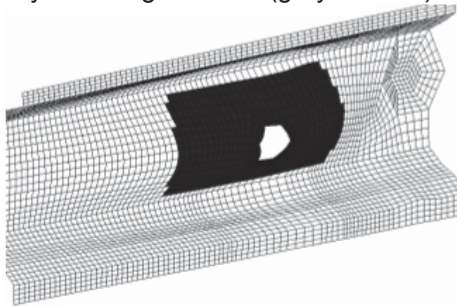
5 Industrial applications

In this section, we present some industrial applications by keeping industrial confidentiality: we do not mention the customer, the vehicle, and we briefly present the problem and the validated solution.

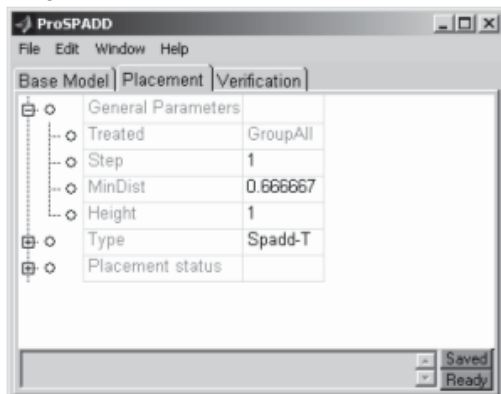
Curative study of a automotive rail side near a hole – SPADD® T shape

Study constraints:

- The treatment is only possible near the considered hole. Hence, the designer starts by selecting the area (grayed zone):

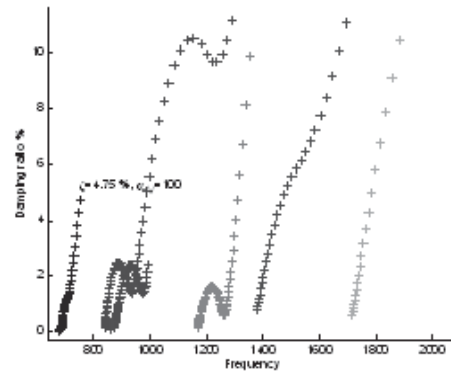


- The kind of SPADD® technology retained is a T-shape SPADD®, with a maximal height of 1mm:

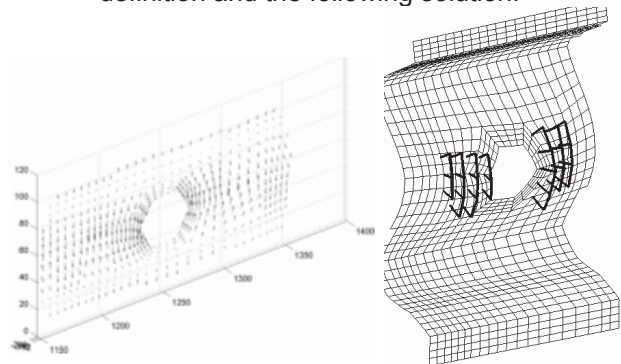


Solution:

- ProSPADD displays the optimisation evolution during the computation in terms of potential damping added versus frequency:



- ProSPADD proposes the best area definition and the following solution:

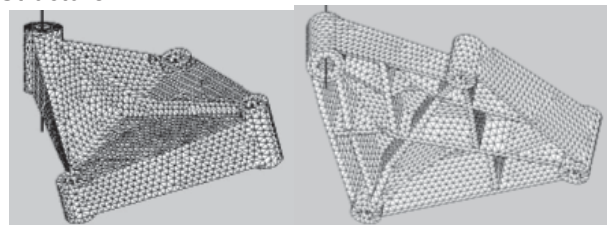


Curative study of an engine bracket – SPADD® strut

Study constraints:

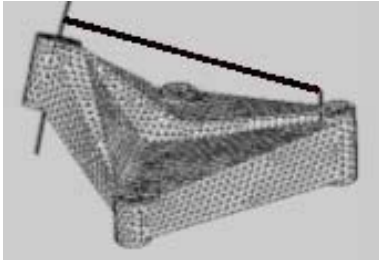
- Motor interface (static and crash behaviour)
- Stiffness constraint (decoupling modes 2 and 4)
- Curative study: no change on the part, but add a damping device
- SPADD® technology: strut
- Limitation of felt resonances by the motor bracket

Structure:

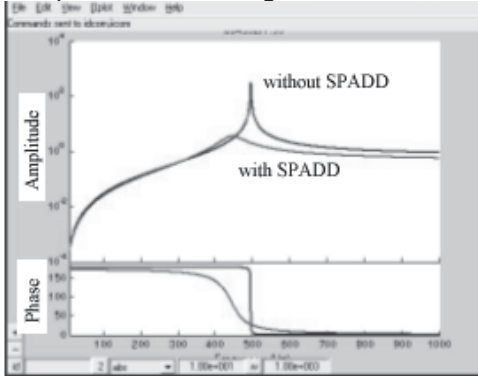


Solution:

- Additional potential damping: 5%
- Geometry with the strut:



- Impact on the FRF: gain = 15 dB



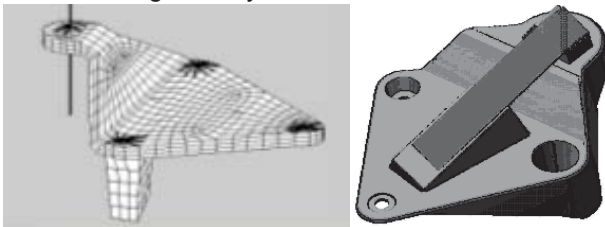
Re-design using SPADD®

The previous study has been extended taking into account the following constraints:

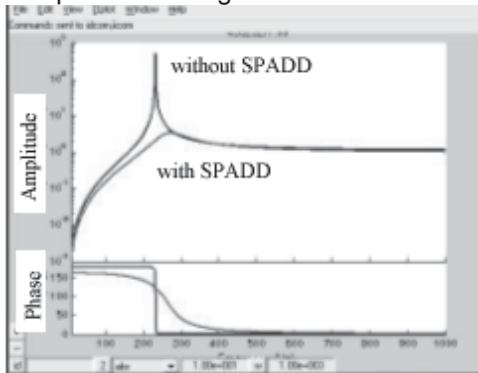
- new design including SPADD®
- mass reduction

With this final version, we have:

- new geometry:



- simplified sizing and manufacturing process (pressed steel)
- mass reduction: around 60% gain
- cost reduction: around 50% gain
- Impact on FRF: gain = 20dB



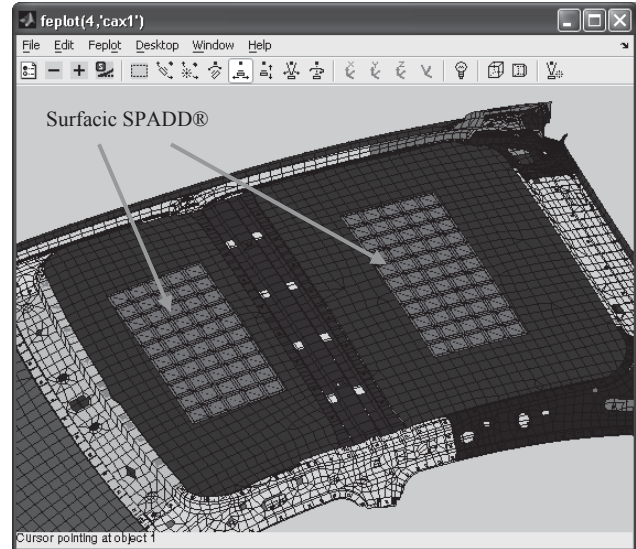
Optimization of a roof – Surfacic SPADD®

Study constraints:

- Optimise the mass of IFF used to damp a car's roof

- Due to the lack of space, the surfacic SPADD® will be used

Solution:



- Impact on FRF: gain = 15dB (more than IFF)
- Mass reduction: 30% gain compared to IFF

As a conclusion of the industrial projects, we can say that the SPADD® technology has already been used by several car manufacturers and validated by them.

Since SPADD® devices have shown their ability of solving some real problems encountered by car manufacturers, they are not used, at this time, as serial parts, but the technology is validated to be part of the technologies to be included in future cars.

6 Conclusion

In this short paper, we briefly presented the SPADD® technology and methodology and the related software ProSPADD.

These tools have been validated by car manufacturers and will probably be used as serial solution in a near future.

Some selected problems have been briefly presented to demonstrate the SPADD® capacity in term of damping.

The main point is that the damping can really be considered as a dimensioning parameter in the equation of dynamics, even if for practical use, it is necessary to have the knowledge of both the geometry of the dedicated device and the characteristics of the constitutive materials.

Acknowledgements

Special thanks to the European Community for its financial support through the Craft DEMARITS project (Development of design and Manufacturing Rules of an Innovative Thin Shell technology / EC Contract N° G3ST-CT-2002-50202), concerning the development of ProSPADD and the first stages of validation.