# Modelling of Transmission loss for trimmed vehicle components

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In the automotive industry, the influence of poro-elastic components on acoustic comfort has been mostly investigated for air borne noise at mid- and high frequency ranges. However, due to the lack of adequate theoretical formulations, the influence of poro-elastic in numerical vibro-acoustic simulation at lower frequency range has often been ignored or roughly approximated by the addition of distributed spring/mass on the BIW structure. Recent theoretical developments removed this limitation by providing a FEM formulation for poro-elastic material modelling. Using a FEM only approach, this new theory was successfully used to compute the coupled vibro-acoustic response of a fully trimmed vehicle, which includes the BIW structure, the acoustic fluid and the poro-elastic materials (seats, carpet, dash insulator…). The latest development of powerful algorithms allows the automatic model setup and high performance parallel calculation to be performed fast enough to be implemented into the sound package design process of large OEMs. Most recent developments allow the automatic Transmission Loss (TL) model building process of complex components such as trimmed dash or floor. This paper presents a comparison between different types of cabin side dash insulators using the development described above and compares these predictions with test.

Key Words: Transmission Loss, Porous media, Dash Insulator, Air Gap, Numerical , Experimental (1)

## 1. INTRODUCTION

In order to answer car manufacturers requests, Treves and Kotobukiya Group define, at the early stage in the project, the "light" sound packages in the cabin and in the engine compartment. That's why we use adapted calculation software and innovative products. With the transmission loss simulation, we are able to define and optimise acoustic treatment, as a dash insulator, to achieve acoustic specification with a minimum weight.

## 2. FOUNDATION OF METHOD

Theory used for transmission loss (TL) modeling is based on displacement-pressure formulation (u,P) proposed by Atalla et al. [1,2] . This formulation has been extended to study vibro-acoustic problems involving interactions between a master structure, a fluid cavity and trim components made of poro-elastic material. This formulation has been implemented in the Trim Designer software from ESI-Group and details of this formulation are given in [3,4].

Complex industrial applications require the modeling of interactions between porous media and infinite fluids of the emission and reception rooms. The method proposed consists in adding an air gap between the porous media and the infinite fluid. On the coupling surface $\sum$ separating the air gap and the external fluid (Figure 1), two boundary conditions are defined: a) continuity of pressure: $p^g = p^e$ and b) continuity of normal displacement: $u_n^g = u_n^e$. Symbols g and e denote respectively the air gap and the external fluid. The weak formulation of the porous media including the air gap is given by:

$$Z(U,V) + A(p,q) - \hat{C}(p,V) - \hat{C}(q,U) =$$
$$\tilde{C}_S(T,V) + C_S(q,\phi(U_n^f - U_n))$$

Where,

- $Z$ represents the mechanical impedance of the skeleton
- $A$ represents the admittance of the interstitial fluid and the air gap
- $\hat{C}$ represents volume coupling terms between the skeleton and the interstitial fluid
- $\tilde{C}_S$ represents surface coupling term between the porous media

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and the elastic structure

-$C_S$ represents surface coupling terms between the porous media, the air gap and the external fluid

The use of this formulation combined with integral representation of pressure in the emission and reception domains and the use of the boundary conditions defined above enables the creation of a linear matrix system hat yields Transmission Loss values of the component. The demonstration will not be presented in this paper but theoretical background can be found in [5,6].

## 3. NUMERICAL SIMULATION

To demonstrate the validation of this TL calculation, a dash insulator has been proposed by TREVES Company. The simulation has been realized by ESI Group and the experimental test has been realized by TREVES. The transmission loss setup is shown in Figure 1. The Dash Insulator is placed in a rigid baffle which separates the reverberant room and the anechoic room. In the reverberant room a diffuse sound field is applied to load the elastic structure. The dash insulator is coupled with the fluid of the reception domain. TL is defined by the ratio of incident acoustic energy induced by the diffuse sound field in the emission fluid domain and the acoustic energy radiated in the reception fluid domain: TL (dB) =10 log(Ei/Er).

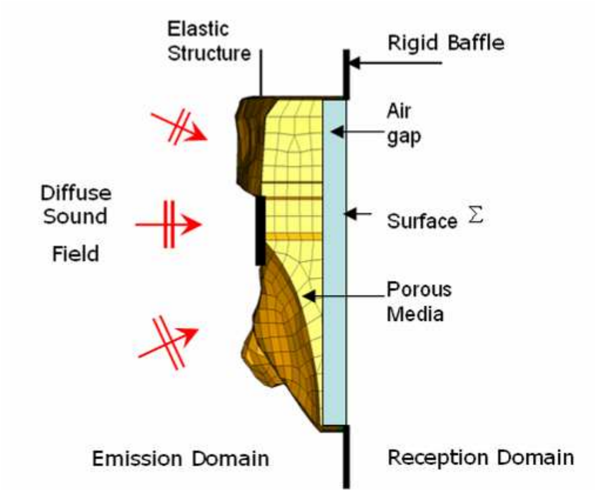


Figure 1: Transmission loss setup

Dimensions of the dash are 1.2 x 1.0 meters. To model the diffuse sound field a set of 17 uncorrelated plane waves is used. The computation is done in the 100-1500 Hz bandwidth. Two dash insulators are studied: a) two layers of felt, b) one layer of felt and a heavy layer.

### 3.1 Finite Element Model of the dash

The elastic structure of the DASH is meshed with 5987 nodes and 5462 shell linear elements as shown in Figure 2. A modal decomposition is used to model the dynamic behavior of the DASH. The modal base is computed using MSC NASTRAN up to 2kHz with clamped edges as boundary condition. For the vibro-acoustic response a 2% of modal damping value is assigned to each mode. Note that an air cavity is also included to represent the cowl.

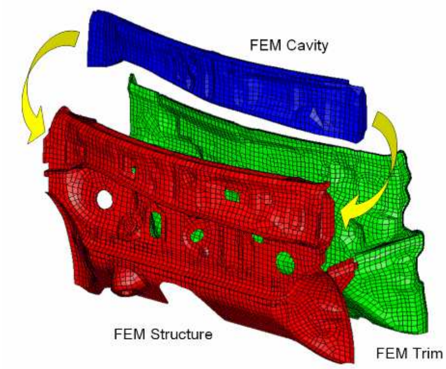


Figure 2: Model of the dash with cowl cavity and trim

### 3.2 Finite Element Model of dash insulator

As shown in Figure 3, the dash insulator is meshed with three Finite element in the thickness. The finite element model includes 11148 linear solid elements and 15208 nodes. The surface of the first layer is coupled to the structure with a sliding boundary condition. For the dash insulator A (2 felt layers), the two layers are modeled using poro-elastic elements. For the insulator B (1 felt layer + heavy layer) the first layer is modeled by poro-elastic elements and the second layer is modelled by solid elastic elements and a thin shell.

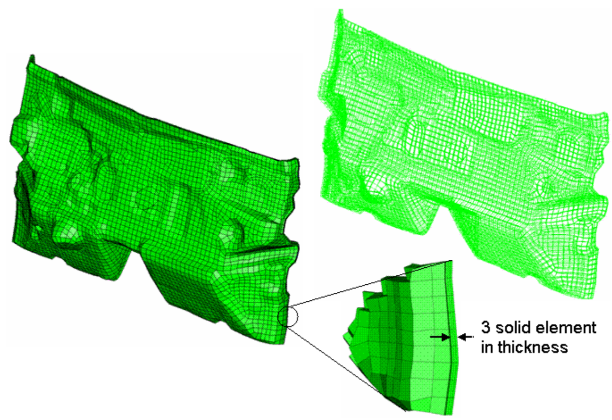


Figure 3: Finite Element Model of dash insulator

The BIOT parameters of the felt and the physical properties of the heavy layer have been provided by TREVES. Modelling the dash insulator with finite elements enables a detailed modelling of the varying material properties such as surface density and thickness of the dash insulator (Figure 4). In front of the dash insulator a gap of air is added in order to couple it to the BEM reception fluid domain as shown in Figure 7. This simplifies the vibro-acoustic problem and provides all types of coupling necessary in the modeling of a complex component such as a dash and its trim.

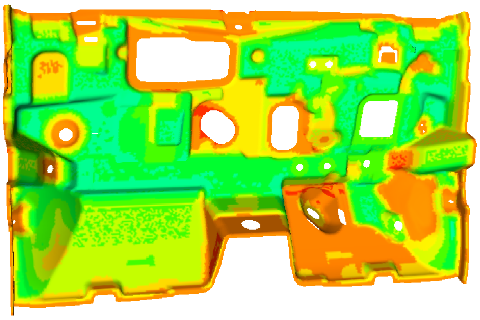

Figure 4: Thickness distribution of the heavy layer

### 3.3 Fluid Domain Boundary Element Models

The emission and reception fluid domains are modelled by shell elements. Figure 5 and Figure 6 show respectively the emission and reception fluid domains. Only the parts of surface in contact with the elastic structure are coupled, the other parts are defined as rigid (w=0) to avoid the direct communication between the emission and reception fluid domains.

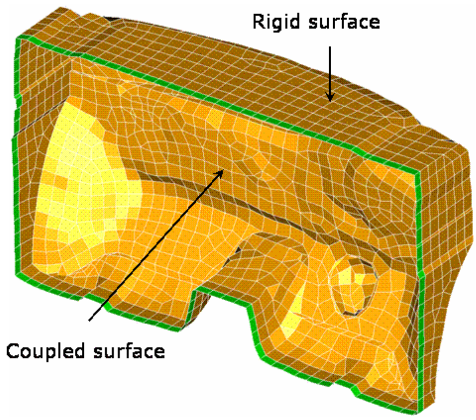


Figure 5: Emission fluid Domain

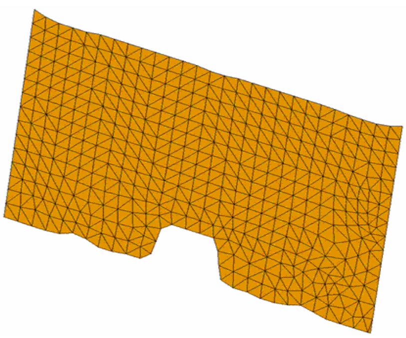

Figure 6: Reception fluid Domain

Figure 7 shows the complete numerical model used to compute the transmission loss of the dash and its insulator.

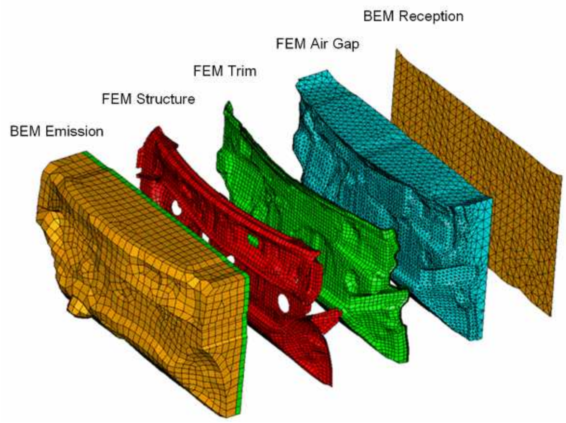


Figure 7: Complete BEM/FEM mesh model

## 4. VALIDATION RESULTS

Experimental results are obtained from classical reverberant/reverberant transmission loss measurements. All pass-through's are sealed as shown in Figure 8.

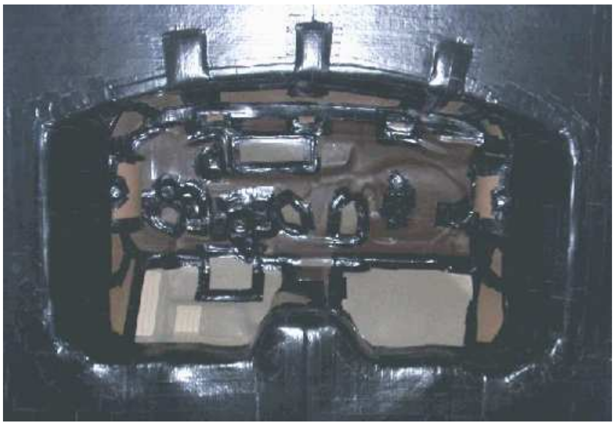

Figure 8: Experimental setup

Transmission loss is presented for the three configurations:

- Bare panel
- Dash insulator A (2 felt layers)
- Dash insulator B (1 felt layers and heavy layer)

Figure 9 shows in 1/3 octave band the comparison between the experimental results provided by TREVES and numerical results computed by ESI-Group (the numerical results are also presented in narrow band in Figure 10).

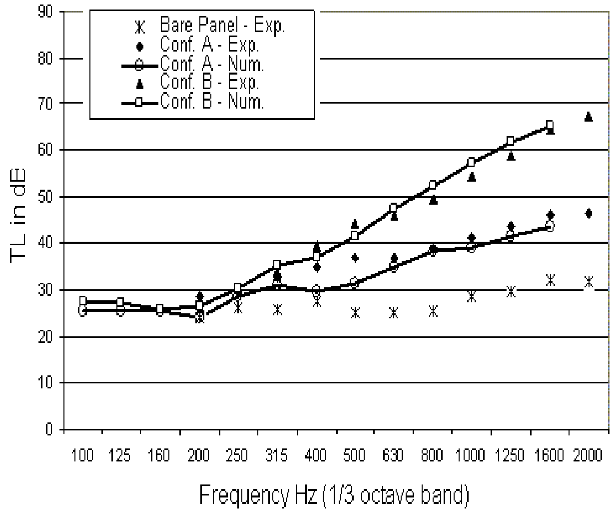


Figure 9: Comparison experimental and numerical results

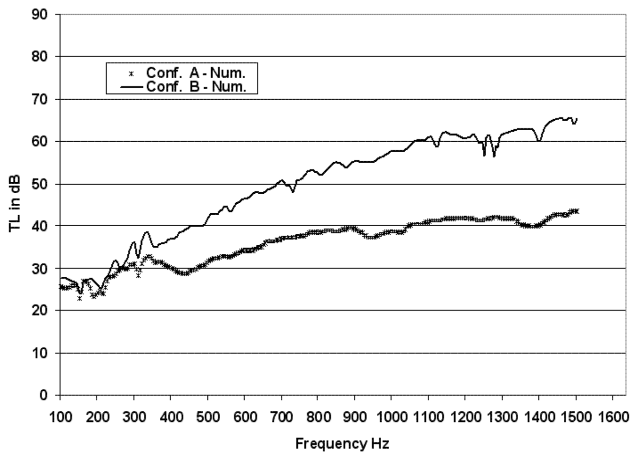


Figure 10: Numerical results in narrow band

## CONCLUSION

The numerical results obtained by the new developed TL module, implemented in Trim Designer show good agreement with test results performed by TREVES. It accurately predicts the effect of a design change such as a "2 felt layers" vs "1 felt layer and a heavy layer".

The new design improves the acoustic efficiency with the absorbing dash insulator in high frequencies and provides a weight reduction of 50 %.

The acoustic efficiency of the front sub-system need to be optimised not only with the dash insulator but with all other components (Pass-through – air conditioning – water box – link between steel panel – dash board…).

TREVES & KOTOBUKIYA used Trim Designer and AutoSEA2 software to design all acoustic parts in the cabin.

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