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DEVELOPMENT OF A NEW INTERLAYER FOR LAMINATED GLASS TO IMPROVE SOUND QUALITY WITHIN CARS

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ABSTRACT
The most important implications of glass concerning NVH within cars are booming noise and wind noise. Booming noise is dealing with low frequencies (below 200 Hz), wind noise with high frequencies (glass contributes above 1000 Hz). All laminated glazings use standard PVB, which has not been developed for acoustic purpose. To replace it, the properties of a new interlayer have been adjusted by the use of modelisation: finite elements for low frequencies, specially developed computational model and SEA for medium and high frequencies. The influence of glazings had to be studied concerning booming by coupling of windscreen modes to cavity modes and coincidence effect on income of aerodynamic noise through sidelites. Measurements under running conditions have been done, and psychoacoustic parameters had to be introduced. Special acoustic interlayer has been found to have great interest.

1 - INTRODUCTION
Occupant's ear in a car is very close to the glass, and increase of glass surfaces is a general trend among car manufacturers. Working on the glass component itself becomes very important. Modelisation and measurements have been done to improve the glass, specially laminated glass.

2 - PARAMETERS OF MODELISATION
The input parameters of calculation are the shape and the dimensions of the glazing, the thickness of the glasses, the material properties of the fluid around the structure and the boundary conditions.
For laminated glazing, the interlayer is taken into account by its thickness and its complex shear modulus G described by the WLF theory [1]. Figure 1 shows the viscoelastic properties of the interlayer which are frequency and temperature dependent. Real part G' and the damping loss factor tanδ are calculated by the following equations:

$$\log\left(\alpha_T\right) = -C_1 \times \left(T - T_{ref}\right) / \left(C_2 + T - T_{ref}\right) \tag{1}$$

$$\tan\delta = g\left(\alpha_T, f\right) \tag{2}$$

$$G' \times T_{ref}/T = h\left(a_T, f\right) \tag{3}$$

where a_T is the shift factor, f is the frequency, T and T_{ref} are the ambient and the reference temperatures, C_1 and $C_{\ 2}$ are the shifting coefficients, g and h are given functions which are temperature and frequency dependent.

3 - LOW FREQUENCY NOISE
A finite element model has been studied and validated for the simulation of the behavior of monolithic and laminated glazings, specially windscreens, taking into account boundary conditions. At the first stage, during the definition of the shapes, frequencies and shapes of the ten first modes of windscreens

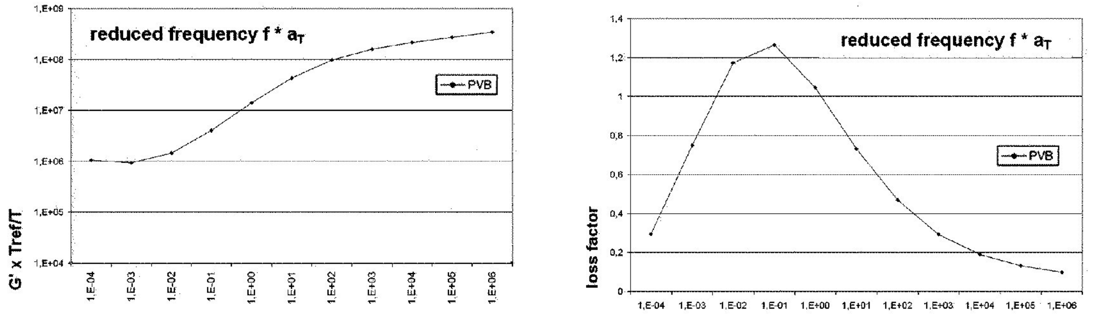

Figure 1: Real part of the complex shear modulus and loss factor in function of reduced frequency.

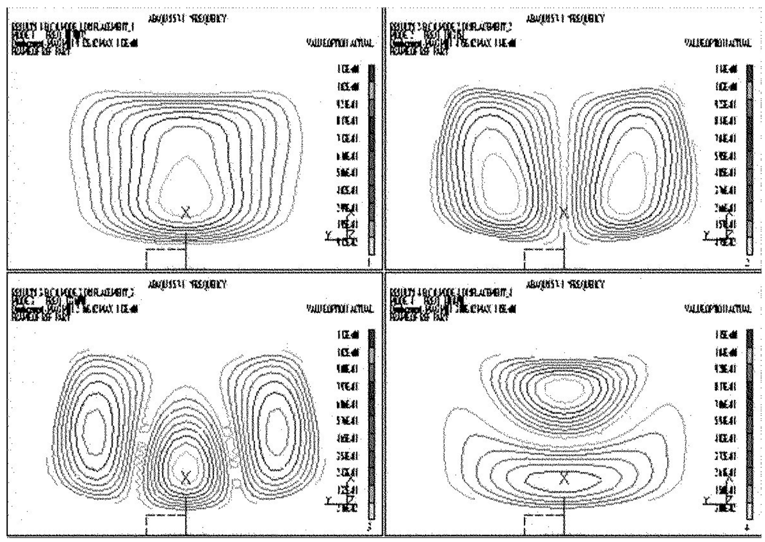

Figure 2: 4 eigenmodes of a windscreen.

are now requested by some car manufacturers. Fig 2 shows an example of what can be done in that topic, eigenmodes of a windscreen glued with the most common sealant for windscreens.
Chosen FEM code is Abaqus, boundary conditions are designed as equivalent springs.
It has been put into evidence that changing the interlayer of the windscreen could suppress important booming effects in some cases. Fig 3 shows the evolution of the booming, 3rd gear, full throttle, which was observed on a car, with a standard windscreen, compared with a windscreen laminated with the special acoustic interlayer. The problem was located at around 3000 rpm, that is 100 Hz for the second order, and corresponded in 5th gear at a current speed on motorways. It was so very important to solve and at that stage it was impossible to change other parameters.

4 - WIND NOISE

For modelisation of the sound transparency of glazings, a specific software has been used [2].
This software deals with multilayered finite plane plates, with dissipative boundary conditions. Simple methods can also be used, by using equivalent stiffness and damping for laminated panes. These data can then be used within SEA models to simulate sound pressure level within the car on different locations. Coincidence effects on glass have specially to be taken into account.
Measurements have been done in an anechoïc wind tunnel using masks method, which were compared with simulation of the noise through a sidelite to driver's ear, with replacement of a glazing by another. It has then been necessary to choose a parameter correlated with the sound quality: the first criterion used in those cases is often overall sound pressure level, or loudness when dealing with psychoacoustics, but loudness does not change very much. So two other parameters have been introduced: sharpness and intelligibility, which seem to be correlated with annoyance. Fig 4 shows some results.

5 - CONCLUSIONS

A new interlayer for laminated glass increasing in the same time sound quality towards booming noise

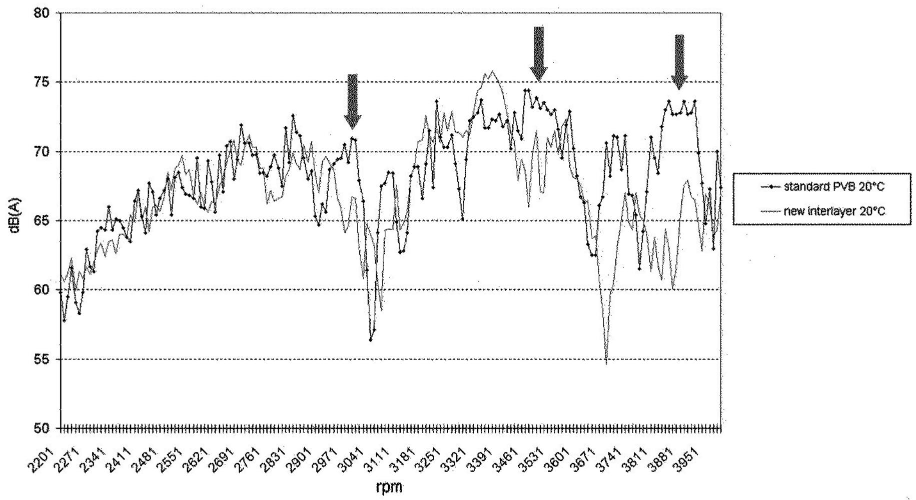

Figure 3: Drivers's right ear 3rd gear full throttle on roller benchstandard windscreen vs special acoustic windscreen.

and aerodynamic noise has been developed and validated.
This interlayer has already been chosen by some car manufacturers, concerning the windscreen for a booming problem in a very popular small car, and concerning laminated side lites for a high range car.

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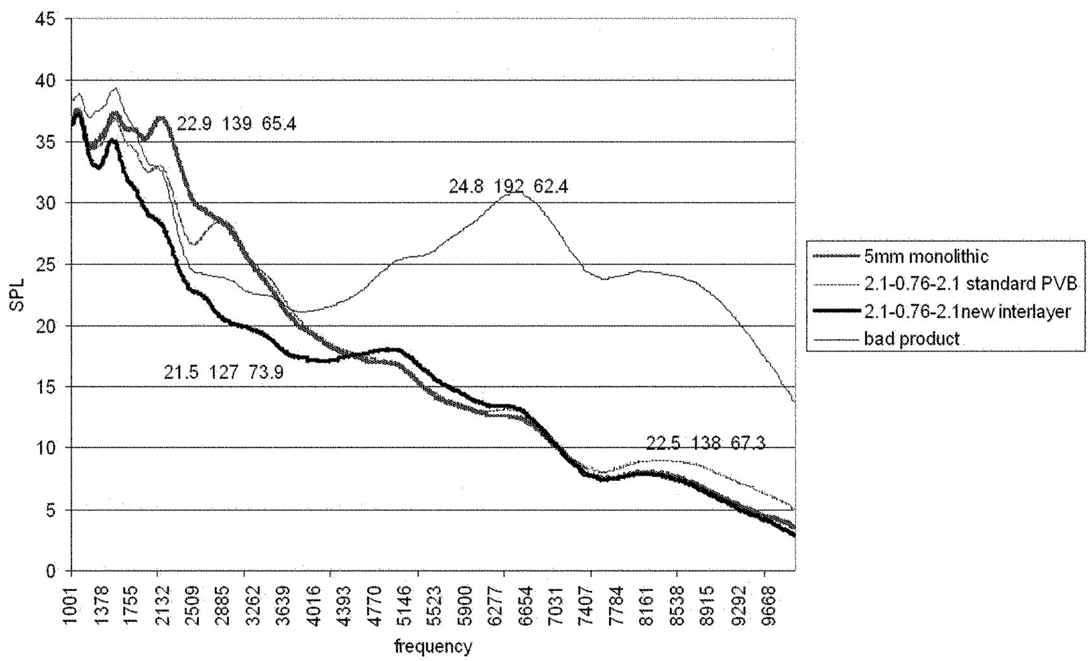

Figure 4: Noise to driver's left ear for different side lites with values of sound quality within a car in terms of loudness (sones), sharpness (centiacum) and intelligibility (AI %).