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NUMERICAL ANALYSES OF THE SOUND TRANSMISSION THROUGH DOUBLE-GLAZING SYSTEM AT LOW FREQUENCIES

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ABSTRACT

The acoustic performances of building elements such as windows are performed in laboratory according to standards. In addition to the high cost of the experimental tests, the measurements at low frequencies, face some difficulties such as the lack of reproducibility, the diffuseness of the acoustic field and the effect of the modal behaviour of the rooms. To overcome this, a numerical analysis of the transmission loss of a double-glazing structure is developed in this work. To this end, four numerical configurations, based on experimental conditions, are proposed. The differences concern the modeling of the emitting and receiving rooms. The numerical model used for the double-glazing was calibrated through the Experimental Modal Analysis. Results show that there is a significant effect of the rooms on the transmission loss at low frequencies and so of its properties such as the acoustic absorption. A comparison with experimental results is also established to validate the chosen configuration with which parametric analyses are carried out, however, results are not presented in this paper.

Keywords: Double-glazing, Transmission Loss, Experimental Modal Analysis, Numerical analysis.

1 INTRODUCTION

Double-glazing is often used in noise reduction since a relatively high transmission loss is achieved by the introduction of an acoustic gap between the panels. Due to various effects of fluid-structure interaction, boundary conditions and the modal behaviour in low frequencies, the prediction of the acoustic performance of the double wall remains complicated. In the literature, Antònio et al studied experimentally the transmission loss through single, double and triple glazing [1], while, in Ref [2], the effect of boundary conditions on this acoustic indicator of double panels was investigated. A comparison of different type of glass can also be found in Ref [3]. Regarding the numerical prediction approaches, several methods are available. The choice of the method depends on the computational cost and the considered frequency band. The Finite Element Method (FEM) is suitable to treat problems in low frequencies. For example, Larbi et al used it to develop a model of a sandwich plate with viscoelastic core [4]. Another example can be found in Ref [5] which studied the prediction of sound transmission through double-wall with elastic porous lining.

In this paper, a numerical analysis based on an experimentally calibrated FEM model is proposed to predict the vibroacoustic behaviour of double-glazing.

2 NUMERICAL CALIBRATION OF THE DOUBLE-GLAZING FROM EMA

In this section, we are interested in the calibration of a numerical model of the double-glazing through the Experimental Modal Analysis (EMA). The studied structure presented by Figure 1 is an Insulating Glass Unit. It consists of two glass and a separating edge which forms an air or gas gap. The complexity is located along the edge. In fact, the stainless hollow steel spacer is filled at least half by molecular sieve in the form of beads called the desiccant and used to dry out the cavity. In addition, a dual seal combination has a primary seal of polyisobutylene between the spacer and the panes, and a secondary seal of silicone around the outside edge is used to glue all the parts. So, to calibrate a model of the group "spacer + desiccant + seal", an EMA is carried out for the full system in order to determine the mechanical properties (E , ν and ρ) for an equivalent homogeneous isotropic material for this group.

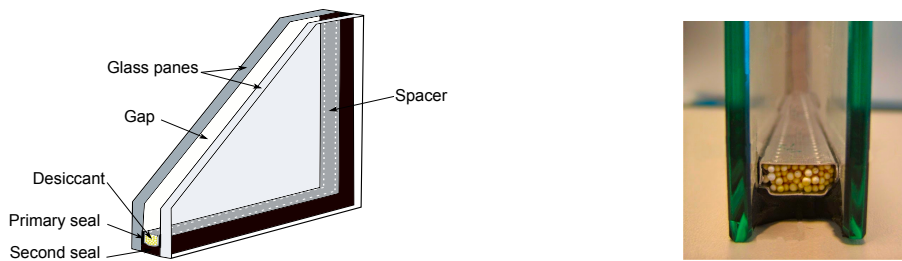


Figure 1. Details of the Insulating Double Unit

2.1 Experimental Modal Analysis

For performing the EMA, a home-made Matlab toolbox has been developed and includes several approaches like LSCF and its polyreference version. The suspended double-glazing (see Figure 2), composed of two glass of 6 mm and 4 mm separated by 18 mm of argon, is meshed into 153 nodes in order to obtain a good visualisation of the mode shapes. The application of the method implemented in the toolbox requires the measurement of the Frequency Response Function (FRF) at different points of the structure after its excitement. In this work, the roving hammer test is used with an impact hammer and three reference accelerometers.

2.2 Numerical calibrated model

The double-glazing experimentally tested is calibrated numerically with the finite element method. The numerical model consists of two 2D shells representing the two panels separated by a 3D cavity filled with argon. An equivalent solid for the group "spacer + desiccant+ seal" (see Figure 2) is defined. Quadrilateral elements for the glass panels and hexahedral ones for the fluid and the

equivalent spacer are used for the finite element discretization, and their sizes are controlled by the wavelength of each subdomain.

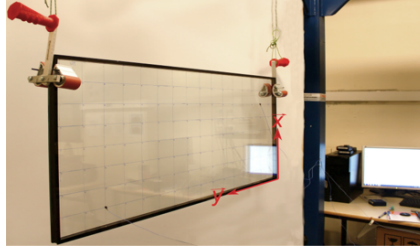


Figure 2. Suspended double-glazing

2.3 Results and discussion

Table 1 shows the comparison of the first ten natural frequencies of the structure obtained from the experimental and numerical analysis after calibration of the numerical model on the first natural frequency. For a such complex structure, results are considered satisfying since the maximum difference of natural frequency is 6.8 %, observed for Mode 8. Therefore, this calibrated model is used to evaluate numerically the transmission loss.

Mode	1	2	3	4	5	6	7	8	9	10
Experimental	29.9	37.7	41.2	56.4	60	75.5	93.9	94	98.4	117.6
Numerical	29.8	36.6	38.6	56.4	63.8	72.9	98.9	100.4	102.7	113.9
Gap (%)	0.4	2.9	6.3	0.1	6.4	3.4	5.4	6.8	4.4	3.1

Table 1. Experimental and numerical eigenfrequencies of the double-glazing

3 DETERMINATION OF THE SOUND TRANSMISSION LOSS

The airborne sound insulation of building elements is evaluated in laboratory according to standards ISO 10140. Measurement are done between two adjacent reverberation rooms. In low frequencies, tests face some difficulties such as the lack of reproducibility, the diffuseness of the acoustic field and the effect of the modal behaviour of the rooms. To study these different problems, four numerical configurations have been carried out. In the first one (Figure 3.a), a realistic laboratory configuration is considered. It consists in two reverberant rooms modelled with a spherical acoustic source in the emitting one. In fact, standards assume that the acoustic excitation is a diffuse field for the entire frequency band of measurement. However, this condition is respected only beyond the "Schroeder frequency" which marks the limit between the modal and the diffuse field behaviour. So, a second configuration (Figure 3.b) considering the source side as a diffuse field even for the very low frequencies while modelling the receiving room is considered. Numerically, this condition is ensured from the superposition of set of plane waves with random phase. For the third configuration (Figure 3.c), to avoid the modal behaviour of the receiving room, an acoustic radiation in a half-space while modelling the emissive room is considered. The Rayleigh condition, which references to a vibrating structure in the plane of a rigid baffle, is used. Finally, the fourth configuration (Figure 3.d) combines the diffuse field in the source side and the Rayleigh radiation in the receiving one. The advantages of this model is a significant reduction in the model size, but considers perfect experimental conditions in both sides of the structure under test.

4 RESULTS

A comparison of the results in narrow band and third octave band is established and presented in Figure 4. As expected, in very low frequencies (below 100 Hz), the TL is sensitive to the presence of the acoustic rooms due to their modal behaviour. Of course, this observation is not observed for the results of the fourth configuration which presents only the modal behaviour of the double-glazing. From 125 Hz, TL has the same trend regardless which configuration is used with a difference of 3 dB at 500 Hz.

5 CONCLUDING REMARKS

The double-glazing is calibrated numerically with the Experimentally Modal Analysis. The established model is used to carry out numerical acoustic analyses. The results show that the presence of the acoustic rooms has a significant influence on the TL at very low frequencies. However, above 125 Hz, all TL converge. For that, the fourth configuration is considered satisfying especially since it is the most profitable in terms of calculation cost. In addition to a comparison with experimental results, parametric analyses have been done but not presented in this paper.

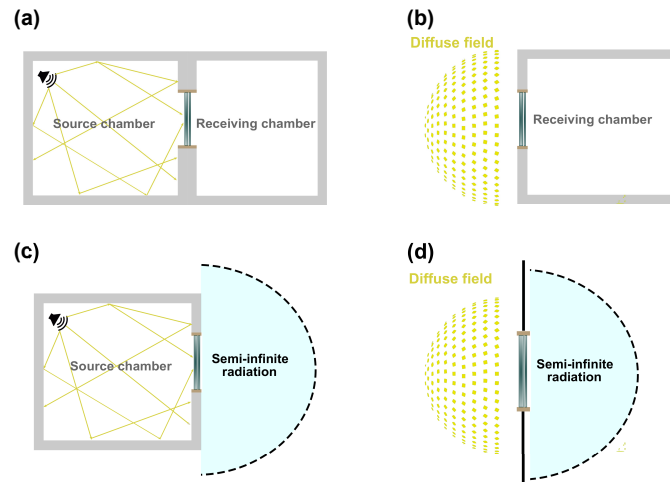


Figure 3. Numerical configurations considered for the prediction of the TL

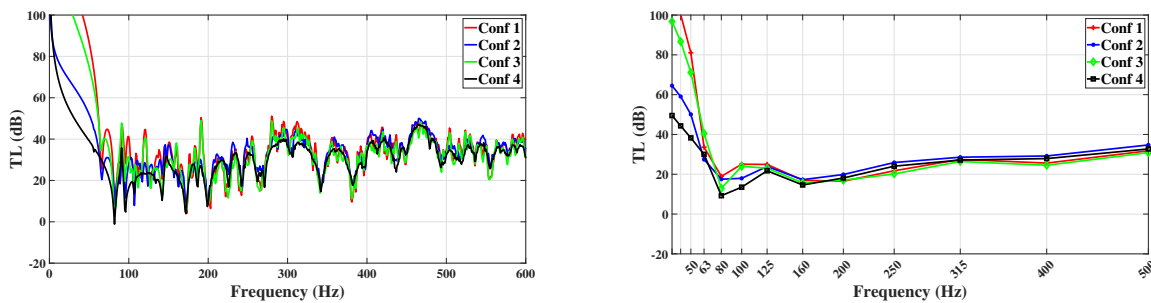


Figure 4. TL from the four numerical configurations

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