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EXPERIMENTAL INVESTIGATION OF SOUND RADIATION: INFLUENCE OF STRUCTURE-BORNE TRANSMISSION

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ABSTRACT

Double-leaf partitions constituted by plasterboard panels installed on steel studs creating an air-cavity or filled with sound absorbing material are widely employed in building constructions. It is well known that, due to the presence of the studs, the sound insulation of these structures is significantly lower than the theoretical value computed by neglecting mechanical connections. However, the influence of studs in the case of mechanical excitation and structure-borne sound transmission has not been thoroughly investigated. This study experimentally analyses the influence of studs on sound radiation, by comparing the radiation efficiency of a single plasterboard plate and a double-leaf partition. The vibration velocity was measured on the investigated structures, excited by an electro-dynamic shaker. The results highlight the importance of the studs' elasticity. At higher frequencies, lower vibrational levels are measured on the radiating panel of the double-leaf system. However, at the lower frequencies, the double-leaf partition exhibited a higher radiation efficiency, probably due to the modal behaviour of the system.

Keywords: *double-leaf partitions, sound radiation test facility, stud connections, vibroacoustic measurements*.

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1. INTRODUCTION

Double-leaf partitions are widely used in building constructions, providing a good sound insulation performance while limiting the thickness of the wall, optimised by adjusting the surface mass of each leaf and the depth of the cavity between them [1]. Such structures have been thoroughly investigated and their acoustic behaviour can be modelled with different approaches, ranging from analytical formulations to empirical models. Moreover, it is well known that the presence of studs, which can be seen as bridges between two parallel layers [2], plays an important role in sound transmission [3]. Some experiments were performed to describe the impact of studs on sound insulation [1,3,4]. However, the influence of studs on sound radiation has not been thoroughly studied experimentally, even though it might be crucial in structure-borne sound transmission from building service equipment or appliances.

This article presents an experimental analysis of the structural dynamic response to a structural excitation, describing the influence of steel studs on sound radiation. Vibroacoustic parameters are calculated, including radiation efficiency σ describing the structure's capability to convert vibrational energy into acoustic energy. The description of the experimental setup is presented in Section 2, while Section 3 presents the obtained results. Finally, Section 4 presents conclusions and further work to be done.

2. EXPERIMENTAL SETUP

In this work two different structures were investigated. The first one was a simple reinforced plasterboard panel 12,5 mm thick, while the second one was a double-leaf structure made of two identical reinforced plasterboard plates connected with steel studs placed with 60 cm spacing, fixed with screws equally distributed at a 20 cm distance. The total thickness of the second specimen was 7,5 cm. The specimen was set in a metal frame, by clamping two boundaries while leaving the two orthogonal ones unconstrained. The structures were excited by using an electro-dynamic shaker driven with a sine-sweep signal generated from 30 Hz up to 6000 Hz, located on the bottom side of the structure in a point with coordinates x = 84 cm, y = 92 cm. The structural dynamic response was measured on the upper side of the structure by using accelerometers. Impulse responses were obtained on 400 points distributed over a regular square grid with a spacing of 0.05 m, giving a square-shaped working space with an edge length of 0.95 m. Three accelerometers were simultaneously used to measure the plate response while, to keep a consistent phase relationship between different measurements, the reference signal was obtained from the force transducer of the impedance head connected at the excitation point. All vibration acceleration measurements were executed on the upper plate of the construction, while the bottom plate was excited with a structure-born sound source. The radiation efficiency of each investigated structure was determined by using the Discrete Calculation Method (DCM) proposed and described in detail by Hashimoto in reference [5].

3. RESULTS

The spectra within the frequency range 50-5000 Hz presented in Figure 1 and Figure 2 are calculated according to the DCM [5]. The spectra given in Figure 1 are the FRF values, calculated as a logarithmic ratio of velocity averaged over the structure's surface and force.

The FRF values obtained for a double-leaf construction are noticeably lower than levels obtained for a single-leaf panel. As shown by the differences between the two curves, above the mass-spring-mass resonance at approximately 80 Hz, due to the presence of the structural connections, the upper plate is still excited even though it exhibits lower velocity levels. The FRF of the double-leaf panel is almost constant for frequencies above 80 Hz, while FRF for the single plate constantly increases, providing a difference of about 20 dB for the values obtained for the highest analyzed frequency.

Coincidence frequency, where the highest *FRF* value is determined, is the same in both cases investigated. For both systems, the critical frequency f_c was identified around 3600 Hz, since the radiating element was an identical plasterboard panel.

Radiation index shown in Figure 2, defined as $10\log(\sigma)$, where σ is the radiation efficiency, is a non-dimensional vibro-acoustic descriptor which quantifies the capability of the structure to convert energy of vibration to acoustic energy, and is calculated according to Eqn. (1).

$$\sigma = \frac{W}{\rho c \langle v^2 \rangle S} \tag{1}$$

where W is radiation sound power, ρ and c are air density and speed of sound in the air, respectively, $\langle v^2 \rangle$ is the mean square velocity in the range over the vibration object, and S is the entire area of the object.

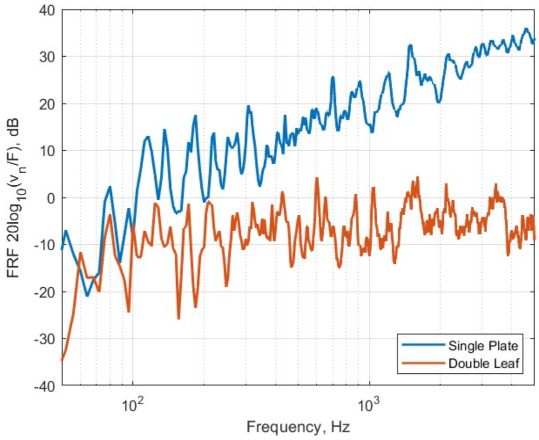

Figure 1. Frequency response function - single plate and double-leaf partition.

Higher values of the radiation index, observed in the low frequency range for the double-leaf system, mean that, for a given vibration velocity level, the structure radiates sound energy more efficiently than a single plasterboard panel. This might be due to the modal behavior of the double-leaf structure and, possibly, to the contribution of airborne excitation of the top plate from the sound field generated inside the cavity. Above 400 Hz, the differences between two radiation index spectra are negligible. Lower sound power levels are expected to be radiated by the double-leaf system, since it was characterized by lower velocity levels.

The role of the studs is clearly transmitting the vibration from the excited panel to the radiating one. Since these mechanical connections are not infinitely stiff, unlike what is assumed in some prediction models, as the frequency increases the transmissibility is reduced and a lower vibration velocity is observed on the radiating panel.

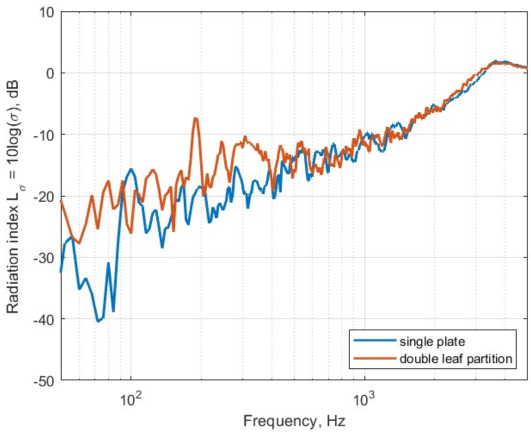

Figure 2. Radiation coefficient comparison - single plate and double-leaf partition.

However, to accurately consider the influence of the studs in prediction models, several aspects need further investigation. The follow-up of this study will analyze how their presence affects the plate impedance, or the modal behavior of the system, which governs sound radiation at the lower frequencies, and how their dynamic response is influenced by the surface mass of the structure's leaves.

4. CONCLUSION

This work presents the influence of steel studs in structure-borne sound transmission, investigating the vibration velocity levels over single and double-leaf systems. The DCM method was used to evaluate the radiation efficiency of the investigated structures. The studs exhibited a higher efficiency in transmitting vibration between the two plates of a double-leaf system at the lower frequencies, while, due to their elasticity, lower vibration levels were measured on the radiating panel above 80 Hz. The level difference between single and double-leaf structures is close to 20 dB for the highest frequency analyzed. A higher radiation efficiency can be observed for the double-leaf system, probably due to the modal behavior of the structure. However, this aspect needs a deeper investigation. Above 400 Hz negligible differences were observed between the radiation index for a single and double-leaf system, highlighting lower sound power levels radiated by the latter structure. Different aspects will be further investigated to better understand how studs affect the plate impedance, or the modal behavior of the system, and how their dynamic response is influenced by the surface mass of the structure's leaves.

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