Perceptual based solution design for the annoyance produced by a washing machine over a lightweight floor: a case study in the Netherlands

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Objectives

Improving the sound insulation in lightweight buildings starting from the annoyance caused by a washing machine

Introduction

In contemporary lightweight construction, washing machines represent difficult equipment to insulate, due to their complex dynamic behaviors and the variety of phases during their working cycle. A unique solution is not yet available to tackle the washing machine sound problem in which the elements to consider are multiples: machinery (source), structure (receiver), coupling condition (connection) and annoyance perceived by users. The core idea of this project is to split the characterization of the problem into two binaries, merging technical solutions and user perception. The investigation took place is a two-storey masonry house in The Netherlands where dwellers were looking for a solution to tackle the annoyance caused by their washing machine which is installed on a wooden lightweight slab. As shown in Figure 1, the case study is a detached house in which the first floor (source room) is used as laundry while the room underneath (receiving room) is used as bedroom.

Figure 1:View of the house (left), laundry room (upper right), bedroom (lower right).

Measurements

A series of in-situ recordings and measurements were carried out (Figure 2). Sound in both the source room and the receiving room were measured when the washing machine has two different loads: 1) 4-7 kg dry/wet towels, resembling a common realistic load for the machine; and 2) 300g magnets, a load which allow good repeatability of measurements.

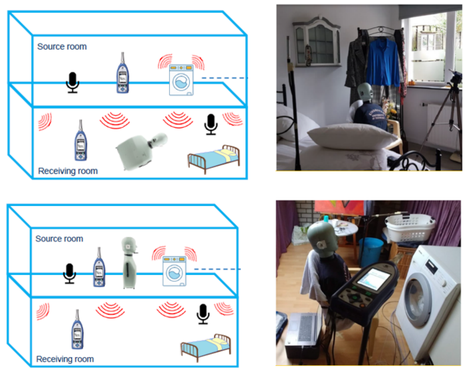

Figure 2:Recordings in the receiving and source room.

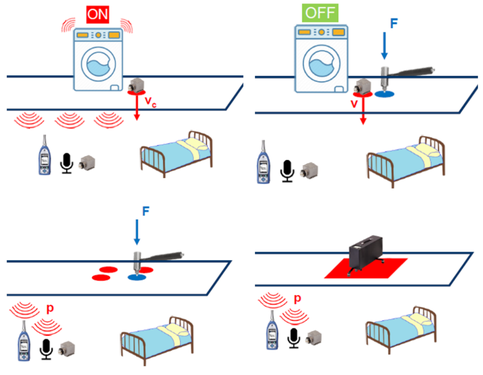

Figure 3:Measurements of operational velocities (upper left), coupled mobilities (upper right), and transmission function (lower left: force hammer, lower right: tapping machine).

Listening test

The recordings were then used in the listening test. For its setup, some clips from the binaural recordings of the spinning cycle with the towels load were extracted.

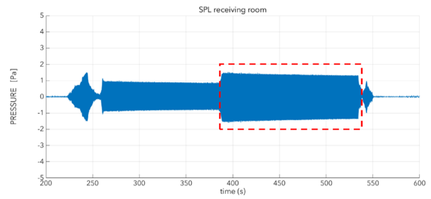

Figure 4:Spinning cycle, 1600 rpm.

The signals were digitally filtered to simulate different floor configurations when:

- adding an additional carpet finish;
- adding a floating floor;
- adding a floating floor and a suspended ceiling

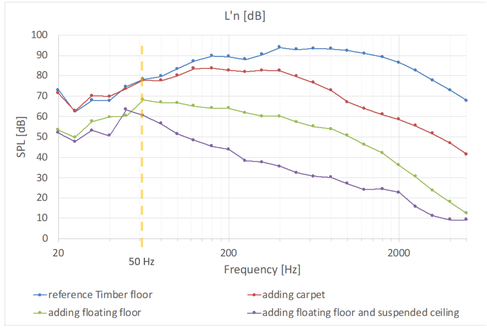

Figure 5:Filtering of recordings with three measured insulation profiles to generate samples.

The listening test set up:

- 26 participants (working at Siemens)
- Siemens TestLab – Jury Test application
- Binaural recordings from dummy head reproduced with headphones (Sennheiser HD 600)

Results

No significant difference was found between the two loading conditions in terms of velocity level of the floor and sound pressure level in the receiving room. The spinning cycle phase was identified as the loudest part. A frequency spectrum analysis highlighted a peak in the low frequency range, 120dB at 26.6Hz, which is due to the rotational speed of 1600rpm during the spinning cycle.

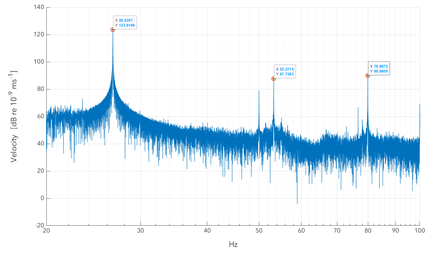

Figure 6:Velocity of the floor.

Decreasing annoyance was found when simulating the installation of a carpet, a floating floor or a floating floor with suspended ceiling. Similar trend is followed by the perceived loudness while when asking how thumbing the sound was the ratings made almost no difference between the three solutions.

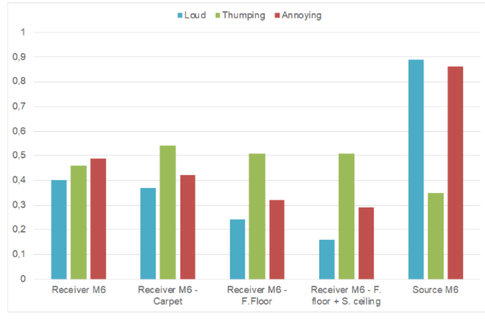

Figure 7:Listening test results.

Acknowledgements

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