Simulation of Acoustical Transfer Paths for Active Noise Control

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Introduction: Nowadays, reducing noise is one of the most challenging tasks in technical plants, especially if there are additional requirements regarding the costs of the technical solution. In a research project called “Low Cost Mechatronic Systems” members of the Bielefeld University of Applied Sciences investigated low cost active noise control systems for this purpose [1]. The research work was undertaken for a harvester cabin as an example for a typical situation where an operator might be exposed to annoying machine noise. In order to develop a low cost system an all encompassing model based design approach was chosen. Besides modelling the algorithms, the technical components (e.g. microphones, amplifier, loudspeaker) the knowledge of the acoustical transfer paths is important. Two test setups were chosen for basic investigations on modelling, simulation and validation.

Test setup 1: Tube made of PMMA

The first setup was a tube in order to keep the geometrical modelling constraints simple. For model verification and validation a measuring setup with an adjustable length of the tube was assembled (Fig. 1).

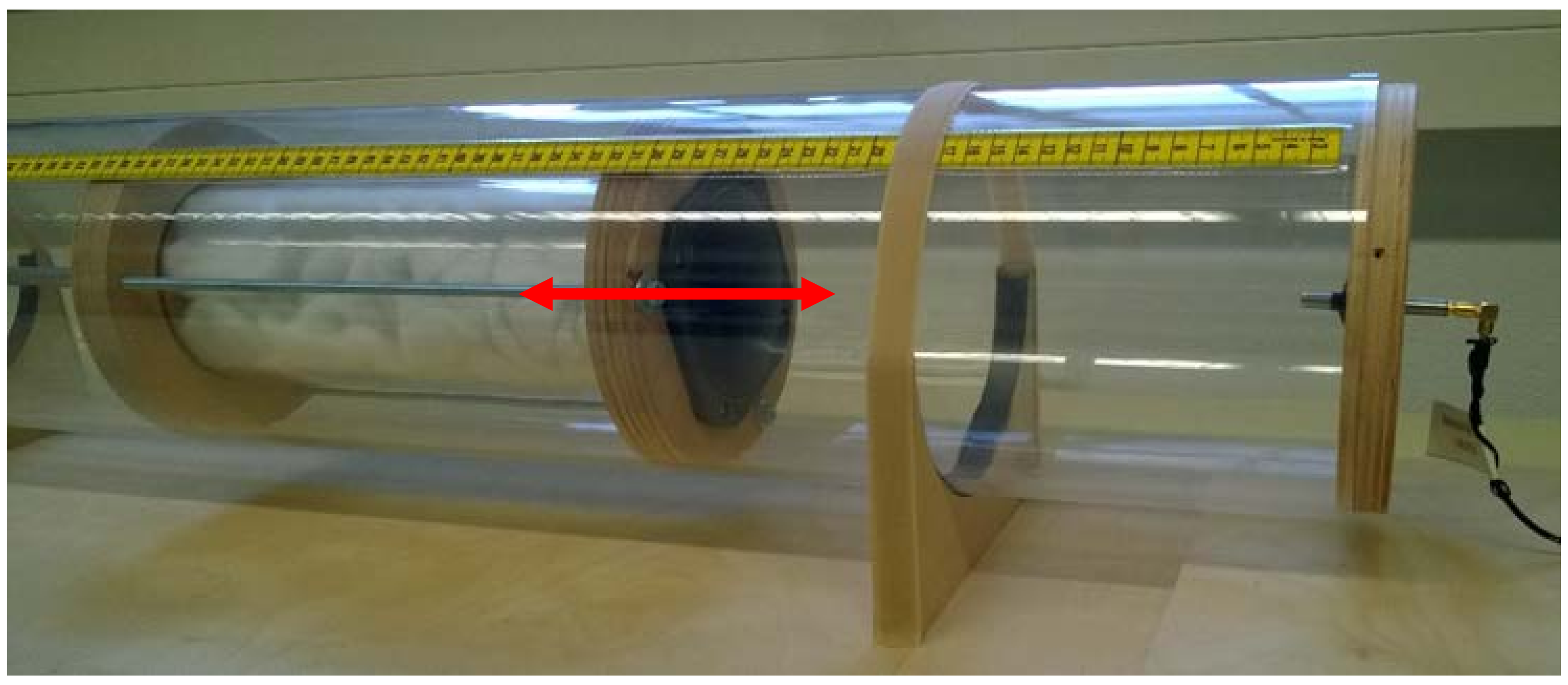

Figure 1. Tube made of polymethyl methacrylate (PMMA) with a movable speaker at one and a microphone at the other side of the tube.

For different lengths of the tube the system was stimulated by a speaker with sinusoidal signals with frequencies from 50 Hz to 5000 Hz while the sound pressure level (SPL) was measured by the microphone. The corresponding model was built in COMSOL Multiphysics using the pressure acoustics interface and the sound hard boundary conditions for the surfaces. The speaker was modelled in a few different ways (monopole point source, acceleration of a plane: flat, spherical or cone shaped) to analyze its effect on the SPL. The best results were reached, when a cone shaped plane was used for the speaker. The simulation results are in good agreement with the measured data (Fig. 2).

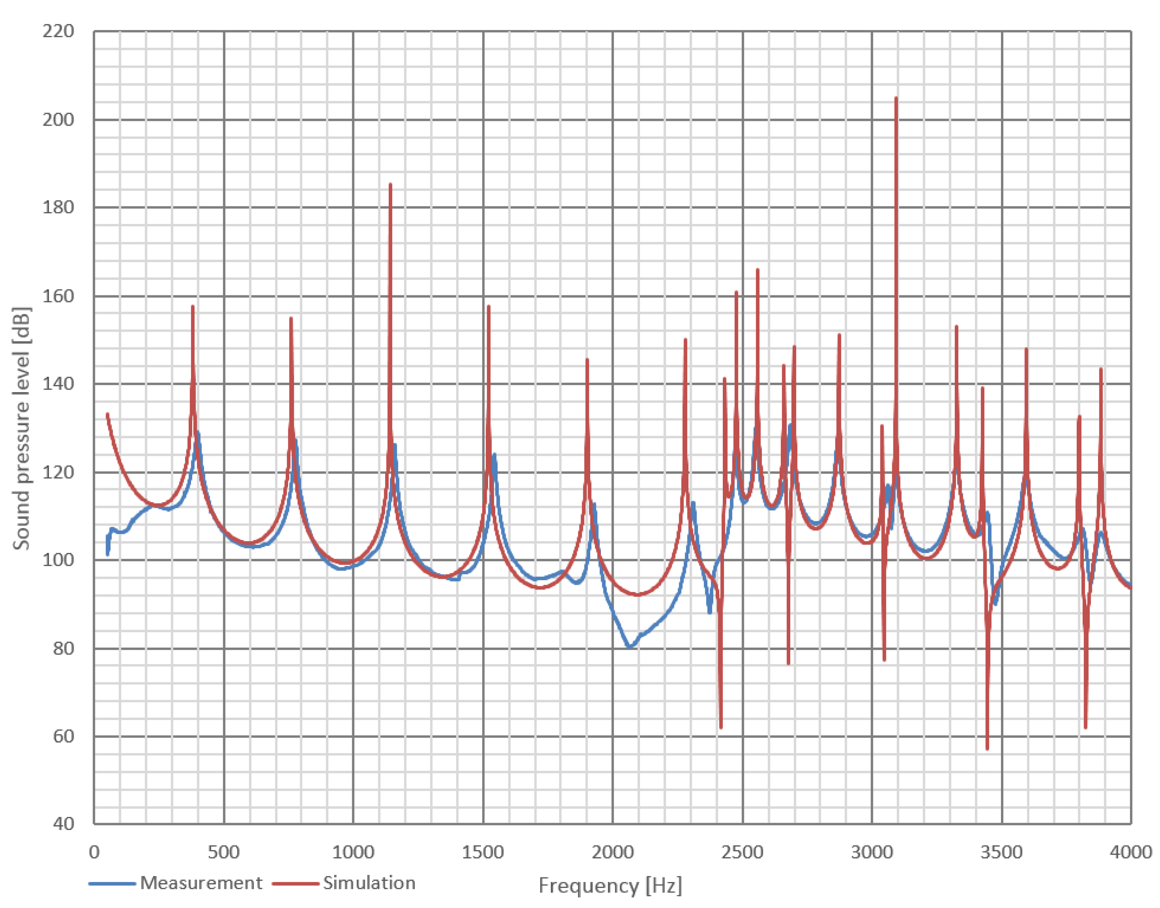

Figure 2. Comparison between measured data (blue line) and numerical results (red line). In this case the length of the tube was 450 mm.

Test setup 2: Harvester cabin

As an example for a real world application the interior of a harvester cabin was analyzed. A loudspeaker was used as a sound source inside the cabin and a microphone was placed at the listening position (Fig. 3a).

Figure 3. a) Harvester cabin. The red boxes mark the position of the sound source and microphone. b) Air domain for the COMSOL Multiphysics model.

For the COMSOL model first a reduced geometrical model of the interior air volume (Fig. 3b) was build from the CAD data. The loudspeaker was defined as a monopole point source and the windows as sound hard boundaries. Since damping effects have to be taken into account, the floor and the roof trim panel of the cabin as well as the absorbing and damping surfaces of the seat were modeled using the porous layer option in the impedance boundary condition [2]. The simulation results using this simple approach are encouraging (Fig. 4). The model can be improved by adding more geometrical details (especially for the loudspeaker) and using more advanced models for the porous material.

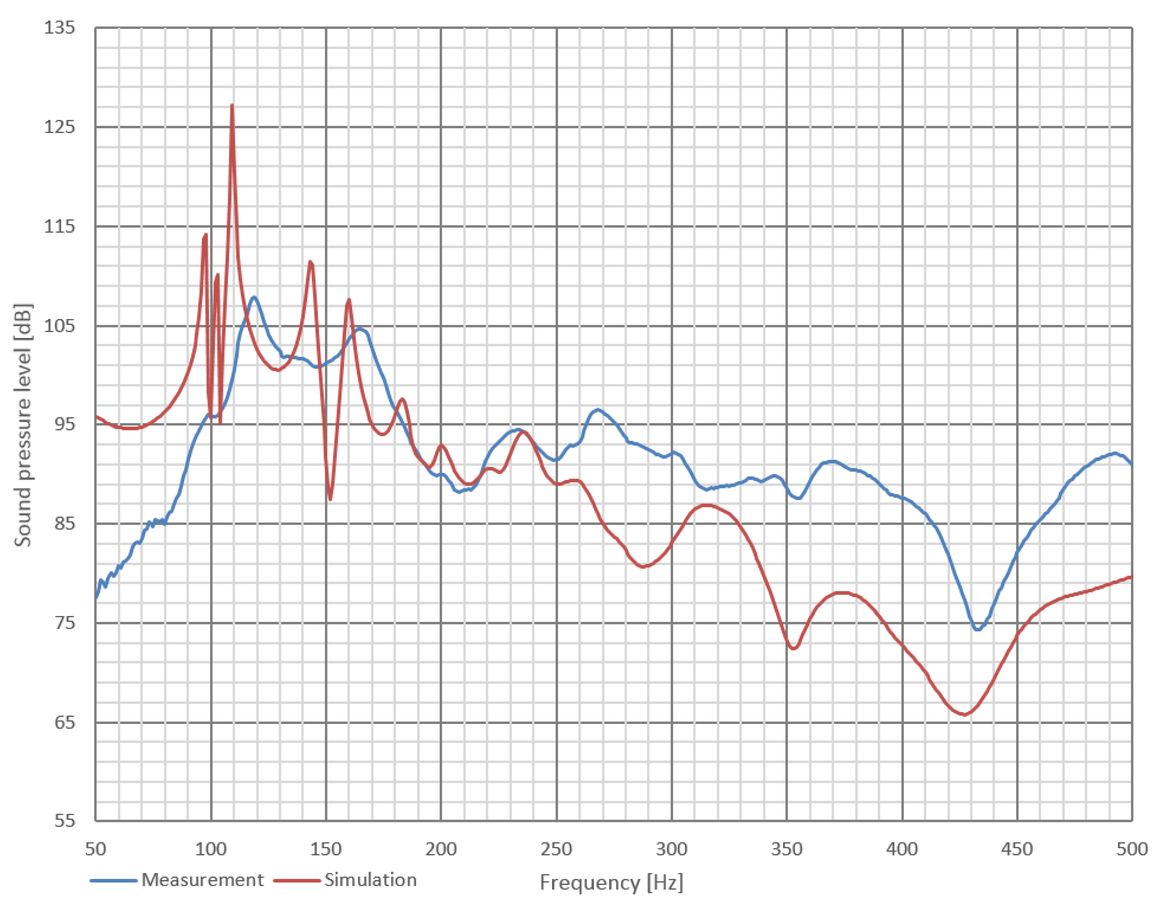

Figure 4. Comparison between measured data (blue line) and numerical results (red line). The porous material here was modeled with the semi empirical Delany-Bazley-Miki model [2].

Conclusions: The knowledge of the acoustical transfer paths in active noise control systems is very important for the performance of the system. Unfortunately, simulation is challenging since even simple configurations require comprehensive experience in physics and modelling. However, the first results presented here are encouraging. Future investigations will deal with more advanced models as well as the export of dynamical systems models (e.g. state space models) via model order reduction if possible.

References:
[1] Kaupmann, D., Lehmann, T. Waßmuth, J.: Methodische Entwicklung kostengünstiger Störschallkompensationssysteme, VDI Fachtagung Mechatronik, 2015
[2] COMSOL Multiphysics, Acoustics Module – User’s Guide, V5.1, 2015