A new method to describe valve noise

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Introduction

Valves in plumbing systems often lead to complaints about noise pollution in adjacent rooms. While in the past, fluid-borne sound, which transforms to structure-borne sound in the pipe work, has been regarded as the single most important source for acoustical emission of water taps, increasingly structure-borne sound produced within the valve is recognized as an equally or even more important noise component [1]. However, currently there aren't standardized methods for testing valves as sound sources for structure- and fluid-borne sound [2]. Noise control engineers need a tool to improve the sound emission of valves, that includes all components of acoustical excitation and deliver results to predict their performance in buildings.

Approach

Before a new standardized measurement method can be applied, the underlying physical phenomena need to be investigated thoroughly. The emission of a valve can be described on a power basis using mobilities and free velocity [3]:

$$\overline{P} = \frac{1}{2}\frac{\left|\overline{v}_{fS}\right|^2}{\overline{Y}_S} \cdot \frac{\overline{Y}_S + \overline{Y}_R}{\left|\overline{Y}_S + \overline{Y}_R\right|^2} \qquad (1)$$

The first term of the equation is the so called source descriptor, which is an independent function of the source. The second term, the coupling function, gives the degree of matching between a source and a receiver. Measurements to obtain the structure-borne power have been undertaken on a single lever mixer, as can be seen below.

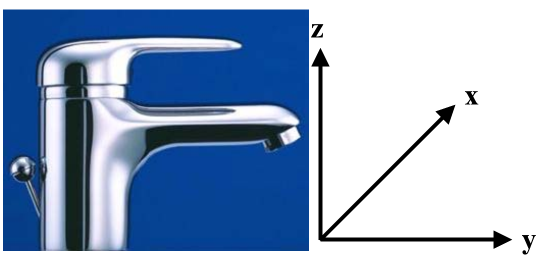

Figure 1: Single lever mixer, similar to investigated one.

In general six degrees of freedom need to be considered to obtain the total power of a source. For the single lever mixer, three excitation components can be neglected, which are the moment around the z-axis (weak coupling between basin and tap) and the forces in x- and y-direction, because of the low in-plane mobilities of the basin in these directions.

Source and receiver mobility Y_S / Y_R

Point mobility measurements of different single lever mixer taps, in this case in the z-direction, showed that they are mass controlled in the whole frequency range of interest. Therefore mobility measurements of similar taps are not likely to be necessary in the future, since the values can be obtained by calculation.

In a next step the receiver mobilities have to be obtained, which are the force and moment mobilities about the hole where the tap is connected to the basin.

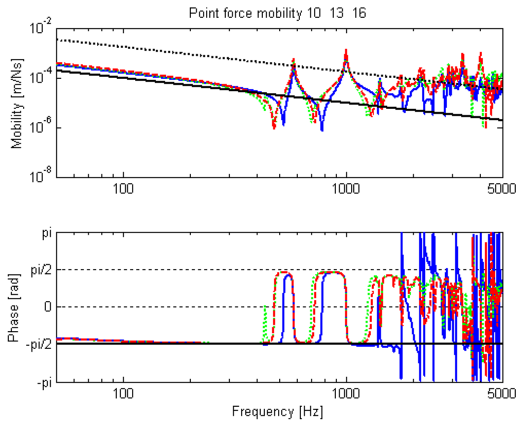

Figure 2: Results for point mobility of the tap hole (upper figure shows magnitude, lower the phase)

The mount point is mass-controlled up to about 400 Hz followed by a stiffness-controlled region and then the resonance's. The moment mobilities are shown in Figure 3, which were obtained, using a moment actuator to a design by Petersson [4].

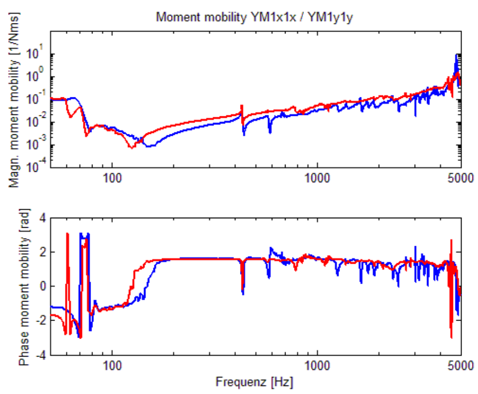

Figure 3: Results for moment mobility of the tap hole (upper figure shows magnitude, lower the phase)

Free velocity v_{fS}

The remaining component for calculating the power was the free velocity of the source at the contact with the receiving structure which can be measured relatively simply

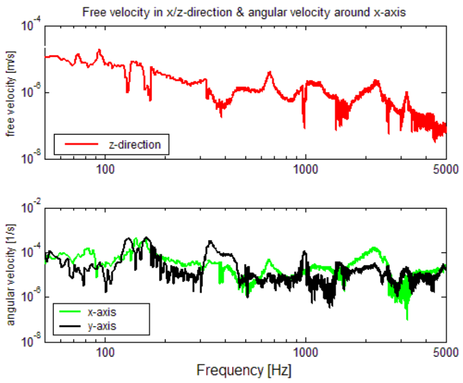

Figure 4: Free velocities of the tap in operation, fully open (upper shows translational, lower figure shows angular velocities)

It is now possible to calculate the contributions of each component of excitation and thereby neglect the least significant contributions to the total emission.

Fluid-borne sound intensity

Fluid-borne power can be included with the structure-borne power in characterising the source on a power basis. In typical pipes in housing only plane waves can propagate in the frequency range of interest since the cut-off frequency for higher order acoustic modes is well above 10 kHz. The fluid-borne emission can be obtained by intensity techniques, because a semi-infinite condition can be obtained either by an Anechoic Liquid Termination or by using a flexible pipe. The latter has been chosen in this study, so that the fluid-borne sound power can be obtained as a product of sound intensity $I_{\Delta f}$ multiplied and cross-sectional area.

$$I_{\Delta f} = -\frac{1}{2\pi\rho\Delta r}\int_{f_1}^{f_2}\frac{\mathrm{Im}[G_{AB}(p_A, p_B, f)]}{f}df \qquad (2)$$

Since the measurements have to be conducted for pressure of the order of 0.5 MPa, the pressure transducers had to be mounted into a copper pipe and a flexible pipe was attached to this rigid pipe as non-reflective termination. However because of reflections occurring at the connection of the soft and rigid pipe, the stiffness of the flexible pipe had to be adapted to the value of the copper pipe by use of reinforcing metal rings. The rings were attached with increasing distance from the transition zone. The intensity is obtained from the cross-spectral density between two closely spaced pressure transducers, mounted flush with the pipe internal surface. Measurement were undertaken for both connected pipes (hot and cold water).

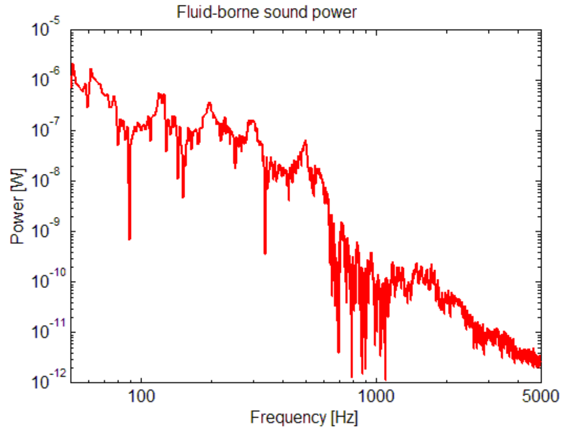

Figure 5: Results for fluid- and structure borne sound power.

The fluid-borne sound power is of importance up to about 700 Hz, but than sharply drops of and can be neglected for higher frequencies.

Concluding remarks

It has been shown that water taps can be described using the free velocity and mobility approach to obtain the structure-borne sound power for each component of excitation. The method allows a hierarchy of excitation powers from which the least important can be neglected. This is likely to lead to significant data reduction. It has been shown that sound intensity measurements in a pipe is an appropriate method to obtain the fluid-borne sound power directly.

As a next step it is planned to consider the basin and tap as a combined sound source, using the same approach as described above. Results for the structural sound power will than be compared with measurement results using the reception plate method.

Early indications are that the measurement methodologies described should lead towards a practical method of test and rating.

References

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