Monopole Breathing of the Organ Pipe Body

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Introduction

The choice of pipe material and its wall profile is an important parameter for organ builders, which influences the sound quality. Early works on this subject do not adhere the same idea [1, 2]. The pipe wall was modelled as a perfectly stiff tube providing well-defined boundary conditions for the air column resonances. During recent investigations an elliptic oscillation of the pipe cross-section was reported. Vibration patterns can be described as a planar quadrupole [3]. Using a new measurement technique, the four pipes were investigated, regarding the oscillation of the pipe resonators cross section. From these experiments, it was observed that the pipe not only shows a quadrupole oscillation but also a monopole oscillation.

Monopole breathing

The open flue organ pipe is an acoustic $\lambda/2$-resonator having longitudinal resonances of the air-column resulting to standing waves inside the pipe. The sinusoidal pressure distributions may lead to a change in cross-section 2. This "breathing" phenomenon is superimposed onto the known elliptic oscillation. The probable oscillation for one period of the pipe cross-section is shown in Figure 1, where the dimensions are exaggerated.

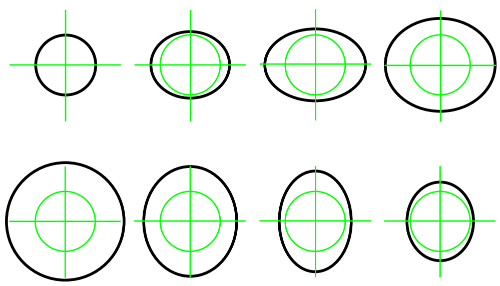

Figure 1: The elliptic oscillation of the organ pipes cross-section, superimposed by a monopole breathing. Dimensions are exaggerated.

Investigated pipes

Four flue organ pipes with identical diapason (principal) scaling were manufactured by Schuke Orgelbau Potsdam. The pipes consist of a resonator of 590 mm length and 44 mm inner diameter. The foot length is 160 mm. The tuning of all pipes is around 263 Hz. Two different groups of pipe materials were investigated, one made of 66:33 tin-lead alloy and the other made of 95:4-tin-lead alloy. Within the two different groups of material, two of the pipes were made from plane-parallel metal sheets, leading to a constant wall profile (thickness of 0.7 mm). The two other pipes were made of wedge-shaped metal sheets giving them a conical wall profile with a decrease in thickness from 0.7 mm at the middle of the pipes to 0.4 mm at the open end.

Measurements

The measurements were carried out with piezoelectric polymer sensors. These kind of sensors give an electrical signal when stretched or pressed. The sensor is compliant and its voltage signal is proportional to its change of length [4].

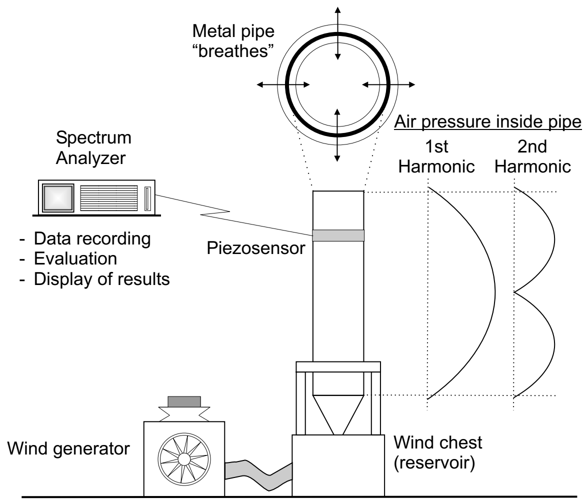

Figure 2: Experimental setup for the detection of circumference changes ("breathing") of organ pipes by a piezoelectric sensor film.

The polymer film was wrapped around the pipe bodies applying slight tension. The piezoelectric sensor had a size of 2.5 cm × 14 cm and a thickness of 25 μm. Measurements were performed on all of the pipes at locations 2 cm apart along their lengths, resulting in 25 data points for each pipe.

Results and Discussion

If the phenomena of breathing due to the air pressure distribution of the air-column resonances exists, a trend following the pressure signal could be expected as shown in Figure 2. However, it must be kept in mind that the pipes made from wedge-shaped metal-sheets may additionally show an increase of the investigated breathing towards their open end, because of the decrease of wall-thickness between the pipe middle and open end.

In Figure 3 the results of the pipe made from plane-

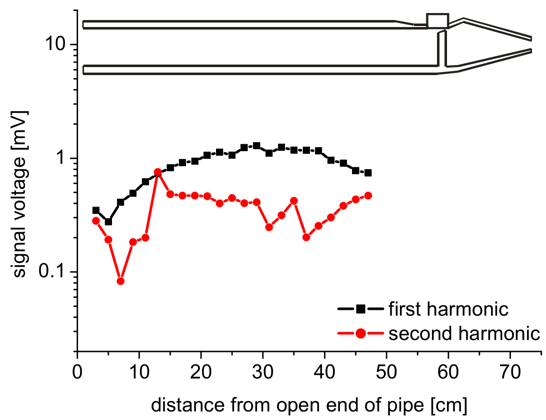

Figure 3: Change of circumference of a pipe made from plane-parallel metal-sheets of 66:33 tin-lead alloy.

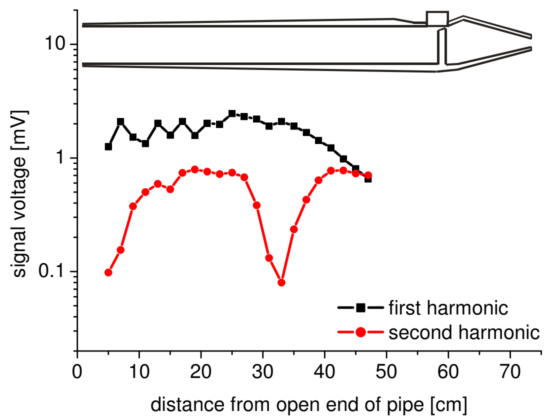

Figure 4: Change of circumference of a pipe made from wedge-shaped metal-sheets of 66:33 tin-lead alloy.

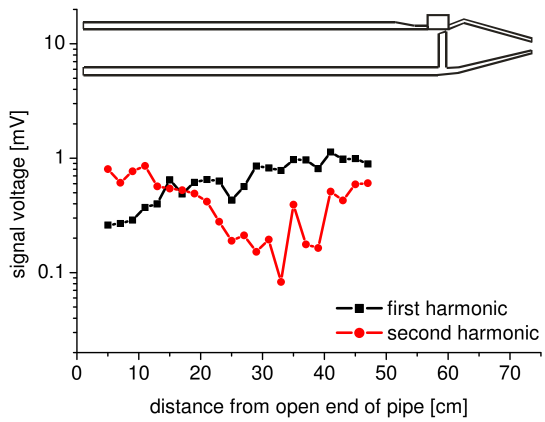

Figure 5: Change of circumference of a pipe made from plane-parallel metal-sheets of 95:4 tin-lead alloy.

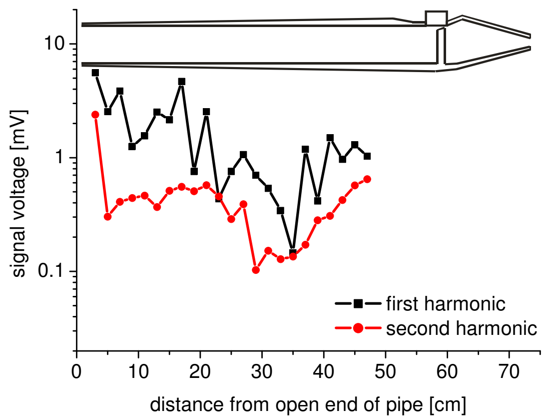

Figure 6: Change of circumference of a pipe made from wedge-shaped metal-sheets of 95:4 tin-lead alloy.

parallel metal-sheets of 66:33 tin-lead alloy are observed. For the first harmonic a very good coherence to the first air-column resonance is detected. The second harmonic also shows minima at the end. The expected minimum in the middle of the pipe is not clearly visible. The results of the pipe made of the same 66:33 tin-lead alloy, but with a wedge-shaped (conical) wall profile are shown in Figure 4. Here the second harmonic clearly shows minima in the middle and at the both ends of the pipe. The first harmonic is a superposition of the change of circumference due to the first air-column resonance and the decrease of wall-thickness from the middle towards the open end of the pipe.

The results for the pipes made of 95:4 tin-lead alloy are in Figures 5 and 6. The breathing of the pipe made from plane-parallel metal-sheets matches very well to the pressure distribution of both harmonics. The pipe made from wedge-shaped metal-sheets clearly shows an increase in the breathing towards the open end, which does not agree with the air pressure distribution.

Conclusions

It can be recapitulated that at the investigated organ pipes a breathing occurs, depending on the pressure distribution of the inner air-column resonance. The thickness of the resonator wall influences the strength of this breathing phenomenon. More research should be done in order to discern the effect of the material on the breathing.

References

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