SOUND FREQUENCY SPECTRUM VERSUS LENGTH OF CLOSED ORGAN PIPES

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Abstract: In the history of the pipe organ, we can observe different pitch standards, which are connected to the musical aesthetics of the time or the intentions of the builder. These differences are often noted based on provenance, meaning the origin or location where the organ was made. Each historical period had its own aesthetic and technical requirements, which were reflected in the tuning and pitch of the organ. The retuning of organs occurred mainly at the turn of the 19th and 20th centuries, with a change in the intonation of these instruments. In the territory of Slovakia, this change primarily involved a shift from the original pitch of approximately 412 Hz to 440 Hz. This change, of course, affected mainly older instruments and was part of a broader process known as the romanticization of organs. This process marked a departure from the original sound ideal of the Baroque period and a transition to the romantic sound ideal. Study examines the limitations of tuning height for wooden closed organ pipes, specifically the Copula stop, which has undergone significant retuning and intonation adjustments in the past. By using a gradual retuning method, the research analyses the sound's frequency spectrum to determine the optimal tuning range. The results show that significant changes in tuning height can lead to substantial degradation in sound quality. The research emphasizes that ill-considered restorative modifications to the air column length of these organ pipes lead to undesirable and permanent changes in the instrument's sound characteristics.

Keywords: Organ pipes, wood, sound, tuning, restoration.

1. INTRODUCTION

Tuning of historical organs and the related intonation of pipes is one of the most serious problems in the restoration of historical organs. In the past, these instruments were tuned to different pitches, so there was no single standard. Historically, we record a range from below 400 Hz to over 500 Hz [1, 2]. Since these instruments were often rebuilt over the centuries, these changes also affected their tuning and intonation. To properly assess this issue, it is important to know the historical and musical-aesthetic context of the stylistic period as well as the acoustic possibilities of the stops and pipes [3].

The fundamental problem is whether a change in tuning results in an undesirable change in the original sound quality of the modified instrument. Our previous research on the wooden pipe organ revealed a clear finding that the wooden pipe organ functions optimally (from the point of view of the sound spectrum) for a certain height of the air column. This height can be changed (while maintaining sound quality) only within a relatively narrow range. Exceeding this range in both directions leads to a significant depletion of the spectrum and thus to an undesirable change in the sound quality of the generated tone. The study captures the development of the spectra of generated tones with extreme changes in the height of the air column. We focused on the wooden Copula stop, which was significantly retuned, and intonation adjusted in the past, including in Slovakia [4].

2. METHODS

For the purposes of the experiment, we created a wooden organ stopped pipe with an overlength, which was subsequently gradually retuned. This tuning modification aims to provide information on the actual range of possible tuning within the context of the specific scale of the given pipe. This simulation aims to answer the question of whether there was a change in tuning at the turn of the 19th and 20th centuries that fundamentally affected the sound character of wooden stopped organ pipes. We retuned the experimental organ pipe in one-centimetre increments, measuring the sound frequency spectrum at each step. For recording the sound frequency spectrum of the pipes, methodology developed by our research team was used. The method for recording the sound frequency spectrum is based on two main parts of the technological equipment (Fig. 1).

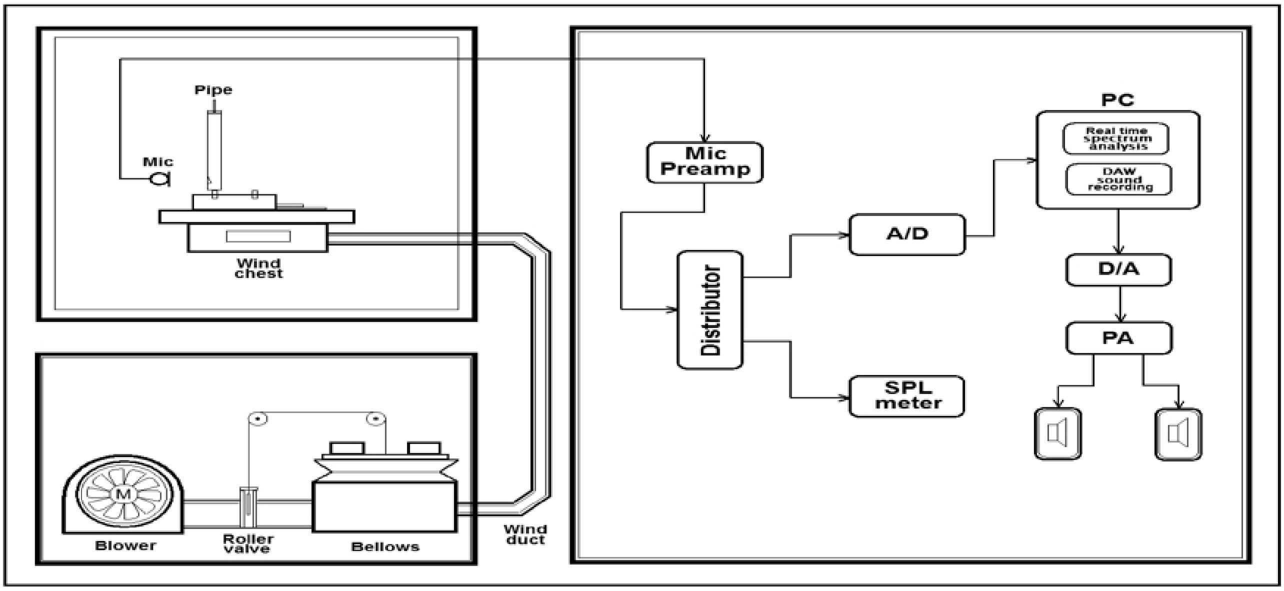

Fig. 1: Measurement apparatus scheme

The primary part consists of tone excitation of individual pipes, provided for by the experimental wind-chest connected to bellows, pressure regulator and blower (Laukhuff). The secondary part is used for evaluating the sound frequency spectra in the real time using the acoustic software ARTA. DAW software Samplitude 11 is installed to the PC a well, and its task is to record and edit signals from individual pipes that are being processed. Such configuration enables us to match every evaluated sound spectrum to the corresponding sound signal. The signal from the measurement microphone (Mini SPL), recording the sound of the organ pipe in question, is amplified in the microphone preamplifier, and from its outlet it proceeds to the distributor, where it is divided into two ways. The first one leads to the A/D converter, and the signal digitalised this way is subsequently evaluated in the acoustic software. The signal is then recorded in the sound programme, and a corresponding sound file is created to the analysed sound spectrum. The second signal way leads from the distributor to the acoustic analyser used for evaluating the sound pressure level (SPL).

During the experiment, following parameters were set for the RTSA: sample frequency 44.1 kHz; the number of samples in the measured window 8,192; weighting window “Hanning” and linear averaging from 100 samples. During the entire experiment, a constant pressure of 60 mm H_2O (1 mm H_2O = 9.8 Pa / 62 mm H_2O = 607.6 Pa) was kept in the experimental organ wind-chest. Length of the air column of experimental pipe was 57 cm and area of pipe was 6.5 cm^2 (2.1 x 3.1 cm). The measurement was carried out from the 55-centimeter mark with a 1-centimeter increment down to 5 cm (Fig. 2).

Fig. 2: Experimental organ pipe

3. FINDINGS AND ARGUMENT

Based on the measurement results, we have identified several locations that represent significant sound changes (Fig. 3).

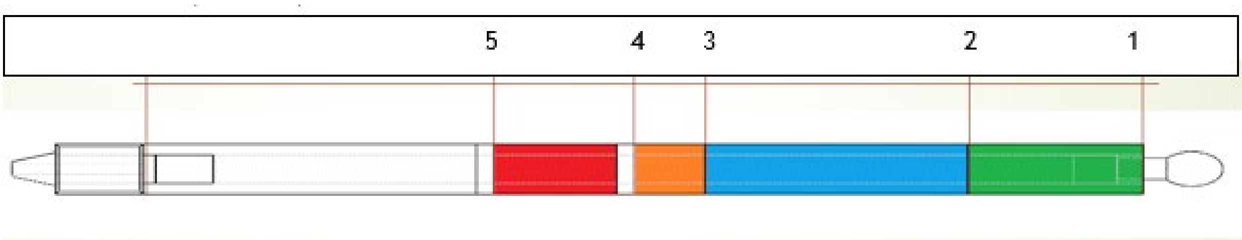

Fig. 3: Locations with significant sound changes

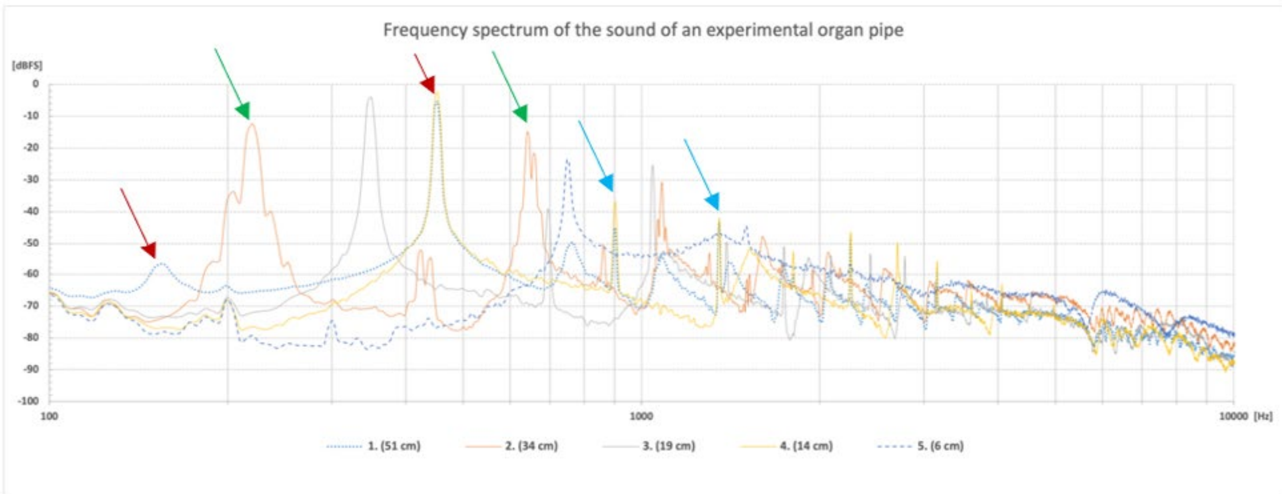

Fig. 4: Frequency spectrum of sound of an experimental organ pipe

Measurement Point 1 – Measurement at air column height of 51 cm: After analysing the frequency spectrum of the sound, we see that the fundamental component is significantly suppressed, and the third harmonic component dominates the sound (see the red arrow in Fig. 4).

Measurement Point 2 – Measurement at air column height of 34 cm: At this measurement stage, there was an increase in the first harmonic component, balancing with the third (see the green arrow in Fig. 4).

Measurement Point 3 – Measurement at air column height from 19 cm to 15 cm: The pipe operates in an optimal mode, as evidenced by the largest representation of higher harmonics in the spectrum, with this range being approximately a major third. This is for our experimental pipe, this range is (350 – 450) Hz, which represents 435 cents (see the red arrow in Fig. 4).

Measurement Point 4 – Measurement at air column height of 14 cm: The pipe no longer operates in an optimal mode, and the second harmonic begins to even prevail over the third harmonic component. The second harmonic is significantly suppressed in closed pipes operating in an optimal mode (see the blue arrow in Fig. 4).

Measurement Point 5 – Measurement at air column height of 6 cm and lower: In this range, the pipe has lost the ability to generate a real tone (compare the spectrum).

4. CONCLUSION

The study clearly showed that wooden closed organ pipes of a given cross-section cannot be arbitrarily shortened or lengthened without negatively affecting their sound quality [5]. Tuning adjustments of these pipes can be made within a very narrow range (interval) of a major third to avoid significant deterioration of the sound spectrum. Inconsiderate interventions in organ pipes for the purpose of changing tuning can lead to a significant deterioration of the sound quality of the instrument and potentially cause irreversible damage. The study provides important knowledge about acoustic principles that are essential for better restoration and tuning of historical organs [6, 7]. For the relevance of the research, it will be necessary to expand this knowledge to include whistles with other intonations.

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He was born in 1993 in Banská Bystrica. He graduated from the Faculty of Electrical Engineering and Information Technology of STU in Bratislava in 2018. He completed his PhD studies at the same faculty in 2022. His specialization is electrical power engineering with a focus on the field of renewable energy sources. He is engaged in research and managing the operation of the photovoltaic power plant in the smartgrid in the Slovak Academy of Sciences in Bratislava. It focuses on the thermal management of principal parts of energy resources, the accumulation of thermal energy and the use and recycling of waste heat from industrial factories. Together with the research team, he participates in the development of thermal batteries with the unique technology of aluminum foam and PCM wax. He is the author or co-author of more than 26 scientific articles, 6 of which are registered in the Scopus or WOS databases.

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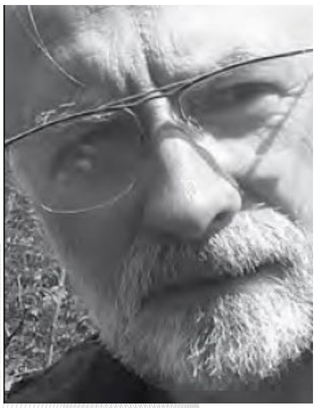

Štefan Nagy

Štefan Nagy was born in March 1962. Studied and graduated at the Slovak Technical University in 1985. In the same year, he started to work at the Slovak Television as a sound technician and later as a chief of dubbing studio and lastly as a chief of sound department before his leaving of Slovak Academy of Sciences in 2003. His current work in Institute od Musicology is focus on historic pipe organs. Besides that, he is also lecturing at several universities such as: Pan-European University (SK), Academy of Performing Arts (SK) and Tomas Bata University in Zlín (CZ).