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NEW TIMBRES OF ST. CATHERINE'S CARILLON

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St. Catherine's carillon, the largest instrument of its kind in Poland, deserves special attention due to its particular acoustic properties. They were investigated in detail and relevant results reported earlier. Recently, the acoustic possibilities of the carillon and its sound repertory has been significantly augmented thanks to twelve new bells added to the 37 existing so far, and the newly installed keyboard, enabling the carillonist direct exciting of bell sounds. Thanks to the enlarged carillon sound scale and the direct mechanical coupling of keyboard keys to bells, the carillonist gains an enriched possibility of creating new chords and complex timbres resulting in several bells being struck either together or subsequently. These timbres were actually investigated with the same method and equipment as applied during the former investigations, mentioned above. The selected carillon sounds were recorded and the recorded samples analyzed digitally by means of dedicated computer software programs. The results confirm the high quality of the enlarged part of the carillon, comparable to the very high quality of the instrument existing so far. Conclusions concerning particular properties of the St. Catherine carillon are presented at the end of the paper.

1. Introduction

St. Catherine's church, with its monumental belfry-tower, is of important historic value. The tower the construction of which began in 1450 was, for political reasons, not completed until the years 1484 – 1486. In 1634 the gothic roof of the tower was transformed into a beautiful baroque copula, designed by Jacob van den Block [7]. Its exact reconstruction can once more be admired to-day (see Fig. 1).

Much more is to be admired inside the tower. The most spectacular, or rather "auricular", are St. Catherine's bells. Their ringing sounds are well audible over the whole area

Fig. 1. St. Catherine's belfry tower dominating the Old City roofs.

of the Old City of Gdańsk. Not only do they strike hours and sound peals, but also play melodies, thanks to an ingenious facility called the "carillon". The St. Catherine's carillons had a long and interesting history. The one, existing at present, was reconstructed thanks to an initiative of Mr. Hans Eggebrecht, who in 1989 offered the instrument as replacement of the previous one destroyed during the war. The instrument which then consisted of 37 bells was equipped only with an automatic play facility. This instrument, being almost a unique carillon in Poland, underwent extended acoustical investigations. In the meantime, their results were published extensively [1, 4 – 6].

The need to return again to the subject of St. Catherine's carillon arose, however, due to the fundamental improvement of the acoustic qualities of the instrument. In 1998, thanks to financial support of the Gdańsk municipality and individual donators, a further 12 bells were added. A complete mechanical action system was also installed, enabling manual playing on the instrument from a traditional keyboard (Fig. 2). Thus, now, the instrument, with its 49 bells, has become the greatest concert-carillon in Central and

Eastern Europe [7]. Acoustic properties of such carillon deserve to be well known among sound engineers interested in musical instruments. It is the purpose of this paper to supply relevant data and add notices concerning instrument quality.

Fig. 2. St. Catherine's carillon keyboard (the chromatic scale of 49 keys and the transmission rods are well visible, the pedal keys are suspended below).

One more item to be admired inside St. Catherine's tower should be mentioned: the Museum of Tower Clocks [7]. They also enter into the scope of interest of sound engineers, due to their ringing facilities for hour striking, which use clock bells particularly shaped, to produce the sound of a particular clock-timbre. This subject, however, needs separate treatment.

2. Results of earlier studies

As mentioned above, the acoustic properties of St. Catherine's carillon sounds were investigated by the present writers, a few years ago, in order to become acquainted with this special type of musical instruments, and, among others, to check the quality of the internal and external tuning of carillon bells. The results presented in part one of Table 1, prove a very good quality of the 37 bells investigated, made by the renowned

Table 1. Tuning deviations of the St. Catherine's carillon (in cents).

	Hum	Prime	Third	Fifth	Octave	Tenth	Twelfth	Upper Oct.
Part one:								
1. c′	7	1	3	−2	1	−10	9	68
2. cis′	−2	2	4	23	4	−21	11	73
3. d′	14	0	3	50	3	21	12	75
4. dis′		6		29	4	−28	9	75
5. e′	1	5	5	4	−9	−19	16	80
6. f′		5	0	7	8	−60	16	82
7. fis′	9	1	4	−42	3	6	10	73
8. g′	−1	3	5	−63	3	−41	18	86
9. gis′	−3	−1	4	17	3	43	14	72
10. a′			4	26	3	43	14	78
11. ais′	5		6	17	5	49	18	86
12. h′		7	4	12	3		18	86
13. c″	4	3	5	13	4	47	12	55
14. cis″	3	3	3	19	4	62	9	67
15. d″	3		4		4	62	14	77
16. dis″	2	4	2	5	5	−31	13	75
17. e″	5	4	5	−2	6	−58	13	74
18. f″		3	5	13	4	−14	10	70
19. fis″		4	4		3	−26	7	64
20. g″	4	7	6	0	6		11	67
21. gis″		3	3	4	5	−27	14	77
22. a″	2	4	5	16	5	−36	12	72
23. ais″		4	6		6	−29	13	82
24. h″								
25. c‴	2	3	3		4		−1	11
26. cis‴	3	4	9	27	5	15	1	52
27. d‴	4	3	4		6	27	2	79
28. dis‴	3	4	4		6	−35	−6	40
29. e‴	3	6	5		6	42	−3	
30. f‴	3	4	6		4	−10	−10	32
31. fis‴	3	4	−7		2	−66	−26	
32. g‴	5	4	6		6		−14	21
33. gis‴	6	3	11		4	44	−23	3
34. a‴	5	5	6		−4		−22	3
35. ais‴	5	6	8		4			
36. h‴	5	4	15		4	6	−36	76
37. c⁗	3	3	−7		−2		−36	−22

Table 1. [cont.]

	Hum	Prime	Third	Fifth	Octave	Tenth	Twelfth	Upper Oct.
Part two:								
38. cis''''		−4	7		−5		−42	
39. d''''	−4	−3	6		−5		−47	
40. dis''''	−4	−4	−3					
41. e''''	1		13		−2	30	−60	
42. f''''	−4	−7	6					
43. fis''''	−2	−5	15		−4			
44. g''''	−2	−4	10					
45. gis''''	21	−2	7		−3			
46. a''''		−2	8		−3			
47. ais''''	−2		12		−1			
48. h''''	0	2	11					
49. c'''''	−4	−2	7					

Blank spaces denote lack of a measurement result.

Dutch foundry Koninklijke Klokkengieterij Eijsbouts in Asten, and of their successful installation by this factory, in St. Catherine's belfry.

Recordings of the carillon sounds were then done electroacoustically *in situ* within the belfry. Single sounds were excited using a MIDI keyboard, switched into the instrument control panel, from whence, electromagnetically driven hammers were actuated at every bell. The recording microphone was situated on a gallery, on a level with the bells, and sounds were recorded with a digital recorder MZ 1; only one channel being used for further processing and analysis. Recorded sounds were analyzed in the laboratory using either professional software (Sound Designer II) or specially designed own program. More details on the then used equipment and method applied are contained in the above mentioned own publications. Special questions were also studied on the example of St. Catherine's carillon, in particular those concerning peculiar properties of the sounds of large, swinging bells [6].

3. Recent investigation

Basically, the same method was used as before, i.e., sounds of 12 newly installed bells (Fig. 3) were recorded and analyzed, yet, a different sound excitation manner was applied. Instead of the MIDI keyboard the new installed manual keyboard was used. Consequently, the sound intensity obtained may differ slightly for particular notes.

The results obtained are presented in part two of Table 1.

It should be pointed out, however, that the enlarged carillon became an almost new instrument, with new timbres available. Thanks to the installed facilities for manual playing it now exhibits many new acoustic properties.

Fig. 3. The twelve, new installed carillon bells (control levers of mechanical action are visible).

First of all, they are due to newly installed clappers and hammers. When previously, all 37 bells were struck from outside by electromagnetically driven hammers, now, they are struck by mechanically pulled clappers (Fig. 4), or hammers for the four largest swinging bells. These clappers are hung excentrically within the bell mouth in order to reduce the idle motion of action wires and manual keys. Every fixed bell is equipped with an inner rod enabling installation of a spring, which prevents unintended manifold strokes (oscillations) of the clapper against the bell body. This facility was necessary for a few bells only, as for others the clapper masses were sufficient to prevent any unwanted oscillation.

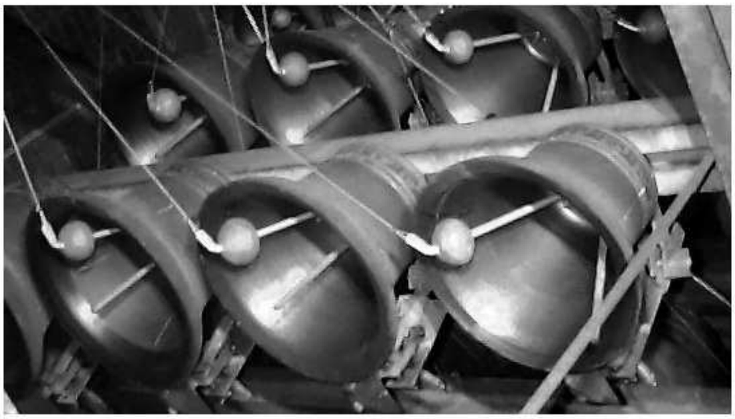

Fig. 4. Carillon bells equipped with a new mechanical system of clappers and pull wires (electromagnetic outer hammers are also visible).

Each of the four largest bells, equipped primarily with clappers (for swinging peals) and electromagnetic hammers (for automatic play, steered from the digital memory) now received an additional hammer, driven by a mechanical action wire (Fig. 5). Thus, hammers are controlled directly from the keyboard levers, using hand or foot strokes of appropriate energy.

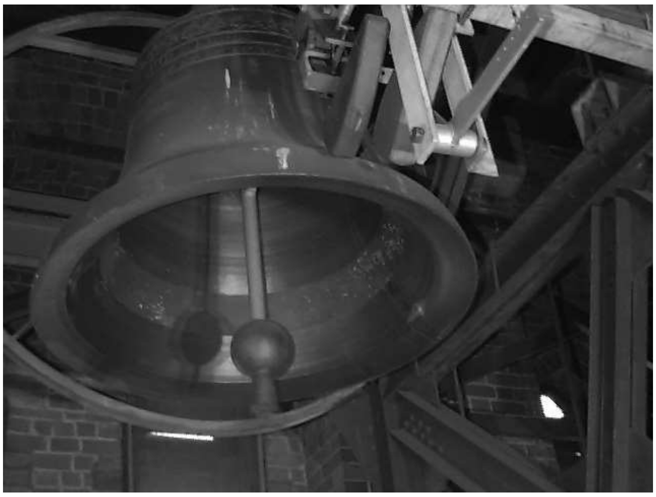

Fig. 5. The largest bell (swinging) with a traditional clapper and two outer hammers: mechanic and electromagnetic one.

The system of mechanical action allows the player to employ variable dynamics of notes played, in contrast to the case of automatic play. Variable dynamics cause variations of timbre, i.e. of spectral content of particular notes. This makes the investigation of the timbre of carillon sounds, which depends on the sound excitation level, much more difficult.

A totally different excitation tool (clapper from inside, vs. hammer from outside) implies a further need for a comparative study of bell sounds excited in both manners mentioned. Although such comparative studies were reported in the literature [3], they were restricted to experiments in laboratory conditions. Thus it seemed reasonable to check and compare results obtained from the existing instrument.

Mechanical action gives the player total freedom in creating time sequences of notes or chords, unattainable e.g. with the electromagnetic action steered from a MIDI system keyboard. Every execution of a piece of music is a genuine one, in contrast to sounds produced by the automatic play system. Thus, music played by a well trained carillonist becomes a true concert activity [2].

4. Subjective assessment

Objective analyses in the domain of Musical Acoustics are inseparably bound with subjective assessments, in particular when applied to quality ranking of musical instruments. Listening to recorded melodies played using the carillon investigated, done before, and after its enlarging, might serve as an example for a comparative assessment method.

Preservation of strictly maintained constant values of all recording conditions in both cases would be necessary. This is, however, impossible, because of the mere fact of the existence of all newly installed elements and facilities within the tower, having changed its acoustic properties significantly. Despite the impossibility of exact realization of such comparison, the two monophonically recorded melodies are presented as illustrations, enabling attempts of subjective judgements to be made.

5. Critical remarks

It should be emphasized that the properties of the instrument investigated were compared to those reported on other great carillons existing in Western Europe [2, 3]. Such comparisons fully justify the very high ranking of St. Catherine's carillon, and its role as a great concert instrument.

It is obvious from the reported results and observations that the presented investigation should be treated as a preliminary one. St. Catherine's great carillon reveals an extended, rich field of interesting acoustical problems, requiring a systematic effort on the part of investigators to be solved successfully. Thus, further studies and investigations are highly desirable.

In contrast to many scientific projects carried out in laboratory conditions, many difficulties arise in practical realization of the reported investigations.

Recordings should be done rather outdoors, at half the distance from the tower, typical for passers-by willing to listen to carillon sounds. This condition is hard to fulfill due to the intense traffic noise from the neighbourhood of the tower. Using night-time for recordings might be a remedy, yet the necessary, intense ringing at night would disturb the quietness of the night for the neighbourhood residents.

The situating of the measuring microphone inside the tower, well insulated from external noise, thanks to very thick tower walls (about 4 m), ensured the required quality of recording. Disadvantageous were, however, possible resonances in the tower interior. These may affect the results of spectral analyses. Thus, frequential characteristics of the reverberation within the tower interior should be measured, and their shape used for possible interpreting of the reported results. The moreso that the measured sound spectra were highly non-uniform.

The precision of the data obtained from analyses is slightly reduced due to the presence of low frequency beats, being below the threshold of frequential sensitivity of the applied method of analysis. Beats in bell sounds are, of course, inevitable, yet the reduction of precision is so small that it may be disregarded. It should be pointed out here that beats in bell sounds are, to some extent, subjectively desirable [2].

6. Conclusion

The St. Catherine's carillon built in 1989 and enlarged over the next ten years is a great instrument of important musical value and of the highest technological quality.

The investigated properties of St. Catherine's carillon, first of all the high accuracy of internal and external tuning of all the 49 carillon bells, proves its highest quality and ensures its beautiful sound. The bells are tuned according to the chromatic, equally tempered scale, ranging from c' to c^{V} (i.e. from C4 to C8), covering the complete four octaves.

The console containing manual and pedal keyboards situated inside a sound insulating cabin offer the carillonist good conditions even during prolongued concerting.

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