Innovative Methods and Tools for the Sound Design of Organ Pipes

The main objective has been to solve practical problems concerning the voicing of labial organ pipes, and to develop innovative methods and tools for helping the voicing adjustments and sound design work of organ builder SMEs. The degree of dissemination to countries with different technical and cultural tradition of organ building has been large.

A better scientific understanding of the voicing steps on the attack and the timbre of labial organ pipes has been necessary to develop innovative tools for helping the work of the voicers though a scientific model of the voicing adjustments which have not been available yet. This goal has been achieved by scientific investigations of the effects of the voicing steps on the pipe sound by laboratory experiments and scientific analyses. The main objectives have been as follows:

Better sound quality of labial pipe ranks of pipe organs with optimization of the voicing methods and steps,

- Reduced costs of voicing adjustments by a scientifically based optimizing of the voicing procedure,
- Reduced costs of pipe manufacturing through innovative methods and tools: user friendly design software based on a scientific sound design method.

These objectives have been achieved by targeted research carried out by the RTD partners of the project. The SME partners contribute to the project by designing the pipes for the investigations, by providing organ pipes and voicers for the laboratory experiments, by evaluating the results in their workshops. A considerable cost reduction and a better quality of the sound of the pipe organs could be expected.

Examples of the *work performed since the beginning of the project:*

Development of optimal scaling of the depth and width of wooden pipes

In case of wooden pipes the reduction of pipe width would be desirable, because the space requirement of the pipe organ could then also be reduced. On the other hand, the sound quality could be worse for too narrow pipes. The aim is *to find the narrowest scaling of wooden pipes with still appropriate sound quality*.

Laboratory experiments

Optimal scaling of the depth and width of wooden pipes has been developed in order to help the design of the instrument to the space requirements of the room. A series of differently scaled wooden pipes has been acoustically investigated in the anechoic room of the IBP (**Fig. 2**).

Fig. 2. Development of optimal scaling and a software for designing the depth and width of wooden organ pipes without changing the sound character

On the basis of the results a design and scaling method have been developed that can take into account the effect of wall dimensions on the stationary spectrum of the sound.

Computer simulation of wooden pipe forms

The eigenfrequencies of the pipe resonator have been numerically simulated by means of the Finite Element Method and/or of the Boundary Element Method (**Figs 3-4**). The influence of the depth and width of wooden pipes on the formant structure of the stationary sound has been investigated and optimized.

Design software for optimal scaling of wooden pipes

On the basis of the elaborated method design software for the optimal scaling of the depth and width of wooden pipes has been developed. With the help of the software the organ builder can optimize the dimensions of the wooden pipes with the aim to reduce the length and so the price of the wind chest, but maintaining an optimal sound quality in the same time.

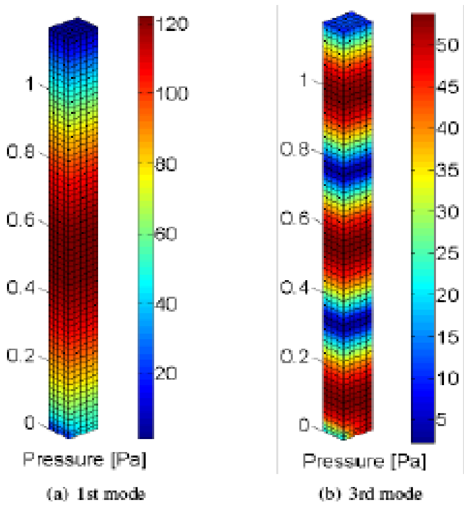

Fig.3. Sound pressure distribution along a wooden pipe, calculated by means of a coupled FE-BE calculation

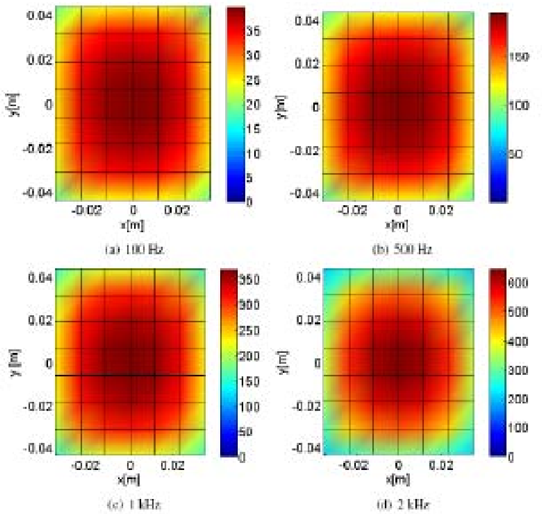

Fig. 4. Simulated distribution of the terminating impedance over the opening of a rectangular wooden pipe

Practical solution for tuning with a tuning slot

Pipes equipped with a tuning slot (Expression) have a specific timbre, which are clearly distinguishable from the timbre of clearly cut pipes or pipes having a tuning roll. The size and position of the tuning slot influences the formant structure of the sound spectrum radiated at the open end of the pipe. However, the tuning slot is also used for adjusting the pitch of the pipe. Therefore the pipe cannot be tuned without changing the sound character. Aim of this

Subtask was to be able to influence the formant structure of the sound spectrum according to the imagination and wish of the organ builder but to be able to tune then the pipe without changing the sound character.

The investigation of the effect of the slot has been carried out on three different pipe models as shown in **Fig. 5**.

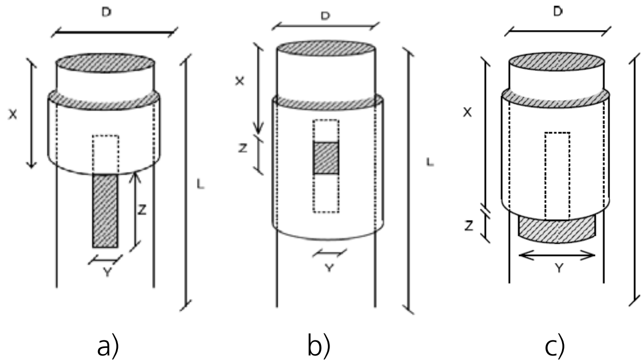

Fig 5. The experimental flue pipe model with a tuning slot with a possibility of **a)** Variation of the length of the slot, holding fixed the bottom edge, **b)** Variation of the position of the slot, holding fixed its dimensions, **c)** Variation of the width of the slot.

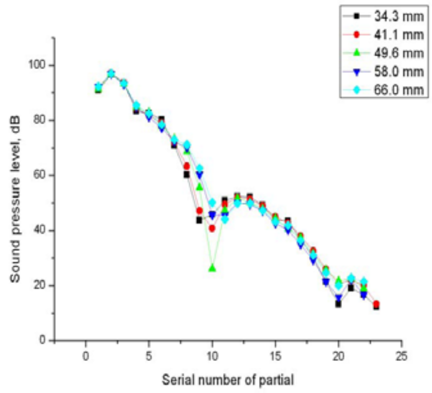

Fig. 6. The stationary sound spectrum of the pipe model with variation of the length of the slot, holding fixed the bottom edge measured in 3 cm distance from the slot.

Fig.6 shows that the fundamental frequency is almost constant. On the other hand the character of the spectrum changes (8-9-10th partials) with the length of the tuning slot. These character changes should be avoided with a new kind of tuning arrangement which can be designed with an innovative software.

Development of *optimal scaling of the chimney and the pipe resonator of chimney flutes*

Optimal scaling and design of chimney flutes (**Fig. 7**) have been developed by means of appropriate laboratory experiments and computer simulations. Design software has also been developed for the optimal scaling of chimney flutes.

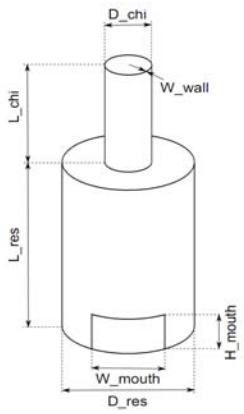

Fig.7. Sketch of the chimney pipe resonator model

Stopped pipes produce mostly odd harmonics; the addition of a chimney adds more even harmonics to the sound. The length and diameter of the chimney varies considerably from builder to builder. The real effect of the chimney on the sound is not known and a method of sound design does not exist until now. Therefore, organ builders cannot utilize the possibilities of this complex pipe form. Because of this it is crucial to investigate the function of the chimney in the sound articulation of the pipe.
A series of differently scaled chimney pipes has been acoustically investigated in the anechoic room of the IBP. The measurement results, together with the results of computer simulations of the BME (**Fig.8**.) have been used for developing a design method of chimney pipes, which takes into account the properties of both acoustical systems and provides an optimal matching of them. New voicing and tuning methods have also been developed for the new chimney pipe constructions.

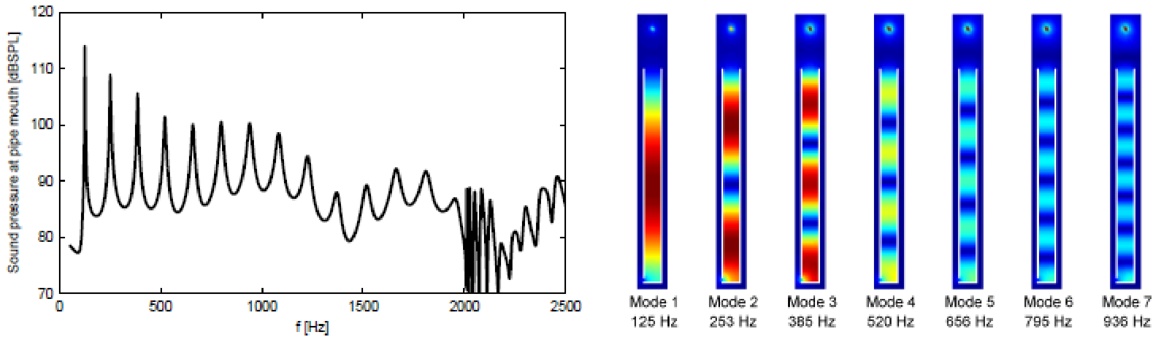

Fig.8. Simulated transfer function (left) and longitudinal modes (right) of a chimney pipe (result of coupled FEM/BEM and FEM/IEM simulations).

Design software for optimal scaling of flue organ pipes (IBP, BME)

On the basis of the elaborated theories according to the different tasks of the project design software has been developed (**Fig.9**) to help the organ manufacturers finding the optimal scaling and voicing for various pipe types and save quite some time in the industrial process of organ builders.

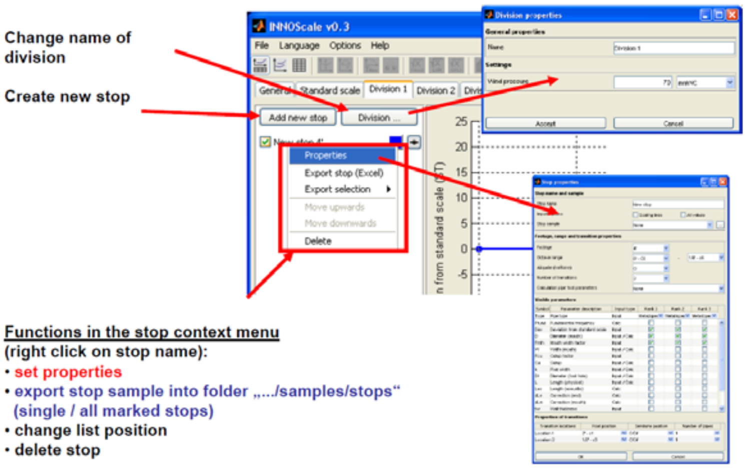

Fig.9. Innovative scaling software for designing the dimensions of flue organ pipes

SME (small and medium-sized enterprise)-Partners:

Werkstätte für Orgelbau Mühleisen GmbH, Leonberg, Germany
Societé de Construction d'Orgues Muhleisen sarl, Strasbourg, France
Flentrop Orgelbouw B.V., Zaandam, The Netherlands
Orgelbau Schumacher GmbH, Baelen, Belgium
Blancafort, orgueners de Montserrat S. L., Collbato, Spain
Oficina e Escola de Organaria, LDA, Esmoriz (Porto), Portugal
Fagmilia Artigiana Fratelli Ruffatti S.n.c., Padova, Italy
Johannes Klais Orgelbau GmbH &Co. KG, Bonn, Germany
Organ Work Manufacture of Pécs, Pécs, Hungary
Orgelmakerij Boogaard, Rijssen, Niederlande

Partners for research and technological improvements:

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