Project about accordions

Overview

Accordion is one of the most common musical instrument nowadays: transport facilities and his large harmonics capacities make him a beloved instrument. Its costs between 15.000 and 120.000 SEK, which makes the market attractive for manufacturers and accordion repairers. These bicentennial instrument is still manufactured and empirically optimized. With a thorough study, significant improvements can be made.

Generic reeds presented in Figure 1 work only in overpressure configuration: due to weight and production costs, manufacturers would like to replace the two reed system producing each notes by a unique reed able to work in overpressure and depression configuration. The number of components is frequently over 2500 elements. The gain for each accordions will be estimate by 35 % of loss in weight and 45% for production costs if this dual reed can replace the actual system.

With more than 30 manufactures in Europe, a dual reed conception based on scientific research is expected and international patents would be removable. This study case needs to develop a model, able to predict the response in time, and thus make possible to compute the time response of the reed. Ergonomics, reed timbre, least energy during playing, duality polyphony | syncope are also important studies as a musical point of view.

Although the subject may be seen as very technical, most of the current problems highlighted in two previous project [dD11] stems from problems in fundamental physics. Self-oscillating systems, directly linked to bifurcation, permit to investigate with phasis-control the minimum energy bifurcation behavior for an oscillator coupled with a resonant cavity.

Can be the complex experience of playing music can teach us much about Fundamental Physics, because it requires exceptional skills and also make complex sensation difficult to observe with generic senors, full of insights.

Generic accordion structure

The accordion is a musical instrument which works thanks to the air flow produced by the musician. As the musician pulls or pushes on the bellow, an air flow is created. Then, as the musician pushes, the air goes out, and if he pulls, the air goes into the structure. If a key is operated, a part of this flow goes through the reed that has to vibrate as long as dimensional parameters meet apt operating criteria. For the man skilled in the art, Musics is the denomination for the operated set of reeds associate to a piece of wood called reed block. As depicted in both figures 1 and **??**, the bass set (left hand musics', Figure 1, Left) and the melodic set (right hand musics', Figure 1, Right) are illustrated.

Manufacturers have found different shapes and reed fabrication process corresponding to low or high frequency reeds as presented in Figure 2.

Considering each note, one up to five reeds may be set to vibrate at the same time. The

Figure 1: Left: Bass accordion musics is this structure where the reeds are glued by wax or nails. Right: Melodic structure without reeds. We can see the cavities and the beveled edge associated to holes trough the foot part. Theses holes permit air communication between the in-cavity- and the out-bellow- of the structure.

Figure 2: On the left, is shown a reed with an added mass, which permits to have lower frequencies keeping the same reed length.

number of reeds that vibrate at the same time is called a voice: when you consider two vibrating reeds at the same time, the instrument comes up with two voices. Considering now the melodic set, you could prefer to produce what is called a vibrato or a clean tuning. In such a case, reeds do not oscillate at the same frequency and operate a sound amplitude modulation, called vibrato by musicians. Conversely, if the reed oscillate to a multiple frequency to each other, musicians use the domination clear tuning.

Unsolved problems

Several problems happen to remain unsolved nowadays with empirical refinements from different disciplines:

- Psychoacoustics: How the frequencies are perceived, especially for vibratos between two reed oscillating by more than one octave to each other,
- Bifurcations and Chaos Theory: The self sustained and oscillating condition according to a given shape,
- Fluid Mechanics: Try to investigate how a given air flow modify the sound pressure level, the frequency and the time response of the reed,

- Acoustics: How a given increase of the cavity volume affects the variation of sound power level, the frequency and the response time of the reed,
- Least Energy: Try to investigate why some reed can only start with a pressure excitation and other with only a air flow excitation,
- System Dynamics: Characterizing self substituted oscillations into Bifurcation, Uncontrolled sustained forced regime and Self-sustained system with minimum energy supply,
- Research & Development: Optimizing time response, timbre, polyphony, reed sensibility,
- Vibro-acoustics & Electronics: Find the best place for integrated sound microphone in the accordion structure,
- Solid Mechanics: Design new reed material for silent instrument, in reducing sound radiated without timber modifications,
- Biomechanics: How to make the instrument more ergonomic, based on joint motion analysis.

Problematic driven during Flora & Evisa projects (2010-2012)

As a traditional way to operate, in Figure 3, both reeds become coupled by way of such cavities, whose dimensions are only determined by trail and fail experiments. Then the main goal of the first research was to identify the influence of the the cavity volume on reed response.

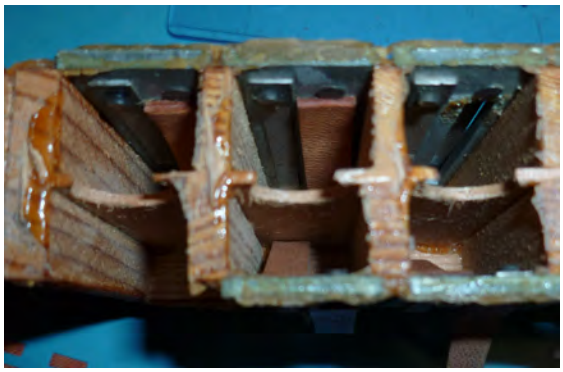

Figure 3: System fitted with reeds. For bass reeds, the cavities are linked with a hole

For both sets, turbulence mechanisms regarding the flow and the reed response have to be analyzed in a future study.

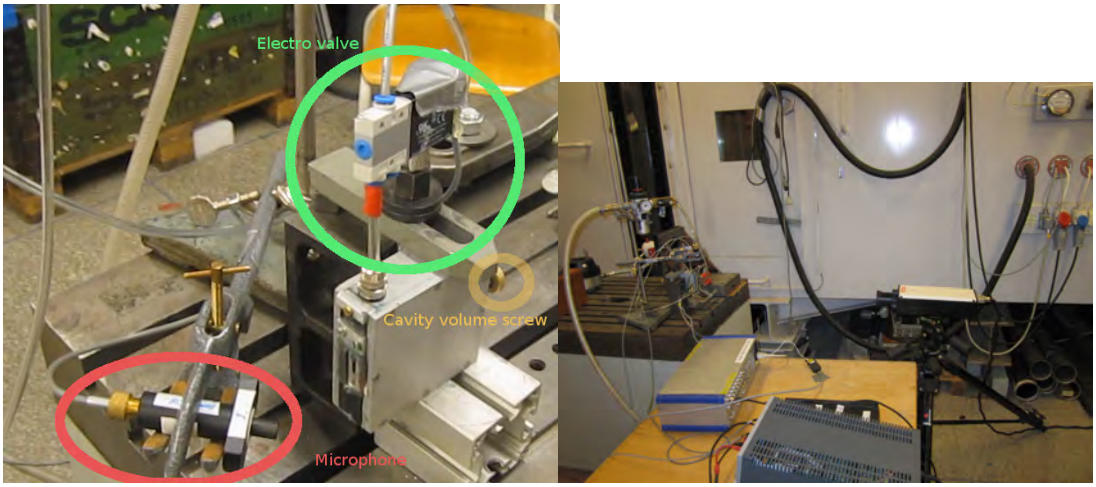

Figure 4: Overview of equipment used during experiments

As presented in last section, many psychological, physiological and musical parameters we have ate to be taken into account. That make this project and field of science totally interdisciplinary and most interesting.

First Results

Experimental methods:

In previous works, experiments have been operated: Shortly, the measurements were carried out to investigate the shift in frequency, in transit time and sound level magnitude in a coupled reed cavity system, when both the inlet pressure and volume cavity is changed.We use a laser-vibrometer to assess the reed velocity, a Ku-Lite microphone for the pressure inside the cavity, a pressure microphone for measuring the radiated pressure in far field, and an electro-valve to allow or not the air to go in the cavity.

Numerical methods:

Basically, such models permit to compute the time response of a certain reed geometry according to an inlet volume flow in a cavity volume, above the reed. The interest is to highlight interactions between reed and cavity, and mainly at bifurcations observed during the experiments. As equations are clearly non linear, our continuum model mix numerical computation and symbolic maths.

Experimental data analysis

The most difficult part was to extract the time response from the signals. All the data analysis were operated with Matlab®. Variations of oscillating frequency and sound

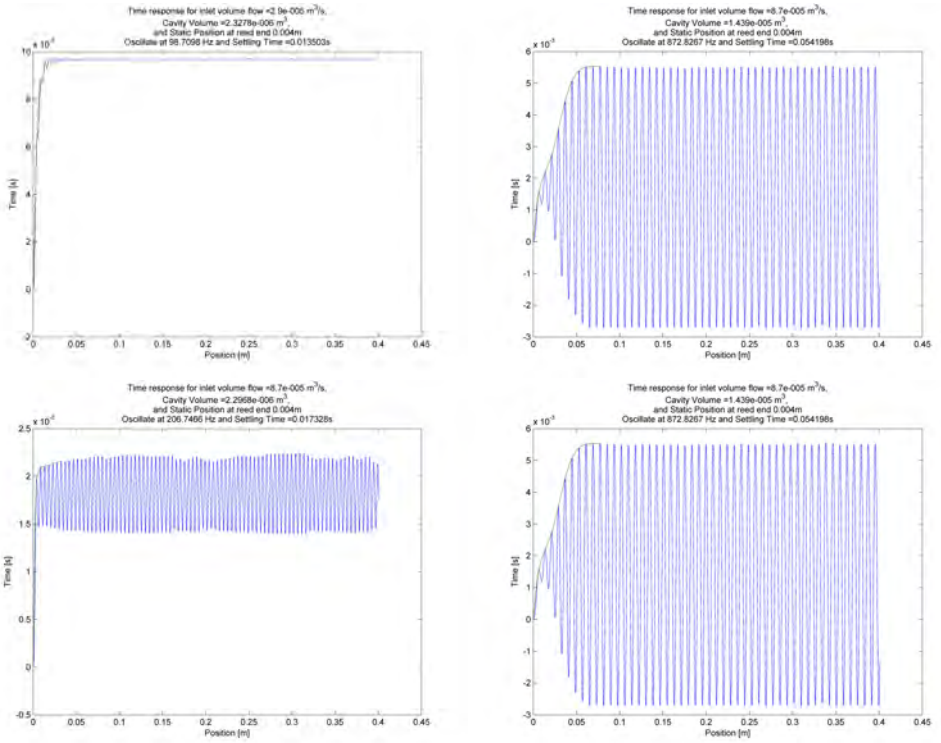

Figure 5: Time response predicted by the model.

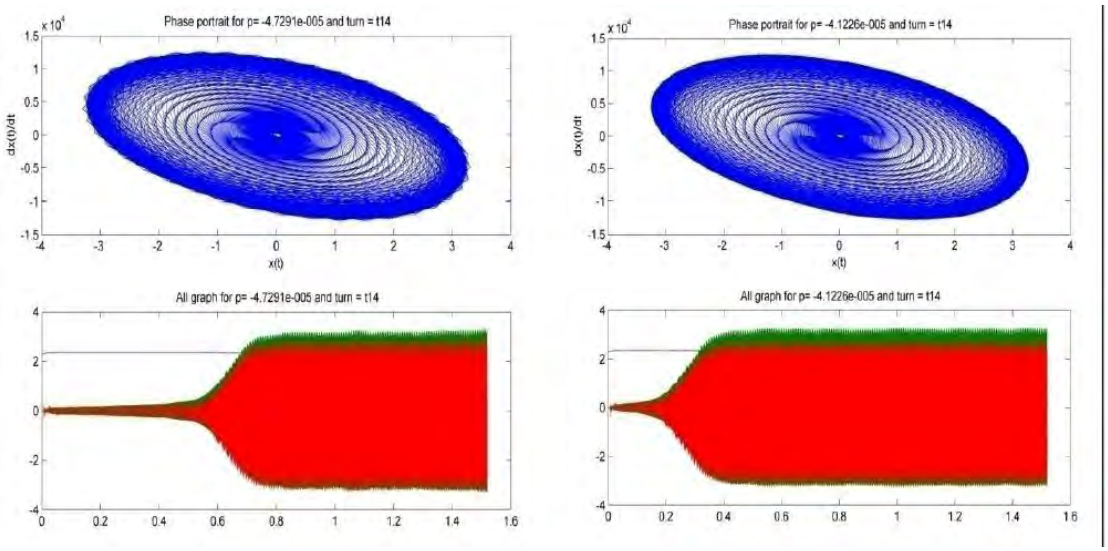

Figure 6: Graph after data-analysis: In blue, the response in phases plane and in red gives the position where the green gives the pressure inside the cavity.

level pressure due to cavity volume and the pressure variations where computed. Both time and phase domains are used for the analysis .

Previous works on accordions

Bibliography

As an Historical point of view, "L'Accordéon"[Mon80] is an excellent book which summarizes the technical states used for solving the different problems encountered over time by manufacturers.
E. Leipp reports scientific explanations of those technical statements of accordions in GAM [Lor72], where few relevant equations and conceptual figures complete the historical point of view given by P. Monichon.
Tom Tonon in Papers of the International Concertina Association (PICA) [Ton09] wrote an article about reed and cavity resonance design based on an Helmholtz and quarter-length resonators model.

Flora Project

In 2010-2011, a first project is driven in KTH, on MWL department. The main study was to measure with changing in radiated sound level pressure, in oscillation frequency and transit time due to a variation of inlet air flow and cavity volume.

Evisa Project

In 2011-2012, a second project is driven in ENSIM. The main goal was to make a continuum model of a reed-coupled cavity based on Rayleigh-Ritz equations to predict the response of a reed in time domain[dD11].

Previous works on dynamics

"Dynamique générale des vibrations" [Roc49] published in 1949 demonstrates all the theory of oscillators regarding electronics and mechanics area. A exhaustive development is given about stability criterion prior to oscillation mechanisms.

References

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