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Reed chamber resonances and attack transients in free reed instruments

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Abstract

Western free reed instruments such as the accordion, harmonica, and harmonium do not normally employ pipe resonators to determine the pitch, but all do feature some sort of reed chamber or cavity in which the reed is mounted. The reed chamber will necessarily have resonances which can affect the tone quality and may have some effect on the pitch, but, since the cavity volumes are small and the resonances have high frequencies, the effects on the reed vibration tend to be small. An exception to this can occur in the accordion or harmonica for higher pitched reeds, for which a resonance of the reed chamber can be close to the vibration frequency of the reed tongue. In this case the cavity air vibration can possibly interfere with tongue vibration, inhibiting the sounding of the reed. For various configurations of the reed chamber, reed motion during the initial transient stage of vibration has been analyzed, exploring the role of transverse and torsional modes in the early stages of the transient, as well as effects on the rise time and final amplitude of vibration due to unfavorable reed chamber configurations. [Work partially supported by United States National Science Foundation Grant PHY-1004860]

Keywords: free reed, transient

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1 Introduction

The accordion and harmonica are free reed instruments in which the design of the reed plates allows the instrument to respond to both directions of air flow. Each instrument has pairs of reeds, one mounted on each side of the plate. Accordion reeds are usually made out of steel while harmonica reeds are typically made of brass.

A problem that sometimes occurs with the higher-pitched reeds in both the accordion and harmonica reeds is that coupling between the reed vibration and the reed chamber resonance can inhibit the sounding of the reed, making it difficult for the reed to sound. This phenomenon has been investigated by Tonon [1], who describes it as follows: “The vibrating reed tongue and the air within and about the cavity are acoustically coupled together. In some designs, the effect of the cavity on the musical tone is small or negligible, in other designs, the effect of the cavity can significantly modify the musical tone; and in still other designs, the acoustic effect of the cavity can prevent the reed from speaking properly. As tongue vibration frequency and cavity mode resonant frequency become closer, however, cavity air vibration can become large enough to influence the self-excitation mechanism. Whether this influence assists or interferes with tongue vibration and the resulting musical tone depends upon the resonant mode of the cavity and how the reed is mounted in relation to the cavity. The interference described above can completely prevent the tongue from vibrating: the reed becomes choked. Choking is predicted, then, under certain conditions when tongue vibration frequency is in some neighborhood of cavity mode frequency.”

This paper reports on some experimental studies in which the coupling of a free reed with the Helmholtz resonance of the reed chamber was investigated. This study is ongoing, but the preliminary results reported here show some evidence that this coupling can in some cases inhibit reed oscillation.

2 Description of the experiments

An accordion reed plate from a Hohner accordion (model Verdi I) was mounted on a wooden wind chest. The sounding frequency of the reed pair was 622 Hz. The air supply to the wind chest was reversible so that one set of measurements was done with the airflow (AF_1) out of the wind chest, and another set of measurements were done with the air flowing in (AF_2).

Figure 1: An accordion reed plate of the type used in this study

An artificial reed chamber was placed on top of the reed to simulate the reed chamber in an accordion. The reed chamber is designed to allow changes to the volume, area of the opening, and length of the neck. In these experiments the only variable that was changed was the Helmholtz resonator volume. The artificial reed chamber was placed above the reed plate and made airtight with caulk. A picture of the setup can be found below in Figure 2.

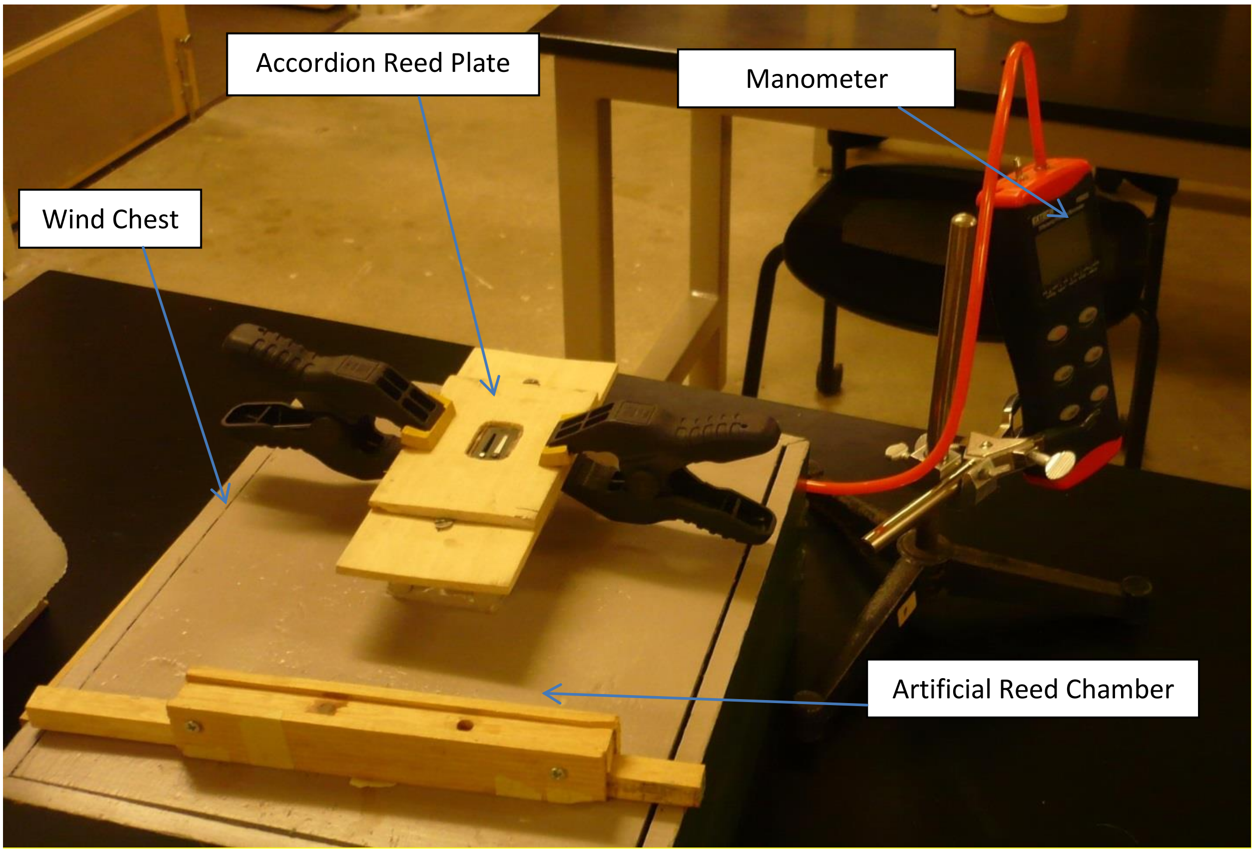

Figure 2: Artificial Reed Chamber and Accordion Reed

3 Measurements

3.1 Helmholtz frequency of the reed chamber

The Helmholtz resonance frequency of the artificial reed chamber was calculated and also measured using the following technique. The reed chamber was excited by inserting an Etymotic EARtone 3A insert earphone, which transmitted a swept sine wave signal. A probe microphone was inserted through a small hole in the reed chamber. The microphone signal to a spectrum analyzer was used to determining the Helmholtz resonance frequency. The measured values, which agreed well with the calculated values, were used in the data and graphs presented here.

3.2 Measurement of threshold pressure levels

The main measurements were the two threshold pressures. The first pressure (TP1) is the pressure at which the appropriate reed of the pair begins to sound as the pressure is gradually increased from zero. The second (TP2) is the pressure at which the reed ceases oscillation as the pressure is reduced from above. As expected TP1 is consistently greater than TP2.The measurement of these threshold pressures was repeated three times for each value of the Helmholtz resonator frequency. The averages of the three pressures were taken and plotted as functions of the Helmholtz frequency. For each value of Helmholtz resonance frequency, the experiment was then repeated with the air flow reversed.

4 Results

4.1 Flow into wind chest

Figure 3 below shows TP1 and TP2 as functions of Helmholtz frequency for airflow into the wind chamber. (For a harmonica this would correspond to a “blow reed.”) It can be seen that the threshold pressures are higher at lower values of the Helmholtz resonance, which is in the general vicinity of the sounding frequency (first dashed line). TP1 seems to show a local maximum near twice the sounding frequency (second dashed line).

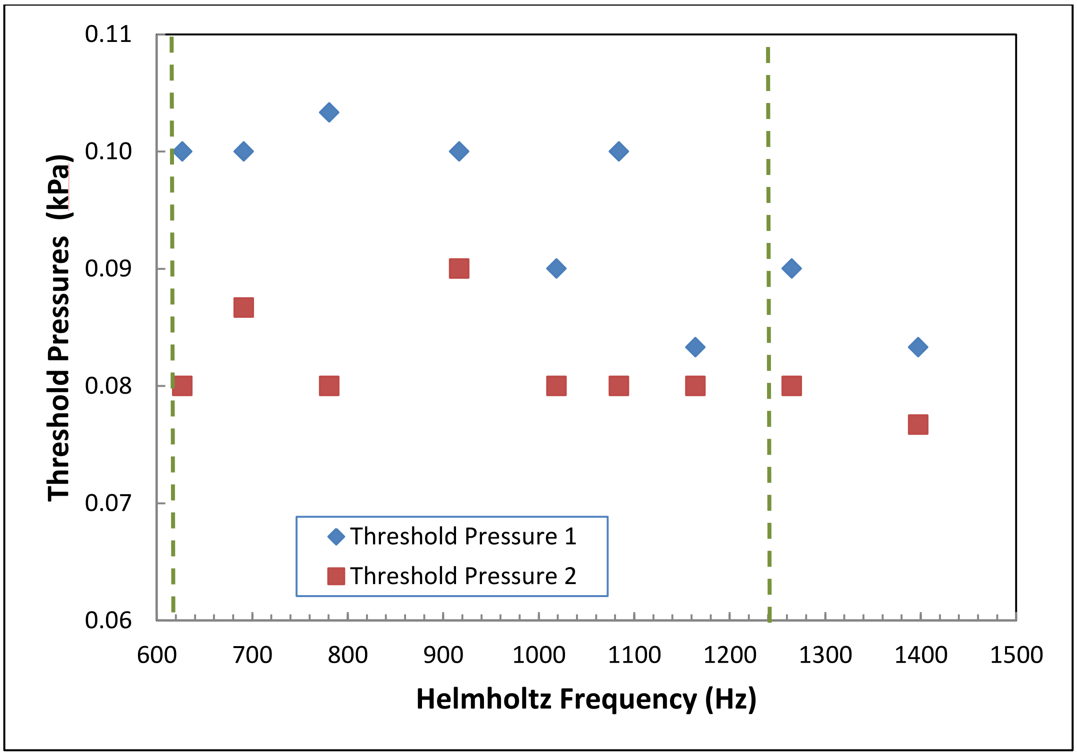

Figure 3: Threshold pressures TP_1 and TP_2 for inward airflow

4.2 Flow out of wind chest

Figure 4 below shows TP1 and TP2 as functions of Helmholtz frequency for airflow out of the wind chamber. (For a harmonica this would correspond to a "draw reed.") It can be seen that the threshold pressures are here lower at the lower values of the Helmholtz resonance, in the general vicinity of the sounding frequency. TP1 seems to show a maximum near twice the sounding frequency (second dashed line).

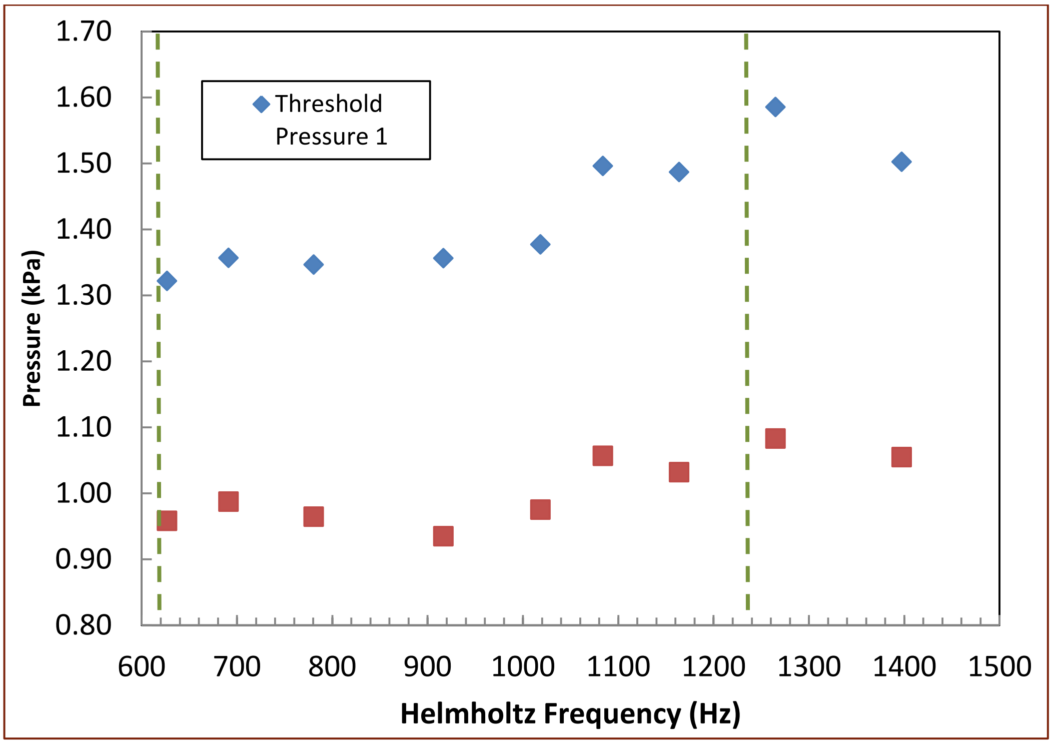

Figure 4: Threshold pressures TP_1 and TP_2 for inward airflow

5 Final remarks

The results summarized here are preliminary, but do suggest a possible role of reed chamber resonances affecting the ease or lack of ease in attack for free reed instruments. The comparison of the results for opposite directions of airflow seems to bear out the statement by Tonon that opposite effects should be expected in this case. Further investigations will include repetition of similar experiments with a variety of different free reeds and reed chambers. This newer work can be incorporated with the results from earlier work on reed chamber resonance as in References 3-5. In addition, it will be of value to study the effects of reed chamber resonances on reed vibration attack transients.

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Acknowledgments

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