Development of Fibre Polymer Sensor Reeds for Saxophone and Clarinet

Alex Hofmann
Institute of Music Acustics
University of Music and Performing Arts Vienna
Vienna, Austria
hofmann-alex@mdw.ac.at

Vasileios Chatziioannou
Institute of Music Acustics
University of Music and Performing Arts Vienna
Vienna, Austria
chatziioannou@mdw.ac.at

Alexander Mayer
Institute of Music Acustics
University of Music and Performing Arts Vienna
Vienna, Austria
mayer@mdw.ac.at

Harry Hartmann
Fiberreed
Leinfelden-Echterdingen, Germany
www.fiberreed.com

ABSTRACT

Electronic pickup systems for acoustic instruments are often used in popular and contemporary music performances because they allow amplification and modification of a clean and direct signal. Strain gauge sensors on saxophone and clarinet reeds have been shown to be a useful tool to gain insight into tongue articulation during performance but also capture the reed vibrations. In our previous design, we used a procedure with cyanacrylate adhesive to glue the strain gauge sensors to the flat side of the synthetic single reeds. The new design integrates the sensor inside a synthetic reed, respectively between layers of fibre polymer and wood. This allows an industrial production of sensor reeds. Sensor reeds open up new possibilities to pick up woodwind instruments and to analyse, to modify, and to amplify the signal. A signal-to-noise analysis of the signals from both designs showed that a sensor, glued to the outside of the reed, produced a cleaner signal.

Author Keywords

Single reeds, Synthetics, Sensors, Saxophone, Clarinet

ACM Classification

H.5.2 [Information Interfaces and Presentation] User Interfaces - Haptic I/O, H.5.5 [Sound and Music Computing] Signal analysis, synthesis, and processing

1. INTRODUCTION

On wind instruments the sound excitation occurs at the mouthpiece. On single-reed instruments the oscillator, the single reed, is coupled to the resonator. The resonance frequency of the resonator determines the oscillating frequency of the reed [7]. Saxophonists and clarinettists are using different dynamics and articulation techniques when they play expressively [5]. To examine the tongue actions in saxophone and clarinet performance, we glued one strain gauge sensors (RS, 2 mm, 120 ohms) on each single reed [3, 1]. Strain gauge sensors change their resistance when they are bent. These sensors are soft, thin and small enough to not significantly change the playing behaviour of the reed. A Wheatstone quarter bridge circuit is used to convert the changes in resistance to voltage. An operational amplifier (TI, INA 126) transforms the signal into the range of 0–5V. Consequently, the deformation of the sensor covered area of the reed can be converted into an electrical output [8]. With this setup, the bending of the reed can be measured during saxophone and clarinet performance. With this method we characterized the tongue actions for certain playing techniques and their influence on the performed timing [3].

Besides capturing articulation techniques, the reed sensor signal also provides information about the pitch and the dynamics of the tones. Apart from picking up the radiated sound of the instrument with a traditional microphone, in some cases (e.g. monitoring on stage, live-electronics) players want to pick up a very direct sound signal to avoid feedback with the sound system. Alternative pick-up systems for clarinet and saxophone exist from various manufacturers[1]. These systems are based on the principle of inserting a special high-pressure microphone into the mouthpiece or the resonator of the instrument. This microphone captures the sound pressure inside the instrument (1–12 kPa). This produces a loud and clear signal, but mounting such a device is a delicate intrusive act to the instrument, because it requires to drill an extra hole into the instrument.

We propose a sensor directly on the reed, as an alternative to pick up single reed instruments instead of using microphones [4]. Nevertheless, the former procedure to build sensor reeds involved manual modifications of the reed to attach the sensor [2] (see Fig. 1). The procedure involved: grinding the area, glueing the sensor, drilling holes into the reed for the cables and lacquering the cables and the sensor. This procedure has a high risk of damaging the reed or the sensor. In this paper we propose a new design where the sensor is integrated into a fibre polymer reed during the manufacturing process. This allows a mass production of sensor reeds which opens up new possibilities to pick up, modify and analyse woodwind performances in live situations, ranging from live-electronic tools to education apps.

[1] e.g. `http://www.rumberger-soundproducts.de`, `http://www.piezobarrel.com/`

NIME'16, July 11-15, 2016, Griffith University, Brisbane, Australia.
.

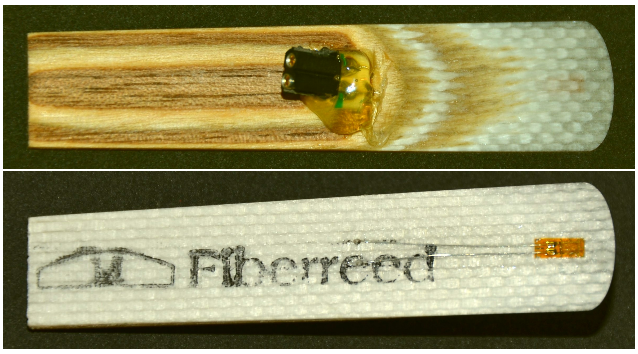

Figure 1: Synthetic alto-saxophone reed by Harry Hartmann's Fiberreed, with a strain gauge sensor glued to the flat side of the reed, following the instructions given in [2].

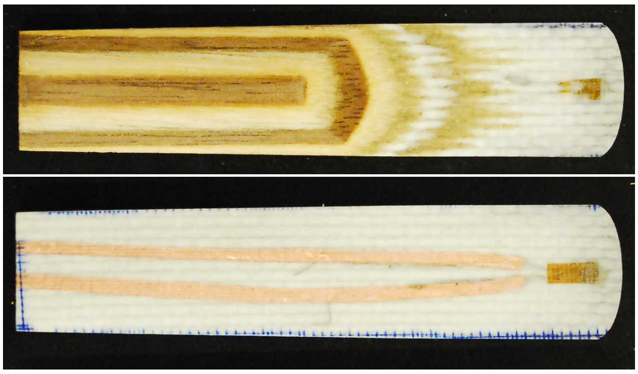

Figure 2: Synthetic alto-saxophone reed where a strain gauge sensor is inserted between the layers of fibre polymer.

2. METHOD

2.1 Intergrated Sensor Reed

Fiberreeds by Hartmann are made of multiple-layers of fibre-reinforced polymers, which are agglutinated with resin under certain temperature and pressure. In the case of "Hempreeds" by Hartmann, additional layers of birch and walnut veneer are added to the composition, in an attempt to make the synthetic product closer to the properties of arundo donax (cane) reeds. Then the compound material is cut into the shape of the final reeds and milled at one end so that it becomes thin. To build an integrated sensor reed, during the procedure of combining the layers with resin, a strain gauge sensor (RS, 2 mm, 120 ohms) was inserted into the compound material. Copper foil stripes on the flat side of the reed are used as connector cables. Figure 2 shows a saxophone reed with an integrated strain gauge sensor.

2.2 Mouthpiece

We propose a design to pick up the integrated sensor reed, where no invasive modifications to the mouthpiece are required. The integrated sensor reed can be mounted as usual and any ligature can be used. Due to the fact that the sensor and the cables are on the flat side of the reed, connectors on the table of the mouthpiece are used. Figure 3 shows a saxophone mouthpiece (Tone Edge 6, Otto Link) with two stripes of self-adhesive copper foil attached to the mouthpiece table where the integrated sensor reed can be connected.

Figure 3: Alto-Saxophone mouthpiece by Otto Link with Copper Foil layer on the mouthpiece table, to connect the Fiber sensor reeds.

2.3 Measurement Procedure

A professional saxophonist played an integrated sensor reed (Fig. 2) and a glued sensor reed (Fig. 1) on an alto saxophone using an Otto Link mouthpiece (Figure 3) and on a clarinet using a Maxton NA-1 mouthpiece. All four reeds had a *medium* (2.5) strength. We recorded the sensor reed signals and the radiated sound from 40 cm distance with an AKG C414 microphone in the anechoic chamber at the Music Acoustics Institute (IWK) of the University of Music and Performing Arts Vienna. The signals were captured simultaneously with LabView 2011 (by National Instruments) using 44100 Hz (16 bit) sampling frequency. The settings on the amplifiers were not changed for all recordings.

3. RESULTS

3.1 Clarity of the signal

Figure 4 shows the recorded signal from the integrated sensor (top) and the signal from the microphone (bottom) for the alto saxophone reed. The signal of the saxophone reed with the integrated sensor was noisier than we expected.

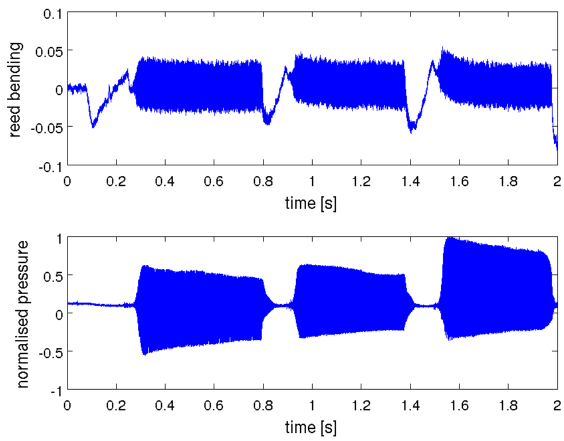

Figure 4: Recorded signals with the new Alto-Sax Fiberreed with an integrated sensor (top) and the AKG C414 microphone (bottom).

We calculated the signal-to-noise ratio (SNR), a measure for the amount of background noise in a signal. All SNR values were calculated using the MATLAB Signal Processing Toolbox (by Mathworks). In the case of our two different designs for sensor reeds, the integrated sensor reed shows a smaller SNR (19.99 dB, Figure 5 top) than when the sensor was glued onto the reed (SNR = 36.23 dB, Figure 6 top). Although both tones were played with almost the same dynamics on the saxophone (approx. 30 dB microphone signal in Figure 5, and 6), the integrated sensor had a significantly smaller SNR by more then 10 dB.

Looking into the same analysis for the clarinet reed shows a similar trend. Although the difference between both reed signals is not as large as with the alto sax, the integrated sensor showed a smaller SNR (22.22 dB, Figure 7 top) in comparison to the signal from a sensor glued on the reed (28.45 dB, Figure 8 top).

A possible explanation for this behaviour in the case where the strain gauge sensor is integrated into the reed might be that the sensor is closer to the neutral axis of the bended material. This would explain why the signal was larger when the sensor was glued on the outside of the reed. Another possibility for the inferior performance of the integrated sensor might be that during the reed production procedure, when the layers are combined under pressure and high temperature, the sensor got damaged. Both cases might affect the signal of the sensors.

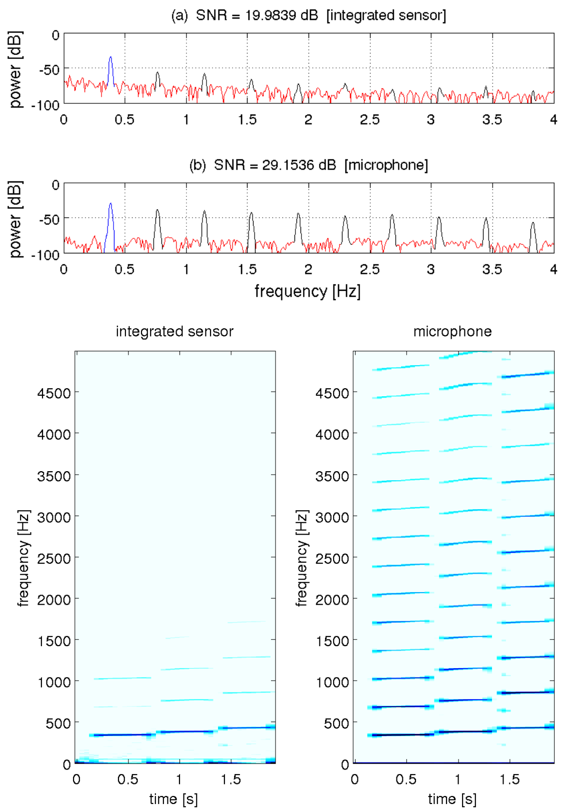

Figure 5: Measurements for saxophone reed with an integrated strain gauge sensor (see Fig. 2): Spectrum and SNR for sensor signal and microphone signal (top); Spectrogram of reed with integrated sensor (bottom left) and the radiated sound of the instrument (bottom right) for three played tones.

3.2 Timbre of the signal

To investigate the timbral quality of the sensor reed, we looked at the spectrograms of the signals. In the case of the saxophone reed with a glued sensor (Figure 6 bottom left), the reed signal shows more energy in the lower frequencies (up to 700 Hz) and softer overtones (above 2500 Hz) compared to the microphone signal (Figure 6 bottom right). This results in a more damped sensor reed sound than the radiated sound of the instrument. For the saxophone reed with the integrated sensor (Figure 5 bottom left), only the first three harmonics were captured.

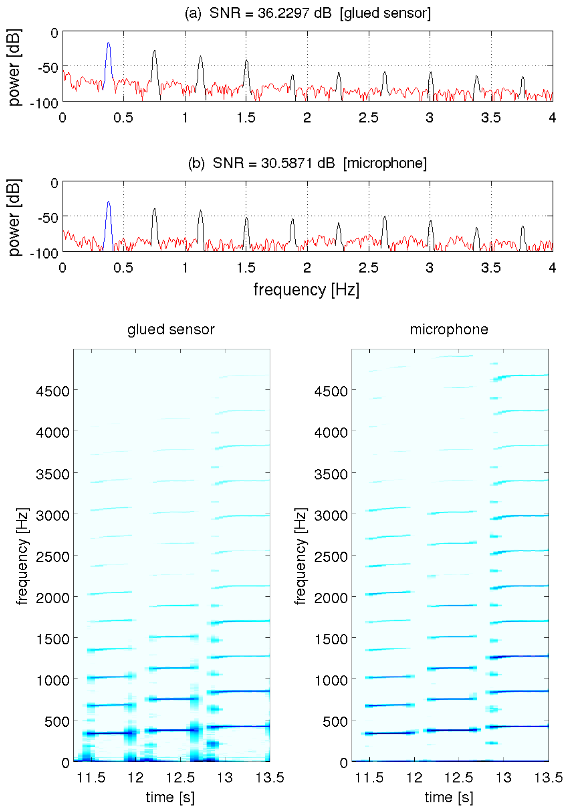

Figure 6: Measurements for saxophone reed with a glued strain gauge sensor (see Fig. 1): Spectrum and SNR for sensor signal and microphone signal (top); Spectrogram of reed with a glued sensor (bottom left) and the radiated sound of the instrument (bottom right) for three played tones.

For the clarinet, for both designs we observed a fundamental difference in the structure of the harmonics of the sensor reed signal compared to the microphone signal. The characteristic sound radiated by a clarinet (especially in the lower register) consists primarily of the odd harmonics. In Figure 8 (bottom right) and Figure 7 (bottom right) this is clearly the case for the microphone signal capturing the radiated sound of the instrument. Surprisingly, the spectrogram of both sensor reeds shows all harmonics (Figure 8 and Figure 7 bottom left). As a consequence, the sound of the sensor reed yields a different timbre than the radiated sound.

4. DISCUSSION

The development of synthetic single reeds with an integrated sensor will give saxophonists and clarinettists new possibilities to enhance the expression of their performances, without drilling extra holes into their instruments to insert microphones. On one hand, the sensor signal may be used for amplification and modification of the sound without the risk of feedback on stage, similar to the functioning of an electric guitar pickup [6]. This would allow for drastic sound modifications in live-electronics with saxophone and clarinet in contemporary music performances. On the other hand,

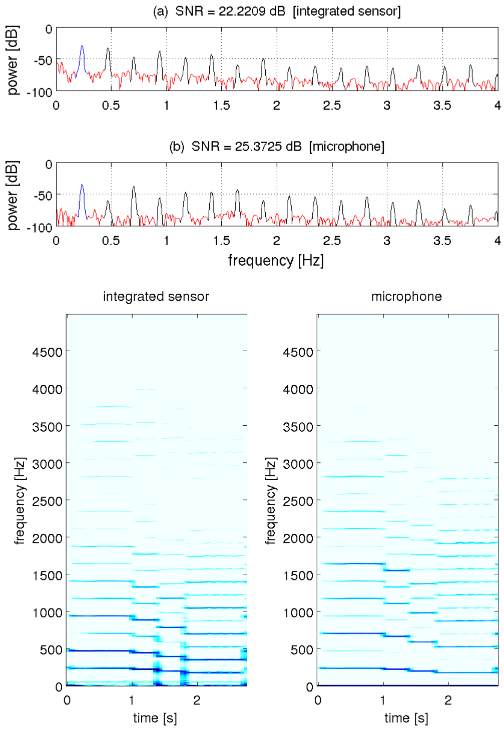

Figure 7: Measurements for clarinet reed with an integrated strain gauge sensor: Spectrum and SNR for sensor signal and microphone signal (top); Spectrogram of reed with integrated sensor (bottom left) and the radiated sound of the instrument (bottom right).

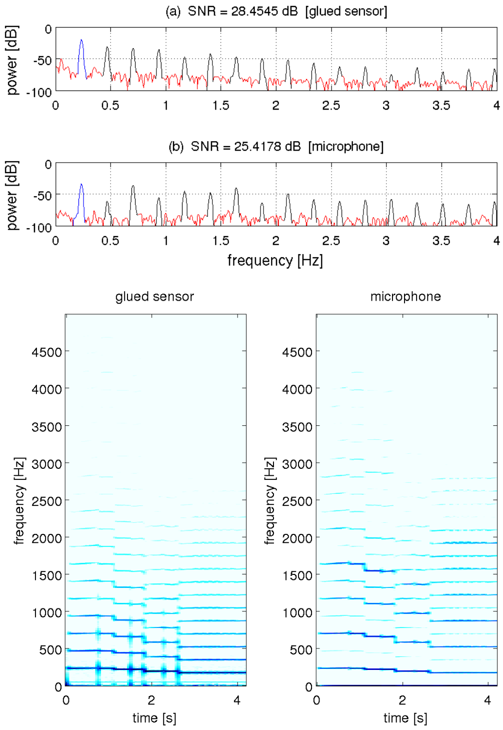

Figure 8: Measurements for clarinet reed with a glued strain gauge sensor: Spectrum and SNR for sensor signal and microphone signal (top); Spectrogram of reed with a glued sensor (bottom left) and the radiated sound of the instrument (bottom right).

the sensor signal can also be used to observe certain playing parameters during practising, which might be of interest for applications in music education [9]. In the future a mobile app could track the pitch, the amplitude and the articulation technique while practising a piece and the player can retrieve a review of his playing. For example, a valuable feedback could be an indication that a tone is too sharp or too flat when played with a certain articulation technique.

Nevertheless, the integrated sensor reeds still need improvements. In the current design we assume that the strain-gauge sensor might be too close to the neutral bending axis of the reed. The positioning of the sensor inside the reed must be experimentally evaluated. Furthermore, an investigation of the manufacturing steps for making the integrated sensor reeds is required to see if the sensor got damaged during the production of the compound material.

In the future, experiments with multiple strain-gauge sensors and other sensors are foreseen, with a focus to investigate the differences of the timbre of the clarinet sensor signal in comparison to the radiated sound. Experiments on the use of piezo technology based sensors are currently carried out.

In terms of usability of sensor reeds for musicians, a wireless solution to transmit the sensor signals is foreseen for future designs. Hereby a low latency transmission of the full sensor-reed bandwidth is required and software to process the the reed signals is under evaluation.

5. ACKNOWLEDGMENTS

This research was supported by the Austrian Science Fund (FWF): P28655-N32

6. REFERENCES

[1] V. Chatziioannou and A. Hofmann. Physics-based analysis of articulatory player actions in single-reed woodwind instruments. *Acta Acustica united with Acustica*, 101(2):292–299, 2015.

[2] A. Hofmann, V. Chatziioannou, M. Weilguni, W. Goebl, and W. Kausel. Measurement setup for articulatory transient differences in woodwind performance. In *Proceedings of Meetings on Acoustics*, volume 19, page 035060, Montreal, Canada, 2013.

[3] A. Hofmann and W. Goebl. Production and perception of legato, portato and staccato articulation in saxophone playing. *Frontiers in Psychology: Cognitive Science*, 5(690):1–10, 2014.

[4] A. Hofmann, A. Mayer, and W. Goebl. Towards a live-electronic setup with a sensor-reed saxophone and csound. In *Linux Audio Conf.*, pages 153–156, 2013.

[5] D. Liebman. *Developing a personal saxophone sound.* Medfield: Dorn Publications, 1989.

[6] P. Lotton, B. Lihoreau, and E. Brasseur. Experimental study of a guitar pickup. In *Proceedings of the International Symposium on Music Acoustics, ISMA 2014*, pages 354–360, Le Mans, 2014.

[7] T. D. Rossing and N. Fletcher. *The physics of musical instruments.* Springer, New York, 2nd. edition, 1998.

[8] A. Window. *Strain Gauge Technology.* An Objective publication. New York: Springer, 1992.

[9] G. Wulf and A. Mornell. Insights about practice from the perspective of motor learning: a review. *Music Perform. Research*, 2:1–25, 2008.