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Radiation Directionality Measurement of Clarinets Made of Different Wall Material

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The radiation-directivity patterns of clarinets are measured using an artificial blowing system which can ensure stable and reproducible tones. A reed is set in a box-shaped mouth and driven by the high-pressured air from an air compressor after adequately adjusting the embouchure formed by artificial lips made of silicone rubber. Our measurement in an anechoic chamber is carried out on three kinds of clarinets whose wall materials are grenadilla and ceramic by applying a common reed-mouthpiece setup. Lateral and circumferential directivity patterns are measured when all keys are untouched. A characteristic conical radiation is commonly indicated in lateral directivity patterns of three clarinets. Also, the effect of tone holes appreciably appears in circumferential directivity patterns measured near the clarinet center or in far field. However, that effect may be almost negligible in circumferential directivity measured near the barrel and bell. Proper improvements of the blowing system as well as careful applications of directivity measurement and near-field measurement will draw some correlations between the wall material and the radiated sound of the clarinet with tone holes closed.

1 Introduction

The effect of the wall material of the wind instrument on the sound has been considered to be vanishingly small in the acoustical physics. Since the mass of wood or brass material is greatly heavier than the mass of the air, the vibration of the air in the horn does not propagate to the shell of the musical instrument[1]. However, professional wind instrument players and musical instrument manufacturers insist on the significance of the instrument wall material. They experientially know that the material of the musical instrument affects its sound. They say that even if they play the same type and the same model instruments, tone quality and playing easiness are completely different. A method of measuring such small difference has not been established. Scientific measurement has not overtaken human sense yet on that point.

How does such a difference come about and how does wall material of wind instruments affect on the sound? In order to clarify these points precise experiments using artificial playing system are absolutely required. In the experiment by human players, some ambiguities are left in reproducibility and reliability. We made a system which plays the clarinet by referring to the system invented by Idogawa et al [2]. When the system plays the clarinet, the reed (the source of the sound) seems to vibrate in almost the same way as human players do. We can hardly discriminate the two sounds generated by artificial playing system and human players. Since the system ensures stable and reproducible tones, we may do quantitative and precise measurement based on the system.

The measurement is carried out on three kinds of clarinets whose wall materials are grenadilla and ceramic. The directivity patterns are measured along a semi-circle in a horizontal plane by placing the clarinet axis on the circle diameter as well as along semi-circles in planes perpendicular to the clarinet axis. These field patterns are measured by a fixed microphone while rotating the clarinet set on a turntable. Such a method is commonly used and was applied to underwater organ pipes [3].

2 Experiment

2.1 Artificial blowing system

Figure 1 shows our experimental setup to measure the directivity patterns of clarinet sounds. Figure 2 is a picture of the equipment. An artificial mouth and a clarinet are fixed by an iron stand. High-pressured air is stored in the tank located outside the anechoic chamber. The pressure is adjusted to the proper value by the regulator inside the chamber. The air is guided through a connector and a rubber tube to the artificial mouth.

This mouth is made of transparent acrylic plate of 5 mm thick. Its net volume is about 3.0×10^{-4} m^3. The artificial lip is made of silicone rubber of 10 mm thick (Shin-etsu Kagaku Co., KE114S). The mouthpiece of the clarinet is secured by the artificial lip. The pressure which tightens the reed is adjusted by rotating a screw through the mouth plate.

We used three kinds of clarinets whose wall materials are different. Two clarinets are made of grenadilla, one is old and cheap model (made by Yamaha), the other is expensive model (made by Buffet Crampon). The last one is made of ceramic (custom-made by Yamaha).

When the blowing pressure is increased gradually, the reed begins to oscillate and generate a sound. Figure 3 shows the measured sound made by grenadilla-Yamaha clarinet whose frequency is 345 Hz. Because we can hardly discriminate the two sounds generated by the artificial playing system and human players, we may consider that when the system blows the clarinet, the reed vibrates in almost the same way as human players play the clarinet.

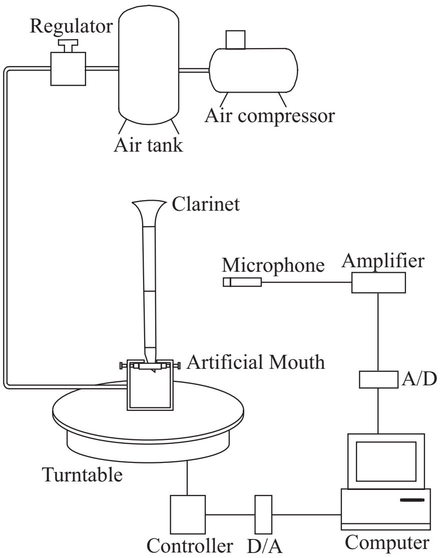


Fig. 1: A system to measure clarinet-sound directivity.

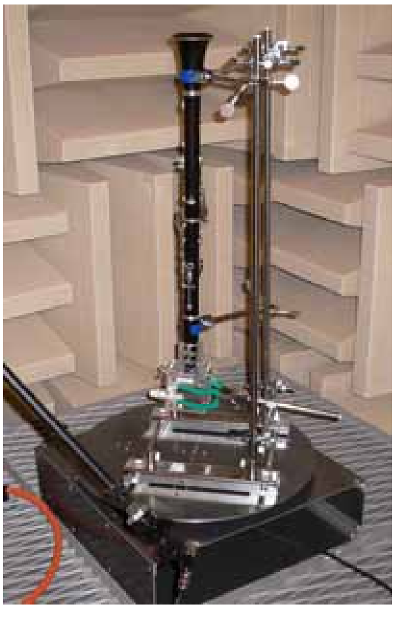


Fig. 2: An experimental clarinet on a turntable.

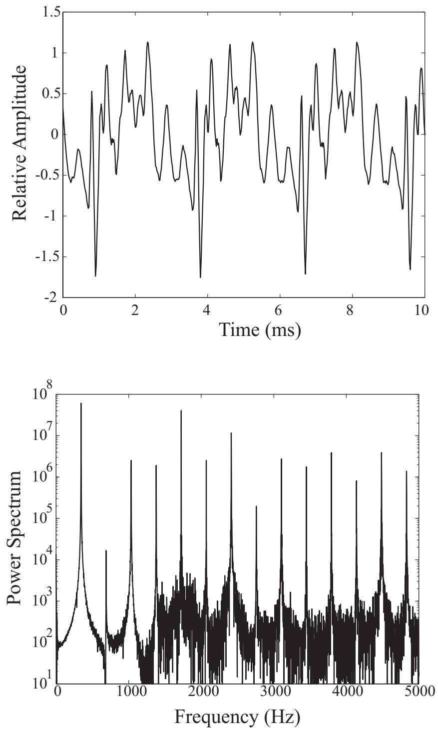


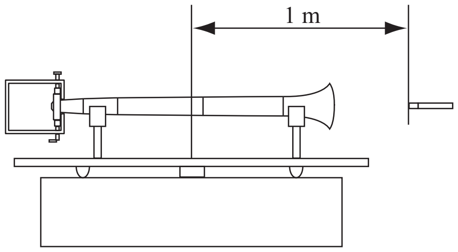
Fig.3: An example of tone produced by an artificial blowing system (grenadilla-Yamaha clarinet, 345 Hz).

2.2 Directivity pattern measurement

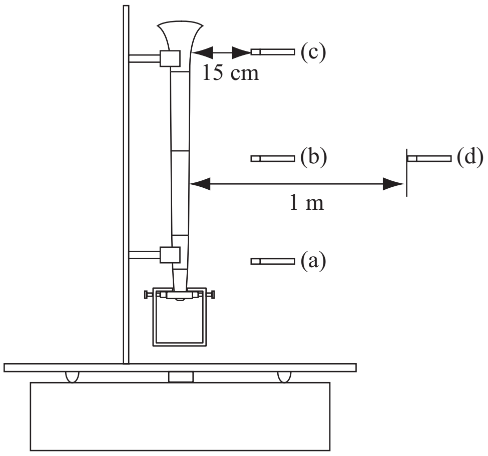
The measurement of radiation-directivity patterns of wind instruments has not been carried out until now in a precise manner, since long stable and reproducible tones as well as a rotating turntable are necessary.

We measure two kinds of patterns, one is in a plane parallel to the axis of clarinet cylinder, and the other is in a perpendicular plane. In this paper the former is defined as "lateral directivity" and the latter as "circumferential directivity". Figure 4 indicates experimental configuration to measure these directivity patterns. The directivity pattern is measured by fixing a microphone and rotating the clarinet using a turntable while making a sound. The table rotates in 7.2-degree steps, and the sound is measured after such a small rotation is finished. The radiated sound is measured along a left semicircle as shown in Fig. 5.

We use a 1/2-inch condenser microphone and fix it at the position distant from the center of the clarinet by 1 m when we measure the pattern in a horizontal plane [cf. Fig. 4 (a)]. When we measure the pattern in a perpendicular configuration the microphone is fixed at four positions near (a) barrel, (b) center, (c) bell, at the distance of 15 cm from the clarinet, and in (d) far field distant from the clarinet by 1 m [cf. Fig. 4 (b)]. The clarinet is held as indicated in Fig. 4 (b) by turning the bell to the top in order to reduce the reflection from the turntable.

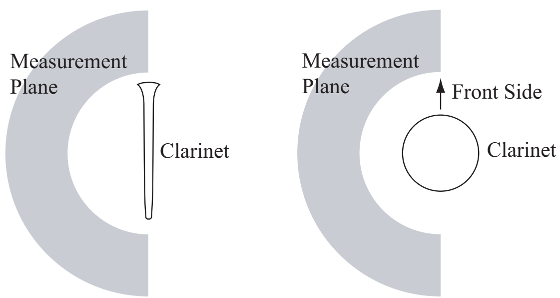


(a) "lateral directivity" measurement



(b) "circumferential directivity" measurement

Fig. 4: Configuration of the clarinet and microphone.



(a) lateral directivity (b) circumferential directivity

Fig. 5: Measurent plane (top view).

3 Results

Figure 6 shows lateral directivity patterns of three clarinets. Since our research is just in the initial phase, a tone (close to B5) is measured without touching any keys. It should be expected that the blowing condition (i.e., adjustment of artificial lips, setup of blowing pressure, etc.) is kept unchanged to compare three clarinets, but the adjustments are very delicate, and it is rather difficult to play all clarinets under the same condition. The sounding frequencies are 969 Hz, 967 Hz, and 972 Hz for grenadilla-Yamaha, grenadilla-Crampon, and ceramic-Yamaha clarinets, respectively.

The pressure level shows a local maximum at an angle a little deviated from the clarinet axis (about at 111-degree direction). Three patterns in Fig. 6 are quite similar, although the pressure magnitude of the grenadilla-Yamaha is a little smaller as indicated in Fig. 6 (a). Our result that the strongest radiation occurs in the direction deviated from the clarinet axis may reflect the conical radiation from a lattice of open tone holes [4].

Figure 7 shows circumferential directivity patterns of grenadilla-Crampon clarinet. The sounding frequency is 356 Hz (close to F4). The patterns at the barrel [Fig. 7 (a)] and the bell [Fig.7 (c)] are almost concentric circles. The pattern at the center [Fig. 7 (b)] indicates stronger radiation in the front side (at 90 degrees) as expected from the effect of tone holes.

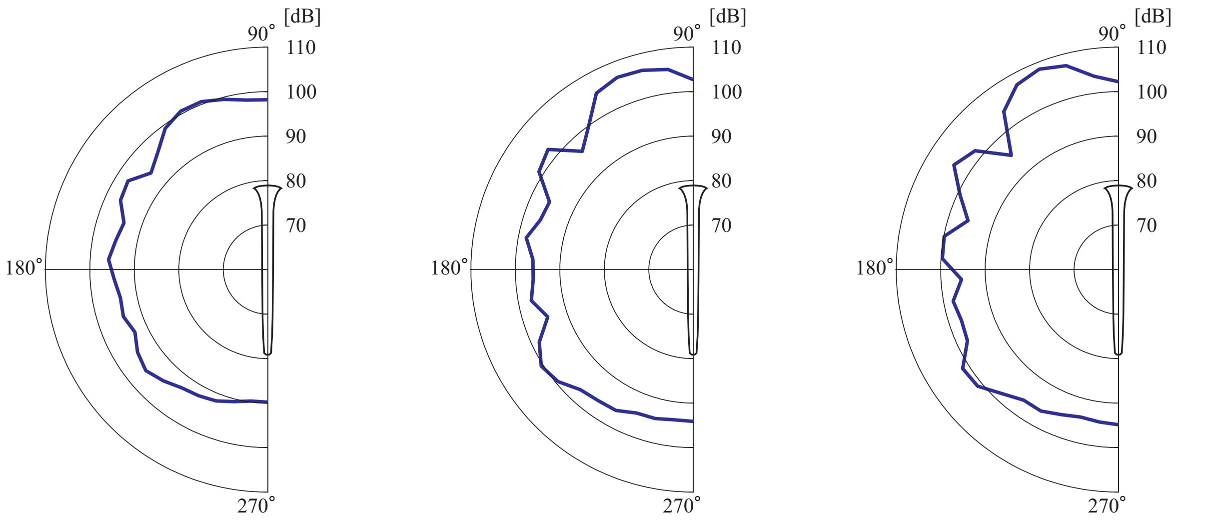
The pattern measured along a semi-circle distant from the clarinet by 1 meter has a local maximum around 159 degrees possibly due to complicated interferences between tone-hole radiations. It is an interesting result that the effect of tone holes may not be involved in radiation field patterns measured around the barrel and bell at a distance very close to the clarinet wall surface.

However, these results are not enough to discuss the correlations between wall materials and directivity patterns. More detailed experiments should be carried out to exactly detect the correlations. For example, an electro-mechanical drive of the reed used together with the blowing pressure may be a solution to make a very stable and appropriate driving system. At the same time an accurate measurement in the near field should be considered.

4 Conclusions

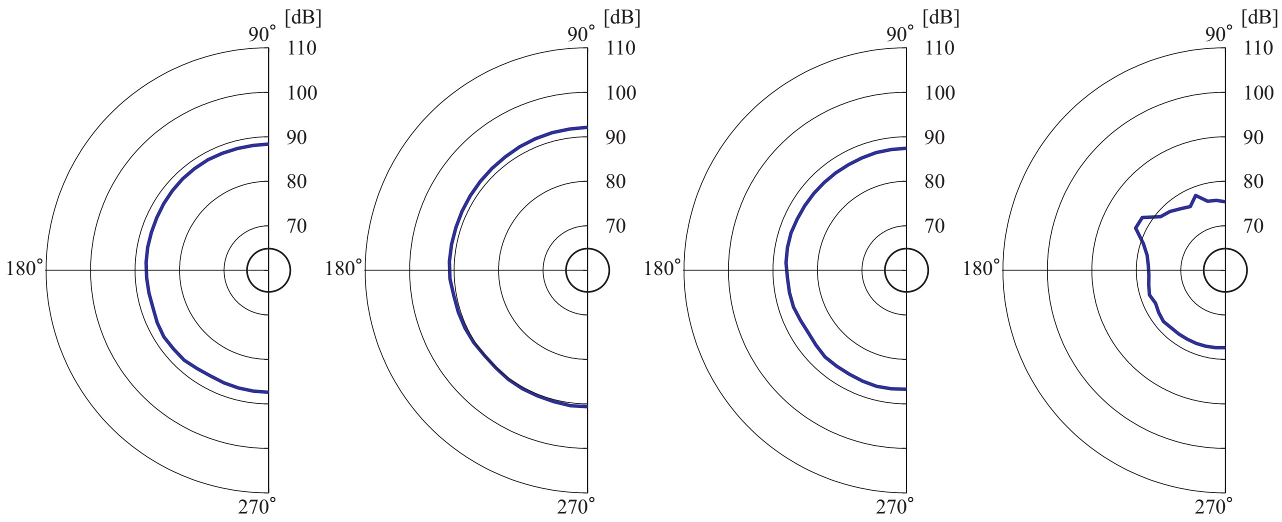
At the beginning of basic research to investigate the effect of wall material on tones of wind instruments, an experimental system has been developed to measure radiation directivity patterns of the clarinet when it is artificially blown. Lateral directivity patterns of the clarinet whose keys are all untouched well indicate the so-called conical radiation from a lattice of open tone holes. On the other hand, circumferential directivity patterns indicate the effect of open tone holes when the measurement is carried out near the clarinet center or in far field, however, such patterns seem to be free from the tone-hole effect when the measurement is carried out near the barrel and bell at the distance of 15 cm from the clarinet axis. This suggests the effectiveness of near-field measurement to detect wall-material effect.

Although our measurement system seems to be stable and reliable, our artificial blowing system needs to be



(a) Grenadilla-Yamaha, 969 Hz (b) Grenadilla-Crampon, 967 Hz (c) Ceramic-Yamaha, 972 Hz

Fig. 6: Lateral directivity patterns of three clarinets.



(a) barrel (b) center (c) bell (d) far field

Fig. 7: Circumferential directivity patterns of grenadilla-Crampon clarinet (sounding frequency: 356 Hz).

improved. Particularly, artificial lips have low reliability to form satisfying embouchure. An electro-mechanical driving of the reed will be a promising candidate for a long and stable blowing of the clarinet. After finishing proper improvements we would like to attack wall-material effects in the clarinet whose tone holes are all closed in the near future.

References

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