

## Resonance frequency changes of Japanese drum (nagado daiko) diaphragms due to temperature, humidity, and aging

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### 1. Introduction

The most popular type of Japanese drums is the one called “nagado daiko (long-body drum),” in which diaphragms are nailed to both ends of a barrel-like wood cylinder. Since it does not have the function to adjust the resonance frequencies of the diaphragms after the assembly, it is a common experience that nagado daikos are out-of-tune when they are played with other musical instruments on very dry or wet days (note that they are categorized as indefinite pitch instruments [1]). This letter reports the resonance frequency changes due to temperature and humidity measured in a temperature/humidity-controlled room (abbreviated as “THCR”) and in a regular office room. This letter also reports the resonance frequency changes due to aging within several months from the assembly.

### 2. Resonance frequency measurement in THCR

Two drum types used for this study are with 42.4 cm and 48.5 cm diameters (referred to as “model A” and “model B,” respectively). Figure 1 left shows a drum/sound-level-meter arrangement and Fig. 1 right shows an example of a sound spectrum of a model A drum. Drums are struck with normal strength and the sound is recorded using an FFT analyzer. The first three resonance frequencies (indicated by the three arrows in the figure) are determined from the frequency spectrum measurements.

The measurement conditions in THCR were changed in two ways. First, the temperature was kept constant at 20°C and the relative humidity was set at 30, 55, and 80%. Second, the humidity was kept constant at 55% and the temperature was set at 5, 20, and 35°C. One measurement condition was kept for at least four hours before the resonance frequency measurement.

It is a common practice that the “front” diaphragm is tuned slightly lower than the “rear” diaphragm at the time of assembly. Relative values of the first three resonance frequencies of the front and rear diaphragms (total six) are shown in Fig. 2 with resonance frequencies measured under the condition  $T = 20^\circ\text{C}$  and  $H = 55\%$  as references. The left side charts are for the constant temperature at 20°C and the right side charts are for the constant humidity at 55%. There are six lines but some of them are overlapped.

Following are conclusions from the results.

- (1) The effect of the humidity is approximately 0.3 octave reduction for 50% humidity increase ( $-0.006$  octave/%).
- (2) The rate of change is larger in the range from 30% to 55% than in the range from 55% to 80% percent.
- (3) The effect of the temperature is approximately 0.1 octave increase when the temperature is varied from 5 to 35°C ( $0.003$  octave/ $^\circ\text{C}$ ).

The effect of the humidity on the resonance frequencies is very severe. The 15% humidity change may cause a semi-tone pitch change. The effect of the temperature is much smaller than that of the humidity, considering the ranges of those two parameters and the resonance frequency variations.

The positive gradient of the right-side charts may be due to the stiffness increase of the air inside the body. However, please note that the increase of the air stiffness from  $T = 5^\circ\text{C}$  to 35°C is less than 0.1%.

### 3. Resonance frequency measurement in an office room

Dependence of resonance frequencies of a model A drum was measured in an air conditioned office room once or twice a day mostly during weekdays from June 2006 to January 2007.

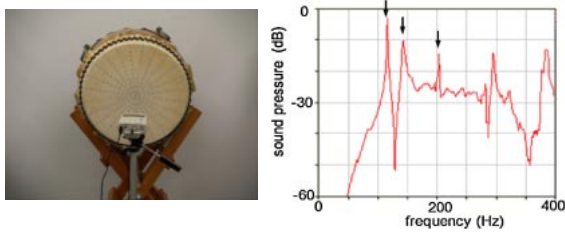
Figure 3 shows results of the resonance frequency dependence on the humidity before and after the measurement described in the previous section, which was conducted during 13–15th November 2006. The top and bottom charts show the data when the room temperature was within 23–24°C and 22–23°C, respectively. A reason for the difference of the trends between the two measurements is not known.

The data of the temperature dependence is not shown because the effect of the temperature is very small and it is difficult to avoid the effect of the humidity when two parameters vary simultaneously.

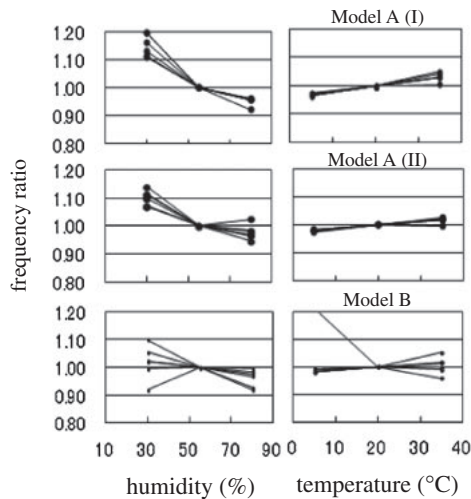
### 4. Resonance frequency changes due to aging

The tension adjustment (tuning) of two diaphragms is made at the time of attaching the diaphragm to a wood body while the diaphragms are kept wet. The diaphragm dries very quickly and the resonance frequencies jump up. Then, they gradually decrease due to the stretching of the diaphragm naturally or by usage.

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**Fig. 1** Measurement setup (left) and an example of pressure spectrum of a model A drum (right).

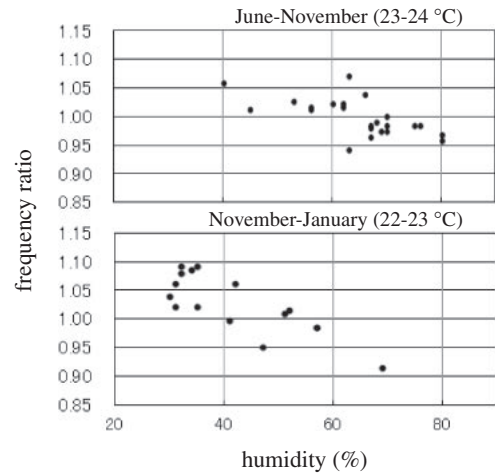


**Fig. 2** Resonance frequency changes due to the humidity and temperature changes measured in THCR.

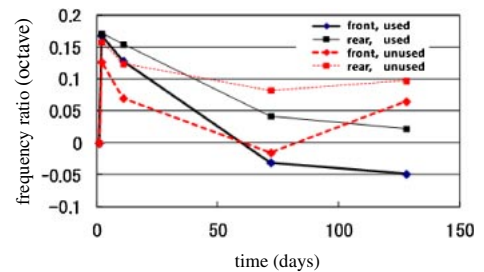
Resonance frequencies of approximately 20 model A drums were measured immediately after the assembly (July 14th), and 2, 11, 71, and 124 days later (Nov. 19th). Average resonance frequency variations of several drums in each category are shown in Fig. 4, where the reference frequencies are those measured right after the assembly. The “used” indicates drums that were used in a studio for practice after the manufacturing. Roughly speaking, the resonance frequencies of the used drums approach to those at the time of assembly in several months. However, the effect of the humidity must be taken into account in understanding the aging trend shown in Fig. 4.

**5. Conclusions**

Resonance frequency changes of nagado daikos due to temperature, humidity and aging were measured. The humid-



**Fig. 3** Resonance frequency changes due to the humidity changes measured in an office room.



**Fig. 4** Resonance frequency changes due to aging.

ity dependence is significant, whereas the temperature dependence seems very minor. Roughly speaking, the resonance frequencies of the drum diaphragm approach several months later to those at the time of assembly if the drums are used during that period.

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**Reference**

[1] T. D. Rossing, *Science of Percussion Instruments* (World Scientific, Singapore, 2001).