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Cover art: Mount Fuji from the mountains of Tōtōmi, (遠江山中 Tōtōmi sanchū) from Thirty-six Views of Mount Fuji (富嶽三十六景 Fugaku Sanjūrokkei) by Hokusai Katsushika (葛飾北斎)

Physical Properties of a Reed (*Phragmites australis*) Used for the Vibrating Reed of Japanese Traditional Oboe (Hichiriki)

Ryo Nakanishi[1] and Eiichi Obataya[1]

ABSTRACT: Hichiriki is a Japanese traditional oboe used for Japanese ancient court music, and the vibrating plate of the hichiriki is made by a reed (*Phragmites australis*). We observed the anatomical structure of reed selected by experts, and measured their density and transverse compressive strength to clarify the basic requirements for quality instruments. Within an internode, the upper part was always thinner and denser than the lower part, depending on the thickness of low density parenchyma layer beneath the cortex. The selected reed was slightly thicker and denser than unselected reed, whereas those differences were not significant. On the other hand, the transverse compressive strength of selected reed was significantly greater than that of unselected reed, and the upper part showed highest strength. It is considered that sufficient transverse strength is required while thinner i.e. deformable upper part is preferred for hichiriki, because an end of reed culm is compressed to form the closed end of double-reed.

KEYWORDS: *Musical instrument, hichiriki, Japanese ancient court music, reed, quality evaluation*

1 INTRODUCTION

Gagaku is Japanese ancient court music. Particularly the gagaku played in imperial palace is listed in UNESCO's Intangible Cultural Heritage of Humanity. The Gagaku is performed by various traditional musical instruments, including hichiriki. The hichiriki is an oboe-like double reed woodwind instrument. The vibrating plate (rozetsu) of the hichiriki is made by a reed (*Phragmites australis*), and the best reed is believed to be harvested in Udono area along Yodogawa river. Figure 1 exhibits the appearance of hichiriki and harvesting of reed by experts[1].

According to those experts, it is getting difficult to harvest high quality reeds. That problem is probably due to the urbanization around the reed field as well as the reduced scale of reed-burning being necessary for the growth of reed. In addition, the skills of reed harvesters also faces the risk of interruption. To conserve the tangible and intangible culture around gagaku, sustainable cultivation of reed as well as the establishment of efficient method for selecting reed are recently required.

Although many investigations have been made on the mechanical and acoustic properties of a reed (*Arundo donax*) used for occidental woodwind instruments[2-4], little information is available for the Japanese reed. In this study, the shape, density, anatomical structure and mechanical properties of reeds selected by experts were compared to those of the other unselected reeds to discuss the physical properties required for the vibrating reeds of hichiriki.

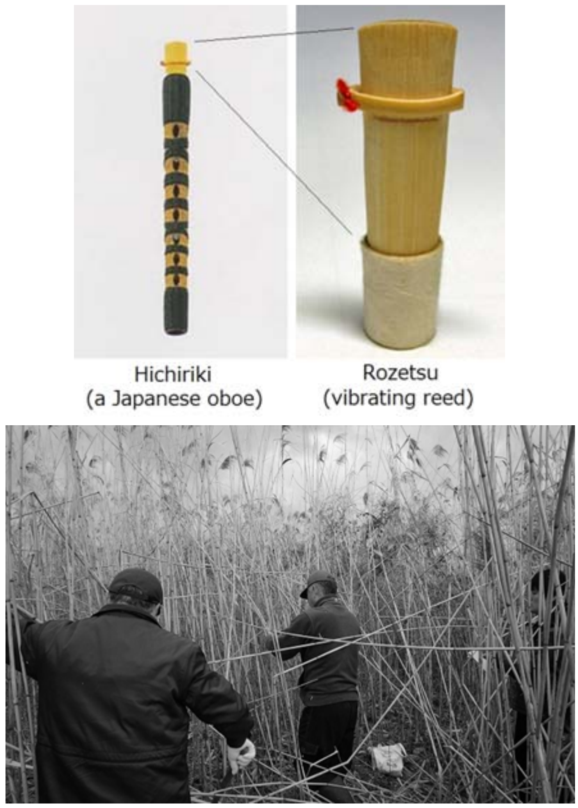

Figure 1: *Hichiriki, rozetsu and harvest of reeds by experts*

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Table 1: Number and diameter of tested reed samples

Place of harvest	Abbr.	Quality	Node number	Numbers of internodes tested	Numbers of samples tested: Density measurement	Numbers of samples tested: Compression test	Outside diameter [b] (mm)
Udono (dry soil)	UD1	Good [a]	1 – 4	28	84	78	12.3 (0.7)
	UD2	Not good [a]	1 – 5	12	36	29	11.0 (0.4)
Udono (in waterway)	UW	Usually not used	1 – 5	9	27	20	11.8 (0.6)
Mukaijima (dry soil)	MD	Usually not used	1 – 5	20	60	53	12.3 (0.6)

a) Evaluated by experts of harvesting reed, b) values in parenthesis indicate standard deviations.

2 MATERIALS AND METHOD

2.1 REED SAMPLES

Reed samples were harvested in two riverside areas (Udono along Yodogawa river and Mukaijima along Ujigawa river). Relatively thick (diameter 11–12 mm) reeds were selected and their lower part (the 1st to 6th internodes from the ground) were used for the experiments. The numbers and diameters of reed samples are listed in Table 1. In Udono area, experts have selected reeds suitable (UD1) and unsuitable (UD2) for hichiriki. The reeds growing in waterway (UW), which are not usually used for hichiriki, were tested to clarify the effects of water condition in the reed field. It has been reported that reeds in waterway are shorter and thinner than those growing in dry soil[5]. In Mukaijima area, engineers of NEXCO West Co. harvested reed samples (MD) whose thickness and appearance were similar to those of UD1.

2.2 DENSITY MESUREMENT

Ring-like specimens were made from reed culms as illustrated in Figure 2. The basic densities of the specimens were calculated from their oven dry mass and wet volume determined by the Archimedes method.

2.3 MICROSCOPIC OBSERVATION

Cross sections of the reeds were photographed by using an optical microscope, and the photograph was analyzed by using image analysis software (ImageJ) to calculate the density variations in the radial direction.

2.4 COMPRESSION TEST

The ring-like specimens were conditioned at 25°C and 60%RH, and their radial strength were determined by compression test at the cross head speed of 0.5 mm/min.

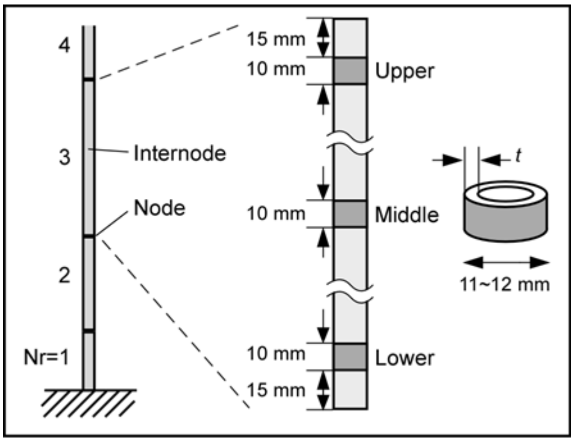

Figure 2: *Shape of reed specimens*

3 RESULTS AND DISCUSSION

3.1 THICKNESS AND DENSITY OF REEDS

Figure 3 shows the thickness of culm (t) and basic density of reeds harvested at different places. The lower part was always thicker and the upper part was always denser than the other parts, irrespective of harvesting place. The t did not depend on the harvesting place, whereas the density of UW was significantly lower than that of the other reeds. Probably dry soil is better to cultivate denser reeds for hichiriki. However, the density cannot be used for the classification of reeds because no significant difference was recognized between the densities of UD1 and UD2.

3.2 STRUCTURE OF REED

Figure 4 shows the cross sections of UD1. The structure of the reed was qualitatively similar to that of *Arundo donax* used for occidental woodwind instruments[2]. Sclerenchymatous fibers (S) form dense layer beneath the epidermal layer (E) and cortical parenchyma (CP). The inner part consists of pith parenchyma (PP) and vascular bundle (VB), and the bundle is surrounded by thick-walled bundle sheath.

As exhibited in Figure 4, porous CP layer is thicker in the lower part. That must be a reason for lower density of the lower part. Figure 5 shows the density variation in

UD1 along the radial direction. The density of reed decreases from its surface to inner part as a whole, but that of lower part exceptionally drops near the surface because of thicker CP layer. Such a trend was recognized in all internodes tested.

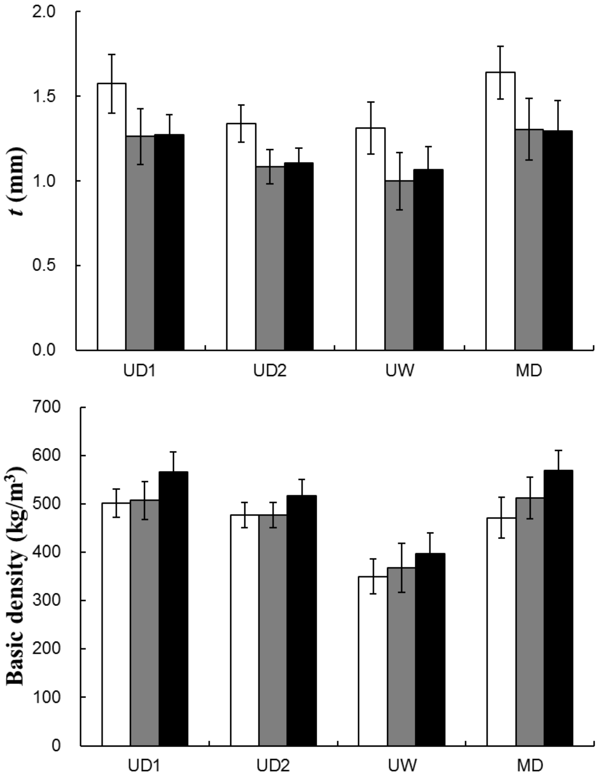

Figure 3: *Thickness (t) and basic density of different reeds*
White bars, lower part; *gray bars*, middle part; *black bars*, upper part. Error bars indicate standard deviations.

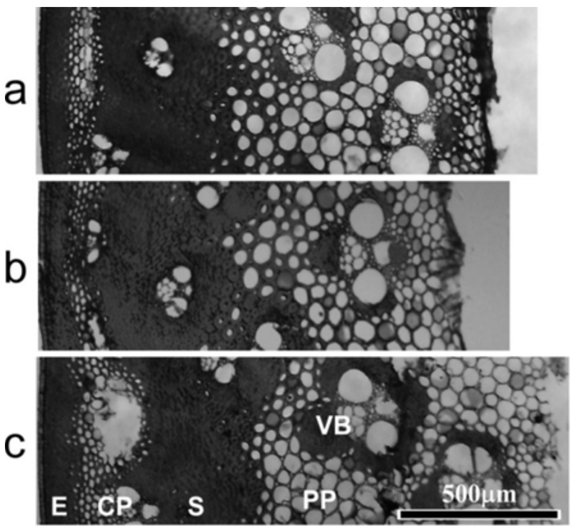

Figure 4: *Cross section of upper (a), middle (b) and lower (c) positions of an internode (UD1)*
E, Epidermal layer; CP, cortical parenchyma; S, sclerenchymatous ring; PP, pith parenchyma; VB, vascular bundle.

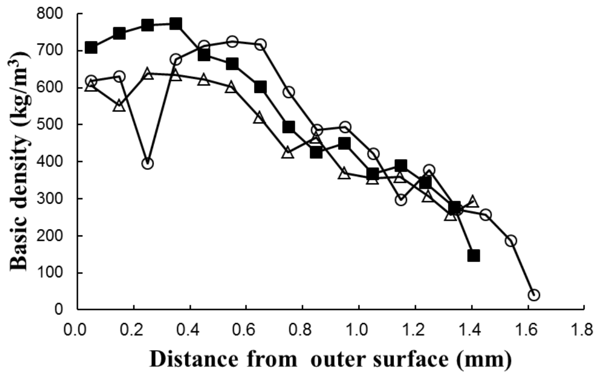

Figure 5: *Density variation of an internode (UD1) along the radial direction.*
Open circles, lower part; *open triangles*, middle part; *filled squares*, upper part.

Figure 6 shows the density variations in the upper part of different reeds. The UW was lighter than the other reeds in all positions, and UD2 showed slight reduction in density near the surface. On the other hand, the UD1 showed no drop in density near the surface. It was speculated that dense surface *i.e.*, thinner cortex parenchyma layer may be required for the reed of hichiriki.

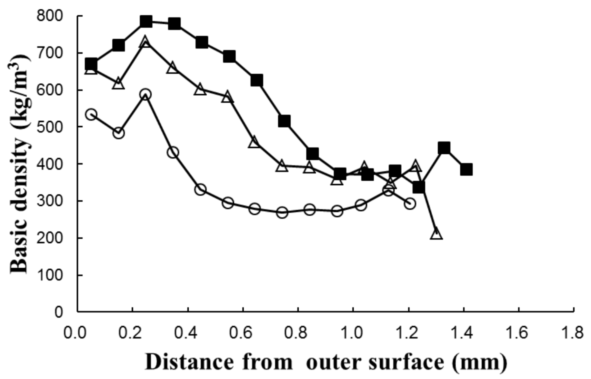

Figure 6: *Density variation in the upper part of different reeds.*
Filled squares, UD1; *open triangles*, UD2; *open circles*, UW. Each plot indicates the average value of 6 internodes.

3.3 STRENGTH OF REED UNDER RADIAL COMPRESSION

As described above, the *t* and density of reed cannot be used for the classification of reeds because those values of UD1 and UD2 were almost the same (Figure 3). On the other hand, the strength of reed under radial compression may be a good indication of its quality. Figure 7 shows the compressive strength (σ_c) of different reeds. The σ_c was calculated from the *t* and breaking load (P_c) according to the following equation,

$$\sigma_c \equiv \frac{P_c}{2Lt}$$

where the *L* is the length of the ring-like specimens.
The σ_c value was the largest in the upper part, and UD1 showed higher σ_c value than UD2 and UW. This fact suggests that the selected reeds are stronger than the

unselected reeds against radial compression. The greater rigidity of UD1 was also recognized in P_c value. It was speculated that the experts evaluate reed culms by their finger to select reeds having higher rigidity.
Here we consider the necessity of radial strength in the traditional processing (hishigi) of hichiriki reed. The hishigi process is schematically illustrated in Figure 8. Different from occidental double reed instruments (*e.g.* oboe and fagot), the hichiriki reed is made by compressing one end of culm with heat. In this case, the reed should not be fragile against the radial compression, and therefore, the compressive strength can be a good indication of processiability of reed. For efficient hishigi process, it is logical to use the upper part because the upper part is thinner and stronger than the middle and lower parts.

From those considerations above, the compression properties (σ_c and P_c) seem useful for rough classification of reeds in the harvest step. In Figure 9, the P_c values of upper part are plotted against those of middle part. There was a good correlation between the P_c values of upper and middle parts. This fact suggests that we can select stronger internodes by testing their middle part, and then use the upper part of the selected internodes.
Finally, it should be noted that the MD, reed harvested in Mukaijima area, was very similar to UD1 with respect to the shape and physical properties tested. Thus, Mukaijima must be a promising reed field for harvesting quality reeds.

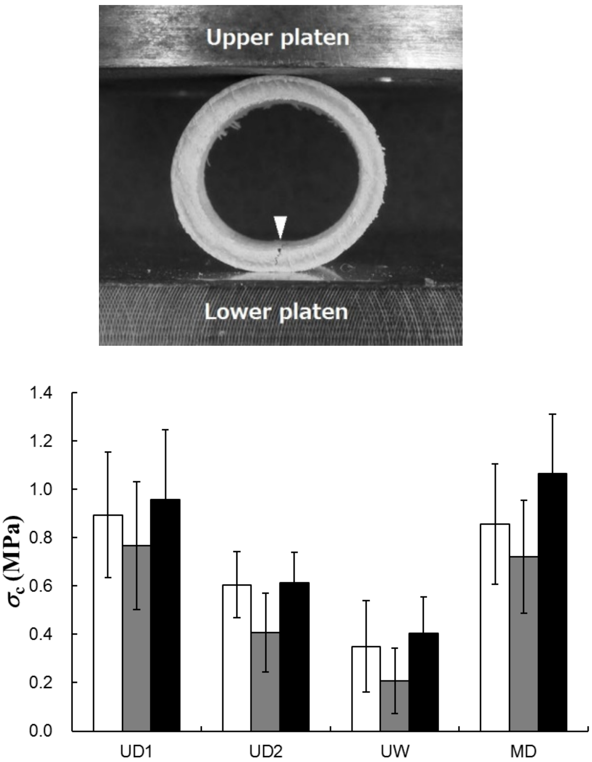

Figure 7: *Cross section of a compressed reed and the compressive strength (σ_c) of different reeds.*
White arrow, breaking part; *white bars*, lower part; *gray bars*, middle part; *black bars*, upper part. Error bars indicate standard deviations.

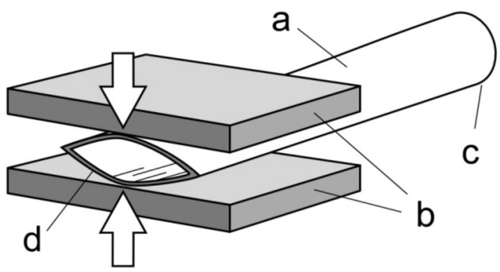

Figure 8: *Traditional compression process (hishigi) to form the double reed shape.*
a, Reed culm; **b**, specially designed metal plier; **c**, cylindrical end to be connected to the instrument; **d**, compressed end to be put in player's mouth.

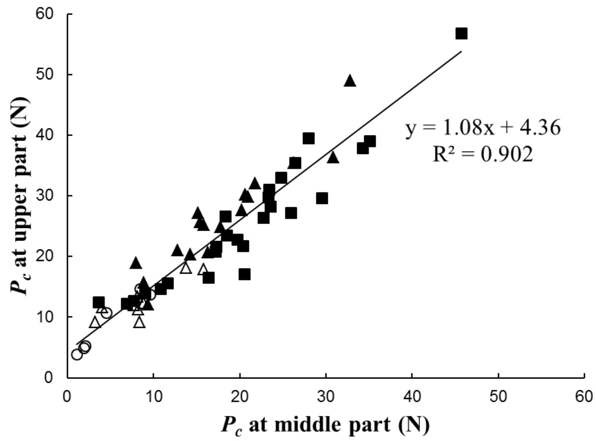

Figure 9: *Relationships between the breaking load (P_c) of upper part and that of middle part.*
Filled squares, UD1; *open triangles*, UD2; *open circles*, UW; *filled triangles*, MD.

4 CONCLUSIONS

The shape, density and compressive properties of a Japanese reed (*Phragmites australis*) were investigated. The results were summarized as follows:

1) Reed growing in waterway was lighter and more fragile under radial compression than the other reeds.
2) Within an internode, upper part was thinner and denser than the other part mainly because of thinner cortex parenchyma layer. In addition, the upper part showed the largest compressive strength. These were possible reasons why the upper part is usually used for hichiriki.
3) The selected "good" reeds showed greater strength against the radial compression, whereas their thickness and densities were not significantly different from those of "bad" reeds. The previous compression test may be an efficient method for the classification of reeds.
4) The reeds in Mukaijima were very similar to those in Udono, with respect to their shape, density and compressive strength. The Mukaijima reed is a fascinating alternative for hichiriki reed.

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REFERENCES

[1] S.Shiba, Gendai hichiriki ko (in Japanese). Nihon Rekishi, 608, 51-54 (1999).

[2] Rüggeberg, M., Burgert, I., Speck T.: Structural and mechanical design of tissue interfaces in the giant reed *Arundo donax*. *J. R. Soc. Interface* 7(44), 499-506 (2010).

[3] Obataya, E., Umezawa, T., Nakatsubo, F., Norimoto, M.: The effects of water soluble extractives on the acoustic properties of reed (*Arundo donax* L.). *Holzforschung* 53(1), 63-67 (1999).

[4] Obataya, E., Gril, J., Thibaut, B.: Shrinkage of cane (*Arundo donax* L.) I, Irregular shrinkage of green cane due to the collapse of parenchyma cells. *J.Wood Sci.* 50(4), 295-300 (2004).

[5] Research team for the environmental protection of reed in Udono: Preliminary report on the growth of reed used for hichiriki, in 2014. http://corp.w-nexco.co.jp/newly/h26/1205/pdfs/2-01.pdf . Accessed 18 July 2016.