Link between stiffness symmetry and perceived quality of clarinet cane reeds

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LINK BETWEEN STIFFNESS SYMMETRY AND PERCEIVED QUALITY OF CLARINET CANE REEDS

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ABSTRACT

The perceived quality of clarinet reeds can be very different from one reed to another, even if they have the same brand, shape and strength. For this reason, there is a strong need for manufacturers to better understand the quality of their production. Many researchers tried to explain these large quality disparities thanks to physical indicators (e.g. mechanical rigidity, modes, reed displacement in dynamic condition) but without totally explaining the perceived quality. Studies on the internal structure have revealed that the wood fibers are not uniformly distributed. Therefore, some authors argue that perceived quality could be related to the stiffness symmetry or the torsional mode symmetry. Based on this observation, the purpose of this work is to evaluate whether the perceived reed quality is related to the symmetry of the reed tip stiffness. This paper presents a preliminary study in which a subjective test and a mechanical measuring bench are designed and discussed.

Keywords: *Clarinet Reeds, Perceived quality, Stiffness, Symmetry*

1. INTRODUCTION

Woodwinds instruments such as the clarinet or the saxophone use a single reed mounted on a mouthpiece coupled to a resonator in order to produce sound using a constant pressure in the musician's mouth. The resonator has been improved for many years and is now well adapted to the musician's needs, particularly thanks to the characterization of its impedance [1]. Mouthpieces begin also to be better understood [2] and can be personalized thanks to 3D printing. However, the reed is still a matter of study. It is defined by two characteristics : its shape and strength. The first one is related to its geometrical profile. The strength is estimated by the reed maker from the measurement of the mechanical stiffness at a certain distance from the reed tip [3]. It is commonly indicated on the reed by a number between 1 and 5 (without any physical unit) or by a letter.

Reeds with identical characteristics from the same reed maker are assumed to be identical by manufacturers. However, musicians agree that their musical quality can be perceived as very different. About 30 % of them are reported as very bad, and only 30 % are of sufficient quality to be played in a concert [4].

In a study by Petiot et al. [5], the perceived quality of 20 tenor saxophone reeds was evaluated by 10 musicians and the results did not show any agreement between players. However, reed makers [3] affirm that there are bad and good reeds and that they can not explain these differences thanks to geometrical parameters or to the reed strength.

The reeds are made of *Arundo Donax L.*, a natural material whose biological characteristics cannot be controlled. Therefore, the distribution of the cane fibers in the plant is not uniform. As a consequence, the local stiffness of the reed tip may not be uniform across the width. Kemp et al. [6] reported that the point stiffness

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is highly correlated with the local fibers density. A perceptive test with a saxophonist conducted by Kemp showed that reeds could be qualified according to their stiffness asymmetry. Furthermore, Casadonte [7] also worked on the relationship between stiffness and quality of clarinet reeds. On the basis of a mild correlation, he concluded that reed asymmetry was correlated with a good perceived quality.

According to these observations and results, the aim of this study is to develop experimental methods that will enable to highlight a possible link between the local stiffness symmetry of the reed tip and the perceived quality of reeds. For this purpose, a panel of reeds has been perceptually tested by two musicians and reeds have been classified into different groups according to their perceived quality. An experimental setup which enables to measure the local stiffness of the reed tip has also been designed. Its operating principle is explained and its accuracy has been evaluated.

2. MATERIAL AND METHODS

2.1 Perceptive test

A perceptive test has been designed to classify reeds with respect to their overall perceived quality. The consistency of the reed evaluation on several tests has also been investigated. For this purpose, two clarinetists had to assess the quality of thirteen reeds from a selected panel.

The clarinetists evaluated the quality of each reed on a 2-point scale (0 for bad reeds, 1 for good reeds that can be used for a recital). The experimenter presented the thirteen reeds to the musician in a random order. He first moistened the reeds in a bowl of clear water and then positioned them on the mouthpiece identically each time. The clarinetist had to answer the following binary question : "Would you use this reed for a recital?". Each musician was free to play whatever he or she wanted to answer the question. This series of tests was repeated 4 times in two separate sessions for each clarinetist. To limit the experimental variability, all tests took place at the same location within the same room. In addition, both clarinetists used the same mouthpiece (*Vandoren B40*). Each musician played his own clarinet (respectively *Buffet Crampon RC Prestige* and *Yamaha 650*). The reeds were disinfected after each session with 70° alcohol and all stored together at ambient temperature and humidity level.

	Mean quality score	
Reeds	Each reed	Reed class
R13	0.375	0.525
R10, R4	0.5	
R12, R3	0.625	
R9	0.75	0.875
R8	1	
R2	0.875	
R11, R7, R6, R5, R1	0	0

Table 1. Mean quality scores for the 13 reeds and the 3 classes.

Figure 1 depicts the hierarchical clustering (or dendrogram) of the reeds with respect to their mean quality scores. The more the reeds were evaluated in the same way, the shorter the horizontal distance between them. The percentages indicate the agreement rate between all the eight evaluations. It is defined as the ratio of the number of identical majority ratings to the total ratings. The mean quality scores of the 13 reeds are presented in Table 1.

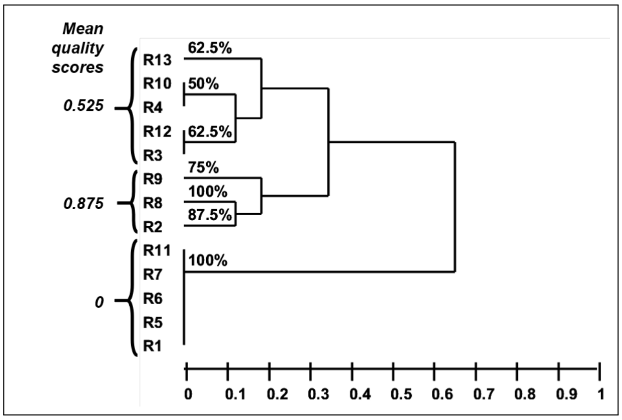

Figure 1. Hierarchical clustering (average linkage) of the 13 reeds according to their mean quality scores. The agreement rates are indicated as percentages.

When focusing on the agreement rate, a classification into 3 main classes can be derived from the dendrogram, as depicted by the dotted line in Figure 1. Two of them obtained a high agreement rate compared to the third one, as indicated in Table 1 :

- The first of these classes obtained the maximum possible agreement rate (100%), indicating a total agreement over the 8 assessments (2 players, 4 repetitions). It consisted of reeds R1, R5, R6, R7 and R11 which could be considered as bad reeds on the basis of the mean quality score of 0.
- The second class also obtained a high average agreement rate (87.5 %). It consisted of reeds R2, R8 and R9 considered as goods reeds on the basis of the mean quality score of 0.875. It should be emphasized that only reed R8 is considered as good by the two players over their four respective assessments (mean quality score of 1) and could possibly be described as a very good reed.
- The third class obtained in comparison a rather poor average agreement rate of 58.3 %. It consisted of reeds R3, R12, R4, R10 and R13 and its mean quality score is 0.525. The quality of these reeds is not consistently assessed over the different repetitions. As an example, the reed R3 obtained a mean quality score of 0.625 with an agreement rate of 62.5 %. In practice, the first player's mean quality score was 0.5 and the second one's was 0.75. Each of the two player was thus not totally consistent over the four assessments. In addition, the two players did not reach the same agreement rate. Therefore, it is not possible to describe such a reed as good or bad.

2.2 Stiffness measurement

In order to relate the subjective quality to objective properties of reeds, a device for measuring mechanical stiffness was designed. It enables the measurements of the local stiffness of the reed tip at different positions. The principle of the bench, inspired by previous work of Ablitzer et al. [8], is presented in Figure 2.

The heel of the reed is clamped and the tip is free. A vertical rod supporting a mass exerts a force on the reed. The deformation profile of the reed is captured by the camera as shown in Figure 3.

The measurement of the reed displacement is carried out by analyzing the images obtained for different added masses (from 38g to 79g). The local stiffness is estimated using a least mean square regression of force versus displacement.

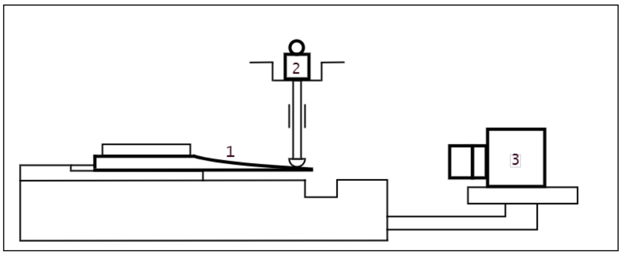

Figure 2. Experimental device designed for stiffness measurements with reed under study (1), added mass (2) and camera (3).

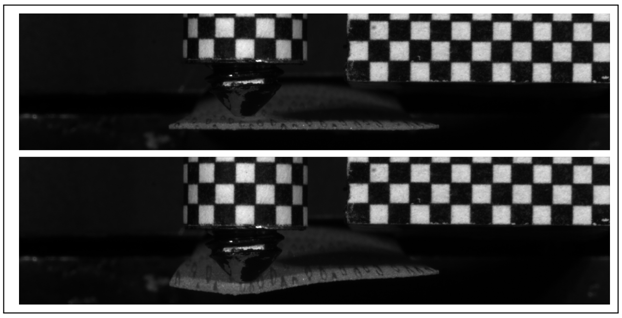

Figure 3. Deformation of the reed by the addition of a mass (top: 0 g, bottom: 79 g) from the camera point of view.

Local stiffness is measured at twenty-two points distributed as depicted in Figure 4. Eleven measuring points spaced every millimeter are aligned across the width of the reed at 3 mm and 10 mm. As the left and right ends of the reed are very fragile, local stiffness at these extreme points is not measured. Results obtained for two identical reeds (Vandoren V21, strength 3) named A and B are shown in Figure 5.

These curves can be fitted by a second-degree equation as equation 1:

$$K = K_0 - K_1(x - x_0)^2 \tag{1}$$

The values of the three coefficients K_0, K_1 and x_0 for the approximation of the four curves are given in table 2.

From the expression of these coefficients, we can deduce their physical meaning. First, K_0 gives the maximum value of the approximated stiffness. In table 2, the stiffness maxima at 3 mm are similar to these measured

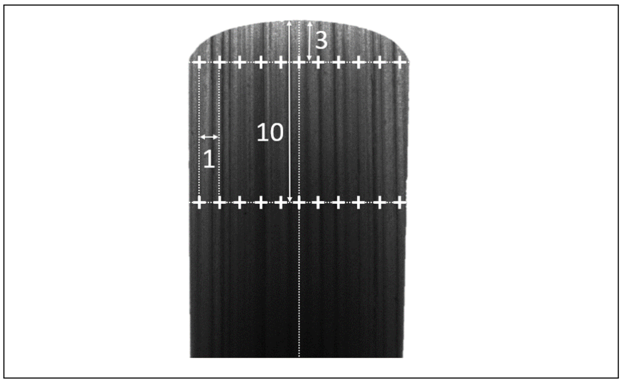

Figure 4. Points where local stiffness is measured. Distances are indicated in mm.

	K_0	x_0	K_1
Reed A, 3 mm	0.977	-0.26	0.019
Reed B, 3 mm	1.081	-0.29	0.021
Reed A, 10 mm	6.880	-0.53	0.142
Reed B, 10 mm	6.563	-0.35	0.111

Table 2. Values of the coefficients of the equation approximating the stiffness profiles

by Kemp [6] and those at 10 mm are similar to these obtained by Gangl [9]. The repeatability of these measurements was tested by measuring 10 times the stiffness of a point located at the center of the reed and 3 mm from the tip. The relative standard deviation is around 3 $\%$. The stiffness values obtained with this bench are therefore reliable.

Secondly, x_0 indicates the lateral position of the maximum. According to Table 2, all coefficients are negative. This shows that the reed's maximum stiffness is not centered on the reed. As a consequence, the reed stiffness is not symmetrical. This is particularly true for the reed A, measured 10 mm from the tip. This may be caused by an asymmetry in the reed positioning prior to the measurement. Besides, based on twenty measurements, the standard deviation of the reed's center position is about $0.13\ mm$ and the relative standard deviation reaches $5.2\ \%$.

Finally, K_1 affects the widening of the parabola and could be assimilated to a lateral stiffness coefficient. In this case, the higher the absolute value of the coefficient, the smaller the sides stiffness compared to the center or,

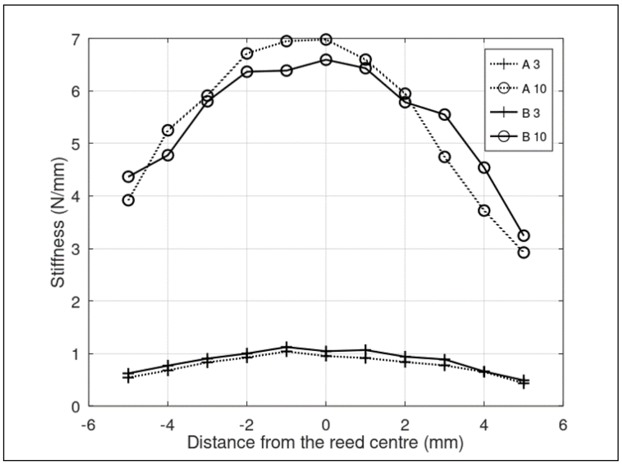

Figure 5. Stiffness profile of two identical reeds : A (dotted line) and B (continuous line) at two distances from the tip : 3 mm (+) and 10 mm (o).

the greater the difference in stiffness between the center and the sides. We can notice that the coefficients are equivalent for reed B and reed A measured at 3 mm. In contrast, K_1 is greater for reed A than reed B for the 10 mm measurement. Reed A's sides are softer than reed B' ones. It would be interesting to carry out measurements on a larger number of reeds to reach a conclusion on this subject.

3. CONCLUSION

A perceptive test was designed in order to measure the perceived quality of reeds on a 2-point scale. Preliminary results obtained with 13 reeds and 2 players show that some reeds are perceived as bad reeds with a very high agreement rate (100%). Some reeds are perceived as good or very good with a high agreement rate. Finally, other reeds can be classified in a third group in which the agreement rate is low meaning that they were not consistently assessed by the two players.

A measuring bench was designed. It enables to measure the stiffness profile of the reeds at different distance from the reed tip. Each stiffness profile curves can be approximated by a second-degree equation which gives 3 describing coefficients. At this step, the stiffness values are reliable but the accuracy of the reed's position on the bench needs to be improved to get a lower uncertainty.

In a future work, excellent and poor reeds could be first selected by an expert and then assessed by a panel of musicians on a 3-point scale (”concert reeds” for excellent reeds, ”rehearsal reeds” for average reeds and ”unplayable reeds” for bad reeds). The local stiffness and the transverse deformation at the tip of these reeds could be measured before and after the perceptive tests to identify a possible link between the perceived quality and the reed stiffness asymmetry.

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