Measuring the stiffness of a table tennis blade by soundwave spectral analysis with a smartphone app.

Among the characteristics of a table tennis blade (TTB) that can be found in a manufacturer's brochure there is flexibility: we often find definitions such as "elastic", "stiff" or "intermediate". This refers to the type of game for which each TTB is designed. Flexibility represents a very important feature for a TTB, since the '*feel*' given by hitting the ball largely depends on it, as well as the racket's rubber material. Since flexibility needs to fit the player's characteristics, it is essential when choosing a suitable TTB to advance or improve our game.

In this article, we will address the following question: can we objectively measure the flexibility of a TTB as we do with weight or thickness, and can this measurement potentially help us assess whether it could be a good fit for us even before trying it? We will herein demonstrate that the flexibility of a TTB can be approximated by analyzing the spectrum of sound produced by bouncing a ball on the TTB using a smartphone application: the most suitable application is called "*FFT Wave*" (available for Android and iPhone).

The application can be tested directly on the website:
http://www.claredot.net/en/sec-Sound/audio-signal-generator.php

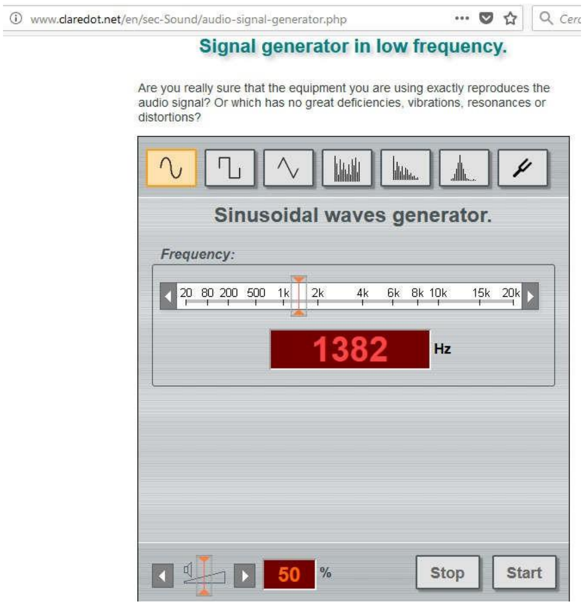

Figure 1

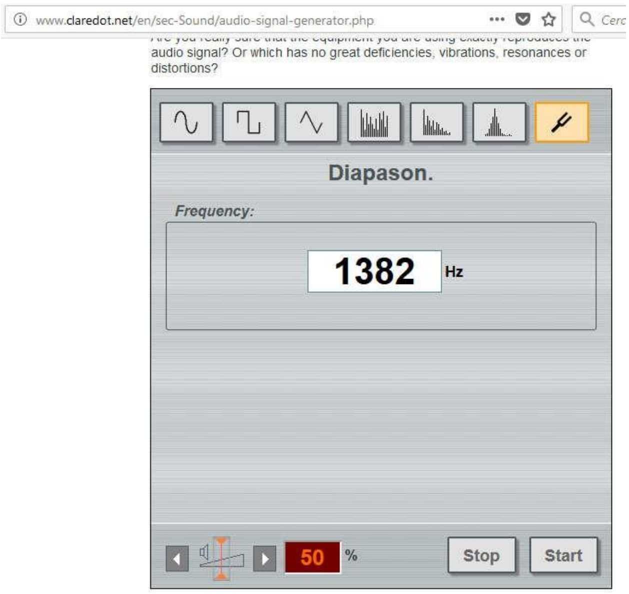

Figure 2

it is possible to generate (for example with a PC or with another smartphone) a sound signal by using for example the "Sinusoidal waves generator" or the "Diapason" function and compare the set frequency with the measurements made by the application: tests performed by me with various devices resulted in excellent reproducibility and consistency.

We now need to explain some concepts concerning the phenomenon that we are evaluating and the graph generated by the application: any noise can be broken up into a set of pure sounds (sinusoids) of different amplitude for each frequency, and by adding up all the single components it is possible to reproduce the original sound. Following the impact of the ball, the TTB starts to vibrate and will produce a sound that is partitioned by the application into its components, thus obtaining the spectrum in frequency of the generated noise.

This is shown in the graph on Figure 3: on the "x" axis (abscissa) is represented the frequency in Hz, and on the "y" axis (ordinate) the intensity in decibel (dB). Frequency signal graphs are conventionally illustrated as

follows: the “x” axis is linear (i.e., the ratio between frequency and abscissa is constant), while the “y” axis (intensity) is represented in a logarithmic scale (on base 10), for example the amplitude 60 dB is 10 times 50 dB.
The amplitude of the spectrum (noise intensity) will depend on the impact speed of the ball on the TTB, but the frequency range in which it occurs and, more importantly, the frequency of the peak (which is the most easily identifiable data) are intrinsic features of that TTB and depend on its size, shape, and material of which it is made.
For example, we can observe in Figure 3 that the frequency peak at 1076 Hz - for the above mentioned reason - has a significantly higher intensity than the components at other frequencies, and therefore it represents the main frequency of theTTB; this frequency is an index of the dynamic stiffness: a low peak frequency suggests that the TTB is elastic, whereas a high peak frequency implies that it is stiff. When performing the test we can hear that the sound generated by a stiff TTB is higher than the one generated by an elastic TTB, and with this application we are able to measure the difference.
Since the ball also generates a sound after it impacts the surface, we may think that its contribution to the soundwave could represent a confounder to our measurements. The generated sound is, in fact an addition of the sounds generated by the TTB and the ball; however, since the ball is much smaller in size than the TTB, the spectral component generated by the ball is also smaller and it is at a higher frequency range (greater than 4 kHz) compared to the one generated by the TTB (always lower than 2kHz); since the two spectral components do not overlap, sounds generated by different types of ball are not expected to interfere with the analysis (see video https://youtu.be/I-5znpJCfT0 “stiffness test made with different playing balls”).

The test therefore consists of starting the FFT smartphone application, bouncing the ball on the TTB and evaluating the peak frequency on the generated graph.
The settings of the application that I modified from the default settings (upon installation) are as follows:

1) Types of graphs \ Spec: this will only display the spectrum.
2) Sampling rate \ 11025 Hz: with this setting the frequency axis extends to 5 kHz; if we want to see higher frequencies (including that of the spectrum component generated by the ball) we should select a higher sampling rate, up to 44100 Hz, but with the recommended setting the graph is more clear.
3) Peak Picking for spectrum: it displays (in red) the spectrum at the time when the ball bounces on the TTB, which is the highest intensity noise; this is the one to evaluate.

Additionally, in order to preserve the accuracy of the test, it is recommended that:
1) The smartphone not be covered, and be oriented towards the TTB at a minimal distance (see the videos).
2) The ball be bounced at the center, and not at the edges of the TTB.
3) The test be performed in a quiet environment and repeated several times in order to find the most frequent value; a sufficient number of measurements should be taken to calculate an average.

The test is to be considered accurate and reproducible if several measurements are observed within 50 Hz.
We will now illustrate some practical examples:

The video available onhttps://www.youtube.com/watch?v=QKwVp_jCqa8 (“ tabletennis blade stiffness measurement”) demonstrates tests performed on three TTB with different characteristics:

Figure 3

The first one is an elastic TTB: the Stiga- Allround Classic - Master (figures 4 and 5 - first part of the video).

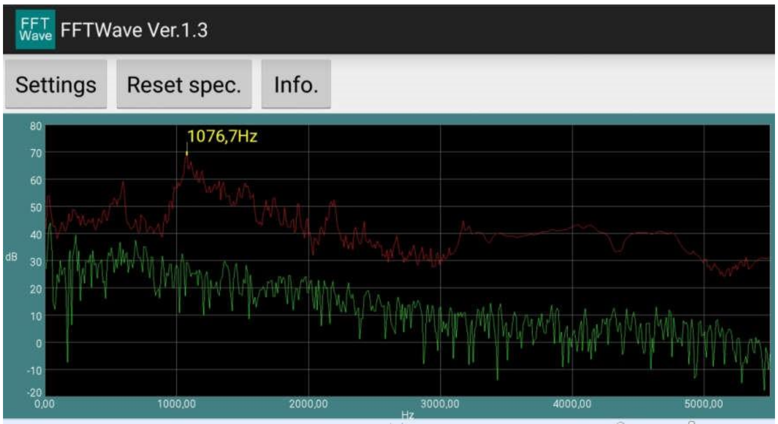

Figure 4: Stiga Allround Classic - Master

Figure 5: elastic

The peak frequency is displayed at 1076 Hz.

The second one is the Tibhar-Samsonov Force Pro, labelled as intermediate (figures 6, 7 - second part of the video).

Figure 6: Samsonov Force Pro

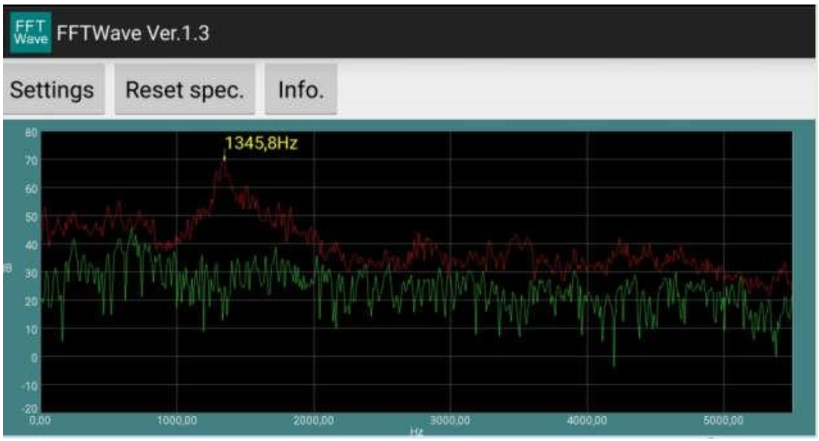

Figure 7: intermediate

The peak frequency is at around 1350 Hz.

The third one is the Donic- Ovtscharov Carbospeed classified as stiff (Figures 8,9 - third part of the video)

Figure 8: Ovtcharov Carbospeed.

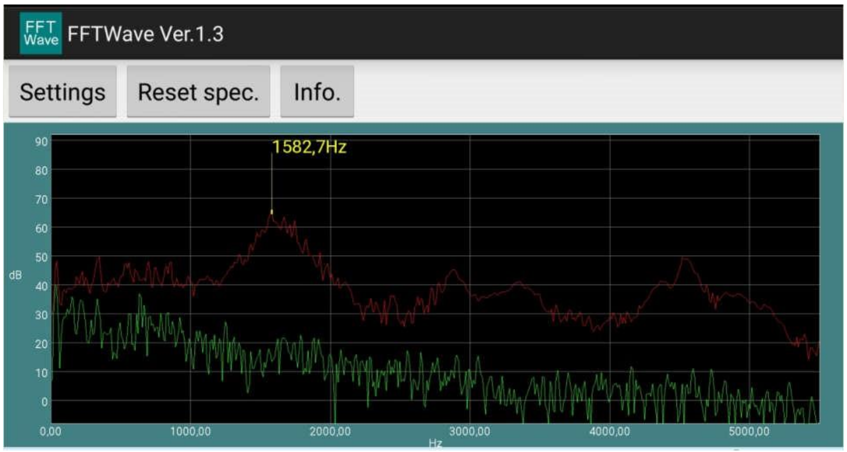

Figure 9: stiff

Here the frequency of the peak is slightly below 1600 Hz

The results of the above tests show a correlation between the stiffness of the blade and the frequency of the peak.

The conditions under which the test is carried out are essential: the cellphone should be kept close to the TTB, surrounding noise should be minimized, and no objects or person should be interposed between the measuring cellphone and the TTB; as mentioned, several measurements are required and averaged out to test the reproducibility of the results.

The above described technique could be helpful to determine which type of TTB is potentially most suitable to the characteristics of our game and to more objectively evaluate a TTB before deciding to buy it. In conclusion, aim of this analysis was to describe an objective methodology which may be useful when choosing a TTB, although there certainly could be other characteristics that need to be taken into consideration.