A Method of Parametrizing Feel and Control of Tennis Rackets

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Introduction

While performance is often the primary consideration for sports equipment design, players and manufacturers seek additional routes to differentiate their equipment from the alternatives. Understanding the human-equipment interaction, specifically perception of feel and control, will be critical to improving equipment design. Studies have been conducted in other sports [1-2]; however, limited work has been done in tennis rackets [3].

Methods

As feel is subjective and player dependent, it is difficult to quantify. One method of parametrizing feel involves examining the vibration signal in a racket (Figure 1). While sound plays a role in player perception, much of the feedback a player receives is dependent on the vibrations felt through the handle of the racket. Furthermore, it has been previously noted [3] that vibration is a common descriptor when rating rackets.

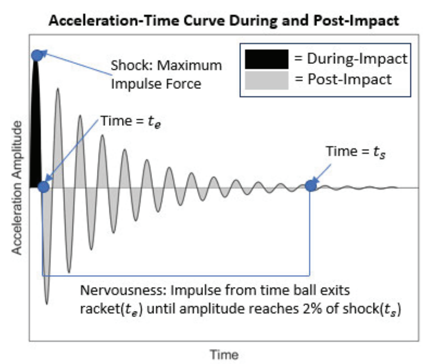

Figure 1: Labeled acceleration curve, perpendicular to the racket face, displaying shock and nervousness.

Several ‘feel parameters’ can be extracted from this vibrational signal, the first of which is shock. Shock, previously measured in [4], is the maximum force experienced by the player.

$$F_{shock} = m \times |a_{max}| \quad (1)$$

As shock (eq.(1)) was highly dependent on the applied hammer force, shock is better quantified as shock ratio (eq.(2)).

$$Shock\ Ratio = \frac{F_{shock}}{F_{applied}} \quad (2)$$

We have defined a new parameter, Nervousness (eq.(3)) as a measure of the lingering vibrations in the racket post impact which could cause an uncomfortable sensation for the player. Nervousness (N) has not yet been quantified in tennis rackets.

$$N = \int_{t_e}^{t_s} m|a(t)|dt \quad (3)$$

The settling time of the vibration signal, and therefore nervousness, is affected by the damping of the system. Damping is dependent on the racket construction and stiffness [5]. This vibration signal was measured through experimental modal analysis [6]. The racket was

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freely suspended on elastic bands, an accelerometer was placed an inch from the racket end and a hammer with a force transducer was used to impact the string-bed. The racket was struck three times at 23 locations evenly distributed across the string-bed. Each signal was processed through a custom-built graphical user interface in MATLAB. Values of shock and nervousness were obtained from the signal directly. The damping coefficient of the first bending mode was calculated using the least-squares complex exponential method through the modalfrf and modalfit MATLAB functions.

Results

The feel parameters of a Head Graphene 360+ Gravity Pro with polyester strings at a tension of 22 to 23 kg are shown in Figure 2.

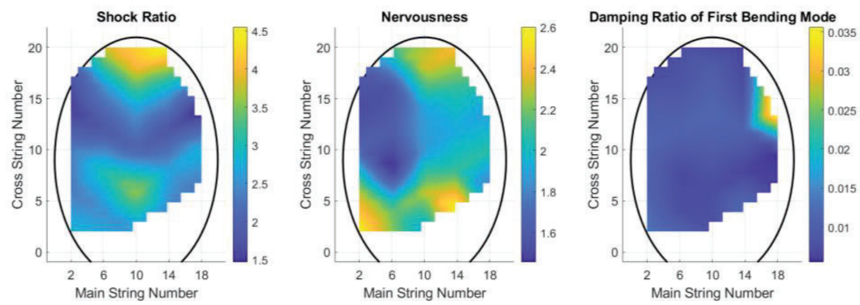

Figure 2: Feel parameters: shock, nervousness, and damping ratio across the racket string-bed.

Discussion

Shock ratio and nervousness increase away from the sweet spot of the racket. This is unsurprising, as the sweet spot or location where vibrations are minimized is located at a vibrational node near the center of the racket [7]. Asymmetry in the maps needs to be investigated further although we suspect it is related to averaging across a few impact locations or a lack of dependency on impact location. This process will be conducted on additional rackets of different materials, weights, swing-weights, and stiffnesses to explore correlations between racket properties and feel parameters.

References

[1] Fischer C, Overney LS, Fauve M, Blanke O, Rhyner H, Herzog MH, Bourban PE, Månson J.A. (2007) What static and dynamic properties should slalom skis possess? Judgements by advanced and expert skiers. J Sports Sci. 25(14):1567-76. https://doi.org/10.1080/02640410701244991.

[2] Hocknell A, Roy J, Rothberg S (1996) Engineering 'feel' in the design of golf clubs. In: Haake (ed.)The Engineering of Sport. Balkema, Rotterdam, pp 333-338

[3] Bauer M, Mitchell S, Elliott N, Roberts J, (2020) Rapid Sensory Profiling of Tennis Rackets. Proceedings 49, 123. https://doi.org/10.3390/proceedings2020049123

[4] Wei SH, Chiang JY, Shiang TY, Chang HY (2006) Comparison of shock transmission and forearm electromyography between experienced and recreational tennis players during backhand strokes. Clin J Sport Med. https://doi.org/10.1097/00042752-200603000-00008

[5] Taraborrelli L, Grant R, Sullivan M, Choppin S, Spurr J, Haake S, Allen T, (2019). Materials Have Driven the Historical Development of the Tennis Racket. Appl. Sci. 9, 4352. https://doi.org/10.3390/app9204352

[6] Avitable, Peter. (2001). Experimental modal analysis – A simple non-mathematical presentation. J Sound and Vibration. 35(01):20-31

[7] Rod C, (2002). The sweet spot of a tennis racket. Sports Engineering 1, 63-78, https://doi.org/10.1046/j.1460-2687.1999.00011.x

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