

Background

The sweet spot of a tennis racket is defined as an area on the racket where the force transmitted to the player's hand is relatively small. On any given racket there are usually three different sweet spots along the axis of the handle. One corresponds to minimal initial shock, another to minimal vibration, and the third corresponds to the maximum coefficient of restitution and results in the most power [1]. For this experiment, I focused solely on sweet spot corresponding to minimal vibration.

The sweet spot corresponding to minimal vibration is defined as the nodal point of the first elastic mode of vibration. For a system, a mode is a sinusoidal motion. Each mode has a fixed frequency associated with it, also known as its natural or resonant frequency. In the case of the tennis racket, the first elastic mode, which occurs at a lowest frequency, typically produces vibrations of highest amplitude [1]. This makes it a top priority because strong vibrations can lead to player injury.

One common tennis injury is called tennis elbow. Tennis elbow (also known as lateral epicondylitis) is caused by injury, abrupt or subtle, of the area where the muscles and tendons of the forearm attach on the outside of the elbow. Although the main cause in tennis player is stress from overusing the forearm, low-frequency vibrations (such as those of the first elastic mode) aid the injury formation process. Li et al. [2] have in the past used finite element simulations to observe the effects of vibration on a tennis racket during a racket collision with a tennis ball. Specifically they focused on investigating how string tension and impact location affected the racket deformation and resultant force on a player's hand as a way to look at ergonomics and injury prevention.

Another past study by Buechler [3] was very similar to the experiment I performed. Buechler analyzed vibration characteristics of a tennis racket through the use of a physical setup aided by modal software analysis to identify mode shapes of the racket with and without commercial dampeners [3]. The study also used finite element simulation to match the experimental data to mode shapes. Although this study gives a more precise location of the sweet spot associated with minimal vibration, it focuses more on quantifying the effects of string tension on sweet spot and mode shapes as well as the effect of vibrational dampeners on the sweet spot. While this focus does help to better quantify the sweet spot as a racket performance measure and give information as to which rackets may be better, it does not look at the area of the sweet in comparison to the overall area of the racket head. Thus, my inquiry into the ratio of sweet spot area to racket head area of various rackets aims to measure the ratio area of the sweet spot which maybe offer insight into a more objective measure of racket performance since racket and string materials vary.

These studies by Mohanty [1], Li et al. [2] and Buechler [3] have done a solid job at creating models for measuring the vibrational sweet spot and observing how different parameters like string tension, vibrational dampeners affect the sweet spot, providing a great base for what the sweet spot is and how it changes. Unfortunately they fail to look at the difference in rackets (in terms of racket and string material properties) and size of the racket head and how that affects not only the size

and location of the spot. My experiment aims to try to encompass all that into a normalized ratio that can be used to compare different racket types (or brands) and even among the same racket at different tension levels.

Bibliography

- [1] Mohanty, P., and Rixen, D. J., 2002, “Measuring sweet spots of tennis rackets,” Proceedings of IMAC-XX: A Conference on Structural Dynamics, February 4, 2002 - February 7, 2002, SPIE, pp. 1539–1545.
- [2] Li, L., Yang, S. H., Hwang, C.-S., and Kim, Y. S., 2010, “Effects of string tension and impact location on tennis playing,” J. Mech. Sci. Technol., **23**(11), pp. 2990–2997.
- [3] Miles A Buechler, L. A. E., “Vibration modeling and supression in tennis racquets.”