Racket Customization: Adding Mass to the Frame

System Tailoring for 'Feel and Control'

Experimental Modal Analysis • Lead Tape • Tennis

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PURDUE UNIVERSITY

Ray Ewry Sports Engineering Center

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Abstract

Customization of tennis rackets, particularly through the addition of lead tape, is a widespread practice among players seeking to enhance a racket's performance. While the physical effects of customization are well-documented, there is limited research investigating how these modifications impact the vibrational profile of the racket, affecting feel and control. Reviewed studies discussed mass's influence on vibrational node location, fundamental frequency, center of percussion, and swing speed. This paper explores the effects of adding mass at the 3 & 9 o'clock position on a racket's vibrational profile through experimental modal analysis. Three carbon fiber performance rackets from three different manufacturers were analyzed with four different amounts of added lead tape (0g, 5g, 10g, 20g). The results were analyzed using an ANOVA test and analysis with confidence intervals to observe how adding mass at the 3 and 9 o'clock position affected the parameters.

The review provides valuable insights for the proposed experiment of investigating how adding mass to the racket frame affects the feel and control of a racket through the scope of its vibrational profile. This paper contributes to the general study of how different forms of customization affect the feel and control of a racket.

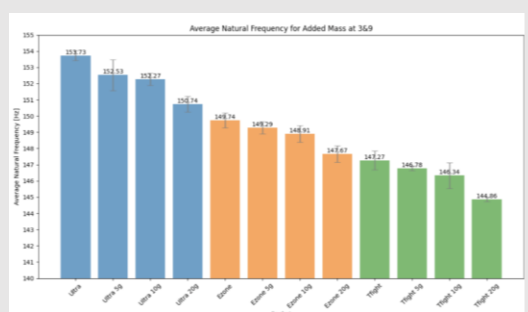

Fig. 1: Comparison of Average Natural Frequency for All Tested Racket Configurations

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Project Overview

Lead tape and other forms of customization are common amongst tennis players looking to change the feel and performance of their rackets. While literature and a general understanding exists with regards to the physical effects of customization, there is little that investigates in detail how the vibrational profile changes.

The project entailed a literature review that provided findings in how adding mass affects inertial properties, reduces injury, and increases racket performance. Then, a study was designed to investigate how adding mass at the 3 and 9 o'clock position of a tennis racket affect a racket's vibrational parameters for feel and control.

This study specifically looked at testing the Yonex EZONE 98, Wilson Ultra 100L V4, and Tecnifibre Tfight ISO and added 5, 10 and 20 grams of lead tape at the 3 and 9 o'clock positions. The process for each configuration entailed tracking the racket specifications, conducting an experimental modal analysis, and performing a statistical analysis to observe differences.

The outcome of the project includes a scripted MATLAB GUI to calculate and store the racket specifications prior to conducting experimental modal analysis. In addition to the reported results, this study is expected to contribute to the understanding of how adding mass to the racket frame affects the parameters of feel and control for tennis players.

Project Method and Results

The project setup consisted of four separate components: (1) a MATLAB GUI constructed to track and store racket specifications, (2) an experimental modal analysis, (3) another MATLAB GUI targeted towards extracting tennis-related parameters from the acceleration and force data, and (4) a statistical analysis to distinguish relevant differences in the data.

Figure 2 illustrates the GUI that was developed to track and store the racket specifications. This workflow included recording what is recorded in the market and what was recorded in the lab. From this GUI, the balance, center of percussion, swingweight, and mgr/I (a parameter discussed in the literature review) is calculated and stored to compare between rackets of different mass configurations.

Fig. 2: MATLAB GUI scripted to record and store racket specifications

Project Method and Results (cont.)

Figures 1, 3, and 4 display a part of the results calculated in this study. Figure 1 is an example of using confidence intervals to evaluate a statistically significant difference between different mass configurations (ranging from adding no mass, 5 grams, 10 grams, or 20 grams). The confidence intervals calculated communicate that there is a 95% chance the results of a particular configuration would fall in that specific range. To compare if there is a statistically significant, the ranges for the two compared sample population means would be exclusive of each other. For an example on the extremes, the Yonex EZONE with 20 grams added had a statistically significant difference with a decreased natural frequency when compared to the Yonex EZONE with no mass added to the frame. The confidence intervals were also utilized for parameters such as swingweight, twistweight, and balance, three of the five parameters extracted from the Racket Specifications GUI in Figure 2. These are an example of the parameters that resulted in the expected trend: It was observed that as mass was added to the 3 and 9 o'clock positions, there was a statistically significant increase in each of the parameters as more weight was being add farther from the handle (see Figure 3 as an example).

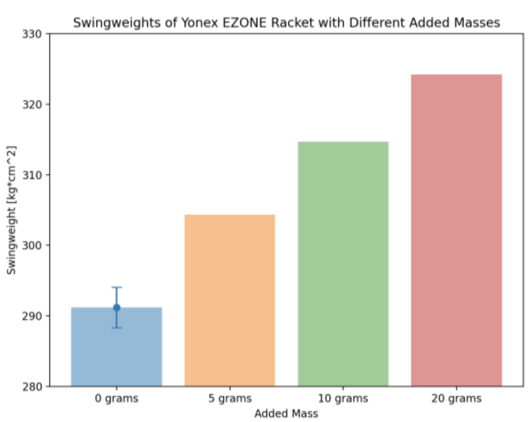


Fig. 3: Calculated Swingweights for Tested Racket Configurations for Yonex EZONE

Another set of results was assessed by conducting ANOVA, or Analysis of Variance, tests with the various mass configurations. This was done comparing every location struck by the hammer between the rackets to see how the parameter outcomes were affected.

Figure 4 displays how the shock ratio parameter varied across the difference configuration. The red markers on the strings communicate a statistically significant difference when compared to the racket with no mass added. The pink tags illustrate an increase in the recorded parameter (while green would have indicated a decrease).

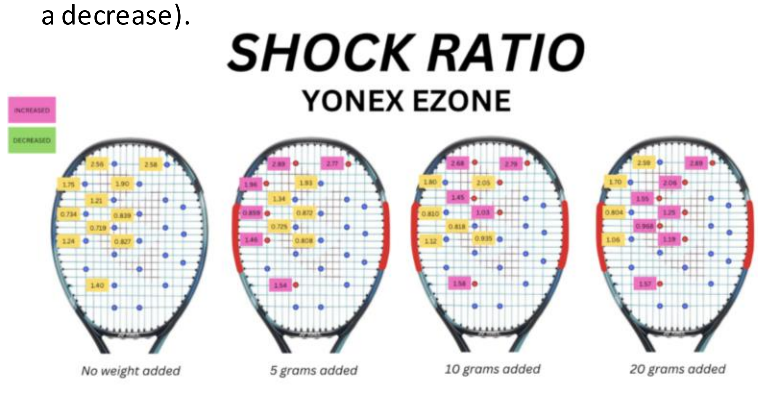


Fig. 4: Statistically Significant Shock Ratio Locations for the Yonex EZONE

From Figure 4, it is difficult to observe a trend or predict where the statistically significant differences will be when adding mass. A similar unpredictive trend occurred with the other parameters with the ANOVA test, such as nervousness.

Conclusions & Future Work

- Study supported literature such as the vibrational node remaining unchanged with mass added at the 3 and 9 o'clock positions
- Parameters such as shock ratio and nervousness produced inconclusive results when adding mass with the ANOVA test due to unpredictable nature of the results when compared to a racket with no mass added
- Swingweight, twistweight, and balance parameters showed statistically significant differences in results when adding mass where the values increased while mgr/I and center of percussion decreased
- Suggested future work includes a review of the statistical analysis while collecting more data with mass added at the 12 o'clock position to observe similarities or differences

Ray Ewry Sports Engineering Center

About RESEC

The Ray Ewry Sports Engineering Center (RESEC) is named in honor of a record-setting Olympian and College of Engineering graduate, Ray Ewry. As a joint effort between Purdue College of Engineering and Intercollegiate Athletics, the center reflects Ewry's passion for both sports and engineering and creates research and learning opportunities to athletes and students alike.

What is Sports Engineering?

Sports Engineering is a multidisciplinary field that uses engineering principles to create solutions to the greatest challenges and opportunities facing sports today. The field utilizes scientific theory, practical application, and technical knowledge to address sports-related challenges through data-driven insights and a results-oriented approach. To contribute to this field RESEC aligns it's investigations with the following priorities

EXCITEMENT

Smart Performance & Fan Experience

How can we use the latest sensors, signal processing, and analytics to improve athlete performance and improve engagement with fans?

INTEGRITY

Fairness, Accessibility & Social Integration

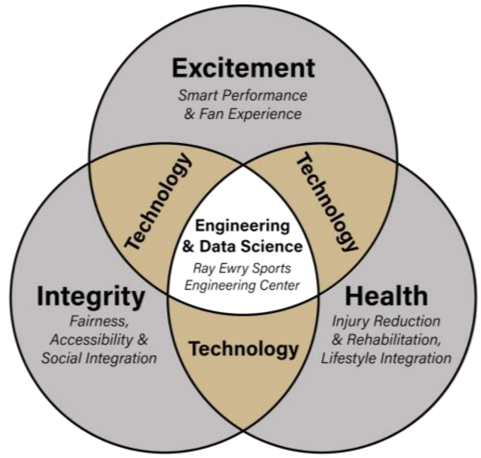
As technology in sports grows, what are the limits of human judgement, and how do we develop technology to ensure a level playing field?

HEALTH

Injury Reduction & Rehab, Lifestyle Integration

What aspects of advanced healthcare and science can be engineered into solutions for sports rehabilitation and performance?

Every sport must balance these priorities to create the best experience for all. RESEC searches for the technology to fill the gaps between each priority and facilitates collaborative research across Purdue through the application of engineering and data science



Research Technology Platforms

RESEC categorizes industry partners and academic affiliates into the following technology platforms for scaling and implementation to streamline collaboration.

- Smart Materials for Performance and Safety
- Accessible Technology for Societal Integration
- Equipment Design for Athlete Feel and Control
- Intelligent Prototyping for Rapid Development
- Digitalization of Sports Ecosystems
- Spectator Experience and Fan Engagement

When ideas arise from industrial partners or internal faculty affiliates, RESEC facilitates the operations necessary turn opportunities into action.

Education Offerings

Purdue's academic prowess offers a unique opportunity to engage talented students, staff and faculty members with sports engineering. In addition to research opportunities for undergraduate and graduate students, RESEC is proud to offer the first comprehensive Professional Masters Concentration in Sports Engineering in the United States. With these capabilities, we are equipping the next generation of sports engineers to redefine what's possible.