Coefficient of Restitution and Impact Location of a Badminton Racquet

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Abstract

The relationship between a shuttle's point of impact on a badminton racquet and its coefficient of restitution (COR) was investigated. A Yonex Aerosensa 10 shuttle was dropped onto various locations on the head of a horizontally clamped Yonex Voltric Z Force II badminton racquet. Video of the impact was recorded and analyzed to find the COR at each location. Results showed that the highest COR occurs on the longitudinal axis of the frame, specifically at the center and near the base of the racquet frame. Impacts at the side caused frame rotation, decreasing COR. These findings contrast with previous research on tennis racquets, highlighting the different responses of badminton equipment.

Keywords: coefficient of restitution, badminton racquet, impact location, badminton shuttle

I. INTRODUCTION

Badminton requires players to manipulate the speed and direction of a dropshot by controlling the point that the shuttle impacts on the racquet frame. This skill is developed over time until it becomes intuitive to the player. However, no study has been published with data on how impact points affect bounce, which might be beneficial for beginning badminton players. This experiment aims to determine the relationship between a shuttle's point of impact on a racquet frame during a low speed dropshot and its coefficient of restitution (COR). The COR of the shuttle is defined as the ratio of the shuttle's bounce velocity to its impact velocity.[1] A higher COR correlates to more energy and speed transferred back to the shuttle post-impact.

A paper published by Pipatnarapong et al[2] focused on how the COR of a tennis ball varies when it hits different points on a tennis racquet at high speed. The group proposed three ways in which energy may be lost during the impact between the ball and the racquet, as shown in Figure 1.

Firstly, the increased bending of the racquet from impacts closer to the top of the racquet frame is expected to lead to a higher amount of energy absorption. Secondly, the increased lateral frame

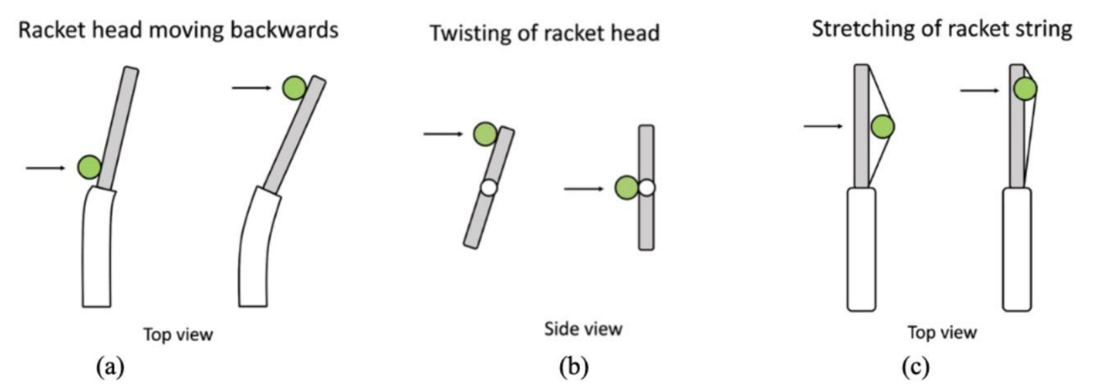

Figure 1. Factors that contribute to energy absorption during the impact of a tennis ball at different positions on the racquet head.[2]

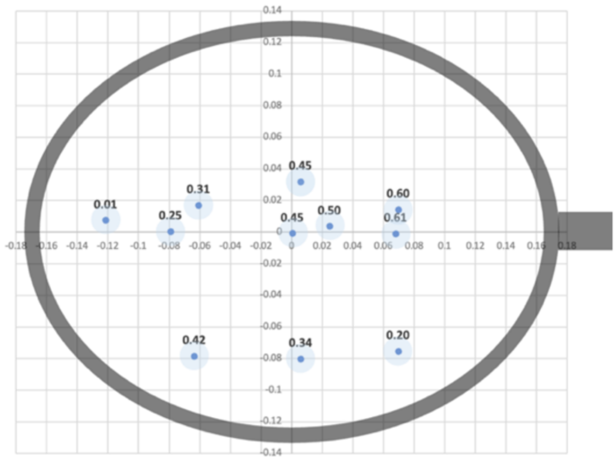

Figure 2. Illustration showing the result from Pipatnarapong et al.

twisting from impacts away from the longitudinal axis may also increase energy absorption. Lastly, the increased relative stretch of the strings from impacts closer to the edge of the frame may increase energy absorption. They predicted that the bending and twisting of the handle would lead to more energy loss than the stretching of the strings. Therefore, they expected the highest COR to be on the longitudinal axis and near the base of the racquet frame, where the racquet experiences minimum bending and rotation upon impact.

Pipatnarapong et al's result, shown in Figure 2, shows that along the longitudinal axis, the COR of the tennis ball increases successively from the top to the base, from 0.01 to 0.61. Moving to the side of the frame, however, the trend appears to be the opposite, with the COR higher near the top, 0.42, than near the base, 0.20. Additionally, near the top of the frame, the COR of the ball appears to be higher at the side than on the longitudinal axis.

A badminton shuttle hitting a badminton racquet is similar in some ways to a tennis ball hitting a tennis racquet. However, Pipatnarapong et al studied high-speed impacts while this study focuses on low-speed impacts, thus it is likely that the results from this experiment will differ from those of Pipatnarapong et al. For a shuttle hitting a badminton racquet at low speed, it is expected for the highest COR to occur along the longitudinal axis near the center of the racquet frame, where, upon impact, bending is moderate, frame rotation is non-existent, and the sweet spot, the region on badminton racquets where energy transfer back to the shuttle after impact is most efficient, exists.

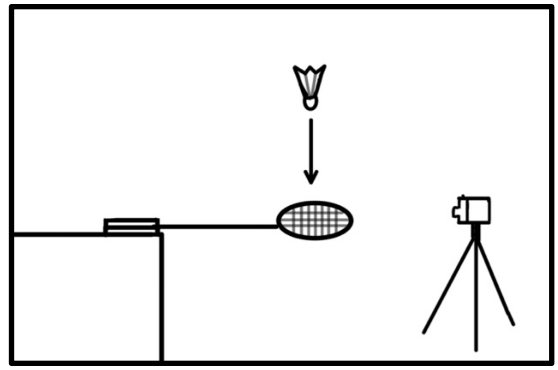

Figure 3. Experimental setup

II. METHOD

The handle of a Yonex Voltric Z Force II badminton racquet strung at 27 lbs was clamped horizontally to the surface of a table, such that the rest of the racquet extended outward and parallel to the ground, as shown in figure x. The Yonex Aerosensa 10 shuttle was released 0.310 ± 0.002 m above a designated impact point on the clamped racquet. The impact was filmed at 240 fps with an iPhone 15 pro max placed 1 m horizontally from the racquet frame. Ten trials were filmed for each impact point shown in Figure 4. The five trials that had the closest proximity to the intended impact point were chosen for video analysis.

The impact points, shown in Figure 4, are represented by coordinates, with the middle of the frame being the origin. The distance from the origin to (7, 0) is 7.0 ± 0.5 cm. The red areas with a radius of 1.3 cm represent the circular uncertainty of each impact point. These points were chosen to represent a variety of impacts that may yield in different shuttle CORs. (0, 0) is located in the center of the frame, where the sweet point is located. (7, 0) and

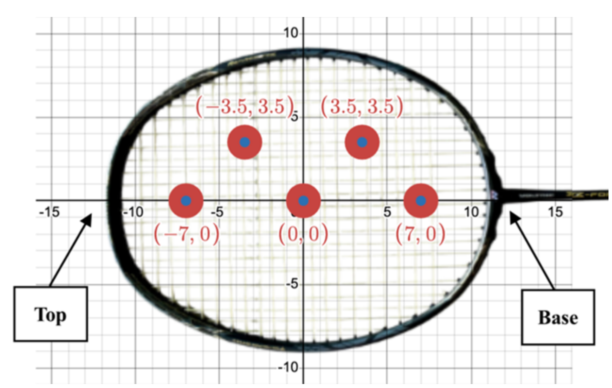

Figure 4: Graphic illustration showing the five impact points chosen.

(-7, 0) are respectively located near the base and the top of the frame on the longitudinal axis, where bending is respectively minimum and maximum. (-3.5, 3.5) and (3.5, 3.5) are located on the side of the frame, where frame rotation occurs upon impact.

III. RESULTS AND DISCUSSION

The result agrees with the theory discussed earlier to some extent. The result suggests that impact points near the base yield higher COR values due to a smaller bending moment than points near the top. It also suggests that striking the side of the racquet causes frame rotation, leading to a significant decrease in COR. Given the uncertainty, ± 0.01, however, there seems to be no significant increase in COR at the center region compared to the region near the base along the longitudinal axis. This may be because, at the center region, the decrease in energy loss from the decreased stretching of the string and the more effective energy transfer due to impacts at the sweet point are just enough to offset but not surpass the increase in energy loss from the increased bending moment compared to the region near the base on the longitudinal axis.

While the result for the badminton racquet shows that the COR is the highest at both the center and near the base of the frame along the longitudinal axis, Pipatnarapong et al's result shows that the highest COR occurs distinctively at the base of the frame along the longitudinal axis. Shifting to the side of the frame, the COR near the top of the frame obtained here is shown to be lower than that near the base. The opposite, however, appears in Pipatnarapong et al's result, with the value near the base being higher than near the top. Lastly, Pipatnarapong et al's result contradicts the hypothesis that an additional frame rotation from the impact at the side of the racquet may cause a decrease in COR, a hypothesis that is proven to be applicable in this experiment.

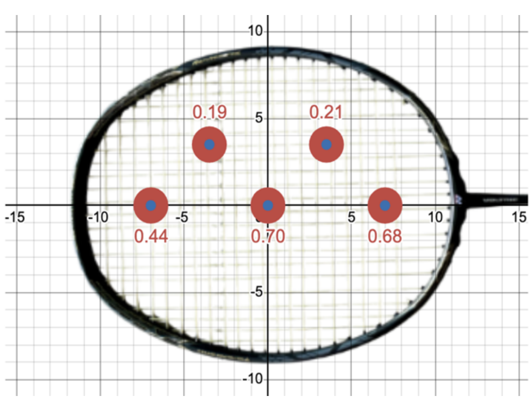

Figure 5. Graphical illustration of the result.

Possible reasons for the discrepancies between the two results may be because tennis balls and racquets have different responses to impacts compared to badminton shuttles and racquets due to their differences in shape, size, and material. Another reason is that the speed of impact in Pipatnarapong et al's experiment was much higher, as they utilized a high-speed ball launcher that ejected the ball at 19.2 m/s. In contrast, the maximum impact velocity here was just 2.7 m/s.

The results shown here are specifically limited to a YONEX shuttlecock vertically striking a YONEX VOLTRIC Z FORCE 2 badminton racquet strung at 27 lbs at speeds between 2 to 2.7 m/s. It is possible that a stiffer racquet with higher string tension and faster shuttle impact speeds would yield results similar to those of Pipatnarapong et al. Further research is suggested to experiment with the COR of the shuttle at high-speed impact.

IV. CONCLUSION

It has been shown that the COR of the shuttle bouncing off a clamped badminton racquet at low speed is the highest at the center of the frame, with a value of 0.70. Along the longitudinal axis, COR decreases as the impact point deviates from the center, with a value of 0.68 near the base and a lower value of 0.44 at the top. Moving to impacts at the side of the frame, there is a drastic decrease in COR, with a value of around 0.2 for shuttles impacting 3.5 cm in the lateral direction from the longitudinal axis of the frame.

V. REFERENCES

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