

Impact Velocity and Coefficient of Restitution for a Tennis Ball Impacting a Tennis Racquet

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Abstract

The impact and exit velocities of a tennis ball impacting on a fixed tennis racquet were measured with high speed video analysis to determine the coefficient of restitution (COR). It was found that there is a negative linear relationship between the COR and the impact velocity of the ball for velocities between 13 and 36 m/s.

Keywords: tennis ball, impact velocity, tennis racquet, coefficient of restitution

I. INTRODUCTION

When a tennis ball impacts a tennis racquet, both the ball and the strings deform, temporarily storing energy that is then transferred back to the ball as kinetic energy. The kinetic energy of the ball after the collision will be less than the kinetic energy before the impact, due to hysteresis¹ in the rubber of the ball and the strings. Compared to impacting a wall, when the ball impacts a tennis racquet the collision time will be of longer duration with a lower maximum force on the ball. This will result in less deformation and thus less energy loss during collision. Since a greater initial velocity will result in greater deformation of the surfaces and more energy loss due to hysteresis, it is expected that greater impact velocity will result in a lower COR².

II. METHOD

A Head Flexpoint tennis racquet with head size of 98 in² and string tension of 50 lbs was fixed rigidly to a column. New Dunlop Fort tennis balls were used. A tennis ball launcher with the ball trajectory aligned to hit perpendicular to the center of the head was placed 1.00 ± 0.02 m in front of the racquet. A camera recording at 1000 fps was placed at right angles to the path of the

ball. Video analysis software was used to determine the entry and exit speeds of the ball over the full velocity range of the launcher.

III. RESULTS AND DISCUSSION

Figure 1 shows the relationship between impact velocity and COR for the tennis ball impacting the racquet,

$$COR = 1 - (0.009)v_i \quad (1)$$

where v_i is the impact velocity. There is a negative relationship between COR and the

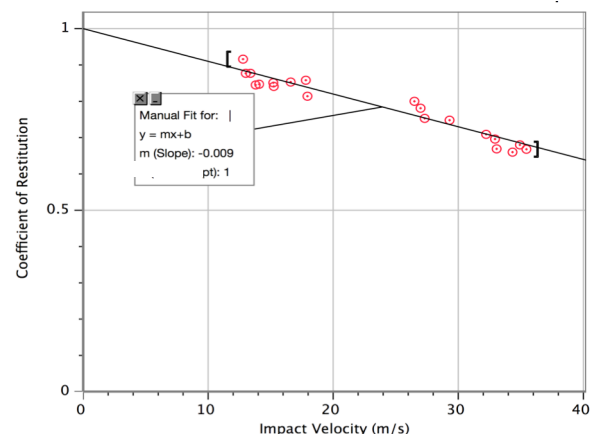


Figure 1. Relationship between impact velocity and COR for a tennis ball impacting a racquet.

impact velocity of the ball, as expected. The COR ranges from above 0.9 at 13 m/s down to around 0.7 at 36 m/s, with the COR decreasing by 0.009 for every 1 m/s increase in the impact velocity.

Andre Roux and Jennifer Dickerson³ investigated the relationship between impact velocity and COR of a tennis ball impacting a wall. A linear fit has been applied to their data and compared to the results of this investigation in figure 2.

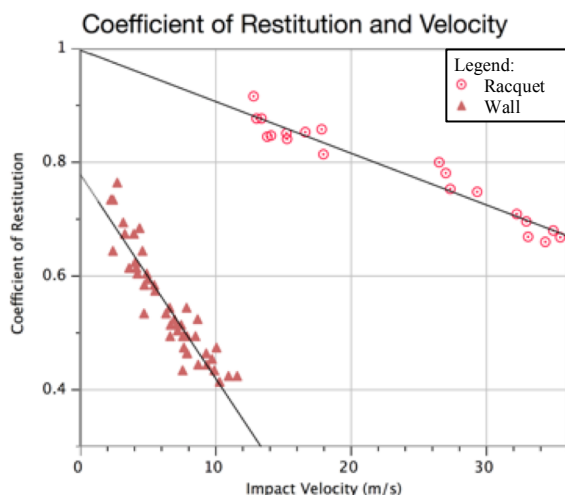


Figure 2. Comparison of COR for a tennis ball colliding with a wall³ and a racquet.

While the range of velocities in these two situations do not overlap, it is clear that the COR of a ball impacting a wall is significantly lower than when a ball impacts a racquet, and the COR decreases significantly more with increasing velocity for a ball hitting a wall as shown by the steeper slope of the line. Tennis racquets have been designed to minimize energy losses and maximize the exit velocity of a hit ball. This is clearly shown in figure 2. Note that the COR of the ball hitting the wall at 3 m/s is approximately the same as the COR of the ball hitting the racquet at 35 m/s meaning that the energy loss and deformation of the ball during these two collisions is approximately the same.

Further research is suggested investigating the behavior of the ball at higher and lower impact velocities than were tested here, since impact

speeds vary from soft drop shots to hard smashes during normal play. Another area for further research is to investigate how string material and tension affect COR.

IV. CONCLUSION

A negative linear relationship was found between the impact velocity of a tennis ball on a tennis racquet and the COR for velocities between 13 and 36 m/s. The COR for a ball impacting a racquet was shown to be significantly higher than for a ball hitting a wall.

REFERENCES

1. Cross, R., (1999). The Bounce of a ball. *American Journal Physics*, 67(3), 222, doi: 10.1119/1.19229
2. Coefficient of Restitution. (n.d.). Retrieved October 5, 2015, from <http://www.topendsports.com/biomechanics/coefficient-of-restitution.htm>
3. Roux, A. and Dickerson, E., (2007). Coefficient of Restitution of a Tennis Ball. *International School Bangkok Journal of Physics*, 1(1).