Paddle Angle and Ball Spin in Table Tennis

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Abstract

The relationship between the impact angle of a table tennis ball with respect to the paddle and angular velocity of the ball leaving the paddle was investigated. A table tennis ball was dropped onto a paddle oriented at impact angles ranging from 10° to 80°. It was found that the sine of the impact angle is proportional to the angular velocity of the ball as it leaves the paddle for all impact angles tested.

Keywords: table tennis, angular velocity, paddle angle

I. INTRODUCTION

In table tennis, topspin is one of the most difficult plays to counter because it is fast, bounces low, and is unpredictable. To create a topspin ball, the player has to hold the paddle at an angle *and* move it relative to the ball velocity when hitting the ball. It is important for table tennis players to understand how the paddle angle and velocity affect the resulting spin of the ball. Players who can control the angular velocity of the ball will have a better chance of defeating their opponent. Here, hitting a topspin ball will be modeled by dropping a ball onto a paddle at varying angles.

Angular velocity is measured as the rate of angular displacement, in radians per second. The impact angle is defined as the angle between the incoming velocity of the ball and the normal to the plane of the paddle.

Measurements made by Dolev Illouz[1] with a racquetball showed that when the ball impacts a surface at an angle without slipping, the angular velocity is proportional to the sine of the impact angle, as shown in figure 1. At angles above 50°, the racquetball slipped during impact, as the angular velocities for those angles are below the trend line.

The theoretical relationship between the impact angle and the resulting angular velocity for a hollow sphere that does not slip across the surface during impact is given by[2]

$$\omega = \frac{3}{5}\left[\frac{v_i \sin\theta_{in}}{r}\right], \qquad (1)$$

where angular velocity (ω) depends on initial impact velocity (v_i), impact angle (θ_{in}), and the radius of sphere (r).

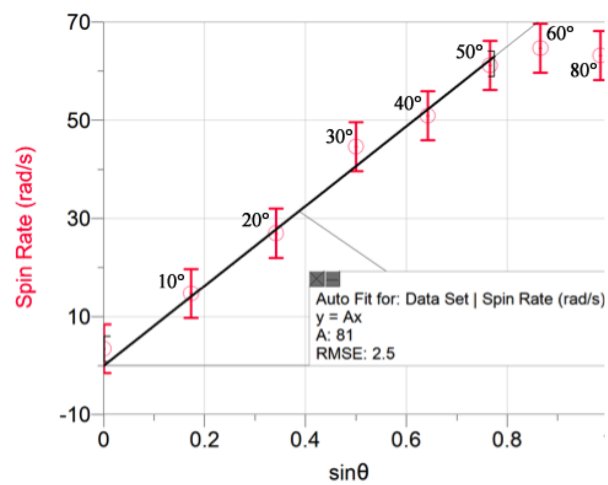

Figure 1. The spin rate of a racquetball is proportional to the sine of the impact for angles up to 50°.[1]

For this investigation, the impact velocity of the table tennis ball was kept constant with a relatively low speed, so no slipping was expected during impact at smaller angles. It is expected that equation 1 would apply and can be used to determine the proportionality constant between impact angle and rotational velocity.

II. METHODS

A pipette bulb was used to hold the table tennis ball with suction, releasing the ball without spin. The bulb was positioned to drop the ball from 43.5±0.5 cm above the center of the face of the paddle. The paddle was clamped horizontally so that the paddle could be rotated to different impact angles. A black line was drawn around the equator of the ball, and the ball was released in the same angular position for each trial. The impact and bounce of the ball was recorded with a high-speed camera at 240 fps. The camera was placed about one meter from the end of the paddle.

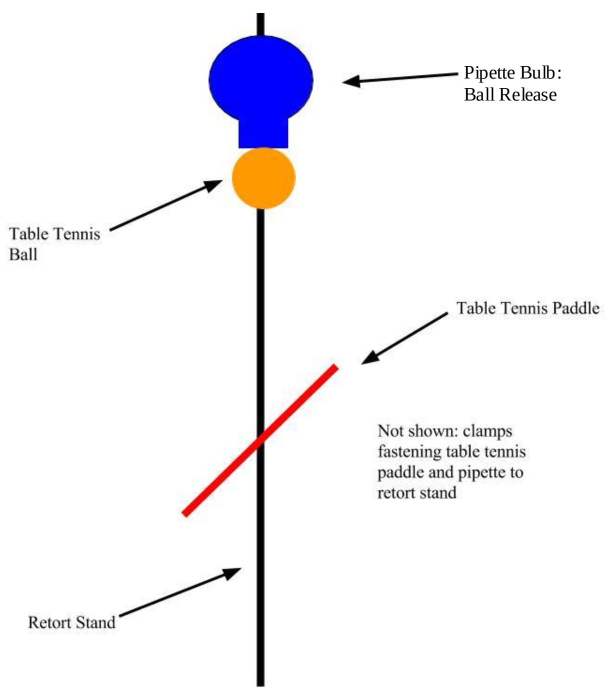

Figure 1. The ball was dropped onto the center of the paddle. The paddle was rotated through the range of impact angles tested.

Seven different impact angles ranging from about 10˚ to 80˚ were tested with 4 trials at each angle. The impact angles were determined by measuring the angle of the paddle. The position of the edges of the paddle was determined using video analysis, as shown in figure 2. The video was then analyzed to determine the angular velocity by measuring the angular position of the ball at two times after impact as shown in figure 3.

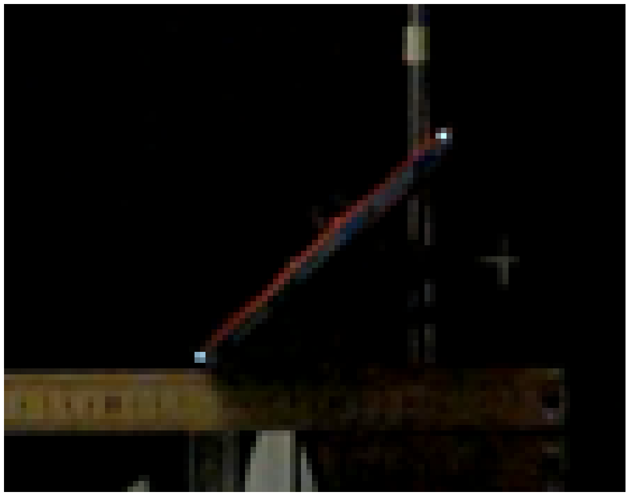

Figure 2. The blue dots placed on the edges of the paddle were used to determine the impact angle of the ball with respect to the paddle.

Figure 3. The blue dots placed on the ends of the line drawn around the center of the ball were used to determine the angle of the ball as it was leaving the paddle (left) and again 5 frames later (right).

III. RESULTS AND DISCUSSION

Figure 4 shows the proportional relationship between the sine of the impact angle and the resulting angular velocity of the table tennis ball. This can be expressed as

$$\omega = (120 \pm 10 \text{ rad/s}) \sin \theta \qquad (2)$$

Using the measured values for impact velocity (2.92 m/s) and ball radius (0.0200 m) in equation 1, the theoretical value of the proportionality constant was calculated to be 87 rad/s. This is lower than the experimentally determined value of 120 ± 10 rad/s shown in figure 4, indicating that unknown factors are causing the spin rate to be lower than theory predicts.

Unlike the racquetball in Illouz's research, which slipped on the surface at angles above 50°, there was no slipping of the table tennis ball at high angles. This can be seen as the

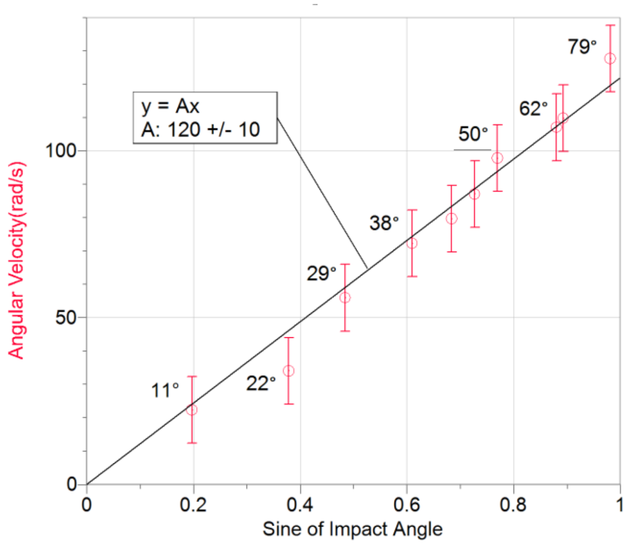

Figure 4. The proportional relationship between sine of the impact angle and the resulting angular velocity of the table tennis ball.

angular velocity continued to increase proportionally to the sine of the angle at high angles.

For further research, the use of a mechanism to shoot the ball at high speeds is suggested. This will more closely model real table tennis matches where balls impact the paddle at much greater velocities than tested here. Another suggestion is to study the behavior of the ball when impacting various paddle models and brands. Finally, using a camera with greater resolution is suggested, as the low resolution of the camera used here made it difficult to accurately determine the impact angle and rotational velocity of the ball.

IV. CONCLUSION

It was found that the angular velocity of the table tennis ball is directly proportional to the sine of the impact angle between 0° and 70°, with a proportionality constant of 120 rad/s. It was further shown that, unlike a racquetball, the table tennis ball did not slip during impact, even at the highest angles tested.

V. REFERENCES

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