Temperature and Coefficient of Restitution of a Table Tennis Ball

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Abstract

The coefficient of restitution (COR) of a bouncing table tennis ball was measured at varying ball temperatures with a Motion Detector. It was found that there is a negative linear relationship between the COR and the temperature of the table tennis ball for temperatures ranging from 5 to 56 ˚C.

Keywords: table tennis ball, temperature, coefficient of restitution

I. INTRODUCTION

The coefficient of restitution (COR) of a table tennis ball affects the performance of the players and consequently, the outcome of the game. In the past, studies have suggested that increase in temperature increases the COR of many balls. One study found an inverse exponential relationship between the temperature and the COR of a solid rubber superball[1]. Another study found an inverse exponential relationship between the pressure and the COR of a rubber handball[2]. This investigation focuses on the relationship between the temperature and the COR of a table tennis ball within the range of temperatures at which table tennis is typically played.

COR is the ratio of the relative velocities of two masses after and before collision, and ranges from 0 to 1, with 0 representing a perfectly inelastic collision and 1 representing a perfectly elastic collision without energy loss[3]. Assuming that the energy loss due to air resistance is negligible when the ball is dropped near a surface due to low impact velocity, the COR can be found with the following relationship:

$$COR = \sqrt{\frac{h_f}{h_i}} \qquad (1)$$

where h_f is the maximum height of the ball after a bounce and h_i is the initial drop height of the table tennis ball[2].

The International Table Tennis Federation (ITTF) states, “The playing surface may be of any material and shall yield a uniform bounce of about 23 cm when a standard ball is dropped on to it from a height of 30 cm[4].” Using Equation 1, the regulation COR of a table tennis ball is approximately 0.88 when dropped from 30 cm. In order to observe the effect of temperature on the COR when the table tennis ball is traveling at a greater speed as in the actual competition, a table tennis ball was dropped from approximately 0.8 meters above the surface rather than 0.3 meters. Therefore, although the observed COR may be slightly lower than the regulation value, the experiment demonstrates findings that may be valuable to table tennis players.

Assuming that a table tennis ball behaves as if it were filled with an ideal gas[5], the air pressure inside a table tennis ball is expected to increase with increase in temperature. This will decrease the loss of kinetic energy due to the decreased deformation of its surface during the collision. However, since thermoplastic softens as

temperature increases, the COR of the table tennis ball may decrease due to the increase in the kinetic energy loss[6] due to greater deformation of the plastic shell of the ball at higher temperatures.

II. METHODS

A motion detector with a sample rate of 45 Hz was set facing the ground approximately one meter above the ground, as shown in figure 1. The temperature of the room was kept constant at 26.5 ± 0.5 ˚C. The temperature of the table tennis ball was adjusted by putting the ball inside a plastic bag and immersing in water at corresponding temperature for one minute.

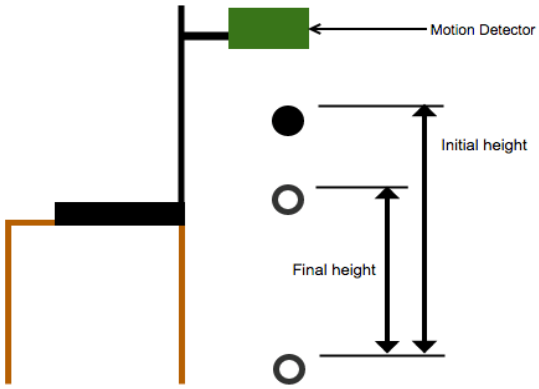

Figure 1. The experimental apparatus.

A table tennis ball of mass 2.78 ± 0.01 g was dropped from a height of 0.786 ± 0.003 m. The drop height and bounce height were determined from the position-time graph, as shown in figure 2. The trials were repeated five times for six temperatures ranging from 5 to 56 ˚C.

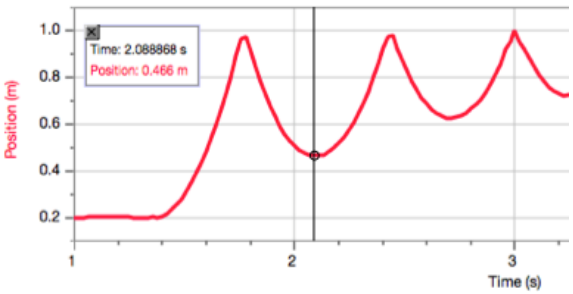

Figure 2. Position-Time graph to calculate h_i and h_f.

III. RESULTS AND DISCUSSION

Figure 3 shows the relationship between the temperature and the COR of a table tennis ball,

$$COR = 0.821 - (0.0003)T \qquad (2)$$

where T is the temperature of the ball in degrees Celsius.

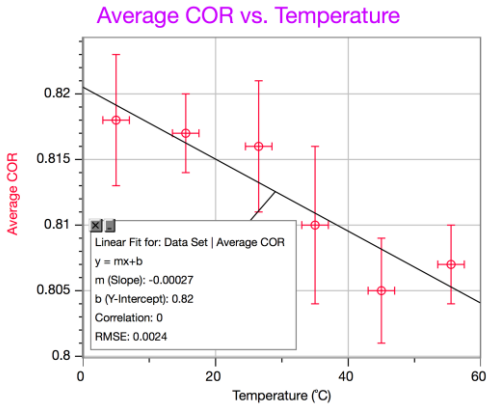

Figure 3. Average COR shows a linear relationship with the temperature of a table tennis ball.

There is a negative linear relationship between the temperature and COR of a table tennis ball. The negative constant in Equation 1 shows that a table tennis ball does not behave like a solid rubber superball or handball because an increase in temperature does not lead to an increase in COR. Table tennis players should be aware of the decreasing COR as the temperature increases.

One source of variability in the results was due to the ball occasionally bouncing on the seam, which decreases the consistency of the results. Therefore, to control the variability, the table tennis ball should be marked and dropped in the same position.

Investigating how the temperature affects the COR for different impact speeds, angles and spin rates would be helpful to table tennis players. Another area of further research is investigating the relationship between the temperature and the COR of the table surface as temperature could affect the COR of the table surface.

IV. CONCLUSION

A negatively linear relationship was found between the COR and temperature of a table tennis ball for temperatures ranging from 5 to 56 ˚C. This suggests that the energy losses and the COR of a tennis ball varies under typical playing conditions, and the ITTF should consider including temperature in the regulations of table tennis.

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