Frustrating golf ball

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Motivation

In cheering for the Taiwan glory, Tseng Ya Ni, on LPGA, we also observe some frustrating phenomenon. When some players are putting, the ball doesn't always serve their minds. Sometimes, the ball may escape from the hole after it goes around the rim for a round or two. The frustrating golf ball brings so many questions to my mind, so I decide to investigate about it.

Tools

The basic tools used for the experiment are shown in the picture.

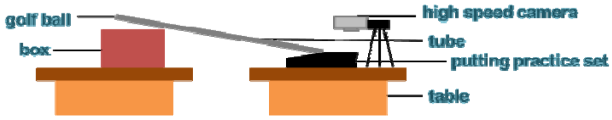

Fig 1. Experiment equipment set

Theory

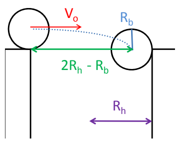

Fig 2. The ball rolls into the hole

1. Velocity and Angular Frequency
   (1) The motion when the ball rolls in to the hole.
   - If V_0<0.457, the ball will rolls for a while on the rim without touching the oppiste site of hole.
   - If V_0>0.457, further consideration should be taken into account.

   (2) When V_0>0.457, the ball touches the opposite side of the hole.
   - If V_0<1.313, the ball will be captured.
   - If V_0>1.313, further consideration should be taken into account.

   (3) When V_0>1.313, two scenarios happen:
   A. If $v_{ft}^2/R_b > g\cos Ø$, the ball escapes by flying.
   B. If $v_{ft}^2/R_b < g\cos Ø$, two situations may occur:
   a. If $\frac{1}{2}mV_{ft}^2+\frac{1}{2}I\omega_t^2 > mgR_b(1-\cos\phi)$, the ball escapes by rolling away.
   b. If $\frac{1}{2}mV_{ft}^2+\frac{1}{2}I\omega_t^2 < mgR_b(1-\cos\phi)$, the ball rolls back into the hole.

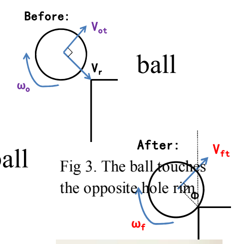

Fig 3. The ball touches the opposite hole rim

2. Putting Accuracy and Critical Volecity
   (1) There is a tolerable deviation from the rolling path for the ball to fall in. Three phenomena happen with different δ(fig 4): flying escape, forward rolling escape, and backward rolling escape.

Fig 4. δ is the deviation from the radius.

   (2) The ball being able to escape requires a critical velocity. The more inaccurate the putting is, the more possible that the ball will escape with smaller critical velocity.

Experiment

1. To test if the actual esacpe initial volecity is 1.313m/s.
   - set different initial volecity for the rolling ball
2. To understand the relationship between critical velocity & δ
   - set the parameter of δ
   - Observe ways the ball escapes

Result

1. According to the data, the realistic velocity is 1.5m/s.
2. By using software(tracker) to analyze the high-speed video of the motions of the golf ball, the result shows that the critical velocity will decrease along with δ/R_h.

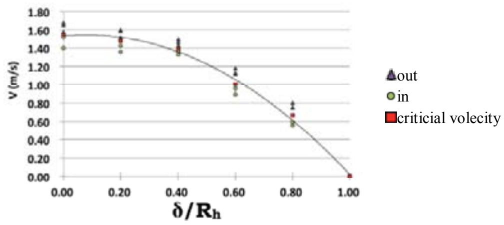

Fig 5. Relationship between accuracy and critical velocity

Conclusion

According to investigation on the preceding phenomena, if the accuracy is neglected, velocity is a key factor to the result whether the ball escapes from the hole. Critical velocity drops sharply when δ gets larger. To sum up, velocity and accuracy are the imperative parameters that lead to the escape of the ball.

References

[1] A. R. Penner, "The physics of putting", Can. J. Phys. 80: 1–14 (2002).

[2] H. Okubo and M. Hubbard, "Dynamics of basketball-rim interactions". Sports Engineering 7, 15–29(2004).