Aerodynamic Characteristics of Baseballs Delivered from a Pitching Machines

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INTRODUCTION

The purpose of this study was to compare aerodynamic characteristics of baseballs delivered by actual pitchers and by pitching machines. The results of this study would suggest useful ideas for the usage of a pitching machine in batting practice.

Although many studies using the wind-tunnel experiment have clarified aerodynamic forces on a pitched baseball, the spin characteristics, such as spin rate and spin axis directions, during the actual ball flight have been hardly quantified. To elucidate the aerodynamics of a baseball more closely, we obtained three-dimensional trajectory, angle of spin axis and the spin rate of the actual pitched baseball.

METHODS

All experiments were conducted indoors in order to minimize wind influence. Nine collegiate pitchers pitched 10 fastballs of 4-seam (FB) and 10 curve balls (CB), respectively. A pitching machine with a propulsion system of spinning wheels was used to fire 10 FBs of 4-seam and 10 CBs.

Trajectories of these balls were filmed with four synchronized video cameras (60Hz) and were analyzed using DLT procedures. The global coordinate system was set as follows; the Z-axis was defined as vertical, the Y-axis was defined as horizontal and pointing toward home plate and X-axis was then defined as the cross product of the Y- and Z-axes, with the origin at the center of the front edge of the pitching rubber. Polynomial function using the least square method was used to derive time-displacement relationships of ball coordinates during flight for each pitch.

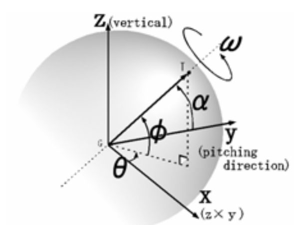

Figure1: Definition of spin axis. The orientation of the angular velocity vector ω is specified by two angles θ and ϕ. α is angle between spin axis and y−axis.

To obtain the ball rotation axis and spin rate, the baseball was filmed just after the delivery with a high-speed video camera (250Hz) set with the lens axis along the Y-axis of the global coordinate system. The direction of spin axis and the spin rate were calculated using positional changes of drawn marks on the ball surface. The direction of the spin axis was defined by two angles, θ (azimuth) and φ (elevation), an angle between spin axis and y axis (α) was also obtained. The spin parameter (r**ω**/**V**; **V** is the free-stream velocity, r is radius of the ball and **ω** is the ball angular velocity) was obtained, following previous studies.

RESULTS AND DISCUSSION

Initial velocity and spin rate of the balls from pitching machine were within the ranges of those for the actual pitchers. However, there was a significant difference in the mean values of total break (composition ⊿X and ⊿Z) between the balls from a pitching machine and the balls pitched by actual pitchers for both FB and CB pitches ($p<0.001$). FB pitches tended to break in the opposite direction to the CBs. The mean value for the break of CBs by pitching machine was approximately 1.9 times larger compared to those for actual pitchers.

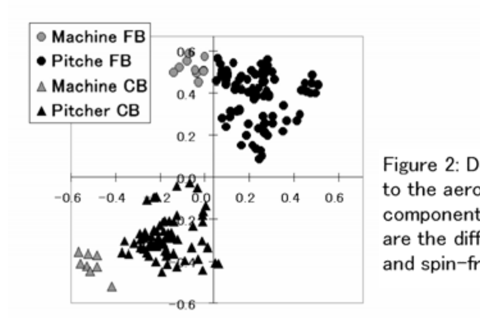

Figure 2: Deflections of trajectory due to the aerodynamic force. The two components of break, X and Z direction, are the differences between the fitted and spin-free trajectories at 18.44m.

Watts and Ferrer (1987) suggested that lift coefficient was proportional to r**ω**/**V** in the wind tunnel. However, in this study, the lift coefficient did not depend on r**ω**/**V** (r=0.429), but had a close relationship with **ω**sinα (r=0.860). This parameter, **ω**sinα, represents the actual effect of spin on lift force.

Magnus effect occurs from rotation of the ball, and act perpendicular to the axis of spin. Magnus effect is largest when the angular and translational velocity vectors are perpendicular to each other, and it indicates that the break of the pitched baseball is decreased when the angle between the two vectors comes closer to 0°. To adapt the features of the balls by a pitching machine to the actual pitchers' balls, it would be necessary to set the propulsion condition of a "screwball" for a fastball, and reduce the spin rate for curve ball.

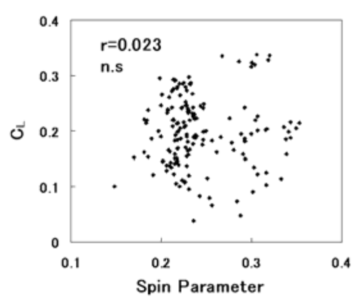

Figure 3: The relation between lift coefficient and Spin Parameter ($r\omega/V$)

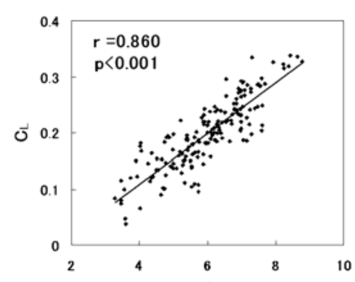

Figure 4: The relation between lift coefficient and $\omega \sin \alpha$

CONCLUSIONS

Balls delivered from a pitching machine whose axis was close to vertical to the pitching direction broke more largely than actual pitcher's balls.

REFERENCES

1. Bearman, P.W., & Harvey, J.K. *Aeronautical Quarterly*, **27**, 112-122, 1976.
2. Watts, R.G.., and Ferrer, R.. *American Journal of Physics*, **55**, 40-44, 1987.