AERODYNAMICS OF BASEBALL

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Aerodynamics of a baseball was investigated by both Computational Fluid Dynamics (CFD) and experimental trajectory analysis. Aerodynamic drag coefficients of the ball whose rotation axis direction is corresponding with ball's moving direction, which is called gyro ball, were calculated using CFD in two cases: two seam rotation and four seam one. The results showed drag coefficient of 4-seam rotation is about half of the drag coefficient of 2-seam rotation. We performed experimental study using trajectory tracking by high speed video to estimate aerodynamic coefficients. We found two-seam and four-seam rotation balls showed different characteristics in drag coefficient when Reynolds number increased and both drag coefficients differ in Reynolds number 0.8 - 1.8 x 10^5 and spin parameter 0.12-0.23.

KEY WORDS: aerodynamic drag, baseball, CFD, high speed video.

INTRODUCTION: The aerodynamic forces acting on a flying object with rotation has been paid so much attention in sport science. In a baseball game, a pitcher plays most important part in the game and the aerodynamics characteristics of pitched balls are very important. In this paper, CFD analysis of flows around a baseball without rotation is firstly compared with wind tunnel results by *Mizota* et al.. Then, this method is applied to the spinning ball whose rotation axis is set as ball's moving direction (sometimes called as a gyro ball). Finally, drag difference of a gyro ball between 2-seam rotation and 4-seam one, suggested by CFD was investigated by experimental study of trajectory analysis using high speed video.

METHODS: A Methods used in this study are computational flow analysis using CFD to solve flows around the baseball and trajectory analysis using a pitching machine and a high speed video to get aerodynamic force.

1. Computational flow analysis

Maximum ball speed in baseball game is around 160km/hour and the flow is regarded as incompressible. We solved incompressible unsteady Navier-Stokes equations using third-order upwind difference scheme with curvilinear grid system. We carefully generated a grid system with a seam line on the ball. Number of grid system is 327 x 181 x 101 and shown in figure1.

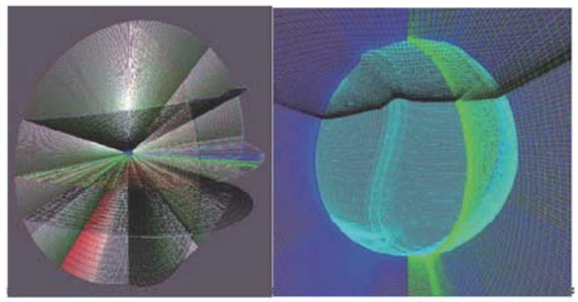


Figure 1 Grid system (327 x 181 x 101)

2. Trajectory analysis using a pitching machine and a high-speed video

To measure aerodynamic coefficient of the gyro ball defined as a spinning ball whose spin axis is directed to its moving direction, used experimental apparatus is shown in figure 2. The pitching machine was altered to pitch a gyro ball as shown in figure 3 and used in experiments. From recorded ball pictures by high speed video, we can ditect time when the ball go across slit lights. Then we can measure the duration time of flight between slit lights and calculate average ball velocities. The difference of two average velocities gives us drag force acting on the ball.

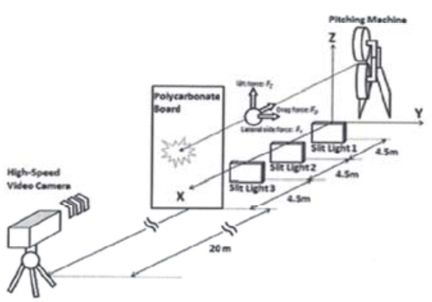


Figure 2 experimental apparatus

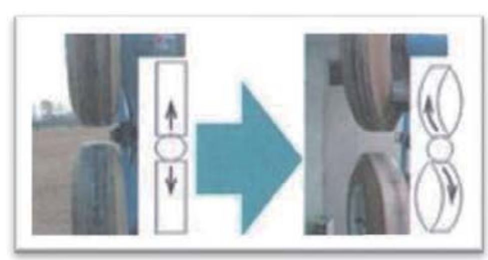
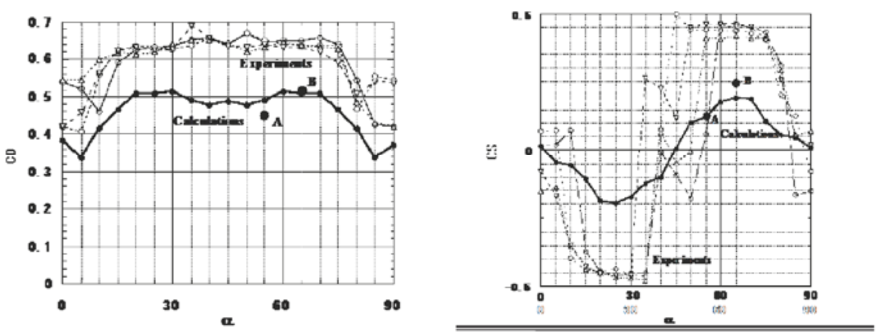


Figure 3 altered pitching machine used

RESULTS: At first, computed aerodynamic coefficients of a baseball without rotation were compared with wind tunnel experiments by *Mizota et al*, Then drag coefficients of gyro ball with both 2 seam rotation and 4 seam rotation were computed using CFD. Thirdly, trajectory analysis to measure aerodynamic drag using pitching machine and high speed video were performed.

1. Comparison of computed aerodynamic coefficients of a baseball without rotation with wind tunnel experiments by *Mizota et al.*

   Figure 4(1) shows comparison of drag coefficients between CFD and wind tunnel results. It agrees qualitatively well but quantitatively not well. The point A and B shows computed results using 4-time higher density grid system which shows finer grid system does not improve the agreement. This discrepancy is partly because of the influence of the supporting rod of the ball in the wind tunnel experiments. On the other hand, sudden change of the side force coefficients in the wind tunnel tests was not captured by CFD(see figure 4(2)). However, calculated flow fields clearly show the difference of wake patterns, one is symmetrical and the other is unsymmetrical.



(1) comparison of drag coefficients (2) comparison of side force coefficients

Figure 4 Comparison of aerodynamic coefficients between CFD and experiments

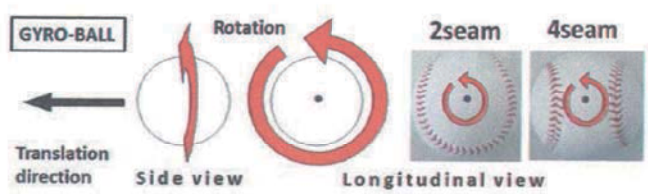
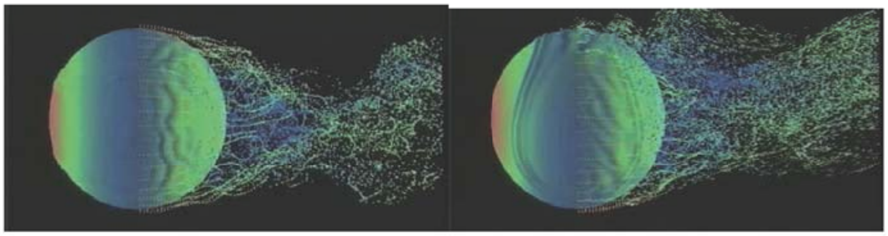


Figure 5 Two kinds of rotation of gyro ball

2. Drag coefficients of gyro ball computed by CFD

   Flows around a spinning ball whose spin axis is same as its moving direction were calculated. Reynolds number is 2.0 x 10^5 and spin rate is 30 rps (spin parameter:0.16). This ball is sometimes called gyro ball or dropping slider. There are two kinds of rotation pattern because of different seam line pattern on the ball surface shown in figure 5. Figure 6 shows flow patterns of both cases. Comparing these two figures, size of these wake region is different each other and the wake of 4-seam rotation ball is smaller than that of 2 seam rotation. Drag coefficient of 4-seam and 2-seam rotation ball is 0.16 and 0.31, respectively. The drag coefficient of the 4 seam case is about half of the 2-seam case.



(1) 4 seam rotation (2) 2 seam rotation

Figure 6 Surface pressure distributions and streak lines.

3. Drag coefficients of gyro ball measured by trajectory tracking

Drag coefficient measured using altered pitching machine and high speed video are shown in figure 7. As predicted by CFD, drag coefficient difference caused by the different seam rotation is validated.

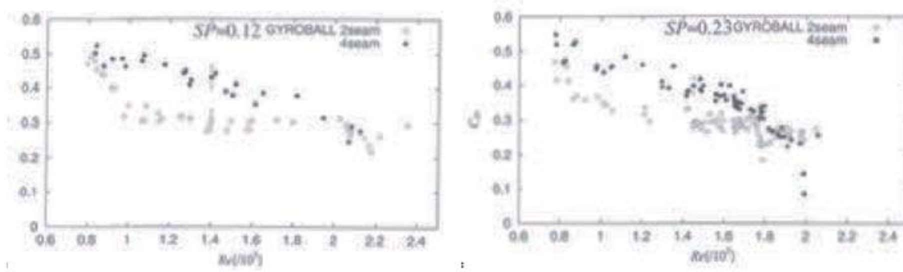


Figure 7 C_D - Reynolds number relationship

CONCLUSION: Influence of the different rotation pattern of gyro ball is investigated by CFD and experiments using altered pitching machine and high speed video. The difference of the drag coefficient of 2 and 4 seam rotation, predicted by CFD is truly observed.

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