<u>How does baseball changes its rotation through different kinds of pitches?</u>

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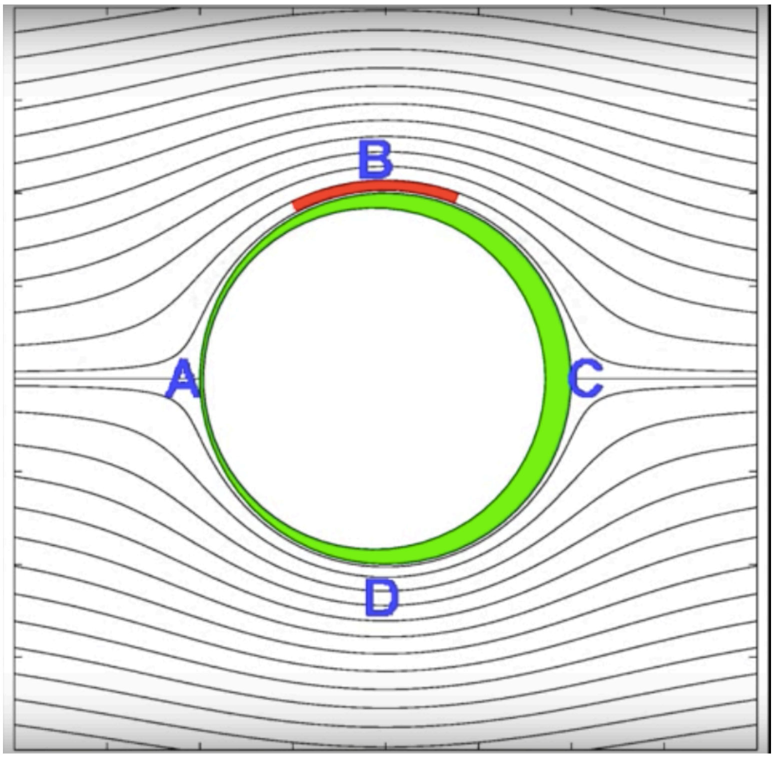
The study will seek to answer the question "the baseball's displacement with different pitches". I chose this question because I have been as a baseball fan for a decade, and I would like to study anything relate to the sport. When I was small, I knew that it was not easy to pitch baseball to the position I want. However, sports players seem can easily control their "best weapon" to the place they want. After all, they play baseball for living. Observing the change of baseball's rotation and displacement is important because we can tell how hard for a hitter to hit a ball while facing unknown pitches within 18 meters.

In order to answer why and how baseball moves through the air, I have structured my analysis section using the following methods: Listing possible statistics from different people and considering the grip while pitching. For example: Pitching a two-seam fastball ball (left picture) is totally a different concept compare to pitching a four-seam fastball (right picture). Except the grip methods are different, the pitching methods are distinct, too. In order to keep the scope of the study manageable, I have made use of a variety of carefully selected sources, in particular the following sources from the Major League Baseball, Baseball-references, and most importantly, Sports Science Index.


Since a moving baseball has to fly through the air and be caught by the catcher at the end, we need to talks about Fluid mechanics. For instance, while an object flies through a pad (paper), the object will make friction with the pad because the object normally has viscosity. Therefore, to the object, as nearer as the pad, the object will move slower, until the velocity decreases to zero. The range that velocity decreases progressively is called boundary layer.

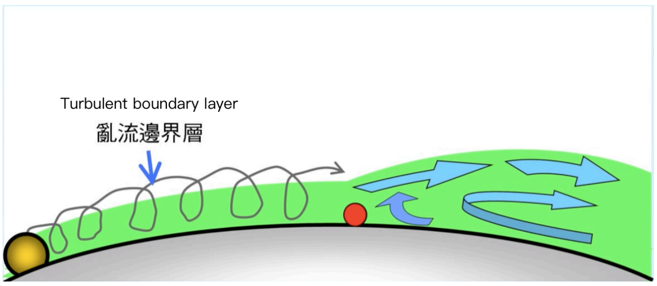
From the picture below, we can see that the area that red rectangle fly through is the boundary layer. When an object (wind) flies through the ball, it moves through Point A, then B/D, and C. According to Bernoulli's principle, Point A and C have the biggest pressure. Point B/D has the lowest pressure through the period.



←Boundary layer

One thing to be mentioned, pressure increases while the object (wind) flies through B to C. The boundary layer will make countercurrent if the pressure difference is large enough. Once the countercurrent is made, the upper boundary layer would be pushed out of the ball's surface. The phenomenon is called Flow separation. The separation point located near around Point B. The object (wind) that breaks through the separation point is extremely unstable and revolving. Later, several vortexes will be made because of the effect, which is called "turbulence". Since the turbulence is born after the ball, it can also be called "Wake." Overall, the turbulence is a low-pressure area, which is also the reason that creates air resistance.

Of course, these all theories depend on using a smooth ball. If we make some sketches or lines such as baseballs on the ball surface, the boundary layer will move backward. Because the protruding parts of the ball create small scale of vortexes, the boundary layer becomes turbulence, which is called turbulent boundary layer. Since we know that the viscous force does not affect the outer boundary layer, the outer surface would have faster speed. The turbulent boundary layer makes mix with the faster fluid due to the effect of vortex. As a result, the average speed of boundary layer increases and the fluid would have bigger momentum to rush to the downstream. Therefore, the separation point moves backward as well.



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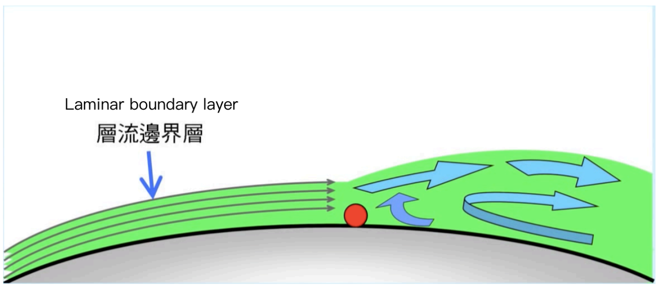


In order to study more about the movement of baseball, we need to look deep and study how does the baseball reacts while changing its boundary layer frequently because of lines and rotation. When throwing a fastball, before the baseball rotates, the wade does not change. Yet, once we change the angle of attack, the wade instantly makes deflection. The wade deflects the most while the baseball rotates twenty-two degree. When the wade deflects, the lower suture is closer to the stagnation to the upper suture. In other words, the lower turbulent boundary layer happens earlier than usual, and the upper turbulent boundary layer happens later, which leads average speed moves up. Then, the baseball continues rotates. When the baseball rotates forty-five degrees, the fluid force return zero.

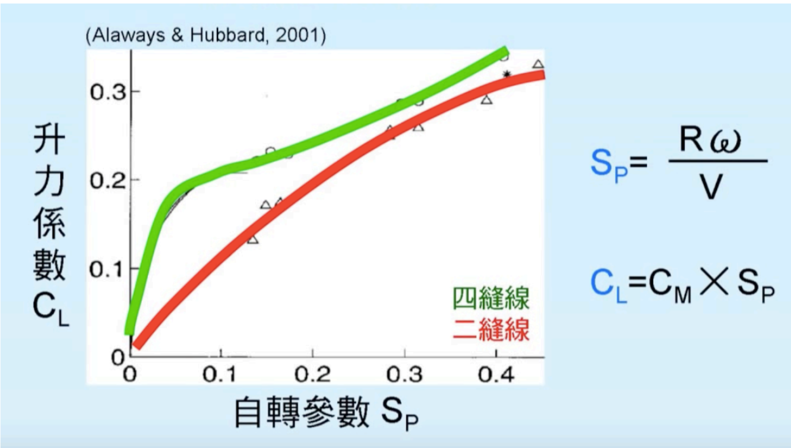
Except the use of boundary layer, we also need to discuss about how does baseball moves different kinds of spiral. The formula of the Magnus force is

$$\vec{F}_M = \frac{1}{2} C_L \rho A v^2 \ (\hat{\omega} \times \hat{v})$$

. Every object's spiral has a direction. Thus, we can use vector to describe a ball's rotation. By observing a baseball's rotation, we can use the right-hand rule. For example: Spin Vector is where the thumb points. The four other fingers symbolize which direction the baseball going to.

The direction Magnus force works is the side our palms facing to.

Now, we can see the green line and red line from the lower diagram. The green line symbolizes the four-seam fastball lift coefficient. The red line symbolizes two-seam fastball lift coefficient. For a 140-kilometer per hour, 20 revolutions per second fastball, the four-seam fastball has double lift coefficient than two-seam fastball. In other words, while a pitcher pitches a baseball as I mentioned, pitching a two-seam fastball will fall thirty centimeters more than pitching a two-seam fastball.



In conclusion, as we can see, after listing several data, we can now partly know how the baseball works while flying through the air. Even now we cannot specifically calculate how fast we can pitch due to gravity and other reasons such as humidity, we can feel how hard it is for a batter to hit a ball in the Major League Baseball.

References:

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