Research on the Application of the Badminton Aerodynamics Characteristic in Hitting

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Abstract: In this paper, the research methods of literature, observation and analysis are used to analyze the force of badminton during its flight in the air and during its swing against the racket. The relevant physics theories are used to analyze and study the factors that affect the flight characteristics and speed of badminton, revealing the laws of badminton movement in the air, aiming at providing reliable scientific basis for the basic swing technology of badminton movement.

1. Introduction

The International Badminton Federation stipulates that the standard quality of badminton is between 4.73 g and 5.50 g. Sixteen feathers are installed on a hemispherical ball support in a similar "impeller" manner to form a vertebral body structure. The feather with a certain angle during installation is also the reason for badminton rotation. Such characteristics make badminton have certain aerodynamic characteristics, and are also the factors influencing the flight speed and trajectory of badminton. The research of badminton aerodynamics can reveal the laws of badminton movement, and it is also the necessary knowledge for Badminton Coaches and players.

2. Stress in Badminton Flight

2.1 Gravity

The total area of a complete badminton court is about 82 square meters, so the badminton gravity can be seen as a fixed value G=mg with a vertical downward direction. (m is the mass of the ball, g is the acceleration of gravity) is the force that makes the badminton fall to the ground.

2.2 Air Resistance

Frontal resistance: when badminton is flying forward, it will face resistance when it is subjected to air pressure opposite to the badminton movement direction.

Friction resistance, during badminton flight, because the air is viscous, a thin layer of air will be adsorbed on the surface of the ball, which is a force generated by mutual motion friction between the air. The air attached to the surface of the sphere rubs with the air of the surrounding environment for energy exchange. The kinetic energy of the badminton flight is consumed, which causes the speed of the badminton flight to decay, which is the friction resistance [1].

Eddy current resistance, when the cone-shaped ball flies, the density, speed and direction of the air flowing through the badminton will change, which will form counter-current in opposite directions and then collide with each other to generate eddy current. Eddy current will cause the thin air layer attached to the sphere to separate from the sphere, and form a sparse space on the rear surface of the badminton. There is eddy current in the sparse space, which will reduce the pressure at the rear of the sphere. The resultant force of the pressure on the surface of the sphere will increase the resistance backward, which is the eddy current resistance. The eddy current resistance is inversely proportional to the ball speed [2].

2.3 Magnus Force

When the shuttlecock rotates and flies, the surrounding fluid can be driven to rotate, so that the fluid speed on one side of the shuttlecock increases and the fluid speed on the other side decreases.

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According to Bernoulli's theorem, an increase in fluid velocity will lead to a decrease in pressure. The fluid velocity decreases and the pressure increases, resulting in a pressure difference between the two sides of the sphere, forming a transverse force, which is called Magnus force. The direction of Magnus force is perpendicular to the direction of the ball's flying speed. There is a centripetal force during the badminton flight, resulting in the horizontal trajectory is not a straight line but an arc.

3. Badminton Flight Path Decomposition

3.1 Rotary Motion

When the racket hits the ball support vertically, the “horn” opening of the badminton is outward. Due to the special physical structure, it is subject to great air flow resistance and a moment R perpendicular to the resistance direction, which causes the ball to generate a turning force, and the ball support rapidly rotates along the swinging direction of the racket.

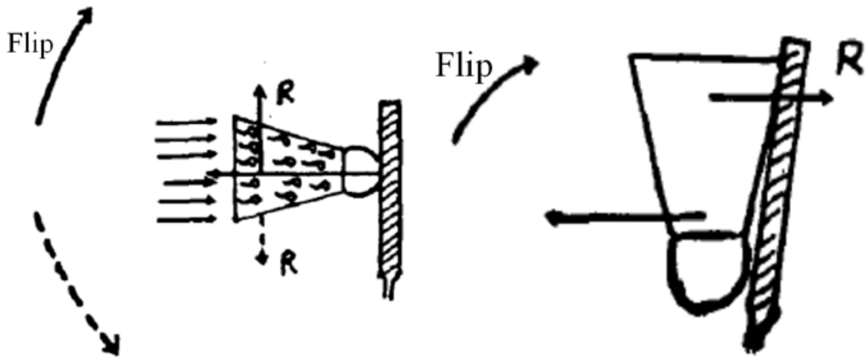

Fig.1 Period of Turning Motion

3.2 Swing Phase

Under the inertial action of the rotary motion, the ball support will coincide with the longitudinal axis of the badminton and continue to deflect to form an angle after coincidence. Under the action of air resistance, the reverse force is formed again, so that the reverse deflection of the badminton gradually coincides with the longitudinal axis of the badminton and continues to deflect after coincidence. This constant back-and-forth swing, due to overcoming resistance and constant energy consumption, causes the swing amplitude to gradually decrease to completely disappear. This is the stable flight of badminton, which is completed in a very short period of time.

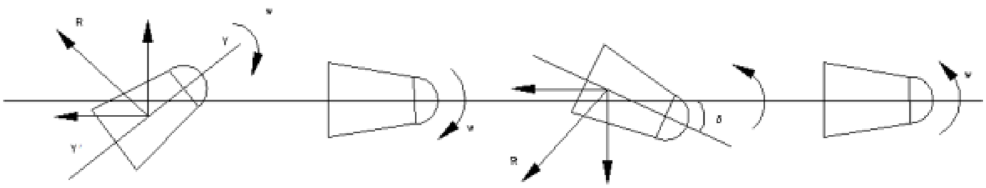

Fig.2 Unstable Period of Rotary Motion

3.3 Stable Stage

Take the high-range ball as an example. After the badminton flies stably, it starts to climb, and when it reaches the highest point, it starts to descend. The movement track of the badminton is an asymmetrical parabola. The climbing phase is longer than the descending phase, but the crawling time is the falling time. The highest point of badminton is close to the landing point due to asymmetric parabola. The aerodynamic characteristics of badminton lead to that when the badminton is at the highest point, the speed is not the slowest, and the slowest point is more backward in the falling stage of the ball. Then the badminton will accelerate to fall due to gravity, and the resistance will also increase. When the speed is about 11.073617 M / s, the badminton will fall at a uniform speed [3].

4. Physical Characteristics Analysis and Hitting Advantage

4.1 Velocity Displacement Analysis

From the velocity displacement formula (s = v0t + 1 / 2at2) ① and the reference formula V0 = V0 '+ 2v1 ② [4], it can be concluded that the larger the initial velocity is, the shorter the flight time is when the badminton is not out of bounds. According to formula (2), the initial speed consists of two factors, the first is the speed of the badminton before hitting the racket itself, and the second is the swing speed of the racket, in which the swing speed of the racket is a controllable factor.

Where V0 is the initial speed of the badminton, V0' is the speed before the badminton hits the racket, V1 is the swing speed of the badminton racket, s is the length of the badminton court, t is the flight time of the badminton, and a is the acceleration generated by air resistance.

4.2 Magnus Force

During the flight of the badminton, the air flow and the ball move relatively, and the air flow flows to the badminton at a certain angle, which will generate friction force on the feather piece, the installation characteristics of the feather piece, and the hitting technique of the player, so that the badminton can perform both translational movement and rotational movement when flying in the air flow. Because badminton is not a sphere structure, the Magnus force generated in the course of rotating flight can be decomposed into horizontal and vertical forces.

Magnus force E =-ρvwh, where ρ air density; V is the flying speed of badminton; W is the rotation angular velocity of badminton; H is the volume of badminton; The minus sign represents the rotation direction of W. If the rotation angular velocity of the badminton is clockwise, negative is taken, and the rotation of the badminton is counterclockwise. Magnus force is as shown in Figure 3[5].

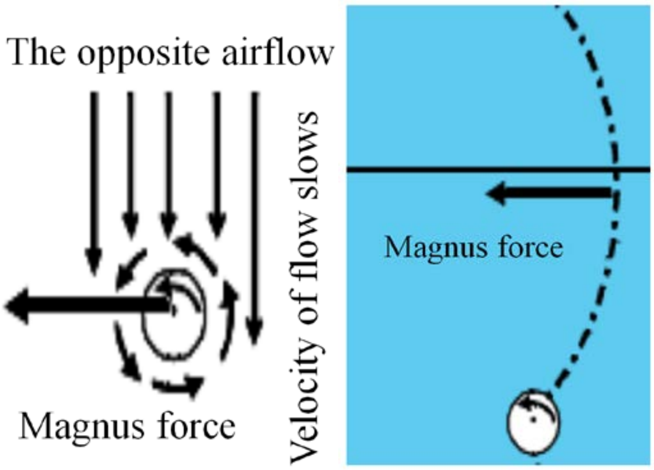

Fig.3 Magnus Mechanical Analysis

In the horizontal direction, taking the right-handed player as an example, the forehand hits the high ball in the back court, and the badminton spins counterclockwise and flies forward after turning over. At this time, the initial speed direction of badminton is to the right, and Magnus force to the left in flight is to the left again, and the projection of flight trajectory on the court is a counterclockwise flight arc [6].

In the vertical direction, take the right-handed player as an example, the player's forehand and backcourt drop ball, Magnus force has a component in the vertical direction, and the direction is vertical and downward, which can accelerate the falling speed of badminton. When flying, the vertical axis of the sphere does not coincide with the direction of the flight trajectory line due to the influence of the gyroscopic effect, resulting in the increase of the windward area and the increase of the resistance, so the horizontal velocity of the sphere decays faster. A downward force is added in the vertical direction, so the parabola formed when the ball is suspended is different from the parabola formed when the ball is hit by the front racket face. As shown in Figure 4, when hitting the ball at the same initial speed and shooting angle, the parabola comparison between the hanging ball and the hitting face is made [7].

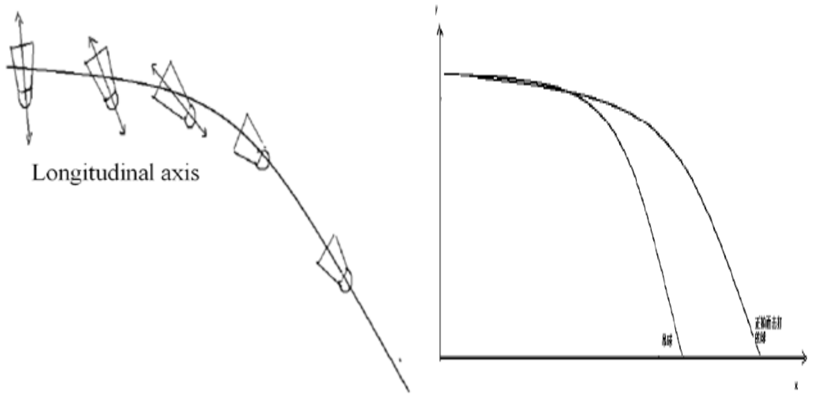

Fig.4 Comparison of the Trajectory of the Drop Shot and the Front Shot

4.3 Rotary Motion Analysis

When the ball is flying forward in parallel, the forward racket face hits the ball, making the ball turn around 180 degrees in the horizontal plane. In this process, the badminton first completes the turning movement, and then flies smoothly. Badminton bell mouth outward will produce great resistance in slewing movement, which is an unstable factor for badminton and hinders the normal flight of badminton. If the resistance in the turning movement can be avoided, the flight stability and flight length of badminton can be properly improved.

In the falling stage, the hitting angle of badminton starts to increase, and the ball speed correspondingly decreases to a minimum of about 35 degrees. After that, the speed increases with the increase of the hitting angle. From this, it can be seen that the hitting angle of about 35 degrees is the most energy-saving hitting angle and the most stable hitting point for controlling the ball. Under the same hitting power, the ball can fly the farthest distance [1].

4.4 The Batting Advantage of the Left-Hand and Right-Hand Grip Players

Due to the feather installation feature, the badminton rotates counterclockwise when flying on its own, so for the player holding the racket with the right hand, the player holding the racket with the right hand spins out and hits the ball fast, and the friction generated on the ball during forehand cleaving and hanging is consistent with the rotation direction of the ball, so that the trajectory of the suspended ball will be higher than that of the net. Forehand chopping and backhand strokes are also faster because the rotation energy after the stroke is kept in the same direction as the autobiography of the ball, while the advantage of left-handed players is that if they want to combine the rotation of the ball, they must hit the ball by using the way of internal rotation arm, which is characterized by heavy killing and skateboarding.

5. Conclusion

1). The flying speed of badminton is directly proportional to the swing speed. The swing speed is a synthetic speed, including the swing speed, wrist speed and the speed of rebound from impact on the racket face. The swing speed is scientifically synthesized from the three speeds.

2). When the ball is hoisted, the cutting will produce rotation, which will produce Magnus force. Such force will accelerate the badminton to fall down, make the falling point of the ball closer to the net and improve the hitting quality. When the ball is pulled, the rotation can make the ball pass through the horizontal position of the defender quickly without leaving the bottom line. For example, Magnus force can give the badminton a left deflection force, and the reasonable use of players in the game can make the quality of badminton better on two sidelines.

3). when the badminton rotates, there will be great air resistance, which can be avoided. Such resistance can be avoided by waiting for the ball holder to go down to the best hit and click the ball, or by actively and appropriately changing the flight direction of the badminton.

4). there is rotation in badminton. The left and right-hand players should make reasonable use of the technology. Only by combining the rotation made by racket with the rotation of the ball can the flight speed of the ball be increased.

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