

# Combining 2018 World Cup Cristiano Ronaldo "Hat Trick" Case Analysis of Football Mechanics Knowledge

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**Abstract.** The football book originated in China and was called "ancient game of kicking a ball" in ancient times. It is recorded in "Warring States Policy" and "Historical Records". However, the modern development of the national football team is hard to say. How to integrate football into subject knowledge in modern education, to promote Chinese football, and to make students understand football in subject knowledge is the responsibility of contemporary educators. To this end, the paper borrows the 2018 World Cup craze case and studies the relationship between mechanics knowledge and football knowledge based on the knowledge of students' popular science football. In the case of Portugal against Spain, Cristiano Ronaldo scored a goal in the 88-minute "hat trick" kicking into the Spanish goal, and discussed the goal of the goal with the students. On the one hand, this case, while cultivating students' interest in football, allows students to understand the mechanics of football, in order to stimulate students' enthusiasm for football learning and improve their self-achievement.

**Keywords:** Knowledge of mechanics; "Hat trick"; World Cup; Cristiano Ronaldo; Football; Sports.

## 1. Introduction

Football is an ancient sports activity. It originated from the ancient Chinese ball game "ancient game of kicking a ball" and is a traditional Chinese game culture. In a sense, the hometown of football is China [1]. However, looking at the national football team is really awkward. The weakness of Chinese football begins with the lack of attention in education. How to integrate football into contemporary student education, from the beginning of students, inherit and carry forward the traditional Chinese game culture.

The 2018 World Cup has caused many football fanatics to prefer to watch the live broadcast with a sigh of enthusiasm and support for their favorite team. With an in-depth understanding of football, it was found that a large amount of mechanics was covered in the sport. As a senior fan, after learning with students, many students love football [2]. As a physical education teacher, I hope that with the help of the World Cup, I can learn the mechanics of football and draw students with students. The distance, cultivate their football interests and improve their knowledge of mechanics. In this course, I focus on Cristiano Ronaldo's "hat trick" goal, analyze the principle of the deciduous ball and the elevator ball, and analyze the mechanics involved in throwing the ball outside the ball, catching the goalkeeper and shoveling the player.

## 2. Case Background

In the 88th minute of the fourth game of the 2018 World Cup group match, Cristiano Ronaldo staged a hat trick and turned the tide to bring the score back to 3:3, which was a draw with Spain. The goal was amazing and caused an uproar in the football world. This goal also inspired a heated discussion in the field of sports mechanics. In the context of the new curriculum reform, the promotion of students' comprehensive quality is advocated, and the integration of disciplines is advocated to enhance students' comprehensive ability [3]. Especially in the physics syllabus, it is clearly pointed out that students should be trained in practical problem-solving skills, closely related to reality, and try to use mechanics knowledge to explain life and problems in nature. The football game contains a lot of teaching materials, especially in the positioning ball, it contains a lot of mechanics. Cristiano Ronaldo's "hat trick" is interpreted as "elevator ball", "banana ball", "deciduous ball", which includes the principle of energy conservation, fluid mechanics, Magnus effect and so on.

### 3. Positioning Ball Aerodynamics

In mechanics, the principle of changing the motion state of an object is force. In the positioning ball, the athlete's footwork and the ball's force point are important reasons that affect the speed and trajectory of the football. After positioning the ball off the ground, it is not only affected by gravity and air resistance, but also affected by the swirling airflow. These factors eventually lead to the strange trajectory of the positioning ball such as "elevator ball", "deciduous ball" and "banana ball". Exercise and break the goal.

The first explanation of the lateral migration of spin objects in mechanics is the German physicist Magnus, who first explained the lateral offset phenomenon in the rotation of the bullet. This principle can also be applied to ball sports [4]. To this end, the principle is first used to study the Cristiano Ronaldo positioning ball. After the positioning ball leaves the ground, the axis of the rotation is perpendicular to the direction of the airflow. Compared with the center of the soccer ball, the direction of rotation and the direction of the airflow have a flow velocity of a fast flow, and the corresponding position of the air pressure is small; the other side of the football, the air flow rate slower, and the pressure is higher, resulting in the two pressures of football cannot be balanced, so after the parabolic motion of the air, the football found a deflection phenomenon, which is called "Magnus effect" in mechanics.

#### 3.1 Bernoulli Equation

Set  $P$  is constant,  $\rho + \rho gh$  is hydrostatic pressure, and  $\frac{\rho v^2}{2}$  is hydrodynamic pressure. The expression is:

$$P = \rho + \rho gh + \frac{\rho v^2}{2} \quad (1)$$

#### 3.2 Quantitative Analysis of the Influence of Magnus Effect Football

As shown in Fig. 1, with respect to the air in front of the football, the left side is in the same direction as the airflow, and the right side is opposite to the airflow. At this time, the speed of the soccer ball is  $v$ , the angular velocity at which the ball rotates is  $\omega$ , and the coefficient is  $s$ . When the ball rotation tangential speed is set to  $\mu$ , the left airflow speed of the soccer ball is expressed as  $v - \mu$ , and the airflow speed on the right side of the soccer ball is  $v + \mu$ . At this time, the mechanical expression of the sphere is

$$\vec{F} = s(\vec{\omega} \times \vec{v}) \quad (2)$$

According to Bernoulli's equation, when the pressure on the right side of the football is stronger than the left side, it is subjected to the pressure to the left. At this time, the force to the left will produce an acceleration opposite to the direction of the football, and the soccer ball will be parabolic. Sports, so the trajectory of football shows an arc shape. According to the Magnus effect, this is the kinematic principle of "banana ball" and "deciduous ball".

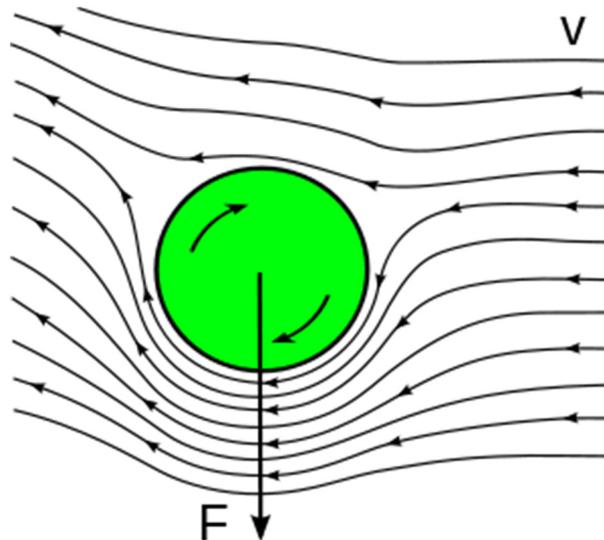


Fig. 1 Positioning ball aerodynamics

In this positioning ball of Cristiano Ronaldo, one more interpretation is "elevator ball", "elevator ball" is a form of "deciduous ball", which first appeared in "Gazzetta dello Sport", which will take Pirlo's free kick. Known as the "lift free kick", "rapidly rose to the sixth floor, but quickly dropped to the first floor", also explained by the Magnus effect [5]. Cristiano Ronaldo chose this ball at the gate of the football. The ball gets high speed at the moment of the volley. For this reason, it can move straight in the beginning, forming a streamlined contact with the surrounding airflow during the movement, forming a turbulence, making the football go up and down, and finally It crashes rapidly with a great slope, and it is like an elevator. The expression for its high-speed motion is as follows.

$$F = \frac{\rho v^2}{2} C_d A \quad (3)$$

Where  $\rho$  is the air density,  $v$  is the ball speed, and  $A$  is the cross-sectional area of the ball.

#### 4. Enhance the Mechanical Factors of Positioning Ball Strength

In combination with the aerodynamic knowledge above, it is necessary to analyze the Magnus effect and analyze how to improve the power of the positioning ball. It is found that the effective way to make football pass through the wall and confuse the goalkeeper is to make a goal. The full rotation of the football, and the power of the full rotation of the football is the force of the foot. Through the study of mechanics, the three elements of force have a major impact. To this end, finding the right size, direction, and point of action is a factor in Cristiano Ronaldo's "hat trick".

##### 4.1 Direction of Force

In a kick, if the athlete's power is located in the center of the football, the force can't form a moment relative to the center of the ball, then it can't trigger the rotation of the football. Only the football can be moved, that is, the football will only be affected. From the influence of gravity and air resistance, the trajectory of the sphere is easily seen by the other player and it is difficult to cross the wall. According to the momentum moment theorem, it is necessary to give the power of the soccer ball to rotate, so that the football rotates in the process of forward translation, and the Magnus effect is formed under the influence of the airflow. An offset occurs, which makes the opponent's players unable to recognize the direction of the football and increase the difficulty of the defense.

## 4.2 The Point of Action of Force

Cristiano Ronaldo's role in the positioning of the ball is very important in the positioning of the ball. From the analysis of the mechanics, the kick is a kind of elastic force. It passes through a certain point on the sphere and is perpendicular to the contact surface and points to the force object, thus affecting the flying of the football. Out of direction. If the force point of the kick is in the lower part of the football, the power is obliquely upward, then the football flies out at a larger elevation angle; the force point is in the middle of the football, the force is centered, and the football flies out in a straight direction; When the point is in the upper part of the football, the football will collide and rub against the ground during the flight, which will reduce the speed of energy loss, resulting in a low speed ball and rubbing the earth. To this end, as a football player needs to pay attention to the balance of the body, so that the technical movements are in line with the norms, constantly adjust the pace, step on the support foot, and constantly adjust the movement. In this positioning ball, Cristiano Ronaldo took a deep breath and continually adjusted the position of the ball before kicking the ball, constantly lifting the trouser legs, gazing forward, looking for the best point of force, driving before the foot, all movements in one go. According to the analysis of the relevant sports people, Cristiano Ronaldo chose to volley at the position of the valve, so that the football was drawn in the air to form an arc and rotate at a high speed, passing through the top of the wall, falling vertically in the upper right corner of the goal, killing the other goalkeeper unprepared.

## 4.3 Magnitude of the Force

The size of the inside of the kicking process can be explained by the momentum theorem, that is, the momentum of the external force is equal to the momentum change of the football. There are equations as follows.

$$F \cdot \Delta t = m \cdot \Delta v \quad (4)$$

The left side of the equation is the product of the force and the action time, which is the impulse; the right side of the equation is the change of the sphere momentum. In football, the quality of the football and the contact time  $\Delta t$  of the spherical surface are certain. In order to obtain greater impact, the football needs to strengthen the strength of the kick. After the football gets a certain speed, under the influence of gravity, air resistance and Magnus [6], the football gets various forms of sports. However, it should be noted that to make the football's range far, it is necessary for the football player to improve the playing power when playing football, so that the initial speed of the football is as large as possible, so that the football flying momentum is rapid and enhances the power of the positioning ball. Studies have shown that a professional soccer shooter's field goal rate is generally 87.4-95.76km/h, and concluded that few players can exceed this limit. However, after the fourth round of the World Cup in Portugal against Spain in 2018, after a slow-motion replay, C scored a goal and scored a stunning speed of 103km/h.

## 4.4 Other Factors

In addition to the above factors, the angular velocity of the rotation obtained by the football is related to the friction coefficient of the foot, which increases the friction coefficient and helps to increase the angular velocity. The position of the contact sphere deviates from the center of the sphere, which makes the football obtain greater torque and promotes it to some extent. Rotation effect.

## 5. Topic Drill

After introducing the above-mentioned principle of Cristiano Ronaldo's "hat trick", in order to deepen the impression of the students and return to the mechanics research itself, the author set the topic for the students. The topics are as follows:

In the fourth game of the 2018 World Cup, Cristiano Ronaldo played a hat-trick in 88 minutes. As shown in the following figure, Cristiano Ronaldo kicks the football of mass  $m$  from the ground point

A at speed  $v$ . At the point B where the football reaches the ground height  $h$ , take the zero-point energy reference plane of point B, excluding air resistance, the following statement the correct one is ( ).

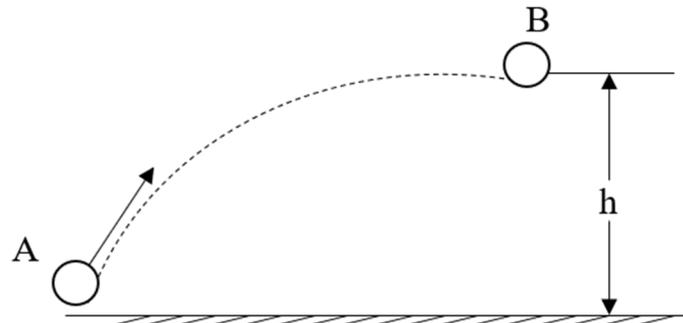


Fig.2 Football shot map

- A. Cristiano Ronaldo's work on football is equal to  $mv^2 / 2$ .
- B. Cristiano Ronaldo's work on football is equal to  $mv^2 / 2 + mgh$
- C. The mechanical energy of football at point A is  $mv^2 / 2 - mgh$
- D. The kinetic energy of football at point B is  $mv^2 / 2$

[Answer] AC

Cristiano Ronaldo's work size for football is equal to the increase in football kinetic energy, i.e.  $W = mv^2 / 2$ , so A is correct and B is wrong. Taking point B as the zero potential energy surface, the mechanical energy of the football at point A is  $mv^2 / 2 - mgh$ , so C is correct. In the course of football, energy is followed. The mechanical energy at point B is equal to the kinetic energy at point B, inherently  $mv^2 / 2 - mgh$ , so D is wrong.

[Pointing] The body uses the kinetic energy theorem analysis of Cristiano Ronaldo's kicking process. The increase in the kinetic energy of football is equal to the work of the person. After the football leaves the foot, the flight continues due to inertia. Only gravity works and the mechanical energy is conserved. (The subject ignores air resistance and the Magnus effect, adapting to high school mechanics teaching).

## 6. Popularization of Other Mechanics in Football

### 6.1 Throwing the Ball out of Bounds

According to the "Physics World" report, Physicists at Brunel University in the United Kingdom believe that the best angle for throwing a ball outside a football match is  $30^\circ$  [7]. The final distance thrown by the ball is two points: the initial speed of the ball throw and the throwing angle. According to the basic mechanical principle analysis, when the throwing model is  $45^\circ$ , the flight distance can be ensured to be the farthest, but the model is based on the theory that the throwing speed is independent of the throwing angle. However, new research shows that when the throwing angle is  $30^\circ$ , it is more conducive to the football player's back and arm muscles, so now many players choose to throw the ball outside  $30^\circ$ .

### 6.2 Other Mechanics Knowledge

As the player moves forward on the court, once it is tripped or shoveled, due to inertia, there will be a forward tilt and the face will fall. In order to alleviate the impact of football, the goalkeeper generally takes the hand block.

## 7. Conclusion

The knowledge of mechanics has a wider application in football. In football games, we often hear that after a wonderful goal, the commentator often uses "this is a goal that violates the laws of mechanics." I would like to admire it, but from an objective point of view, the goal of football must be followed by the laws of mechanics. In the teaching practice, the author borrows Cristiano Ronaldo's classic goal in the 2018 World Cup as an entry point, uses the mechanics principle analysis of the positioning ball technique, is fascinating, and guides students to analyze the mechanics of life, which helps students to understand more deeply. To the knowledge of mechanics. In this course, students show unprecedented activity, which shows the advantages of linking mechanics teaching with current events and life. This method is worth promoting.

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