ISSN 2616-5767 Vol.7, Issue 6: 117-122, DOI: 10.25236/AJETS.2024.070617

Design of Cricket Bowling Machine Based on Catapult Launching and Spiral Spring Recovery

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Abstract: *This paper designs an innovative cricket bowling machine that operates on the principles of catapult launching and spiral spring rebound recovery, aiming to provide a convenient cricket training experience for beginners. The device launches the cricket ball via a catapult mechanism, after the ball is hit, automatically retrieves it using a spiral spring to power a line wheel. During the launching process, a worm pair structure is employed to adjust the angle of the launch tube, accommodating diverse training needs. Meanwhile, precise coordination between a geared DC motor and a boss gear achieves precise control over the launching and retrieval processes. This paper comprehensively introduces the structural design, working principle, and programming of the device. The design is anticipated to stably launch and retrieve cricket balls, thereby significantly enhancing training efficiency and reducing the training burden on users. Furthermore, this paper analyzes the potential challenges of the device in practical applications and proposes improvement suggestions, providing valuable references for subsequent research.*

Keywords: *Cricket bowling machine, Catapult launching, Spiral spring rebound recovery, Worm pair, Programming*

1. Introduction

As a high-profile sport, cricket has become the second most popular sport after football in terms of viewership.[1] It has a considerable number of enthusiasts and participants all over the world, and its influence cannot be underestimated.

1.1. The challenges of batting training

Novice training is difficult: For beginners involved in the field of cricket, in order to master the skills of cricket batting, often need to invest a lot of time for repeated practice.

Professional batsmen must also focus on developing anticipation skills so that they can respond effectively to the throws of the bowler. It should be known that batsmen need to quickly judge the ball situation in a very limited time, and move to the appropriate position to react accordingly, for example, in the face of fast pace bowlers, the time to bowl through may even be as short as 450 milliseconds, so in daily training, batsmen need to constantly face a large number of pitches to hone this skill.[2]

Limitations of traditional training methods: In the traditional training mode, the main reliance on the coach or sparring staff to continuously throw a cricket ball to the novice for hitting practice. This approach not only makes the training cost high, but also limits the efficiency and final effect of training to a large extent.

Bowlers are vulnerable to injury: In addition, there are many natural changes in the sport of cricket itself, and if the bowler continues to pitch for a long time, the body will withstand high intensity impact, which can easily lead to overuse injuries such as lumbar stress fractures, ankle sprains, and knee, shoulder, and waist injuries.[3]

1.2. Athlete development and sports equipment trends

At the same time, in today's competitive sports arena, athletes simply rely on their own superior

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strength or talent is far from enough. To stay on top of the game, athletes must practice skillfully and make full use of all kinds of cutting-edge sports technology. It is worth mentioning that in the current global economic environment, high-tech sports equipment is showing a good trend of vigorous development.[4]

1.3. The design and advantage of cricket ball tee device

Device introduction: In order to effectively solve the problems of the above traditional training methods, we carefully designed a cricket bowling machine based on catapult launching and spiral spring rebound recovery. The device has the unique advantage that it can automatically launch the cricket ball, and after the ball is hit and flown away, it can also realize the automatic recovery function, so as to create continuous and stable conditions for cricket batting training.

Training convenience and effect improvement: With the help of this device, novices can carry out training independently even without the presence of coaches or sparkers to assist, which greatly improves the efficiency and effect of training.

Serve regulating function: In addition, Fuss, F. K., Doljin, B., & Ferdinands, R. E. D. We have thoroughly studied the functional relationship between bowling rate and body (torque) and skill proficiency, and the cricket ball kicker we designed can flexibly adjust the serving Angle and speed, so as to fully adapt to the diverse training requirements of different cricketers.[5]

1.4. Purpose of research

This paper intends to introduce the structure design and program design of this cricket bowling machine in detail, and discuss its feasibility and practicability in practical application. Through in-depth research on the working principle, structural characteristics, control algorithm and many other aspects of the device, we sincerely hope to provide a new and efficient solution for the training and competition activities of cricket. At the same time, we also hope that this study can provide some reference for researchers in related fields, and contribute to the continuous development of cricket training technology.

2. Overall Structure Design

The overall structure of the cricket bowling machine resembles a cuboid, but its top surface is recessed along the wide edge, creating a nested cuboid effect. The device comprises a bottom shell, a middle cover, and a top cover, which are securely fastened together by hollow columns and screws, forming a stable shell structure. The shell houses key components such as the launch tube, line wheel, spiral spring , worm pair, and geared DC motor.The three-dimensional diagram of the overall structure of the device is shown in Figure 1.

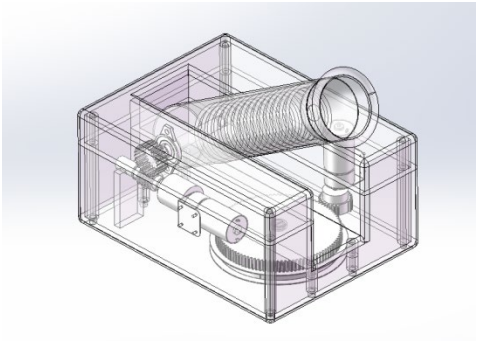

Figure 1: Cricket bowling machine

2.1. Launch tube design

The launch tube is one of the core components of the cricket bowling machine, responsible for loading and ejecting the cricket balls. The launch tube is made of lightweight materials to reduce overall weight and improve launching efficiency. The rotating shaft of the launch tube is fixed to the outer casing through a clamping structure with bearing hexagon socket head bolts.[6] Inside the launch tube, there is a spring and a ball holder. The ball holder is hemispherical with a hole in the middle, used to fix the cricket

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ball and reduce the pressure it experiences during the compression of the spring. The spring is used to store the launching energy, and when released, it ejects the cricket ball out of the launch tube.

2.2. Line wheel and spiral spring design

The line wheel serves to connect the cricket ball to the spiral spring, enabling the recycling of the cricket ball. A line is affixed to the line wheel and connects to the cricket ball via the launch tube, which contains the spring and ball support. The spiral spring is installed within the line wheel, with one end anchored to the line wheel shaft and the other end attached to the perimeter of the line wheel. The spiral spring exerts a gentle retraction force, yet it maintains a consistent retraction tendency, ensuring smooth retrieval of the ball after it has been launched.

The advantage of the spiral spring lies in its ability to provide a continuous and stable retracting force, as well as its compact structure and ease of installation. By reasonably designing the parameters of the spiral spring, we can ensure that the cricket ball will not be subjected to excessive tension during the retrieval process, thus preventing damage to the cricket ball.

2.3. Worm pair structural design

The worm pair structure is utilized to adjust the angle of the launch tube, thereby achieving adjustment of the cricket bowling machine. The worm is fixed to the shaft of the geared DC motor via a coupling, while the worm gear is fixed to the axis of the launch tube. When the geared DC motor is activated, it drives the rotation of the worm, which in turn drives the rotation of the worm gear and the launch tube, enabling adjustment of the launch angle. The structure of the worm pair is shown in Figure 2.

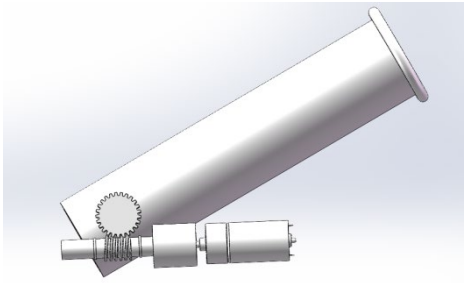

Figure 2: Worm pair structural

The advantage of the worm pair structure lies in its ability to achieve a large transmission ratio and stable transmission effect. By reasonably designing the parameters of the worm pair, sufficient stability and precision can be ensured during the rotation of the launch tube. Additionally, the worm pair structure has the function of self-locking, which means that when the worm stops rotating, the worm gear and the launch tube will remain at the current angle, preventing angular deviation due to external forces.[7]

2.4. Selection of geared DC motors

Geared DC motors are widely used in various machineries and can serve as the power source for cricket bowling machines, driving the rotation of the worm and the rewinding of the line wheel to compress the spring.[8] Geared DC motors boast advantages such as small size, lightweight, high power, and adjustable speed, making them capable of meeting the power source requirements of the cricket bowling machine.

When selecting a geared DC motor, parameters such as its rated power, speed range, and torque need to be considered. By reasonably selecting motor parameters, sufficient power and stability can be ensured for the cricket bowling machine during the launch and angle adjustment processes.

2.5. Enclosure design

The enclosure serves as the protective layer of the cricket bowling machine, safeguarding the internal structure and components from external environmental interference and damage. The enclosure is composed of a bottom shell, a middle cover, and a top cover, which are fixed together through hollow columns and screws. The overall shape of the enclosure resembles a rectangular prism, but with a rectangular recess along the wide side at the top for placing and fixing the launch tube.

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The advantage of the enclosure lies in its compact structure, ease of processing and installation. By reasonably designing the shape and size of the enclosure, sufficient stability and durability can be ensured for the cricket bowling machine. Additionally, the enclosure also serves aesthetic and dust-proof purposes, enhancing the overall performance and user experience of the cricket bowling machine

3. Detailed Design of Key Structural Components

3.1. Detailed design of the spiral spring

For a cricket ball weighing between 155.9 grams and 163 grams, to ensure it can be smoothly pulled back into the launch tube's interior chamber, the tensile force acting on the string-pulled cricket ball must exceed its own gravity. The specific gravity value is calculated as follows:

$$G = mg = 0.163kg \times 9.80N / kg = 0.160N \tag{1}$$

Considering the friction resistance generated when the string slides within the launch tube and the friction energy loss during the rotation of the line wheel, the spiral spring needs to apply at least $3N$ of tangential driving force to the line wheel. The outer diameter of the line wheel's winding section is set to $15cm$. Based on this, the torque required to be generated by the spiral spring should reach approximately $0.225N \cdot m$. Based on the mechanical properties released by the spiral spring,[9] the stiffness coefficient K of the spiral spring can be approximately calculated using the following formula:

$$K = E\mathrm{bh}^3 / 12kl \tag{2}$$

The torque formula is:

$$T = k\theta \tag{3}$$

Selecting a steel strip made of 65Mn spring steel with a length of $7m$, a width of 10mm, and a thickness of 0.4mm as the spiral spring, with an initial number of turns n, and the Young's modulus E of 65Mn being $2.06 \times 10^{11} Pa$, and k being a coefficient typically taken as 1.25. Then the torque is:

$$T = 0.007889nN \cdot m = 0.225N \cdot m \tag{4}$$

That is, the initial number of turns required for the spiral spring is $n = 28.5$ turns.

3.2. Detailed Design of the Spring

Setting the final velocity of the cricket ball as $v_{final} = 3m / s$ and the time from launch to when the trainer hits the ball as $t = 0.4s$. The sum of the rotational inertia of the line wheel and the large gear relative to the axis is $J = 0.00078kg \cdot m^2$. The acceleration of the ball during launch is:

$$a_1 = (\mathrm{F}_{\text{elasticity}} - f) / [m + (J / r^2)] \tag{5}$$

Setting the compression of the spring within the launch tube by the ball to be 10cm, with an initial compression x.

$$F_{elasticity} = (2F + f) - kx(11cm < x < 21cm) \tag{6}$$

$$a2 = f / (m + J / r^2) \tag{7}$$

$$v_0 = v + a_2 t = 7m / s \tag{8}$$

$$E_0 = mv_0^{\ 2} / 2 = 3.92J \tag{9}$$

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$$E_0 = \int ma_1 dx \tag{10}$$

$$F = 48.37N \tag{11}$$

$$k_1 = 483.7N / m \tag{12}$$

The initial compression is approximately $11cm$. The formula for the spring elastic coefficient is:

$$k = Gd^4 / 8nD^3 \tag{13}$$

The shear modulus G is given by the formula $G = E / (1+v)$, where E is the Young's modulus and v is the Poisson's ratio. For a material with a grade of 65Mn, the Young's modulus $E = 2.06 \times 10^{11} Pa$ and the Poisson's ratio $v = 0.3$. If a spring with a length of $35cm$, an effective number of coils n of 30 , a wire diameter d of $4mm$, and a mean coil diameter D of $7cm$ is selected, its elastic coefficient k_2 is calculated to be $492.79N / m$, which meets the requirement.

4. Circuit and program

The circuit and program are the key to achieve the whole control of the system. In order to realize the coordinated operation and remote intelligent control of the Angle adjustment, service and recovery parts of the device, the Arduino UNO board is used for system regulation of the motor, Bluetooth and other modules, which can remotely report the status to the intelligent device and be controlled by the intelligent device, so as to maintain the normal operation of the device. In order to cater to the majority of cricket beginners, the design of single service and multiple consecutive service combined control mode and independent Angle adjustment control, to help beginners adjust the batting habit and further practice.

4.1. Selection of Arduino board

Arduino board is a modular open source embedded development platform. Due to its low cost, easy to learn, flexible and open characteristics,[10] Arduino board has greater advantages compared with other development platforms in simple product development and applications of the Internet, and has a wide range of enthusiasts around the world. Arduino UNO is a basic control center, and the non-extended version has a rich hardware composition,[11] including multiple digital I/O pins, analog input pins, USB interfaces, DC interfaces, and so on. You can use Arduino IDE to finish the code writing and the loading of the program. The Arduino board helps you read information from input devices such as sensors and potentiometers and output it in multiple ways. The device uses Arduino as the core to control the operation of the two motors, uses the position sensor to obtain the state of the motors, and remotely controls the device through Bluetooth.

4.2. Motor control method and system design

After a lot of statistical comparisons, L298N *geared DC motor* drive module is selected to help control motor operation. The L298N has two H-bridge structures inside, which can drive 2 *geared DC motors*, and freely control the positive and negative rotation of the motors by adjusting the pin level signal, which overcomes the direction control problem of the general DC motor. The specific digital I/O pin of Arduino board is used to perform[12] carrier-based PWM regulation on the motor, and the motor speed can be adjusted by controlling the pulse width of the signal and adjusting the duty ratio, so as to meet the needs of the device for motor speed regulation. In addition, the position signal provided by the sensor can accurately control the motor start and stop. The motor is fully regulated by multiple modules to ensure the efficient and stable operation of the system.

4.3. Improvements in remote control

It can realize the remote pairing with Bluetooth module through mobile app. The selected HM-10 Bluetooth module supports the low power Bluetooth 4.0 protocol,[13] and has the characteristics of small size, low cost and low energy consumption. The Bluetooth module can conduct serial communication

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through the I/O pins 0 and 1 of the Arduino UNO development board, input the code of control program into the mobile app, and enable the Arduino UNO development board to read serial information through the serial communication of the Bluetooth module, so as to determine the mode of motor control. In order to promote the user to quickly get familiar with how to control the device, the control key corresponding to the code is designed on the mobile phone app to facilitate the user's use. Each key can correspond to the starting, braking, the speed regulation and other control programs of two motors. At the same time design a beautiful page to make it more humane.

5. Conclusion

The cricket bowling machine designed in this paper fully integrates technologies such as catapult launching, wire retraction using a spiral spring, and angle adjustment via worm pair to achieve automated launching and retrieval of cricket balls. Through precise control of the geared DC motor, the device can launch the cricket ball at a preset angle and force. Meanwhile, after the ball is hit away, the spiral spring automatically drives the line wheel to retract the wire, pulling the ball back to the launch position, greatly enhancing the convenience and efficiency of training.The design of the launch section, particularly the introduction of the worm pair structure, allows for flexible and accurate adjustment of the launch tube's angle. Driven by the geared DC motor, the worm can stably rotate the worm gear, thereby adjusting the angle of the launch tube. This design not only improves the flexibility of the device but also ensures the accuracy of the launch angle, meeting various training needs.The design of the retrieval section is equally ingenious. The introduction of the spiral spring enables the line wheel to automatically retract the wire after the ball is launched, pulling the ball back to the launch position. Additionally, the ball holder design effectively reduces the pressure exerted on the ball during the compression of the spring, lowering the risk of damage to the ball. Furthermore, the tooth-missing design of the boss gear cleverly solves the problem of the geared DC motor being difficult to reverse, ensuring the normal release of the spring and smooth launching of the ball.

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