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RESEARCH ARTICLE

Design of Automatic Tekong Launcher System Using Progressive Methods

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ABSTRACT – The Automatic Tekong Launcher System represents a cutting-edge advancement in sepak takraw equipment, seamlessly blending precision engineering with advanced automation to transform the role of the Tekong. At its foundation, the system is built from durable aluminum profiles, ensuring a robust and reliable structure. The launcher mechanism is crafted using CNC milling technology, reflecting a commitment to precision and optimal performance. Central to the system's operation is a power supply, featuring three 30A AC to DC converters that provide consistent electricity to the motors. These motors include four high-speed 24V DC units and two stepper motors, capable of reaching speeds up to 2800 rpm. This setup allows for meticulous control over the ball's speed and trajectory, essential for precise launches. The brain of the system is a Programmable Logic Controller (PLC), which manages the intricate movements of both motors and sensors, enabling the automation of ball launching with minimal human intervention. For added versatility, the system incorporates joystick control, allowing for semi-automatic operation that enhances user interaction and adaptability to various gameplay scenarios. By integrating advanced automation, precision engineering, and a modular design, the Automatic Tekong Launcher System offers unparalleled performance in both training and competitive environments. Its ability to deliver consistent, accurate launches elevates the standard of sepak takraw, making it a revolutionary tool for players and coaches aiming to refine their skills and strategies.

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1.0 INTRODUCTION

The historical evidence indicates that Sepak Takraw was played in the 15th century in Malaysia, and today, it stands as one of the most popular sports in the country. Despite being the birthplace of Sepak Takraw and a regular participant in prestigious events like the Commonwealth Games, Asian Games, and the Southeast Asian Games, Malaysia faced a setback when the National Sports Council (MSN) removed Sepak Takraw from its list of national core sports in 2017 due to poor performance [1].

Efforts to revive the sport included initiatives like the creation of the Sepak Takraw League (STL). However, a significant challenge faced by the national team was the difficulty in receiving serves from opponents' Tekong, particularly those from Thailand known for their fast and confusing "servis kuda." Additionally, the nature of Sepak Takraw training, requiring at least two players, posed limitations for individual practice, especially in serving and kicking without a partner. They are typically used for training drills that involve straight and bounce shots, either at the baseline or up at the net in tennis, or in cricket. There are a number of benefits to utilizing ball-throwing devices. The first benefit is that players will remain concentrated while practicing thanks to the machine. The portable ball or launcher machine correctly launch the ball for the players in the manner they choose [2]. As a result, players will be able to receive the ball correctly without having to worry about what their training partner is doing since they can maintain their attention on their training. Furthermore, a player's dominance over the ball and controlling it can be developed by repeats. Studies show that repeating the movements results in the player memorizing them in his subconscious. This led to successful results in the match either technically or visually [3]

In response, a solution is proposed - the development of an Automatic "Tekong" Launcher System. This system aims to launch pre-loaded balls resembling "servis kuda" at an average velocity of 55 km/hour toward designated targets ("sasaran 1-6") using two launchers. The areas marked with numbers 1-6 represent the standard targets aimed at by the Tekong in the game (Figure 1). These targets denote specific locations that serve as the focal points when a Tekong executes a serve or "servis kuda" in Sepak Takraw. By specifying these targets within those areas, the Automatic Tekong Launcher System will be designed to ensure precise ball launches toward the designated targets, enhancing training accuracy in receiving serves from opponents. The project includes setting the ball trajectory to the target through a PLC and computer application. Emphasis will be placed on designing and developing the control system using a Programmable Logic Controller (PLC), ensuring precise ball transfers when triggered by a computer. The project also involves creating

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a Ladder diagram and programming for the PLC. Anticipated as a game-changer for Sepak Takraw players, this innovative equipment is expected to significantly impact training patterns, particularly in receiving serves from opponents' Tekongs. Additionally, players may program their portable ball machine to feed and pitch the balls at the appropriate speeds for their skill level. Players have the ability to control how the balls are delivered to them, including how quickly they are travelling toward them as well as their direction and trajectory [4]. The machine is therefore appropriate for players of all skill levels. The ability of players to utilize a ball machine whenever and wherever they choose is its last benefit. They are portable, allowing athletes to exercise effectively whenever it is convenient for them without having to rely on anybody else [5]

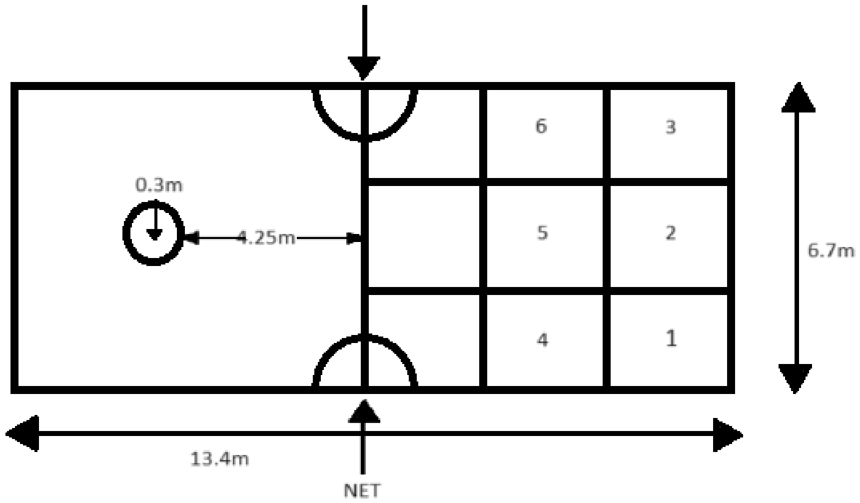


Figure 1. The targets marked with numbers 1-6

Tennis, soccer and cricket players are quite fond of tennis, ball and cricket ball launchers. They utilize it to practice their strokes and receive under various ball-related settings, including varying ball speeds, rotations, kinds of spin, and trajectory angles. There are primarily two types of tennis ball launchers on the market right now. They are pneumatic and mechanical launchers respectively.

A. Pneumatics Ball Launcher

To toss the ball, pneumatic launchers essentially employ compressed air. Utilizing a compressor, the air is compressed and kept in a chamber. To guarantee a decent trajectory for the ball, the pressure of this compressed air is crucial. This is because the ball's initial velocity depends on the pressure of compressed air. While the ball is kept in a tube, the elevation angles of the tube may be changed to get different kinds of trajectory mechanisms [6] Both manual and automated electrical systems are available for setting the elevation angles. Typically, for this type, the ball does not have cavities like a hollow sepak takraw ball.

B. Mechanical Ball Launcher

To propel the balls, a mechanical ball launcher essentially employs two counterclockwise revolving rollers or wheels. Electric motors are typically used to rotate these wheels. The wheels' rotational speed affects the ball's initial velocity. The approaching ball is affected by the tiny openings between the wheels. The ball exiting the ball feeder is subsequently compressed by the wheels [7].

In conclusion, opting for a mechanical launcher over a pneumatic one presents several compelling advantages in sports like sepak takraw. Mechanical launchers ensure consistent ball launches with precise control over speed and direction, enhancing gameplay and training effectiveness. Their durability and lower maintenance requirements translate to reduced long-term operating costs. Additionally, mechanical launchers offer flexibility in accommodating different ball sizes and training scenarios while remaining easy to set up and operate.

2.0 RESEARCH METHODOLOGY

The research methodology for developing a launcher capable of propelling a ball at 55 km/h begins with a thorough review of existing literature on launcher design and ball propulsion mechanisms. This review provides insights into previous approaches, technologies, and challenges associated with achieving the desired ball speed. Based on the findings from the literature review and the defined objective of achieving a ball speed of 55 km/h, specific design specifications are established, outlining parameters such as revolution motor per min and launching mechanism configuration.

Following the design specifications, suitable components including motors, gears, and launching mechanisms are carefully selected based on their compatibility and capability to achieve the desired performance. With the components in hand, a prototype launcher is constructed, paying close attention to assembly precision and structural integrity to ensure reliable performance during testing. A controlled testing environment is set up, and a testing procedure is developed to evaluate the launcher's performance in achieving the target ball speed. Data on ball speed, consistency, and accuracy are collected during testing sessions, and statistical analysis is performed to assess the launcher's performance against the target specifications and identify areas for improvement. Through numbers of testing and optimization, adjustments are made to the prototype launcher to fine-tune its performance, aiming to consistently achieve the desired ball speed of 55 km/h under various operating conditions. Ultimately, the research findings, including the design process, testing results, and performance evaluation, are documented in a comprehensive report to provide insights into the development of the launcher and serve as a reference for future research and development efforts in the field of ball propulsion systems.

2.1 Theoretical Calculation

A. Wheel Rotational Speed

Two counter-rotating wheels are employed to propel the takraw ball from the launcher, as illustrated in figure 2. The ball feeder delivers the ball between these two wheels, where the forces exerted by the wheels result in the ball being propelled at a high velocity. The circumferential speeds of the wheels directly impact both the linear and angular velocities of the ball as a Figure 2[2]

During the launch, the ball's linear and rotational velocities are denoted as V and ω' respectively, while V_1, V_2, ω_1, and ω_2 represent the circumferential and rotational speeds of the wheels. Parameters rw and rl represent the radius of the wheel and the deformed ball radius, respectively, while Δl signifies the deformation of the ball caused by the pressure exerted by the wheels.

B. Motor Calculation

1. Mass of the takraw ball = 180 g
2. Shooting Wheel diameter = 320 mm
3. Shooting wheel mass = 1.8 kg
4. Ball velocity = 55km/h = 15.27 m/s

Calculation:

$$v = {v_1 + v_2}/{2} \tag{1}$$

$$rw = r_1 = r_2 \tag{2}$$

Assume $\omega = \omega_1 = \omega_2$

$$v = rw \tag{3}$$

rw = 160 mm
ω = v/r = 15.27/0.16 = 95.44 rad

Convert to RPM: - ω/2Π = 95.44/2 Π = 15.19 rps = 911.4 rpm (Motor without load)

Assume that factor of safety of load acting in motor shaft is 2.

Suitable motor speed to generate ball speed at 15.27 m/s is = 911.4 × 2 =1822.8 RPM = 190 rad/s
Kinetic energy for ejecting the ball at 15.27 m/s,
KE = $mv^2/2$ = (0.18 X 15.27 ^{2}) / 2 =20.98 J

Amount of energy stored in a shooting wheel, Es,

$$\text{Es} = I\,w^2/2 \tag{4}$$

Where,

$$I = mr^2/2 \tag{5}$$

I = (1.8 X 0.16²) / 2
= 0.023 kg.m²

So, Es = (0.023 x 190²) /2
= 415 J

Where,
r_1, r_2 = radius of shooting wheels
v_1, v_2 = velocity of shooting wheels
v = velocity of the ball
ω_1, ω_2 = angular velocity of shooting wheels

Total energy, E

$$E = KE + Es \tag{6}$$

E = 20.98 + 415
= 435.98 J

Power, P

$$P = E/t \tag{7}$$

P = 1 x 435.98 / 60 (assume only 1 balls/minute to be ejected)
= 7.27 watt

Assume that the factor of safety is 2
Therefore, P = 14.54 watt

From the calculation, takraw ball having 55 km/h velocity and mass 180 g, power required to throw the ball is only 14.54 watt. The motor used must have a minimum rotational speed of 1822 rpm to achieve a sepak takraw ball speed launch at 55 km/h.

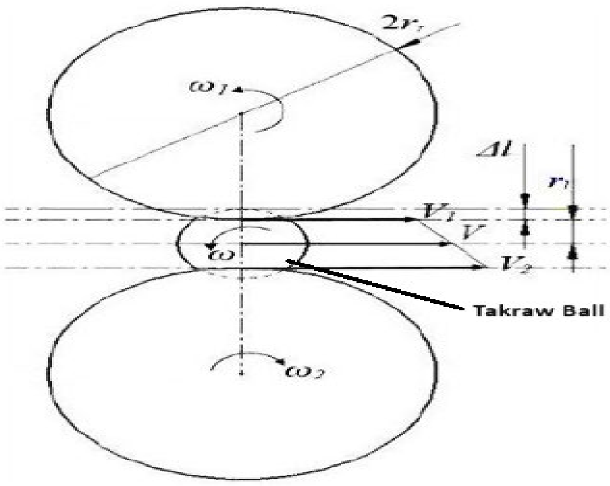


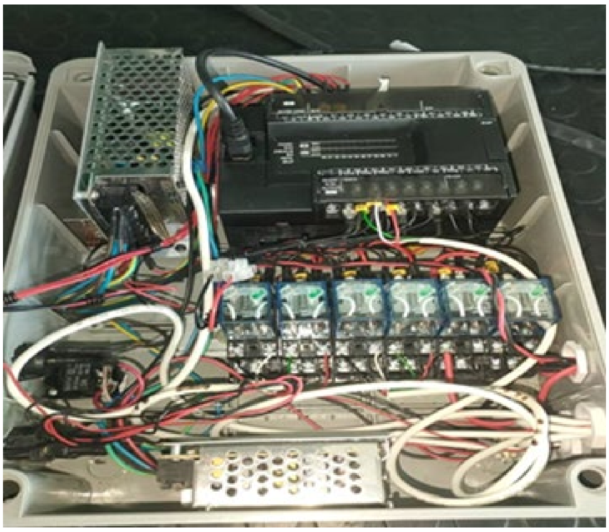
Figure 2. Two counter-rotating wheels

3.0 DESIGN

The Automatic Tekong Launcher System resembles in Figure 3a. The system features two launchers, with each launcher utilizing two motors of equal power to drive the wheels. One launcher is designated for targets 1-3, while the other launcher is designated for targets 4-6. The launcher produced can hold 4 balls at once. All body parts are made of aluminum to prevent rusting.

Two solenoids are installed on the ball storage tray to hold and release the balls according to the sequence set to be launched by the controller. All ball direction, speed, and sequence positions are driven by stepper and DC motors controlled by the PLC in Figure 3b for both automatic and manual movements. The only difference between the two launchers is the angle from the horizontal axis, which is adjusted to suit targets at the back and center.

(a)



(b)

Figure 3 (a) The Automatic Tekong Launcher System (**b)** PLC and Electronic Components

The speed of the DC motor is crucial in this system as the primary objective is to achieve ball launches exceeding 55 km/h. From the calculations in sub-topic 2.1, the minimum speed required is 1822 rpm after accounting for a safety factor of 2. Therefore, for this project, the DC motor used can rotate up to 2800 rpm, as shown in figure 4a. Furthermore, both launchers use stepper motors for directional movement within a 180º horizontal angle, as shown in figure 4b. The components are connected using a 20mm diameter shaft with bearings.

(a)

(b)

Figure 4 (a) DC motor model XYD-6D **(b)** Stepper motor

Two proximity sensors, attached to a 40 cm pipe as shown in Figure 5, utilize their high-speed response capabilities to accurately measure the speed of the Takraw ball as it travels toward designated targets in the launcher system. The sensors work by timing the ball's travel between them. The rotational speed of the wheel connected to the DC motor is influenced by the percentage of electrical power input supplied to the DC motor. Additionally, pneumatic tire pressure also affects the speed of the ball launched from the system [10]. In this system, the tire used can hold the maximum pressure of 50 psi.

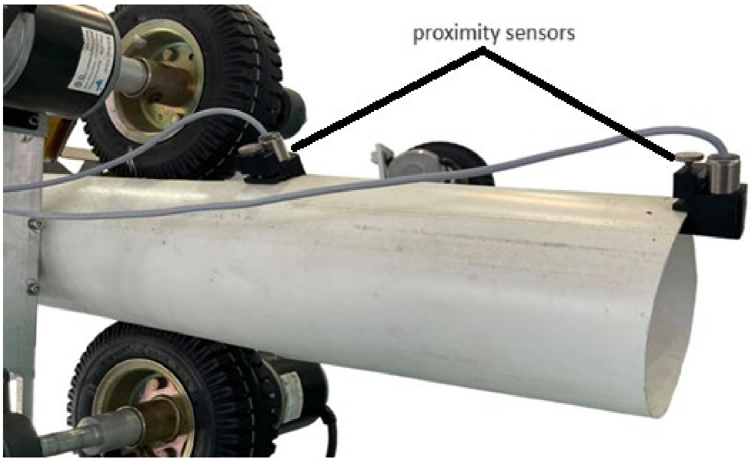


Figure 5: Two proximity sensors attached to the pipe.

4.0 RESULTS AND DISCUSSION

In the important of sports technology, the development of equipment that enhances training efficiency and effectiveness is crucial. The Takraw launcher system, designed to aid Sepak Takraw players in refining their skills, exemplifies such advancements. This system's capability to control and measure ball speed accurately is paramount for training sessions that simulate real-game conditions. The system's performance hinges significantly on two key variables: the percentage of power input and pneumatic tire pressure. This study delves into these factors, presenting a detailed analysis of their impacts on the launcher's reliability and the resulting ball speed. To measure the ball speed, proximity sensors work by detecting the presence of an object (in this case, the Takraw ball) and measuring the time interval between when the ball triggers the first sensor and when it triggers the second. This high-speed response capability is essential for capturing the rapid motion of the ball. The measured time interval is then used to calculate the ball's speed, providing accurate and reliable data for the launcher system.

Figure 6 presents a clear, nearly linear relationship between the percentage of power input and the speed of the Takraw ball. This linearity suggests that the system responds predictably to changes in power input, a critical factor for consistent training outputs. As the power input increases, the speed of the Takraw ball rises proportionately, indicating efficient energy transfer from the launcher to the ball. This predictable behavior allows trainers to precisely control the training intensity by adjusting the power input. The power input to the DC motors in the launcher system directly affects their rotational speed. The rotational speed of a DC motor is influenced by the percentage of electrical power supplied [9]. Higher power inputs increase the motor's rotational speed, which, in turn, increases the ball's launch speed. This mechanism is vital for creating a training environment that can mimic the varying speeds encountered in actual matches.

For practical training, this relationship means that players can experience a wide range of ball speeds by simply adjusting the power input. This capability is essential for developing a player's ability to handle different serve speeds, enhancing their readiness for real-game scenarios. Furthermore, the consistency of the speed increase with power input adjustments ensures that training sessions can be systematically varied to improve specific skills.

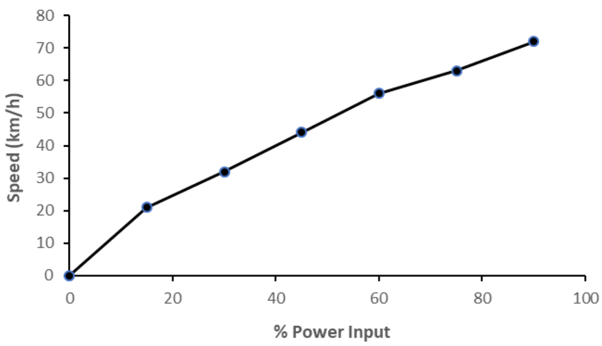


Figure 6. Percentage of Power Input vs Speed (km/h)

In addition to power input, the pneumatic tire pressure within the launcher system plays a significant role in determining the ball's speed. As highlighted by Marhas [10], variations in tire pressure can significantly impact the force exerted on the ball, thereby altering its speed. Higher tire pressures generally result in higher ball speeds due to the increased rigidity and force exerted by the tires on the ball during launch.

The bar graph as shown in Figure 7 illustrates the relationship between tire pressure, measured in pounds per square inch (psi), and the speed of a Takraw ball, measured in kilometers per hour (km/h). This analysis covers six distinct tire pressures: 25 psi, 30 psi, 35 psi, 40 psi, 45 psi, and 50 psi, providing insights into how varying tire pressures impact ball speed. At the lowest tire pressure of 25 psi, the Takraw ball's speed is approximately 45 km/h. As the tire pressure increases to 30 psi, there is a noticeable increase in speed, with the ball reaching around 50 km/h. This upward trend continues with a tire pressure of 35 psi, resulting in a speed of about 55 km/h. The highest speed is recorded at 40 psi, where the ball achieves approximately 57 km/h.

However, the data shows a decline in speed beyond this optimal tire pressure. At 45 psi, the ball's speed decreases slightly to around 55 km/h. This downward trend continues with a tire pressure of 50 psi, where the speed further drops to about 50 km/h. This pattern suggests that while increasing tire pressure initially boosts the ball's speed, there is a threshold beyond which additional pressure becomes counterproductive. The graph indicates that the optimal tire pressure for achieving the highest speed of the Takraw ball is 40 psi. Beyond this point, the speed begins to decline, highlighting the importance of maintaining tire pressure within an optimal range to maximize performance

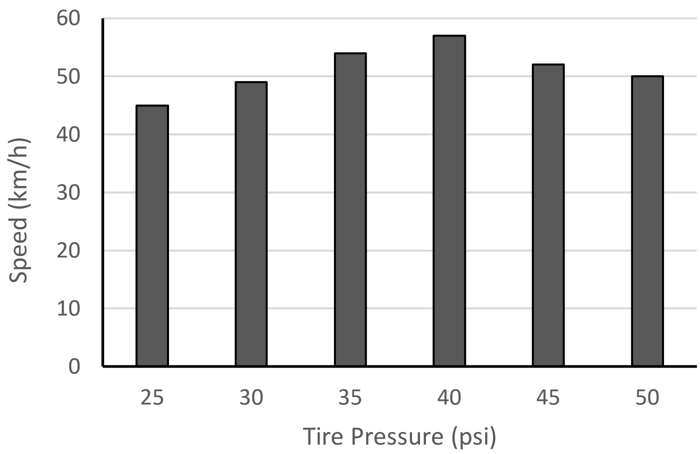


Figure 7. Percentage of Power Input vs Speed (km/h)

5.0 CONCLUSION

In this study, the design of a Takraw launcher aims to enhance convenience for players during training. This launcher is capable to launch the ball with precise timing, needed velocity, and positioning parameters. The ball loading mechanism, capable of holding 4 balls at once, allows individual training sessions for players. These parameters are controlled using PLC software, enabling operators to manage the launcher through an operator panel interface. Trainers can program the launcher to cover all settings either automatically or manually via the operator panel.

6.0 ACKNOWLEDGEMENTS

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