Ring Thrower Control System for Elephant Robot on KRAI 2023

Lancester SyahPutra[1], Rifqi Amalya Fatekha[1], Deni Parendra Sitinjak[1], Adli Samudera Alfaresi[1]

[1]Department of Electrical Engineering, Politeknik Negeri Batam, Batam, Indonesia
lancestersyahputra@gmail.com
rifqi@polibatam.ac.id

Abstract. Abu Robocon is an annual international robot competition that involves students from Asia-Pacific countries. For ABU robocon 2023 held in Cambodia with the theme "casting flowers over Angkor Wat" a robot that can throw a ring onto a pole. The Abu Robot Indonesia (KRAI) 2023 contest is a robot contest that can throw a ring onto a pole. In this study, we are looking for a stable motor speed so that the ring throw can enter the pole. Tests carried out are by using a system without control and also by using PID control. In addition, there are several parameters used such as the distance from the robot to the pole, the height of the pole and the height of the thrower. For the ring thrower itself using a brushless motor which then the motor speed will be transmitted using a gear and the results of ring throwing tests using a motor are obtained. In the first test without using the control system, the values of Rise Time = 2.3 s and Settling Time = 2.8 s are still too long to reach the setpoint so that the ring needs time to be thrown. In addition, the thrown ring also affects the Steady State Error graph where the Steady State Error = 2.46% increases to 12.15% when the ring starts to be thrown. Then testing the system with PID control obtained the calculation value of Rise time, Settling time, Oveshoot, Error Steady State results from manual tuning when the ring is thrown is good with the value of Rise time = 0.9 s and Settling time = 1.3 s. so that the ring can be thrown earlier. In addition, the thrown ring also affects the Steady State Er-ror graph where the Steady State Error = 2.46% increases to 12.15% when the ring starts to be thrown.

Keywords: ABU Robocon. Motor controls, PID, PWM

1 Introduction

The 2023 Abu Robot Indonesia (KRAI) Contest is to create a robot that can throw a ring at a pole to score according to the ABU Robocon 2023 theme [1]. The ring is an important part of the ABU Robocon match because the ring is the media that will be thrown into the pole so as to produce points according to the Abu Robocon rules. The ring used is 200 mm in diameter with a ring thickness diameter of 14 mm and the rings thrown into the pole are 10 rings. In this study the pole is used as a target for throwing

L. Lumombo et al. (eds.), *Proceedings of the 7th International Conference on Applied Engineering (ICAE 2024)*, Advances in Engineering Research 251,
https://doi.org/10.2991/978-94-6463-620-8_23

[2]. The poles have different distances [3], therefore different motor speeds are required as well as a stable motor speed in order to insert the ring into the pole [4].

The speed of the motor used needs to be determined using the PID control method to find the parameter values kp, ki and kd so that the speed of the motor can be stabilized. [5], [6]. Motor speed testing was also carried out without using the PWM control method in ring throwing [7], [8]. The parameters used for throwing the ring to enter the pole include the distance from the robot to the pole, the height of the thrower, and the height of the pole. These parameters will be used to find the motor speed required to throw the ring to the pole.

This research aims to implement a method for throwing rings by finding a stable speed value for the thrower using the PID control method and without using the control method, namely PWM with different pole distances [9]. From this research, it is hoped that a suitable and stable throwing motor speed can be obtained so that it can be applied to ring throwers..

2 Materials and methods

This section describes the method used to throw the ring to the pole by using a system without PWM control and also using a PID control system by determining Kp, Ki and Kd in finding a stable motor speed to throw the ring.

2.1 Parameters of the Pitcher and Rings used

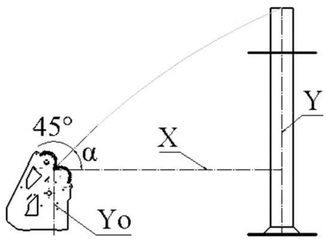

Fig 1. Parameter of Ring Thrower.

Description:
X = distance of the ring thrower to the pole
α = Ring thrower angle
Y = Pole height
Yo = Ring thrower height

Fig 1. X is the distance of the ring thrower to the pole with a distance of 1 meter then the α symbol is the angle of the thrower with a large angle of 45 ° as a fixed angle of the thrower [10]. Y is the height of the pole with a height of 1 meter and Yo is the height of the thrower with the height of the ring thrower is 0.23 meters.

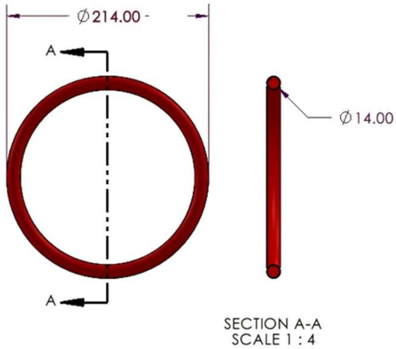

Fig 2. Ring Sizes.

Fig 2. shows the ring size used in the ABU Robocon 2023 competition with a ring diameter of 214 mm and a ring diameter thickness of 14 mm.

2.2 PID Controller

The PID controller has three main controller components including proportional (P), integral (I), and derivative (D) which are used simultaneously or just one of them depending on the desired response of a system [11]. This PID controller continuously calculates the error as the difference between the desired setpoint reference value. PID is a control method with an excellent mathematical model because the error can be changed close to zero, and stability control can be achieved by equalizing the value of the process variable with the set point value. Although PID is a control method that can be said to be superior, the three elements P, I, and D, each of which has its advantages and disadvantages, can stand alone or can be paired, which will influence each other to produce the best output signal or controller response of the controlled system. Then in this PID controller, the Ziegler Nichols method will be used to help determine the optimal values of the PID parameters [12]. The formula of Ziegler Nichols is as follows.

Controller	K_P	K_i	K_d
P	0.5 K_{cr}	Infinity	0
PI	0.45 K_{cr}	$\frac{P_{cr}}{1.2}$	0
PID	0.6 K_{cr}	$\frac{P_{cr}}{2}$	0.125 P_{cr}

Table 1. Formula Ziegler Nichols (ZN).

Section in **Table 1**. Ziegler Nichols formula K_{cr} is the value of the proportional gain (Kp) when constant or steady-state oscillation occurs. When Kp increases from zero, the system will start oscillating. K_{cr} is the value of Kp when the oscillation becomes constant and at that point the system is at the boundary between stability and instability. The K_{cr} value is used as a reference to determine the optimal Kp value to obtain the desired response. Then P_{cr} is the oscillation period where the system is at the boundary point between stability and instability. In some formulations. P_{cr} is also known as trasition time or critical oscillation time. P_{cr} is measured from the peak of one oscillation to the peak of the next oscillation and gives an idea of how quickly the system responds to changes.

2.3 Design and Mechanism of ring thrower

The design and mechanism of the robot refer to the rules of Abu Robocon 2023. The mechanism system of the thrower adopts that of a ball thrower. bola [13], [14] and was later developed for ring throwers. The throwing mechanism is with a fixed angle of 45° where the farthest throwing distance is at an angle of 45°. [15], [16], the pitching mechanism usually requires two wheels to swipe the surface of the ball. [17], However the ring thrower is made using 2 tubes with a tube length of 270 mm and a diameter of 76.2 mm and a plate thickness of 3 mm to function as a tube holder when rotating to throw the ring to the pole, 2 gears that have an outer diameter size of 92.6 mm mounted on each tube and 1 on the motor coupling to transmit the brushless motor movement to the tube, so that the resulting rotation is in the form of rotation in the opposite direction to produce the ability to throw the ring.

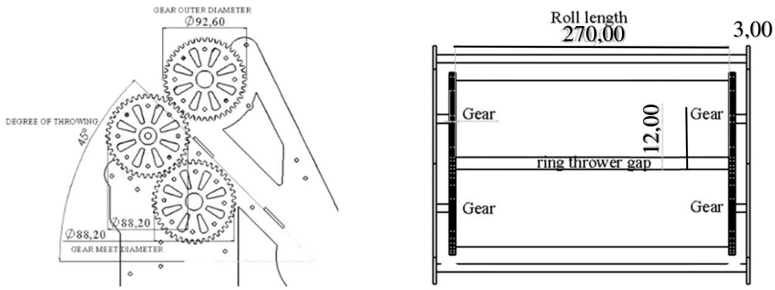

Fig 3. (a) Side view of the pitcher and (b) front view of the ring pitcher.

Fig 3. Making the gear must also be in accordance with the provisions in the manufacture of the gear so that the gear teeth can meet each other and can transmit the movement well. [18], [19] . In **Fig 3.** (a) the ring thrower moves the bottom gear 1 then the movement is transmitted to gear 2 and also 3 at the same speed and the ring will come out in the **Fig** 3 gap. (b) thrown according to the input speed by using the Ziegelr-Nichols method and manual tuning approach and also without the method, namely PWM input.

2.4 Pulse Width Modulation (PWM)

PWM is the process of comparing a carrier signal with a modulated signal to generate square signals with different amplitudes [20]. The pulse width can be adjusted according to the duty cycle. Duty cycle is the percentage of high signal time and low signal time, the duty cycle is equal to the built-in average voltage. The PWM signal has a pulse width that varies depending on the duty cycle. Below is a general definition of PWM signals.

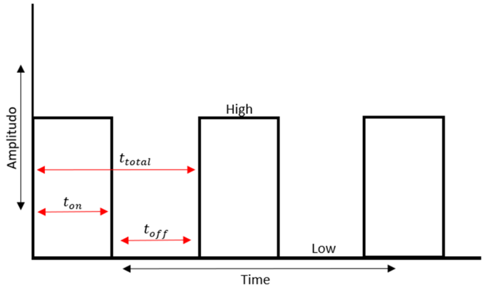

Fig 4. Pwm signal (pulse width modulation).

Fig 4. t_{on} is the time when the output voltage is high, or logic 1. t_{off} is the time when the output voltage is low, logic 0. t_{total} is the time of one cycle or the sum between t_{on} and t_{off} known as "one wave period". In this study using units of revolutions/second (rev/s) with the aim that the data displayed is clearer than with units of revolutions/minute (rpm) the graph data presented is less visible when displayed. This can be seen with the rev/s value equal to 1 rpm divided by 60 seconds. As for the pwm input, which is 0 - 1023 according to the analog write on the Arduino[21]. This research uses a pwm input of 1000-2000 because the throwing motor used is the Falcon motor which has a value of one pwm wave of 2 m/s which is different from other driving motors.

3 Results and discussion

Initial testing was carried out to determine the response value by testing the system without control and further testing using the PID control system in finding a stable thrower speed so as to produce a good ring throw. Then the test was continued by throwing 10 rings with a distance of 1 meter, a pole height of 1 meter and a thrower height of 0.23 meters using a system without control and also using PID control.

3.1 System Testing Without Control

The experiment was conducted by finding the system response without using control by entering a PWM value of 1656. The PWM value of 1656 was obtained with a 1 meter throw experiment because the PWM value below 1656 did not make the ring throw to the pole. The system response graph without control read by the encoder is shown in **Fig 5**.

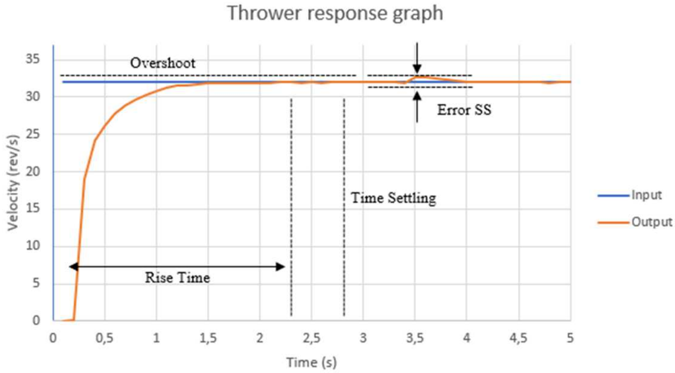

Fig 5. System response graph without PID control.

Fig 5. Shows that the system has Rise time, Overshoot, Setling time and Steady State Error. Rise time is the time it takes for the system to reach 90% of the setpoint in response to a 10% change in the input signal indicating the system response. Then Settling Time is the time it takes for the response curve to reach and settle in the predetermined setpoint region. The formula equations for Rise Time and Set-tling Time are not written down because these values depend on the response itself. Steady State Error is the difference between the output value and the input value in a steady state situation with the following equation:

$$\text{Error SS} = \frac{Maks\ Error\ SS - Min\ Error\ SS}{Setpoint} \text{ x } 100\% \quad (1)$$

Overshoot is the highest value of the response curve with the equation:

$$\text{Overshoot} = \frac{Maks\ Overshoot\ - Setpoint}{Setpoint} \text{ x } 100\% \quad (2)$$

The next test was carried out without control and obtained response results according to **Fig 5**. It can be seen that the response has reached the setpoint with the value of Rise Time = 2.3 and Settling Time = 2.8 s. Furthermore, the value of Steady State Error and Overshoot **Fig 5**. Using equations (1) and (2) with the values of:

$$\text{Error SS} = \frac{32.72 - 31.93}{32} \text{ x } 100\% = 2.46\% \quad (3)$$

$$\text{Overshoot} = \frac{32.72-32}{32} \text{ x } 100\% = 2.25\% \quad (4)$$

The value that has been obtained from testing the system without control, the next test is carried out by throwing the ring to the pole. The response value that has been obtained in the system without control will be used in the next ring throwing from the throwing test, the results of the throw with a throwing distance of 1 meter according to **Fig 1**.

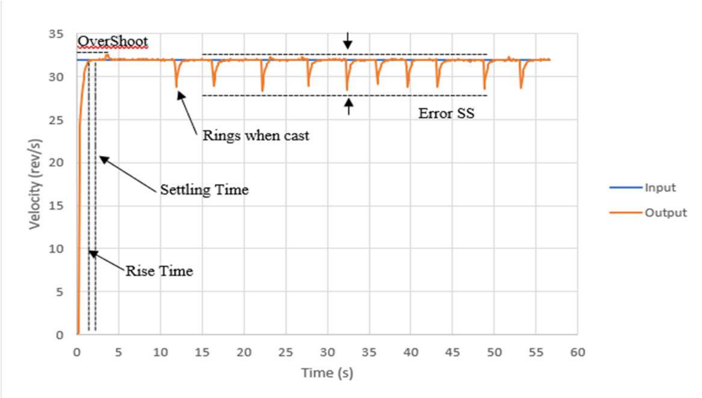

Fig 6. System response graph without PID control when the ring is thrown.

Fig 6. It can be seen that the response graph without using the control system when throwing the ring produces the same value as **Fig 5**. The only difference in value lies in the Steady State Error when the ring starts to be thrown using equation (1) and results in a value of:

$$\text{Error SS} = \frac{32.43 - 28.54}{32} \text{ x } 100\% = 12.15\% \quad (5)$$

Based on the calculation data of Rise time, Settling time, Oveshoot, and Steady State Error when the ring is thrown, it can be seen that using a system without control is still not good. This is because the value of Rise Time and Settling Time is still too long to reach the setpoint so that the first thrower needs time to be able to throw the ring. In addition, the thrown ring also affects the Steady State Error graph. This can be seen by the difference in the Steady State Error value = 2.46% before the ring is thrown and when the ring is thrown the Steady State Error value rises to 12.15%.

3.2 System Testing with PID Control

Tests were carried out using the Ziegelr-Nichols (ZN) method at a setpoint of 30. The setpoint value of 30 was obtained by conducting a 1-meter throw experiment according to Fig 1. Because the setpoint below 30 makes the resulting ring throw not reach the pole. Then the following control parameter values were obtained.

Pengendali	Kp	Ki	Kd
P Controler	4	-	-
PI Controler	3.6	0.981	-
PID Controler	4.8	2.181	2.64

Table 2. Control parameter values with ZN.

Kp = 4 in the PID controller response obtained in Table 2. Is the best form of PID in its oscillation. Then the Kp, Ki, Kd values of the PI and PID controllers are obtained using the ZN formula. So the results can be seen that the PI controller produces a good response according to **Fig 7**.

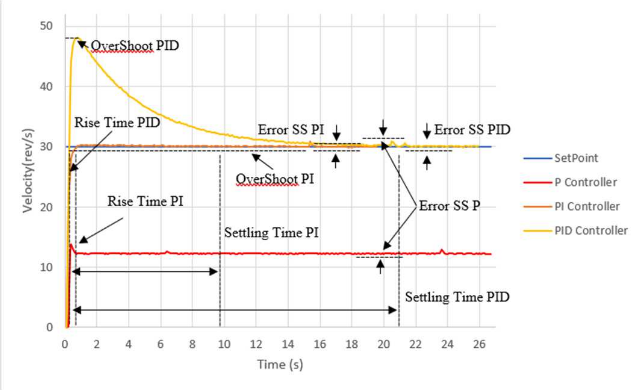

Fig 7. Response of PID controller with parameter ZN.

Fig 7. Above uses the control system with PID. It can be seen that only controller P does not reach the setpoint so that the values of rise time, overshoot and settling time are not visible. Only the P Steady State Error is visible in **Fig 7**. By using equation (1), the results are obtained:

$$\text{Error SS P} = \frac{30 - 12.8}{30} \text{ x } 100\% = 57.3\% \quad (6)$$

PI controller with Kp = 3.6, Ki = 0.981 according to Table 2. Successfully reached the setpoint. However, the value of Rise Time and Settling Time is still too long, this can be seen with the value of Rise Time PI = 0.8 s and Settling Time PI = 9.6 s. Then the value of Steady State Error and Overshoot Fig. 7. Using equations (1) and (2) with the results of the value, namely :

$$\text{Error SS PI} = \frac{30.8 - 29.86}{30} \text{ x } 100\% = 3.13\% \quad (7)$$

$$\text{Overshoot PI} = \frac{30.8 - 30}{30} \text{ x } 100\% = 2.66\% \quad (8)$$

PID controller with Kp = 4.8, Ki = 2.181, Kd = 2.64 according to **Table 2**. Successfully reached the setpoint. However, the value of Rise Time and Settling Time is still too large which is the value of Rise Time PID = 0.3 s and Settling time PID = 21.1 s. Then the value of Steady State Error and Overshoot **Fig 7**. Using equations (1) and (2) with the results of the value:

$$\text{Error SS PID} = \frac{30.8 - 29.86}{30} \text{ x } 100\% = 3.13\% \qquad (9)$$

$$\text{Overshoot PID} = \frac{48.11 - 30}{30} \text{ x } 100\% = 60.36\% \qquad (10)$$

It can be seen in the PID controller that the PI produces a good response value but the value of the Settling Time PI itself is still long to maintain the output value. So a manual tuning is needed by using the previous PI value. Then with this value, a manu-al tuning adjustment will be made to find better throw control parameters and obtained the value of Kp = 4.0, Ki = 0.951, Kd = 2.64 as shown in **Fig 8**.

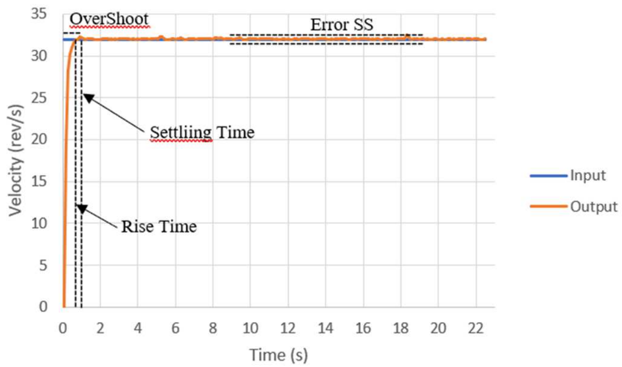

Fig 8. System response with PI controller manual tuning result.

Fig 8. Shows a good response from the PI manual tuning results. The setpoint that was previously 30 (rev/s) was changed to 32 (rev/s) because it will be used in throwing the ring to the pole with a distance of 1 meter according to Fig 1. The value of Rise Time is 0.9 s and Settling Time is 1.3 s. Then the value of Steady State Error and Overshoot Fig 8. Using equations (1) and (2) with the following values:

$$\text{Error SS} = \frac{32.57 - 31.91}{32} \text{ x } 100\% = 3.13\% \qquad (11)$$

$$\text{Overshoot} = \frac{32.57 - 31.91}{32} \text{ x } 100\% = 2.06\% \qquad (12)$$

After getting the system response with PI controller manual tuning results are very good. this can be seen with the value of the Rise Time and Settling time that shrinks. Then the test is continued by throwing the ring to the pole. The PI value of the manual tuning results obtained will be used in ring throwing. Furthermore, from the throwing test, the results of the throw with a throw distance of 1 meter are obtained according to **Fig. 1** with the following test results.

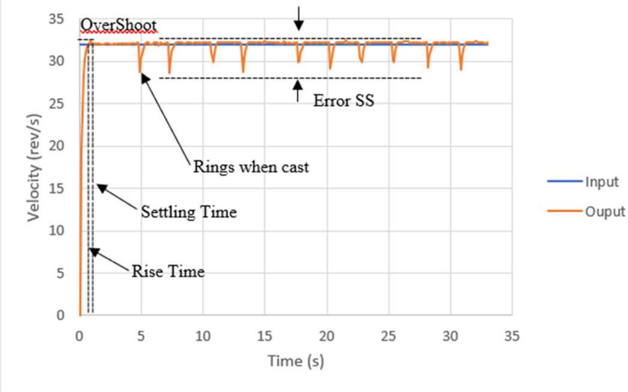

Fig 9. PI response results with manual tuning when the ring is thrown.

Fig 9. The big change in the PI response when the ring is thrown is only located in the Steady State Error. The value using equation (1) is:

$$\text{Error SS} = \frac{32.43 - 28.54}{32} \text{ x } 100\% = 12.15\% \qquad (13)$$

Based on the calculation data of Rise time, Settling time, Oveshoot, Steady State Error when the ring is thrown, it is known that the manual tuning results are very good with a small Rise time and Settling time so that the ring can be thrown earlier. In addition, the value of the Steady State Error when the ring has not been thrown is 3.13%, increasing to 12.15% when the ring starts to be thrown.

4 Conclusion and future work

From the results of testing the ring throwing into the pole to find good and stable ring throwing results using system testing without control and also using a PID control system, it is concluded that the value of the calculation of Rise Time, Settling Time, Oveshoot, Steady State Error is obtained poor results. This is because the value of Rise Time = 2.3 s and Settling Time = 2.8 s is still too long to reach the setpoint so that the ring needs time to be thrown. In addition, the thrown ring also affects the Steady State Error graph where the Steady State Error = 2.46% increases to 12.15% when the ring starts to be thrown. Then testing the system with PID control obtained the calculation value of Rise Time, Settling Time, Oveshoot, Error Steady State results from manual tuning when the ring is thrown is good with a value of Rise time = 0.9 s and Settling Time = 1.3 s so that the ring can be thrown earlier. In addition, the thrown ring also affects the Steady State Error graph where the Steady State Error = 2.46% increases to 12.15% when the ring starts to be thrown. It can be concluded that the faster the Rise Time and Settling Time towards the setpoint, the faster the ring will be thrown to the pole. In addition, the change in the value of the Steady State Error only occurs when the ring starts to be thrown to the pole.

Acknowledgments. Appreciation is expressed to all parties who have provided assistance in terms of human resources, financial support, and facilities during this research. Especially BRAIL at Batam State Polytechnic..

References

1. Penh, P., Contest, A. B. U. A. R. & Penh, P. ABU Asia-Pacific Robot Contest 2023 Theme and Rules Casting Flowers over Angkor Wat. 1–9 (2023).
2. Nur, A., Andriadi, E., Nur, M., Azhary, N. & Putra, I. E. *Rancang Bangun Elephant Robot Pelempar Bunga Berbasis Mikrokontroler*.
3. Saragih, D. H., Dyah, ; & Kusumastuti, P. *Pengaruh Variasi Jarak Tiang Bor Pada Tanah Lempung Terhadap Daya Dukung Dengan Metode Analisis*.
4. Muhardian, R. & Krismadinata, K. Kendali Kecepatan Motor DC Dengan Kontroller PID dan Antarmuka Visual Basic. *JTEV (Jurnal Teknik Elektro dan Vokasional)* **6**, 328 (2020).
5. Pane, J., Surya, A., Novita, S., Mazmur, R., Aryza, A., Hamdani, Rizky, A. Implementasi PID Dalam Mengendalikan Motor Menggunakan Metode PID dan Mikrokontroler Atmega. *Sainteks 2019* 196–201 (2019).
6. Murtono, A. & Kamajaya, L. Implementasi kontrol PID untuk analisis pengaturan kecepatan motor DC menggunakan STM32. *Seminar Nasional Teknik Elektro dan …* 310–314 (2021).
7. Irawan, D., Setiawan, D. & Yetri, M. SIMULASI ALAT TREADMILL ELEKTRIK UNTUK KEBUGARAN BADAN DENGAN TEKNIK PWM BERBASIS MIKROKONTROLER. **4307**, 128–137 (2020).
8. Harefa, A. A. M., Azmi, Z. & Hafizah, H. Implementasi Teknik PWM (Pulse Width Modulation) Pada Wipper Mobil Otomatis Berbasis Mikrokontroler. *Journal of Science …* **4307**, 91–95 (2020).
9. Kurniawan, S. Y., Setiawan, A. B. & Dirgantara, W. Kursi Roda Otomatis Berbasis IoT(Internet Of Things) Menggunakan Metode PID (Proportional Integral Derivative Controller). *Seminar Nasional Fortei Regional* **7**,.

10. Akkase, A. Analisis Gerak Biomekanika Pada Tolak Peluru Gaya 0'brien Analysis Of Motion Biomechanics In 0'brien Shot Put. *Journal Physical Health Recreation* **3**,.
11. Ma'Arif, A., Nabila, H., Iswanto & Wahyunggoro, O. Application of Intelligent Search Algorithms in Proportional-Integral-Derivative Control of Direct-Current Motor System. in *Journal of Physics: Conference Series* vol. 1373 (Institute of Physics Publishing, 2019).
12. Damayanti, R., Syawaludin, B. & Gunawan, H. A. Design of PI and PID Control System for Induction Motor Control on Gamma Irradiator Characterization Prototype Using a Modified Ziegler-Nichols Method. *Journal of Electrical Technology UMY* **6**, 94–102 (2022).
13. Ayuningtyas, N. P., Rustiadi, T. & Pramono, H. Development of Ball Launcher Training Devices for Drill Smash , Block , Passing in Volleyball Sports. *Journal of Physical Education and Sports* **11**, 114–124 (2022).
14. Prashant, A. *et al.* Fabrication of Foot Ball Launcher Machine. *International Journal of Scientific Research & Engineering Trends* **6**, 2395–566 (2020).
15. Gies, V. *et al.* Optimisation of energy transfer in reluctance coil guns: Application to soccer ball launchers. *Applied Sciences (Switzerland)* **10**, 1–24 (2020).
16. Baharin, A., Nasir, S. H. & Sadun, A. S. Design Improvement Study on a Mobile Rugby Ball Launcher Robot for Indoor Training Purpose. **3**, 647–655 (2022).
17. Chudinov, P., Eltyshev, V. & Barykin, Y. Analytical construction of the projectile motion trajectory in midair. *Momento* **2021**, 79–96 (2021).
18. Maláková, S., Urbanský, M., Fedorko, G., Molnár, V. & Sivak, S. Design of geometrical parameters and kinematical characteristics of a non-circular gear transmission for given parameters. *Applied Sciences (Switzerland)* **11**, 1–24 (2021).
19. Luo, B. & Li, W. Investigation on the influence of heat on the dynamic characteristics of a gear transmission system. *Eng Fail Anal* **116**, 104724 (2020).
20. PENGATURAN-KECEPATAN-PADA-MOTOR-BRUSHLESS-DC-BLDC-MENGGUNAKAN-PWM-PULSE-WIDTH-MODULATION.
21. dos Reis, W. P. N., Couto, G. E. & Morandin Junior, O. Direct current geared motor data: Voltage, current, and speed measured under different experimental conditions. *Data Brief* **40**, (2022).