Conference of Electrical, Marine and Its Application
Vol. xx, No xx, Month-Year ISSN:

Implementation of DC Motor Speed Control Using Distance Sensor on Harbour Mobile Crane

* Novita Anjarsari[1], Hendro Agus Widodo[2], Anggara Trisna Nugraha[3],Rama Arya Sobhita[4]
[1,2,3,4] Marine Electrical Engineering, Shipbuilding Institute of Polytechnic Surabaya, Indonesia
*Correspondence author: novitaanjarsari@student.ppns.ac.id

ABSTRACT

Loading and unloading activities at ports heavily depend on cranes, with the Harbour Mobile Crane (HMC) being one of the commonly used types. The HMC utilizes a spreader equipped with flippers at each corner to securely hold the container. However, it is often observed that the flippers break due to excessive speed controlled by the operator using a joystick, causing the spreader to collide with the container. To address this issue, speed regulation using a distance sensor was proposed. This study aims to design and understand the working mechanism of a prototype HMC. The research method began by identifying the problem of broken flippers, which were replaced 857 times in 2021. A literature review was conducted, followed by the development of a concept and design for a prototype HMC with load-free and anti-sway testing. After building the prototype, repeated testing was carried out to optimize the results. The findings showed that when the joystick is pushed backward, the motor reverses, causing the spreader to rise at a stable speed. When the joystick is pushed forward, the motor moves forward, and the spreader descends, gradually slowing down until it reaches a distance of 2cm, at which point the motor stops moving forward and only reverses. An ultrasonic sensor (HC-SR04) was used to measure the distance. The designed system operates as intended, with the motor slowing down as the spreader descends and running steadily as it rises. The distance and speed are monitored through an LCD16x2 display.

Key Word: *HMC (Harbour Mobile Crane),Speed, Spreader*

I.INTRODUCTION

Ports are areas consisting of both water and land that are used for docking ships, loading and unloading passengers, and handling cargo. In the process of loading and unloading, cranes are used to move goods from ships to the port and vice versa. A crane is a heavy-duty machine designed to move goods or containers that are too heavy for human labor. Several types of cranes are commonly used in ports, including Container Cranes (CC), Harbour Mobile Cranes (HMC), Rubber Tyred Gantry Cranes (RTG), and Automatic Stacking Cranes (ASC). The part of the crane that handles the containers is called the spreader. The spreader is powered by a DC motor with a separate power supply, capable of providing between 234 kW and 2,500 RPM, with speeds ranging from 1,080 RPM to 2,500 RPM.

The spreader is equipped with four flippers designed to grip and position the container securely. Based on the author's observations, the Harbour Mobile Crane (HMC) at Tanjung Perak Port typically has fewer than four flippers. This issue arises from the excessive speed at which the operator controls the spreader, causing it to crash into containers and leading to flipper damage. A spreader with fewer than four flippers results in a longer operation time compared to a spreader with four flippers. This is because the operator finds it difficult to position the spreader at each corner of the container effectively. The inadequate number of flippers, therefore, compromises the efficiency of the crane, leading to delayed operations.

The consequences of this problem result in significant time loss for the company, as delays in crane operations affect overall port productivity[1]. Additionally, broken flippers incur financial losses, as the company is forced to replace the damaged components[2]. Data from PT BIMA at Tanjung Perak Port revealed that they had to replace 857 flippers in 2021 alone. This not only presents a financial burden but also contributes to operational inefficiency. To address this issue, the author proposes a solution involving speed regulation for the DC motor based on the distance between the spreader and the container[3]. By integrating a distance sensor, the motor will automatically reduce its speed when the spreader approaches the container, minimizing the risk of damage and improving the crane's overall performance[4][5].

The proposed solution, which includes the design of a prototype that adjusts the motor speed based on the distance, offers several benefits. Primarily, it aims to reduce the costs associated with frequent flipper replacements by minimizing the likelihood of flipper damage. Furthermore, this solution enhances the safety of the area surrounding the Harbour Mobile Crane (HMC), as the distance sensor not only detects containers but can also identify other objects beneath the spreader[6]. This advancement not only addresses the technical issue of speed control but also aligns with the goal of improving operational safety and efficiency in port operations, thus contributing to the broader scope of community service by ensuring safer and more cost-effective working environments for port workers.

II.METHODOLOGY

The working principle of this research involves the motor controlling the spreader's movement to the left and right. When the spreader detects a specific distance, the motor stops automatically[7]. This system aims to enhance the safety of the spreader, particularly on Rubber Tyred Gantry (RTG) cranes. The key difference between the spreader on an RTG crane and a Harbour Mobile Crane (HMC) lies in their operational mechanisms. The RTG crane moves in four directions: left, right, up, and down, while the HMC is capable of moving vertically and rotating 360°. The primary advantage of this study is its potential to reduce accidents and operator negligence by implementing automatic speed control based on distance.

However, the research also presents certain limitations. For instance, when the spreader reaches a specific distance from the container, the motor stops completely, which can slow down the unloading and loading operations at the port. This delay may affect overall operational efficiency[8]. Such a situation could lead to increased downtime for the crane, impacting the port's productivity. The automatic stop mechanism is designed to protect both the crane and the container from potential damage, but it can result in slower work processes, which needs to be carefully balanced against the benefits of increased safety[9].

To address this issue, the study proposes a solution using a DC motor with speed regulation based on the distance from the container[10]. By adjusting the motor's speed as the spreader approaches the container, this method could optimize crane performance. It would allow for smoother and more efficient operations, minimizing unnecessary delays while still maintaining the safety mechanisms designed to protect the equipment[11]. The implementation of this speed control system not only improves operational efficiency but also enhances safety, aligning with the broader goal of community service by improving port safety and productivity for workers, thus contributing positively to the local economy and operational practices.

1. Planning

The problem began where the author frequently observed that the number of flippers on the Harbour Mobile Crane (HMC) spreader at the Tanjung Perak Port was less than four at each corner. Upon further investigation, the author identified that the root cause of this issue was the excessive speed at which the spreader was being controlled by the operator. The high speed led to collisions with containers, which caused the flippers to break. This observation highlighted a critical problem that affected both the operational efficiency and the maintenance costs at the port.

To address this issue, the author collected data from existing literature and developed a concept and design for a system aimed at reducing the risk of flipper damage. The proposed system utilized an ultrasonic sensor to control the speed of the DC motor based on the proximity of the spreader to the container. As the spreader approaches a container and the distance decreases, the motor's speed would automatically reduce. This approach was designed to prevent the spreader from moving too quickly and colliding with the container, ultimately preventing damage to the flippers[12].

The motor in this study is controlled via a joystick, allowing the operator to adjust the spreader's movement. Once the device was built, testing began to determine if the system functioned according to the original concept. If the results were in line with the design, data collection could proceed; however, if the system failed to meet expectations, the issues were analyzed and addressed before retesting the device. This iterative process ensured that the system would be fine-tuned for optimal performance[13].

The data collected during the testing phase included joystick direction, the distance traveled by the spreader, and the spreader's speed. Testing was carried out on various components, including the power supply, the LCD 16x2 display, optocoupler sensor, ultrasonic sensor (HC-SR04), DC motor, and joystick. These individual components were tested for their functionality before the full system was evaluated.[14][15] During the testing phase, sensor errors were also considered, as environmental factors could influence the accuracy of the sensor readings. Any discrepancies were addressed by calculating the error margin using a standard formula, as shown in Equation (1).

$$\text{Error} = \frac{Measurement - Sensor}{Measurement} \times 100\% \quad (1)$$

After testing, the tool runs according to the concept, that is, the further the spreader goes down or the lower the distance, the slower the motor will be and if the spreader touches an object beneath it the motor will stop and the spreader can only be raised.

The testing process was designed not only to evaluate the performance of the individual components but also to assess how well they worked together within the integrated system. The overall aim was to develop a system that would help reduce operational delays at the port, minimize maintenance costs, and improve safety[16]. By controlling the spreader's speed based on distance from the container, the system was expected to reduce the likelihood of accidents and damage, thus supporting better operational practices and contributing to the overall efficiency of the port's operations[17][18]. This research aligns with the field of community service by addressing practical challenges faced by port workers, improving their working conditions, and enhancing port management practices[19][20].

III.RESULT & DISCUSION

After the design and construction of the device were completed, the next step involved recording the results of the tests. The testing process was conducted repeatedly to ensure optimal performance and reliability of the system.

The first test conducted was to check the power supply. This test aimed to verify whether the output of the power supply matched the specifications listed on the nameplate. Using a multimeter, the output voltage was measured and found to be 12.20 V, which was within the expected range. This confirmed that the power supply was functioning properly and providing the necessary power for the system.

The second test involved the 16x2 LCD display. This test was crucial to ensure that the LCD was functioning correctly, displaying information clearly and without any issues. The successful operation of the display was necessary to provide real-time feedback on system performance, such as motor speed and distance measurements.

The third test focused on the Ultrasonic HC-SR04 sensor, which was used to measure the distance between the spreader and the container. The purpose of this test was to compare the sensor's measurements with those obtained from a physical ruler. The results of this comparison confirmed that the sensor was accurately measuring distance, which was critical for the speed control system's functionality. Accurate distance measurement ensures that the motor speed is properly adjusted as the spreader moves closer to the container, thus preventing any potential damage or accidents.

Table 1.Testing sensor 1

No	Tool		Different (cm)	Error (%)
	Ruller (cm)	Ultra sonic Sensor HC-SR04 (cm)		
1	1	Un-read	-	-
2	2	2	0	0
3	3	3	0	0
4	5	5	0	0
5	7	7	0	0
6	10	10	0	0
7	15	15	0	0
8	20	20	0	0
9	25	24	1	0,04
10	50	49	1	0,02
11	60	57	3	0,05
Averange error				0,01

Table 2.Testing sensor 2

No	Tool		Different (cm)	Error (%)
	Ruller (cm)	Ultra sonic Sensor HC-SR04 (cm)		
1	1	Un-read	-	-
2	2	2	0	0
3	3	3	0	0
4	5	5	0	0
5	7	7	0	0
6	10	10	0	0
7	15	14	1	0,07
8	20	19	1	0,05
9	25	24	1	0,04
10	50	48	2	0,04
11	60	57	3	0,05
Averange error				0,02

Table 3.Testing sensor 3

No	Tool		Different (cm)	Error (%)
	Ruller (cm)	Ultra sonic Sensor HC-SR04 (cm)		
1	1	Un-read	-	-
2	2	2	0	0
3	3	3	0	0
4	5	5	0	0
5	7	7	0	0
6	10	10	0	0
7	15	15	0	0
8	20	20	0	0
9	25	25	0	0
10	50	48	2	0,04
11	60	57	3	0,05
Averange error				0,01

The fourth test involved the Optocoupler sensor, which was used to evaluate its accuracy in measuring the rotational speed of the DC motor. This test aimed to compare the readings from the Optocoupler sensor with those obtained from a tachometer, a reliable instrument for measuring rotational speed. The comparison of the two measurements helped assess the sensor's performance and accuracy in providing data for controlling motor speed.

The results of this test demonstrated the effectiveness of the Optocoupler sensor in providing consistent and reliable readings. By ensuring the accuracy of the sensor, the system's ability to adjust motor speed based on the distance sensor input was validated. This step was crucial for optimizing the overall performance of the Harbour Mobile Crane and minimizing potential errors in the speed control process.

Table 4.Testing sensor 4

No	Setting PWM 0-255	Measurment		Error (%)
		Optocoupler Sensor (rpm)	Tachometer (rpm)	
1	0	0	0	0
2	5	0	0	0
3	20	0	0	0
4	40	0	0	0
5	45	0	0	0
6	50	42	48	12,5
7	60	53	64	17,2
8	100	94	108	12,9
9	150	100	130	23
10	180	106	147	27,8
11	210	112	142	21,1
12	230	114	145	21,3
13	255	120	147	18,3

The fifth test involved evaluating the direction of the DC motor using a joystick. In this test, when the joystick was moved forward, the motor was expected to rotate in the forward direction, and when moved backward, the motor reversed. This functionality was crucial in ensuring precise control of the Harbour Mobile Crane's spreader. The joystick provided intuitive control for the operator, allowing them to manipulate the spreader efficiently based on operational needs.

The final test was a comprehensive evaluation of the entire system, designed to assess the motor's response to both the ultrasonic sensor and the joystick input. The system's performance was evaluated under real-world conditions, where if the joystick was pushed forward, the motor would rotate forward, and as the spreader approached a certain distance, the motor's speed would gradually decrease. Conversely, when the joystick was moved backward, the motor would reverse at a constant speed, ensuring smooth operation for the crane's functions.

Table 5 presents the results from this comprehensive testing phase, offering valuable insights into the system's overall effectiveness. The data confirmed that the motor responded accurately to the joystick's direction commands and the distance sensor input.

Table 5.Testing tool

Joystick	Ultra Sonic Sensor					
	1 (cm)	2 (cm)	3 (cm)	4 (cm)	Speed (rpm)	Condition *Spreader*
Back	2	2	2	2	0	up
	3	3	2	3	0	
	7	6	6	6	32	
	11	10	11	11	32	
	15	15	16	16	32	
	20	19	19	20	58	
	24	23	23	24	58	
	29	21	28	28	58	
	31	31	32	32	60	
	35	35	37	38	60	
	39	41	42	42	60	
	40	43	43	41	30	
	40	43	43	41	0	
Front	41	43	44	42	0	down
	39	41	42	40	10	
	29	27	29	29	54	
	24	22	23	24	54	
	21	19	19	21	54	
	19	17	17	18	48	
	15	13	13	13	48	
	13	12	12	12	28	
	10	9	8	9	28	
	8	6	6	6	22	
	7	4	4	5	22	
	3	2	2	2	6	
	2	2	2	2	0	

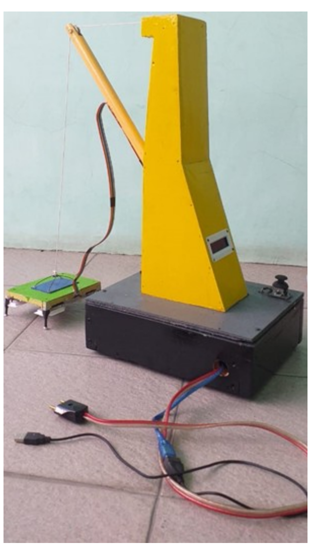

Figure 1.Prototype HMC

2.Discussion

Based on the testing conducted, the system and device performed as expected according to the initial design. Starting with the power supply, the output was consistent with the nameplate specification, providing 12.20V, and the LCD functioned properly. The ultrasonic sensor tests showed very minimal errors, with sensor 1 having an error of 0.01%, sensor 2 at 0.02%, sensor 3 at 0.01%, and sensor 4 at 0.01%. These minor errors could be attributed to various factors, including the properties of the material blocking the sensor or the object reflecting the signal back to the ultrasonic sensor. These results confirm the system's accuracy in measuring distance, which is crucial for controlling the speed of the spreader.

The optocoupler sensor was tested for its accuracy, with results showing that the sensor's performance was aligned with expectations. The testing was conducted using a driver to adjust the PWM (Pulse Width Modulation), and the results demonstrated that as the PWM value increased, the motor speed also increased proportionally. This finding is vital for controlling the motor's speed during crane operations, ensuring that the system could respond dynamically to the joystick inputs.

The joystick was tested to ensure it operated according to the design concept. The tests showed that when the joystick was pushed backward, the motor rotated steadily at a constant speed, and when pushed forward, the motor's speed decreased as the spreader approached a set distance. This reduction in speed was managed by adjusting the PWM settings on the L298N driver, which allowed for smoother and safer crane operations. The system adjusted the PWM to lower values as the spreader moved closer to the target container, ensuring the motor gradually slowed down to avoid damage. When the spreader reached a distance of 2 cm from the container, the motor could no longer move forward and would only reverse, preventing further collision and damage.

This research ultimately slows the spreader's motion when operating at low heights. While the prototype system demonstrated the expected results, it is important to note that this study did not include direct testing on a Harbour Mobile Crane (HMC). Instead, the study focused on the prototype model, specifically testing the hoist system for vertical movement without sway control, and without load lifting experiments. These limitations highlight areas for future research and practical application in real-world crane operations, focusing on minimizing operational risks such as flipper breakage and optimizing the overall safety and efficiency of port operations.

IV.CONCLUSION

In the following section, the conclusions drawn from the research will be presented. This section aims to summarize the key findings and insights gained throughout the study, providing a comprehensive overview of the outcomes and their implications. By highlighting the core results, this conclusion will serve as a reflection of the research objectives and the effectiveness of the proposed solutions.

The analysis and testing conducted during the study have led to important conclusions that contribute to a better understanding of the issue at hand. Below, the findings will be discussed in detail, emphasizing how they address the challenges identified in the earlier sections. This summary will offer a clear overview of the research's contributions and its potential impact on future developments in the field.

1. The development of the prototype began with conceptualizing and designing the hardware, procuring components, writing the program, assembling the hardware, wiring, and conducting tests. This comprehensive approach ensured that the system functioned as intended.
2. The prototype operates according to the design concept, where the motor reverses at a steady speed when the spreader moves upward. This ensures smooth and controlled movement when the spreader is raised.
3. As the spreader descends, the motor moves forward, with its speed progressively decreasing as the spreader moves lower. This reduction in speed is in direct correlation with the distance the spreader travels, ensuring a safer and more controlled descent.
4. The rotation direction and motor speed are regulated through the L298N driver by adjusting the PWM (Pulse Width Modulation) values, which allows for precise control over the motor's performance and enhances the overall system's efficiency and safety.

V.REFERENCE

[1] Nugraha, Anggara Trisna. RANCANG BANGUN TEKNOLOGI PEMURNI AIR. Deepublish, 2022.

[2] Abduljabbar, B. H. (2021). Control of cranes with a swinging load, an investigation of pragmatic control (Doctoral dissertation, University of Southern Queensland).

[3] Awad, A. H., Alsabaan, M., Ibrahem, M. I., Saraya, M. S., Elksasy, M. S. M., Ali-Eldin, A. M., & Abdelsalam, M. M. (2024). Low-Cost IoT-Based Sensors Dashboard for Monitoring the State of Health of Mobile Harbor Cranes: Hardware and Soft-ware Description. Heliyon.

[4] Kim, G. H., & Hong, K. S. (2019). Adaptive sliding-mode control of an offshore

container crane with unknown disturbances. IEEE/ASME Transactions On Mechatronics, 24(6), 2850-2861.

[5] Nugraha, A. T., Pambudi, D. S. A., Utomo, A. P., Priyambodo, D., Hari, M. D., & Febrianto, R. RANCANG BANGUN BATERY CHARGER PADA PEMBANGKIT LISTRIK PORTABEL ENERGI TERBARUKAN BERBASIS ARDUINO UNO R3. Deepublish, 2022.

[6] Appiah, O., Quayson, E., & Opoku, E. (2020). Ultrasonic sensor based traffic information acquisition system; a cheaper alternative for ITS application in developing countries. Scientific African, 9, e00487.

[7] Gabriel, M. M., & Kuria, K. P. (2020). Arduino uno, ultrasonic sensor HC-SR04 motion detector with display of distance in the LCD.

[8] Sharma, S. K., Phan, H., & Lee, J. (2020). An application study on road surface monitoring using DTW based image processing and ultrasonic sensors. Applied Sciences, 10(13), 4490.

[9] Dermawan, Deny, et al. "Kendali Kecepatan Motor Dengan Kontrol Pid Menggunakan Metode Metaheuristik." Seminar MASTER PPNS. Vol. 8. No. 1. 2023.

[10] Wibowo, Muhammad Ferdiansyah, and Anggara Trisna Nugraha. "PERENCANAAN SISTEM PROPULSI ELEKTRIK PADA FAST PATROL BOAT 28 METER." Proceedings Conference on Marine Engineering and its Application. Vol. 6. No. 1. 2023.

[11] Agna, Diego Ilham Yoga, Rama Arya Sobhita, and Anggara Trisna Nugraha. "Penyearah Gelombang Penuh 3 Fasa Tak Terkendali dari Generator Kapal AC 3 Fasa." Seminar MASTER PPNS. Vol. 8. No. 1. 2023.

[12] Apriani, Mirna, et al. "Coastal Community Empowerment Recovery of cockle shell waste into eco-friendly artificial reefs in Mutiara Beach Trenggalek Indonesia." Frontiers in Community Service and Empowerment 1.4 (2022).

[13] Prastyawan, Rikat Eka, and Anggara Trisna Nugraha. "PENERAPAN TEKNOLOGI INFORMASI UNTUK PEMBELAJARAN TEST OF ENGLISH FOR INTERNATIONAL COMMUNICATION PREPARATION." Jurnal Cakrawala Maritim 5.1 (2022): 4-8.

[14] Cook, M. D., Bonniwell, J. L., Rodriguez, L. A., Williams, D. W., & Pribbernow, J. (2020, July). Low-cost dc motor system for teaching automatic controls. In 2020 American Control Conference (ACC) (pp. 4283-4288). IEEE.

[15] Suksabai, N., Waikoonvet, J., & Chuckpaiwong, I. (2020, July). Modelling method investigation of drive and motor for an industrial overhead crane. In IOP Conference Series: Materials Science and Engineering (Vol. 886, No. 1, p. 012030). IOP Publishing.

[16] Mohamed, K. T., Abdel-razak, M. H., Haraz, E. H., & Ata, A. A. (2022). Fine tuning of a PID controller with inlet derivative filter using Pareto solution for gantry crane systems. Alexandria Engineering Journal, 61(9), 6659-6673.

[17] Parenrengi, A. M. F. (2024). Analisis Dan Implementasi Sistem Kontrol Posisi, Anti Sway Dan Anti Collision Pada Prototipe Rubber Tyred Gantry Crane (Doctoral dissertation, Politeknik Negeri ujung Pandang).

[18] Aprilia, I. W., Kristiyono, A. E., Pribadi, T., Sonhaji, S., & Sandi, W. M. (2024). Prototype Pendeteksi Beban Berlebih Untuk Keamanan Operasi Hydraulic Crane Di Kapal Penumpang. Jurnal

Teknik Mesin, Industri, Elektro dan Informatika, 3(3), 15-31.

[19] Rusli, T. L. (2024). Sistem Kontrol Posisi Menggunakan Feedback Control Pada Overhead Crane (Doctoral dissertation, Politeknik Negeri ujung Pandang).

[20] Perdana, J. P., & Wellem, T. (2023). Perancangan Dan Implementasi Sistem Kontrol Untuk Tempat Sampah Otomatis Menggunakan Arduino Dan Sensor Ultrasonik. IT-Explore: Jurnal Penerapan Teknologi Informasi dan Komunikasi, 2(2), 104-117.