Monitoring and control of material surface evenness in the Dosimat Feeder Hopper at Finish Mill V PT Semen Padang

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ABSTRACT

The dosimat feeder is a device used to weigh additional materials before entering the mill for grinding. It includes a hopper that functions as temporary storage before the material is transferred to the belt conveyor. The main issues addressed in this study are frequent material shortages that can disrupt industrial operations, and uneven filling that may affect system performance and reduce production efficiency. This research adopts the Research and Development (R&D) method, aiming to develop a product and evaluate its effectiveness. The system is designed using an Arduino Uno microcontroller to process data from sensors. Ultrasonic sensor 1 is configured to control material filling, while ultrasonic sensors 2, 3, and 4 are used to monitor material evenness, with a maximum distance tolerance of 2 cm for ultrasonic sensor 1. A DC vibrator motor is activated when the material inside the hopper is detected to be uneven. The results of the study show that the material level and surface flatness status are successfully displayed on a 16x2 LCD.

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1. INTRODUCTION

PT Semen Padang is a cement industry that plays an important role in supporting national infrastructure development [1]. The cement production process requires continuous and efficient material processing, including the stage of mixing additional materials such as gypsum before entering the mill. One of the main components in this stage is the dosimat feeder system, which functions to accurately deliver material from the hopper to the belt conveyor [2].

The hopper is designed to ensure that material flows steadily and evenly to the feeder, thereby reducing the risk of unstable material flow. The hopper's capacity can be adjusted as needed to support the production process. However, in practice, various technical issues often arise that affect the system's efficiency. One of the main problems occurs when the hopper fails to discharge additional material, causing the dosimat feeder to run at overspeed. This condition can lead to overloading, which poses a risk of system damage and disrupts the production process. The issue is further complicated by the hopper's closed structure, making it difficult to visually monitor the material level inside [3]-[4]. In addition, material depletion in the hopper is a critical issue, as it can disrupt the continuity of supply to the mill and reduce production efficiency. Another common problem is uneven material filling, which can lead to accumulation within the hopper. This uneven distribution hinders the hopper's performance in terms of both storage and discharge, directly impacting the stability of cement plant operations as a whole [5]. To address these problems, monitoring and controlling material evenness inside the hopper is essential to achieve better material flow regulation. The implementation of Arduino Uno as an innovative solution for material monitoring in the hopper is also expected to enhance the effectiveness of the milling process.

Arduino is an open-source electronic platform that is flexible and easy to use, both in terms of hardware and software [6]. The Arduino Uno is a microcontroller board based on the ATmega328, featuring

14 digital input/output pins (6 of which can be used as PWM outputs), 6 analog inputs, a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. The Arduino Uno can be connected to a computer using a USB cable [7]. In a study titled "Design and Development of a Waste Oil Level Monitoring System Based on Arduino Uno at PT. Megapower Makmur Tbk in Bengkalis", the research discusses the design and implementation of a monitoring system for waste oil levels using an Arduino Uno and an ultrasonic sensor to detect the height of the waste oil. The system is also equipped with LED indicators and an alarm that activates when the waste oil reaches a high-level threshold [8].

The importance of monitoring and controlling material flatness in the dosimat feeder is due to the fact that cement production is a continuous process, while the hopper is enclosed. Monitoring is an activity aimed at observing or supervising something to ensure that the results are in accordance with the plan. Control over the flatness of material inside the hopper is essential so that the space within the hopper can be fully utilized, the material can flow smoothly, and material buildup inside the dosimat feeder can be avoided [9].

In this final project, an Arduino Uno will be utilized as the microcontroller along with several components and sensors, such as ultrasonic sensors, to detect the height or quantity of material inside the hopper. The ultrasonic sensors are used to control the flatness of the material within the hopper. In addition, the system will also be equipped with a DC vibrator motor to provide vibrations to the hopper, thereby helping to level the material inside. The DC motor also functions to operate the belt conveyor that transports the material into the hopper [10]-[15]. Thus, this system is expected to provide an effective solution to improve efficiency and productivity. Therefore, this final project is titled "Monitoring and Control of Material Flatness in the Dosimat Feeder Hopper at Finish Mill V PT. Semen Padang Based on Arduino Uno."

2. METHOD

This research employs the Research and Development (R&D) method, which aims to design a prototype system based on Arduino Uno and test the effectiveness of the product. The system is designed to automatically monitor the condition of the hopper and display data on an LCD as an indicator of incoming material flow. The system uses four ultrasonic sensors to detect the presence of material. These sensors are used to measure the distance of the material inside the hopper, thereby making the filling process more efficient and preventing overloading. The overall system block diagram is shown in Figure 1.

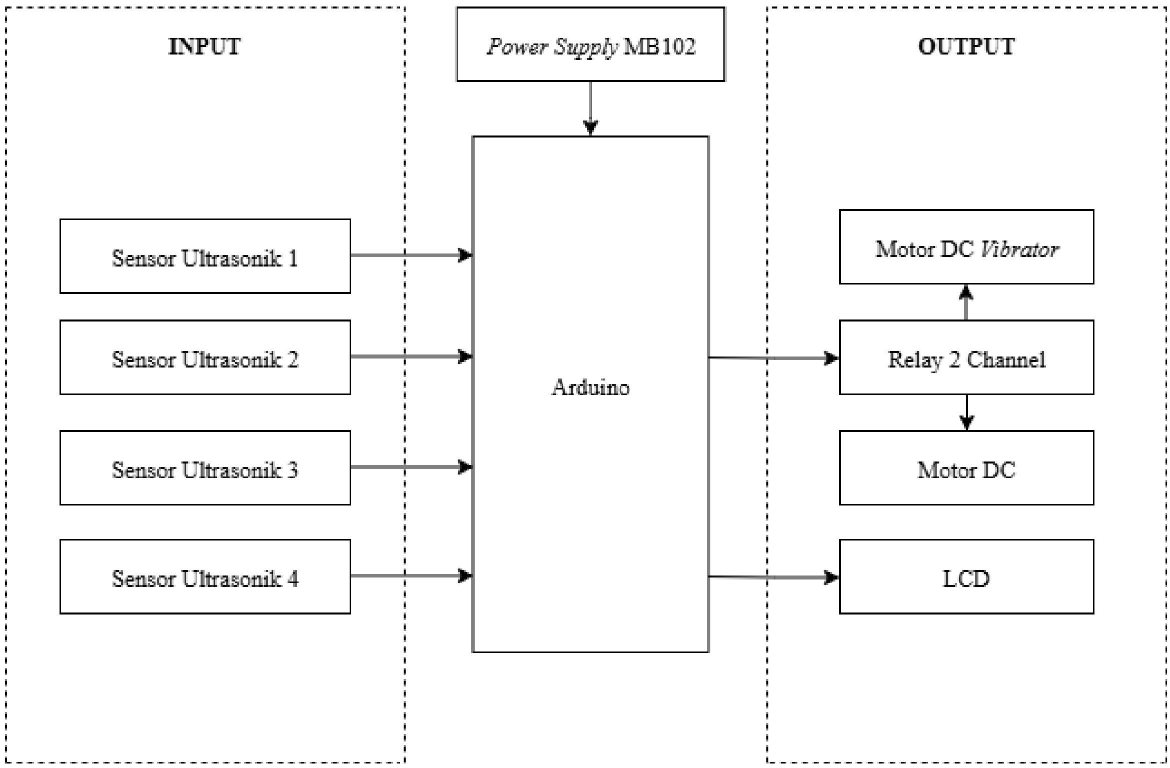


Figure 1. Blok Diagram

Figure 1 shows the block diagram of the dosimat feeder prototype, which aims to provide a basic overview of how the device will be constructed. This diagram illustrates the overall connection of components with the Arduino as the main controller. The system consists of interconnected input and output components. On the input side, there are four HC-SR04 ultrasonic sensors used to measure the material level in the hopper and to monitor surface evenness. On the output side, the Arduino Uno controls a 2-channel relay to operate the DC motor and the DC vibrator motor. An LCD is also included to display data such as the material level and whether the surface is even or uneven. The Arduino Uno receives power from an MB102 power supply.

The overall system operates by utilizing Ultrasonic Sensor 1, which is configured to control material filling. If the material distance is more than 30 cm, the material status will be considered "LOW." If the distance is between 11–30 cm, the status will be "MEDIUM," and if it is less than 11 cm, the status will be "HIGH." When the material level is still low (30–45 cm), the filling motor is activated (Relay 1 ON). Once the hopper is full (below 11 cm), the motor will automatically turn off. In addition, Ultrasonic Sensors 1, 2, 3, and 4 are used to monitor the material surface evenness. A tolerance of 2 cm is set for surface flatness. The shaker motor (Relay 2 ON) will be activated if the distance between Ultrasonic Sensors 2, 3, and 4 exceeds 2 cm relative to the reading from Sensor 1. The material measurement results are displayed on the LCD, where the data reflects the real-time readings of the material level inside the hopper. The distance categories are based on the height of the prototype, which is 45 cm. Therefore, the thresholds for the LOW, MEDIUM, and HIGH material levels are determined proportionally to that height. A maximum tolerance of 2 cm on Ultrasonic Sensor 1 is established because the device is still in prototype form. With a total height of 45 cm, a 2 cm tolerance is considered significant enough and represents an acceptable margin of error for measurement. The overall electrical design of the system is shown in Figure 2.

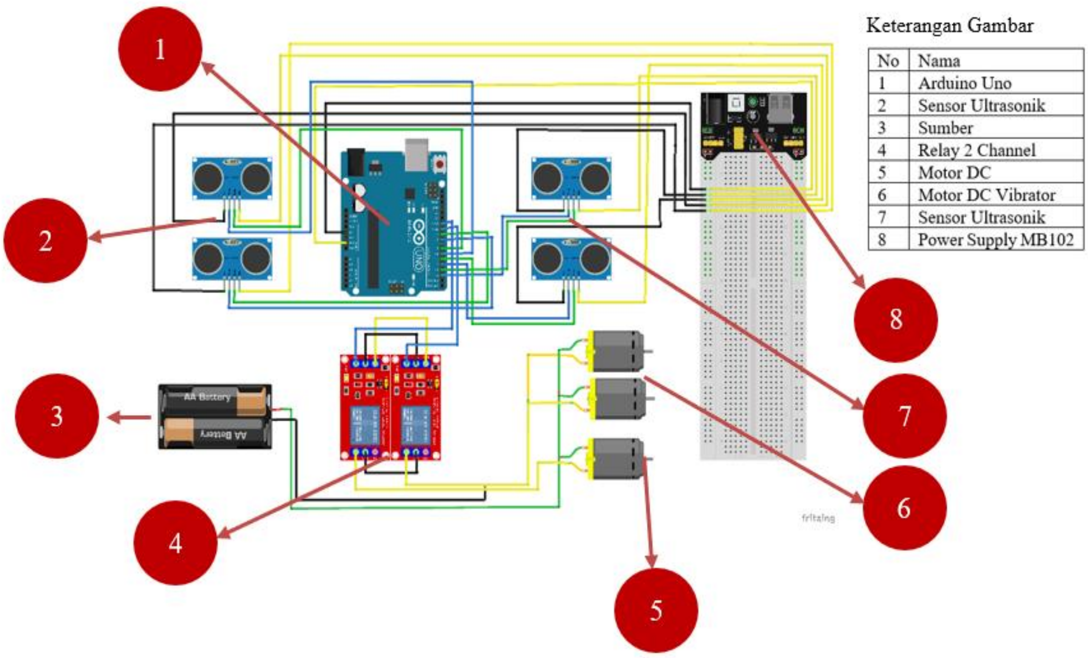


Figure 2. Overall Electrical Design of the System

The operation process of this system begins when the device is powered on and all components are initialized to be ready for operation. The DC motor will activate and drive the belt conveyor. After that, Ultrasonic Sensor 1 starts to operate by detecting the material level inside the hopper. The filling process begins at the LOW condition, then increases to MEDIUM, and continues until it reaches the HIGH condition. Once the material level reaches HIGH, the DC motor will automatically stop. If the material surface is detected to be uneven, Ultrasonic Sensors 2, 3, and 4 will become active. These three sensors will check the surface evenness with a maximum allowable distance variation of 2 cm. If an uneven surface is detected, the system will activate the DC vibrator motor to shake the material so the surface becomes level. All sensor measurement data will be displayed in real time on the LCD screen. The overall workflow of the system is illustrated in the flowchart shown in Figure 3.

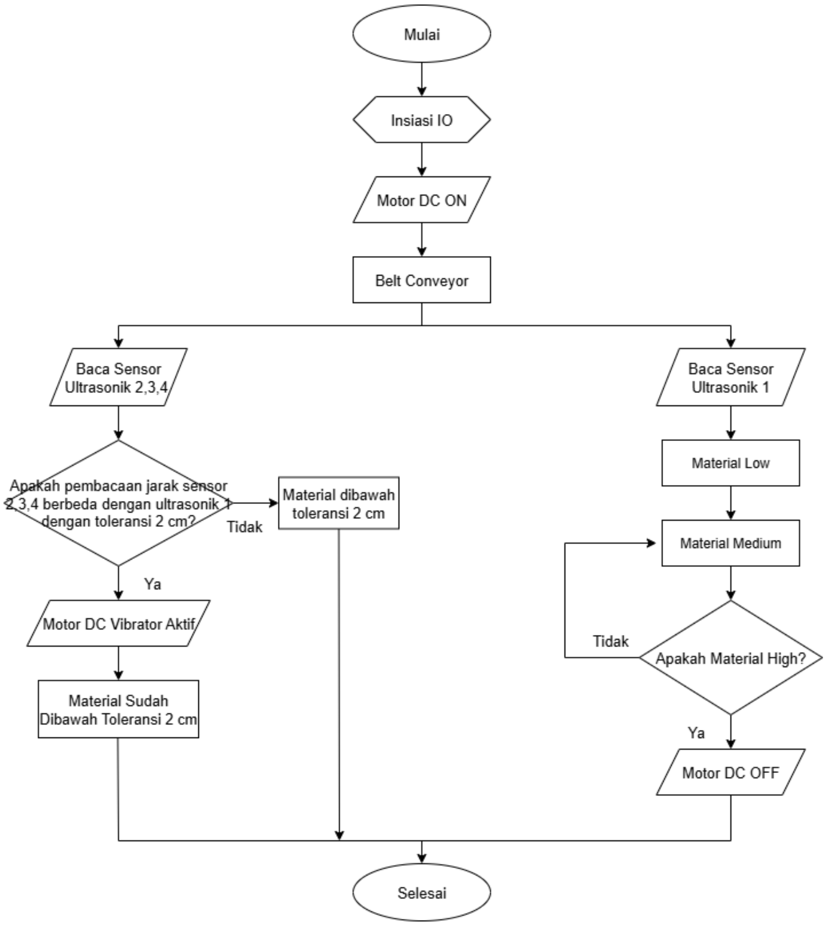
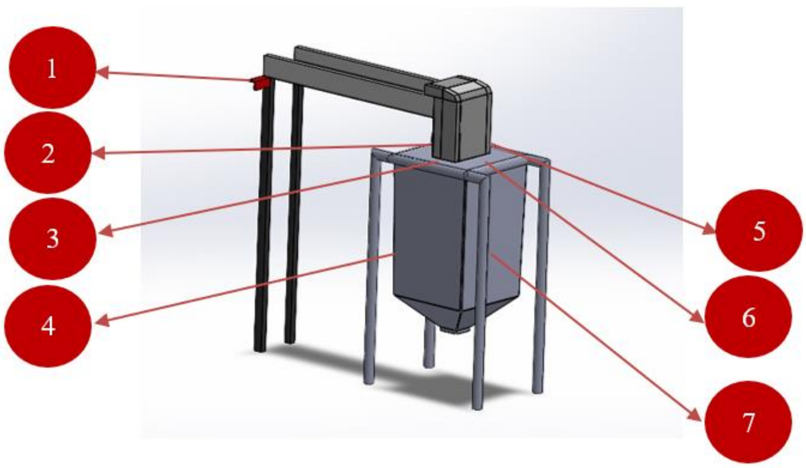


Figure 3. Overall system flowchart

In addition to the electrical design and system workflow, the mechanical aspect is also comprehensively designed by considering the arrangement of each component to ensure efficient and integrated functionality. This design includes the placement of ultrasonic sensors, the DC motor, and other supporting components. The mechanical design aims to ensure system stability and ease of assembly. The mechanical design is illustrated in Figure 4.



Keterangan Gambar

No	Nama
1	Motor DC
2	Sensor Ultrasonik 1
3	Sensor Ultrasonik 2
4	Motor DC Vibrator
5	Sensor Ultrasonik 3
6	Sensor Ultrasonik 4
7	Motor DC Vibrator

Figure 4. Overall Mechanical Design of the System

To prevent material buildup inside the dosimat feeder hopper, vibrator motors are installed on the left and right sides of the hopper walls. These motors function to generate vibrations that help distribute the material evenly throughout the hopper. The vibrator motors used operate at a working voltage of 12 Volts. The shape of the vibrator motor is shown in Figure 5.

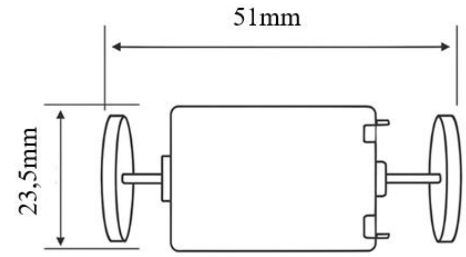
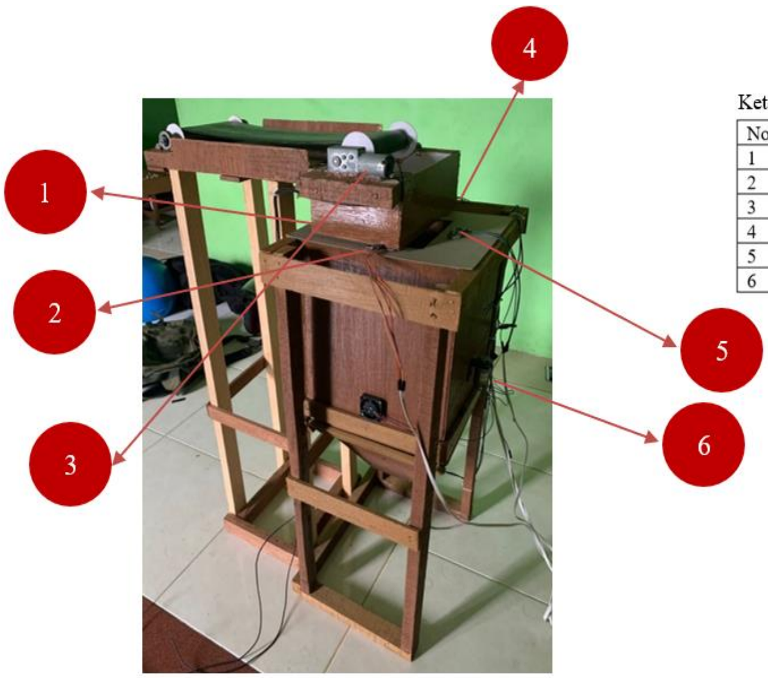


Figure 5. Motor Vibrator

3. RESULTS AND DISCUSSION

After the research phase was completed, the next step was the fabrication stage. The results from this stage include both the mechanical and electrical design outcomes.The final design of the prototype hopper wall is made of plywood and supported by four wooden legs. Ultrasonic sensors 1, 2, 3, and 4 are installed on the top cover of the hopper. Two motors are also mounted at the bottom of the hopper walls. In the center of the hopper cover, there is a hole that serves as the inlet for material from the filling conveyor.

The filling conveyor located above the hopper is designed with a wooden supporting structure. The conveyor section uses a belt that functions as the material transport medium. This belt is made of rubber material to provide good flexibility and resistance to load and friction. Under the belt, there is a plywood base that serves as a platform to allow the belt to move smoothly. The mechanical fabrication result of the tool can be seen in Figure 6.

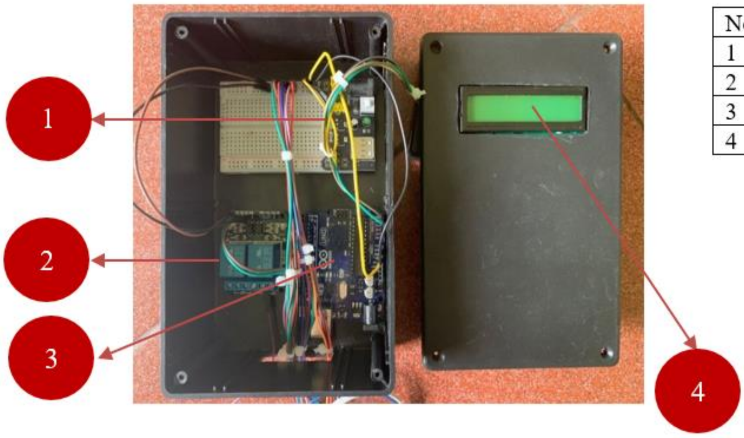


Keterangan Gambar

No	Nama
1	Sensor Ultrasonik 1
2	Sensor Ultrasonik 2
3	Motor DC
4	Sensor Ultrasonik 3
5	Sensor Ultrasonik 4
6	Motor DC

Figure 6. Mechanical Result

In the electrical design, a box with dimensions of 10.5 cm in length, 17.5 cm in width, and 5.8 cm in height is used to house components such as the Arduino Uno, MB102 power supply, 2-channel relay, and LCD. For more details, refer to Figure 7.



No	Nama
1	Power Supply MB102
2	Relay 2 Channel
3	Arduino Uno
4	LCD

Figure 7. Electrical Result

Testing was conducted to evaluate the system's response under various operating conditions, such as when the hopper is full or empty. In addition, tests were carried out to assess the motor's ability to vibrate the hopper when the material surface is uneven.Ultrasonic sensor testing was carried out by adjusting the distance between the ultrasonic sensor and the material. Distance values were recorded at different points for each trial. The test was conducted three times for each distance. The accuracy of each data point was calculated using the following formula: The test results can be seen in Table 1

$$\%Error = \frac{jarak\ terhitung\ (terbaca) - jarak\ terukur}{jarak\ terukur} \times 100$$

$$Error = \frac{jarak\ terhitung\ (terbaca) - jarak\ terukur}{jarak\ terukur}$$

$$Akurasi = 100 - error$$

.Table 1. Ultrasonic Sensor Test 1

No	Measured Distance (cm)	Calculated Distance (Read) (cm)	Error (%)	Accuracy
1	5	4,6	8	99,92
2	10	10,7	7	99,93
3	15	15,5	3,3	99,967
4	20	20,6	3	99,97
5	25	25,1	0,4	99,96
6	30	29,4	2	99,98
7	35	34,6	1,1	99,98
8	40	38,4	4	99,96
9	45	44,7	0,6	99,994
Average			3,4	99,96

Table 2. Ultrasonic Sensor Test 2

No	Measured Distance (cm)	Calculated Distance (Read) (cm)	Error (%)	Accuracy
1	5	4,7	6	99,94
2	10	10,6	6	99,94
3	15	15,8	5	99,95
4	20	20,6	3	99,97
5	25	25,5	2	99,98
6	30	30,3	1	99,99
7	35	34,6	1,1	99,989
8	40	39,1	2,2	99,978
9	45	44,6	0,89	99,991
Average			3,02	99,96

Table 3. Ultrasonic Sensor Test 3

No	Measured Distance (cm)	Calculated Distance (Read) (cm)	Error (%)	Accuracy
1	5	5,3	6	99,94
2	10	9,9	1	99,99
3	15	14,4	4	99,96
4	20	19,9	0,5	99,995
5	25	24	4	99,96
6	30	29,2	2,6	99,2
7	35	34,8	0,57	99,9943
8	40	38,8	3	99,97
9	45	44	2,2	99,978
Average			2,65	99,89

Testing of DC motor and DC vibrator motor was conducted to evaluate the system's response by inserting material into the hopper. Observations were made to determine whether the DC vibrator motor could generate vibrations in the hopper and level the material inside. The test results are shown in Table 4.

Table 4. DC Motor and DC Vibrator Motor Test

No	Distance (cm)	DC Motor	Vibrator DC Motor
1	5,3	OFF	ON
2	9,9	OFF	ON
3	14,4	ON	OFF
4	19,9	ON	OFF
5	24	ON	OFF
6	29,2	ON	OFF
7	34,8	ON	OFF
8	38,8	ON	OFF
9	44	ON	OFF

Table 5. Vibrator Motor Testing

No	Readable Material (cm)	Time (Sec)	Information
1	5,3	19	Material is not flat
2	9,9	30	Material is not flat
3	14,4	45	Material is not flat
4	19,9	72	Flat Material
5	24	120	Flat Material
6	29,2	160	Flat Material
7	34,8	180	Flat Material
8	38,8	197	Flat Material
9	44	201	Flat Material

The overall system testing was carried out to determine whether the developed device functions successfully. After testing each component and completing the assembly process, a full system test was conducted. The overall system test was performed once the power supply was connected and the Arduino was properly integrated with the other components. The results can be seen in Table 6.

Table 6. Overall Equipment Test 1

No	Distance between Sensor and Material (cm)	Relay condition	Vibrator DC Motor	LCD Indicator	Time (Sec)
1	44,7	On	Off	Material: Low Permukaan Rata	203
2	38,4	On	Off	Material: Low Permukaan Rata	196
3	34,6	On	Off	Material: Low Permukaan Rata	178
4	29,4	On	Off	Material: Medium Permukaan Rata	159
5	25,1	On	Off	Material: Medium Permukaan Rata	121
6	20,6	On	Off	Material: Medium Permukaan Rata	73
7	15,5	On	Off	Material: Medium Permukaan Rata	46
8	10,7	Off	On	Material: High Permukaan Tidak Rata	29
9	4,6	Off	On	Material: High Permukaan Tidak Rata	18

Table 7. Overall Equipment Test 2

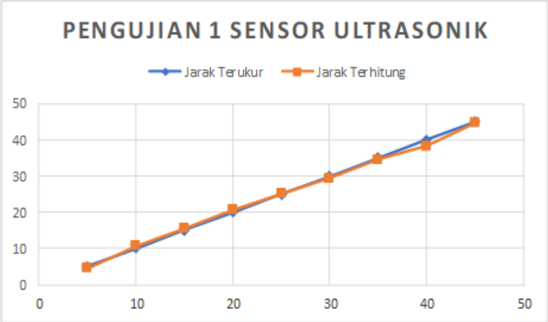
No	Distance between Sensor and Material (cm)	Relay condition	Vibrator DC Motor	LCD Indicator	Time (Sec)
1	44,6	On	Off	Material: Low Permukaan Rata	202
2	39,1	On	Off	Material: Low Permukaan Rata	199
3	34,6	On	Off	Material: Low Permukaan Rata	179
4	30,3	On	Off	Material: Medium Permukaan Rata	158
5	25,5	On	Off	Material: Medium Permukaan Rata	122
6	20,6	On	Off	Material: Medium Permukaan Rata	73
7	15,8	On	Off	Material: Medium Permukaan Rata	46
8	10,6	Off	On	Material: High Permukaan Tidak Rata	31
9	4,7	Off	On	Material: High Permukaan Tidak Rata	17

Table 8. Overall Equipment Test 3

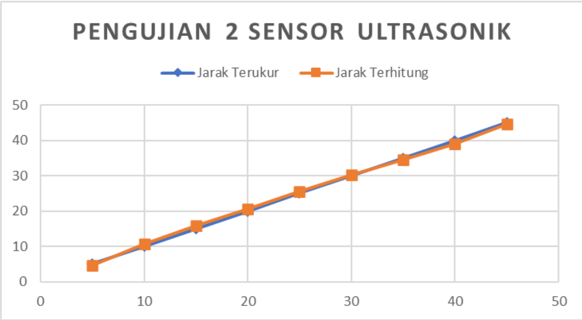
No	Distance between Sensor and Material (cm)	Relay condition	Vibrator DC Motor	LCD Indicator	Time (Sec)
1	44	On	Off	Material: Low Permukaan Rata	201
2	38,8	On	Off	Material: Low Permukaan Rata	197
3	34,8	On	Off	Material: Low Permukaan Rata	180
4	29,2	On	Off	Material: Medium Permukaan Rata	160
5	24	On	Off	Material: Medium Permukaan Rata	120
6	19,9	On	Off	Material: Medium Permukaan Rata	72
7	14,4	On	Off	Material: Medium Permukaan Rata	45
8	9,9	Off	On	Material: High Permukaan Tidak Rata	30
9	5,3	Off	On	Material: High Permukaan Tidak Rata	19

After conducting a series of tests, an analysis was carried out on the obtained results to evaluate the overall performance of the system. Based on the data in Tables 1, 2, and 3, it is shown that at close distances, the sensor produces a relatively high error rate.

The graph in Figure 8 shows that at close range, the sensor produces a relatively high error rate. In the first test, the error was recorded at 8%, in the second test at 6%, and in the third test again at 6%. This is due to the fact that ultrasonic sensor readings at close distances tend to be less stable. Conversely, at longer distances, the sensor showed lower error rates: 0.6%, 0.89%, and 0.57% in each respective test. This indicates that the ultrasonic sensor operates more stably and accurately at greater distances. Therefore, the HC-SR04 sensor is more suitable for measuring material height within the range of 15 cm to 45 cm, as it provides more stable and accurate readings at these distances compared to very short distances. Based on the test results shown in Table 4, the system performs according to its designed function, which is to detect the surface evenness of material inside the hopper and to control the activation of the DC motor and DC vibrator motor. At relatively short sensor reading distances, ranging from 5.3 cm to 9.9 cm, the DC motor is in the OFF state, while the DC vibrator motor is ON. Then, when the sensor reading distance ranges from 14.4 cm to 44 cm, the system state switches: the DC motor turns ON, while the DC vibrator motor turns OFF. Overall, the test results indicate that the system responds well to the material surface conditions. The DC vibrator motor is activated only when the material surface is uneven (very close sensor readings), and the conveyor DC motor is reactivated when the surface is considered even based on the sensor distance readings. This confirms that the control logic of the system operates as designed.



(a)



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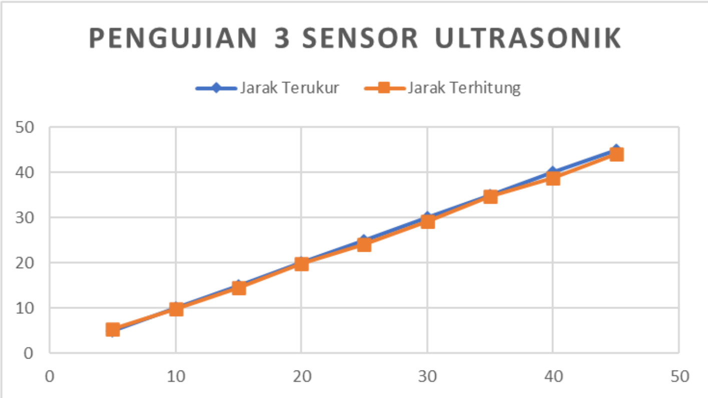

(c)

Figure 8. Graph of ultrasonic sensor testing. a) First Tetsing, b) Second testing, c) Third testing

Based on the results of three test trials, it was observed that Ultrasonic Sensor 1 functions to detect the material level during the filling process into the hopper. Meanwhile, Ultrasonic Sensors 2, 3, and 4 are used to check the evenness of the material surface. When the height detected by Sensor 1 reaches a certain level, Sensors 2, 3, and 4 are activated to verify whether the material surface is even. If one side of the surface is detected to be too high, the system activates the DC Vibrator Motor (shaker) to level the material. The time required to fill material into the hopper is more than 3 minutes and 30 seconds for each trial. Overall, the test results show that material filling is most effective when the upper belt conveyor runs at a fast or constant speed. However, if the speed of the lower belt conveyor is too slow, a leveling process is required. The purpose of this leveling is to ensure that the space inside the hopper is used optimally so that the filling motor continues to operate, the material flows smoothly, does not accumulate in the dosimat feeder, and the hopper space efficiency is achieved.

3. CONCLUSION

Based on the design, testing, and analysis results, the system has been successfully developed using Arduino Uno as the control center. The ultrasonic sensors are capable of detecting the material level entering the hopper and controlling the evenness of the material by activating the DC Vibrator motor to level the material inside the hopper. The system measures the material height with 99.96% accuracy using the HC-SR04 sensor and can activate the DC Vibrator motor at distances ranging from 5 cm to 11 cm. Test results show that the system operates responsively and accurately, with monitoring displayed through the LCD. Overall, the system is considered effective in addressing material level issues within the hopper. Based on the results achieved, it is recommended that the system be enhanced with remote monitoring capabilities by adding a WiFi communication module, allowing real-time monitoring of material levels via an application or Telegram. Periodic sensor calibration is also advised to maintain reading accuracy, along with the addition of alarm or LED indicators to notify when the material level is nearly full or too low.

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