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Arduino-based control and monitoring system for minimum material weight on Belt conveyor Dosimat Fedder at PT. Semen Padang

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ABSTRACT

The Dosimat feeder is a device used to accurately weigh additional materials before they enter the mill for the grinding process. The Dosimat feeder adjusts the material weight by increasing the motor speed when the hopper does not release supplementary materials such as gypsum. This research employs the Research and Development (R&D) method, which aims to produce a specific product and test its effectiveness. The results show that the measured weight data is displayed on a 16x2 LCD via an I2C module. A buzzer activates when the material weight drops below 331 grams, and the motor stops until the minimum weight is reached. Testing indicates that the load cell has an average accuracy of 98% (with an error margin of 0.6%–5%) for weights ranging from 100 to 400 grams. Motor speed decreases from 32 rpm (at 360 grams) to 21 rpm (at 480 grams) as the load increases. The system operates optimally when Dosimat 2 and 3 are active and all three LEDs are on, thereby improving production efficiency and preventing losses due to material shortages.

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1. INTRODUCTION

PT. Semen Padang, part of the Semen Indonesia Group (SIG) under the state-owned enterprise (BUMN) umbrella, is located in Indarung, West Sumatra. It is a large-scale cement producer with an annual production capacity of 8.9 million tons. To support its massive output, PT. Semen Padang operates packing plants in multiple regions, including Indarung, Teluk Bayur, Belawan (North Sumatra), Batam, Tanjung Priok, Ciwandan (Banten), and Malahayati (Aceh). One of its key facilities is the Indarung V Plant, which began operations in 1998 with a capacity of 2.3 million tons per year. This plant comprises a raw mill, kiln, and finish mill to support cement production [1]-[3].

Indarung V Plant has a finish mill for the final grinding of clinker into cement. Within the finish mill, three additive materials pozzolan, gypsum, and limestone are ground together with the clinker inside the mill [4]-[6]. The dosimat feeder system encounters a significant operational issue when the hopper fails to properly discharge additive materials, particularly gypsum. This malfunction triggers an overspeed condition in the feeder as it attempts to compensate for the missing material weight by continuously increasing motor speed. According to PT. Semen Padang's operational standards, gypsum must maintain a precise 5% composition of the total raw material weight in cement production. When this imbalance persists beyond the 10 minute threshold, plant protocols mandate an immediate mill shutdown.

This critical control measure serves two primary purposes. First, to implement proper minimum material weight regulation on the belt conveyor system, and second, to prevent quality deviations in the final product. The shutdown is essential because insufficient gypsum content not only generates material waste but also critically affects cement quality by accelerating the hardening process beyond specification limits [7].

Mill stoppages during production can result in significant operational losses, as all material present in the mill must be removed and subsequently reground. This regrinding process can only commence once the dosimat feeder's material supply is properly replenished. The dosimat feeder's primary component a precision belt conveyor system plays a critical role in material weight measurement to ensure consistent cement quality [8]-[9].

The need for precise control and monitoring of material weight in the dosimat feeder arises from the continuous nature of cement production. Monitoring refers to the systematic observation and tracking of processes to ensure outcomes align with operational targets [10]. Conversely, inconsistencies in material proportions may result in substandard cement, rendering it unsuitable for distribution [11]-[12]. Thus, implementing a robust monitoring and control system is essential for maintaining both production efficiency and product quality in industrial-scale cement manufacturing. Therefore, the author is particularly interested in developing a final project entitled Control and Monitoring System for Minimum Material Weight on the Dosimat Feeder Belt Conveyor at Finish Mill Indarung V, PT. Semen Padang, based on Arduino. The Arduino microcontroller is a mini-computer system on a single chip that is used to automatically control electronic devices that use various types of microcontrollers (e.g., ATmega328, ATmega2560, ESP32, etc.) as the processing core [13]-[15]. The use of Arduino as a control device for the proposed system is expected to improve system performance.

2. METHOD

This system consists of several interconnected input and output components. On the input side, there is a load cell sensor used to measure the weight of the material, and its readings are sent to the HX711 module, which functions to convert the analog signal into a digital signal so that it can be processed by the Arduino. There is also an FC-03 sensor used to measure the speed of the DC motor. The Arduino acts as the control center, processing the sensor data and sending commands to the output components.

On the output side, the Arduino controls the BTS 7060 driver to regulate the speed of the DC motor that drives the belt conveyor. LEDs are used to indicate whether dosimat 2 and dosimat 3 are on or off. A buzzer is used as an alarm if the material does not reach the minimum required weight. Sensor readings can be monitored on an LCD screen using I2C as the communication interface between the Arduino and the LCD. The entire system is powered by the Arduino, except for the Arduino itself, which is supplied by a 5-volt power supply, and the DC motor, which is powered by a 12-volt power supply. The system block diagram is shown in the Figure 1.

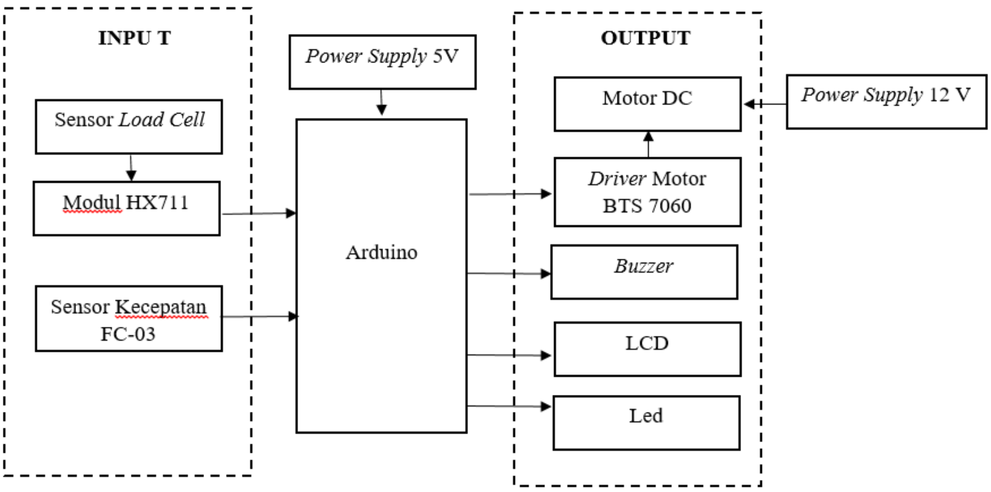


Figure 1. System block diagram

The flowchart begins with system initialization. When both dosimats are on, the load cell sensor measures the material weight. If the minimum material weight is not met, the buzzer will sound and the DC motor will stop. The DC motor will activate once the minimum material weight is met. After the material is weighed, the DC motor adjusts its speed based on the material weight, and the FC-03 speed sensor measures the speed so that the data can be displayed on the LCD. The overall system flowchart is shown in the Figure 2.

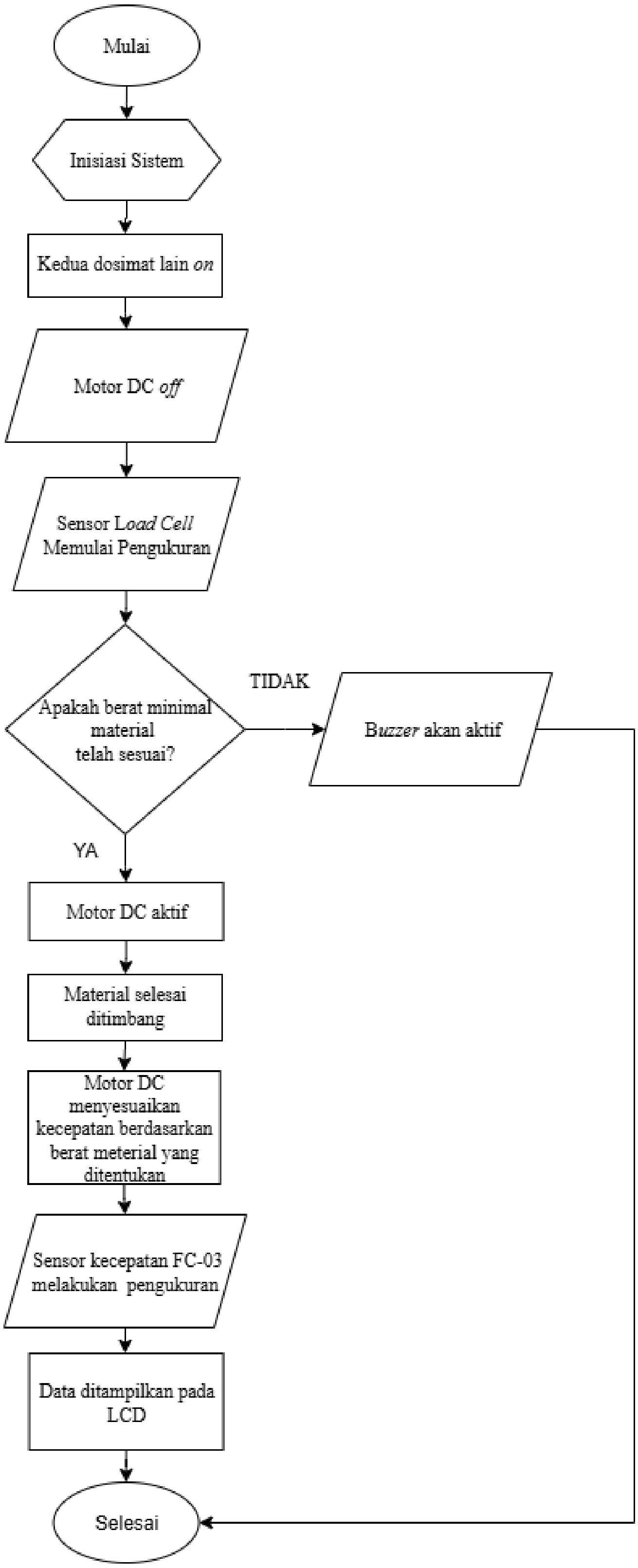
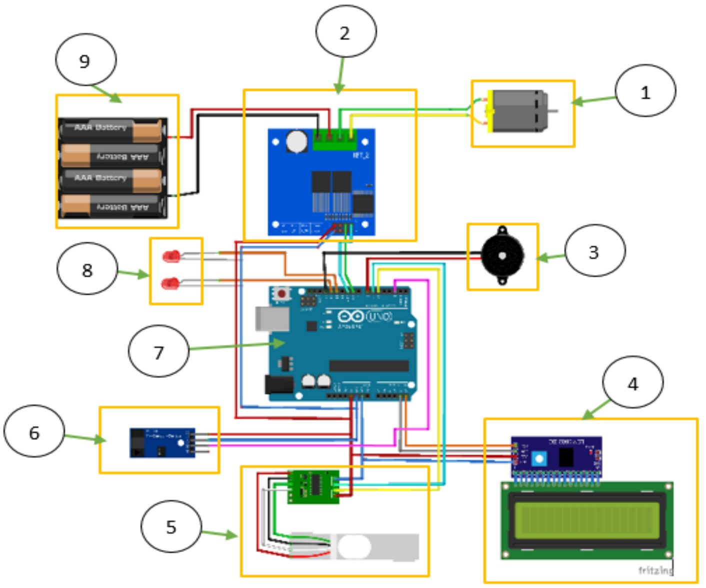


Figure 2. Flowchart of proposed system

This system consists of several components, including an Arduino, a Load Cell sensor, an HX711 module, a DC motor, an L298N motor driver, an FC-03 speed sensor, and a buzzer. The overall system electrical wiring diagram can be seen in the Figure 3.



No	Keterangan
1	Motor DC
2	Driver BTS 7060
3	*Buzzer*
4	LCD dan I2C
5	Sensor *Load Cell*
6	Sensor FC03
7	Arduino
8	LED
9	*Power Supply* 12 V

Figure 3. Circuit scheme

The mechanical design is intended to provide a physical visualization of the device, facilitating the positioning of components during system operation. The system is designed at a 1:4 scale, with the belt conveyor—serving as the main component measuring 50 cm in length and 15 cm in width. Mechanical design is shown in the figure 4.

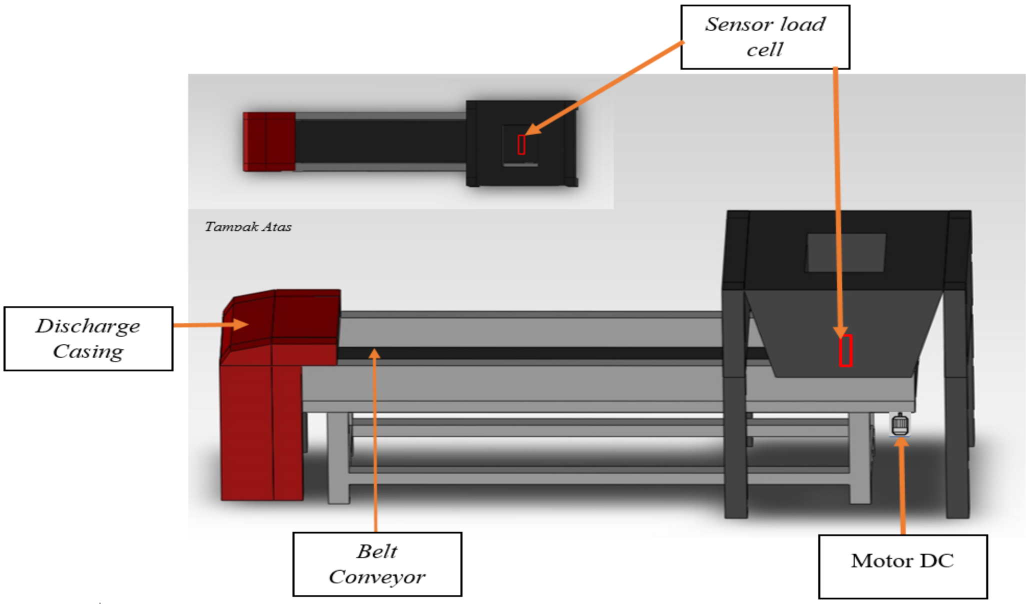


Figure 4. Mechanical Design

3. RESULTS AND DISCUSSION

In The test was carried out by placing a material of known weight on the load cell in 12 different trials, with the material positioned in various locations such as the right, center, and left. The percentage error was then calculated. Eccentric load testing on a load cell as shown in the Table 1.

Table 1. Eccentric load testing on a load cell

Actual Weight (grams)	Material Position	Load Cell Reading (grams)	Error (%)
100	Right	105	5 %
100	Right	205	2,5 %
100	Right	306	2 %
200	Center	102	2 %
200	Center	202	1 %
200	Center	302	0,6 %
300	Left	104	4 %
300	Left	204	2 %
300	Left	306	2 %

The test was conducted by placing a material of known weight in 20 trials, with each weight tested five times. The weight measurements were performed using three weight classifications: 100 grams, 200 grams, and 300 grams. The results of the weight measurement tests, comparing known weights with the readings from the load cell sensor, are presented in Tables 2.

Table 2. Test Results for Weight Variation

No	Material Weight (grams)	Load Cell Reading (grams)	Accuracy (%)
1	100	102	98%
2	100	101	99%
3	100	102	98%
4	100	102	98%
5	100	101	99%
6	200	204	98.03%
7	200	203	98.5%
8	200	203	98.5%
9	200	205	97.5%
10	200	204	98.03%
11	300	307	97.71%
12	300	304	98.6%
13	300	305	98.3%
14	300	304	98.6%
15	300	305	98.3%
16	400	405	98.7%
17	400	406	98.5%
18	400	406	98.5%
19	400	408	98%
20	400	407	98.2%

Based on the results, it can be observed that the material weighing device demonstrates good performance, with an average accuracy above 98%. The device achieved the highest accuracy at a weight of 400 grams, with an average accuracy of 98.38%, and the lowest accuracy at 100 grams, with an average accuracy of 98.2%. The accuracy test results indicate that the lighter the material weight, the lower the average accuracy tends to be.

The calculation of the minimum weight on the prototype is based on the actual weight on the belt conveyor, as shown in the formula below:

$$\text{Berat}_p = \left(\frac{Lp}{La}\right)^3 \text{ x } \left(\frac{massa\ jenis\ p}{massa\ jenis\ a}\right) \text{ x Berat}_a$$

$$\text{Berat}_p = \left(\frac{1}{4}\right)^3 \text{ x } \left(\frac{508\ kg.m3}{7870\ kg.m3}\right) \text{ x } 328.953 \text{ kg} = 0{,}331 \text{ kg} = 331 \text{ gram}$$

The above calculation represents the minimum weight of the prototype based on the actual material weight, with a length ratio of 1:4. From the calculation, the minimum weight on the prototype's belt conveyor is 331 grams, corresponding to the actual material weight of 328.953 kilograms

The prototype uses a 12-volt DC motor with a maximum speed of 60 RPM. The testing was conducted using various weights ranging from 300 grams to 480 grams, with Dosimat 2 and Dosimat 3 turned on (LEDs on). Test results of material weight on motor speed as shown in the Table 3.

Table 3. Test Results of Material Weight on Motor Speed

Minimum Weight (grams)	Material Weight (grams)	Motor Speed (rpm)
331	300	0
331	330	0
331	360	32
331	390	28
331	420	25
331	450	23
331	480	21

The test results show that when the weight reading from the load cell is equal to or below the threshold value, the motor remains inactive and the motor speed reading stays at 0. However, when the weight exceeds this minimum threshold, the motor becomes active. It is observed that the greater the weight detected by the load cell, the lower the motor speed becomes. This indicates the presence of a control system that regulates motor speed inversely proportional to the load as shown in the Figure 5.

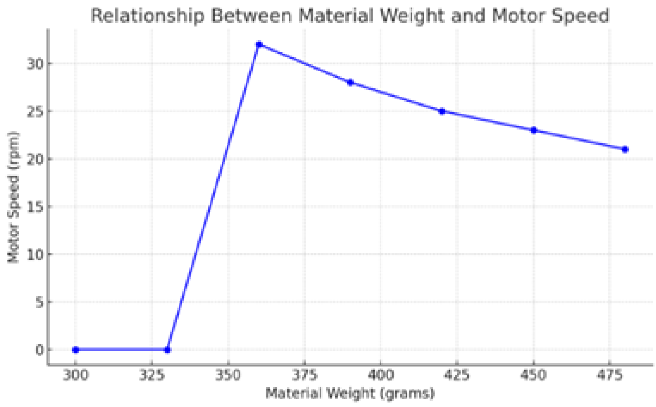


Figure 5. Graph of the Relationship Between Weight and Motor Speed

The graph of the relationship between weight and motor speed above shows that when the weight is below the minimum required weight, the motor speed is zero. The motor speed begins to register at 360 grams with a speed of 32. As the material becomes heavier reaching 480 grams the DC motor speed decreases to 21. The device was tested using various weights ranging from 100 grams to 500 grams, with Dosimat 2 and Dosimat 3 either turned on (LEDs on) or off (LEDs off). Overall system performance test results as shown in the Table 4.

Table 4. Overall System Performance Test Results

No	Minimum Weight (gram)	Material Weight (gram)	Weight Reading (gram)	Motor	*Buzzer*	Motor Speed (rpm)	LED Dosimat 2	LED Dosimat 3
1	331	100	*105*	*off*	*Off*	0	*off*	*Off*
2	331	100	*107*	*off*	*On*	0	*On*	*On*
3	331	150	*153*	*off*	*Off*	0	*off*	*Off*
4	331	150	*156*	*off*	*On*	0	*On*	*On*
5	331	200	*207*	*off*	*Off*	0	*off*	*Off*
6	331	200	*206*	*off*	*On*	0	*On*	*On*
7	331	250	*253*	*off*	*Off*	0	*off*	*Off*
8	331	250	*255*	*off*	*On*	0	*On*	*On*
9	331	300	*307*	*off*	*Off*	0	*off*	*Off*
10	331	300	*304*	*off*	*On*	0	*On*	*On*
11	331	350	*355*	*off*	*Off*	0	*off*	*Off*
12	331	350	*356*	*on*	*Off*	33	*On*	*On*
13	331	400	*409*	*off*	*Off*	0	*off*	*Off*
14	331	400	*407*	*on*	*Off*	27	*On*	*On*
15	331	450	*456*	*off*	*Off*	0	*off*	*Off*
16	331	450	*458*	*on*	*Off*	23	*On*	*On*
17	331	500	*505*	*off*	*Off*	0	*off*	*Off*
18	331	500	*507*	*on*	*Off*	19	*On*	*On*

After testing, the maximum weight that the belt conveyor can handle is 500 grams, as exceeding this weight prevents the belt from moving due to overload. The testing process also includes conditions where both Dosimat LEDs are on (indicating the Dosimats are functioning normally) or off (indicating they have stopped), as the Dosimats are interconnected in the production process.

Based on the test results shown in Table 7, the system functions properly. In experiments using weights ranging from 100 grams to 500 grams, when both Dosimat 2 and Dosimat 3 LEDs are off, the system does not operate even if the minimum weight requirement is met, causing the motor to remain off and the buzzer to stay silent, resulting in a motor speed reading of zero. In experiments using weights from 100 grams to 300 grams with both Dosimat LEDs on, the system operates; however, since the required minimum weight is not met, the conveyor motor remains off and the buzzer sounds to indicate that the material weight is below the required threshold, which also causes the motor speed reading to be zero.

4. CONCLUSION

Based on the research conducted, the following conclusions can concluded that The design of a control and monitoring system for the minimum material weight on a belt conveyor using Arduino was successfully implemented. The design process involved selecting appropriate components such as a load cell for weight measurement, a DC motor as the drive mechanism, and an Arduino as the main controller. Based on the testing results and data analysis, the material weighing device achieved an average efficiency of over 98%. Furthermore, the minimum weight monitoring system functioned properly when both Dosimat 2 and Dosimat 3 LEDs were on.

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