



Load Cell Application using Three Sensing Point Method in Dynamic Data Monitoring of Tray Dryer Machine

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ABSTRACT

Keywords

Tray Dryer
Load cell sensor
Monitoring

The drying process was a method of evaporating moisture from the material to extend its shelf life. One of the drying methods used was Tray Dryer machine. Tray Dryer machine was needed to do research in Laboratory to know optimal temperature, energy capacity, humidity which needed in drying process till the material was dry and cooked properly. During the drying process, data on changes in materials weight relative to air flow temperature and time was needed to determine the reduce water content in real time. So, this Tray Dryer needed to be equipped with an electronics substrate weight meter. The substrate weight measurement process used three load cell sensors with the capacity of 5 kg to measure changes in substrate weight relative to time and airflow temperature. The Tray Dryer was equipped with the data acquisition capabilities required for the real time monitoring process of the substrate weight condition regarding temperature, air flow, and time parameters. As a result, the substrate weight measurement system on the Tray Dryer had a weight reading accuracy of $\pm 0.45\%$. The dynamic changes in the weight of materials dried using Tray Dryer decreased by 29% with temperature of 80 C and airflow speed of 2 m/s for 75 minutes. The changes in the weight of this material could also be monitored in graphical form using LabVIEW and stored on Ms. Excel.

1. Introduction

The Food Industry is an industry with a big prospect in Indonesia[1]. The food industry does several processes in processing food ingredients, one of which is drying process. Drying process is a process to remove or decrease water content from the materials by evaporating most of the water content in the materials using heat energy[2]. This drying process aims to preserve products so that the shelf life is longer. The uses of drying process example are instant noodle, shrimp paste, biscuit, etc.

Along with the development of technology, the conventional drying process is abandoned. The drying process in industry usually uses a dryer machine. This aims to increase efficiency in production process.

Beside in industry, the drying process is also done in research laboratory to determine the correct treatment for a material to be dried. The correct treatments for the material include the need for an optimal temperature, humidity monitoring, the weight decrease of materials that dried against time required until the material dried and cooked properly. Therefore, the dryer machine with a smaller scale than the one used in industrial application is required for the laboratory needs. The dryer machine is also necessary equipped with the monitoring system of temperature, humidity, and changes of material weight parameters against time parameter.

One of dryer machine type is Tray Dryer because it has economical design compared to another dryer machine[3]. Tray Dryer is a dryer machine the form of a rack which is supplied with hot airflow to dry materials[4]. Hot airflow is produced by air from the fan which is passed through a heater to dry the materials. The material which dried will reduce its water content. It involves the weight material decrease. So that, Tray Dryer machine must be equipped with weight measurement meter and electronic weight change monitoring system. The weight monitoring system uses three load cells





with maximum capacity 5 kilograms. The monitoring system is used to monitor change of weight material during drying process. The weight change is monitored to know the efficiency of drying process.

The previous research about drying food material was using to dry cocoa[5]. That research examined temperature setting and monitored cocoa weight against time, but the drying machine have not been equipped with dynamic weight data logger, so an innovation is required to made dynamic weight data logger by Tray Dryer machine to monitor change of weight material which dried. Another research was a drying noodle use Tray Dryer machine[6]. In this research, performance of Tray Dryer machine was tested by varying temperature and drying time. However, that research had not already been discussed about humidity and optimal temperature monitoring against drying time and data acquisition system. Another previous research of Tray Dryer discussed about the effect decreasing water content, heat transfer rate, and thermal efficiency on drying time for silica gel[4]. Nevertheless, that research was not equipped with monitoring system.

From the background above, it can be concluded that the dryer machine which be equipped with dynamic weight data changes, weight material data logger, and other parameters such as temperature, airflow, and time monitoring system for laboratory is needed. This research aim is to design and develop weight measurement tool to monitor and log data of weight changes materials that dried in the Tray Dryer process. It is necessary to monitor material weight changes and others parameters such as temperature and air flow against time which needed until the material is dried and cooked properly.

2. Method

In this research, the method that used is research and development. The method is to study the literature; design system; design the mechanic, electronic, and software; develop based on design; and test the Tray Dryer.

2.1. Literature Study

First is study the literature. The literature that needed are previous research and data sheet of component. Previous research is to be reference of this research. The data sheet is to determine several components that needed in this research. The electronics components that required to research is load cell sensor, HX711, and ESP32 microcontroller.

- a) Load cell sensors is a sensor which is used to measure weight of load. Load cell has 4 wire which 2 cable has function as output signal and 2 cable is as excitation[7]. In this research, load cell is required to monitor the material weight change;
- b) HX711 is the 24 bits analog to digital converter for weight measurement sensor. HX711 is connected to HX711 and microcontroller ESP 32. HX711 is used to convert analog signal from load cell sensor to digital signal. Then, the digital signal can be processed by ESP 32[8];
- c) ESP 32 microcontroller is a chip microcontroller that is designed with 40 nm low watt TMS320C32 Technology. This microcontroller has 48 pins. ESP 32 has 2 I2C communication pins and 3 UART communication pin. This pin will be used as communication in data sending system of this research. The material weight data from the sensors will send to microcontroller master use UART communication[9].

2.2. Weight Measurement System Design

In this research, maximum capacity of Tray Dryer is 5 kilograms with temperature used is 80 degrees Celsius and airflow used is 2 m/s. The method for weight measurement uses three load cell sensors which is assembled in the base of rack. The block diagram of electronics design shows in Figure 1.



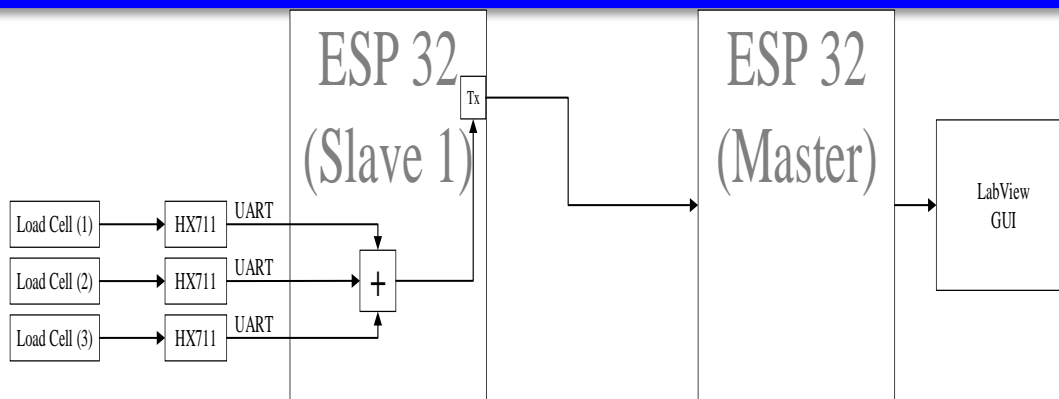


Fig 1. Diagram block of tray dryer machine weight monitoring system design

Figure 1 shows diagram block of Tray Dryer machine weight monitoring system design. 3 load cells measure the weight of measurement. The result of measurement is converted to voltage in 0-5 V range using HX711. The results of the measurements will be sent to the ESP 32 slave microcontroller. Then, the results will be sent to the master microcontroller using UART serial communication. The data will be displayed to LabVIEW and GUI (Graphical User Interface).

2.3. Mechanics Design

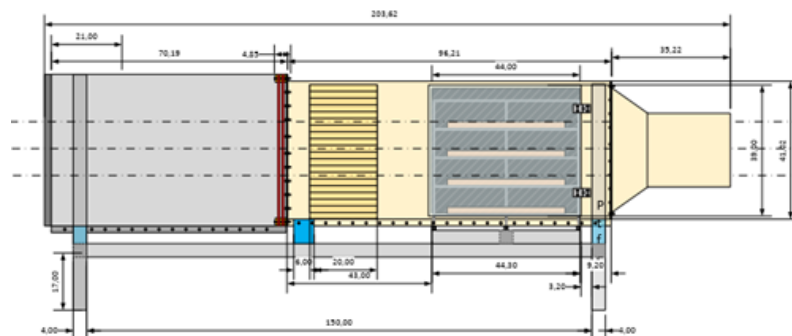


Fig 2. Mechanics design of tray dryer

The mechanical design of the Tray Dryer machine is shown in Figure 2. The material used in the manufacture of the Tray Dryer machine mechanics is stainless steel. The overall mechanical dimensions of the Tray Dryer machine are divided into 3 parts. The first chamber is 200 cm long, 45 cm wide, and 41 cm high. The size of the middle chamber containing the rack is 100 cm long, 41 cm wide, and 39 cm high with a door hole size of 37 cm high and 45 cm wide. The exhaust size is 39 cm long and 39 cm wide with an elevation of 51.30° . The size of the rack is 36 cm high, 44 cm wide, and 36 cm high. The Tray Dryer machine has a door measuring 46 cm x 40 cm.

2.4. Electronics Design

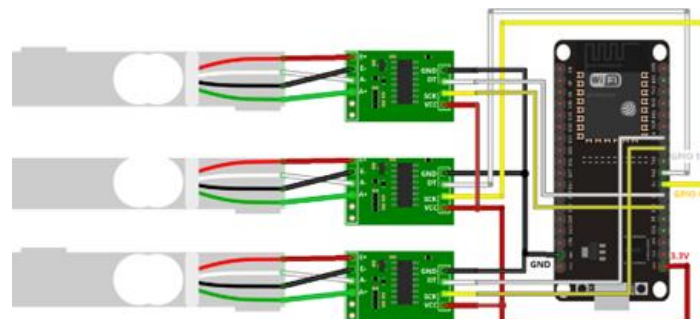


Fig 3. Electronics design of tray dryer

Figure 3 shows the electronic circuit of the dynamic weight measurement system of the Tray Dryer machine. Electronic design of the weight monitoring system on the Tray Dryer machine using three load cell sensors. Then, the Load cell sensor is connected to the HX711 module and becomes the weight input on the microcontroller. HX711 functions as an ADC and Load cell output signal

conditioner. The microcontroller will read and sum the measurement results by the three sensors. Furthermore, the data will be sent to the master microcontroller using Tx/Rx serial communication.

2.5. Software Design

The monitoring and weight recording system using Arduino IDE software and C++ language. The following is an explanation of the program flow as shown in Figure 4.

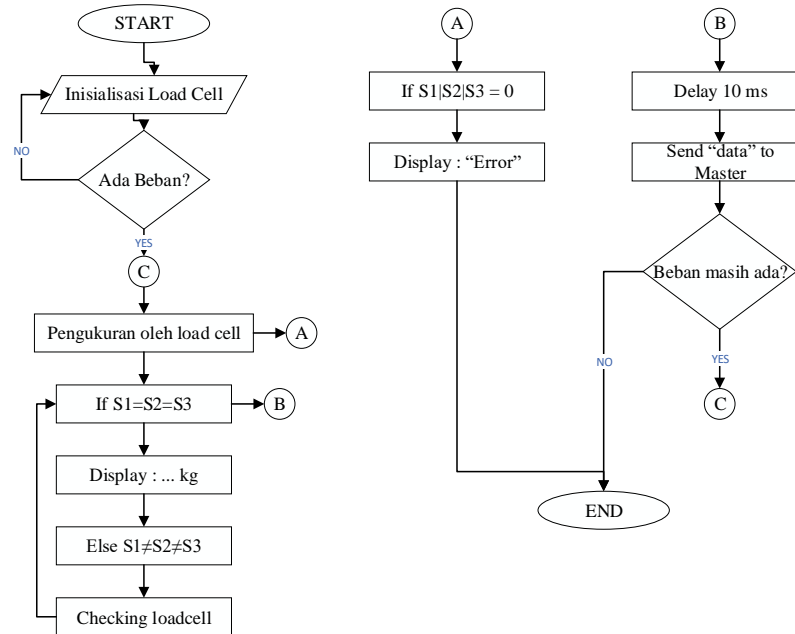


Fig 4. Software design of tray dryer

From Figure 4, the first step is the initialization of the Load cell sensor and also the microcontroller. Next, the microcontroller waits for the load to be read by the sensor. If the load is detected, the microcontroller will read the load from each load cell. If the readings of the three sensors are the same or have differences that can still be tolerated, the microcontroller will send data to the master microcontroller to display the reading value and graph it in the LabVIEW GUI. If the difference in readings from each load cell is quite large or one of the load cells has a value of 0, the reading will look far apart and the graph will decrease by a third or more from the measured load. If this happens, it is necessary to check for damage to the load cell.

2.6. Testing Plan

Tray Dryer machine testing is carried out in several stages. The first step is testing and calibrating each Load cell sensor. Calibration is the process of comparing measuring instruments according to national or international standard comparators to determine the accuracy of the measuring instrument and measuring material indication values. In this test, the measurement results of each load cell sensor are compared with standard scales. This test is carried out to determine the performance conditions and suitability of each Load cell with the existing standard scales and to determine the Load cell calibration coefficient. The measurement test is continued using the three Load cell sensors which are compared with the standard scales. This is done to determine the suitability of the weight measurement using three Load cells to the standard scales. The last step is testing the performance of the load cell in the entire Tray Dryer System and analyzing the dynamic weight measurement system in the Tray dryer system.

3. Result and Discussion

Tray Dryer machine testing was carried out at the Mechatronics Laboratory of the State Polytechnic of Malang. The material dried in the overall system test was wet noodles. The following are the results and analysis of the tests that have been carried out:

3.1. Calibration Results of Each Loadcell

Each load cell sensor is calibrated to obtain a calibration coefficient value. The calibration coefficient value is used to adjust the accuracy of the three Load cell sensors with standard scales.

How to find out the calibration coefficient using a program and a measured load, namely water in a bottle weighing 522 grams. The results show a calibration factor of 212976. So, the coefficient value is obtained:

$$\text{Calibration Coefficient} = \frac{212976}{522} = 408$$

The calibration coefficient values will be entered into the program. Next, the three sensors will be combined and all three will be calibrated simultaneously.

3.2. Calibration Results of Three Loadcell Sensor Measurements Using Standard Scale Comparators

The results of the measurement calibration of three Loadcell sensors using a standard scale comparator are shown in Table 1 below:

Table 1. Result of 3 load cells calibration

The load is measured using standard scales (grams)	Load measured using three load cell sensors (grams)	Error (%)
204	203	0.5
213	211	0.04
522	522	0
59	58	1.7
35	35	0
<i>Average of error</i>		<i>0.45</i>

From Table 1 above, several loads are used that are measured by standard scales. Then the load is measured using a load cell sensor. The results show an average error value of material weight measurement using three Load cell sensors of 0.45%.

3.3. Results of Sending Data from ESP 32 to be Displayed in LabView and Logging in Excel

The following is a display of the results of weight measurements using LabVIEW as shown in Figure 5:

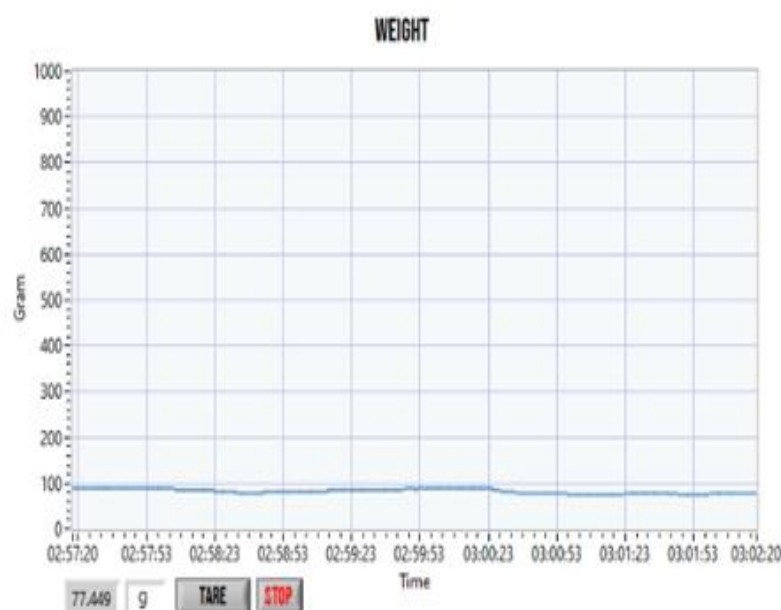


Fig 5. Weight data



Figure 6 shows that the weight measurement data using three load cell sensors can be displayed in LabVIEW.

	A	B	C	D	E	F	G	H
18268	33.200	61.120	54.090	44.57	14.35	18.93	55.716	
18269	33.090	61.120	54.090	44.57	14.35	18.93	55.701	
18270	33.090	61.120	54.090	44.57	14.35	18.93	55.662	
18271	33.090	61.120	54.090	44.77	14.35	18.93	55.681	
18272	33.090	60.920	54.090	44.77	14.50	18.93	55.691	
18273	33.090	60.920	53.910	44.77	14.50	18.93	55.662	
18274	33.090	60.920	53.910	44.77	14.50	18.93	55.640	
18275	32.950	60.920	53.910	44.77	14.50	18.99	55.647	
18276	32.950	60.920	53.910	44.77	14.50	18.99	55.635	
18277	32.950	60.920	53.910	44.94	14.50	18.99	55.630	
18278	32.950	60.670	53.910	44.94	14.50	18.99	55.623	
18279	32.950	60.670	53.770	44.94	14.56	18.99	55.591	
18280	32.950	60.670	53.770	44.94	14.56	18.99	55.608	
18281	32.950	60.670	53.770	44.94	14.56	19.06	55.610	
18282	32.950	60.670	53.770	44.94	14.56	19.06	55.593	
18283	32.880	60.670	53.770	45.13	14.56	19.06	55.544	
18284	32.880	60.430	53.770	45.13	14.56	19.06	55.544	
18285	32.880	60.430	53.770	45.13	14.63	19.06	55.527	
18286	32.880	60.430	53.630	45.13	14.63	19.06	55.537	
18287	32.880	60.430	53.630	45.13	14.63	19.16	55.537	
18288	32.790	60.430	53.630	45.13	14.63	19.16	55.549	
18289	32.790	60.430	53.630	45.13	14.63	19.16	55.564	
18290	32.790	60.230	53.630	45.31	14.63	19.16	55.571	
18291	32.790	60.230	53.630	45.31	14.63	19.16	55.571	
18292	32.790	60.230	53.630	45.31	14.63	19.16	55.569	
18293	32.790	60.230	53.510	45.31	14.77	19.16	55.559	

Fig 6. Result of data logger

Figure 6 shows that the results from the data logger can also be displayed in Excel.

3.4. Mechanics Result of Tray Dryer



Fig 7. Result of tray dryer mechanics

Figure 7 shows the results of the mechanical manufacture of the Tray Dryer machine. The overall length of the chamber is 200 cm. The size of the rack is 44×37×37 cm with a capacity of 5 kg. The mechanical results are in accordance with the mechanical design of the Tray Dryer machine.

3.5. Overall Test Results of Tray Dryer Machine Weight Monitoring System

The overall test of the Tray Dryer machine was carried out using 100 grams of wet noodle material. The test was carried out 2 times. The first test, the entire sample was dried for 75 minutes. The second test consisted of 5 samples weighing 25 grams each taken at 5 different times. Then the final results were compared with standard scales to verify that the measurements of the three load

cells were in accordance with the specified standards. The following is the data on the results of measuring the weight of the noodles during the Tray Dryer drying process as shown in Table 2:

Table 2. Dynamic data logger results of wet noodle drying process on tray dryer machine



Time (Minutes)	Weight (grams)
1	100,976
5	95,765
10	93,765
15	88,567
20	85,025
25	83,128
30	80,478
35	77,449
40	78,025
45	77,349
50	74,988
55	72,005
60	72,026
65	71,776
70	71,559
75	71,241

From Table 2 above, the weight of the dried wet noodles decreased from 100.976 to 71.241. So that during the drying process the percentage of the weight of the wet noodles lost was 29%.



3.6. Results of Testing Changes in Material Weight per 25 Grams

To verify the results of the dried wet noodles, a retest of the drying of the wet noodles is required. So that 100 grams of wet noodles are divided into 4 parts and taken at different times for 75 minutes. The following are the drying results of each wet noodle:

Table 3. Wet noodle weight testing per 25 grams as a comparison parameter

Time (Minutes)	Weight (Grams)	Result
0	25	
30	21	



Time (Minutes)	Weight (Grams)	Result
60	19	
75	17	

From Table 3, the noodles that are released will be measured using a standard scale. The results of the measurements using a standard scale will be used as a reference parameter for the results of dynamic data collection using three Load cell sensors.

3.7. Comparative Analysis of Material Weight Change Test Results

The results of both tests are compared to verify the accuracy of the readings from the dynamic weight data recorder in the Tray Dryer process. The following is a comparison as shown in Table 4:

Table 4. Comparison of test results

Data Logger (grams)	Standard Scale (grams)
25,2440	25
20,1195	21
18,0065	19
17,8103	17

From Table 4 above, it can be seen that the dynamic data collector uses three Load cell sensors and standard scales have a weight difference of around 0.2 to 1 gram. The highest error occurs when the weight of the material is getting lighter. This is because the movement of air flow affects the movement of the rack and the reading on the load cell.

4. Conclusion

The conclusion of this study is that the weight measurement using three Load cell sensors has an accuracy that is still tolerable, which is $\pm 0.45\%$. The weight of the monitored wet noodles decreased by 29% in the drying process at a temperature of 80 0C and an air flow speed of 2 m / s for 75 minutes. The results of dynamic data collection of wet noodle weight on the Tray Dryer machine can be monitored in real-time graphs using LabVIEW and the data results can be seen on the data logger in Excel.





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