Effective use of combined moisture and temperature sensor for in situ measurement in Process Control for Composting Machines

Authors: Kanchan V. Tilak [1*], Dr. P. B. Buchade[2] and Dr. A. D. Shaligram [3]

[1] Department of Electronic Science, M.E.S. Abasaheb Garware College, Pune – 411004.
Email: mbkarandikar@gmail.com, Ph. No. +91 7350546200

[2] P. Jog College of Science and Commerce, Pune, India

[3] Savitribai Phule Pune University, Pune, India

Abstract:
Composting is an environment friendly method of recycling organic waste material. The composting process involves maintaining optimal conditions for microbial activity, including temperature and moisture content. Composting machines are designed to provide an optimal environment for the decomposition of organic waste on large scale at a time. This situation involves a range of parameters such as temperature, moisture content, oxygen levels, and pH besides the biomass content of browns and greens. In order to achieve high-quality compost, these parameters must be monitored and controlled effectively. In recent years, electronics and sensors have been used to automate the process control in composting machines. In situ measurement sensors are essential for real-time monitoring of these conditions and effective process control. In this paper, we present a review of the effective use of combined moisture and temperature sensing for in situ measurement in process control for composting machines. The review highlights the advantages of using combined sensors for process control and the importance of real-time monitoring of moisture and temperature in composting.

Keywords: composting machines, in situ measurement, combined sensors, moisture sensing, temperature sensing, process control

Introduction:
Wet waste composting is a natural process of organic waste decomposition that can be accelerated using a controlled environment. The process involves creating a composting pile that is maintained under specific environmental conditions, including temperature, moisture content, and oxygen levels. Efficient and successful composting requires careful monitoring and control of these environmental conditions. On a small scale it is easier task to monitor and control the influencing parameters, however it becomes very difficult to observe and regulate for large volumes of biomass. To overcome such situations composting machines can be used for achieving quality of final compost. Composting machines are widely used in various industries, including agriculture, food processing, and waste management, to convert organic waste into compost.
Figure 1 explains the very basic construction of composting machine comprising Agitator for mixing the biomass inside Composting chamber called Digester, Crusher which is used to make smaller pieces of input material for faster composting, Heaters installed on outer surface of digester to heat the content and process controller to set the heater cycle and agitator motor control.

ISSN NO: 2230-5807

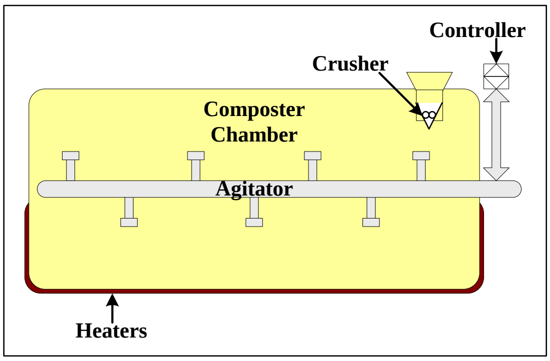


FIGURE 1. Typical Wet Waste Composter

The typical ingredients of biomass to be converted to good quality compost shall include the 'Browns' and 'Greens' in the ratio of 3:1. Browns means the material having high carbon content which helps in breathing of biomass by allowing air to circulate through gaps. It also acts as a food for organisms whichwill break down the contentswith the help of microbes. The biodegradable dry wastes like dried leaves and branches, saw dust, papers, cotton etc are considered as browns. Wet wastes in general like grass clippings, tea bags, vegetable and fruit scraps etc are considered as Greens. Green components are nitrogen rich and assist the microorganisms to grow and increase quickly.

Objectives:

Objective 1: Survey the composting machines having measurement of temperature and moisture of biomass while processing.

Objective 2: Analyse the potential benefits of using the combined moisture and temperature sensor in process control for composting machines.

Objective 3: Develop a methodology for integrating combined moisture and temperature sensors into composting machines, ensuring accurate and real-time measurements.

Objective 4: Validate the findings through experimental tests and field trials, considering different composting scenarios and machine configurations.

Need:

The composting process involves the breakdown of organic matter by microorganisms, which release heat and carbon dioxide as by-products. The process requires specific conditions of temperature, moisture, and oxygen to be maintained for optimal decomposition. Deviations from these conditions can result in the production of odours, the growth of pathogens, and excessive greenhouse gas emissions. The need of composting machines to handle large quantity of biomass was acknowledged and machines were developed to serve the purpose. However, many of the machines have temperature sensors in built but very few have moisture sensors. Further these sensors are used to measure the parameters at the time of loading the biomass into the machine. Based on the initial temperature values heater cycle set point as adjusted and process starts.

Setting parameters based on initial conditions and not updating the settings based on actual parameter values when process is ongoing may result into over heating or excess moisture content in the biomass at the end of the process cycle. Overheating can lead burning of biomass and catch the fire while excess moisture can produce the foul odours.Low temperature setting limits the microbial activity and moisture control.

Aggravated microbial activity releases the heat in the biomass which leads to increase in temperature. In process monitoring of temperature is required to control the temperature for preventing biomass from catching fire due to increased temperature because of microbial activity. Actual in process moisture readings can help in maintaining the optimum moisture for microbial activity to decompose the biomass completely to avoid foul odours and pathogens growth.

Research Methodology:

In Situ Measurement of Moisture and Temperature:

In situ measurement of moisture and temperature using sensors is a valuable tool for real-time monitoring and control of the composting process to assure quality of final compost produced out of machine. Moisture sensors are used to monitor the moisture content of the biodegradable mass and ensure that it remains within the optimal range for complete decomposition. Temperature sensors are used to monitor the temperature of the biodegradable mass and ensure that it remains within the optimal range for the proper growth of microorganisms that break down organic matter.In situ measurement sensor is designed to measure moisture and temperature in real-time and provide feedback for process control. In situ combined sensor is typically placed directly in the composting drum and can provide accurate and reliable measurements of moisture and temperature throughout the composting process.

In Situ Measurement of Moisture and Temperature using combined sensor:

Temperature sensors can be used to monitor temperature of biodegradable massand adjust if required in real-time. Thermocouples, thermistors, and resistance temperature detectors (RTDs) are commonly used temperature sensors in composting machines. These sensors can be integrated with microcontrollers and data acquisition systems to provide accurate and reliable temperature readings.The most common K type thermocouple is used to sense the temperature of the biomass inside the chamber. It is inexpensive, accurate, reliable, and has a wide temperature range.

Moisture is another critical parameter in the composting process, as it affects the activity of microorganisms and the availability of oxygen. Moisture sensors can be used to monitor the moisture content of the biodegradable mass and adjust it in real-time. Capacitive sensors, resistive sensors, and optical sensors are commonly used moisture sensors in composting machines. These sensors can be integrated with microcontrollers and data acquisition systems to provide accurate and reliable moisture readings.

For moisture readings a conductive type of sensor is developed. It works on the electrical conductivity principle. Conductivity of the material varies proportional to the moisture content of the material. As a result, the output voltage produced by the sensor alters as the water content in the material changes.

Combined moisture and temperature sensor is designed to measure both moisture and temperature in real-time and provide data for process control. Combined sensor is typically placed directly in the composting drum and can provide accurate and reliable measurements of both moisture and temperature throughout the composting process.

As shown in Figure 2, temperature sensing is achieved by electrode 1. The moisture sensor consists of two stainless steel electrodes (2 and 4) made up of SS304 for avoiding corrosion due to acidic nature of half degraded biomass and separated by a ring (3) of alumina ceramic substrate forming an annular ring. The shape of the electrodes helps to increase the surface area in contact with actual material. Greater surface area helps to achieve better sensitivity.

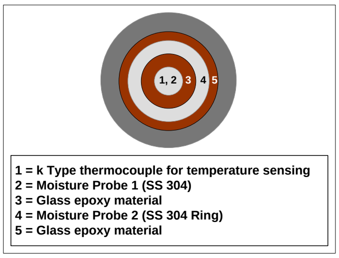
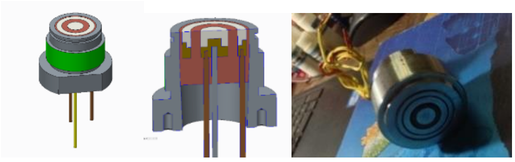


FIGURE 2: Internal sensor arrangement

Figure 3 shows the 3D view, cross sectional view and actual photograph of combined moisture and temperature sensor.



(a) (b) (c)

FIGURE 3: Actual Sensor views; (a) 3D view, (b) Cut Section, (c) Actual Sensor

The developed sensor is interfaced with microcontroller-based process control unit through local signal conditioning units as shown in below Figure 4.

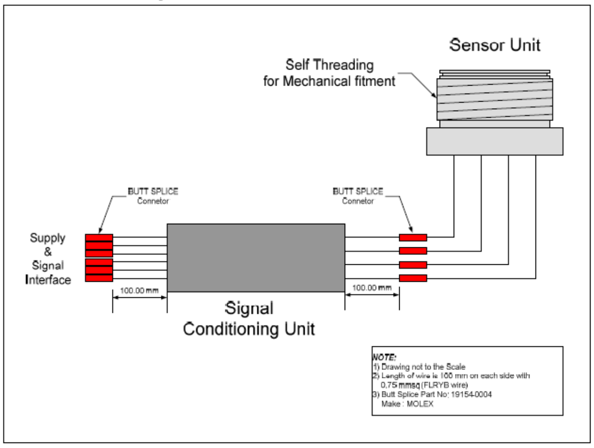


FIGURE 4: Interfacing of sensor and controlling unit

Signal conditioning units mainly comprises the temperature compensation circuit for k Type thermocouple and rail to rail opamp based circuit to improve low signal strength of moisture sensor by amplifying and noise filtration.

Data Collection:

As a conclusion after various trials conducted on different capacity machines, at different sensor mounting locations in the machines and different number of physical sensors, the arrangement shown in Figure 5 was finalized.

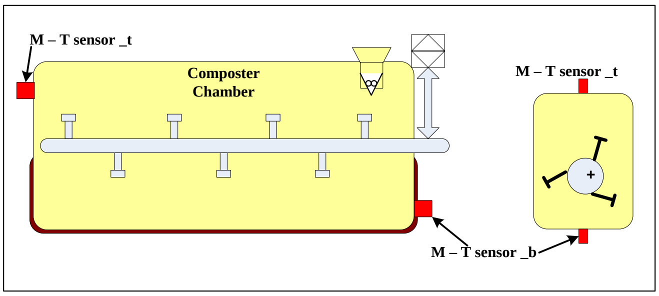


FIGURE 5: M-T Sensor at sides of drum, top (t) and bottom (b)

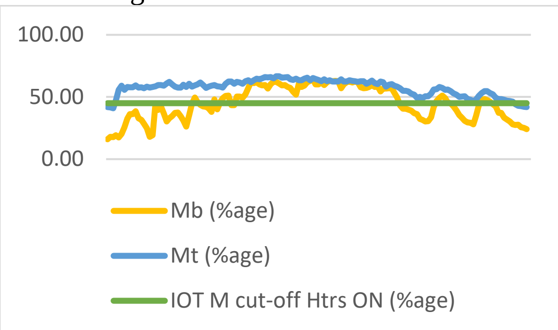
Arrangement of two sensors, one at top and second at bottom for 100KG capacity machine was used to acquire actual data. Table 1 below represents the obtained data as a sample.

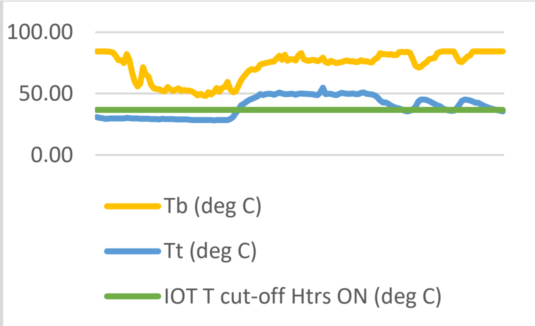
ISSN NO: 2230-5807

Time stamp	drum T (V)	drum T (deg C)	Mb (V)	Mb (%age)	Tb (V)	Tb (deg C)	Mt (V)	Mt (%age)	Tt (V)	Tt (deg C)	Set T (deg C)	Cut Off T (deg C)	IOT T cut-off Htrs ON (deg C)	IOT M cut-off Htrs ON (%age
Wed Sep 11 15:15:41	1.45	42.78	2.03	15.98	4.02	84.42	1.13	41.77	1.47	30.87	85.00	80.00	36.75	45.00
Wed Sep 11 15:23:42	1.44	42.48	1.96	17.99	4.02	84.42	1.14	41.48	1.44	30.24	85.00	80.00	36.75	45.00
Wed Sep 11 15:31:44	1.39	41.01	1.97	17.70	4.02	84.42	1.16	40.91	1.43	30.03	85.00	80.00	36.75	45.00
Wed Sep 11 15:39:46	1.41	41.60	1.92	19.13	4.02	84.42	0.95	46.93	1.41	29.61	85.00	80.00	36.75	45.00
Wed Sep 11 15:47:48	1.43	42.19	1.98	17.41	4.01	84.21	0.64	55.81	1.41	29.61	85.00	80.00	36.75	45.00
Wed Sep 11 15:55:49	1.42	41.89	1.88	20.28	4.00	84.00	0.53	58.96	1.42	29.82	85.00	80.00	36.75	45.00
Wed Sep 11 16:03:51	1.41	41.60	1.69	25.72	3.98	83.58	0.64	55.81	1.42	29.82	85.00	80.00	36.75	45.00
Wed Sep 11 16:03:51	1.40	41.30	1.45	32.60	3.84	80.64	0.56	58.10	1.42	29.82	85.00	80.00	36.75	45.00
Wed Sep 11 16:11:53	1.39	41.01	1.32	36.32	3.68	77.28	0.57	57.81	1.42	29.82	85.00	80.00	36.75	45.00
Wed Sep 11 16:19:54	1.39	41.01	1.32	36.32	3.68	77.28	0.57	57.81	1.42	29.82	85.00	80.00	36.75	45.00
Wed Sep 11 16:27:56	1.39	41.01	1.24	38.62	3.57	74.97	0.52	59.25	1.42	29.82	85.00	80.00	36.75	45.00
Wed Sep 11 16:35:58	1.40	41.30	1.44	32.89	3.92	82.32	0.58	57.53	1.44	30.24	85.00	80.00	36.75	45.00
Wed Sep 11 16:44:00	1.40	41.30	1.49	31.45	3.70	77.70	0.57	57.81	1.43	30.03	85.00	80.00	36.75	45.00
Wed Sep 11 16:52:01	1.39	41.01	1.59	28.59	3.19	66.99	0.60	56.95	1.42	29.82	85.00	80.00	36.75	45.00

TABLE 1: Actual data acquired by developed sensor on actual machine

Data Analysis:
The nature of temperature and moisture variation in the live measurements on an actual machine can be seen in below Figure 6.





(a) Moisture (b) Temperature

FIGURE 6: In process sensor performance on actual machine; (a) Moisture (b) Temperature

The observations show the settling of moisture and temperature to an optimal setpoints over the cycle.

Findings:
The effective use of electronics and sensors in process control for composting machines has numerous benefits. It increases efficiency, improves compost quality, and reduces the risk of environmental pollution. As technology continues to advance, the use of electronics and sensors in composting machines is likely to become even more widespreadleading to more efficient and sustainable composting practices.

In situ measurement of moisture and temperature using sensors is a valuable tool for real-time monitoring and control of the wet waste composting process. By monitoring these conditions, adjustments can be made to maintain optimal circumstances for efficient and successful composting.

Real-time monitoring of both moisture and temperature using combined sensors offers several advantages over using multiple sensors, including improved accuracy and reliability, increased efficiency, and reduced costs.

Combined in situ measurement sensors offer several advantages for process control in composting machines. First, the use of combined sensors reduces the need for multiple sensors, simplifying the installation and maintenance process. Second, real-time monitoring of both moisture and temperature allows for more accurate and reliable process control, resulting in more efficient and effective composting. Finally, the use of combined sensors can reduce the overall cost of monitoring by combining multiple functions in a single device.

References:
1. Kanchan V. Tilak, Dr. P. B. Buchade, Dr. A. D. Shaligram (2021). Building an empirical model for wet waste composting process, by in situ measurement of moisture and temperature. AIP Conference Proceedings 2335, 040005 (2021).

2. Sun, X., Cao, Y., Huang, G., & Zhan, Q. (2017). Application of wireless sensor networks in composting systems: a review. International Journal of Agricultural and Biological Engineering, 10(6), 1-13.
3. Kim, J. K., Park, J. Y., Lim, T. T., & Kim, S. H. (2012). Monitoring and control of composting process using electronic noses. Biosystems Engineering, 112(4), 300-308.
4. Li, Y., Zhao, Y., Li, X., & Li, Y. (2019). Optimization of composting process using sensor technology: a review. Journal of Cleaner Production, 232, 658-666.
5. Gao, X., Li, Q., & Liang, Y. (2019). In situ monitoring of moisture content in composting process based on capacitive sensor. Waste Management, 94, 137-144.
6. Sponza, D. T., &Tokat, E. (2018). In-situ monitoring of temperature and moisture during the composting of sewage sludge
7. Rong, X., Li, S., Li, H., Li, M., Li, Z., & Li, J. (2021). In situ monitoring of composting piles using a combined moisture and temperature sensor. Journal of Environmental Management, 279, 111759.
8. Chen, J., Li, L., & Xu, G. (2020). Design and implementation of a composting machine control system based on IoT technology. Journal of Physics: Conference Series, 1599(1), 012063.