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Design of Moisture Content Detection System

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Abstract

In this paper, a method for measuring the moisture content of grain was presented based on single chip microcomputer and capacitive sensor. The working principle of measuring moisture content is introduced and a concentric cylinder type of capacitive sensor is designed, the signal processing circuits of system are described in details. System is tested in practice and discussions are made on the various factors affecting the capacitive measuring of grain moisture based on the practical experiments, experiment results showed that the system has high measuring accuracy and good controlling capacity.

Keywords: detection system; moisture content; grain; measurement error;

1. Introduction

The moisture content plays an important role in grain storage and food processing, So, the detection of moisture has great significance and it is the inevitable steps in the grain production, transportation, storage, and so on[1-4].

In recent years, with the development of detection technology, many moisture detection methods have been proposed. Generally, they can be divided into two categories: direct method and indirect method. The direct method is detecting the absolute moisture content in grain through drying methods and chemical methods directly; it has high precision, but time-consuming, and not suitable for online and on-site testing[5]. The indirect method is to measure the water of substance through detecting the water-related physical quantities such as material conductivity, dielectric constant, etc.. It is generally fast, easy to implement online testing. In an indirect measurement, because many factors affect the moisture content, so

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the design of the sensor should be given enough attention, so that the output signal can effectively reflect the water feature[6][7]. Capacitive method is one of an effective method of moisture testing. So, based on it, a moisture detecting system is designed by adopting intelligent control algorithm. It can collect data, display data and determine whether to alarm when the data overreach, and has the features such as low cost, small size, high precision.

The rest of this paper is organized as follows. Section 2 introduces the principle of moisture consent. Section 3 described the design of capacitive sensor. After that, the overall structure of system is presented in section4. In section 5, the measurement error is analyzed and the corresponding strategies are introduced. Finally, the last section gives the conclusion.

2. Measuring principle of moisture content

The measuring principle of this system is that it adopts capacitor as the sensor, and uses the grain as capacitor electrolyte. Capacitive sensor is a device which converts the changes of non-electricity into the changes of capacitance. It has the advantages such as simple structure, high resolution and non-contact measurement. In addition to this, it can work under harsh conditions such as in high temperature, radiation, and a strong vibration. With the development of integrated circuit technology and computer technology, capacitive sensor has become one of the promising sensors.

Capacitive sensor has many forms. Ignoring the impact of edge effect, the electric capacity is related to the vacuum permittivity ε_0 , the relative dielectric constant of the medium between the plates ε_r the effective plate area A and the distance d between the two plates.

$$C = \varepsilon_0 \varepsilon_r A / d \tag{1}$$

If there is any change of three parameters, it will cause the changes in capacitance and can be converted to electricity by measuring circuit.

3. Design of capacitive sensor

According to this, the moisture content of grain can access to be measured. The system used the concentric capacitor as the sensor, which consists of two concentric cylindrical metal components. The specific shape of cross section is shown in Fig.1. The inner core of cylinder is insulator, which formed the two electrodes of capacitive sensor with outer cylindrical. And the outer cylinder at the bottom of intramural left some space in order to ensure the flow of grain, and full in the cylinder[8-9].

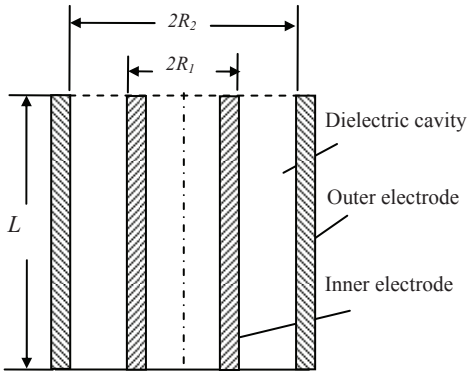

Fig.1 Structure of concentric capacitive sensor

In Fig.2, the height of two cylinders is L, the outer surface radius of the inner cylinder is R_1, the inner surface radius of the outer cylinder is R_2.

When $L >> R_2 - R_1$.

Then, the effect of cylindrical edge ends can be negligible. Suppose the charges of the bipolar plate of capacitor are $-q$ and $+q$, respectively, the charge distributed on the inside surface and outside surface of cylinder evenly. Then, the absolute value of electric charge per unit length on cylinder will be:

$$\lambda = q / L \tag{2}$$

Because of the axis symmetry of the cylindrical electric field, so the strength of electric field with the distance s from cylinder axis will be:

$$E = \frac{\lambda}{2\pi\varepsilon_0 s} \tag{3}$$

Therefore, the potential difference between polarization plates is:

$$U = U_2 - U_1 = \int_{R_1}^{R_2} E ds = \int_{R_1}^{R_2} \frac{\lambda}{2\pi\varepsilon_0 s} ds = \frac{q}{2\pi\varepsilon_0 L} \ln \frac{R_2}{R_1} \tag{4}$$

The capacitance of capacitive sensor can be obtained:

$$C_0 = \frac{q}{U} = \frac{2\pi\varepsilon_0 L}{\ln \frac{R_2}{R_1}} \tag{5}$$

When the grains are placed in, the relative dielectric constant will be ε_r, then

$$C = \varepsilon_r C_0 == \frac{2\pi\varepsilon_0 \varepsilon_r L}{\ln \frac{R_2}{R_1}} \tag{6}$$

It can be seen from those, the change of sensor capacitance has the linear relationship with the relative dielectric constant of grain, and the relative dielectric constant changes with water contained in the grain. So, the moisture content of grain can be obtained accordingly. In actual application, the difference between inside and outside cylinder radius should be minimized, which is related with system sensitivity. In the outside, a metal shield plate is installed; it can reduce the external electric field interference, reduce the distributed capacitance of human body and metal around the cylinder.

4. Design of system

Based on the principle of capacitive sensor, the diagram of detection circuit can be described as: Capacitive sensor converts the changes of grain moisture to that of capacity, after the amplification by amplifier, the analog is converted to digital and send to the MCU system. It is shown in Fig.2.

Fig.2 The design diagram of system

So, the hardware of system is designed based on microcontroller and capacitive sensor, and it is mainly composed of keyboard module, power supply module, display module, alarming module, watch dog module and time module, et al.. When the collected data is overpass the threshold, then, it enters the alarm interrupt with the LED glomming, and the buzzer will make different alarm times according to settings.

5. Conclusions

In this paper, a new grain moisture detection system is designed based on capacitive sensor. Comparing with the traditional methods, it can not only improve the detection accuracy of grain moisture, but also improve the grain automation degree in the drying process. Although the capacitive sensor with detection circuit can detect the capacitance value of grain samples, only the capacitance value detected to determine a parameter of water is not accurate. Because the capacitance moisture detection is influenced by many factors such as temperature, variety, quality, etc.. Only to conduct the comprehensive analysis to deal with these factors, the detection accuracy of moisture meter can be improved. In later studies, the depth analysis will be conducted on the factors which impact the measurement accuracy, and further enhance the robustness of the system to achieve more ideal results.

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