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Development of Probe Type Moisture Meter for Quick Measurement of Grain Moisture in Sacks

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Abstract: ***In this paper, a method for measuring the moisture content of grain has been 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.***

Index Terms: Dielectric properties, moisture content, capacitive sensor, signal conditioning.

I. INTRODUCTION

Moisture content is one of the most critical grain quality measurements because of the direct economic significance of the fraction of the total product weight that is water and because moisture content largely determines the rates at which the grain will degrade during handling and storage. Grain is bought and sold on the basis of weight. Accurate moisture determinations serve as the basis for appropriate price adjustments. If the moisture content is above the level that ensures safe storage, the grain must be dried to a suitable level. The energy and handling costs associated with drying grain and the reduction in weight of the grain during drying result in substantially reduced prices for high moisture grain. Concomitantly, overly dry grain is discounted from its weight basis and this dockage is partially justified by the increased susceptibility to breakage during handling for drier grain. The direct discounts assessed for moist grain and the indirect penalty (giving away dry matter) for dry grain are powerful inducements to deliver grain with a moisture content that is very close to the established safe storage level. Because of its significance, moisture content is determined virtually every time grain is bought and sold. An air oven method is the most common rapid reference method for grain moisture determinations. Standard air oven methods vary widely in procedures and results, but all are based on heating a known mass sample for a prescribed period of time (or until the sample no longer loses mass) at a prescribed temperature and measuring the loss of mass. The amount of mass lost is assumed to be the amount of water that was present in the sample. Unfortunately, water is not the only constituent that is driven off by heating. In the "ideal" oven method, The heating times and temperatures would be set so that the amount of no aqueous material driven off is approximately equal to the amount of water that remains after drying. Those parameters are determined by comparing the air oven method to other more basic (and more difficult) methods such as the phosphorous pentoxide (P2O5) method or the Karl Fischer method. Most air oven methods require hours to complete. Clearly, grain producers, handlers, and processors need rapid methods to assess moisture content.

Many technologies have been applied to rapid grain moisture measurement. Rapid indirect methods measure some physical parameter (such as dielectric or conductive) and predict moisture content using calibration equations or charts. These calibrations can change due to changes in crop varieties planted and seasonal variation in climatic conditions. Invariably, other sample constituents or sample geometry interfere with the signal caused by water.

Temperature usually affects both the water signal and the interfering signals. Therefore, calibration equations attempt to achieve a best fit between the measured parameters and the moisture content as defined by an accepted moisture reference method.

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II. 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 0 , the relative dielectric constant of the medium between the plates r the effective plate area A and the distance d between the two plates.

$$C = \epsilon_0 \epsilon_r \frac{A}{d}$$

If there is any change of three parameters, it will cause the changes in capacitance and can be converted to electricity by measuring circuit. In order to offer a portable, quick and precise method and instrument for measuring moisture content of coarse cereals, a moisture meter is proposed based on dielectric properties and microcontroller programming.

DC charge/discharge circuit, digital temperature sensor and equal-arm bridge circuit were used to detect the values of capacitance, temperature and bulk density of coarse cereals. Mathematical model, describing their relationship, was regressed and verified. The accuracy in predicting moisture content from obtained capacitance and temperature was tested. The results showed that the measurement precision for moisture content was ±0.5% and the response time was less than 3s when the moisture content in wet basis was within 11%-19% and in temperature of 5-40^{0}C.

III. 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].

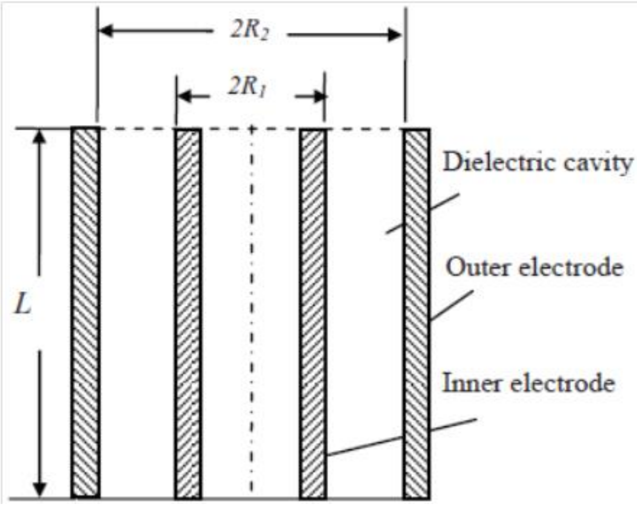

Fig.1 Structure of Concentric Capacitive Sensor

IV. 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.

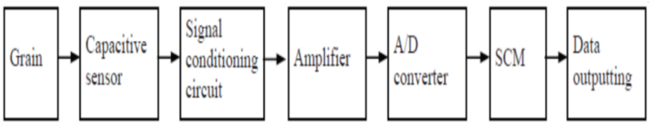

Fig.2 The design diagram of system

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, 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.

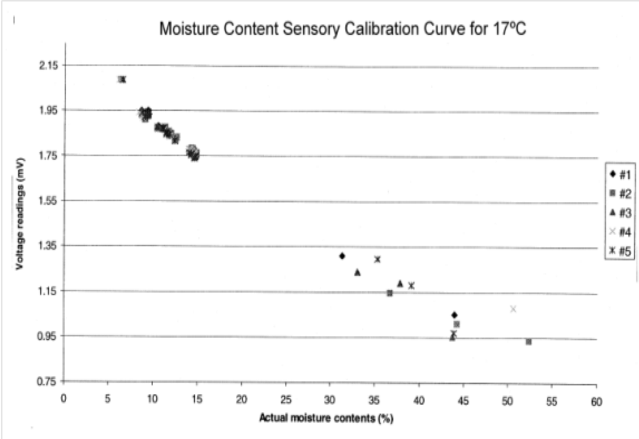

Fig 3 Calibration of data points at 17^{0}C

V. 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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