DESIGN AND EXPERIMENTAL STUDY OF MOISTURE CONTENT DETECTION DEVICE BASED ON CAPACITIVE METHOD
/
基于电容法含水率检测装置设计与试验研究

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ABSTRACT
To enable the accurate detection of grain moisture content and improve the efficiency of the drying process, a parallel-plate moisture content detection device (PPMCDD) was developed in this study. Firstly, the detection principle and influencing factors of this device are analyzed. Then the effects of three key factors as distance, thickness, relative area on the accuracy of the device were determined through simulation, and the optimal combination of parameters was obtained through analysis of variance of a regression model and response surface methodology. Finally, a simple test bench is built to verify the effectiveness of PPMCDD by comparative experiment. Through simulation and response surface analysis, the optimal combination parameters are as follows: thickness =1 mm, pacing =19.54 mm, relative area =4023.17 mm2, corresponding to the measured capacitance value of 37.676 pF. By comparative experimental analysis, it is found that the maximal relative error of the moisture content detection device evaluated in this study was 1.58%. The detection error is small, and the device exhibits high accuracy and stability and meets the design requirement.

摘要
为了提高烘干机谷物含水率的检测精度和干燥过程的效率，本研究开发了一种基于电容法的平行板式含水率检测装置(PPMCDD)。首先，根据电容检测原理和影响因素进行了分析，并对平行极板模型进行了初步设计；然后通过仿真确定了距离、厚度、相对面积三个关键因素对装置精度的影响，并通过回归模型方差分析和响应面法得到最佳参数组合；最后通过对比实验验证 PPMCDD 的有效性。通过仿真和响应面分析得到最佳的组合参数为：厚度=1mm，间距=19.54mm，相对面积=4023.17mm2，对应实测电容值为 37.676pF；并且通过对比实验分析，本研究评估的含水率检测装置的最大相对误差为 1.58%。PPMCDD 检测误差小，具有较高的检测精度及稳定性，满足设计要求。

INTRODUCTION

Moisture content is one of the important quality parameters of grain, which is related to the value of the grain. It is of great significance in the grain harvest, processing, storage and trade. When harvesting grain in the field, the grain moisture content is the key index affecting the operational performance and efficiency of the combined harvester. With the rapid development of science and technology, grain output is increasing constantly; however, for various reasons, a large quantity of grain is rendered unusable each year. *Yigit et al., (2018),* reported that defects in the drying process and in the moisture detection technology employed in grain dryers directly lead to the deterioration of many grains, which may develop high moisture content if stored for too long. Geographical location, seasons, and harvesting methods affect the moisture content of grain. If the moisture content exceeds the recommended value because of insufficient drying, the grain is affected by the excess moisture and mildew. Many scholars found that excessive drying can also damage the grain's quality (*Fan et al., 2020; Zambrano et al., 2019; Sosa-Morales et al., 2010*). Therefore, a rapid and accurate moisture content detection instrument and real-time monitoring can improve the drying process and preserve the quality of grains.

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Many scholars have made outstanding contributions to the development of moisture detection devices. *Rai et al., (2008),* used the principle of the dielectric constant changing with moisture content to develop a model for measuring moisture content. *Wang et al., (2009),* proposed an online method based on electrical capacitance tomography for the measurement of solid moisture after intermittent drying in a fluidized bed dryer. *Kandala and Puppala, (2013),* employed a parallel-plate capacitance sensor and an impedance meter to determine the average moisture content of peanuts, wheat, and other grains by measuring impedance and the phase angle. *Kim et al., (2000),* studied the effect of the permittivity of rice with moisture content of 11%–27% and wheat with the moisture content of 11%–21% in South Korea and developed a grain moisture meter that uses 10.5-GHz microwave attenuation and water density.

Jiang and Hua, (2009), studied multiple sensing mechanisms and developed an improved back-propagation neural network for the online detection of moisture in corn; the authors developed hardware for a corn moisture detection system using an STM32F103C8T6 microcontroller unit (MCU) as the core. *Casada and Armstrong, (2009),* tested the applicability and accuracy of an edge effect capacitive sensor in measuring grain moisture content. *Mcintosh and Casada, (2008),* studied a fringing field capacitive sensor for measuring the moisture content and temperature of agricultural products.

Laleicke et al., (2018), studied a four-channel planar capacitance sensor and calibrated it on maple veneer. *Fan et al., (2020),* studied the online detection method based on capacitance method through the combination of AD7745 chip and single chip microcomputer, and proved the correlation between capacitance change and moisture content.

The accuracy of grains moisture content detection performed using dryers devices is low because the calculations do not account for individual influential factors. Furthermore, such systems often do not allow for the real-time transmission of information. In this paper, we describe a parallel-plate moisture content detection device (PPMCDD) developed on the basis of capacitance method, which allows for real-time monitoring of the test bench, optimization of structural parameters, performance testing, and calibration of the platform based on individual factors. The consideration of the aforementioned capabilities in the design and development contributed to the device's high accuracy and reliability.

MATERIALS AND METHODS

Measuring Principles and Factors Influencing PPMCDD

Grain moisture detection methods can be divided into two categories: direct detection and indirect detection *(Nelson et al., (2016)*. Direct detection methods include drying measurement and chemical measurement, which are often used for the detection of moisture content in small amounts of grain or laboratory samples. Indirect detection methods include resistance, capacitance, microwave, infrared, nuclear magnetic resonance, neutron, and radiofrequency impedance methods. The PPMCDD presented in this paper employs a design based on the principles of capacitance sensing. Compared with a cylinder-type moisture detection device, the proposed device requires less space, has a simpler structure, is more convenient and cost inexpensive to install, and has fewer requirements for installation related to the surrounding working environment. The basic structure of the PPMCDD consists of two metal plates, as illustrated in Figure 1. The basic formula for calculating the capacitance of the parallel plates is as follows:

$$C = \frac{\varepsilon_0 \varepsilon A}{D} \tag{1}$$

Where:

ε_0 is the permittivity of vacuum (8.85 × 10^{-15} F/m), ε is the relative permittivity between the two plates, A is relative area of the plates (mm^2), D is spacing between the plates (mm).

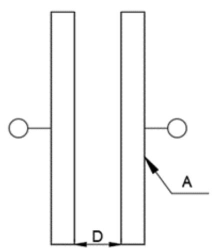

Fig. 1 - The basic structure of parallel plates

To test the performance of the PPMCDD, the composition of the media inserted between the parallel plates can be simplified into the grain, water, and air to facilitate our study. The simplified model is illustrated in Figure 2, and Figure 3 presents the size of the gap between the parallel plates.

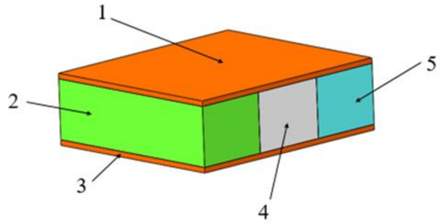

Fig. 2 - Equivalent model of medium between parallel plates
1 - Upper plate; 2 – Grain; 3 - Lower plate; 4 - Air 5 - Water

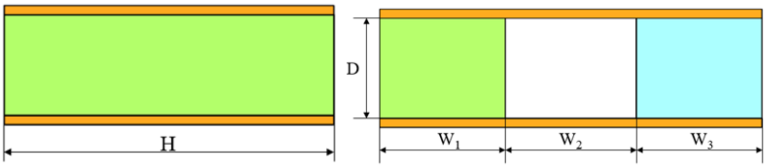

Fig. 3 - Structural dimensions between parallel plates

The three relative permittivity values of the parallel-plate device are ε_1, ε_2, and ε_3, and the corresponding capacitance values of the cavity are C_1, C_2, and C_3. Therefore, the total capacitance of the two plates can be calculated as follows:

$$C=\frac{\varepsilon_0 A}{D}\left(\frac{A_1}{A}\varepsilon_1+\frac{A_2}{A}\varepsilon_2+\frac{A_3}{A}\varepsilon_3\right) \tag{2}$$

Where:

A_1, A_2, and A_3 are relative areas of the grain, water, and air media.

The moisture content w of grain is then calculated as follows:

$$w=\frac{m_2}{m_1+m_2}\times 100\%=\frac{\rho_2 A_2}{\rho_1 A_1+\rho_2 A_2} \tag{3}$$

Where:

m_1 and ρ_1 are mass and density of the grain in the parallel plate, m_2 and ρ_2 are mass and density of the water in the grain.

Korkua and Sakphrom, (2020), concluded that the density of water is $\rho_2=1$ and the dielectric constant of vacuum is $\varepsilon_0=8.85\times 10^{-12}\,\mathrm{F/m}$. A_3/A represents the pore ratio of the parallel plates and is denoted by e. In the final design of the PPMCDD, A and D are fixed values and are therefore treated as constants. With $k_0=\frac{\varepsilon_0 A}{D}$, the aforementioned formula (2-3) can be presented as follows:

$$C=k_0\varepsilon_1+k_0\left(\varepsilon_2-\varepsilon_1\right)\left(1-e\right)\times\frac{w\rho_1}{1+w\left(\rho_1-1\right)}+k_0 e\left(\varepsilon_3-\varepsilon_1\right) \tag{4}$$

According to Eq. (4), the moisture content of grain exhibits a one-to-one correspondence with the capacitance value. From the capacitance, the moisture content of the grain at a given temperature can be calculated. However, because the permittivity between the parallel plates changes with the ambient temperature, a temperature sensor is required and can be used by the MCU to accordingly adjust the dielectric constant. When grain moisture is measured using a PPMCDD, the pore ratio is affected by the bulk density of the grain. Therefore, the bulk density must be accounted for to minimize the effect of the pore ratio on the accuracy of the collected data. To summarize, when the PPMCDD is used to detect grain moisture content, the reported values are affected by the ambient temperature and bulk density of the grain in the sensor. Therefore, in the design and optimization of a sensor, these factors should be considered to maximize the detection accuracy and practicability of the device.

Material Preparation and Test Methods

A national standard drying method (the 105°C constant weight method) was used to measure the moisture content of Anhui 185 indica hybrid rice planted in the vicinity of Lu'an in Anhui province. The main test equipment used comprised Petri dishes, a precision balance, and an electric air-drying oven. The test was conducted as follows. First, clean Petri dishes were placed into an electric blast box, dried for 30 min, and placed into a drying container for cooling. The Petri dishes were weighed using a precision balance; the weight of an empty Petri dish was recorded as M_1. An appropriate amount of rice was placed into each dried Petri dish for weighing. After drying, the rice was weighed, and the weight was recorded as M_2. To ensure the accuracy of the experimental results, the total amount of rice to be measured was evenly divided into three parts, which were dried and measured successively, and the average value of the measurements was recorded.

The Box–Behnken method was used in this test to determine the optimal device parameters for measuring capacitance (*Boateng et al., 2021; Khatib et al., 2021*). The factors considered comprised the plate spacing *D* (mm), plate thickness *H* (mm), and relative area *A* (mm^2). The Box–Behnken method was used to design a three-level test accounting for these factors, and the capacitance measured by the PPMCDD was considered the response value. The influencing factors and their optimal levels were determined through simulation. The optimal levels of each of the factors are presented in Table 1.

Table 1

Factor level table

Order	Independent variable	Value of each factor level		
		1	0	-1
1	Distance (mm)	30	20	10
2	Thickness (mm)	3	2	1
3	Relative area (mm2)	6000	4500	3000

RESULTS

Data processing and analysis

Design-Expert software was used to process the test data of Table 1. The test results are presented in Table 2.

Test results **Table 2**

Source	Sum of squares	df	Sum of mean square	F-value	P-value
model	200.51	9	22.28	45.26	0.0001
X1	52.69	1	52.69	107.04	0.0001
X2	7.16	1	7.16	14.55	0.0066
X3-	0.42	1	0.42	0.86	0.3846
X1X2	1.11	1	1.11	2.26	0.1763
X1X3	20.34	1	20.34	41.33	0.0004
X2X3	6.30	1	6.3	12.8	0.009
X12	10.53	1	10.53	21.4	0.0024
X22	37.94	1	37.94	77.08	0.0001
X32	53.49	1	53.49	108.68	0.0001
Residual	3.45	7	0.49		
Lack of fit	2.34	3	0.78	2.83	0.1703
Pure error	1.10	4	0.28		
Cor total	203.96	16			
R^2=0.9831, *Adj* R^2=0.9614					

[a] X_1=Thickness (mm), X_2=Distance (mm), X_3=Relative area (mm^2).
[b]A p-value <0.01 was considered extremely significant, a p-value ≤0.1 was considered significant, and a p-value >0.1 was considered nonsignificant.

After nonsignificant factors were removed, the regression equation for the capacitance Y_c was determined:

$$\begin{aligned}Y_C &= 14.36375 - 4.05925X_1 + 0.81333X_2 - 9.42367\times10^{-3}X_3 \\ &+0.05275X_1X_2 + 1.50333\times10^{-3}X_1X_3 + 8.36667\times10^{-5}X_2X_3 \\ &-1.58175X_1^2 - 0.03002X_2^2 - 1.58411\times10^{-6}X_3^2\end{aligned} \tag{5}$$

Where: Y_c is capacitance value (pF), X_1 is plate thickness (mm), X_2 is plate spacing (mm), X_3 is relative area (mm^2).

The fitted model accurately described the relationship between measured capacitance and the characteristics of the parallel plates, as indicated by the table 2 results that were significant at $p < 0.01$. The effects of plate thickness ($p = 0.0001$) and plate spacing ($p=0.0066$) on capacitance were extremely significant; however, the effect of relative plate area was nonsignificant ($p = 0.3846$). The calculated coefficient of determination ($R^2 = 0.9831$) and adjusted coefficient of determination ($Adj\ R^2 = 0.9614$) indicate that the proposed model is highly accurate in predicting capacitance.

Optimization of Structural Parameters

The edge effect of a parallel-plate capacitor affects the moisture content detected by the device. The edge effect is mainly caused by changes in the electric field lines from parallel to open lines as the width of the space between the plates increases; the edge effect causes the distribution of the electric field lines to concentrate at the edges of the plates, resulting in additional capacitance. Therefore, optimization of the plate structure is key to minimizing the influence of the edge effect and improving the accuracy of capacitance detection.

The effects of the interactions among plate thickness, spacing, and relative area on capacitance, as determined through the analysis conducted using the Design-Expert software, are presented in Figure 4. The effect of the interaction between plate thickness and plate spacing is nonsignificant; however, the interactions of plate spacing and plate thickness with relative area strongly affect capacitance measurement. As the plate spacing decreases and the plate thickness and relative area increase, the measured capacitance increases.

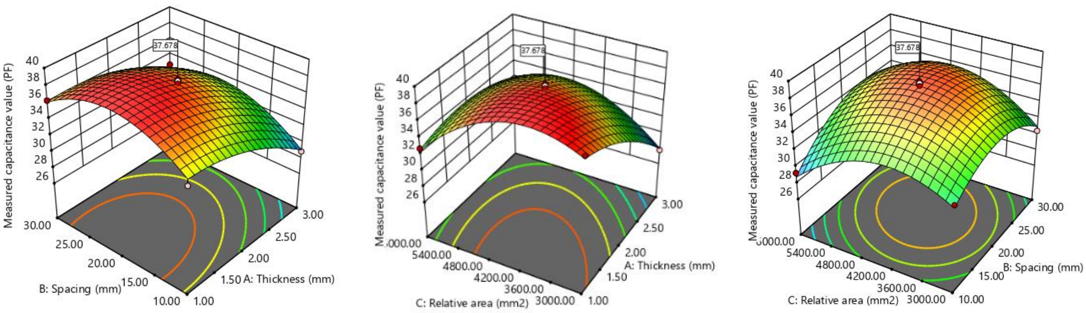

Fig. 4 - Influence of interaction of various factors on capacitance value

According to the regression equation and the response surface diagram presented in Figure 4, the relative area of the parallel plates exerts a nonsignificant effect on capacitance. Nevertheless, a smaller relative area is associated with less friction damage and longer service life. Therefore, the relative area should be minimized. The following optimization model was obtained with consideration given to the edge effect, regression equation, and response surface:

$$\begin{cases} 30 \le Y \le 40 \\ MinA \\ 1 \le D \le 3 \\ 10 < H \le 20 \end{cases} \tag{6}$$

The optimal dimensions of the parallel plates were calculated using the Design-Expert software to be a plate thickness of 1 mm, plate spacing of 19.54 mm, and relative area of 4023.17 mm^2. The capacitance value corresponding to these parameters is 37.678 pF, as indicated in Figure 5.

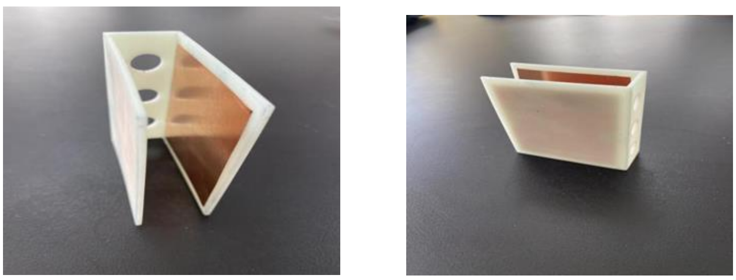

Fig. 5 - Trial-produced parallel-plate structure

Structural Design of PPMCDD

Through the field investigation and theoretical analysis of grain elevators, we determined that the optimal position for a moisture detection device is at the head of the grain elevator. This device position ensures that a sufficient amount of grain enters the sampling box and that the grain sampling is random. Just before the grain enters the detection chamber of the parallel-plate device, the upper polar plate is opened by a push-pull electromagnet to allow the grain to enter. To avoid clogging caused by grain accumulation, a triangular structure is fixed on the upper plate. When the parallel-plate detection cavity is filled with grain, the upper polar plate is closed, and the triangular structure allows the remaining grain to return to the granary without interrupting grain circulation. After the detection cycle is completed, the lower polar plate opens to allow the grain to return to the granary through an inclined chute. Subsequently, the lower polar plate is closed, the upper polar plate is opened, and the next detection cycle begins. This process is illustrated in Figure 6.

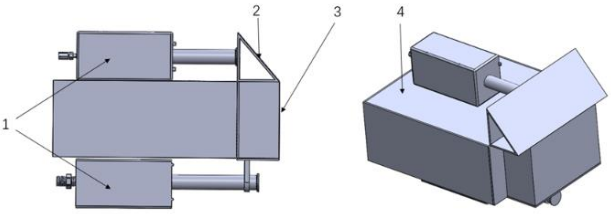

Fig. 6 - Structure diagram of PPMCDD

1 - Push-pull type electromagnet; 2 - Tripod construction; 3 - Detection cavity; 4 - Circuit board seal box

Establishment of Moisture Content Model

Frequency Processing

The change in capacitance between the plates of the parallel-plate device described herein is converted into a change in frequency, and the moisture content of a grain sample is calculated indirectly from this difference in acquisition frequency. The moisture content of the rice was 10%–30%, and the frequency range was 8–40 kHz. The frequencies measured by the parallel-plate sensor indicated that frequency drift had occurred during the moisture detection process. Because of the interference from the motion of the rice and the vibration of the machine during the drying process, the moisture content within the rice becomes unstable after the rice enters the parallel-plate detection cavity, which leads to fluctuations in capacitance and indirectly causes fluctuations in frequency.

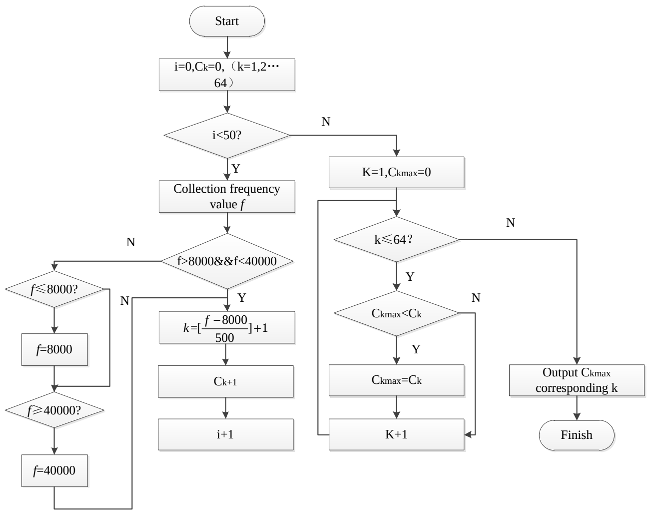

Fig. 7 - Frequency acquisition and processing

On the basis of the aforementioned problems and a study by *Huang et al., (2015),* on fuzzy logic–based multi-input data processing algorithms for nuclear power plant control systems, we implemented feature coding for our device to evaluate frequency. As illustrated in Figure 7, when a set time delay expires, the parallel-plate device measures the frequency. When the frequency is <8 kHz, it is read as 8 kHz, and the coding value is 1. When the measured frequency is >40 kHz, the frequency is read as 40 kHz, and the coding value is 64. When the frequency is in the range of 8–40 kHz, the corresponding coding value is in the range of 1–64. This method can be used to address the problem of frequency drift and improve the measurement accuracy of the parallel-plate device. The frequency coding value is calculated as follows:

$$K = \left[\frac{f - 8}{0.5} \right] + 1 \tag{7}$$

Where:

K is coding value, *f* is the frequency (kHz), [ ] is the integer notation.

Moisture Content Model

In this study, samples of indica hybrid rice (Anhui 185) with various moisture content were obtained from the Lu'an area of Anhui province to test the proposed device. The moisture content of the Anhui 185 rice was 14%–21%, and the rice temperature was between 20°C and 36°C. We used the KETT Grain PM-8188-NEW grain moisture detecting (measurement range: 8%–35%, error: <0.5%) to obtain moisture content measures for each of the rice samples. The rice samples with different moisture content were placed into 20 x 14 mm bags, which were sealed, stored, and labeled with their corresponding moisture content.

Fig. 8 - Calibration experiment diagram

To more accurately simulate the drying environment, we tested the detection of the PPMCDD in an electric air-drying oven, as illustrated in Figure 8. We first adjusted the electrothermal blowing temperature to the minimum temperature required by the experimental design. We subsequently debugged the PPMCDD placed in the drying oven. When the temperature of the oven met the requirements of the experimental design, the rice was placed in the sampling box, and random sampling of the rice was conducted. We observed and recorded the temperature, coding value, and moisture content presented on the display panel, as presented in Table 3.

Table 3

Coded values detected by weight and temperature of rice with different moisture content

Order	Coded values	Weight [g]	Temperature [℃]	Moisture content [%]	Order	Coded values	Weight [g]	Temperature [℃]	moisture Montent [%]
1	50	256	35.3	17.64	31	49	256	25.6	17.89
2	49	260	35.1	17.71	32	51	253	26.9	16.56
3	50	253	34.6	17.58	33	50	254	25.7	17.68
4	50	248	34.4	17.52	34	51	256	29.6	16.57
5	50	255	33.2	17.53	35	51	258	28.4	16.72
6	50	251	32.6	17.45	36	51	259	27.6	16.84
7	50	252	32.3	17.5	37	50	254	27.8	17.09
8	50	258	31.8	17.46	38	51	251	27.3	16.82
9	50	256	31.3	17.25	39	48	253	32.5	18.56
10	50	258	28.9	17.23	40	51	254	35.6	16.52
11	51	254	22.3	16.83	41	54	259	31.6	14.53
12	51	258	21.4	16.78	42	53	257	32.7	14.86
13	51	253	20.4	16.56	43	53	256	31.8	14.95
14	46	259	28.6	20.56	44	51	253	29.6	16.86
15	47	254	21.4	19.78	45	50	251	28.3	17.51
16	47	256	28.3	19.67	46	51	254	27.6	16.59
17	47	253	35.6	19.45	47	49	258	30.8	17.83
18	47	258	32.6	19.23	48	52	256	31.2	16.24
19	47	256	28.9	19.58	49	51	257	30.6	16.55

Order	Coded values	Weight [g]	Temperature [℃]	Moisture content [%]	Order	Coded values	Weight [g]	Temperature [℃]	moisture Montent [%]
0	48	251	27.6	18.98	50	46	259	30.9	20.13
21	49	253	25.6	18.56	51	46	253	32.4	20.23
22	48	252	28.4	18.64	52	47	258	32.7	19.86
23	49	256	27.2	18.13	53	48	260	31.7	18.64
24	49	254	28.3	18.25	54	47	263	29.3	19.61
25	51	253	24.9	16.54	55	51	254	32.5	16.79
26	52	259	26.8	16.23	56	49	259	34.6	17.69
27	51	257	27.6	16.52	57	51	254	33.6	16.62
28	52	256	25.1	15.75	58	48	256	33.8	18.56
29	53	253	26.7	15.45	59	47	257	29.6	19.83
30	53	254	25.4	15.23	60	48	258	28.7	18.67

The temperature range of the oven was 20°C–35°C, and the moisture content of rice samples was between 14%–21%. Each group of samples was measured three times to more accurately evaluate the device's detection ability. Regression equation fitting was performed using Origin software, and the resultant fitting equation is as follows:

$$W = -0.01492G - 0.01372T - 0.72828K + 58.01498 \quad (8)$$

Where: W is the moisture content (%) of the rice, G is the weight indicated by the pressure sensor, T is the temperature displayed by the temperature sensor, K is the frequency coding value.

The coefficient of determination (R^2) of Eq. (8) was 0.981, and the comprehensive error rate was 0.0163. The moisture content of each rice sample was calculated using Eq. (8), and the calculated value was displayed in real-time on the display panel.

Experimental Platform

In this study, Laboratory Virtual Instrument Engineering Workbench (LabVIEW) was used to design an upper computer display panel, grain temperature, weight, and moisture content data were collected by the STM32 MCU and transmitted to the upper computer LabVIEW for display. The panel consisted mainly of three waveform chart displays, a sliding column moisture content display, and a moisture content alarm. The experimental platform is illustrated in Figure 9.

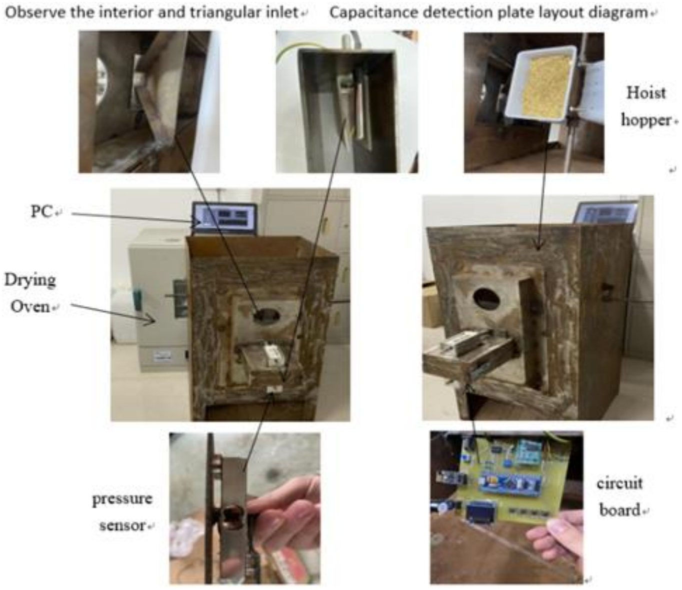

Fig. 9 - Experimental platform

Experimental Verification

To test the reliability of the model, 40 rice samples with 8%–35% moisture content were randomly and successively fallen into the detection chamber through the grain hopper. After data were collected for each sample, the results were compared with values obtained using the international standard drying method. Each sample was tested 10 times, and the average value was used for comparison, as illustrated in Figure 10.

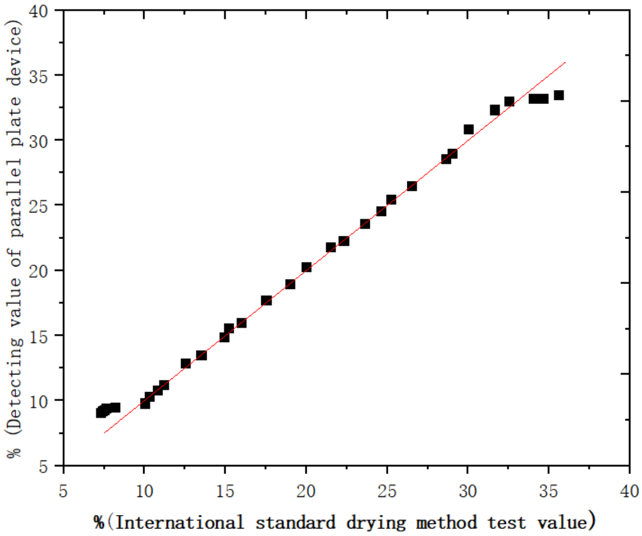

Fig. 10 - Comparison of measured values by drying method and measured values by the detection system

As illustrated in Figure 10, when the moisture content of a sample is 10%–28%, the results obtained using the PPMCDD are generally consistent with those obtained using the international standard drying method. When the moisture content of a sample is >28% or <10%, the results obtained using the device yield large errors in comparison with those obtained using the international standard drying method. Therefore, the moisture detection range of the PPMCDD developed in this study is 10%–28%.

Experimental Analysis

Detection accuracy is a key indicator of a sensor's practical applications. In this study, the PPMCDD and the international standard drying method were used to test rice samples with various moisture content. Test data were collected and analyzed to compare the methods.

The test was conducted at 24°C and 50% relative humidity. The international standard drying method was used to prepare 10 rice samples with moisture contents of 12.45%, 15.12%, 17.45%, 18.53%, 19.63%, 21.34%, 23.65%, 25.19%, 26.58%, and 27.63%. The PPMCDD was used to conduct 10 tests for each sample, and the average value for each set of test data for each sample was calculated, as listed in Table 4. When the moisture content of a rice sample was low, the maximal relative error of the data obtained using the proposed device was also low; when the moisture content of a rice sample was high, the maximal relative error of the corresponding data was also high. However, when the moisture content of the rice sample was >21%, the maximal relative error of the PPMCDD and the international standard drying method was the same, and the maximal relative error of the device was 1.58%, which indicates the great effect of employing the device for moisture content detection.

Table 4

Experimental results of detection of the device

Values measured by standard drying method /%	PPMCDD test value /%	Maximum relative error/%
12.45%	12.29%	1.31
15.12%	14.93%	1.28
17.45%	17.21%	1.35
18.53%	18.27%	1.41
19.63%	19.00%	1.52
21.34%	21.67%	1.53
23.65%	24.02%	1.55
25.19%	25.65%	1.54
26.58%	26.32%	1.58
27.63%	28.06%	1.56

CONCLUSIONS

In this study, a model of capacitance parallel-plate detection was established, and a regression equation for capacitance was derived through a combination of quadratic regression and orthogonal selection. After adjustment for the edge effect, the optimal combination of plate parameters was determined to be a plate thickness of 1 mm, plate spacing of 19.54 mm, and relative area of 4023.17 mm², which correspond to a capacitance value of 37.678 pF.

Origin software was used to fit the collected data and obtain the formula for calculating the moisture content of rice. The coefficient of determination (R^2) of the formula was 0.981, and the comprehensive error rate was 0.0163.

This paper takes a test bench that was performed as a static test. The results revealed that the detection range and maximal relative error of the PPMDD were 12%–28% and 1.58%, respectively. The detection error of PPMDD is small, and the accuracy and stability of the device are high.

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