Research and Development of Intelligent Drying Detection Technology for Machine-Made Sand

Shaoying Jia*, Xiong Zhang and Yelin Lu

Huahao Zhongneng Testing Technology Group Co., Ltd. Beijing 100086, China

Abstract. This paper aims to develop a high precision variable dielectric constant capacitor detector for mechanical sand water content testing. The non-contact on-line test method can effectively solve the problems of low repeatability of test data, large hysteresis error and poor linearity due to the non-uniform water content. In terms of hardware, CAV444 is a high-precision integrated chip, which matches the corresponding test circuit. The system communicates with PC through serial interface and implements the man-machine interface of PC system based on VS. Secondly, the distribution map method is used to measure the water content of machine-made sand, and the error analysis is carried out. The test shows that the output of the capacitive hygrometer is 0-5 V. The delay time should not exceed 0.15%. The repetition rate was within 0.33%. The measurement accuracy of this method is less than 3.52%.

Keywords: mechanical sand; water content; Intelligent monitoring; on line monitoring; capacitor type sensing.

1. Introduction

In cement production, the measurement of water content of mechanical sand is the key factor affecting the final quality of concrete. Using the traditional drying method to determine the moisture content is not only time-consuming but also easy to cause the sample is not typical. This method can realize the real-time monitoring of moisture content with higher frequency, better representativeness, higher real-time performance and lower error. In cement production, an important technical development is to change the traditional drying method to on-line moisture measurement, in order to improve the real-time moisture measurement and improve the accuracy of match comparison. Although there are special workers to test the moisture content of fine aggregate powder in the production of concrete mixing field, it can only be carried out twice a day. In order to obtain the data faster, the fine aggregate is usually heated by microwave, which will cause the complicated process, resulting in artificial errors, thus affecting the water content of the product. In the laboratory, the oven is usually used for determination, also known as the standard oven drying, is currently a measurement method widely used in the world. In this case, real-time monitoring technology comes into being [1]. The method of measuring moisture and moisture had been used since the 1940s, beginning with the measurement of moisture in soil and paper. At the beginning, the testing equipment was very simple, consisting only of an antenna and a waveguide containing samples, and the accuracy of the testing equipment was very poor. Therefore, before this, Online measurement of water content has not been well developed. Due to the progress of technology and the development of technology, the determination of moisture content has been widely used, such as crude oil, seeds, tobacco, etc., the application of circuit is more and more widely, MOSFET and IC and other modern components come out, so that the test method has been greatly developed. The basic principle of microwave testing has also been developed from the original resonant cavity method to microstrip technology, expanding from 300 KHz to 20 GHz, and the test field has changed from the original test without EMI to the harsh production conditions. In this paper, based on the capacitor, the use of monolithic microprocessor technology, developed a mechanical sand moisture detection device suitable for large-scale engineering construction site, real-time detection from the source, wear small, high precision, can effectively reduce the cost, improve production efficiency, for enterprises to obtain good economic and social benefits.

2. Design of intelligent water content measurement system for machine-made sand

2.1 Circuit Design

Microwave mixing technology and IQ mixer (AD8349) are used to mix the basic frequency of 400 KHz and the carrier signal of 2.4 GHz and transmit and modulate in the

* Corresponding author: 34080575@qq.com

transmission array. Demodulation is performed by IQ demodulator (AD8347) and compared with oscilloscope. Figure 1 shows the high frequency circuit of the microwave.

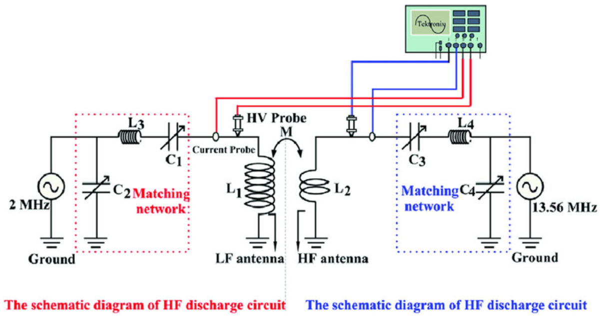

Figure 1. Schematic diagram of high frequency circuit

The microwave circuit's electronics include ADF4351, filter, isolator, power divider, amplifier, Q demodulator, IQ mixer, and so on. ADF4351 is a kind of integrated VCO with external filtering and baseband frequency and has the effect of noise reduction. It can be operated by pins and software and has an auxiliary transmitting power source [2]. The filter used in the test is a band-pass filter, only 2.45 GHz+500 MHZ microwave signal can pass through, other interference is eliminated. The experiment uses a 14 dBi antenna, which is characterized by a single direction of radiation and electromagnetic wave receiving especially strong, its transverse and longitudinal angles are 30°; IQ demodulators are mainly used to modulate and filter mixed signals to get a weakened baseband. The IQ mixer is used to mix the base frequency of 400 KHz at 2.4 GHz with the carrier signal at 2.4 GHz. Here, the IQ mixer and demodulation machine works as shown in Figure 2.

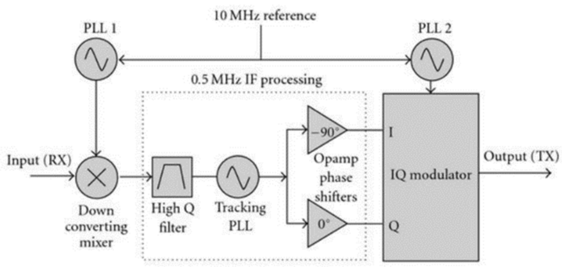

Figure 2. Schematic diagram of IQ mixer

The incoming signals are two orthogonal signals. They're called $B\cos\omega_B t$ and $B\sin\omega_B t$. Carrier signals are $A\cos\omega_A t$ and $A\sin\omega_A t$, and Y signal is obtained after the signals are multiplied and added by the multiplier and adder respectively. Its expression is shown in Equation (1)

$$Y=\frac{1}{2}\left(B\cos\omega_B t \bullet A\cos\omega_C t - B\sin\omega_B t A\sin\omega_C t\right) \quad (1)$$
$$=\frac{AB}{2}\cos\left(\omega_B+\omega_C\right)t$$

The measurement of phase shift is the key to determine the water content of fine bone. In the experiment, the thickness of machine-made sand should be less than the wavelength of microwave as far as possible [3]. Due to the short wavelength and poor penetration of microwave, too thick sample will lead to microwave signal reflection, affecting the experimental results. In addition, certain phase compensation is required for the calculated phase shift results, as shown in Equation (2).

$$\Delta\phi=\phi_s-\phi_0-2\pi n \quad (2)$$

2.2 Working principle of the sensor

The purpose of this paper is to detect the change of capacitor capacity due to the difference of sand moisture content by using the boundary action between the two ends of the capacitive sensor, so as to reduce the sand wear. In addition, it is also necessary to develop a testing mechanism, which can install the capacitive sensor based on the edge action principle into the feed hole and detect the water content of the feed sand in real time. The CAV444 chip is used to collect the capacitor's electric quantity, and then the obtained electric quantity is converted into a voltage signal that can be read through the signal conversion circuit [4]. Then STM32 is used as the main control unit. By communicating with PC and displaying it on PC, real-time and real-time detection of flow can be realized. This capacitive sensor has excellent accuracy and is harmless to human body. It can measure the moisture content of sand grains in real time to improve the quality of cement after mixing.

3. System architecture and function realization

3.1 System Architecture

This project makes use of the edge effect between the two plates of the capacitor sensor, so that the sand can measure the change of the capacitance value caused by the different water content of the sand without touching the plate, and effectively reduce the wear. At the same time, it is fixed at the feed port to realize real-time measurement of the water content of the feed sand (Figure 3). The variation of capacitance value detected by the measuring device designed based on capacitance edge effect can be changed by using sand with different water content [5]. The capacitance is collected by CAV444 chip, and then converted into readable voltage signal output through the supporting signal conversion circuit. After a series of circuit design, calibration and fitting including STM32 main control chip circuit, general voltage regulator power circuit, USB program download circuit, clock reset circuit, etc., the serial port is directly communicated with the PC end, and displayed on the display screen. Finally, the online real-time measurement of the mechanical sand water content passing through the measuring plate is realized.

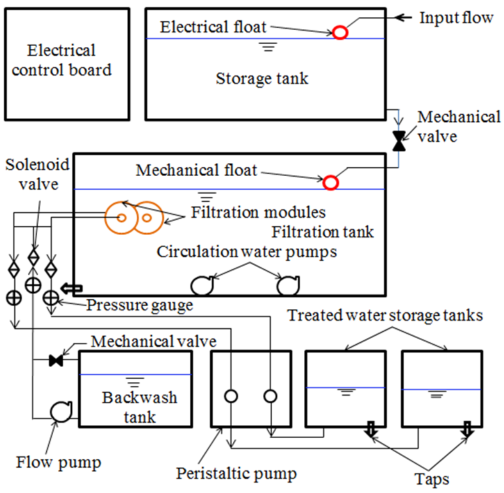

Figure 3. System block diagram

3.2 Design of data acquisition module

On this basis, the test results of the capacitive sensor are used to convert the capacitors of CAV444 into a voltage value, which is compared with the input reference voltage and then fine-tuned. The architecture of the entire data acquisition module is shown in Figure 4.

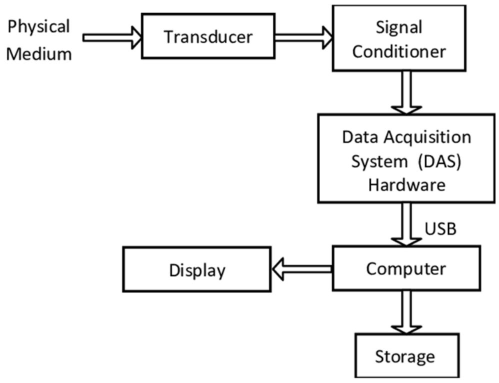

Figure 4. Structure diagram of data acquisition module

3.3 Design of data processing module

Due to its high sensitivity, high digital-analog transformation is required. The moisture content of mechanical sand is very low and difficult to determine accurately. The ADS1115 is a miniature 16-bit ADC with a built-in ADS1115 (ADC) converter chip that can transmit signals through CI2 compatible CI2 ports. Suitable for -40~-140 degrees Celsius [6]. The high measurement accuracy of 16 bits ensures the correctness of the system. The transistor pins of the ADS1115 are shown in Figure 5.

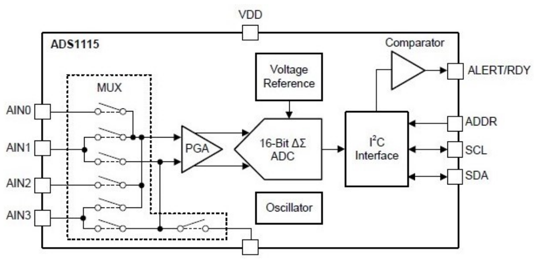

Figure 5. Pin diagram of ADS1115 chip

4. Test platform implementation

4.1 Static test platform

Figure 6 shows a microwave test bench. A sample box loaded with mechanical sand is placed in the middle of two antennas with the same orientation, and it is fixed on a horizontal aluminum plate with screws to ensure that the two antennas are on the same plane, so that the sending and receiving area of the two antennas is maximum, and the maximum microwave signal is obtained [7]. Aluminum alloy sheet is connected with the movable sliding device with screws, easy to adjust the test, so that it can move freely on the sliding track, so that the distance between it and the mechanical sand can be adjusted arbitrarily, to achieve the maximum frequency signal; After measuring the distance between the antenna and the mechanical sand, a locking mechanism is set on the sliding bar, so that the sliding block can be fixed at any time, so as to ensure the influence on the test piece and test piece during the test process, and reduce the deviation in the test process. The biggest advantage of the whole test platform is that it can be adjusted at will. When changing the antenna and adjusting the distance between the mechanical sand and the mechanical sand, the sliding device can be used for free movement, which greatly simplifies the debugging process of the test.

Figure 6. Microwave test platform

4.2 Dynamic test platform

In order to meet the requirements of industrialization, it is necessary to simulate the production situation of the enterprise and adopt dynamic method to test the determination of machine-made sand moisture. Mechanical sand is fed into the metering bucket through the silo. In order to monitor the water content of machine-made sand in real time, an antenna must be set at the outlet side [8]. In order to imitate the actual output, the materials in the silo are compressed according to a certain size. The overall height of the silo is 1800 mm, the width is 750 mm, the mouth of the silo is 1000 mm from the ground, the length of the discharging hole is 300 mm, the width is 200 mm, and the silo is loaded with 225 kg of machine-made sand. The mechanical sand was pushed down from the ground by means of hook traction. The overall silo is in the shape of a bucket, and mechanical sand is accumulated in the silo for a long time due to its large surface area, which is easy to adsorb on the side wall of the silo. It must be measured after mechanical sand filling (FIG. 7) [9].

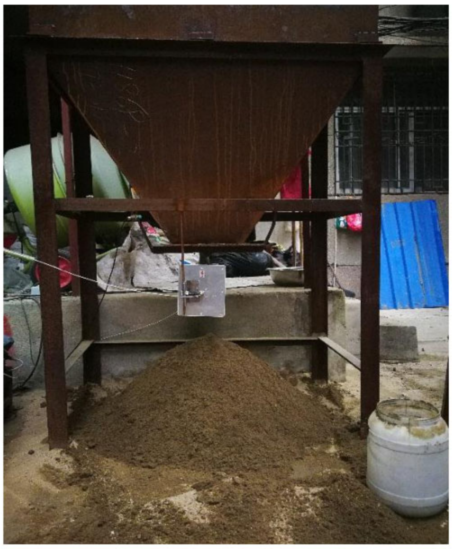

Figure 7. Front view of dynamic test platform

5. System inspection

When correcting, there must be more than two centers. Each point is a non-converted reading taken by the material flow through the sensor as the actual moisture of the material after drying is obtained from the sensor. When using Hydro-Prob II for calibration, ensure that the materials tested and samples collected are representative. This is usually done using Hydronym's own Hydro-Com software and the calibrated data is stored in the sensor. As an example, data correction is performed by obtaining data from two points. As can be seen in FIG. 8, if the range of moisture content measured during calibration is relatively large, and there is a 0.3% deviation in the measured results in the high moisture area, the 0.3% deviation will decrease with the increase of moisture content (FIG. 8).

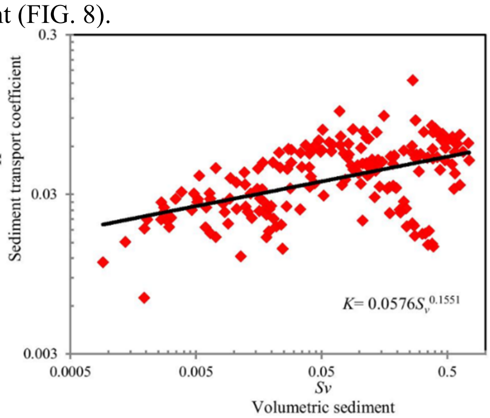

Figure 8. Schematic diagram of error control

6. Conclusion

This paper adopts a capacitive sensing probe with quadratic boundary effect, which can be used to detect the change of capacitance due to the difference of water content, so as to reduce the wear on the sand grains. By installing it in the feed port, the moisture content of the material can be detected in real time. Through different moisture content, the capacitance between the plates can be affected by different media.

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