

Research on Measuring System of Sodium Hydroxide Concentration in Impregnation Solution Based on Ultrasonic Velocity Method

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Abstract: A sound velocity measurement system based on FPGA was designed. The time of flight was calculated by using the wave crest of ultrasonic signal to achieve high precision measurement of sound velocity. The high-speed data communication between field programmable gate array (FPGA) and host computer system is realized by using AN9238, DPRAM and 485 communication port. On the basis of FPGA hardware, high-speed AD chip is used for sampling to complete data storage and processing. The experimental results show that compared with the standard system, the time-of-flight measurement accuracy of the designed system is 0.1 μ s, and the measurement accuracy of the solution sound velocity is better than 2 m/s, which verifies the reliability of the scheme.

Keywords: Time of flight measurement; Field programmable gate array; Ultrasonic sound velocity; Concentration detection.

1. Introduction

As a new type of fiber, regenerated cellulose fiber has abundant raw material resources, excellent performance and cheap price, which can partially or even completely replace natural fiber to a certain extent. Cellulose fiber, as a fiber with excellent performance, has been widely concerned by people. Viscose fiber is a kind of regenerated cellulose fiber. It is made of natural fiber wood and cotton short wool as raw materials, made of viscose through alkalization, aging, yellowing and other processes, and then made of fiber by wet spinning. It belongs to the range of biomass fiber and is an important chemical fiber product for the sustainable development of circular economy. The viscose fiber production process basically includes the following basic units: impregnation, pressing, crushing, aging, sulfonation, spinning. At present, the most widely used method for removing hemicellulose is alkali treatment[1].

Pulp and sodium hydroxide solution impregnation, there are two main purposes, one is to make cellulose and sodium hydroxide reaction, alkali cellulose as viscose fiber raw materials; The second is to remove the hemicellulose in the slurry, which has a great impact on the process and product quality. Therefore, the stability and control of sodium hydroxide solution concentration are crucial to product quality. If continuous measurement and automatic control can be carried out, it will play an important role in improving the quality of viscose fiber.

For the measurement and control of sodium hydroxide solution concentration, regular sampling off-line analysis and chemical titration are generally adopted in the factory. Although the analysis results obtained in this way have high accuracy, the analysis time interval is long, and the specific situation of sodium hydroxide concentration cannot be grasped and controlled in time. There is a lag, which greatly affects product quality and enterprise benefits. And the working environment of manual sampling analysis is bad, which increases the labor intensity of workers.

The sodium hydroxide concentration detection system is based on the above problems. It can realize on-line

measurement and control of concentration in a large concentration range, and the measurement is fast and accurate. It can be automatically adjusted according to the preset concentration target value. It is easy to operate, stable and reliable, low measurement cost, and has a wide range of industrial application prospects.

2. Principle of Concentration Measurement Based on Ultrasonic Velocity Method

The basic principle of ultrasonic measurement is to use the acoustic characteristics of the medium, such as sound velocity, attenuation coefficient, acoustic impedance and other parameters. Some industrial non-acoustic quantities are determined by studying the relationship between acoustic parameters and the measured medium. Based on the acoustic parameters, three methods of measuring liquid concentration, namely sound velocity method, sound attenuation method and acoustic impedance method, are proposed. The sound velocity method is more sensitive to the change of the concentration of the immersion solution, and the change of the concentration can be timely reflected by the sound velocity value. Acoustic attenuation method is suitable for suspension with large acoustic attenuation, such as mud, pulp and so on. Acoustic impedance method is used to measure hardness, strength and viscosity. Therefore, the ultrasonic velocity method is selected to measure the concentration of sodium hydroxide[2].

The velocity of sound wave is an important acoustic parameter of material. The velocity of sound is the parameter with the highest measurement accuracy and the widest application in acoustics. In a certain state (temperature, pressure, etc.) conditions, when the physical characteristics of the medium such as specific gravity, concentration, chemical composition, etc., change, sound velocity variables generally also change accordingly, so you can measure the change in the state of the medium by measuring sound velocity, which is the basis for acoustic measurement. The transmission speed of ultrasound in the medium is referred to as the sound speed

of the medium, which is represented by C. The methods of sound speed measurement mainly include interference method, pulse echo method, superposition method, repetition method, etc[3]. In this study, pulse echo method is adopted to measure the sound speed of ethanol solution. Under a fixed sound path, sound speed c is expressed as follows.

$$c = \frac{l}{t} \quad (1)$$

The speed of sound varies with the medium and its state such as temperature, for example, at room temperature, the speed of sound in air is about 340m/s, and the speed of sound in water is about 1450 m/s. In addition, the speed of sound in the fluid will increase with the increase of pressure, and the speed of sound has a direct or indirect relationship with many characteristics of the medium, which can be expressed by theoretical formulas through analysis. Under specific conditions, some empirical formulas can also be established, such as the composition of the medium, the proportion of the mixture, the concentration of the solution, the specific gravity of some liquids, etc., by establishing a functional relationship with parameters such as sound speed and sound attenuation, and then the concentration of the measured liquid can be deduced. The linear wave equation of sound waves in a uniform ideal fluid is as follows.

$$\frac{\partial^2 P}{\partial t^2} = c^2 \frac{\partial^2 P}{\partial x^2} \quad (2)$$

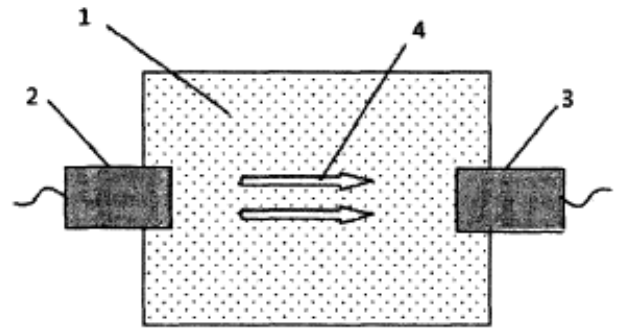
B is the bulk elastic modulus of the liquid and P is the density of the liquid. When the liquid concentration changes, the elastic modulus B and density P change, and the speed of sound also changes. Equation 2 is the wave equation on an ideal fluid, and it will no longer be applicable if the medium contains viscosity and amplitude. Even under ideal conditions, it is very difficult to theoretically derive the relationship between sound velocity and concentration from formula 2. Therefore, the common method is to establish the mapping between sound velocity, temperature and concentration by experiment. Experiments show that, like many solutions, the concentration of ethanol is a function of temperature and sound velocity, and has a one-to-one correspondence, the relationship between the three can be written as:

$$N = f(v, T) \quad (3)$$

Where N is the concentration, v is the speed of sound, and T is the temperature. Formula 1 is used to measure the sound velocity in the medium. As long as the temperature and sound velocity are measured, the concentration can be calculated by substituting formula 3[4].

3. Measurement System and Device

Using ultrasonic velocity to calculate its concentration, the main hardware system includes ultrasonic transmitting and receiving module, signal conversion and acquisition module, echo signal velocity calculation module and host computer system module. A clamping device for receiving and receiving ultrasonic transducer is designed, the transducer is immersed in the solution to be tested, and the ultrasonic propagation path is fixed as L [5].



1- Medium under test 2- transmitting transducer 3- Receiving transducer 4- ultrasonic signal

Figure 1. Principle of dual transceiver detection scheme

A signal generator is used to stimulate the ultrasonic signal of the transmitting probe. The following figure shows the 2MHz square wave pulse signal given by the signal generator.

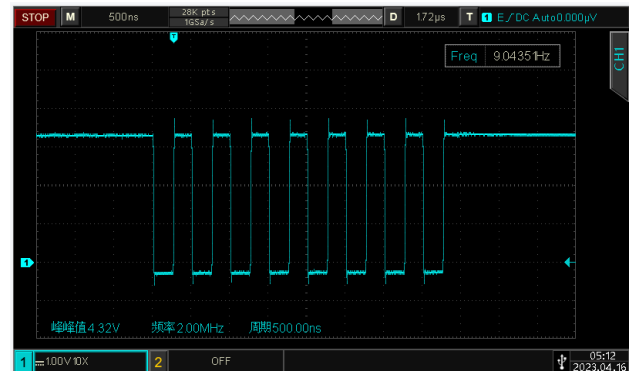


Figure 2. Square wave pulse signal

Band-pass filtering and envelope amplification are carried out on the electrical signal received by the receiving probe, and then high-speed analog-to-digital conversion module is used to perform analog-to-digital conversion on the processed weak point signal, and the converted digital signal is transmitted to the FPGA. The FPGA calculates and processes the ultrasonic echo digital signal under a fixed acoustic path L to obtain the flight time T and calculate the corresponding ultrasonic sound velocity V . The ultrasonic sound velocity of multiple groups of solutions with different concentrations under the same temperature environment can be measured respectively, and the sound velocity data can be transmitted to the measurement system of the upper computer. After data preprocessing, interpolation processing and data fitting, the concentration curve is modeled by the least square method, and the fitting function is programmed into the measurement system of the upper computer, so as to realize the rapid measurement of the unknown concentration solution.

The ultrasonic echo collected by the receiving probe is shown in the figure below. It can be seen that the amplitude of the wave crest is continuously attenuated, which is caused by the acoustic attenuation in the propagation process of the ultrasonic wave. The flight time of the ultrasonic wave is calculated and the propagation sound speed is obtained by calculating the fixed acoustic path.

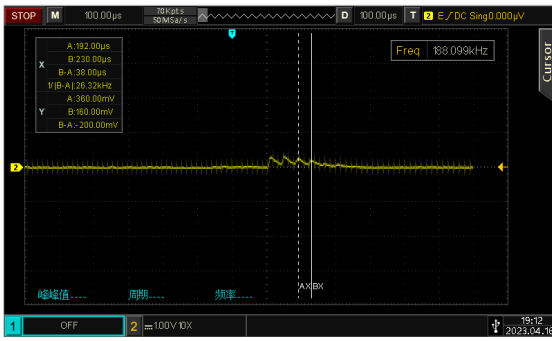


Figure 3. Transmission wave shape diagram

4. Analysis of Experimental Results

The ultrasonic transducer was used as the sensor to measure the sample liquid repeatedly and get the average value, and the sound velocity of different concentrations was measured.

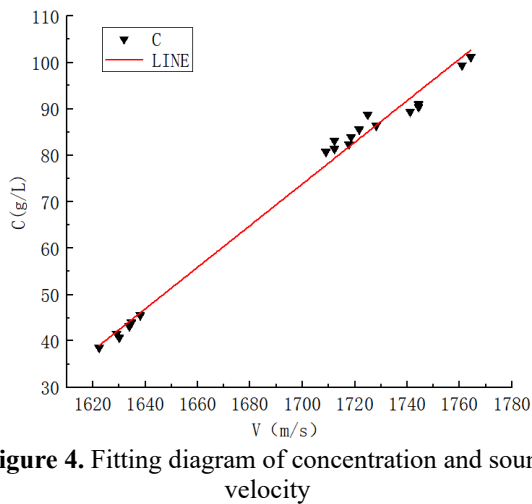


Figure 4. Fitting diagram of concentration and sound velocity

Linear regression was used to fit the mathematical model to predict the concentration. Compared with the chemical method, the relative error was less than 5%, which met the demand of actual industrial production and the measurement requirements.

5. Conclusions

Ultrasonic transducer with frequency of 2MHz was used to measure the mass concentration of sodium hydroxide in the immersion solution, and the concentration was verified by acid-base neutralization method. The relative error was less than 5%, which verified the feasibility of online detection technology of sodium hydroxide concentration in the immersion solution based on non-invasive ultrasonic velocity method, reduced the measurement time and detection cost. It can meet the needs of industrial field measurement and provide a theoretical basis for further realizing the automation of production process.

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