Full Length Research Paper

A novel measurement system for dry rubber content in concentrated natural latex based on annular photoelectric sensor

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A novel measurement system for dry rubber content in concentrated natural latex is presented and designed in this paper. The measurement system is composed of annular photoelectric sensor, laser diode, distance detector, two-stage amplifier module of weak photocurrent signal, signal conversion module, microprocessor and so on. According to the principle of Lambert, the reflectivity of samples will be different when the dry rubber contents of samples are different. The reflectivity can be calculated by the reflection beam intensity, which could be characterized by the output voltage of the amplifier module. The distance between sensitive module and the surface of the sample is fixed by a lifting stage and the temperature of the sample is controlled by thermoelectric cooling modules (TEC). The system adopts indirect measurement method and confirms that the prediction performance of the binary linear standard equation, established by the data measured at the temperature 25 and 30°C, is relatively good. Simultaneously, the experimental verification of the system is illustrated in this paper and the result shows that the dry rubber percentage content in concentrated latex can be measured rapidly and the real time application is effective. Furthermore, the anti-counterfeiting function can be realized in measurement of the adulterate latex.

Key words: Dry rubber content, photoelectric sensor, indirect measurement, concentrated latex.

INTRODUCTION

As one of the four major industrial raw materials, natural rubber is extracted from the plant containing rubber. Natural latex is a white flow liquid with protection function located under the subcutaneous tissue of rubber tree. The main components of natural latex are rubber particles (30 - 40%), water (55 - 65%), protein (2 - 3%), sterol glycosides (0.1 - 0.5%), resin (1.5 - 3.5%), ash (0.5 - 1.0%), carbohydrate (1.0 - 2.0%) (Poh, 1989; Tomazic-Jezic et al., 2004).

So the rubber particles and water are the most in natural latex relative to other components. The concentration of latex is usually expressed by the dry rubber content or total solid content. The definition of dry rubber content is the ratio of the weight of dry substance solidified by the acid to the weight of latex, while the ratio of the weight of dry substance obtained after direct heating to the weight of latex is defined as the total solid content. The dry rubber content of fresh latex is between 20 and 40% in normal case and it is lower than total solid content usually. The dry rubber contents of different latex are different because the strains of rubber tree, tree ages, seasons, tapping intensity, chemical stimulation are different.

People need more and more natural latex in the industrial production because of its superiority, which leads to very high price of natural latex. The natural latex is concentrated for preservation usually, so the concentrated natural latex is the most common in the market. The

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standard method of chemical analysis is adopted as the measurement method of dry rubber content in concentrated latex commonly. Firstly, the concentrated natural latex is diluted and acidized. Then it is squashed and moved to the oven for drying. Finally, we can weigh the dry substance and calculate the dry rubber content. The whole operation process should be very careful and the operation should be taken according to its standard requirement (Hamza et al., 2008). Hamza and his partners replaced conventional convection oven by microwave oven to measure the total solids content (Alex et al., 2003). Heating in a microwave oven can reduce the measurement time considerably. Alex et al., 2003 presented a titration method for measuring the dry rubber content of fresh natural rubber latex. Tillekerathe et al., 1989 pointed that the dry rubber content of field latex could be determined roughly using metrolac hydrometer. A buoyancy method was applied by Chen for determination of dry rubber content in field latex based on Archimedean principle (Chen, 1982). Although these direct and indirect measurements are different in local operation and reagent dosage, their basic principles are the same generally and their operations should be taken more carefully, in addition, these measurement equipments are very expensive (Li, 2006).

Some other measurements are also used to measure the dry rubber content in latex. Li et al. (2008) developed a microwave-based method to determine the dry rubber content of natural latex. Kumar et al. (2007) presented that the dry rubber content could be determined with a capacitive transducer. Schulz et al., 1984 designed a volumetric analysis device for determining the dry rubber content of latex. Jayanthy et al. (2005) carried out an experimental study on measurement of the dry rubber content based on microwave measurement technique. The demerits of these measurements are high price and maintenance cost of the equipment, hence, most of these methods are hard to apply in practice.

In recent years, laser technique and spectral measurement technique have been widely used in the measurement of sample component content. For example, Zhao et al. (2008, 2009) used spectral analysis technique to measure the component content of the blood. Guo et al. (2005) presented the light-cured material based on laser technique. Tøgersen et al. (2003) studied the chemical composition of semi-frozen ground beef using near infrared spectroscopy technique. Zhang et al. (2008) investigated the composition analysis of food using near infrared spectroscopy with double detector. Simultaneously, some self-made measurement instruments relative to spectroscopy measurement are also used in component analysis, for examples, the portable spectroscopy measurement instrument based on AOFT is putted forward by Bi et al. (2005). As the development of photoelectric technology, the cheap LED makes the output of light in high precision without bulk white light source or light splitter (grating or AOFT), and the price of the high performance amplifier for amplifying weak photocurrent signal reduces gradually.

This paper designs a novel measurement system for dry rubber content in concentrated natural latex. According to the principle Lambert, the reflectivity of samples will be different when the dry rubber contents of samples are different. The reflectivity can be calculated by the reflection beam intensity, which could be characterized by the output voltage of the amplifier module. The distance between the sample and photoelectric sensor is fixed by a lifting stage and the temperature of the sample is controlled by a thermoelectric refrigerator TEC before measurement starting. The system adopts indirect measurement method and this paper puts forward that the prediction effect of binary linear standard equation established by the data measured at the temperature 25 and 30℃ is relatively good. The experimental verification of the system is also illustrated and the result shows that the dry rubber percentage content in concen-trated latex can be measured rapidly and real-timely by the system. Furthermore, the anti-counterfeiting function can be implemented in measurement of the adulterate latex. With its small bulk and light weight, the system can realize the measurement of dry rubber content indoor or outdoor, and it can also be used in on-line composition analysis in order to control other equipment to filter the inferior products.

THE PRINCIPLE OF OUR MODEL

Basic principle

Chemical composition of samples containing C-H, N-H and O-H functional groups will cause characteristic absorption, and the concentration of tested composition is linear to the logarithm of the reciprocal of transmittance in the characteristic absorption wavelength according to Lambert- Beer law, that is to say,

$$\lg\left(\frac{1}{T}\right) = K\,b\,C \qquad (1)$$

Where; C is the concentration of tested composition in the sample; K is the absorptivity, which is related to the wavelength of the incident light and the temperature of the sample; b is the length of the colorimetric dish; T is the transmittance, which is the ratio of transmitted light intensity to incident intensity, and the following is its definition,

$$T = \frac{I_t}{I_0} \qquad (2)$$

Table 1. Training samples and parameters.

Number of training samples	Predictive quality index	Absorption peak1	Absorption peak 2	...	Absorption peak m
1	y_1	x_{11}	x_{12}	...	x_{1m}
2	y_2	x_{21}	x_{22}	...	x_{2m}
...	...	...	...	...	...
N	y_n	x_{n1}	x_{n2}	...	x_{nm}

Where; I_0 is the incident intensity of monochromatic light, while I_t is the intensity of emergent monochromatic light.

We can obtain different T_i (I = 1, 2…n) of the same sample using different wavelength light source, for example, if we obtain three values of T_i (I = 1, 2, 3) and use y_1 to express the concentration of tested composition in the sample. Similarly, we can obtain many values of T based on different y using different concentration samples. Now it needs to build a multiple linear equation, such as $y = a_0 + a_1 x_1 + a_2 x_2 + a_3 x_3$, and x_i is the logarithm of the reciprocal of T_i. The values of a_i (I = 0, 1…3) can be determined in the calibration, so we can calculate the concentration y of unknown samples using the above equation with obtained T_i.

However, it just needs to build one-dimensional equation when we obtain one value of T of the same concentration samples only using the same wavelength light source. The one-dimensional equation is similar to the multiple linear equation except that there is only one variable.

Establishment of the linear equation

Take the multiple linear equation building for example, as showed in Table 1, let n be the number of training samples, and let m be the selected number of near infrared spectroscopy. The number of training samples is more than the number of spectrum in the multiple linear regression analysis, namely $n > m$. Quality index y can be expressed as follows:

$$y_i = b_0 + b_1 x_{i1} + b_2 x_{i2} + ... + b_m x_{im} \qquad (3)$$

Equation (3) can also be expressed in the following matrix form:

Let $Y = \begin{pmatrix} y_1 \\ y_2 \\ ... \\ y_n \end{pmatrix}$, $\mathbf{X} = \begin{pmatrix} 1 & x_{11} & \cdots & x_{1m} \\ 1 & x_{21} & \cdots & x_{2m} \\ ... & ... & ... & ... \\ 1 & x_{n1} & \cdots & x_{nm} \end{pmatrix}$

Then $Y = XB$

Coefficient B can be calculated by these linear equations. We should take a significant test for judging the linear relationship between y and x_i. Variance analysis principle is shown as follows:

$$S_{total} = S_{yy} = S_{reg} + S_{res} = \sum_{i=1}^{n}(y_i' - \bar{y})^2 + \sum_{i=1}^{n}(y_i - y_i')^2 \qquad (4)$$

Where; $S_{reg} = \sum_{i=1}^{n}(y_i' - \bar{y})^2$ and $S_{res} = \sum_{i=1}^{n}(y_i - y_i')^2$, y_i' is the real concentration of the composition, y_i is the regressive concentration, $\bar{y}$ is the average of the regressive concentration.

Obviously, if S_{res} = 0, then the experimental points all fall on the regression line and there is no error of the whole experimental data. If S_{reg} = 0 and $y_i' = \bar{y}$, then y and x_i have no relation. As S_{reg} changes with x_i , y changes linearly according to the regression equation and S_{res} expresses all the residual sum of the squares except the deviation caused by the regression model. Consequently, F-statistics is showed as follows:

$$F = \frac{S_{reg}/m}{S_{res}/(n-m-1)} \qquad (5)$$

Where; F can be calculated by the regression equation, and a table lookup method is used to obtain F_a $(m, n-m-1)$ when the significance level a is determined. If $F > F_a$, it is called the deviation caused by regression sum of squares and is relatively big and it explains that re-gression effect is significant. Conversely, the regression effect is not significant. The regression coefficient can be obtained in the calculation of regression equation using least square method even if the data is unrelated. In order to characterize the correlation between x and y, a quantity index is usually adopted, namely multiple correlation coefficient R, where $S_{yy} = S_{total}$.

$$R = \sqrt{S_{reg}/S_{yy}} \qquad (6)$$

If the residual sum of squares $S_{res} = 0$, then $R = 1$ and it means that variable y changes linearly as independent variable $x_1, x_2 ..., x_m$ change, namely S_{yy} is all expressed by S_{reg}. Similarly, if $S_{reg} = 0\,°C$ then S_{yy} is all expressed by S_{res} and it has no effect to y when x_i changes, so that the regression effect is the worst. R can be calculated by the above equation, and we need to compare R_a with R. The regression effect is significant when $R > R_a$ while the regression effect is not significant when $R < R_a$.

MATERIALS AND DESIGN OF THE MEASUREMENT SYSTEM

Materials

The sample of concentrated natural latex (dry rubber content is 61%) used here is obtained from the rubber tree plantation in the south of China, which is diluted to several other samples in different dry rubber content with water.

Hardware design of the system

System structure

The general design structure of the system is showed in Figure 1. The measurement system is composed of annular photoelectric sensor, laser diode, distance detector, two-stage amplifier module of weak photocurrent signal, signal conversion module, microprocessor, data storage, data display module and key module.

The dry rubber content in the sample affects the scattering and reflection of the incident light, and the output photocurrent of the sensitive module increases as the dry rubber content increases at constant sample temperature. According to this principle, the light source of the system is composed of multi-LED with emergent light obliquely incident to the surface of the sample. The lifting stage and distance detector are used to fix the distance between sensitive module and the surface of the sample because the surfaces of samples in the vessel are different when changing samples. The temperature of the sample is fixed to our required temperature by the TEC temperature module. Finally, the weak signal is amplified by the two-stage amplifier module and then it is sent to the microprocessor. An indirect measurement method is used in the system, that is, it need to establish the standard equation in advance and the microprocessor calculate the equation with the real-time data in order to obtain the dry rubber content.

The annular photoelectric sensor

The annular photoelectric sensor is composed of light module, sensitive module, optical system, TEC temperature control module and lifting stage module.

The core parts of the annular photoelectric sensor are light module and sensitive module, and their physical structure is showed in Figure 1. The light module surrounds the sensitive module regularly. The position relation between these light modules and sensitive module are the same according to this annular distribution, and multi-LED light sources make the photocurrent signal increase, which is beneficial to the amplifying of the weak signal. The wavelength of the light source is determined by the characteristic reflection wavelength of the dry rubber, as showed in Figure 2, three reflection peaks exist at the wavelength of 1276, 1631 and
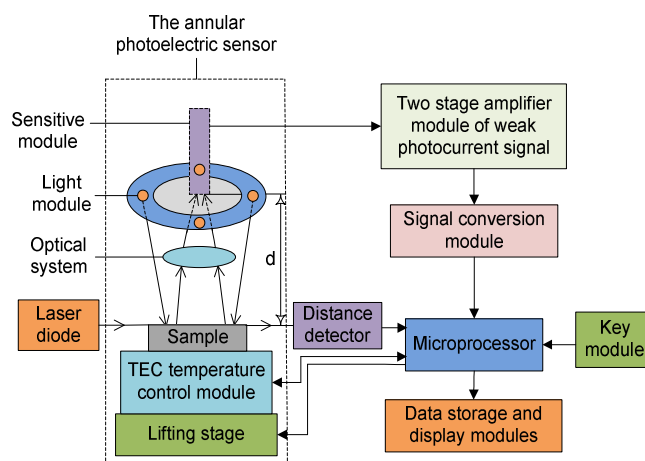

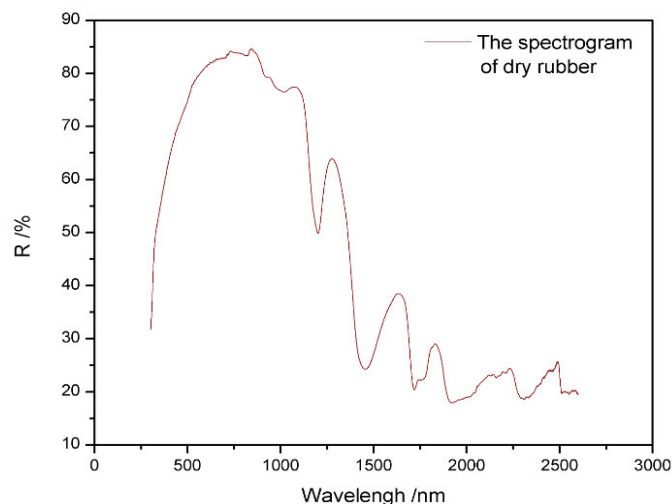**Figure 1.** System structure diagram.

Figure 2. Spectrogram of dry rubber.

1831 nm. The wavelength of the multi-LED light source used in the system is near 1276 nm because of the high reflectivity of the dry rubber at the wavelength of 1276 nm. Meanwhile, the photodiode fitting to 1276 nm wavelength is adopted as the sensitive module.

The optical system is composed of a short-focal length convex lens, and the emergent light from the surface of the latex is converged to the sensitive module by the lens. The position between optical system, sensitive module and light module is fixed while the distance between the sensitive module and the surface of sample is adjustable. As to the samples of the same dry rubber content, the photocurrent changes as the above distance changes at the same sample temperature. As showed in Figure 3, the plate built by barium sulfate is used as the standard reflection material and the output voltage signal firstly increases and then decrease as the above distance increases. The slope of the inflection point (the abscissa is 3.4 cm) in Figure 3 is the minimum, that is, the effect to the output signal is minimum when the above distance changes in a small range at the inflection point. The intensity of the output signal
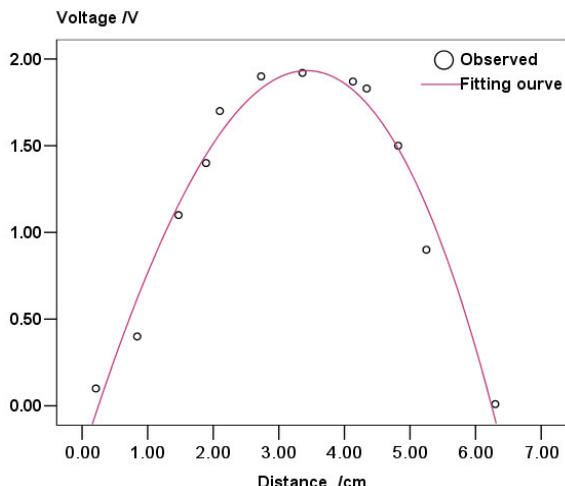
Figure 3. Output voltage at the different distances between the sample and sensitive module. The abscissa distance shows the distance between sample and sensitive module, and the ordinate voltage shows the voltage output from the two-stage amplifier module. The plate built by barium sulfate is adopted as the standard reflection material.
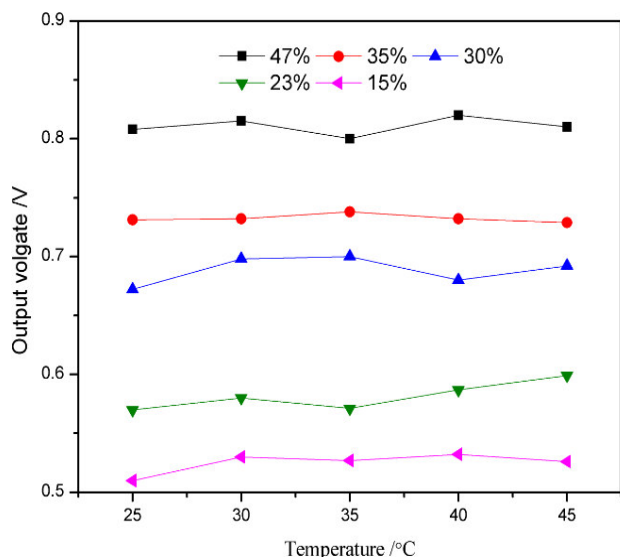

Figure 4. Output voltage at different sample temperatures.

in the inflection point is the biggest so that this best distance (the distance between the surface of the sample and sensitive module is 3.4 cm) is used as the constant distance in the whole measurement process. The lifting stage will make the distance fix at the above best distance.

The variation of sample temperature will also affect the output voltage. As showed in Figure 4, there is no linear variation trend of the output voltage basically as the sample temperature increases. However, the changing voltage value caused by temperature variation is of the same order as the changing value caused by the different dry rubber content, so we should make sure that the
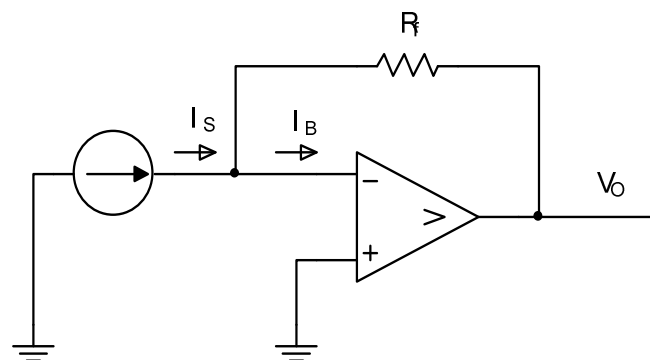

Figure 5. Amplification circuit of micro-current.

sample temperature is constant when we build a model equation at a certain temperature. The water in latex is easy to volatilize at high temperature, consequently, 25 and 30°C are adopted as the measurement temperatures for building model equations.

The temperature control module uses the thermoelectric refrigerator TEC-12704, whose working voltage is 12 V and maximum working current is 2 A. TEC-12704 is driven by the chip LMD18200, in which there is internal integration of high power H-Bridge. The LMD18200 whose working voltage is up to 55 V and maximum working current is 3 A can output bipolar current so that the TEC-12704 can be changed in the mode of heating or refrigerating optionally (Zhou and Bi, 2006). DS18B20 is adopted as the temperature sensor of the system. The microprocessor changes the PWM duty cycle according to the real-time measured temperature in order to change the driven current of TEC-12704. Since the thermoelectric refrigerator can work in the mode of heating or refri-gerating, the microprocessor can control TEC-12704 to refrigerate sample when the real time sample temperature is higher than our required temperature caused by thermal inertia, so the sample temperature can be fixed at required temperature quickly and accurately.

Two-stage amplifier module of weak photocurrent

Since the output photocurrent of the sensitive module is of micro-ampere level, a two-stage amplifier circuit is adopted in the system. The preamplifier uses the high precision and high gain amplifier ICL7650 based on the principle of micro-current amplification. As showed in Figure 5, the output voltage $V_O = -I_S R_f$ when the amplifier is considered as perfect amplifier with infinite input impedance and amplification. I_S is measured current and R_f is feedback resistance in the equation. Even if I_S is very small, the output voltage V_O will be big when using large enough R_f theoretically. However, the input impedance of amplifier is not infinite and the increasing of feedback resistance is limited by input impedance. Because of the existing of bias current I_B, the output voltage $V_O = -(I_S-I_B)R_f$, and if $I_B > I_S$, then I_S cannot be measured.

Figure 6 shows the scheme of preamplifier based on ICL7650. R_1 is input current-limiting resistance; R_3 and **C2** are used to filtrate the chopper pike noise; C_1 and R_2 form the feedback compensation network in order to decrease bandwidth in case of self-oscillation cased by R_2, R_3, R_4 and phase shift of C_2; Instead of high resistance R_f (bigger than $10^9 \Omega$), the T network is composed of small resistance R_2, R_3 and R_4 in order to increase the stability of high gaining and
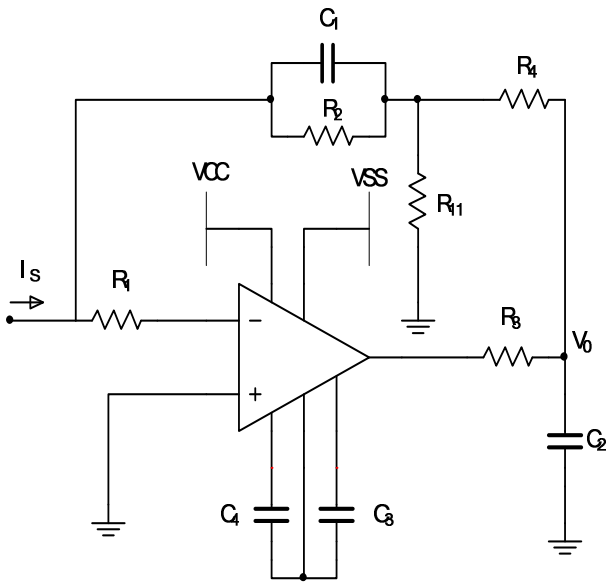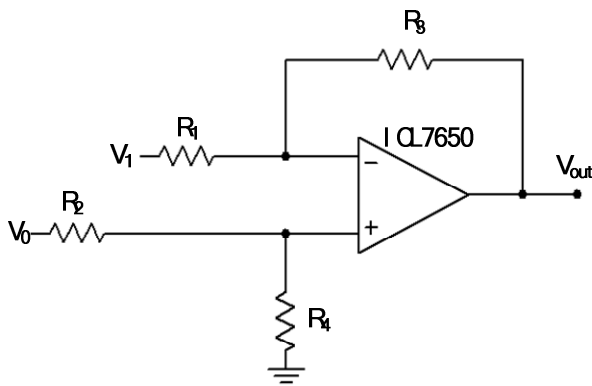
Figure 6. Preamplifier circuit based on ICL7650.

Figure 7. Second stage amplifier circuit based on ICL7650.

reduce the noise. Subsequently, the output voltage $V_O = -I_S(R_2+R_4+R_2R_4/R_3)$. In order to decrease the effect of environmental temperature changing, a reference signal is adopted in the system. The sealed sensitive module and preamplifier circuit used in the reference circuit are the same of the aforesaid measurement circuit. The second stage amplifier circuit is used to amplify the different value between measurement signal and reference signal actually. ICL7650 is also adopted as the amplifier of the second stage amplifier circuit, whose amplification can be changed by the adjustable feedback resistance if necessary. As showed in Figure 7, the second stage amplifier adopts differential amplifier and the output voltage V_{out} can be expressed as follows:

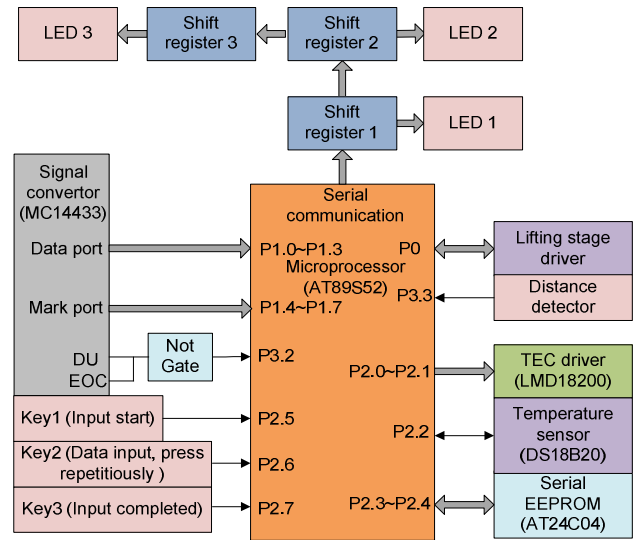$$V_{out} = \left(1 + \frac{R_3}{R_1}\right)\left(\frac{R_2}{R_2 + R_4}\right)V_O - \frac{R_3}{R_1}V_1 \qquad (7)$$

Figure 8. Hardware block of the microprocessor.

Where; V_0 is the output voltage of the preamplifier of the measurement circuit; V_1 is the output voltage of the preamplifier of the reference circuit. Make sure that the values of R_1 and R_2 are the same, and the values of R_3 and R_4 are same. Consequently, the expression of the output V_{out} is changed as follows:

$$V_{out} = \frac{R_3}{R_1}(V_0 - V_1) \qquad (8)$$

Signal convertor module and microprocessor

According to the experimental results, the output voltages are between 0.45 V and 0.85 V when we measure the samples of different dry rubber content. The output value is more than 5 mV variation as measuring the sample in which the dry rubber content increases by 2% interval. Consequently, MC14433 is adopted as the A/D convertor with 1 mV resolution when its reference volt is set to 2 V.

AT89S52 is used as the microprocessor in the system. As showed in Figure 8, P1 port of the microprocessor is joined with the data port and mark port of MC14433, and the microprocessor obtains the output data of MC14433 when the DU and EOC are in high level. Key module is joined with P2.5 to P2.7 of the microprocessor. After one time pressing of the key1, we can input our require data though repetitiously pressing of the key 2 and 3. P0 port is joined with the driver of lifting stage while the distance detector (distance between sensitive module and the surface of the sample) is joined with P3.3. If the emitted light from the laser diode is blocked by the sample when the lifting stage is rising, the output value of the detector is in low level, now the distance is 3.4 cm and the lifting stage will be stopped timely. P2.0 and P2.1 ports are joined with the driver (LMD18200) of thermoelectric refrigerator TEC. 1-wire temperature sensor DS18B20 is joined with P2.2. Microprocessor reads the data of MC14433 and calculates the standard equation with real time data after the temperature of the sample reaches our require temperature. The calculation results are saved in the chip serial EEPROM AT24C04 through P2.3 port and P2.4 port. Besides, the results are static displayed by LED

after transmitting the display data to the shift register by microprocessor in serial communication mode.

Software design of the system

As showed in Figure 9, software flow is divided into two parts. The left part is peripheral control flow chart while the right one is the data processing flow chart. The system reads 16 data of A/D convertor and effectively screens the 16 data. The principle for screening is that schedule the 16 data from small to big, then average the middle 10 data of the scheduled 16 data, and use x_1 to express the average. The operation process can effectively decrease the measurement error caused by the instability of latex surface.

Besides, the sudden error caused by external factors can be also reduced mostly. Finally, the value of dry rubber content is calculated by the system with real time measured valued x_1 through the standard equation. The standard equation is established in the calibration experiment. Dispose several samples of different dry rubber content, and take one variant linear regression analysis with many measurement data of samples in order to determine the coefficient a_0 and q_1 of the equation $y = a_0 + x_1 q_1$. If the calculated value y is bigger than 45% or smaller that 15%, LED will display the mark of overflow and if the calculated value is between 15% and 45%, LED will display the value of dry rubber content. The value will be saved whatever it is.

RESULTS AND DISCUSSIONS

Calibration

The distance between sensitive module and surface of the sample is fixed at 3.4 cm and the temperature of the sample is fixed at 25 or 30°C in the process of calibration experiment. The output voltages are recorded by multimeter. We choose 16 concentrated natural latex samples, whose values of dry rubber content are from 15 to 47% with an interval of 2%. The results are showed in Table 2. From the Table 2 we can see that the output voltage is proportional to the dry rubber content at the same temperature. To some extent the output voltage presents a linear increasing trend as the value of dry rubber content increases with an interval of 2%. Consequently, we can take one-dimensional linear fitting with the data at 25 or 30°C and take binary linear fitting with the data at above two temperatures. The fitting standard equations are as follows:

Model Equation 1:

$$y_1 = -34.57 + 94.965 x_1 \tag{9}$$

Model Equation 2:

$$y_2 = -37.987 + 98.85 x_2 \tag{10}$$

Model Equation 3:

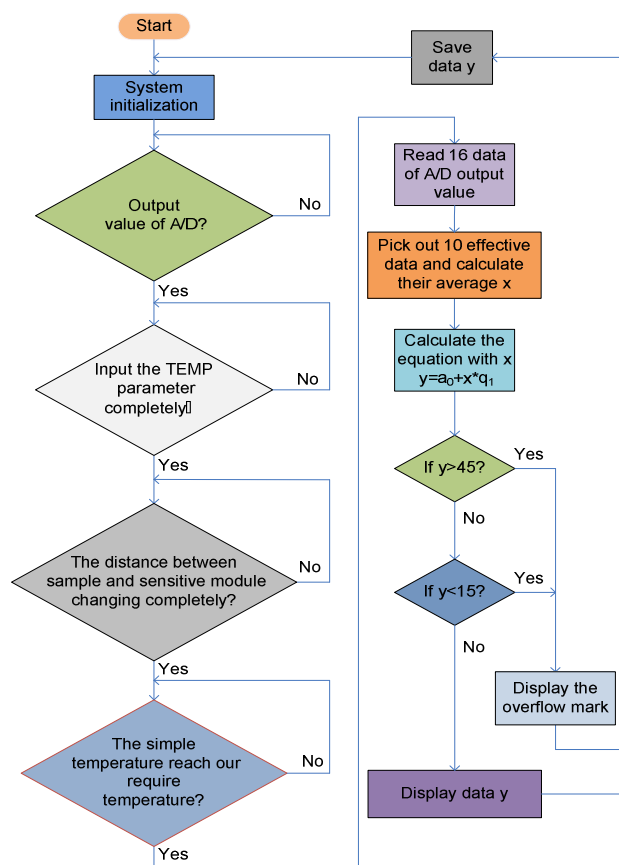$$y_3 = -36.533 + 54.572 x_1 + 42.657 x_2 \tag{11}$$

Figure 9. Software flow chart of the system.

Where; x_1 is the voltage measured at 25°C, x_2 is the voltage measured at 30°C, y_1, y_2 and y_3 are the prediction values of the three equations respectively.

The correlation coefficient R and check value F are showed in Table 3. The correlations R of the three equations are all near to 1 and the values F are relatively big. When let $F_{0.05} = 4.08$, the values F are all bigger than $F_{0.05}$. At the same time, the values of adjusted R square are near to 1.

Consequently, the regression effects of the three equations are all significant. The data read by microprocessor from the A/D convertor are digital signals while the analog signal data are adopted in the calibration, so the microprocessor should convert the digital signal to analog signal. The conversion formula of the MC14433 is as follows:

$$y_{out} = 1999 \frac{V_x}{V_R} \tag{12}$$

Where; V_R is 2V and V_x is input analog voltage. The microprocessor can calculate the above formula with real

Table 2. Calibration data.

Serial number	Dry rubber content/%	Output voltage x_1 /V temperature 25°C	Output voltage x_2 /V temperature 30°C
1	15	0.510	0.530
2	17	0.540	0.554
3	19	0.565	0.571
4	21	0.570	0.580
5	23	0.611	0.620
6	25	0.632	0.638
7	27	0.658	0.663
8	29	0.672	0.698
9	31	0.707	0.719
10	33	0.731	0.732
11	35	0.750	0.743
12	37	0.759	0.765
13	39	0.773	0.779
14	41	0.790	0.787
15	43	0.803	0.809
16	45	0.808	0.815

Table 3. Parametric test of three model equations.

Model	R	R^2	Adjusted R^2	F
1	0.991	0.983	0.981	787.599
2	0.991	0.983	0.982	811.907
3	0.992	0.984	0.982	401.134

time y_{out} to obtain V_x.

Dry rubber content prediction

We prepared 7 samples, in which dry rubber contents are 16, 19, 21, 33, 38 and 42%. Then we adopted Equations 12 to predict the dry rubber content. Figure 10 shows the prediction results. From Figure 9 we can see that the absolute prediction errors of the three equations are all smaller than 1%. The absolute prediction errors of model equation 1 and 2 change very little in the whole range of dry rubber content from 15 to 45%. The errors of measuring samples of high dry rubber content are bigger relative to the samples of low dry rubber content because the surfaces of high dry rubber content samples will form a membrane layer easily and the membrane layer will affects reflection or dispersion of the incident light. As showed in Figure 10d, the prediction effect of model equation 3 is better than model equation 1 and 2 when measuring the samples of dry rubber content from 15 to 35%. The average absolute prediction errors of three equations are 0.65, 0.73 and 0.37%. Consequently, we adopt the model Equation 3 as the standard equation in the practical application.

Experiments of anti-counterfeiting

The principle of chemical analysis method is as follows: Dilute the concentrated latex to total solid content of 20% and acidize it with acetic acid. Squash and dry the coagulated latex at 70°C, then weight the remainder. So some unlawful businessmen usually add some non rubber solids whose prices are lower than latex, such as flour or mortar. In order to create a fair environment in natural rubber marketing system, the experiments of anti-counterfeiting are carried on here to verify the forgery prevention performance of the system.

Two groups of natural concentrated latex are prepared. There are 5 samples in each group, which dry rubber content are 40, 35, 30, 25 and 20%. We add 5 g flour to each sample in a certain group with even agitation. The system is used to measure the dry rubber content with Equation 3. The results are showed in Figure 11. For the same dry rubber content samples, the prediction values of samples which are added with flour do not rise significantly and these values are close to the prediction values of samples without flour. However, the values predicted by chemical analysis method will rise significantly. So the purpose of forgery prevention can be achieved using this measurement system.
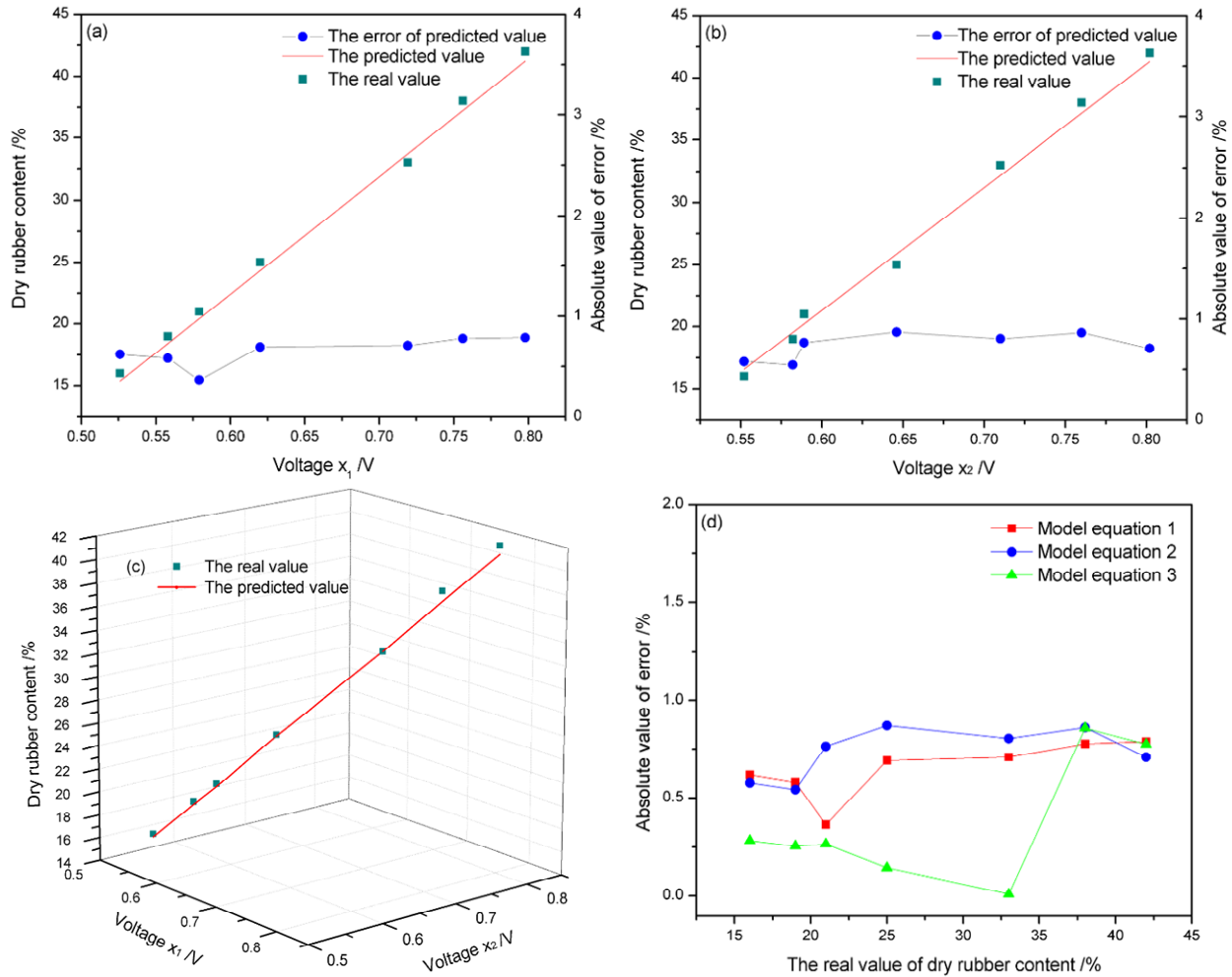
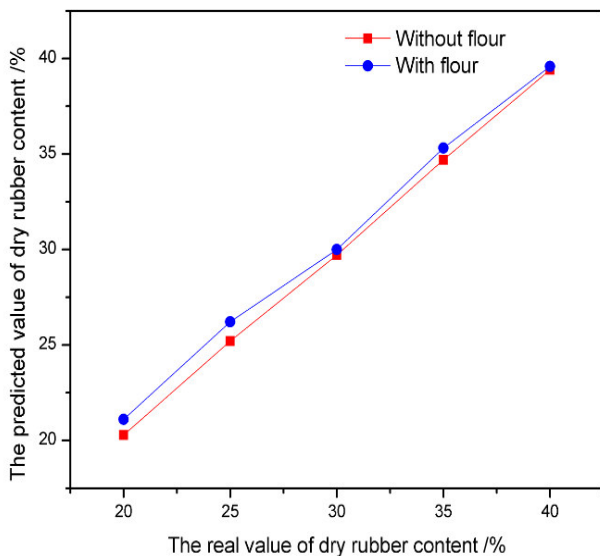**Figure 10.** Prediction effect diagrams of the three model equations.

Figure 11. The diagram of anti-counterfeiting effect.

CONCLUSION AND OUTLOOK

This paper designs a measurement system for dry rubber content in concentrated natural latex based on annular photoelectric sensor at different temperatures. The annular photoelectric sensor is used to obtain the dry rubber content information of concentrated natural latex and the lifting stage is used to fix the distance between sensitive module and surface of the sample at the best distance in the system. The temperature of samples is controlled by the thermoelectric refrigerator TEC. This paper analyzes and discusses the measurement effect of different model equations, which are established with the data measured at different sample temperatures. We got a conclusion that the prediction effect of this system via model Equation 3 is the best. Tested by the experiments, this system is of a certain accuracy and stability with the function of anti-counterfeiting. The system designed here can also be applied to measure the content of other compounds with changing of the wavelength of annular

photoelectric sensor, for example, measuring the fat content or protein content in milk. This paper provides a new method to measure the dry rubber content in the natural concentrated latex, which can promote fairness and efficiency in natural latex marketing system.

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