MATEC Web of Conferences 39, 03007 (2016)
DOI: 10.1051/matecconf/20163903007

Designing of Instruments which detect water content in Petroleum Products

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Abstract. In order to detect the water content in the petroleum products, A measurement system of the water content is designed by using the electromagnetic resonant technique. The method uses capacitor as a sensing element. The capacitor is connected to a electromagneticresonant circuit. The water content can be calculated by detecting the change of capacitance . Furthermore, temperature error is compensated using phase transition temperature control technology .It is possible to detect the water content of different petroleum products under different temperature conditions. This instrument can also detect water content online in real-time. It posesses high measuring precision, wide measuring range, simple operation,and does not need any reagents, fully able to meet actual needs
Keywords: electromagnetic resonance, petroleum products, water content,detect.

1 Introduction

At present, the method of detecting water content in petroleum products can be divided into two types[1], one of which is a chemical process (i.e., the Carle Fischer Reagent Method). Although this method posesses high precision, the chemical reagents (Pi Ding)produce foul odor causes severe pollution. In addition, the standard reagent need to be tomixed and need a skilled worker to operate; the other method is the distillation method. This method is simple, but the precision is lower and the operation time is long,. It also needs cooling circulating water. The two methods are subjected to the constraints and limitations of the base oil laboratory, especially in field conditions, and cannot satisfy the need of oil quality analysis real-time and online oil quality analysis. Therefore, a new method for the detection of the water content in petroleum products online was created which gradually became popularised in the industry. The physical parameters of a mixture of oil and water (dielectric constant, density, electrical conductivity, thermal conductivity, viscosity and so on) have some differences in principle. Using these differences, one is able to detect the rate of water in petroleum products[2]. In recent years, the most commonly-used method world-wide is the capacitance method [3]. In the capacitance method, the change of dielectric constant of the oilwater mixture is used to measure water content. Using the capacitance method for online oil quality analysis has the advantages of convenient operation and low energy consumption.

But as a result of the flow, temperature, oil-water mixedstate as well as the influences of boundary condition of the electromagnetic field, the measuring accuracy is not high,usually 5 level or so. Furthermore, the calibration cycle is short. One may also experience considerable difficulty while repairing the instrument . Many other factors may also limit the effectiveness of this method. This paper presents a method for the measurement of water content in petroleum products by using the electromagnetic resonant technique. The instrument can achieve the real-time online measurement of water content, while achieving high measuring precision, wide measuring range, simple operation. It also does not require any reagents, and is thus able to fully meet the detecting water content in petroleum products.

2 The measuring principle of instruments

In this system capacitor is a sensor, when the water content in the protleum products chang, the dielectric constant of the mixture of oil and water is also changed, if the capacitor is connected with electromagnetic resonant circuit, we can detect the chang of capacitor because of the difference of water content[4].

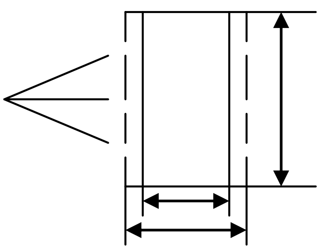

Fig. 1 sensor configuration

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the sensor is the cylindrical capacitor, its structure as shown in Figure 1, then the capacitance of the capacitor is:

$$C = \frac{2\pi\varepsilon L}{\ln\left[\frac{D}{d}\right]} \tag{1}$$

In Figure 1, D, d: diameter of two poles; ε : dielectric constant; L: the effective length of capacitor.

For a fixed capacitor, Hypothesis

$$K = \frac{2\pi L}{\ln\left[\frac{D}{d}\right]}$$

Then (1) can be written as:

$$C = K\varepsilon \tag{2}$$

Changes of dielectric constant of absorbent materialre presented by formula:

$$\varepsilon_m = \varepsilon_1 s_1 + \varepsilon_2 s_2 \tag{3}$$

Of which ε_m : dielectric constant of wet material; ε_1 : the dielectric constant of water: ε_2 ; dielectric constant of dry material; s_1 :water content volume filling coefficient of wet material; s_2 : dry material content volume filling coefficient of wet material,apparently. $s_2 = 1 - s_1$

According to (2), (3) :

$$C = K\varepsilon_2 + K(\varepsilon_1 - \varepsilon_2)s_1 \tag{4}$$

Because K, ε_1 and ε_2 is constant, so capacitance variation is proportional to water content variation , as long as the capacitance variation can calculate water content s_1 .

The dielectric constant of petroleum products changes with temperature, the formed error is different with the dielectric sensitive to temperature . When water content of petroleum products is the same, the capacitance itself also changes with temperature, the temperature effective on the capacitance or the working frequency is quite large, and the variation is very complicated, so it is difficult to use mathematical model to compensation, temperature effctive on curve method is commonly used to eliminate or reduce the temperature error .

The biggest advantage of temperature effective on curve method is simple in principle, and easy to implement[5], if the temperature effective on curves obtained is close to the actual environment, compensation precision is a high. But its shortcomings are also obvious, in addition to the workload is large, due to the thermal inertia of temperature is large, lag will have greater, for the same oil products in the heating and cooling process, the temperature effective on curves are different, then eliminate temperature error is very difficult .

Therefore, the phase transition temperature control technology is proposed to realize temperature compensation. The basic idea is to design special phase transition temperature control structural in a cylindrical capacitance sensor, and encapsulate suitable phase change materials in the phase transition temperature control structure, it is to implementate temperature control according to that phase change materials can absorb or release a large amount of latent heat during the phase change process but its temperature remains essentially constant. The biggest characteristic of phase change temperature control structure is fully using heat transfer law and the feature of phase change temperature control material , so that the controlled capacitor remained constant in the temperature in the effective measurement length.

In order to reduce the influence of temperature lag, pole of capacitor inside and outside sensing head should choose conductive materials having good thermal conductivity.

3 The instrument hardware

Hardware is mainly composed of single chip computer and peripheral circuit, which comprises a moisture sensor, temperature sensor, result display unit and transmission to upper monitor[6][7][8]. The block diagram is shown as follows:

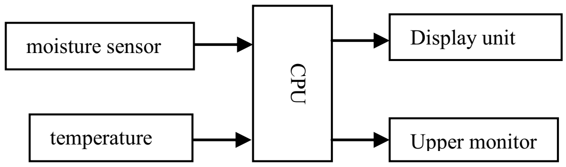

Fig. 2 the hardware composition diagram

The working process of the system is that AC voltage associated with the moisture is generated by the electromagnetic resonance circuit shown in Figure 3, the AC voltage is rectified and filtered through the detection circuit into a DC voltage, and then through the A/D conversion, the generated digital is load into single chip computer ,and figure out water content of the petroleum products . In the electromagnetic resonant circuit, capacitance (also known as the tuning capacitor) is a sensitive element, namely sensor probe.

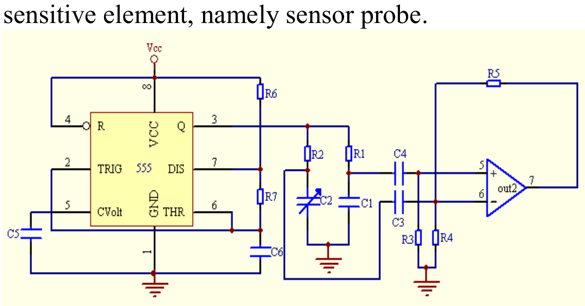

Fig.3 Electromagnetic resonant circuit

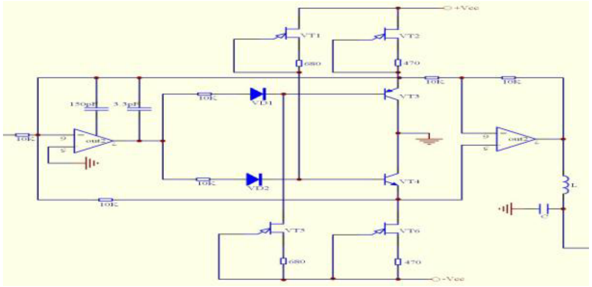

Fig. 4 detection circuit diagram

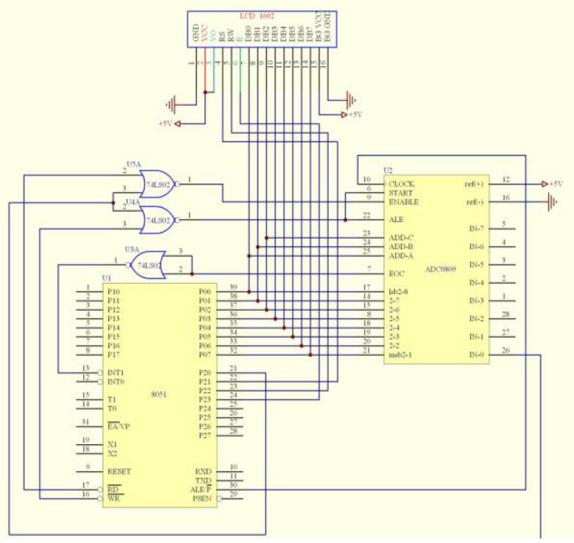

Fig.5 display circuit diagram

Detection circuit as shown in Figure 4, it receives the output signal from the electromagnetic resonance circuit,and the output DC voltage is transferred to single chip computer after A/D conversion.

Figure 5 is circuit of a single chip microcomputer and LCD display, display the water content of petroleum products.

4 results analysis

Because nominal values of each element of the electromagnetic resonance circuit failed to give, and its parameters will be given after engineering tuning, here only gives the principle circuit, in fact it is not working, so using analog potentiometer to provide the DC voltage for A/D conversion. The simulation software with Proteus[5]will be programmed into the chip, adjusting potentiometer (maximum voltage of 5V), to provide a number of different input voltage to the A/D conversion, observation and recording LCD display value. The simulation diagram as follows:

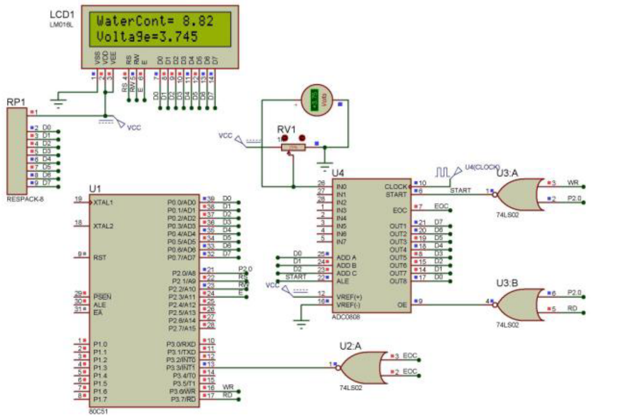

Fig.6 simulation diagram

Because the input range of analog voltage of ADC0809 is 0 ~ 5V, so in programming the input voltage of calibration results table 1 is drop in as one of the 2.5 original, corresponding with the water content. Similarly, with a maximum voltage 5V potentiometer instead of the analog input voltage through step-down treatment, so the simulation of water content corresponding to actual voltage should be 2.5 times the value of the input voltage.

Table 1 calibration results (20℃)

α (%)	0	1	2	3	4	5
U(V)	4.21	4.56	4.96	5.40	5.88	6.48
α (%)	6	7	8	9	10	11
U(V)	7.13	7.84	8.64	9.52	10.44	11.51

From the table, the data shows the accuracy and reliability of the system is higher, the design of hardware and software are reasonable, accord with the design requirements. But it is found that continuity of data is not very good because of the limited resolution and accuracy of the A/D converter and analog potentiometer.

5 Summary

The measuring principle that detecting water content in the petroleum products based electromagnetic resonance technology is feasible, and can accurately measure the water content of petroleum products. temperature compensation precision based on phase transition temperature control technology used for temperature error is higher, and avoid complex repetitive manual labour doing in order to obtain the temperature curve . Intelligent of instrument is high, operation is simple, without any chemical reagent.

When adjusting electric parameter of oscillation circuit, the sensitivity of instrument will be higher, so that meet the need of measuring low water content; also can be to expand the measurement range by changing the oscillating circuit and electrical parameters (0% ~ 100%), to meet the needs of the measurement of high water content.

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