Study on effect of temperature and humidity on the CO$_2$ concentration measurement

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Abstract. In the application of non dispersive infrared (NDIR) carbon dioxide (CO$_2$) concentration measurement, we need avoid the interference factors (such as temperature, pressure, gas, fluctuation of the light source and dust pollution etc.). In the past experiments only single factor, such as temperature, is often emphasized to the influence on the measurement results, without considering the effect of multiple factors. In order to study the change of gas concentration with measurement parameters, we constructs a CO$_2$ detecting device with a BM530 gas detecting module, TMD10 temperature and humidity sensor. The experimental results show that: there is a correlation between the two interference factors: temperature and humidity. With the decreasing temperature, gas concentration measurement value decreases too. In developing process of instruments, we can make correction of the concentration-temperature instead of that of the measurement results under different temperature and humidity conditions.

1. Introduction

As a rapid and accurate gas analysis technology, NDIR has been commonly applied in the continuous CO$_2$ monitoring systems in the Agricultural Sciences. The current NDIR gas analyzer generally uses the infrared sensor, the electric modulation light source and the embedded system with low power consumption. This makes the instrument have many incomparable advantages in the volume, power consumption, performance and price $^{[1-8]}$. However, in its practical application, the CO$_2$ sensor need to avoid the interferences of the external measurement conditions (such as temperature, humidity, pressure, other gas component in the gas mixture, the fluctuation of the light source and the influence of dust pollution, etc.). According to the related research literatures, interferences of the hybrid gas, dust pollution and other relative factors can be effectively eliminated by the adoption of NDIR technology. The stability of light source fluctuation can ensured by the stabilized power supply. In the relative experimental study before, we usually make a single measurement condition changes, such as the temperature, the humidity, etc., ensure the other parameters constant, so as to get experimental results of the gas concentration change with the interference parameter $^{[9]}$. When we calibrate the instrument, we can not only use one of these factors which have an influence on the measurement result. How can we make our calibration on this instrument convincing? This paper mainly studies the CO$_2$ gas with same concentration to be measured by NDIR infrared gas analyzer. We simultaneously change the measurement conditions: temperature and humidity, then study the law describing the CO$_2$ concentration with the measurement parameters, then we can make calibration on the output of gas concentration analyzer.
2. Test Platform
In order to study the measurement value of the CO2 concentration changes with the measurement conditions: temperature and humidity, a test platform is set up. The platform consists of B-530 NDIR CO2 sensor, TMD10-SPI temperature and humidity sensor, single-chip system, keyboard control module, LCD module. NDIR CO2 sensor converts gas concentration information into a corresponding digital signal, at the same time, TMD10-SPI temperature and humidity sensor convert the temperature and humidity measurement conditions information into digital signal. These measurement results can be saved into the microcontroller system memory through the communication interface, and can be displayed on LCD. Switch regulated power supply is used on the test platform. In order to reduce power ripple, a filter is added in the power supply. The hardware platform of the system is shown in Fig. 1.

![Fig. 1 The Structure diagram of CO2 detection platform](image)

B-530 module is selected as the NDIR sensor for CO2 concentration measurement. According to the testing need, measuring range of the module is limited at 0-50000ppm in factory. The block diagram of the NDIR sensor is shown in Fig.2. TMD10-SI module is selected as the temperature and humidity sensors. This module is from Cheung Riverstone Technology Co. in China.

![Fig. 2 Block diagram of the Infrared CO2 sensor module](image)

The experimental platform is tested and the properties of the instrument is: CO2 concentration measurement range of the NDIR CO2 module is 0-50000ppm; the measuring accuracy is ± 30ppm; the sampling interval is 3 seconds. Measurement range of the temperature of the TMD10-SI module is -40-70 degrees, the measurement resolution is 0.1 degrees. Humidity measurement range is 18-98%, its resolution is 1%.

3. Experimental Design
In the experimental process, a certain amount of air with known concentration is sealed in the detection box. Then close the gas path inside and outside of the box so as to ensure real detecting concentration of the gas is always constant. Changing the environment temperature caused the gas temperature and humidity changes slowly, the measurement concentration of the gas can not keep constant, it changes
slowly with the change of the measurement parameter. In order to clearly observe the process of measurement, LCD module of the experimental platform is set closely to the transparent glass of the box body, concentration of the gas can be display in real time.

The trigger works once every 5 seconds, measuring temperature, humidity and gas concentration and then display on the LCD, transform to personal computer and saved.

The trend equation of gas concentration changing with measurement conditions: temperature and humidity can be obtained by data fitting. Data fitting is finished by 1stOpt mathematica\textsuperscript{[10]}\textsuperscript{,} analyzed software package, developed by seven dimensional Co. Ltd.

4. Results and Discussion
Experiments were carried out in a quiet clean lab. We change gas temperature in the box by change laboratory air temperature, simultaneously measure temperature, humidity and gas concentration every five seconds and saved in personal computer. 146 data were selected and used to fit the law between the concentration and the measurement parameter. Formula between CO2 concentration and the temperature and humidity is fitted out by quasi Newton method (BFGS) + universal global optimization method using the 1stOpt software. As is shown in Eq. 1.

\[ z = p_1 + p_2 x + p_3 x^2 + p_4 x^3 + p_5 y + p_6 y^2 + p_7 y^3 + p_8 y^4 + p_9 y^5 \]  

(Eq. 1)

The numerical coefficients in the formula are shown in Table.1.

| coefficient | value          | coefficient | value          |
|-------------|----------------|-------------|----------------|
| p1          | -122304.827954597 | p6          | -1884046.22528529 |
| p2          | 5420.9575012248    | p7          | 1749351.78760737  |
| p3          | -195.944936343794 | p8          | 1191371.85647522 |
| p4          | 2.36182806127216   | p9          | -2122702.79768627 |
| p5          | 634340.418393413   |             |                 |

The relationship between experimental data and the curve fitting is shown in Fig. 3. The curve fitting results is list below. The root mean square error (RMSE): 1.8386447497129, the correlation coefficient (R): 0.994045403085275, the variance: 0.988126263394966.
Because the gas box has been sealed, the outside steam can not enter the box, the internal water vapor could not run out. Through the experiment, we found that the trend of gas concentration changes with the temperature is similar to that of gas concentration change with humidity. Therefore, we conjecture whether there is a strong correlation between temperature and humidity under a closed experimental conditions or not? Then, we studied the correlation between temperature and humidity. From the test, we can find that with the decrease of temperature, the humidity inside the box changes also. The changing curve is shown in fig.4. The correlation coefficient between temperature and humidity is 0.978448947024758. We can learn that there is a strong correlation between humidity and temperature.

Calibration using several measurement conditions should be able to make measurement more accurate. But it also has a shortcoming in the instrument design, the software programming and data storage process may become more complex. Since there was correlation between the temperature and, and the correlation is very strong, temperature and humidity can be used as one variable to consider. That is to say, in the instrument development, we can only consider the relationship between...
concentration and temperature to rough calibrate the measuring instrument. Thus, instrument design, related software programming and data storage process will all become easier.

5. Conclusions
This paper studied a certain amount of gas with fixed concentration. The gas concentration measured varies with the outside temperature and humidity. We fit the law of the gas concentration change with temperature and humidity. We total draw the following three conclusions:

(a). There is a strong correlation between the measurement conditions: temperature and humidity.
(b). With the decrease of temperature and humidity, gas concentration measured decreased too. The formula between the gas concentration and measurement condition has been given.
(c). Because of the strong correlation between temperature and humidity, and the correlation is very high, therefore, the measurement results of different temperature and humidity can be approximate corrected using the concentration - temperature formula.

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