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# Measurement Method for Wire Resistance Temperature Coefficient Based on Heat Transfer Model

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**Abstract**. The voice coil temperature coefficient is a crucial parameter in the field of voice coil temperature measurement technology, speaker thermal effect, and others. A measurement method for wire resistance temperature coefficient based on heat transfer model is presented in this paper. Measure the voltage at both ends of the coil and the current through the coil before and after the temperature rise by simply energizing the coil in the heat resistance box under the condition of stable ambient temperature. The temperature coefficient of the coil can be obtained according to Ohm's law and heat transfer model in the method.

## 1. Introduction

A loudspeaker is an electroacoustic transducer which converts an electrical audio signal into a corresponding sound. The voice coil converts most of the electrical energy into heat energy during operation. Excessive heating of the loudspeaker will directly cause some serious consequences, such as the change of some characteristic parameters of the loudspeaker unit, the compression of the power, the overheating of the voice coil and so on [1]. In order to improve the performance of loudspeaker, it is very necessary to study the heating mechanism of loudspeaker. The voice coil is the source of heat, so the accurate measurement of the voice coil temperature is an important step to study the heat transfer process of the loudspeaker [2]. Voice coil temperature measurement measures the temperature indirectly by measuring the change of voice coil resistance. The resistance temperature coefficient of voice coil is the physical quantity which reflects the relationship between the change of voice coil resistance and the change of temperature.

The measurement method of the resistance temperature coefficient of metal by using the linear relationship between resistance and temperature of metal is proposed in “GBT6148-2005 Test method for temperature-resistance coefficient of precision resistance alloys”. In the method, the coil to be test should be placed at different ambient temperatures. The temperature coefficient of the measured metal can be obtained by measuring the resistance and temperature of the coil [3].Based on this standard and combined with the heat transfer model, a more practical measurement method of the voice coil temperature coefficient is proposed. Compared with the direct measurement method proposed in GB code, this method omits the coil temperature measurement, Simplifies experimental device and fast measuring velocity [4]. It can be used in measuring resistance temperature coefficient of loudspeaker voice coil and other fields.

## 2. Theoretical Basis

### *2.1. The Theoretical Analysis*

The resistance temperature coefficient reflects the relationship between the change of the conductor resistance and the change of temperature, as in

$$A = \frac{R_c - R_0}{R_0 * \Delta T(t)} \tag{1}$$

$R_c$ is the resistance of the coil after heating up; $R_c$ is the initial temperature of the coil at normal temperature; A is the resistance temperature coefficient of the coil.

"GBT6148-2005 Test method for temperature-resistance coefficient of precision resistance alloys" proposed a method for directly measuring the temperature coefficient of conductor based on definition. According to (1), the parameter to be measured is the temperature and resistance before and after the conductor's heating up. The experimental installation of this method is complex, time-consuming and costly.

The coil converts electrical energy into heat energy while the current is passing through the coil [5]. Equation (2) shows the heating power under the condition of DC voltage source or low frequency AC voltage excitation.

$$P = \frac{U^2}{R} \tag{2}$$

P is coil heating power; R is Coil resistance; U is the effective value of the voltage at both ends of the coil.

After the coil is energized, the heat will spread from the coil to the environment gradually. The heat transfer process can be described by a circuit diagram as "Fig.1".

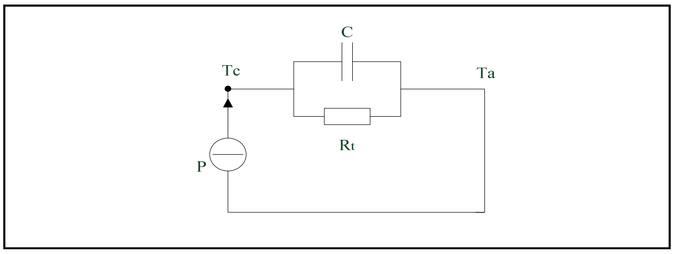


**Figure 1.** Circuit diagram of heat transfer process

$R_t$ is the heat resistance from the final diffusion of heat from the coil into the environment; C is the heat capacity from the final diffusion of heat from the coil into the environment.

In the experiment, the initial temperature was $T_c$=$T_a$=$T_0$

The temperature of the coil is steadily rising after being electrified, and finally stable at $T_c$, while the temperature of the environment is $T_a$ at the same time. Equation (3) shows the relationship between the heating power of the coil and the temperature.

$$T_{ca} = T_c - T_a = PR_t \tag{3}$$

Equation (4) shows the relationship between the resistance of the coil and the temperature.

$$T_c - T_a = \frac{R_{c\infty} - R_0}{A * R_0} \tag{4}$$

On the assumption that the environmental temperature is stable, as in

$$T_a = T_0 \tag{5}$$

Equation (6) can be obtained by (3), (4) and (5)

$$A * R_t = \frac{{R_{c\infty}}^2 - R_{c\infty} * R_0}{R_0 U^2} \tag{6}$$

Among them, $R_0$ and $R_c$ can be obtained by measurement.

The thermal conductivity of the air is greatly influenced by the temperature, therefore, the coil shall be placed in a container filled with materials with stable thermal conductivity (Thermal resistance box) on account of the thermal conductivity of the air is greatly influenced by the temperature [6]. Thermal resistance box ensures the stability of thermal resistance on the heat transfer path [7]. The thermal resistance of the thermal resistance box is related to the thermal conductivity of the filling material of the coil, as in

$$R = L/(S * k) \tag{7}$$

L is thickness of filling material; S is the contact area of the coil and the filling material; K is the thermal conductivity of filled materials. The average thermal resistance on the heat transfer path can be obtained by parallel connection of the thermal resistance in each direction of the coil.

$$\bar{R} = R1//R2//R3 \ldots\ldots//Rn \tag{8}$$

$R_1$, $R_2$, $R_3$ …… $R_n$ are thermal resistance in different directions.

In order to ensure $T_a$=$T_0$, the thermal resistance box shall be placed in a constant temperature environment, such as flowing air or liquid.

The indirect method of measuring the resistance temperature coefficient of coil follows:

Experimental test conditions: Reference coils with known parameters; the test coil; the shape parameters of the thermal resistance box; Resistance temperature coefficient of reference coil. The voltage of the coil and the current through the coil can be measured by the experimental device. The thermal resistance box is placed in a temperature constant environment.

### *2.2. Experimental Procedures*

(a) According to (8), Calculate the ratio of thermal resistance between the reference coil and the ith test coil on the heat transfer path, as in

$$r_{tsi} = \frac{R_{ti}}{R_s} r_{tsi} \tag{9}$$

(b) The reference coil is loaded into the thermal resistance box to cover the filling material. The coil cannot contact with the thermal resistance box. The thermal resistance box is placed in a constant temperature environment.

(c) The coil in the thermal resistance box is energized to measure the voltage and current after just electrified. The resistance $R_{c0}$ of the coil is calculated according to the Ohm's law. As the coil temperature rises, the resistance increases and the current decreases. When the current is stable, record the voltage and current at this time. According to Ohm's law, the resistance $R_{c\infty}$ after the coil is stabilized is calculated.

(d) According to (6) and step (a), Thermal resistance $R_s$ and $R_{ti}$ are obtained by $r_{tsi}$.

(e) The measured coil is put into the thermal resistance box. Repeat step (c) to get the measured coil resistance after stabilization. The resistance temperature coefficient of the test coil can be calculated according to the $R_{ti}$ obtained by (6) and step (d).

(f) Repeat step (d) to get the resistance temperature coefficients of all the test coils.

## 3. experimental verification

The purpose of the experiment was to measure the resistance temperature coefficient of the test coil. The material of the test coil was unknown. For this purpose, the experiment was conducted at room temperature of 26°C and the fluctuation range of temperature was around 1°C in the experimental environment.

The material of the heat resistance box is iron. The heat resistance box was filled with quartz sand for 80~120 mesh. Furthermore, the heat resistance box was placed in the flowing air supplied by the electric fan.

The power supply uses audio power amplifier to produce 5Hz sinusoidal signal. Therefore, a multimeter and a current transformer are used to measure voltage and current. The experimental device diagram is shown in Figure 2.

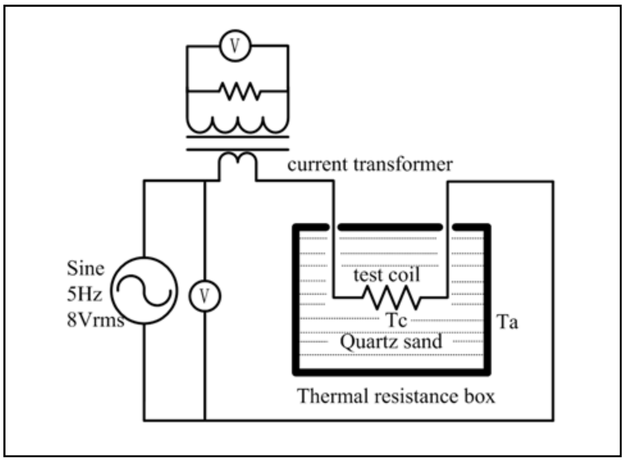


**Figure 2.** Experimental device diagram

The reference coil was made of red copper. The resistance temperature coefficient is $A_s$=0.00393/K. $r_{ts}$=1.71638 was calculated according to (8), (9) and the shape of the two coils.

The 500mV value voltage was used to energize the coil. Measured the initial value of the current and voltage. Then according to Ohm's law, calculated the reference coil resistance at room temperature is 8.698Ω, and the resistance of the test coil is 6.937 Ω.

It was necessary to use the reference coils to verify the stability of the device before the resistance temperature coefficient of the test coil was measured [8]. The results of thermal resistance measured by different voltages is shown in Fig 3, and the amplitude of temperature rise is shown in Fig 4. According to Fig. 3, the thermal resistance stable voltage range is 5V-8V. When the voltage is low, for example 1V, the temperature of the coil rises little. The fluctuation of the air temperature around the thermal resistance box has a great influence on the measurement, resulting in erroneous measurement results. When the voltage is too high, such as 11V, the temperature of the air around the thermal resistance box is high. Because the fans could not cool the air around the heat box in time, $T_a$=$T_0$ did not set up, and finally got the wrong measurement result. Thus, 8V voltage is used to measure the $A_t$. According to Fig. 3 and (9), $R_s$=7.45717K/W, $R_t$ =$R_s$*$r_{st}$=12.79933K/W.

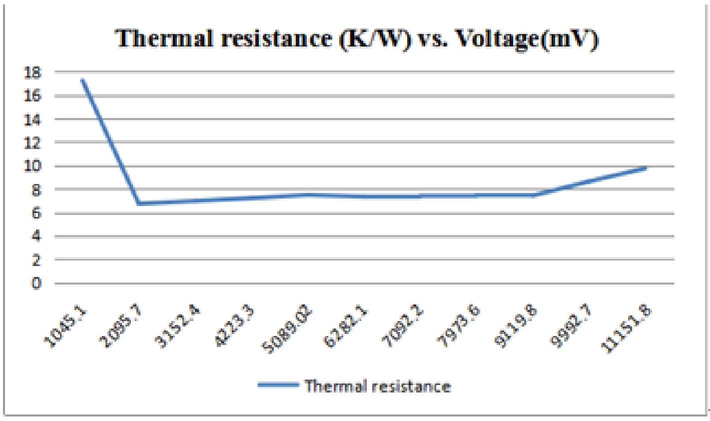


**Figure 3.** Change of thermal resistance

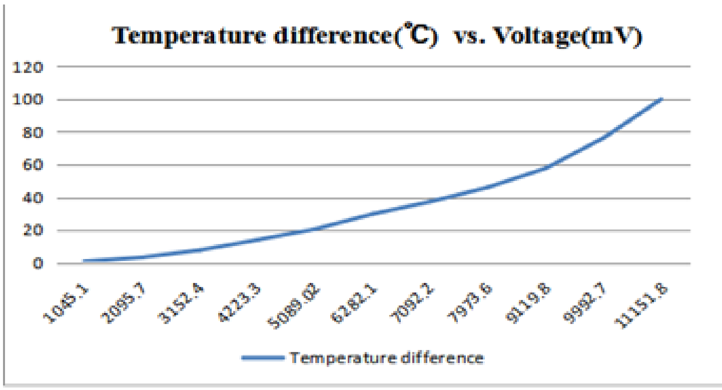


**Figure 4.** Change of temperature difference

According to the method mentioned in the chapter 2, the calculation results can be obtained as Table 1.

**Table 1.** Test Coil Temperature Coefficient

| Voltage(mV) | $A_t*R_t$ | Temperature coefficient |
|---|---|---|
| 8194.85 | 0.05011 | 0.00391 |

## 4. Conclusion

In the experiment, a new method of measuring the temperature coefficient of the coil is adopted, which is consistent with the theoretical temperature coefficient. It is verified by the experiment that the resistance temperature coefficient of the coil can be measured accurately through the indirect measurement method. It takes about 15 minutes to stabilize the coil temperature in the experiment. Compared with the traditional method, the experimental time is greatly reduced on the premise of ensuring the accuracy of measurement. The measuring velocity can be improved when other filler materials are selected. The experimental device is simple and low-cost. Using audio power amplifier to supply power in the experiment, the measurement method can be used in measuring the resistance temperature coefficient of loudspeaker voice coil and other fields.

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