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STUDY ON THERMAL DRIFT OF NOBLE METAL THERMOCOUPLES

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ABSTRACT

We set up the temperature - running period CM (Characteristic Modelling) of the noble metal thermocouples (S/B type). Using CM, we got the both thermocouples max error reduced, type S is 2.1 ℃ and type B is 1.8 ℃ which were 5.8 ℃ and 4.3 ℃ before using CM and the coefficients of determination in CM are 82.1 % and 72.5 %. It shows 85 % difference between CM and error less than 1.0 ℃, especially in type B. So it is necessary to use CM to measure temperature accurately.

Keywords: thermal drift, characteristic modelling, type S thermocouple, type B thermocouple

1. INTRODUCTION

Thermometry technique is classified in two methods, a contact method and a non-contact method. A contact method is measuring the object by contacting thermometer directly, and non-contact method is using thermal radiation of the object. Thermocouple, resistance thermometer and thermistor are a contact method, radiation thermometer and pyrometer are a non-contact method. They are used in various areas according to their purposes and uses.

Of these, thermocouple, included in a contact method, is measuring temperature by EMF (Electro Motive Force) which is occurred due to the temperature difference of two junctions. It can measure temperature accurately in a wide range and is simple to use. For this reason, it is used in various fields of industry. Especially type S, B thermocouples, which are noble metals, are widely used in the steel, chemical and glass industry for measuring temperature accurately above 1 000 ℃.

There are many cases in noble metal thermocouples used in these areas to use long term when they are once installed in industry. In this case, the thermo drift are occurred as changes in EMF by deterioration of metal. So it is necessary to compensate the thermo drift characteristic in accordance with terms of use. There are many people wondering about this drift in industry, but it is very hard to get information about thermocouples used in a long term.

In this study, we set up the temperature-running period characteristic modelling through inspection thermocouples used in industry for long term.

2. MAIN PARTS

2.1 THERMAL DRIFT OF THERMOCOUPLES

Temperature drift means the changing phenomenon of sensor's in/output characteristics or the values. The drift of the thermocouple occurs by the wires material and the EMF changes [1].

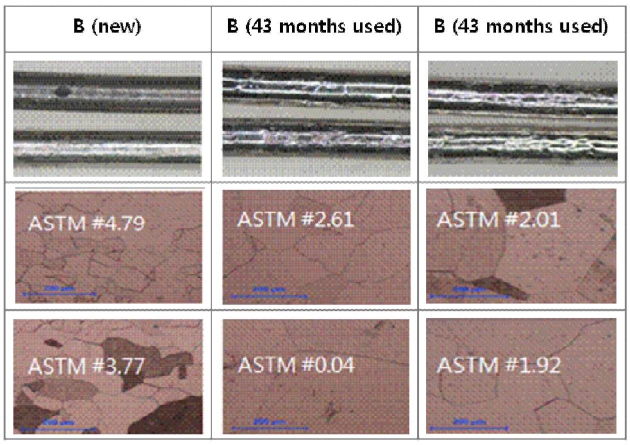


Fig.1 Grain size of Wire

Fig.1 is a result of thermocouple wire's ASTM No. and average area using an image analysis program. (a) is a new thermocouple, (b) and (c) are thermocouples used for 43 months. They were all 1.0mm diameters and manufactured by J company. We can see the change of wire's grain size in thermocouples used for 43 months unlike the new one. We also found that they had about - 3.2 ℃ temperature variations at Palladium melting point. The drift's phenomenon can be determined in other ways. Fig.2 is the picture of temperature measuring junctions that were used for 43 months. We can see many scratches on the wires. Table.1 is the result of wire's components analysis using

SEM-EDS. In type B thermocouple, the Rhodium ratio should be respectively 30 %, 6 % in (+), (-) wires. However, the many changes occurred due to drift phenomenon.

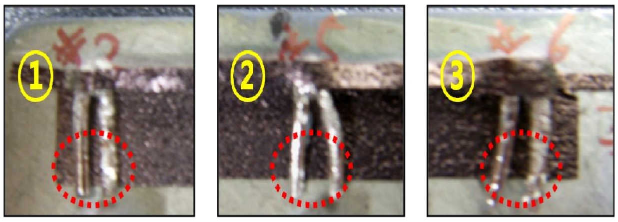


Fig.2 Wire corrosion according to long-term use

Table.1 Components of Wire used for 43 months

Polarity	+		-	
Components	Pt (%)	Rh (%)	Pt (%)	Rh (%)
Standard (B)	70.0	30.0	94.0	6.0
①	91.2	8.8	96.9	3.1
②	91.3	8.7	97.3	2.8
③	93.5	6.5	97.7	2.3

Homogeneity of material, diameter of wire, the contact method of measuring junction, insulator and protection tube cause EMF drift [1]. But it's very difficult to find out the amount of drift in process.

Therefore in this study, tests were conducted on samples in identical conditions except terms of use to determine the temperature-running period characteristic. Samples used in this study are total 49 set of type S and B thermocouples and they had been used in industry for 8 to 43 months. They were 1.0 diameter and manufactured under the same conditions by H company. They were used in the range which is not exceed the limit of common use range; type S thermocouple is 1 300 ℃ ~ 1 400 ℃ and type B thermocouple is 1 400 ℃ ~ 1 500 ℃. High-purity alumina insulators and protection tubes were used and the installed environment outside of the protection tube is oxidizing atmosphere.

$$0.9\ CH_{4(g)} + 0.1\ C_2H_{6(g)} + 2.6\ O_{2(g)} \longleftrightarrow 2.1\ H_2O_{(g)} + 1.1\ CO_{2(g)} + 0.45\ O_{2(g)} \qquad (1)$$

2.2 EXPERIMENTAL METHOD

In order to check the thermocouple's temperature variation by thermo drift, it is necessary to analyze absolute error by inspection before and after use. Fig.3 is a four-step process to analyze absolute error. First step is that we inspected initial state of thermocouple wires, and the second step is that thermocouples were manufactured using the wire which was inspected at the first step. The third step is that thermocouples were used in industry and the final step is that we inspected used thermocouples in the same method as the first step. Through this process we could analyze the absolute error.

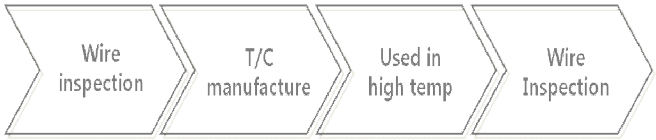
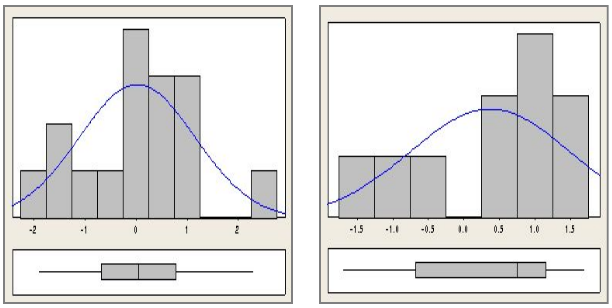


Fig.3 Analysis process

In the case of thermocouples that was not inspected in the initial state, we estimated the initial error based on the J companies' wire certification supplied to us. J company is a thermocouple wire supplier to us and H company which is a manufacturer of thermocouple. Our inspection data and J companies' wire certification show similar results within 0.5 ℃ difference (Fig.4). Through analyzing the wires' temperature variation supplied to us, we found that they showed uniform distribution by each types (Fig.5). Through these facts, the analysis was conducted estimation of initial errors for which were not inspected in initial.

Fig.4 Comparison of inspection (J Company vs SCP)



(a)S Type (b) B Type

Fig.5 Distribution of inspection results supplied to SCP

Inspection was conducted at palladium melting point (1 553.5 ℃) which is used in steel industry to calibrate temperature sensor [2]. To realization of fixed-point, 99.99 % palladium wire supplied by C company was used. We used wire bridge method and measured EMF [3].

The furnace has heat pipe with kanthal material and it is controlled by PID system. When the furnace is used, temperature pattern is shown in Fig.6.

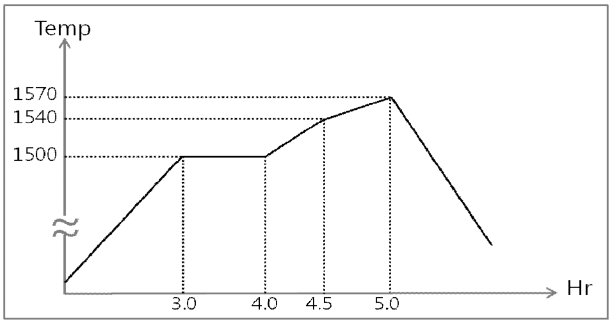


Fig.6 Temperature pattern of furnace

Freezing point was implemented with distilled water for the reference junction of thermocouple and compensation wire made based on KS was used [4]. EMF was measured using the Agilent 34972A (LXI Data Acquisition).

Measured EMF was converted to temperature by revised thermocouple reference tables and analyzed with regression analysis [5].

2.3 RESULT

Fig.7 shows the each type's temperature variation according to the duration of use. Fig.6 (a) is type B thermocouple, Fig.6 (b) is type S thermocouple and their regression equations using least squares are as follows.

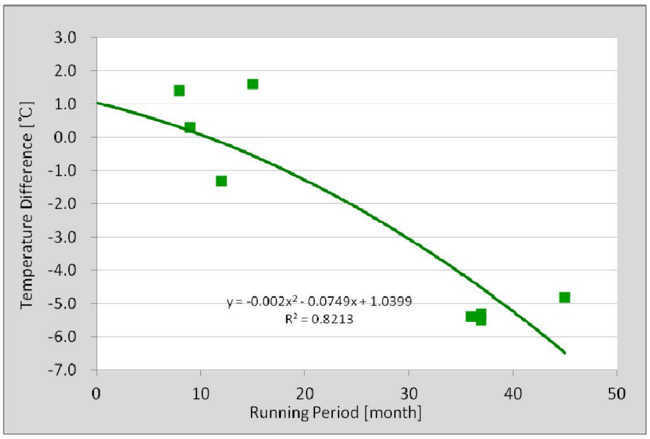
$$\Delta T_{B1} = -\ 0.0017\,x^2 - 0.0054\,x + 0.2051 \quad (2)$$
$$\Delta T_{S1} = -\ 0.0020\,x^2 - 0.0749\,x + 1.0399 \quad (3)$$

ΔT_{B1} : Thermal drift (B, 1.0 mm, 1 400 ℃ ~ 1 500 ℃)
ΔT_{S1} : Thermal drift (S, 1.0 mm, 1 300 ℃ ~ 1 400 ℃)
x : running period (months)

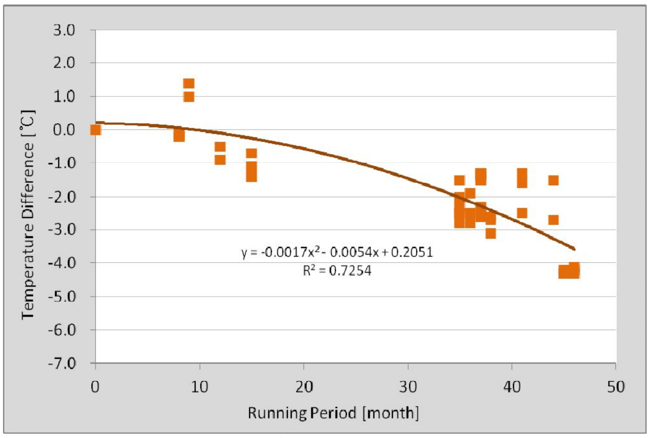
R-squared value is what the degree of the dependent variables explained by the estimated regression equation [6]. This value has 0 to 100 %. The higher value is, the more reliable estimation of the equation is. R-squared for the current analysis are high value; type S thermocouple is 82.1 %, type B thermocouple is 72.5 %.

The temperature variation within 1.0 ℃ between the inspection results and regression equation are 50 % in type S (4 of the 8 samples) and 85 % in type B (36 of the 41 samples). The maximum deviation of type S is 2.1 ℃, and type B is 1.8 ℃. R-squared value is higher in type S than type B, but we think the difference between equation and inspection result is occurred by the number of samples, 8 samples are significantly small for analysis.

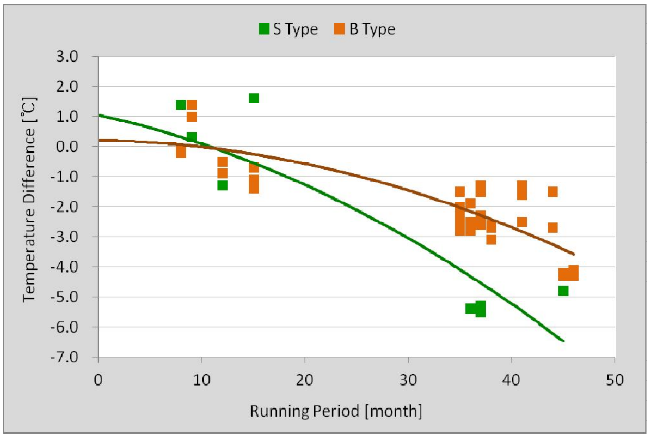
Type S and B are compared in the Fig.6 (c). As shown in the Fig, type S has more temperature drift than type B if it had used in high temperature for a long term. We think it caused by platinum content which is more in type S.



(a) B Type



(b) S Type



(c) S Type vs B Type

Fig.7 Thermal Drift Data of Thermocouples

3. CONCLUSION

We set up the temperature-running period characteristic modelling through inspection of thermocouples used in industry in a long term. The model equations of both type (S and B) show high R-squared value, especially it is possible to reduce the reading errors using the characteristic modelling in type B. Type S has high value in R-squared, but we have a plan for higher reliability through the inspection of thermocouples that will have been used in high temperature for long terms.

The results through this study, it seems to be able to apply in industry and it will be a database for high temperature drift studies.

4. REFERENCE

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