THERMOCOUPLE USED FOR TEMPERATURE MEASUREMENT OF ALUMINIUM CELLS BY DYNAMIC METHOD①

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ABSTRACT

The structure of the thermocouple used to measure temperature of aluminium cells by dynamic method has been investigated. In order to meet the requirement of temperature measurement error a new thermocouple was designed. The results verified that heat insulation material in protective tubes can reduce the error of temperature measurement by dynamic method.

Key words: electrolyser dynamic method temperature measurement thermocouple

1 INTRODUCTION

The accurate measurement and control of temperature can improve electric current efficiency[1] and reduce power consumption, but it isn't still solved because the electrolyte has powerful corrosiveness and the temperature is high. For this reason, the life of protective tubes was short when thermocouple was used to measure the temperature in electrolysers. At present there are two main ways to prolong protective tubes' service. One way is to develop a new protective tube with corrosion resistivity and long life; another is to shorten the contact duration between the tube and molten electrolyte. The first way hasn't still made obviously progress [2, 3], so many people take interest in the second way and lot of research works have been done. One of them is using thermocouple to measure the temperature in electrolysers by dynamic method [4].

This method can reduce the duration when the tube contacts with electrolyte, so that the life of protective tube is prolonged greatly. In order to measure electrolyte's temperature precisely, a new thermocouple using for dynamic method has been developed in this paper.

2 DESIGN THEORY

2.1 *Thermal Transmitting Test*

In order to prove that it takes some time for heat to transmit from outside of the tube to centre through heat insulation material, we design a special thermocouple, see Fig. 1.

We used a computer to record the temperature when thermocouple was inserted into the electrolyte. From the results (Table 1), we found that the central temperature didn't rise immediately i. e. existed a time lag depending on the kind and thickness of heat in sulation material, when the special thermocouple was inserted into the electrolyte. It isn't difficult to understand this phenomenon because the thermal conductivity of heat insulation material is poor.

2.2 *Thermal Conduction Analysis*

It is well known that thermal conduction is very complicated. All factors which influence ther-

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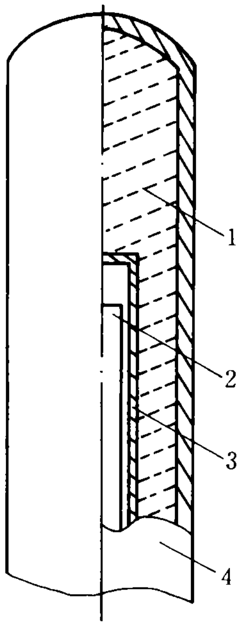

Fig. 1 Special thermocouple structure

1—heat insulation material; 2—armored thermocouple; 3—inside protective tube; 4—outside protective tube;

mal current on thermocouple wire affect temperature on wire measurement point. It is obvious that we cannot remove every influencing factor, so the effective measure is to reduce the factors' influence on thermocouple's temperature rising during temperature measuring using dynamic method.

Table 1 Temperature rising value ΔT ℃

No	t/s				
	0	5	10	20	50
1	6.65	9.50	12.85	16.90	23.75
2	15.80	18.75	21.50	26.85	37.20
3	17.20	21.60	24.25	28.75	38.35
4	25.75	29.60	32.15	37.00	47.60

Notes: (1) Electrolytic temperature is 957 ℃;
(2) the material of No. 1 was the same as No. 2 but varied in thickness each other;
(3) the material of No. 3 was the same as No. 4 but varied in thickness

When the temperature on two point of thermocouple wire changes, the electric potential difference between those points changes also. If the one point's temperature is fixed, the temperature's change on another point can be reflected by the potential difference's change.

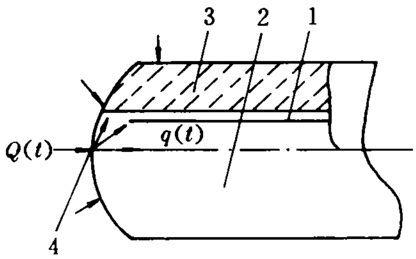

Fig. 2 Heat transmitting in high reproducible thermocouple

1—thermocouple wire; 2—outside protective tube; 3—heat insulation material; 4—wire measurement point

We define the change rate of temperature on the wire measurement point as (dT/dt), which depends on absorbing heat rate $Q(t)$, and giving out the heat rate $q(t)$ on the measurement point then

$$dT/dt = (Q(t) - q(t))/(mc)$$

where m, c are measurement point's mass and specific heat; $q(t)$ includes thermal conduction through thermocouple wire and surrounding medium.

If the change rate of ($\partial T/\partial n$) and the heat transmitted through the surrounding medium are unchanged the change rate of $q(t)$ will be also kept at the same each time. In order to realize this purpose, we should fill enough heat insulation material between outside protective tube and inside protective tube to avoid heat transmitting from outside protective tube to themocouple wire in short time. As a result the influence of all factors on $q(t)$ and $Q(t)$ is strongly reduced and (dT/dt)'s change rate tends to be the same. At last, the reproducibility of dynamic thermocouple is improved.

Besides reproducibility, we consider the aluminium electrolytic surrounding and requirements to manufacture thermocouple. In this paper a kind of thermocouple with high reproducibility is developed on these theories.

3 HIGH REPRODUCIBLE THERMOCOUPLE

High reproducible thermocouple (Fig. 3) should still meet the following requirments: (1) the material of outside protective tube must be corrosion and thermal shock resistant. (2) The

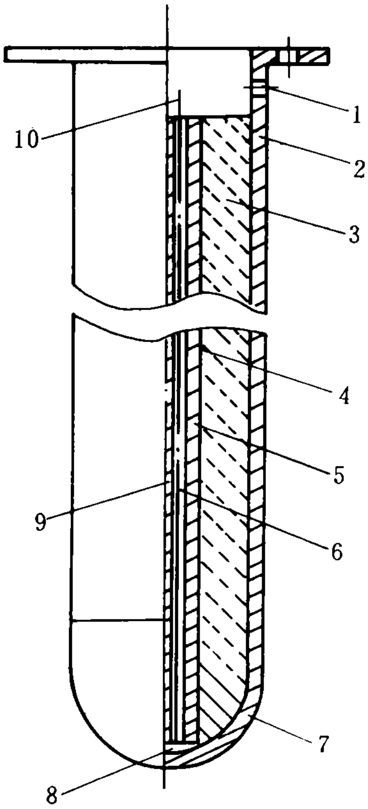

Fig. 3 High reproducible thermocouple structure
1—compensation wire exit; 2—outside protective tube; 3—heat insulation material; 4—inside protective tube; 5—ceramic insultor; 6— hole in insulator; 7— measurement head; 8—wire measurement point; 10—thermocouple wire

heat insulation material must have enough thickness and ability to resist high temperature. The thickness depends on the duration of thermocouple in electrolyte and thermal conductivity of heat insulation material. (3) The wire measurment point must contact close with the measurement head.

4 TEMPERATURE MEASUREMENT

We used armored, conventional, high reproducible thermocouple to measure temperature in electrolyte separately by dynamic method, their operating parameters were kept the same each time and temperature was recorded and handled by computer. Part of results is given in Table 2.

From Table 2, we find the error of high reproducible thermocouple is the smallest and the error's absolute value is less than 20 ℃. At present, the temperature in aluminium cells is controlled mainly by experience and the error's absolute value is often higher than 20 ℃. High reproducible thermocouple can improve the precision of temperature measured and controlled and economize on electricity during aluminium electrolysis.

Table 2 Temperature value

Thermocouple	No	True(℃)	Experiment(℃)	Error%
Armored	1	9595.6	994.6	3.6
	2	964.9	986.3	2.2
	3	953.5	927.2	2.8
	4	950.8	910.2	4.3
Conventional	1	951.5	990.4	4.2
	2	967.2	903.2	6.6
	3	965.3	987.6	3.3
	4	964.2	942.7	2.3
High reproducible	1	957.9	966.4	0.9
	2	963.7	981.1	1.8
	3	962.3	977.4	1.7
	4	958.8	978.8	2.1

5 CONCLUSIONS

(1) Although there are a lot of factors giving influence on temperature measured by dynamic method, the thermocouple improved can reduce their influence on measuring precision.

(2) The heat insulation material in thermocouple must have enough thickness and the measurement point must contact closely with the measurement head. These are key to improve the reproducibility of thermocouple.

(3) The error of high reproducible thermocouple is the smallest.

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