Gas-Tungsten-Arc Electrode (Report 2)†

— Measurement of cathode temperature —

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Abstract

Measurement of electrode temperature of GTA cathode has been done by the use of spectroscopic method. Infrared light intensities of 850 and 1000 nm in wave length were compared and temperature is determined from their intensity ratio.

3220, 3110 and 2930 K in Th-oxide Tungsten, Y-oxide Tungsten and La-oxide Tungsten, respectively were obtained under the condition of 200 A in current, 3 mm in arc gap, 3.2 mmϕ in electrodes diameter, 24 mm in electrode extention length with Ar shielding.

KEY WORDS: (Tungsten) (Oxide Tungsten) (GTA Welding) (Nonconsumable Electrode) (Refractory Metals) (Electrode Temperature)

1. Introduction

In a previous paper, it's shown that La-oxide Tungsten and Y-oxide Tungsten electrodes for Gas-Tungsten-Arc (GTA) has the more superior characteristics in arc starting characteristics, arc pressure and electrode consumption etc. compared to Th-oxide Tungsten electrodes.

In order to clarify the reason why La-oxide Tungsten and Y-oxide Tungsten electrodes have the more superior characteristics, it is necessary to analyze the physical and metallurgical condition of the cathode surface.

GTA cathode has a high temperature of around 3000 K and is covered with an arc plasma. In the measurement of such a high temperature, it is useful to use a spectroscopic method of infrared radiation.

In this paper, the procedures and results of temperature measurement of the cathode of GTA is described.

2. Electrode Produced

Various types of tungsten-oxide electrode were produced by the conventional powder metallurgy process, which are tabulated in **Table 1**. These are 3.2 mmϕ in diameter, centerless ground. The shape of electrode tip is a cone angled at 45°. Direct current is applied in electrode negative polarity.

3. Experimental Procedures

Electrode tip operating as the cathode has very high temperature and is covered with arc plasma. It is necessary to avoid the effect of plasma in order to measure the spectral energy radiated from cathode surface. Arc current was interrupted in a very short time to extinguish the plasma light and during its time the spectral intensities of 850 and 1000 nm in wave length emitted from a very small area of cathode surface were measured. From the intensity ratios of light of those two wave length, the temperature were determined according to the calibration curve, which was taken by using the ohmically heated electrode and the same measuring alignment.

3.1 Electrode temperature operating as the cathode

In **Fig. 1**, experimental alignment is shown. At first,

Table 1 Electrode produced and its oxide content.

Electrode material		Oxide content (%)
Pure-Tungsten	(P-W)	0
Thorium oxide-Tungsten	(ThO_2-W)	2
Yttrium oxide-Tungsten	(Y_2O_3-W)	2
Lanthanum oxide-Tungsten	(La_2O_3-W)	2

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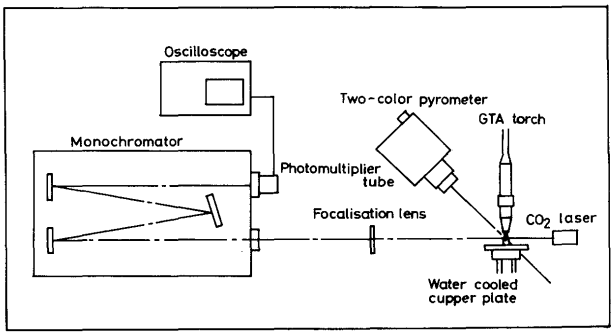

Fig. 1 Experimental alignment for measuring electrode temperature.

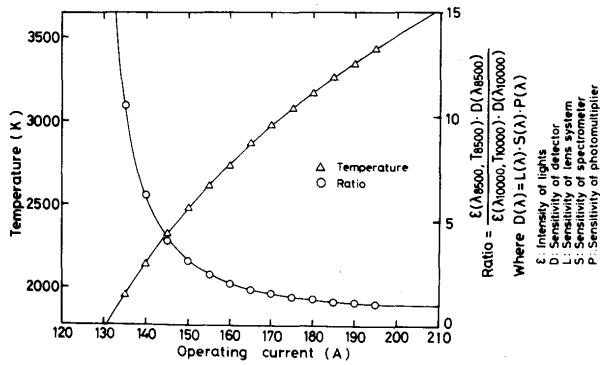

Fig. 2 Calibration curve, the relation between temperature and light intensity ratio.

the electric current was applied to pure Tungsten electrode with no space gap, and the relation between the electric current and the electrode temperature was obtained by the two-color pyrometer. Subsequently, the spectral intensities of 850 and 1000 nm in wave length was measured by the monochromator system. Then, the relation between the electric current and the intensity ratio was determined, as shown in **Fig. 2.**

The monochromator receives the radiation emitted from the small area, 150 X 200μm at 1 mm far from the electrode apex along axis.

In **Fig. 3**, the change in arc current and infrared radiations from arc plasma and cathode are shown. The used arc current is 200 A, 10 sec in the burning stage and has the interruption of 0 A, 5 msec. The arc current of 200 A, 10 sec is enough to accomplish a thermally steady state of

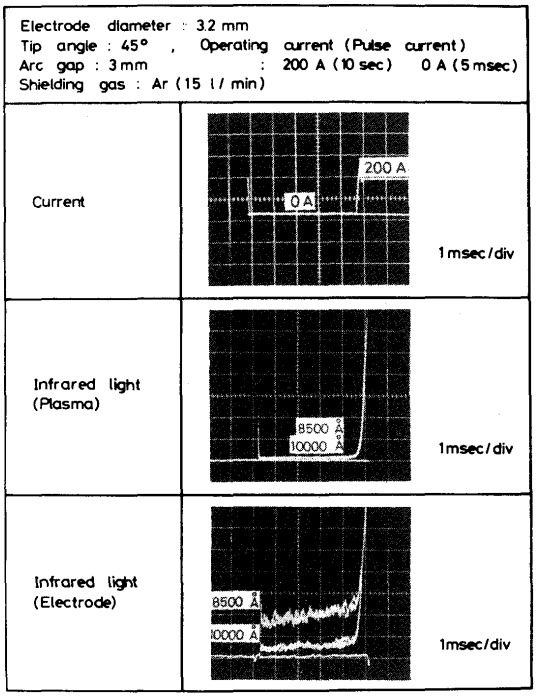

Fig. 3 The change in arc current, infrared light emitted from arc plasma, and infrared light emitted from cathode.

cathode. As soon as the arc current is electronically interrupted, the infrared light of arc plasma disappears very quickly. While the arc is off, the radiation from the cathode gradually decreases, as shown in Fig. 3. The radiation emitted from cathode in the instant of disappearing of arc plasma was assumed to represent the thermal state of cathode under arc burning condition. And the temperature of cathode was determined from the intensity ratio of two wave lengths, 850 and 1000 nm, by the use of the calibration curve.

3.2 The electrode temperature distribution along axis

The electrode temperature distribution along axis was measured by the usual two-color pyrometer of noncontact type thermometer in pure argon. The two-color pyrometer was scanned along the axis. Applied lengths were 850 and 1000 nm and the emissivity was assumed constant.

4. Experimental Results and Discussions

In **Table 2**, it's shown the cathode temperature measured by the method described in the preceding subsection. The temperature of Th-oxide Tungsten is 3220 K, one of Y-oxide Tungsten is 3110 K and one of La-oxide Tungsten is 2930 K under the same operation condition. This corresponds the fact the radiation energy measured for the Th-oxide Tungsten is significantly high compared to those of La-oxide Tungsten and Y-oxide Tungsten. It's considered that the true cathode temperature is not lower than the measured electrode temperature. Because there is a very short time until the influence of the infrared light of plasma gets to be nothing perfectly.

The error of this measurement comes mainly from the spectral emissivity. Namely, the spectral emissivity of the cathode is assumed to be same as that in the case of ohmically heated tungsten.[1)2)] In the experiment generating calibration curve the surface is under polished condition, but in the case of arc burning the cathode surface is

Table 2 The electrode temperature operating as cathode.

Electrode diameter : 3.2 mm Tip angle : 45° , Operating current (Pulse current) Arc gap : 3 mm : 200 A (10 sec) 0 A (5 msec) Shielding gas : Ar (15 l/min)			
Material	ThO_2(2%)-W	La_2O_3(2%)-W	Y_2O_3(2%)-W
Temperature(K)	3220	2930	3110

considered to be slightly molten as shown in **Fig. 4**, which is the microstructure of cathode surface after arc burning.

In **Fig. 5**, is shown the electrode temperature distribution along axis. According as being distant from the electrode tip, the electrode temperature decreases. And the extraporated temperature at 1 mm distant from the electrode tip well agree with the temperature measured by the monochromator.

In the electrode including oxide, the measured curve show an abnormal peak. It reflects the change in surface state and the micro structure of arc. It is considered to be corresponding to formation of a weak glow in the outside of main arc plasma. However, the cause is not clear yet.

5. Conclusion

(1) The temperature of the oxide tungsten electrode operating as the cathode of GTA was measured by spectroscopic method under the condition of 200 A in arc current, 3 mm in arc gap, 3.2 mmϕ in electrodes diameter, 24 mm in electrode extention length with Ar shielding.

a) The temperature of Th-oxide Tungsten electrode was 3220 K.

b) The temperature of Y-oxide Tungsten electrode was 3110 K.

c) The temperature of La-oxide Tungsten electrode was 2930 K.

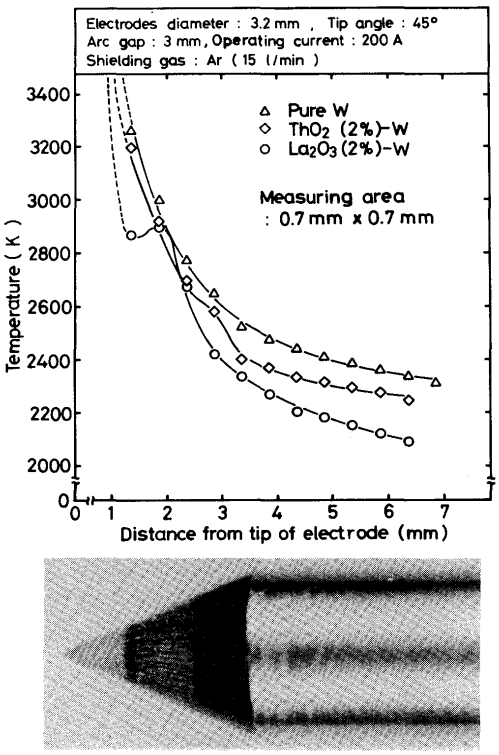

Fig. 5 The electrode temperature distribution along axis.

(2) The electrode temperature distribution along axis was measured by two color pyrometer under the condition of 200 A in arc current, 3 mm in arc gap,

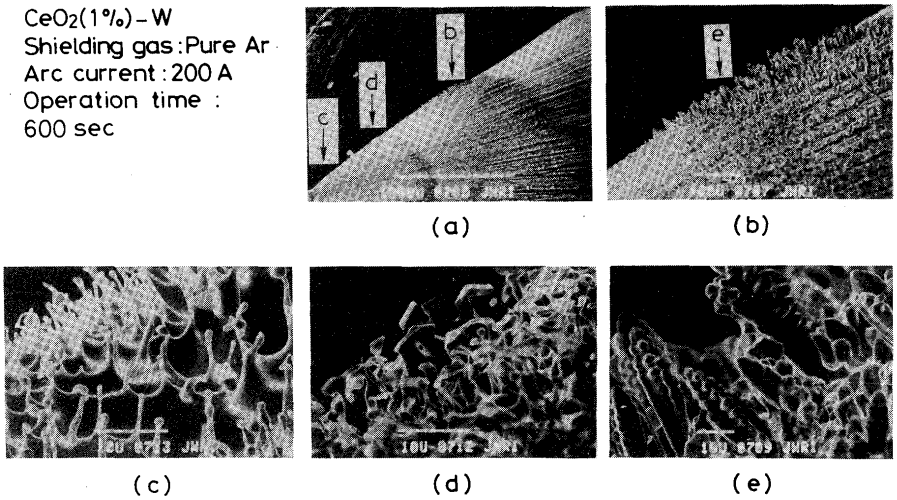

Fig. 4 Microstructure of electrode surface after long term operation in pure argon.

3.2 mmϕ in electrode diameter with Ar shielding. La-oxide Tungsten showed low electrode temperature followed by Th-oxide Tungsten and pure tungsten in that order.

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