# Properties of $LaB_6$-W electrode

*Kazushi Tanaka and Masao Ushio**
*Electrotechnology Applications R&D Center, Chubu Electric Power Co., Inc. Nagoya Aichi 459 Japan*
**Welding Research Institute of Osaka University, Ibaraki Osaka 567 Japan*

**Abstract**

Tungsten hot cathode activated by rare-earth metal (REM) oxides were shown good durability for relative low current[1]. But using at high current condition, those electrodes showed severe erosion[2]. At the same time it occurred that the rare-earth metal oxides were extremely concentrated near the tip, associated with formation of vacant holes. This phenomena should impede highly smooth and regular transport of REM oxide to the electron-emission area.

As is well known, Lanthanum-hexa-boride($LaB_6$) is good emitter of electron[3], and it will behave as a very good emitter even if it is contained extremely low in tungsten.

In this study, consumption of tungsten electrode including 0.05-0.8% $LaB_6$ was studied under the condition of 350 A for 2.4mmϕ electrode. Some of those electrodes showed good durability compared with those including REM oxide.

## 1. Introduction

Various types of tungsten electrode which contain a small amount of REM oxide such as $La_2O_3$, $Y_2O_3$ and $Ce_2O_3$ have been developed, however in high current condition, their performances are not completely satisfactory. It sometimes occurs extremely excessive concentration of REM oxide and formation of vacant holes. The mechanism of formation of holes is not clear but excess migration of REM oxide and their decomposition are considered to be strongly related with the phenomena. $LaB_6$ is the low work-function material, not containing oxygen. And it should behave as the good emitter of electron, even if the amount is very low.

In this paper, the excellent properties of W-electrode containing very small amount of $LaB_6$ are reported in comparison with $La_2O_3$-W.

## 2. Experimental Procedures

The newly developed electrode is a tungsten electrode which contains small amount of $LaB_6$(0.05-0.8w%). (see table 1). In almost cases, electrode diameter used in this study were 2.4 mmϕ. Experimental conditions were below 350A for 2.4mmϕ (current density: 77A/mm$^2$) . This current was just below the burnout current. The consumption test was carried out for 1-5 hours for various amounts of $LaB_6$ content and various shapes of tip. A direct current was applied between the tungsten cathode and water cooled copper anode. A constant arc length of 3 mm and torch orientation perpendicular to the anode were used through out the series of experiments.

Table 1 Electrodes and additives content in this study.

| Electrode | content(wt%) | |
|---|---|---|
| $La_2O_3$-W | 0.2 | ($La_2O_3$) |
| | 2 | ($La_2O_3$) |
| $LaB_6$-W | 0.05 | ($LaB_6$) |
| | 0.1 | ($LaB_6$) |
| | 0.2 | ($LaB_6$) |
| | 0.4 | ($LaB_6$) |
| | 0.6 | ($LaB_6$) |
| | 0.8 | ($LaB_6$) |

The metallurgical structure of electrode cross-section after test was observed using SEM and analyzed by EDX. The distribution of electrode temperature during arcing also measured by infrared thermal monitor (MODEL #3008) produced by VANZETTI SYSTEMS INC. The measured spot diameter is 0.56mmϕ.

## 3. Results and Discussion

### 3.1 Electrode consumption

Fig. 1 shows the electrode weight losses measured for three kinds of electrodes. From this result, $LaB_6$(0.2%)-W electrode showed the lowest consumption rate among them. This figure also shows that the very low content of oxide also provides satisfactory results in this condition.

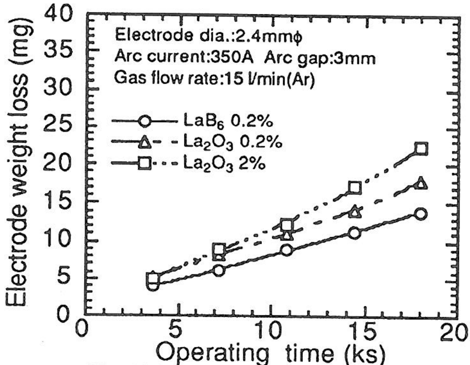

Fig. 1 Electrode consumption as a function of arcing time.

Fig. 2 shows the SEM microstructure of electrode cross-sections after arc discharge for 5 hours. White points represent additives like $La_2O_3$ and $LaB_6$. There appears that the conventional type electrode ($La_2O_3$(2%)-W) has some holes at the tip, but both low content (0.2%) type electrodes $La_2O_3$ and $LaB_6$ have no holes at the tip. In case of $La_2O_3$(0.2%)-

W electrode, the area appears has no white points. At that area there is no oxide, this area will behave like a pure tungsten. It will be melt down in a few hours later. $LaB_6$(0.2%)-

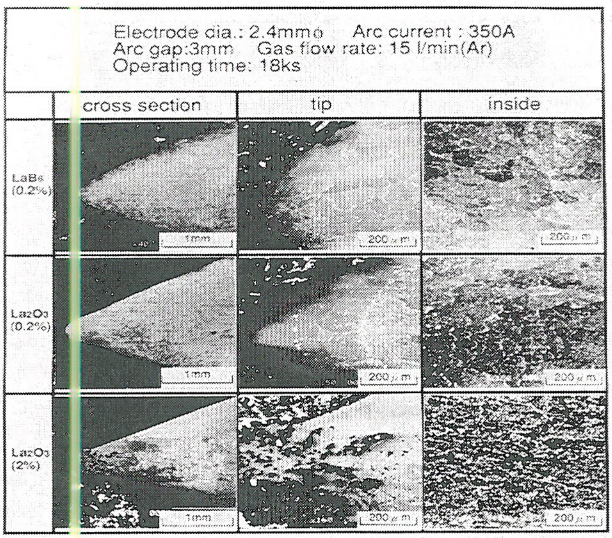


Fig.2 SEM microstructure of electrode cross-section after arc discharge.

W electrode has no such area. Its life time should be longer than that of $La_2O_3$(0.2%)-W electrode.

Fig. 3 shows the effect of $LaB_6$ in tungsten for consumption of electrode. The variety of content is from 0.05 to 0.8 wt% in tungsten. From this result, the content of 0.6% $LaB_6$ shows the lowest consumption among them.

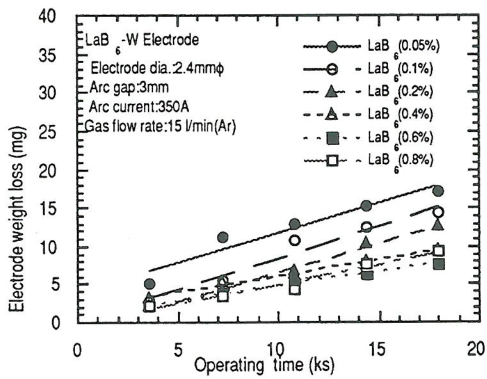


Fig. 3 Electrode consumption as a function of arcing time.

Fig. 4 shows the SEM microstructure of electrode cross-sections after arc discharge for 5 hours. This photograph shows that all electrodes have uniform distributions of $LaB_6$ inside the electrode. The consumption of the electrode contain 0.05 and 0.1% $LaB_6$ shows a little more than the other electrodes. But there are

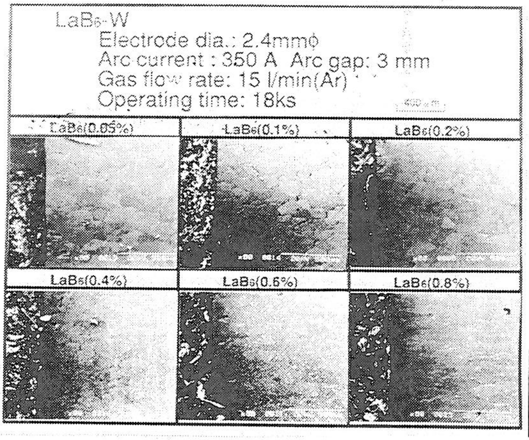


Fig.4 SEM microstructure of various content of electrode cross-section after arc discharge.

not so much difference in life time between them.

### 3.2 Effect of tip shape of electrode

The tip shape affects the consumption of electrode and arc stability. The tip shape influences to the arc current density and attachment of arc root area.

Fig. 5 shows schematic illustration of various electrode tip shapes. Using these shape electrodes the consumption test was carried out for 5 hours at 350A.

Arc roots attachment are stable for shape1 to 4 electrodes, but for shape5 and 6 the arcs are not stable.

Fig. 6 shows the effect of tip shape on electrode consumption. From this result, shape 4 is the best among 6 shapes, and the rate showed 0.9 ng/C

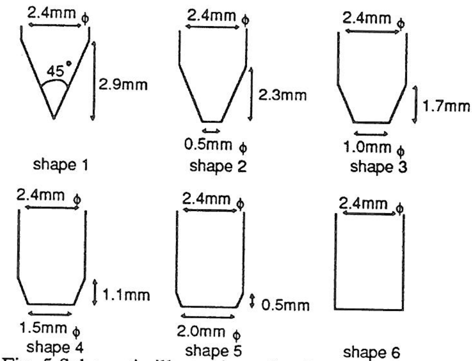


Fig. 5 Schematic illustration of various electrode.

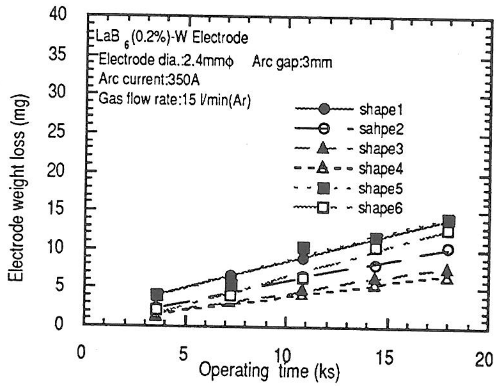


Fig.6 Electrode consumption as a function of arcing time.

at 350A for 5 hours.

Fig. 7 shows the appearance of various tip shape electrodes after arc discharge. From this photograph, in cases of shape 1 and shape 2, the tip melted and the shape changed a little. But in cases of the shape 3-6, the tip shape were not changed.

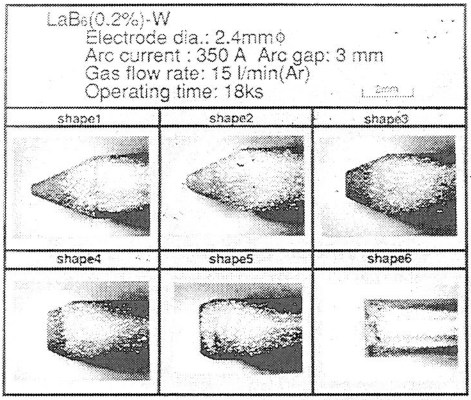


Fig.7 Appearence of various electrode tip shapes after arc discharge.

To explain the effect of shape on the consumption, current density of the tip was measured. In calculating the current density, the surface area are measured based on the morphology change due to arc rooting. The results are shown in Fig. 8. The current densities of shape 1-3 electrode were higher than those of shape 4-6. Thus, the shape 4-6 are better for electrode consumption. But already described at preceding subsection shape 5 and

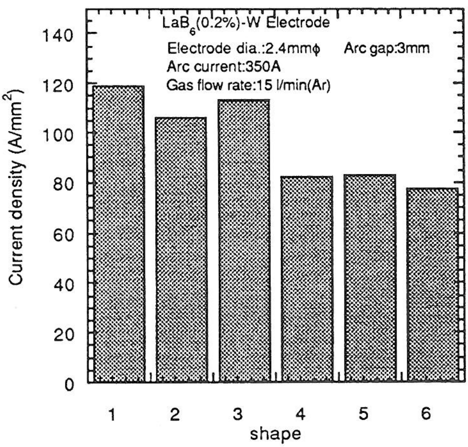


Fig. 8 Current density of various tip shape electrode.

6 did not show stable arc rooting. From those reason, the optimum shape under this condition seems to be the shape 4.

### 3.3 Electrode temperature

The temperature distribution along the electrode axis was measured using infrared thermometer.

In measuring temperature, arc radiation is also integrated into radiation energy from the electrode. The estimation of radiation energy coming from the arc plasma is necessary. By the experiment, it was around 4 % of total radiation energy integrated in the thermometer.

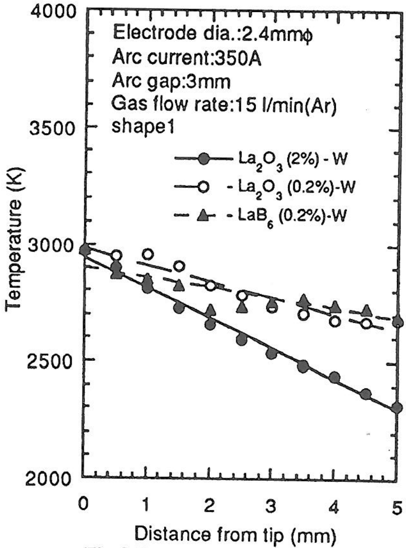

Fig.9 Temperature distribution along electrode axis.

Fig. 9 is examples of measured temperature distribution. In case of $La_2O_3$(2%)-W, temperature gradient is steep in proportion to the distance from tip. But in case of low content of $La_2O_3$ and $LaB_6$ tungsten electrodes, the temperature gradient were sot so steep. This temperature gradient might be related to the migration mechanism of additives[4]. If the gradient is steep, the migration rate should be fast, and evaporate from the tip rapidly.

## 4. Conclusions

Low content of $LaB_6$ in W electrode shows good durability compared with $La_2O_3$(2%)-W electrode.

The temperature distribution of $LaB_6$-W electrode are different from that of conventional type electrodes.

## References


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