Performance of LaB_6-W Arc Cathode†

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Abstract

Tungsten cathodes activated by rare-earth-metal (REM) oxides have shown good durability in the current densities applied for the usual GTA welding (recommended as below 50 A/mm^2 for a 2.4 mm diameter electrode). However, at higher current conditions, these electrodes showed severe erosion, similar to the thoriated tungsten. In this study, the performance of tungsten arc cathodes including 0.05~0.8 wt% LaB_6 was studied under the condition of 350 A for a 2.4 mm diameter electrode in Ar shielding gas. The electrodes containing 0.2~0.8% of LaB_6 showed superior durability and stability compared with those including rare-earth metal oxides.

KEY WORDS: (GTA Welding) (Arc) (Cathode) (Tungsten) (LaB_6) (Rare Earth Metal)

1. Introduction

Various types of tungsten electrode containing small amounts of rare-earth-metal (REM) oxides, such as La_2O_3, Y_2O_3 and Ce_2O_3, have been developed and experiments and field tests have shown the good durability and stability of performance particularly at the current densities applied for the usual GTA welding (in the case of 2.4 mm diameter electrode, the recommended current density is below 50 A/mm^2), compared with that of thoriated tungsten.[1,2,3] However, at higher current conditions, these electrodes suffered severe erosion.[4] At the same time it appeared that REM oxides were excessively concentrated in the narrow region near the tip and associated with the formation of vacant holes. The mechanism of formation of holes is not yet clear but excess migration of REM oxides and their decomposition are considered to be strongly related with the phenomenon. However, these phenomena would impede the smooth and regular transport of REM oxide to the cathode area; the electron-emission area of the electrode surface.

In order to avoid the occurrence of this phenomenon, it is considered useful to suppress the excess migration of REM oxide. In the previous paper,[1,2] the behavior of REM oxide in the electrode was described as follows: REM oxide reacts with W and forms tungstate and/or oxytungstate. Since these compounds have rather low melting points, the migration of REM to the tip zone is effectively accelerated, and the balance between the evaporation of REM from the cathodic surface and the feed of REM from the inside by migration governs the durability of the electrode and stability of the arc. Also it was made clear that the temperature distribution and the type of REM oxide influence the migration rate. Therefore the a-material, which does not form a compound of low melting point but has high migration rate, compared with Thoria, may be preferable.

As is well known, Lanthanum-hexa-boride(LaB_6) is a low work-function material and does not contain oxygen. However, the simple substance of LaB_6 is weak mechanically and susceptible to thermal shock. To overcome these disadvantage, a tungsten electrode including LaB_6 was newly developed. It will behave as a good emitter even if the LaB_6 content is extremely low.

In this paper the performances of tungsten electrodes containing very small amounts of LaB_6 are reported and compared with the La_2O_3-W electrode.

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2. Experimental Procedures

The newly developed electrodes contain small amounts of LaB_6 (0.05~0.8%) (see **table 1**). In almost all cases, electrode diameters used in this study were 2.4 mm. Arcing conditions were controlled at below 350 A for 2.4 mmϕ (current density: 77 A/mm^2). This current was just below the burnout current. The consumption test was carried out for 1~5 hours for various contents of LaB_6 and various shapes of tip. A direct current was applied between the tungsten cathode and a water cooled copper anode. A constant arc length of 3 mm and torch orientation perpendicular to the anode were used throughout the series of experiments.

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

3. Results and Discussion

3.1 Electrode consumption

Figure 1 shows the electrode weight losses measured for three kinds of electrodes. From these results, the LaB_6 (0.2%)-W electrode showed the lowest consumption rate. This figure also confirms that a very low content of oxide produces satisfactory results.

Figure 2 shows the SEM microstructure of electrode cross-sections after arc discharges for 5 hours. White points represent additives like La_2O_3 and LaB_6. It appears that the conventional type of 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 tip area appears to have no white point. This suggests that it will behave like a pure tungsten, and the tip will melt off in a few hours. LaB_6 (0.2%)-W electrode has no such area. Its life time should be longer than that of La_2O_3 (2%)-W electrode. By using electrodes with various contents of LaB_6, the next two experiments were made with an un-tapered tip.

Figure 3 shows the effect of LaB_6 content in tungsten on the electrode weight loss. In the figure, the electrode of around 0.6% LaB_6 shows the lowest loss among 0.05~0.8% LaB_6 electrodes. The weight losses of the electrode containing 0.05~0.1% LaB_6 shows a little more than the other electrodes. But there seems to be not so much difference in life time among them.

Figure 4 shows the microstructure of electrode cross-sections by SEM after arc discharges for 5 hours. All the electrodes keep rather uniform distributions of LaB_6.

Table 1 Electrodes and additives used 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)

3.2 Effect of tip shape of electrode

Tip shape affects the arc stability and consumption of electrode through the temperature distribution. **Figure 5** shows a schematic illustration of various shapes of electrode tip. Using these differently shaped electrodes, a comparison of electrode weight loss was made under the condition of 350 A and 5 hours. Arc root attachment for electrodes shape 1~4 were fixed and stable, but for electrodes with shape 5 and 6 the arc root lost the axi-symmetry.

Figure 6 shows the effect of tip shape on electrode weight loss. The shape 4 electrode showed the least loss of 0.9 ng/C at 350 A after 5 hours.

Figure 7 shows the estimation of current density at the arc root for various tip shapes. The arc root area measurement was based on the morphology change due to arcing. The current densities for shapes 1~3 electrodes were higher than those of shape 4~6. This may be attributable to rather high erosion rate for shape 1~2 electrode. Thus the shape 4~6 are better for electrode

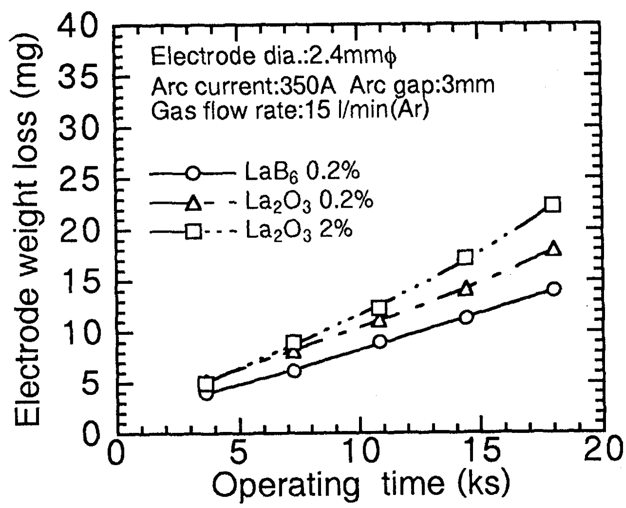

Fig.1 Electrode consumption as a function of arcing time.

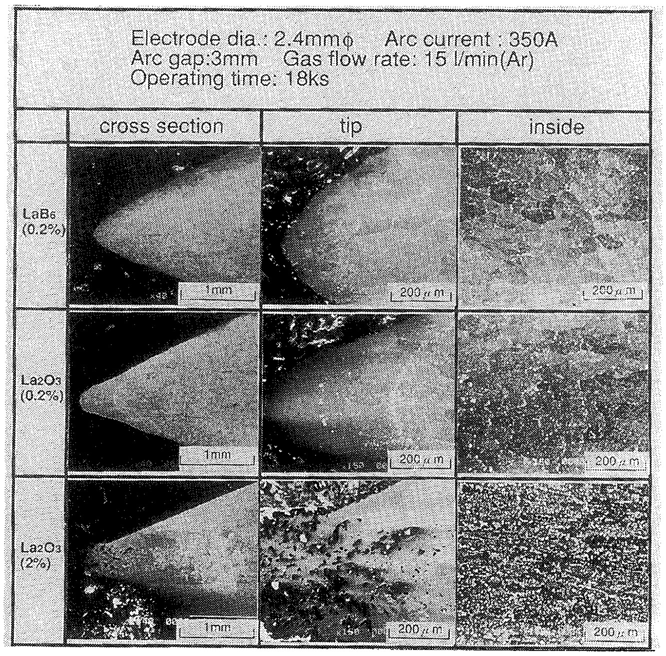

Fig.2 SEM microstructure of electrode cross-section after arc discharge (2.4 mmφ, 350 A, Ar, 5 hours).

consumption, although shape 5~6 did not provide stable arcing as mentioned above. For these reasons the optimum shape under the conditions used is the shape 4.

3.3 Electrode temperature

The temperature distribution of the tip surface along the axis was measured by the use of an infrared thermometer. This thermometer measures the radiant power (wavelength: 0.5~1.05 μm) from the small spot area (0.56 mmφ). Since the electrode tip is covered by arc plasma, radiant power from the arc is also integrated to the one from the electrode tip itself. The influence of arc radiation on the measured radiant power was estimated at around 4%.

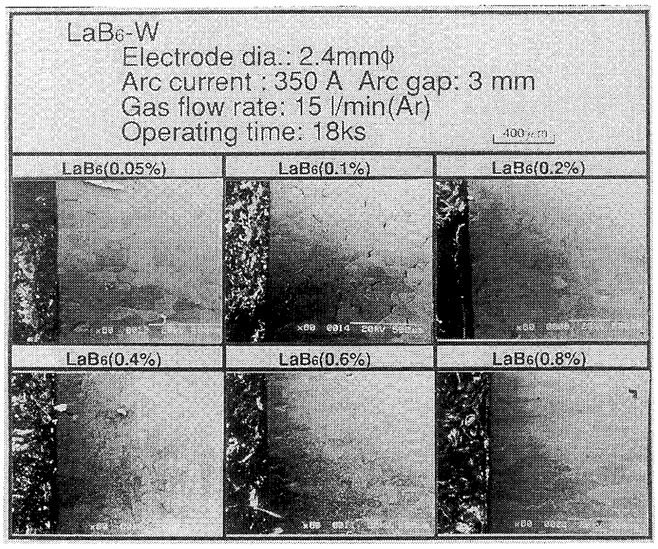

Fig.4 SEM microstructure of cross-section of electrode with various contents of LaB_6, after arc discharge.

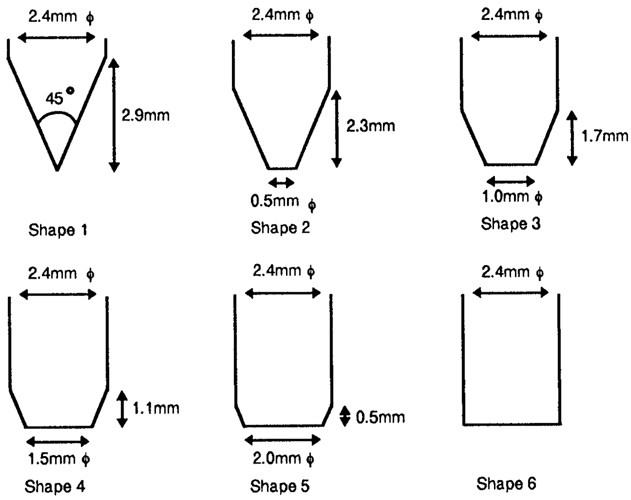

Fig.5 Schematic illustration of various tips.

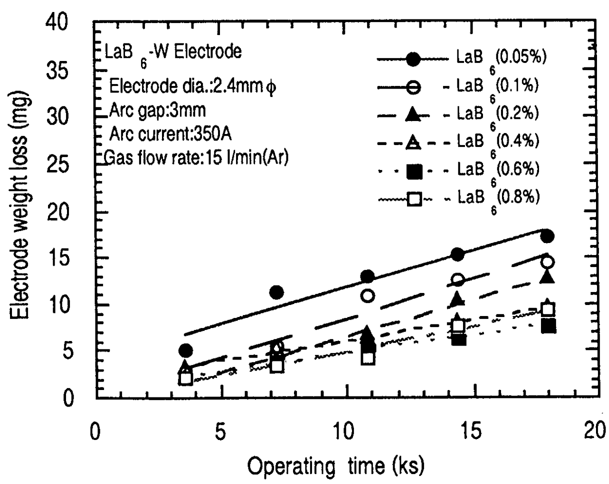

Fig.3 Weight-loss of electrode with various content of LaB_6 as a function of arc time (2.4 mmφ, 350 A).

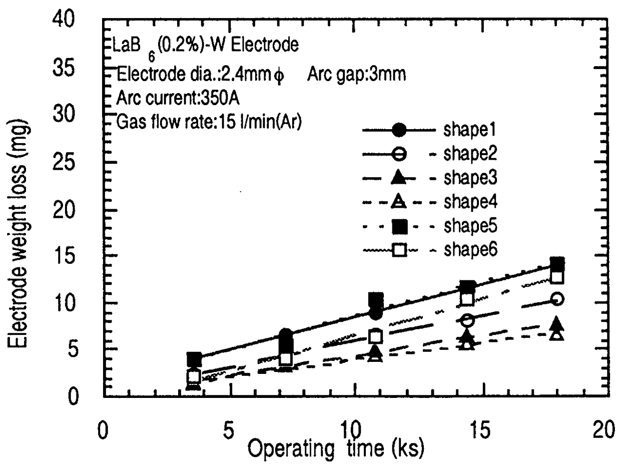

Fig.6 Difference in weight-loss of electrode with various shapes of tip.

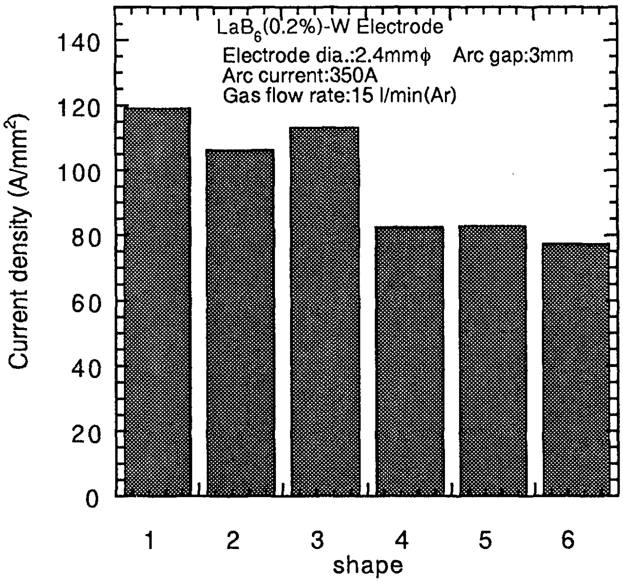

Fig.7 Current density of various tip shape electrode.

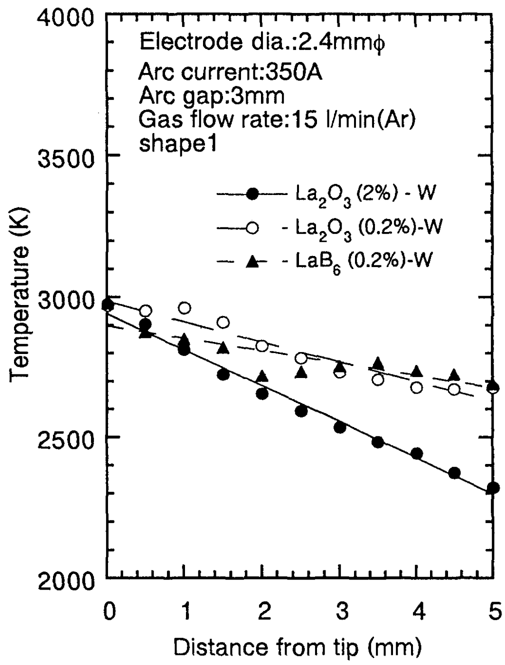

Fig.8 Temperature distribution along electrode axis.

Figure 8 shows examples of measured temperature distributions. In the case of La_2O_3(2%)-W, the temperature gradient is steep in proportion to the distance from tip. But in the case of low contents of La_2O_3 and LaB_6, the gradient is not so steep. This difference might be related to the migration mechanism of additives, as well as the differences in thermal and electrical conductivities. If the gradient is steep, the migration rate should be high, and additives will evaporate from the tip rapidly regardless of the balance between them.

4. Conclusions

Tungsten electrodes including a small amount of LaB_6 (0.2~0.8%) showed good durability under the condition of 350 A Ar arc for 2.4 mmφ. This is very heavy current for the electrode.

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