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Author(s)	Koike, Kazuo; Ono, Norifumi; Kobayashi, Akira
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Behavior of arc plasma for thermal barrier coating preparation†

—Plasma plume length determined from light intensity—

KOIKE Kazuo *, ONO Norifumi * and KOBAYASHI Akira **

KEY WORDS: (Plasma jet) (Image analysis) (Light intensity) (Gas tunnel type plasma spraying) (Thermal barrier coatings) (Atmospheric pressure)

1. Introduction

Thermal Barrier Coatings (TBCs) have been synthesized with plasma aided techniques such as the thermal plasma spraying method[1-4]. In plasma sprayed TBCs, flow and thermal characteristics of spraying plasma affect the performance of TBC materials. Therefore, it is important to obtain a better understanding of the behavior of arc plasma during synthesizing the materials.

From this view point, light intensity analysis was conducted to consider the behavior of the plasma flow in the preparation of TBC materials by plasma spraying techniques. The effects of powder feed rate on plasma plume length were mainly examined in the present study. The spraying plasma was observed with a digital single-lens reflex camera. Contours of light intensity in the plasma are visually determined from RAW image files of the camera with the software for analyzing the RAW format. Simple consideration of thermal characteristics was done on the basis of the obtained results.

2. Experimental Procedure

Plasma jet was generated under atmospheric pressure by using a gas tunnel type plasma spraying torch [5]. Working gas is argon, with a flow rate set to 200 l/min. Powders for TBCs were fed into the plasma plume with carrier gas. Argon was also used as the carrier. The flow rate was specified to about 5 l/min. In this study, TiO_2(titanium dioxide), ZrO_2(Zirconium dioxide) and Al_2O_3(Aluminum oxide) were employed as injected powders. In addition to them, HA(hydroxyapatite) was also examined. Feed rate of each powder is shown in **Table 1**. The plasma arc current *I* was set to certain values that were practically used for the experimental studies of plasma sprayed coatings in the case of each powder. These were 200A, 300A and 400A in the case of TiO_2 and HA and 200A and 300A in the case of ZrO_2 and Al_2O_3. The behavior of spraying plasma was observed under the same conditions of shutter speed and exposure time with a digital single-lens reflex camera (Nikon D2x, 12.4Mpixels) through the viewing window that can observe the plasma jet flowing out from the torch exit. RAW data format, which records data directly from the image sensor of the camera and has precise information on the light intensity, was employed as image format. Digital data on light intensity in the plasma are determined from the RAW image files with the software for analyzing the RAW format [6]. Digital data on light intensity were averaged over 10 RAW data sets as illustrated in upper photograph of **Fig. 1**. Lower figure of Fig. 1 indicates contour plot of light intensity in the domain bounded by the rectangle-shaped solid line in the upper image. Since the image sensor of the camera has a Bayer filter, whose pattern consists of red, blue and two green filters, data on red, blue and green can be captured. Averaged light intensity

Table 1 Feed rate of each powder.

Powder	Feed rate (g/min)				
	Case 1	Case 2	Case 3	Case 4	Case 5
TiO_2	0	<5	~10	~15	
HA	0	<5	~10	~15	
ZrO_2	0	~5	~7	~10	~15
Al_2O_3	0	~5	~7	~10	~15

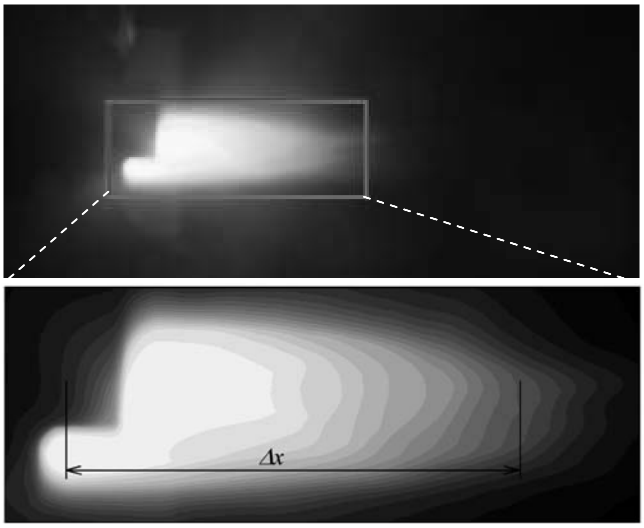

Fig.1 Image of plasma jet and contour plot of light intensity (*I* =300A, without powder).

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* Department of Mechanical Engineering and Intelligent Systems, Tohoku Gakuin University, Tagajo, Japan

** JWRI, Osaka University, Osaka, Japan

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between two green filters was mainly used in the present analysis. The length Δx between the torch exit and the boundary of specified threshold intensity was determined from the light intensity contours.

3. Results and Discussion

Figure 2 shows variation of the length Δx with feed rate of powder in the case of TiO_2 and HA. Δx is normalized with respect to $(\Delta x)_{400A,NP}$ that denotes Δx for a plasma torch current I of 400A without powder. In the case of HA represented by circles, Δx shows a tendency to decrease by the injection of powder for I =200A and 300A. The influence of powder addition on the plume length is not obvious for I =400A. It is thought that the effect of powder injection on the plasma plume becomes less due to higher input to the plasma generation. On the other hand, the length is not influenced much by feeding of TiO_2 powder as denoted by squares. This is partly because the flow rate of the plasma jet increases due to the addition of carrier gas. Moreover, there does not appear to be a clear effect of powder feed rate on the length.

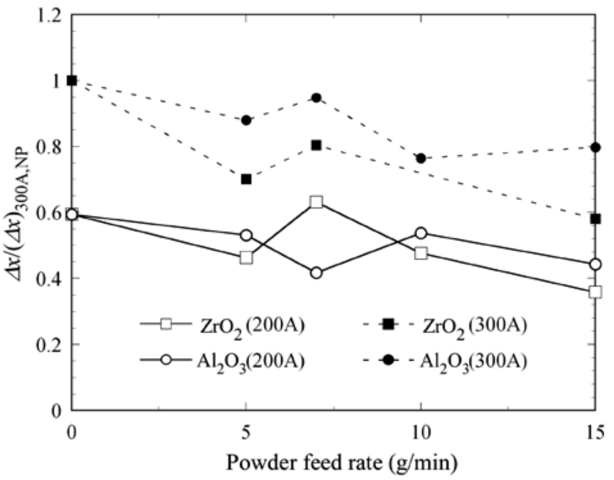

Fig. 3 Variation of length Δx with powder feed rate for ZrO_2 and Al_2O_3.

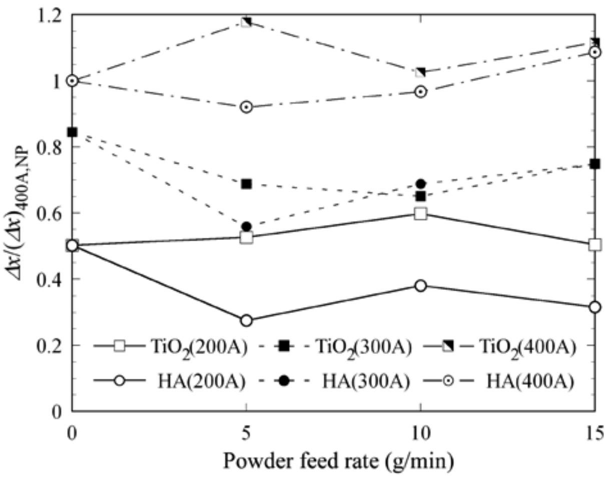

Fig. 2 Variation of length Δx with powder feed rate for TiO_2 and HA.

Figure 3 indicates variation of the length Δx with feed rate of powder in the case of ZrO_2 and Al_2O_3. Plasma arc current I was set to 200A and 300A in these cases. Δx is normalized with respect to $(\Delta x)_{300A,NP}$ that stands for Δx in the case of plasma torch current I of 300A without powder. The results of ZrO_2 and Al_2O_3 are indicated by squares and circles, respectively. Δx shows a tendency to shorten due to the injection of powders in both cases. It also decreases with increases in powder feed rate. These results are thought to be caused by the somewhat high rate of energy given to powders since plasma arc current is relatively low. In the present experiment, different results were obtained according to the kinds of feeding powders. Therefore, it is necessary to consider not only powder properties but also properties of feeding powders for plasma as working fluid.

4. Conclusions

To obtain a better understanding of the behavior of arc plasma in the preparation of TBC materials by the plasma spraying techniques, light intensity analysis was conducted by utilizing RAW image files. The results obtained here are summarized as follows.

(1) Different results of the influence of powder injection on plasma plume length were obtained according to kinds of injected powders.
(2) The plasma plume length is not obviously affected by powder injection in the case of higher plasma arc current.
(3) The plume length shows a tendency to decrease with increases in feeding rate of ZrO_2 and Al_2O_3 powders in the case of relatively lower plasma torch current.

5. Acknowledgement

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References

[1] A. Kobayashi: Surf. and Coat. Technol., 90 (1990), pp.197-202.
[2] A. Kobayashi, T. Kitamura: Vacuum, 59-1 (2000), pp.194-202.
[3] G. Shanmugavelayutham, S. Yano and A. Kobayashi: Adv. in Appl. Plasma Sci., 5 (2005), pp.259-264.
[4] J-L. Zhang and A. Kobayashi: Adv. in Appl. Plasma Sci., 6 (2007), pp.113-116.
[5] A. Kobayashi: J. High Temp. Soc. 11 (1985), pp.124-131.
[6] K. Koike and N. Ono: Adv. in Appl. Plasma Sci., 6 (2007), pp.33-36.