The University of Osaka
Institutional Knowledge Archive

Title	Deposit Characteristics of Sprayed Powder by Gas Tunnel Type Plasma Spraying Apparatus(Physics, Process & Instrument)
Author(s)	Arata, Yoshiaki; Habara, Yasuhiro; Kobayashi, Akira
Citation	Transactions of JWRI. 1987, 16(1), p. 31-36
Version Type	VoR
URL	https://doi.org/10.18910/5264
rights	
Note	

The University of Osaka Institutional Knowledge Archive : OUKA

https://ir.library.osaka-u.ac.jp/

The University of Osaka

Deposit Characteristics of Sprayed Powder by Gas Tunnel Type Plasma Spraying Apparatus†

Yoshiaki ARATA*, Yasuhiro HABARA** and Akira KOBAYASHI***

Abstract

The deposit characteristics of alumina powder which was sprayed on the substrate by the gas tunnel type plasma spraying apparatus were studied. The shape, the weight and the state of deposit powder on the substrate were observed. The relations between these deposit characteristics and the torch condition, such as the input to the torch and the spraying distance, were clarified. The alumina coating on stainless steel was examined on the hardness, porosity, and as the result, it was proved that the quality of the coating was influenced by these conditions. To examine the deposit characteristics was very effective in order to decide the proper spraying condition. This method is useful to apply other spraying methods to decide the best spraying conditions.

KEY WORDS: (Thermal Spraying) (Gas Tunnel) (Plasma Jet) (Coating) (Alumina)

1. Introduction

This type of plasma jet is generated in the gas tunnel which is produced inside the plasma jet torch by the special vortex nozzle. This torch is the high voltage type in volt-ampere characteristics. Therefore the damage of electrode is so less and a high power can be easily obtained[1]. This plasma jet was stable and had a high temperature and high energy density[2,3], being applied to the ceramic coating. As the result, at a lower power compared with the conventional plasma spraying apparatus, the coating was very hard and less porosity[4]. This gas tunnel type plasma spraying apparatus is able to feed the powder to the plasma through the center electrode of spraying torch. Supplied powder is enough melted through the long plasma jet and sprayed at a high speed.

In this work, the deposit characteristics of the powder sprayed by the gas tunnel type plasma spraying apparatus were clarified. The study of deposit by the thermal sprayings was rare[5,6] and the relation between the sprayed coating and the deposit particle has not been reported. And the spraying conditions, such as the power input to the torch, the spraying distance, the working gas flow rate and the kind of working gases have been examined only experimentally. In this work, for the decision of proper coating conditions, the shape, the weight and the state of deposited alumina powder on a substrate are observed and the deposit characteristics are clarified. Some characteristics of alumina coating is examined in the relation to the powder deposit characteristics.

2. Experimental Method

Gas tunnel type plasma spraying torch used in this experiment is the same one in the previous report[4]. Experimental conditions are shown in **Table 1**. The plasma spraying was carried out at various input to the torch and spraying distance. Experimental arrangement is illustrated in **Fig. 1 (a)**. Powder was sprayed on the aluminium substrate ($1.0^t \times 100 \times 100$) at a spraying distance L. The substrate was vertically set to the torch axis. The copper slit set between the spraying torch and the plate is movable, and was moved after the stable spraying began. The sprayed powder passed through the slit was deposited on the aluminium plate. The slit speed was adjusted so as to spray only for about 0.1 sec, in order that the individual deposits were observed with ease.

Another method is shown in **Fig. 1 (b)**. The substrate aluminium plate ($1.0^t \times 50 \times 250$) was tilted $\theta = 26°$ from the torch center axis. On spraying the tilted plate traversed a plasma jet. This method has a good advantage of observing the effect of spraying distance on a coating at one time. Then the plate was divided into the width 10 mm and set side by side. The powder was sprayed on each plate. The increase of the sprayed plate weight was measured at each distance.

The deposit powder on the plate was observed by the optical microscope. The coating thickness in a radial distance was measured at the cross section.

In this experiment, the composition of coating powder is 99.5% Al_2O_3 and the size 10–40μm. The micrograph of this powder is shown in **Fig. 2**. The powder was spray-

† Received on May 6, 1987
* Professor
** Research student
*** Research instructor

Transactions of JWRI is published by Welding Research Institute of Osaka University, Ibaraki, Osaka 567, Japan

ed on blasted SUS 304 stainless steel (2.0^t X 25 X 50) at each distance. The coating was examined in the Vickers hardness and the porosity of the cross section. The load weight of the hardness measurement is 300g. The porosity rate was measured from the picture of the coating cross-section by means of the point counting method.

Table 1 Spraying conditions

Gas divertor nozzle diameter	12^{ϕ} mm
Current	200 – 300 A
Working gas (Ar)	200 l/min
Powder carrier gas (Ar)	10 l/min

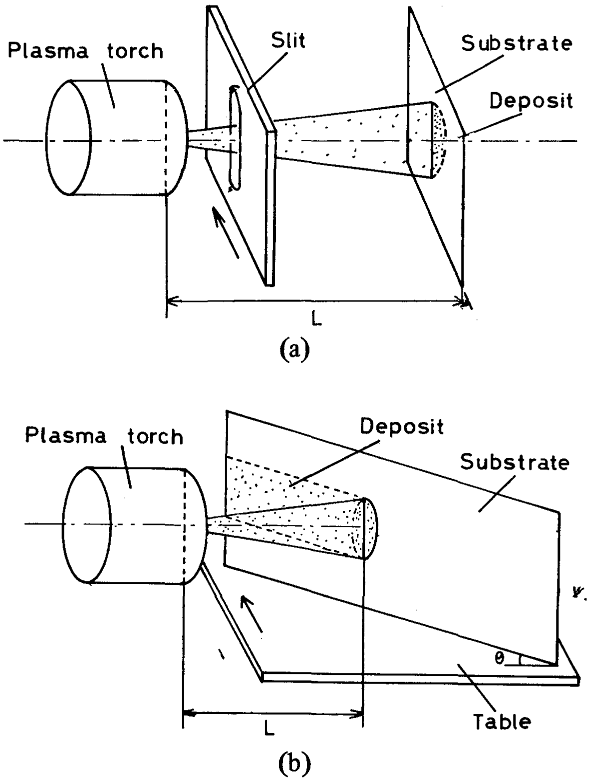

Fig. 1 Experimental arrangement for observing the sprayed deposit on the substrate.
(a) vertical plate type, (b) tilted plate type

3. Experimental Results and Discussion

3.1 Sprayed deposit on vertical plate

The alumina deposits sprayed vertically on the aluminium plate are shown in **Fig. 3 (a)–(c)** at a spraying distance $L = 100$, 150 and 200 mm respectively. Then, the power input to the torch was $P = 20$ kW and the powder feed rate 50 g/min. Sprayed powders seen in Fig. 3 (a) are hardly damaged on the plate at a spraying distance $L = 100$ mm. Some of them are spattered. In Fig. 3 (b) at $L = 150$ mm, three typical types of deposits are observed. These are classified into a severely damaged particle, a flat round particle and a spattered small particle. The flat round particle is considered to be formed because of the temperature decrease on flying. In Fig. 3 (c) at $L = 200$ mm, the severely damaged deposits are not observed, while the flat round particles are increased, compared with the case of $L = 150$ mm. In the case of $L = 150$ and 200 mm, the deposits like sphere are also observed on the aluminium substrate. It seems that this deposit had been

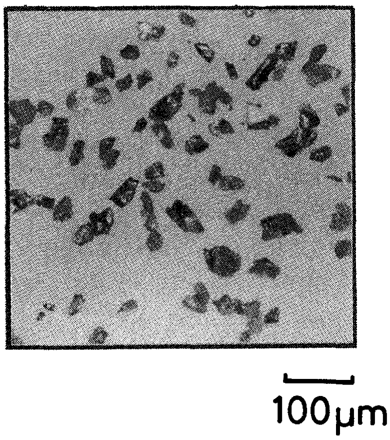

Fig. 2 Micrograph of alumina powders

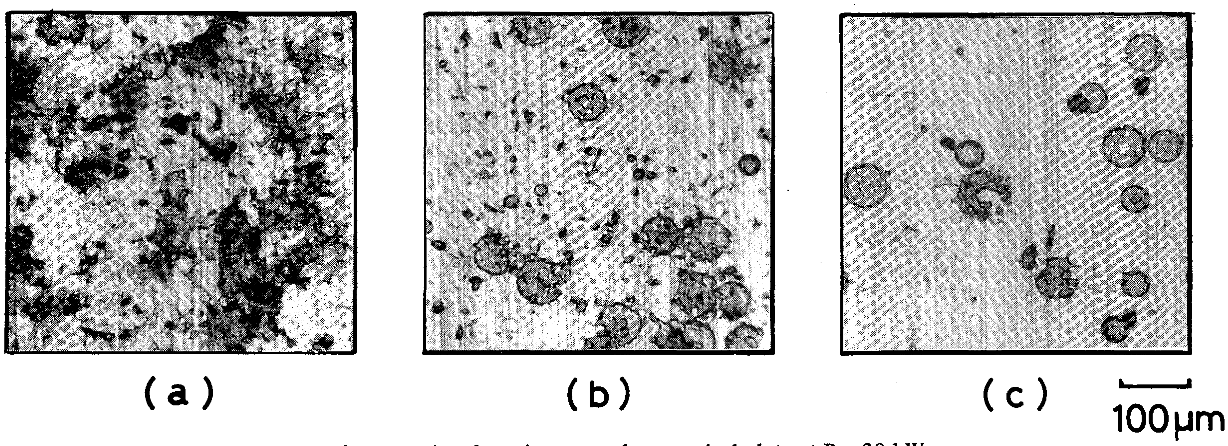

Fig. 3 Alumina deposits sprayed on vertical plate at P = 20 kW.
(a) L = 100 mm, (b) L = 150 mm, (c) L = 200 mm

solidified on flying. As the spraying distance is increased, the temperature of the deposits is decreased and its shape becomes flat round.

The spraying distance is one of the important spraying conditions which influences the solidification of sprayed powder. The coatings are made from these deposits, therefore the coating properties will be affected by the spraying distance.

3.2 Sprayed deposit on tilted plate

The sprayed alumina powder on the tilted aluminium plate is shown in **Fig. 4**. The black part in the photograph is aluminium plate and the white is sprayed powder. The horizontal direction shows the distance from torch and its vertical direction shows the radial distance of plasma jet. In this case the powder feed rate is 50 g/min. Fig. 4 (a) is the case of $P = 21$ kW and (b) is the case of $P = 35$ kW. The sprayed powders flew straightly to the torch axial direction, and didn't spread in the radial direction. The increase of the input to the torch elongated the adhered distance.

The shapes of sprayed powder were observed by the optical microscope at some distances. This result is shown in **Fig. 5** (a)–(c), when the input is $P = 21$ kW, the observed position is the radial distance $r = 0$ mm. At a spraying distance $L = 50$ mm, the shapes of sprayed deposits cann't be distinguished, but at $L = 100$ mm each deposit can be seen. These deposits have the tail where the alumina has flown on the plate. At $L = 150$ mm, the number of the elliptic particle is increased more than that with a tail. This elliptic deposit without a tail can be considered to correspond to the flat round deposit seen in Fig. 3 (b) at $L = 150$ mm.

The deposit with a tail is formed by the powder at a high temperature and high speed. The elliptic particle is deposited at a low temperature and has been solidified on flying. In the case of a higher power $P = 36$ kW, even at a spraying distance $L = 200$ mm, the deposits with a tail are many. But, as the increase of spraying distance, those deposits become less.

At a distance, the deposit powder weight on aluminium plate ($1.0^t \times 10 \times 50$) was measured, and the relation of spraying distance and the deposit weight are shown in **Fig. 6**. The plate was moved at a traverse speed of 280 cm/min. In order to increase the deposit weight on a plate, the spraying was carried out three times, and the weight of the deposit powder was measured in the case of $P = 24$ kW and 36 kW. In each input, as the increase of spraying distance, the deposit powder weight is decreased, but the decrease rate of deposit weight is a little, up to a certain distance. The spraying efficiency is high in this region. At $P = 24$ kW, $L > 130$ mm or $P = 36$ kW, $L > 170$ mm, the weight are greatly decreased. At more longer distance of $L > 210$ mm at $P = 24$ kW, the deposit weight is very little. This tendency of deposit weight is related to the shapes of deposit powder in Fig. 3 or Fig. 5. As decreasing of the alumina deposit with a tail, the flat round particles, which adhere on the substrate at a low temperature, are recognized.

At $L = 100$ mm, the radial distribution of the thickness of alumina coatings was measured at the input to the torch $P = 24$ kW or $P = 36$ kW. These results are shown in

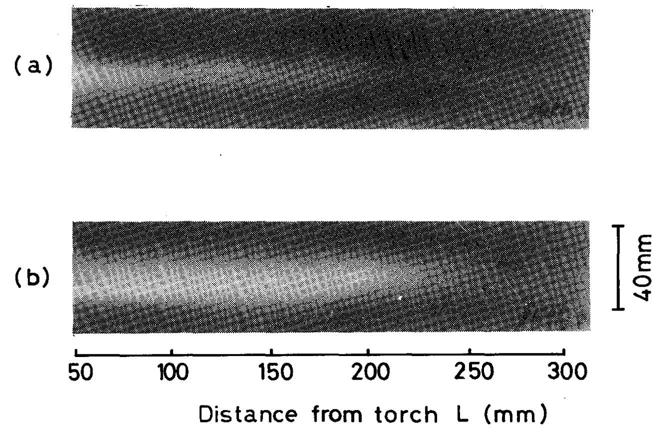

Fig. 4 Sprayed alumina powder on tilted plate.
(a) P = 21 kW, (b) P = 35 kW

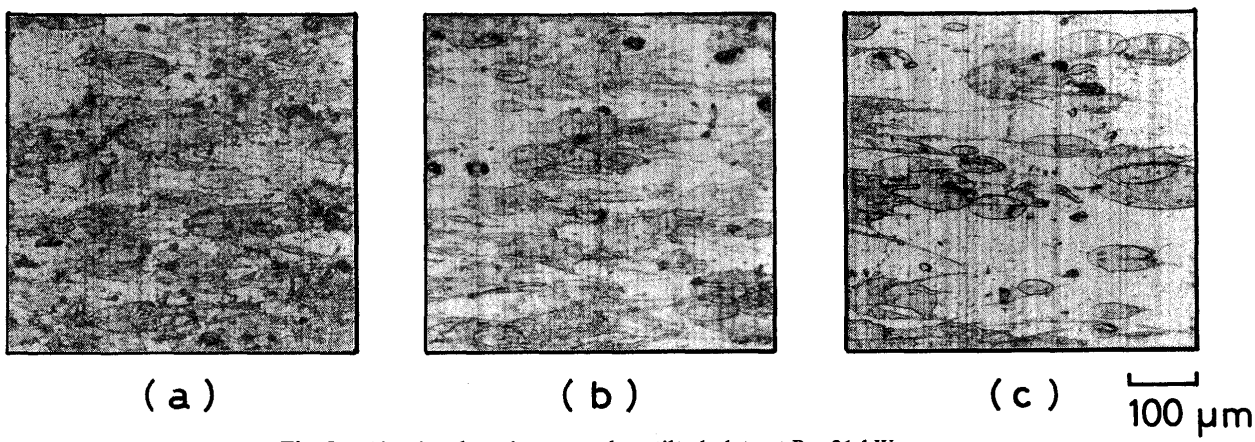

Fig. 5 Alumina deposits sprayed on tilted plate at P = 21 kW.
(a) L = 50 mm, (b) L = 100 mm, (c) L = 150 mm

Fig. 7. This distribution of the coating thickness t_c seems to be proportional to the radial distribution of adhesion weight. In the gas tunnel type plasma spraying, the powder is sprayed through the long-length plasma jet, so well melted powder near the torch center axis adheres effectively on the plate. These radial distributions are symmetrical to the center axis.

The radial distributions of the coating thickness at each spraying distance are shown in **Fig. 8**. The input is $P = 24$ kW. As the spraying distance is increased, the coating thickness t_c at the center axis is decreased largely. On the contrary, the width of the deposit is nearly constant, about 30 mm.

3.3 Characteristics of alumina coating

The cross section of alumina coatings sprayed on the stainless steel is shown in **Fig. 9**, where the input is $P = 21$ kW or 35 kW. Under the same condition of the torch, the thickness of coating is decreased with the spraying distance. At $P = 21$ kW, $L = 160$ mm, the interface of the coating and the substrate is separated. The porosity size is greater as increasing the spraying distance. If the spraying conditions under which the deposit powder is well melted and crashed on the plate are selected, the less porosity coating can be obtained, and the joining of the coating and substrate becomes stronger.

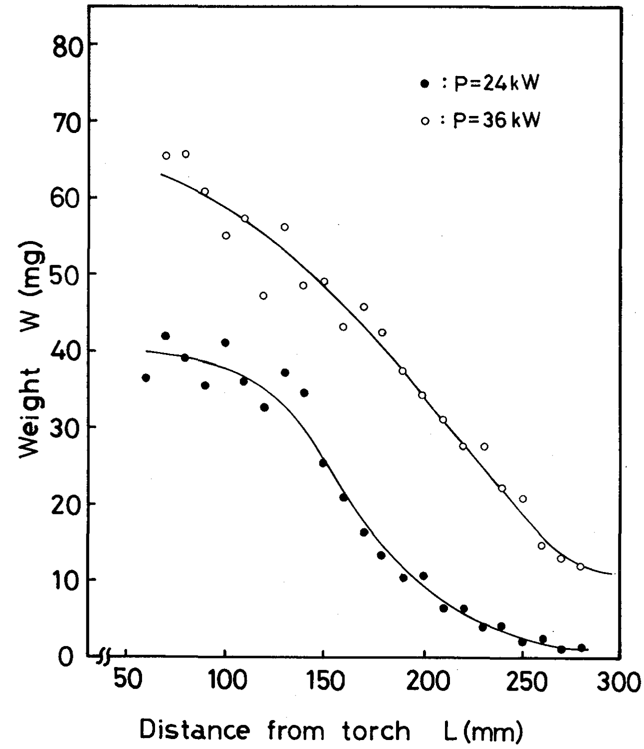

Fig. 6 Relation between deposit weight and distance from torch

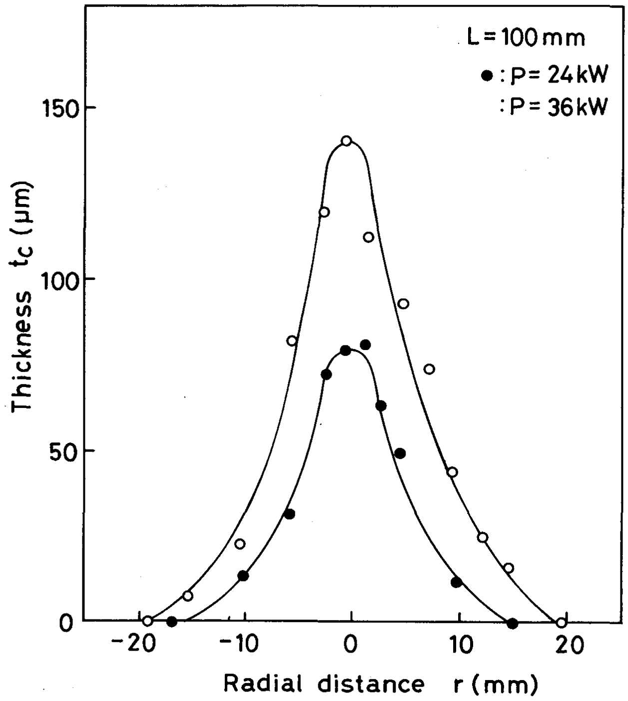

Fig. 7 Radial distributions of coating thickness at L = 100 mm

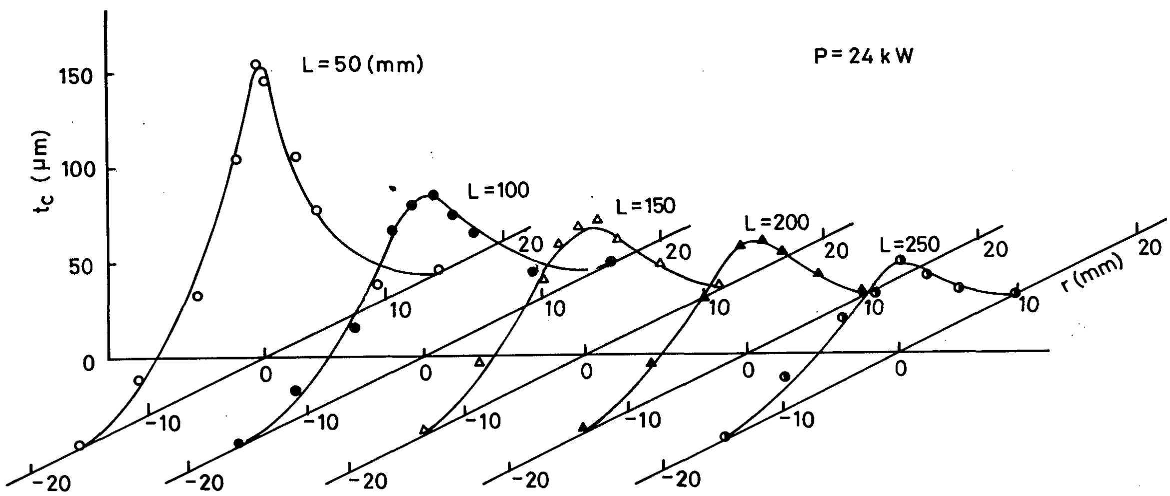

Fig. 8 Dependence of radial distributions of coating thickness on distance from torch

becomes good condition.

The coating at the condition of L = 100 mm, P = 35 kW has less porosity than that of P = 21 kW. In the case of P = 35 kW at even spraying distance L = 160 mm, the porosity is as little as that of P = 21 kW, L = 100 mm. The results of the Vickers hardness measurement of coating are shown in **Fig. 10.** As the increase of spraying distance, the hardness is decreased. The joining of each sprayed deposit seems to be weaken as the increase of spraying distance.

The porosity rate was measured from the picture of the cross section. The porosity rate was increased with the increase of spraying distance as shown in **Fig. 11.** As the round deposit is observed, the porosity rate is increased. It is considered that the state of melting and the shape of deposit are strongly influenced to the coating quality.

4. Conclusion

Alumina powder was sprayed using the gas tunnel type plasma spraying apparatus. The deposit powder on the substrate was observed and its relation to the Vickers hardness and the porosity was clarified.

(1) The deposit powders consist of severely damaged particles, flat round particles and spattered small particles.

(2) If the flat round particles are observed, the porosity of coating is increased and the hardness is decreased. Thus, the ratio of these deposits affects strongly to the properties of coatings.

(3) The method of examining the shape and the weight of deposit is convenient to decide the proper spraying conditions.

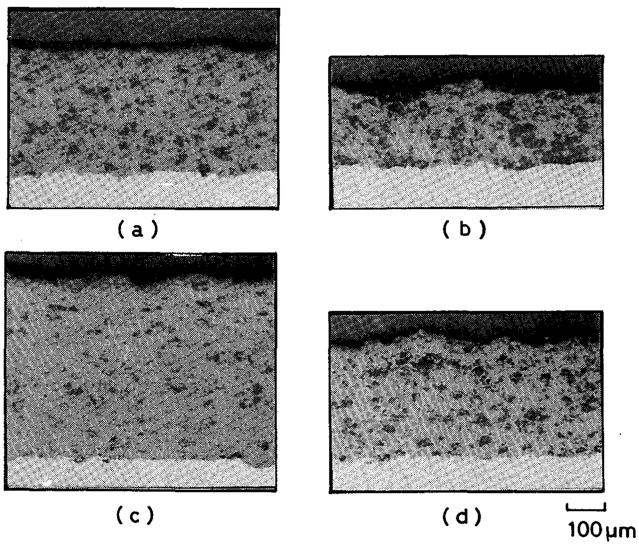

Fig. 9 Cross section of alumina coating
(a) P = 21 kW, L = 100 mm
(b) P = 21 kW, L = 160 mm
(c) P = 35 kW, L = 100 mm
(d) P = 35 kW, L = 160 mm

Acknowledgement

Authors wish to express their thanks to Mr. Setsu KURIHARA, a graduate student of Osaka University, for his helpful work in this study. This work was financially supported in part by a Grant-in-Aid for Scientific Research from the Ministry of Education.

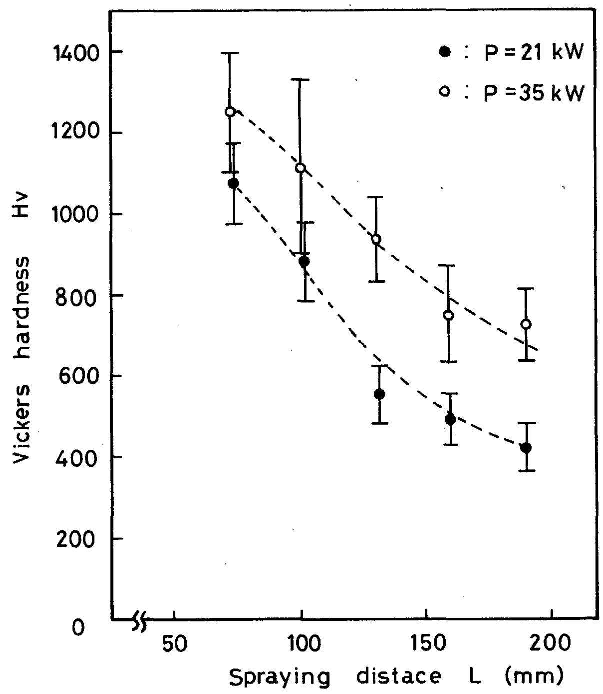

Fig. 10 Dependence of Vickers hardness of alumina coating on spraying distance.

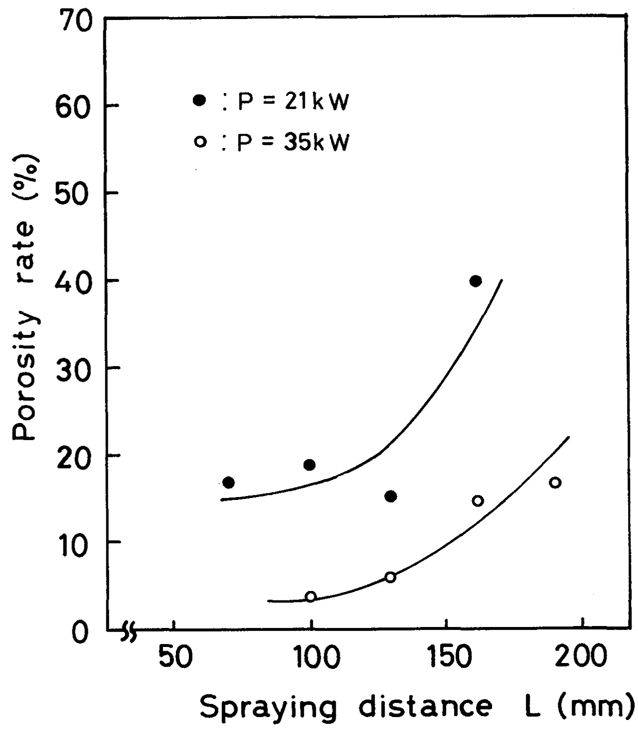

Fig. 11 Dependence of porosity rate of alumina coating on spraying distance.

References

1) Y. Arata and A. Kobayashi: J. High Temp. Soc., **11** (1985) 124.

2) Y. Arata, A. Kobayashi and Y. Habara: Trans. JWRI, **14** (1985) 235.

3) Y. Arata, A. Kobayashi and Y. Habara: Jpn. J. Appl. Phys., **25** (1986) 1697.

4) Y. Arata, A. Kobayashi, Y. Habara and S. Jing: Trans. JWRI, **15** (1986) 227.

5) J. M. Houben: "Thermal Spray Coatings", American Society for Metals (1985) 1.

6) J. Madejski: J. Heat Mass Transfer, **19** (1976) 1009.