Trans. JWRI, Vol. 22 (1993), No. 2

Wear Resistance of Zirconia Coating Produced by Gas Tunnel Type Plasma Spraying†

Akira KOBAYASHI* and Kiyoshi KOMAI**

Abstract

The Zirconia Coating produced by the gas tunnel type plasma spraying have high qualities, i. e. high density, high hardness and low porosity. In the previous report, the characteristics of those zirconia coating have been investigated by experiments and those analysis.

In this paper, the zirconia coating coatings produced by means of gas tunnel type plasma spraying under various experimental conditions were investigated mainly on the wear resistance of those coatings, and the following results were obtained.

The average wear weight of the zirconia coating produced at the spraying distance of L=30mm, when the power input was P=22kW, was very low value of w=0.0035g/hour. This average wear weight of the zirconia coating was increased as the spraying distance was increased. The wear resistance of the zirconia coating was improved as the spraying distance was decreased and also as the power input was increased. As for the size of zirconia spraying powder, the zirconia coating with finer size powder had higher wear resistance.

The relation between the characteristic of Vickers hardness and the wear characteristic of those zirconia coating was investigated and it was found that the wear resistance was improved as the Vickers hardness was increased.

These zirconia coatings produced by means of gas tunnel type plasma spraying had a high wear resistance as well as high Vickers hardness in comparison with that by the conventional type plasma spraying.

KEY WORDS: (Wear resistance) (Zirconia coating) (Gas tunnel type plasma spraying) (Vickers hardness) (Mean wear weight)

1. Introduction

In the case of the conventional type plasma spraying, there are some problems in the ceramic coating qualities, namely weakness of bonding strength among sprayed particles, the lowness of density caused by many pores in the coating, the weakness of bonding strength between the coating and the substrate[1,2].

On the other hand, in the case of gas tunnel type plasma spraying, a high quality ceramic coating was obtained easily[3,4]. And the zirconia coating produced by the gas tunnel type plasma spraying was investigated in the former studies.

The Vickers hardness of the zirconia coating was increased with decreasing spraying distance, and high hardness zirconia coating could be obtained at a short spraying distance. This high hardness coating had a high hardness layer, where the pore was a little and the microstructure was very dense[5].

Moreover, the effect of thermal process on the characteristic of such a high hardness coating has been studied. It is found that the hardness of the high hardness layer becomes to the lower value[6].

In this way, the surface layer is very important for the property of high hardness zirconia coating by means of gas tunnel type plasma spraying. Therefore, the roughness of the surface of this zirconia coating was investigated, and the effect of the spraying conditions on the roughness characteristic of the coating was clarified[7]. The relation between the surface roughness and deposit phenomena of this coating were discussed.

Considering above results, it was thought that these zirconia coatings had high wear resistance as well as other high qualities. Then, in this report, the zirconia coatings were produced by means of gas tunnel type plasma spraying in various experimental conditions, and the wear resistance of those coatings was studied using the wear testing device developed in this study.

† Received on December 20, 1993
* Associate Professor
** Student of Kinki University

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

The average wear weight of the zirconia coating produced at various spraying distance was measured and the result of wear resistance was described. Then, the effect of the power input on the wear resistance was also clarified.

Moreover, the characteristic of Vickers hardness was studied and the relation to the wear characteristic of those zirconia coating was investigated. And the spraying experiment using different size of zirconia powder was carried out in order to examine the effect of powder size on the wear resistance.

Finally, the wear resistance of the zirconia coating produced by gas tunnel type plasma spraying was compared to that by the conventional type plasma spraying.

2. Experimentals

2.1 Experimental method

The experimental method to produce the zirconia coating coatings by means of gas tunnel type plasma spraying have been described in the previous papers. In this study, the zirconia coating was formed on the blasted SUS304 substrate by the gas tunnel type plasma spraying. The thickness of the coating were from 100 μm 200μm. In this case the spraying distance and the power input to the torch were mainly changed, and the spraying conditions are shown in **Table 1**.

As the spraying powder, we used three types of partial stabilized zirconia (PSZ) powder: A, B and C, which are shown in **Table 2**. These type of powder were commercially prepared type K-90 and consist of the similar chemical compositions, but the size was different each other. In this study, the medium size of zirconia powder B was mainly used.

The property of zirconia coating produced under various experimental conditions were mesured by Vickers hardness tester and so on.

Table 1 Spraying conditions for producing zirconia coating. Gas divertor nozzle diameter: 15mm.

Power input	P = 21 - 34 kW
Working gas	Q = 225 l/min
Powder carrier gas	15 l/min
Powder feed rate	25 - 35 g/min
Traverse speed	96 cm/min
Spraying distance	L = 30 - 80 mm

2.2 Measurement of wear weight

The wear resistance of those coatings was studied using the wear testing device developed in this study. **Figure 1** shows the concept of this tester.

The zirconia coating was worn by the emery paper attached on the polisher. In this case, the load weight for polishing was constant value of 300g, with constant speed for the testing time. The size of test piece was 10mm x 10mm as shown in Fig.1.

The average wear weight of the zirconia coating was measured by the micro scale.

At first, the performance of this wear testing device with SUS304 of substrate was investigated. **Figure 2** shows the relation between wear weight of SUS304 and the revolution number of the testing device. This result indicated that the error of wear weight was the smallest when the revolution was 300rpm. Also, it was found that the wear weight was increased linearly for the testing time.

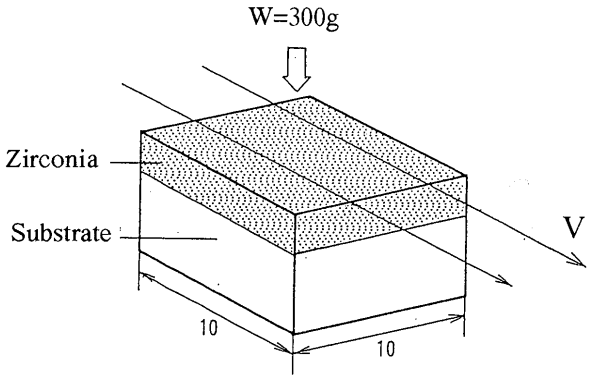

Fig. 1 Concept of wear testing device.

Table 2 Chemical composition and particle size of zirconia powder used.

Powder type	Chemical composition (wt%)					Size(μm)	
	ZrO_2	Y_2O_3	Al_2O_3	SiO_2	Fe_2O_3	Range	Average
B | K-90	90.78	8.15	0.38	0.20	0.11	10-44	26.3
A | K-90 25-4	90.72	8.38	0.50	0.21	0.12	4-25	10.7
C | K-90 75-45	90.65	8.71	0.21	0.17	0.10	45-75	58.0

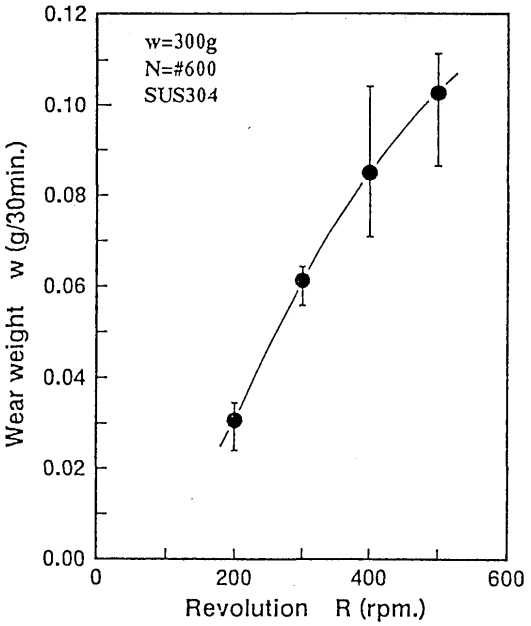

Fig. 2 Relation between wear weight and revolution.

Table 3 shows the testing condition of this wear testing device. The measuring accuracy was within ± 9% for the case of stainless steel.

For zirconia coating by produced at various spraying distance, the wear weight was measured and the wear speed was not constant, therefore the average wear weight Δw (g/hour) was introduced for the indicated value.

Table 3 Wear testing conditions.

Mesh number	#600
Revolution	300 rpm
Speed	1.88 m/s
Load weight	300 g

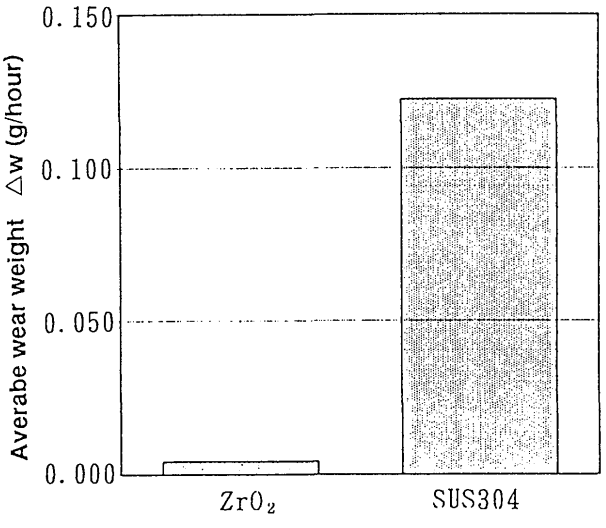

Fig. 3 Comparison of average wear weight between zirconia coating and SUS304.

Figure 3 shows the result of wear resistant test on both zirconia coating and SUS304. In the case of zirconia coating, the average wear weight was very small value compared with the case of stainless steel. This is generally due to the high hardness of ceramics.

3. Results and Discussion

3.1 Effect of spraying distance on wear weight of zirconia coating

The zirconia coating coatings were produced by means of gas tunnel type plasma spraying at various spraying distance, and the wear resistance of those coatings was studied using the wear testing device described above.

Figure 4 shows the dependence of the average wear weight of the zirconia coating on the spraying distance, when the power input was P=22kW.

At the spraying distance of L=30mm, the average wear weight of the zirconia coating was very low value of Δw=0.0035g/hour, which shows to be high wear resistance. This average wear weight of the zirconia coating was increased as the spraying distance was increased, and the value was Δw=0.0114g/hour at L=80mm.

Figure 5 shows the dependence of the Vickers hardness of the zirconia coating on the spraying distance, under the same spraying conditions as in Fig.4. When the spraying distance was L=30mm, the Vickers hardness
of the zirconia coating was very high value of Hv=935, which corresponds to the low average wear weight. The Vickers hardness of these zirconia coatings was decreased

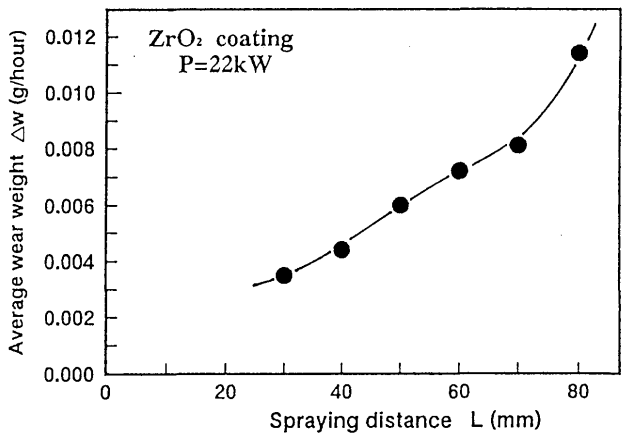

Fig. 4 Dependence of average wear weight of zirconia coating on spraying distance.

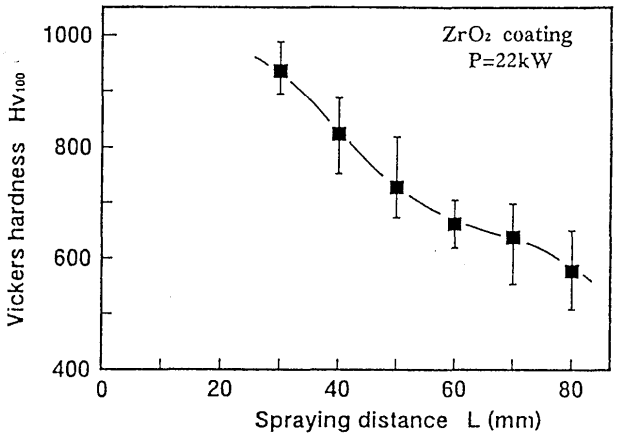

Fig. 5 Dependence of Vickers hardness of zirconia coating on spraying distance.

as the spraying distance was increased, which is the same results as the former reports.

3.2 Influence of power input on wear characteristic

Next, the influence of power input to the torch on the characteristic of zirconia coatings produced by means of gas tunnel type plasma spraying (mainly the wear resistance of those coatings) was investigated.

Figure 6 shows the dependences of the average wear weight of the zirconia coatings on the power input at the spraying distances, L=60mm, 70mm and 80mm. Then the power input was changed from P=22kW to P=30kW.

The average wear weight of the zirconia coating produced at the spraying distance of L=60mm was Δw=0.0072g/hour when the power input was P=22kW, and became a low value of Δw=0.0055g/hour when P=30kW.

At the spraying distance of L=80mm, the average wear weight of the zirconia coating was a large value, but the dependence of the average wear weight on the power input was a similar, namely the wear weight decreased as the power input was increased.

Thus the wear resistance of the zirconia coating was improved as the power input was increased, as well as the case that the spraying distance was decreased.

Figure 7 shows the dependence of the Vickers hardness of the zirconia coating on the power input, under the same spraying conditions as shown in Fig.6. The Vickers hardness of these zirconia coatings was increased as the power input was increased at any spraying distance. At the spraying distance of L=60mm, when P=30kW the Vickers hardness of the zirconia coating was a value of Hv=752.

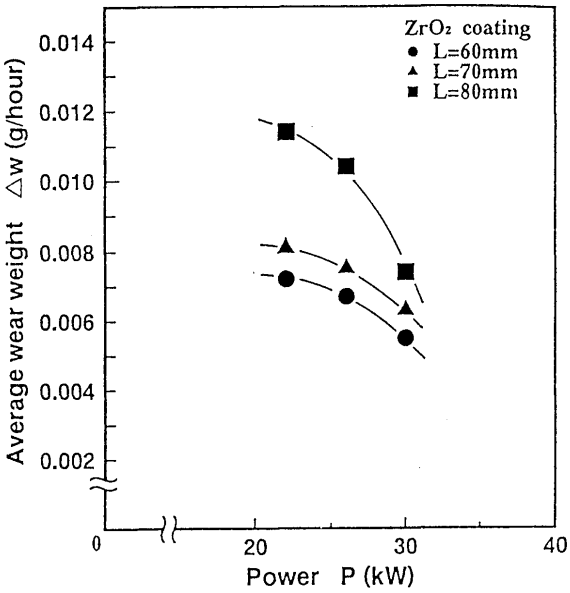

Fig. 6 Dependence of average wear weight of zirconia coating on power input.

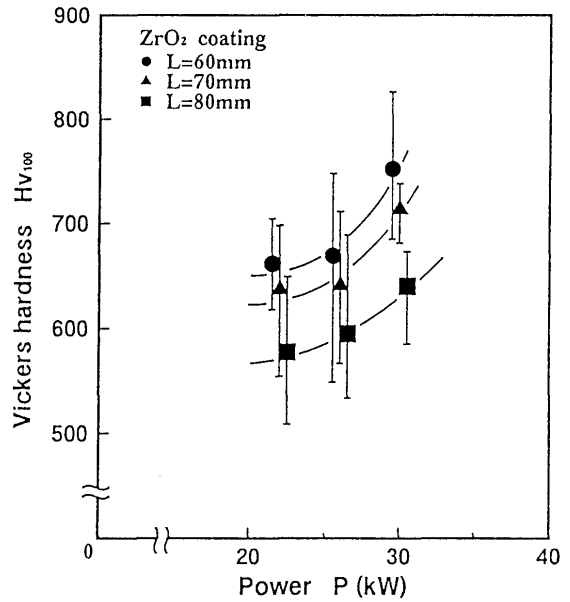

Fig. 7 Dependence of Vickers hardness of zirconia coating on power input.

3.3 Relation between average wear weight and Vickers hardness

From above results of wear characteristic and characteristic of Vickers hardness, it was found that high Vickers hardness corresponds to the low average wear weight of zirconia coating. Then the relation of both characteristic was studied.

Figure 8 shows the relation between the average wear weight and the Vickers hardness of the zirconia coating. This result was obtained from Fig.4 and Fig.5,

namely, by changing the spraying distance, when the power input was P=22kW.

The average wear weight of the zirconia coating was decreased as the Vickers hardness was increased. Then Vickers hardness of Hv=935 corresponds to the low average wear weight of Δw=0.0035g/hour.

Also, **Figure 9** shows the relation between the average wear weight and the Vickers hardness of the zirconia coating obtained from Fig.6 and Fig.7. Thus the good relation was obtained under various spraying conditions as shown in Fig.8 and Fig.9.

In this way, it was found that the wear resistance was improved as the Vickers hardness was increased.

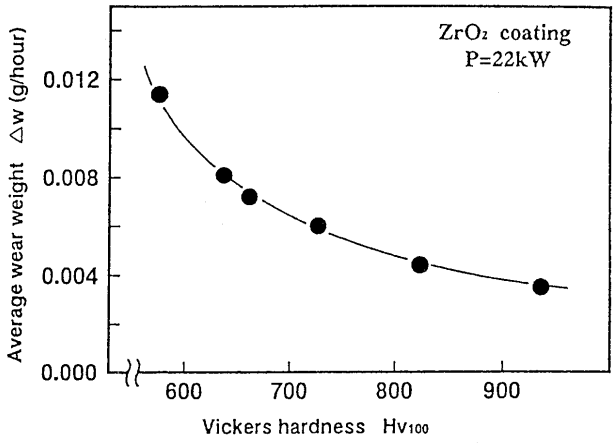

Fig. 8 Relation between average wear weight of zirconia coating and Vickers hardness.

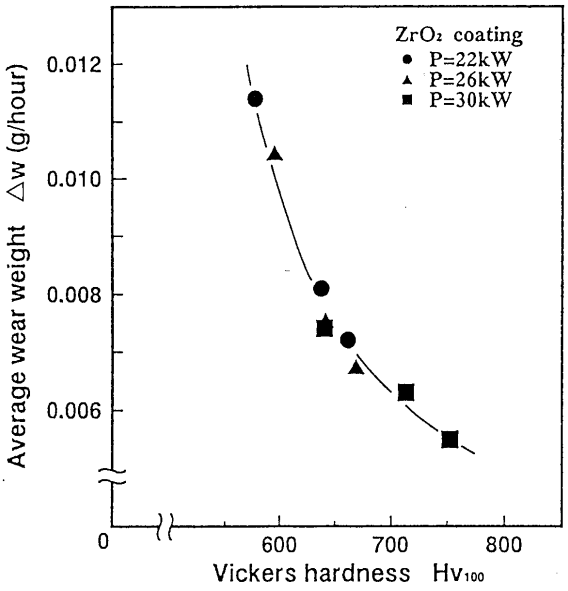

Fig. 9 Relation between average wear weight and Vickers hardness of zirconia coating.

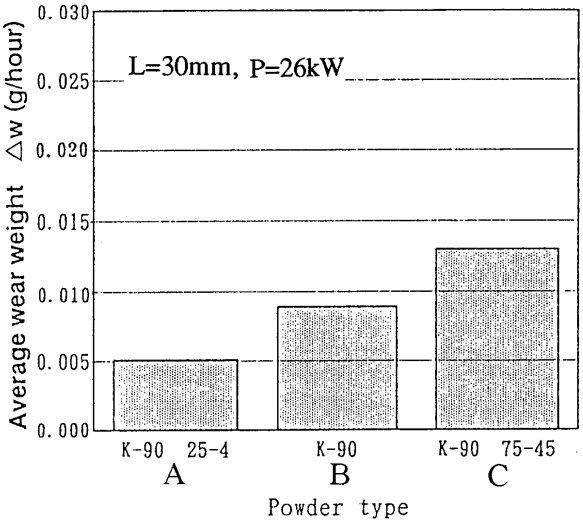

Fig. 10 Comparison of average wear weight using different size of zirconia powder.

3.4 Influence of powder size on wear weight of zirconia coating

Figure 10 shows the comparison of average wear weight of zirconia coating by using different size of sprayed powder: A, B and C which are shown in Table 2, at the spraying distance of L=30mm, when P=26kW.

From those results of spraying experiment by using three types of different size of zirconia powder, the average wear weight of the zirconia coating by using fine size powder A was lowest value of Δw=0.005g/hour. The average wear weight of the zirconia coating was increased as the size of spraying powder was larger, and the value was Δw=0.016g/hour for the largest size powder C. Thus, the zirconia coating with finer size powder had higher wear resistance.

While, the Vickers hardness of these zirconia coating was respectively Hv=950 for A, Hv=870 for B, Hv=780 for C. The coating by using finer size powder had higher hardness.

In this way, by using fine spraying powder, we can obtain high quality zirconia coating.

3.5 Comparison with zirconia coating by conventional type plasma spraying

Figure 11 shows the comparison of the average wear weight and Vickers hardness of the zirconia coating between gas tunnel type plasma spraying and conventional type plasma spraying, under the same spraying conditions at L=70mm when P=32kW.

In the case of gas tunnel type plasma spraying, the average wear weight of the zirconia coating produced at L=70mm when P=32kW was Δw=0.0114g/hour, about

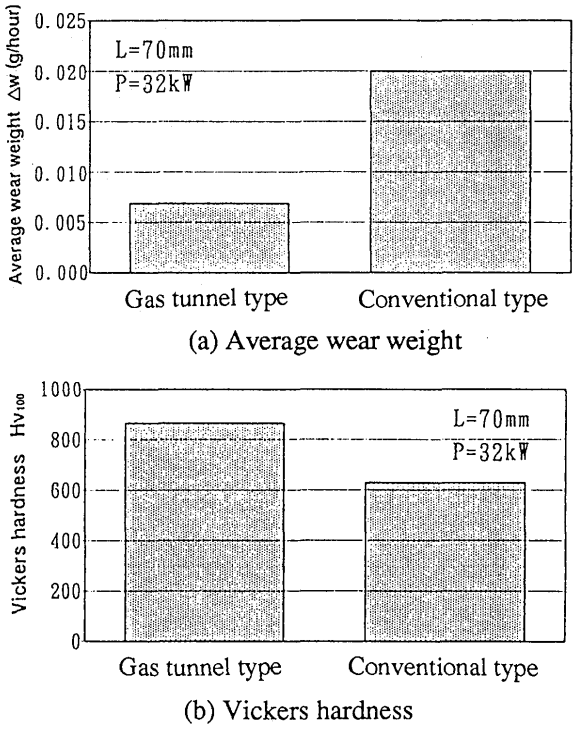

Fig. 11 Comparison of average wear weight and Vickers hardness between gas tunnel type plasma spraying and conventional type plasma spraying.

a half value of the zirconia coating produced by the conventional type plasma spraying.

In addition, the Vickers hardness of the zirconia coating produced by gas tunnel type plasma spraying was very high value of Hv=860, compared with the Vickers hardness of these zirconia coatings by conventional type plasma spraying.

Thus, by means of gas tunnel type plasma spraying we can obtain higher quality zirconia coating, namely high wear resistance and higher Vickers hardness.

4. Conclusion

The zirconia coating coatings were produced by means of gas tunnel type plasma spraying in various experimental conditions, and the wear resistance of those coatings was studied using the wear testing device developed in this study. The main results obtained are as follows:

(1) The average wear weight of the zirconia coating produced at the spraying distance of L=30mm, when the power input was P=22kW, was very low value of Δw=0.0035g/hour. The average wear weight of the zirconia coating was increased as the spraying distance was increased, and the value was Δw= 0.0114g/hour at L=80mm.

(2) The average wear weight of the zirconia coating produced at the spraying distance of L=60mm was Δw=0.0072g/hour when the power input was P=22kW, and became a low value of Δw = 0.0055g/hour when P=30kW. Thus the wear resistance of the zirconia coating was improved as the power input was increased.

(3) By the result of consideration on the characteristic of Vickers hardness and the wear characteristic of those zirconia coating, it was found that the wear resistance was improved as the Vickers hardness was increased.

(4) From the spraying experiment with different size of zirconia powder, it was shown that the zirconia coating with finer size powder had higher wear resistance.

(5) In the case of gas tunnel type plasma spraying, the average wear weight of the zirconia coating produced at L=70mm when P=32kW was Δw=0.0114g/hour, about a half value of the zirconia coating produced by the conventional type plasma spraying. Thus the zirconia coating produced by means of gas tunnel type plasma spraying has a high wear resistance as well as high Vickers hardness.

Acknowledgement

This study was financially supported in part by a Grant-in-Aid for Scientific Research from the Japanese Ministry of Education, Science and Culture.

References

1) Japan Institute of Thermal Spraying; "Thermal Spraying Handbook", Shingijutsu Kaihatsu Center, (1987) (in Japanese).
2) Y. Arata et. al.; "Ceramic Thermal Coating and its Application", Nikkankogyo Shinbunsha, (1990) (in Japanese).
3) Y. Arata, A. Kobayashi and Y. Habara; J. High Temp. Soc., 13-3 (1987) 116 (in Japanese).
4) A. Kobayashi, N. Hasegawa and H. Namikawa; Trans. JWRI, 18-1 (1989) 13.
5) A. Kobayashi, N. Bessho and M. Higuchi; Trans. JWRI, 19-2 (1990) 117.
6) A. Kobayashi, K. Yamafuji and T. Kitamura; Trans. JWRI, 20-1 (1991) 47.
7) A. Kobayashi, K. Yamafuji and T. Kitamura; Trans. JWRI, 21-2 (1992) 187.