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Evaluation of Sprayed Coatings by Electrical Method

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Abstract

A method for evaluating the adhesion of metallic thermally sprayed coatings by measuring the electrical resistance of the coating sprayed on a metal substrate was carried out. The thermal sprayed coatings were made of zinc alloy on carbon steel substrates, The electrical resistance levels between the substrates and coatings were evaluated. The electrical resistance increases with increasing measurement time. The larger the rate of increase of the electrical resistance, the lower the adhesive strength. There is a possibility to evaluate qualitatively the adhesion properties.

Introduction

Nondestructive testing is a method of evaluating a sample or a product without destruction. Typical examples are radiographic testing, ultrasonic testing, eddy current testing, liquid penetrant testing, and stress measurement. Nondestructive testing is also used for on-site evaluation. An adhesion property of the thermal sprayed coatings is an important factor to understand the product quality on surface reformation. Therefore, the improvement of non-destructive evaluation of the adhesion is required.

A possible method by using ultrasonic nondestructive analysis was proposed by Suga et al (Ref 1). The ultrasonic nondestructive analysis can evaluate the coefficient of adhesion of thermal sprayed coatings by measuring acoustic impedance, surface echo and bottom face echo. This analysis gives a high correlation between the adhesion of thermal sprayed coatings and the calculated coefficient. The ultrasonic nondestructive analysis can be used to simultaneously evaluate the specifications and the adhesion of thermal sprayed coatings.

However, using the ultrasonic method requires immersing the test piece into water. Therefore the method cannot be used for samples that corrode easily or are unwieldy to immerse, for example, structures to be directly sprayed on the construction on site, such as bridges and towers.

In this study, to evaluate the adhesion of thermal sprayed coatings which cannot be measured by using other method, the method by measuring electric resistance is attempted. Here, we propose a method to evaluate adhesion properties by measuring electrical resistance between thermal sprayed coatings and the substrate.

Experimental Procedure

Specimen and Spraying Condition

A wire flame spraying was performed to spray zinc alloy onto a carbon steel substrate without pre-heat. Table 1 shows the conditions of pretreatment and the thermal spraying.

Table 1: Blasting condition and thermal spraying condition.

Blasting time	10 sec
Blasting angle	90 °C
Carrier gas pressure of blasting	0.4 MPa
Diameter of alumina grit	555 μm
Composition of wire	Zn-15mass%Al
Wire diameter	1.6 mm
Combustion gas	Acetylene and Oxygen
Carrier gas pressure of spraying	0.3 MPa
Spraying distance	75, 125, 175 mm
Spraying time	10, 15, 25 sec
Wire feed rate	4.2 m/min

To prepare the sprayed coatings having different coating properties, the spray distance was varied. The porosity in the thermal sprayed coatings is changed by changing the spray distance (Ref 2). The porosity in thermal sprayed coatings is estimated to be about 7 ~ 10%, when the spray distance is 75 ~175 mm, respectively.

The top surface of thermal sprayed coatings was ground. A coating thickness was controlled to be 1mm by surface grinding to obtain even surfaces. The adhesion was measured by the extrusion method (Ref 1)

Measuring Electrical Resistance
Figure 1 shows the experimental equipment to measure the electric resistance of thermal sprayed coatings and a substrate. The voltage between two terminals of the specimen was 65mV.

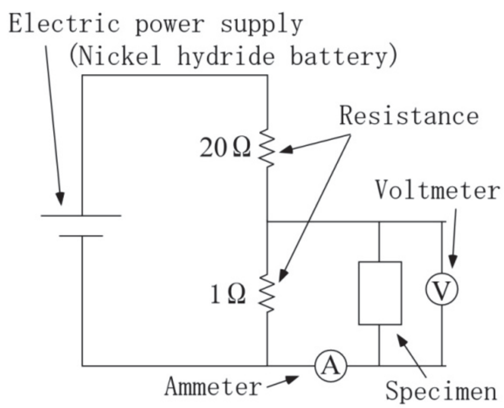

Figure 1: Layout of electric circuit to measure the electric resistance of sprayed coatings on a substrate.

Figure 2 shows schematic diagram of connecting terminal with sprayed coatings. A copper plate was used as a terminal contacted with the top surface of the thermal sprayed coatings.

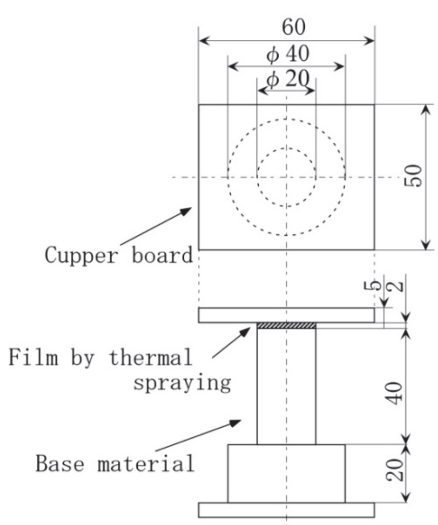

Figure 2: Schematic diagram of connecting terminal with sprayed coatings.

The voltage and the electric current were measured with a multimeter, the electrical resistance values were calculated from Ohm's law shown in Eq 1.

$$R=V/I \qquad \text{(Eq 1)}$$

Where R (Ω) is the electrical resistance, V (V) is the voltage, and I (A) is current. Sampling time of the measurement was 1s. The correlation between the property of thermal sprayed coatings and the electrical resistance during the measurement was measured.

Measuring Adhesion Property
The adhesive strength was evaluated by the extrusion method as shown in Fig. 3. A sleeve-type specimen as substrate (ϕ20) was combined with a cylinder-type specimen (ϕ15), and these specimens were fixed with a bolt. Boron nitride was coated on the surface of the cylinder-type specimen to remove the cylinder-type specimen after spraying. The bolt was unscrewed, and a plunger was inserted into the sleeve-type specimen after removing the cylinder-type specimen. The adhesive strength was measured by using a tensile testing machine (Amsler type).

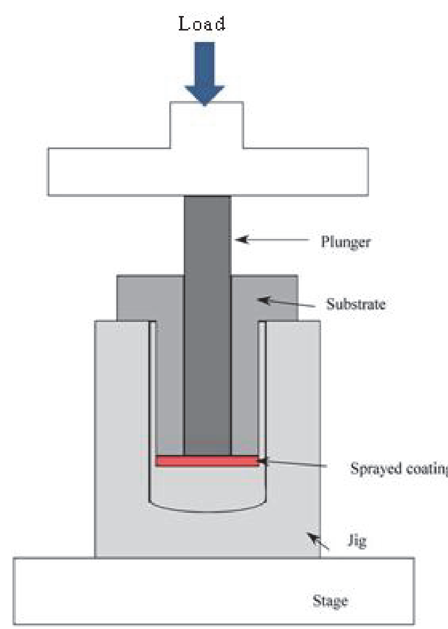

Figure 3: The schematic representation of adhesion test by extrusion method. The area between the substrate and the sprayed coatings is the evaluated area, and the area between the plunger and the sprayed coatings is the unbounded area.

Estimation of Porosity

Figure 4 shows the relationship between spraying distance (mm) and porosity (%) (Ref 1). The porosity was estimated by the relationship. As shown in Fig. 4, 7%, 8.5%, and 10% of the porosity were estimated by 75mm, 125mm, and 175mm of the spraying distance, respectively.

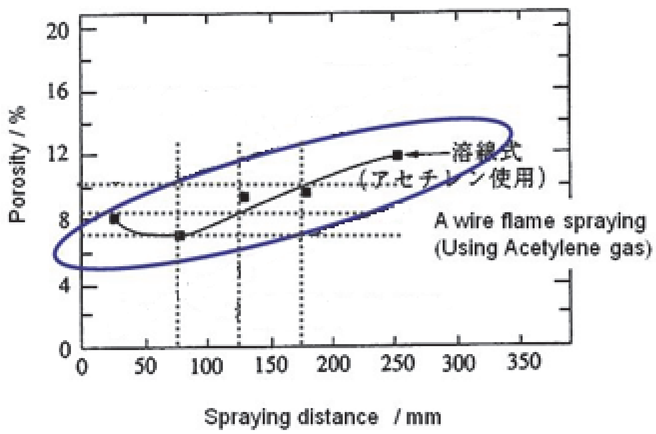

Figure 4: Relation between porosity and spraying distance.

Results and Discussion

Figure 5 shows relation between spraying distance and the adhesion of thermal sprayed coating.

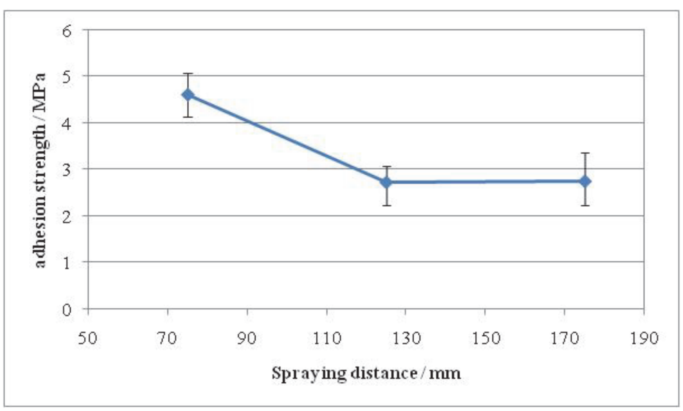

Figure 5: Relation between thermal spraying distance and adhesive strength on thermal spraying film.

The adhesion decreases with increasing spray distance. The porosity in the coatings and between the coatings and the substrate may increase with increasing spraying distance. The adhesion decreases due to the porosity.

Figures 6, 7, and 8 show change in electrical resistance, current and voltage with time, of the sample sprayed in 75, 125, 175 mm spray distance, respectively.

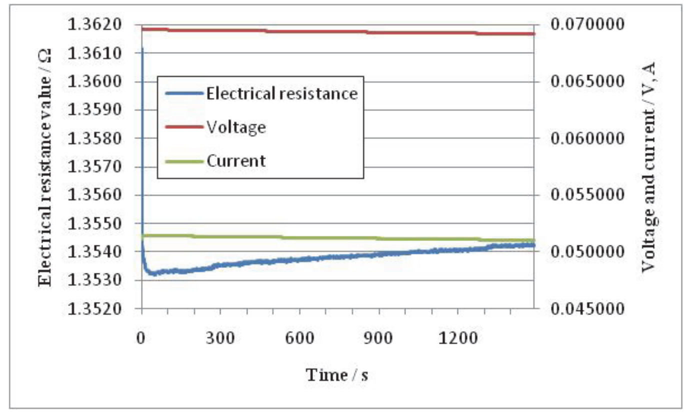

Figure 6: Change in electric resistance, current and voltage with time, of sample sprayed in 75mm spraying distance.

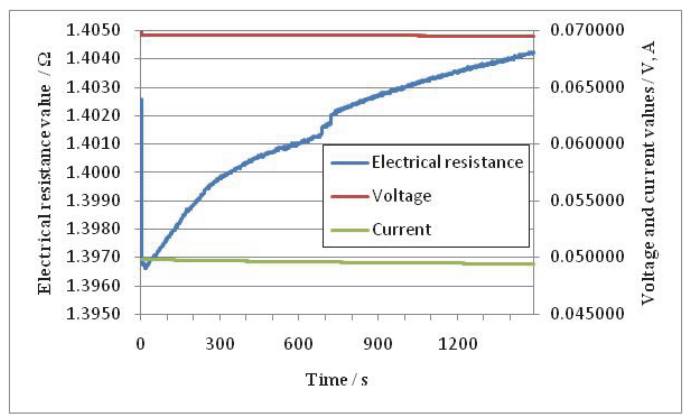

Figure 7: Change in electric resistance, current, and voltage with time, of sample sprayed in 125mm spraying distance.

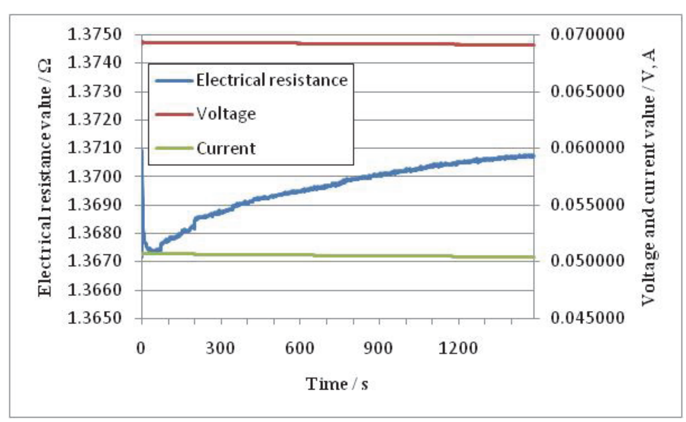

Figure 8: Change in electric resistance, current and voltage with time, of sample sprayed in 175mm spraying distance.

The electrical resistance decreases for a few minutes from start of measurement as shown in Fig. 6, 7, and 8. The decrease in electrical resistance occurs due to the actual contact are increased area by deforming the surface between the cupper board and the specimen. After the increase of the electric resistance, the resistance increased. A chemical alteration might occur during the increase.

Figure 9 shows the relationship between spraying distance and the rate of the increase of the electrical resistance. The rate might show a coating property, such as amount of porosity. Figure 10 shows the relationship between the rate of the electrical resistance and the adhesive strength of the sprayed coatings of zinc alloy. The adhesive strength decreased with increasing the rate of the increase of the electrical resistance of the specimen. There is correlation between the rate of the electrical resistance and the adhesive strength. This correlation may be useful to evaluate the properties of metallic sprayed coatings on a metal substrate.

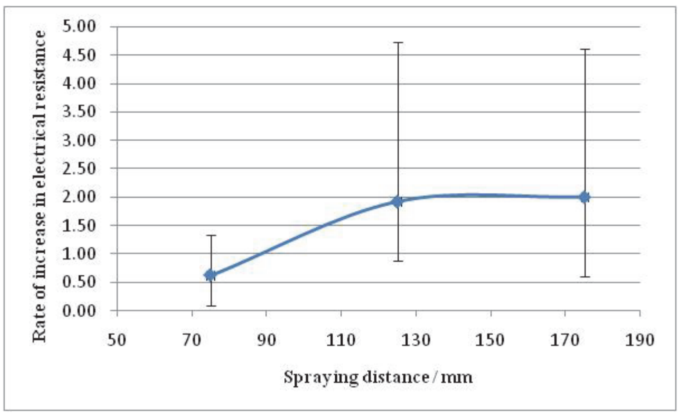

Figure 9: Relationship between spraying distance and the rate of the increase of the electric resistance.

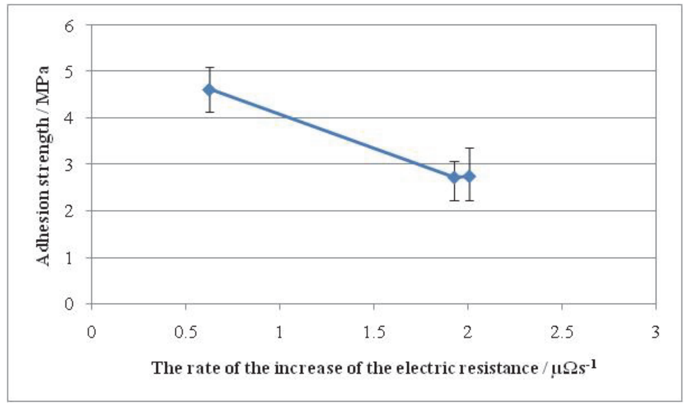

Figure 10: Relationship between the rate of the electric resistance and adhesive strength.

Conclusion

The rate of the increase of the electrical resistance was measured by loading direct current to sprayed coatings. The adhesive strength decreases with the increasing rate.

Reference

1. A. Hasui, *Yosya Kougaku*, Sanpo Publications, 1996, p.170-179.
2. Y. Ssuga, D. Lian, and A. Ikeda, Evaluation of Properties of Thermal Sprayed Coating by Ultrasonic Testing Method, *Proceedings of Symposium of Yosatsu-Kouzo*, 1997, p.213-220.
3. T. Maruyama, T. Kishita and T.Kobayahi, Effect of Hardness in Blasted Substrate Surface on Adhesive Strength of Sprayed Coatings, *ITSC 2011:* Pre- & Post-Treatment 1, on CD-ROM, p.575-578.