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Adhesion Properties of Sprayed Coatings on Substrate Blasted by Multiangle Blasting

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Abstract

Adhesion properties on the substrate blasted by multi-angle blasting with white alumina grit were examined. The low carbon steel substrates were blasted at two blasting angles (high and low angles) in a multi-angle blasting process. The sprayed coating of zinc alloy was evaluated by an adhesion test. The surface roughness levels after the multi-angle blasting were lower than those in the case of normal blasting. The multi-angle blasting was an effective blasting process to obtain improved adhesive properties. The low blasting angle may have contributed for removing contamination from the substrate surface. The high blasting angle may have contributed for an effective surface roughness to enhance the adhesive properties.

Introduction

The blasting process as a pre-treatment of a substrate is the most common process to obtain bonding between the substrate and the sprayed coatings. Many researches have shown the surface roughness and/or the surface roughness parameter is the most effective to improve the adhesion between a substrate and sprayed coatings (Ref 1-8). However, some reports showed that the surface roughness is not always dominant parameter to improve the adhesion. Day et. al. showed that poor relationship between the adhesion and the surface roughness changed by changing girt size (Ref 9). Maruyama et. al. also showed that there was poor correlation of the adhesion with roughness peak slope (Ref 10). Any variable parameters may cause this inconsistent.

One of the variable parameters is contamination, for example, oil, grease, etc. Therefore, degreasing is also carried out as a common process for surface preparation before girt blasting. However, the process consumes time. A part of the contamination can be removed by grit blasting. It is highly valuable if the optimum condition for grit blasting exists to remove the contamination and to obtain appropriate surface roughness simultaneously.

Changing the blasting angle during grit blasting is considerable. The grit blasted by low blasting angle may shave substrate surface with the contamination. The grit blasted by high blasting angle can roughen substrate surface. However, it is not clear how the adhesion property on the substrate changes when changing blasting angle. The purpose of this paper is to clarify the effect of multi-angle blasting on the adhesion properties.

Experimental Procedure

Substrate Preparation

A carbon steel plate, which had 0.45 mass% carbon, was used as a substrate. The carbon steel plate was a cold-rolled plate with the dimensions of 25 × 25 × 6 mm. The substrate polished by using emery paper (600 mesh) was roughened by a suction-head grit blasting machine. The inner diameter of the nozzle was 6 mm. The pressure exerted by the air that acts as the grit carrier gas was fixed at 0.4 MPa. The blasting material was white alumina grit with the mean diameter of 555 μm (30 mesh). The blasting distance was fixed at 150 mm. The mean velocity of the grit particles was 28.3 m/s, as measured with a high-speed camera. The number of particles fed per second was 183 g/s.

The blasting time was changed from 5.0 s to 25.0 s. The blasting angle was the angle between the blasting direction and the substrate surface. The blasting angle was changed from 30° to 90°. In the multi-angle blasting, a substrate was blasted in two periods of time. In the first period, low blasting angle was applied, and high blasting angle was applied in the second period. Table 1 shows the blasting time and the blasting angle in each period for the multi-angle blasting. The blasting angles of the first period was 30° or 60°, and of the second period was a constant angle of 90°.

The center-line-average roughness, *Ra*, on the blasted substrates was evaluated by using a traceable surface roughness tester. The stylus, which had a tip radius of 2 μm, was moved at the speed of 0.100 mm/s. The scan length was 2.5 mm.

Table 1: The blasting time and the blasting angle in each period for the multi-angle blasting.

Run number	First period		Second Period	
	Blasting angle	Blasting time/s	Blasting angle	Blasting time/s
1	90°	5.0	-	-
2	90°	10.0	-	-
3	90°	25.0	-	-
4	30°	5.0	90°	5.0
5	30°	5.0	90°	10.0
6	30°	5.0	90°	25.0
7	30°	10.0	90°	5.0
8	30°	10.0	90°	10.0
9	30°	10.0	90°	25.0
10	60°	5.0	90°	5.0
11	60°	5.0	90°	10.0
12	60°	5.0	90°	25.0
13	60°	10.0	90°	5.0
14	60°	10.0	90°	10.0
15	60°	10.0	90°	25.0

Thermal Spraying and Adhesion Test

Zn-15mass%Al alloy was sprayed by a wire flame spraying process without pre-heating to the substrate. The wire diameter was 1.6 mm. The spray material was sprayed with 10 s of the spraying time, 150 mm of the spraying distance, and 4.2 m/min of the wire feed rate. The thickness of the sprayed coatings was 2 mm.

The adhesive strength was evaluated by the extrusion method as shown in Fig. 1. 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 undid, 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).

Results and Discussion

Figure 2 shows the relationship between blasting time and adhesive strength of zinc alloy sprayed coatings on a carbon steel substrate blasted with 90° of blasting angle (run number 1-3). 'n' in the figure means the number of measurement. The adhesive strength increased with increasing blasting time.

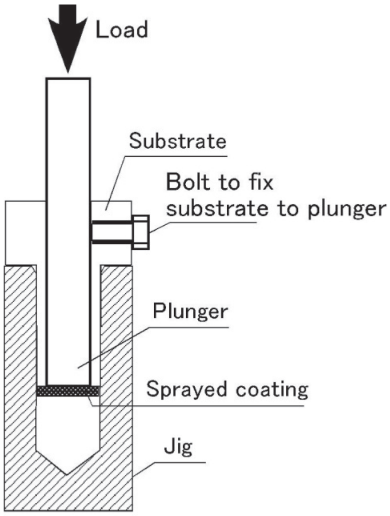

Figure 1: The schematic representation of adhesion test by extrusion method. The area between the substrate and the sprayed coatings is the evaluated area, and the area between the plunger and the sprayed coatings is the unbounded area.

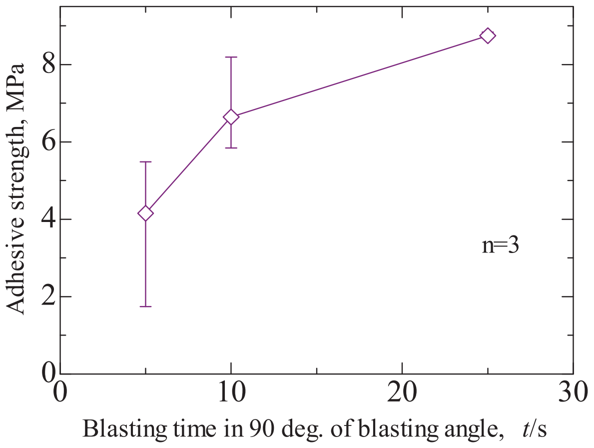

Figure 2: Relationship between blasting time and adhesive strength of zinc alloy sprayed coatings on a carbon steel substrate blasted with 90° of blasting angle.

Figure 3 shows the relationship between blasting time and adhesive strength of zinc alloy sprayed coatings on a carbon steel substrate blasted with 30° and 90° of blasting angle (run number 4-9). The adhesive strength increased with increasing blasting time. The adhesive strength of the sprayed coatings on the substrate blasted with 5 s in 30° of blasting angle before blasting in 90° of blasting angle is larger than that on the substrate blasted with 10 s in 30° of blasting angle.

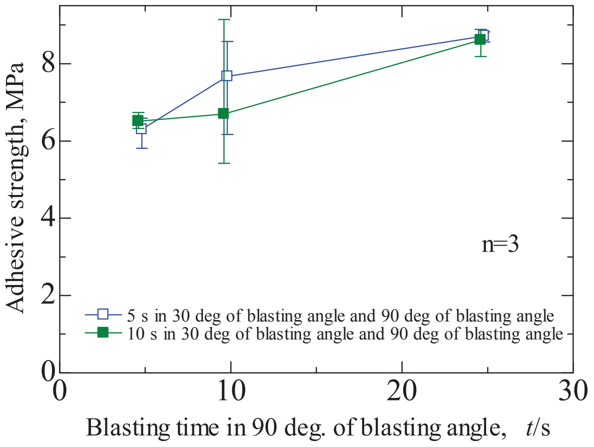

Figure 3: Relationship between blasting time and adhesive strength of zinc alloy sprayed coatings on a carbon steel substrate blasted with 30° and *90° of blasting angle.*

Figure 4 shows relationship between blasting time and adhesive strength of zinc alloy sprayed coatings on a carbon steel substrate blasted with 60° and (run number 10-15). The adhesive strength decreased with increasing blasting time. The adhesive strength of the sprayed coatings on the substrate blasted with 10 s in 60° of blasting angle before blasting in 90° of blasting angle is larger than that on the substrate blasted with 5 s in 60° of blasting angle.

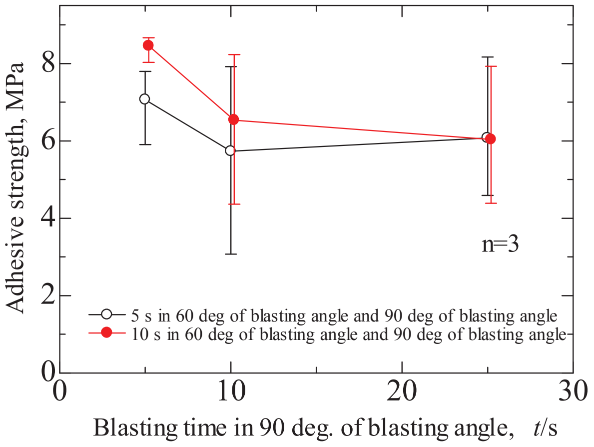

Figure 4: Relationship between blasting time and adhesive strength of zinc alloy sprayed coatings on a carbon steel substrate blasted with 60° and *90° of blasting angle.*

Figure 5 shows comparison between the adhesive strength of multi-angle blasting and normal blasting. The accumulated time of blasting is 15 s. The value of 15 s in 90° of blasting angle was estimated by straight-line approximation from the result of Fig. 2. The multi-angle of 60° and 90° was the most effective combination.

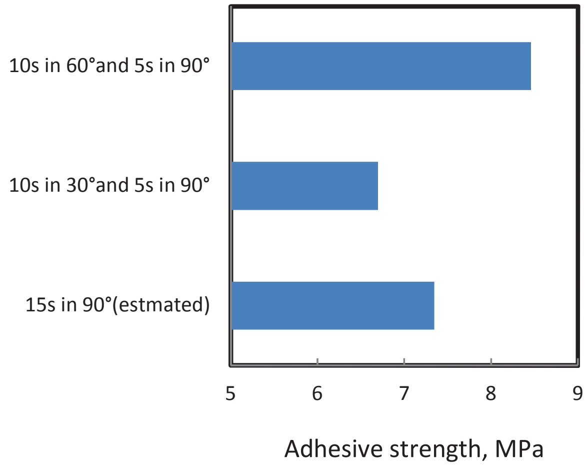

Figure 5: Comparison between adhesive strength of multi-angle blasting and normal blasting.

Figure 6 shows secondary electron images of the substrate surface blasted for 10 s in blasting angle of 30°, 60° and 90°. Scratch was observed on the surface blasted with 30° of the blasting angle. The blasting material may slice a part of the surface. The surface contamination on the substrate may be removed by grinding the surface. The adhesive strength would be expected to improve due to removal of the surface contamination. However, as shown in Fig. 5, the adhesive strength of the sprayed coatings on the substrate basted by multi-angle blasting with 30° and 90° was smaller than that with 90° of blasting angle. The roughened surfaces were observed on the surface blasted with 60° and 90°. The blasting material hit onto the surface, and a part of the blasting material remained on the blasted surface as shown in Fig. 6. The residual grit could deteriorate the adhesion of the sprayed coatings. The amount of residual grit on the substrate blasted with 90° must be larger because the residual grit increases with increasing blasting angle (Ref 11).

Figure 7 shows the center line average roughness with multi-angle blasting. The surface roughness with multi-angle blasting was smaller than the roughness without multi-angle blasting even the blasting time in 90° was same. In the first period in the multi-angle blasting, the substrate surface may harden, and the deformability of the surface decreases. One of reason why the adhesive strength in which the multi-angle blasting was carried out with the combination of 30° and 90°

was smaller, as shown in Fig. 5, can be attributed to smaller surface roughness. The multi-angle with the combination of 60° and 90° is efficient to shorten the blasting time and to improve the adhesion. However, over blasting with 90° of blasting angle decreases the adhesion.

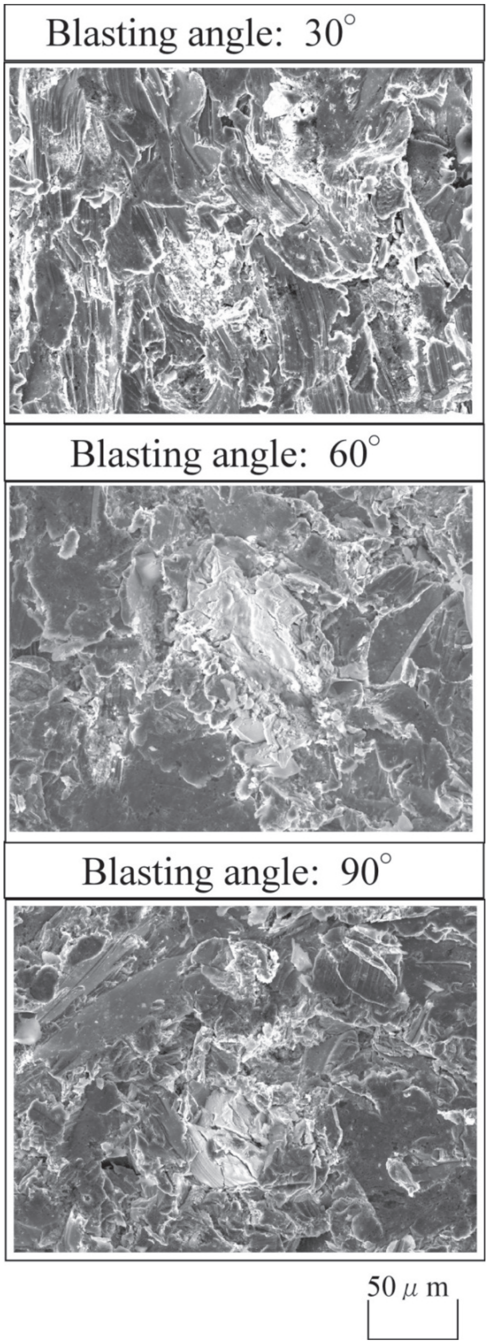

Figure 6 shows secondary electron images of the substrate surface blasted for 10 s in blasting angle of 30°, 60° and 90°.

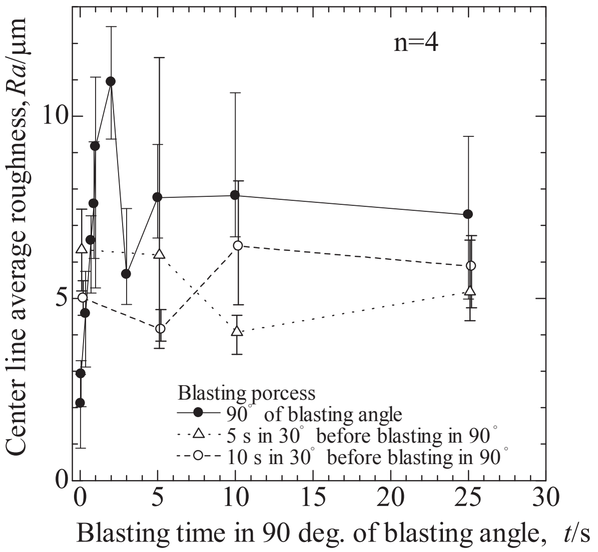

Figure 7 Change in center line average roughness with blasting time in 90° of blasting angle with multi-blasting.

Conclusions

Multi-angle blasting was applied to improve the adhesion of thermal sprayed coatings of zinc alloy on carbon steel substrates. The combination of 30° - 90°, and 60°- 90° in the multi-angle blasting was examined, and the results are as follows:

(1) The adhesive strength of the sprayed coatings on the substrate blasted with the combination 60° and 90° is higher than that in case of normal blasting with 90° of blasting angle.
(2) In the combination 30° and 90°, the surface roughness and the adhesive strength level are lower than those in the case of the normal blasting.

References

1. E. Bardal, The Effect of Surface Preparation on the Adhesion of Arc-Flame-Sprayed Aluminium and Zinc Coatings to Mild Steel, *Proc. 7th Int. Met. Spraying Conf.,* Welding Institute, 1973, p 215-223.
2. C. P. Bergmann, Influence of the Substrate Roughness on the Adherence of Plasma Sprayed Coatings, *Proc. 7th Int. Thermal Spray Conf.*, 1994, p 683-686.
3. B. J. Griffith, D. T. Gawne, G. Dong, The Role of Grit Blasting in the Production of High-Adhesion Plasma Sprayed Alumina Coatings, *Proc. Inst. Mech. Eng.*, *Part B*, 1997, **211**, p 1-9.

4. I. Hofinger, K. Raab, J. Möller, M. Bobeth, Effect of Substrate Roughness on the Adherence of NiCrAlY Thermal Spray Coatings, *J. Therm. Spray. Technol.*, 2002, **11**, p 387-392.
5. D. E. Packham, Surface Roughness and Adhesion, *Surfaces, Chemistry and Applications* (M. Chaudhury and A. V. Pocius, Ed.), Elsevier, Amsterdam, 2002, p 317-349.
6. T. Maruyama, T. Kobayashi, Influence of Substrate Surface Roughness on Adhesive Properties of Sprayed Coating, *Proc. Therm. Spray 2004, ITSC*, 2004, p 266-271.
7. R. Van Tijum, J. T. De Hosson, Effects of Self-Affine Surface Roughness on the Adhesion of Metal-Polymer Interfaces, *J. Mater. Sci.*, 2005, **40**, p 3503-3508.
8. H. J. Roper, R. E. Weaver, J. H. Brandon, The Effect of Peak Count or Surface Roughness on Coating Performance, *J. Protect. Coat. Lin*, 2005, **22**(7), p 52-64.
9. J. Day, X. Huang, N. L. Richards, Examination of a Grit-Blasting Process for Thermal Spraying Using Statistical Methods, *J. Therm. Spray. Technol.*, 2005, **14**, p 471-479.
10. T. Maruyama, T. Kishita, T. Kobayashi, Effect of Hardness in Blasted Substrate Surface on Adhesive Strength of Sprayed Coatings, *Proc. ITSC2011*, 2011, p. 575-578.
11. T. Maruyama, K. Akagi, T. Kobayashi, Effect of the Blasting Angle on the Amount of the Residual Grit on Blasted Substrates, *Proc. ITSC2007*, 2007, p. 1059-1063.