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TECHNICAL NOTE

An Evaluation of Adhesion for Plasma Spray Coated Materials †

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KEY WORDS: (Plasma Spray) (Adhesion) (Four-point Bend Test)

In the previous studies, several tests for adhesion of plasma sprayed coatings on their substrates have been proposed.[1] The adhesive testing of the coatings is normally conducted by conventional bend and tensile tests.

In this note, We attemped to evaluate the adhesion of the coatings by the four-point bend test. The schematic diagram of the apparatus used for the four-point bend test is shown in **Fig. 1**. After, as shown in Fig. 1, the specimen (A) placed on the loading bar (B) was slowly pressed up by the oil pressure pump (C), the value of the strain when cracks appeared on the surface of the coating (**Photo. 1** and 2), ϵ_c, was measured by the strain gauge (D) attached to the loading stage (E). The bending load, P_c(kg), was determined from ϵ_c. In addition, the bending angle, θ_c, was measured by the profile projector in order to compare with P_c (**Fig. 2**). Each measurement was carried twice. SUS 316 and 304 stainless steels pretreated with sand blasting or grinding were coated with the Fe (P91) or Mo(P64) powder. The condition of the plasma spraying and the physical properties as follows:

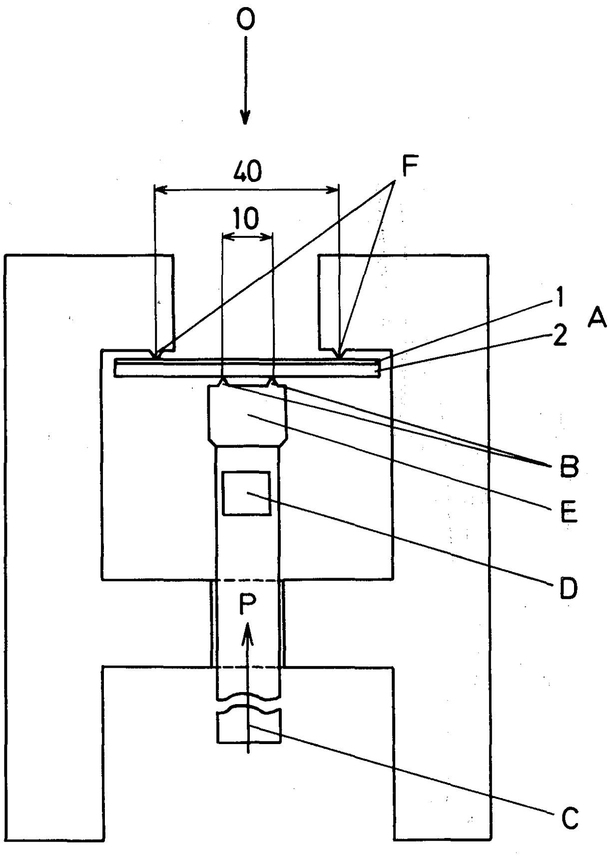

Fig. 1 Schematic diagram of apparatus for four-point bend test. A: specimen (1: sprayed coating; 2: base stainless steel); B: loading bar; C: oil pressure pump; D: strain gauge; E: loading stage; F: supporting bar; O: camera; P: load

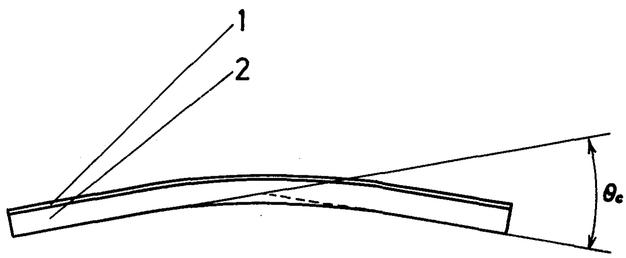

Fig. 2 Bending angle θ_c.
1: sprayed coating; 2: base stainless steel

SPRAY GUN	Type: 7MB; Nozzle: 706 (6.25 mm diameter); Air Pressure: 5.5 kg/cm^2; Cross Jets: 150 mm
GAS	Flow-Primary: Ar 40.0 (l/min); Secondary: H_2 7.5 (l/min)
POWER	Unit: PTR-1000; Arc Amps: 800A; Arc Volts: 64V
POWDER FEED	Unit: 3MP-D; Meter Wheel: S; RPM: 30; Carrier Gas Flow: 40
SPRAYING	Spray Distance: 100 mm; Spray Rate: 5.0 kg/hr

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Table 1. Results of P_c and θ_c obtained from four-point bend test.
B : sand blasting; G : grinding

Specimen No.		Specimen Coating	Specimen Substrate	Bending Load P_c (kg)	Bending Angle θ_c (°)
Test 1–	1(B)	Fe	SUS 316	118	20.5
	2(B)	Mo	SUS 316	129	12.3
	3(B)	Fe	SUS 304	91	17.1
	4(B)	Mo	SUS 304	98	17.3
	5(G)	Fe	SUS 316	96	5.7
	6(G)	Mo	SUS 316	102	12.4
	7(G)	Fe	SUS 304	71	5.1
	8(G)	Mo	SUS 304	87	10.4
Test 2–	1(B)	Fe	SUS 316	110	20.6
	2(B)	Mo	SUS 316	112	16.8
	3(B)	Fe	SUS 304	95	11.6
	4(B)	Mo	SUS 304	89	14.7
	5(G)	Fe	SUS 316	87	3.8
	6(G)	Mo	SUS 316	99	11.7
	7(G)	Fe	SUS 304	79	6.8
	8(G)	Mo	SUS 304	96	15.4

PHYSICAL PROPERTIES

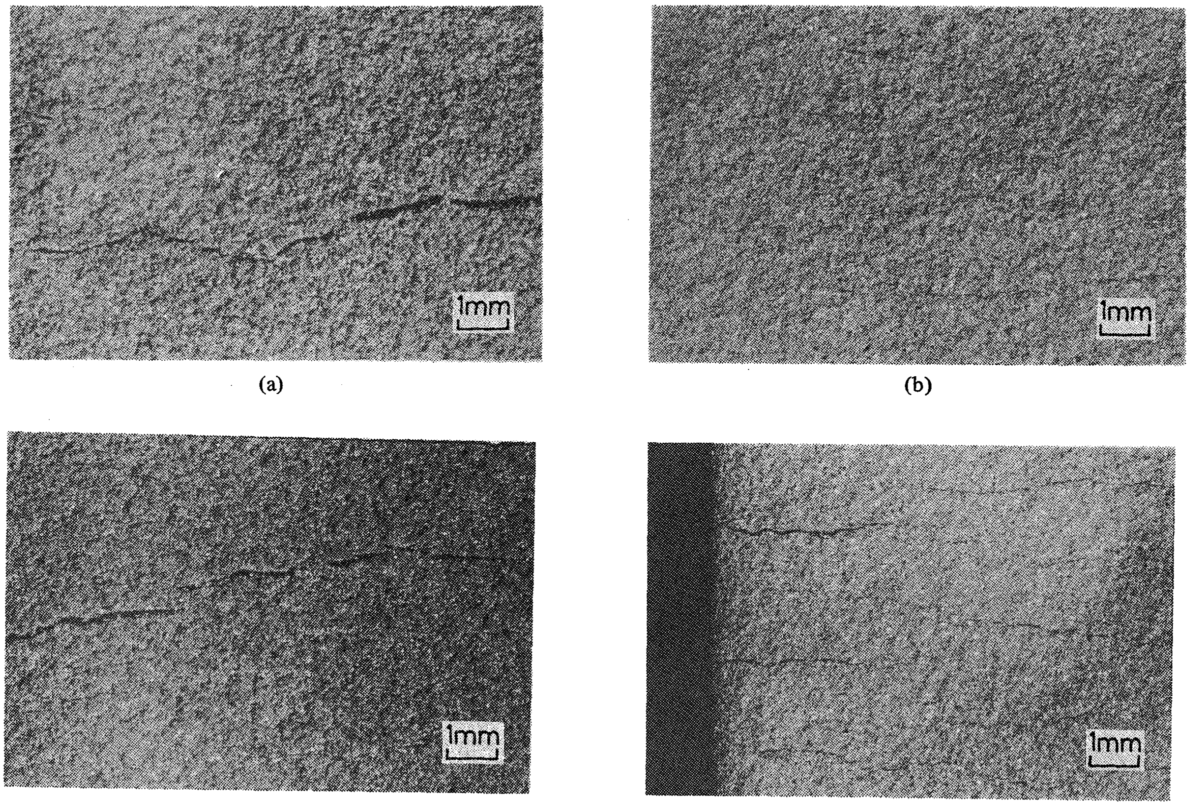
Coatings:	Mo (P64)	Fe (P91)
Hardness (Rb)	87	90
Cross Section (DPH300)	390 - 490	260-330
Density (g/cc)	8.93	6.95
Porosity (%)	<1	<1
Tensile Strength (kg/mm^2)	5.75	23.4

The results of the measured P_c and θ_c are showed in **Table 1**. The results obtained can be summarized as follows:

(1) In the same surface pretreatment and the same base stainless steel, P_c of Mo coating is greater than that of Fe coating (except for the specimen No. 3 and 4 of test 2 in Table 1). If P_c is due to the adhesion of the plasma sprayed coating on the base stainless steel, the result obtained shows that Mo coating has better adhesive property to SUS 316 and/or 304 than Fe coating.

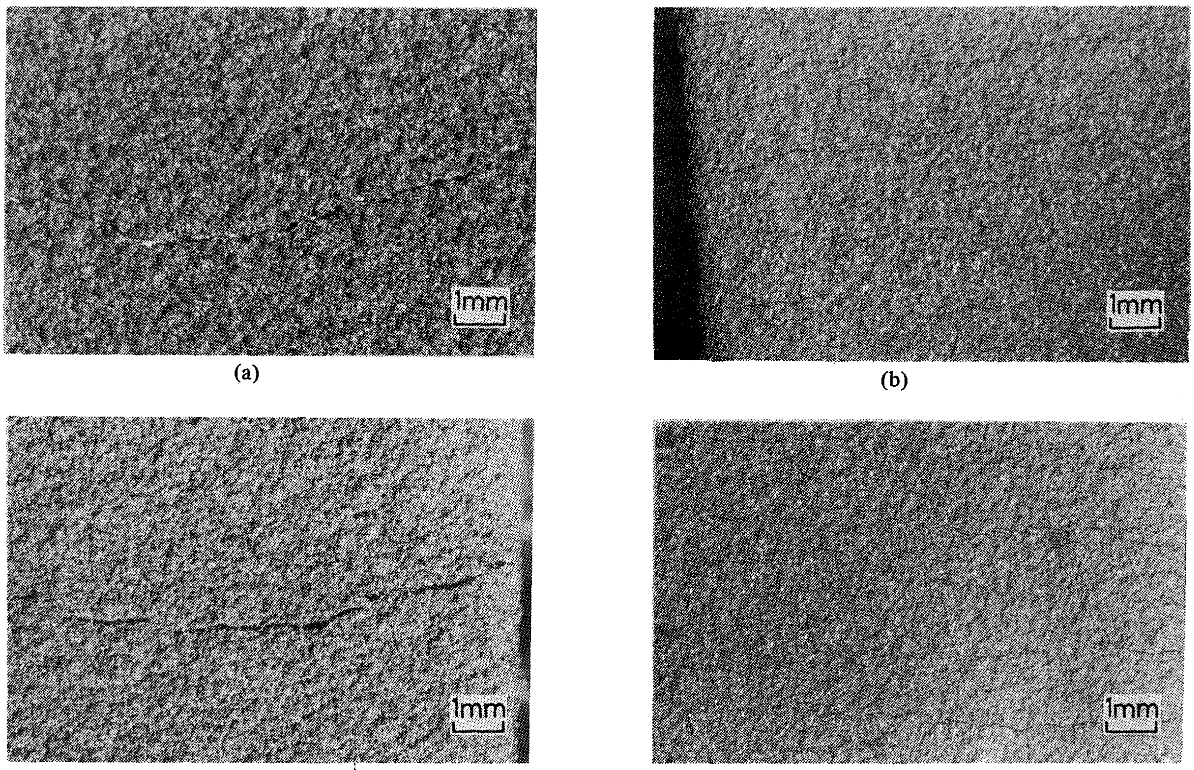
(2) In the same pretreatment and the same coating, P_c of SUS 316 shows greater value than that of SUS 304. It is considered that the difference between P_c of SUS 316 and 304 is caused by the different mechanical properties of these stainless steel.

(3) In the same coating and the same base stainless steel, P_c of the coating pretreated with the sand blasting is greater than that with the grinding (except for the specimen No. 4 and 8 of test 2 in Table 1). This result must be attributed to the roughness of the surface of the base stainless steel caused by the sand blasting. On the other hand, in the same surface pretreatment and the same base stainless steel, the bending angle θ_c of the stainless steel coated with Mo is greater than that with Fe (except for the specimen No. 1 and 2 of both 1 and 2 tests). However, the angles θ_c obtained vary widely between 1 and 2 tests. Therefore, it is difficult to evaluate the adhesion for these coatings. In future, in order to analyze quantitatively, it is necessary to increase the number of the measurements. In the bend test, there exists a stress distribution between the surface and center area of the specimen, and the tensile stress on the surface area is maximum. So the cracks would appear on the surface rather than the interface of the coating. Therefore, it will be necessary to examine the effect of the thickness of the coatings. As can be seen from Photo. 1 and 2, cracks generate from the edge to the center of the specimen, and so it is necessary to take into account the edge effect. We will compare four-point bend test reported in this note with other tests, such as tensile test.



(a) (b) (c) (d)

Photo. 1 Cracks on surface of coating with sand blasting pretreatment.
(a) Fe coating on SUS 316; (b) Mo coating on SUS 316;
(c) Fe coating on SUS 304; (d) Mo coating on SUS 304



(a) (b) (c) (d)

Photo. 2 Cracks on surface of coating with grinding pretreatment.
(a) Fe coating on SUS 316; (b) Mo coating on SUS 316;
(c) Fe coating on SUS 304; (d) Mo coating on SUS 304

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Reference

1) H.S. Ingham, Jr: Adhesion of Flame-Sprayed Coatings, ASTM Special Technical Publication 640, 1978, p. 285-292.