Materials and Design 123 (2017) 54–63

Contents lists available at ScienceDirect

Materials and Design

journal homepage: www.elsevier.com/locate/matdes

Interfacial bonding properties between cobalt-based plasma cladding layer and substrate under tensile conditions

Yang Li [a], Xiufang Cui [a,*], Guo Jin [b,*], Zhaobing Cai [a], Na Tan [a], Bingwen Lu [a], Zonghong Gao [a]

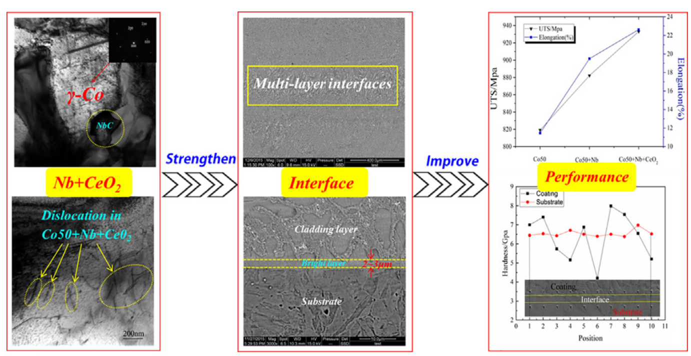
[a] *Institute of Surface/Interface Science and Technology, Key Laboratory of Superlight Material and Surface Technology of Ministry of Education, College of Material Science and Chemical Engineering, Harbin Engineering University, Harbin 150001, China*

[b] *College of Material Science and Chemical Engineering, Harbin Engineering University, Harbin 150001, China*

HIGHLIGHTS

- Metallurgical interface is face-centered cubic structure and the main elements are iron and cobalt near the interface.
- Bonding properties were tested by tensile test with the aid of a special fixture.
- The bonding strength between coating and substrate was stronger than that of the coating itself.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 19 November 2016
Received in revised form 11 March 2017
Accepted 11 March 2017
Available online 14 March 2017

Keywords:
Bond strength
Interface
Micro-plasma cladding
Elastic modulus
Tensile test

ABSTRACT

Bonding strength is critical to the service life of components in the surface engineering field. To identify the interfacial bonding behavior of metallurgical coating and substrate, micro-plasma cladding technique was used to fabricate cobalt-based metallurgical coating, meanwhile niobium and cerium oxide as reinforced particles were added to the composite coating. The elastic modulus of coating and substrate were measured to assess the matching degree of elastic coefficient between coating and substrate. In addition, the bonding properties of coating and substrate were tested. Result, the microstructure was refined by the addition of niobium and cerium oxide. The composite coating mainly consisted of γ-Co, $Cr_{23}C_6$, M_7C_3, Ni_2Si and NbC. Interface is face-centered cubic structure and the main elements are iron and cobalt near the interface. Tensile and elastic modulus tests demonstrate an excellent match between the coating and substrate. With the addition of niobium and cerium oxide alone or in combination, the tensile performance was improved significantly. The bonding strength of the coating and substrate is superior to that of the coating itself. The fracture occurred in the interface between the two coatings instead of interior of single plasma cladding layer.

1. Introduction

Nowadays, in the field of aerospace, ship and high-tech electronics, a variety of coating technologies are widely used to improve the performance of mechanical components. Therefore, it is essential to

* Corresponding authors.
E-mail addresses: cuixiufang@hrbeu.edu.cn (X. Cui), jinjg721@163.com (G. Jin).

http://dx.doi.org/10.1016/j.matdes.2017.03.035

Table 1
Composition of the cladding material-Co50 and substrate material-FV520B.

	Element										
	C	Mn	Si	Cr	Ni	Mo	Nb	Fe	B	Co	W
FV520B	0.02–0.07	0.3–1.0	0.15–0.70	13.0–14.5	5.0–6.0	1.3–1.8	0.25–0.45	75.48–79.98	–	–	–
Co50	0.07	–	1.80	21.5	1.90	–	–	–	2.55	66.56	5.62

understand the characteristics of coatings in order to further expand their industrial application. The characteristics include mechanical properties and durability under specific environments [1–3], furthermore it is equally important to maintain integrity of coating and substrate manufactured by surface engineering technologies [4], so as to ensure the safety of mechanical components. In the past, the researches on cladding layers focus on single-layer coating. The research on multi-layer coating is limited, but the multi-layer coating has more widespread application than single-layer in practice application [5–8].

For surface modification technique, bonding strength includes three aspects: the bonding of coating internal strength, which is the bonding of multi-layer coating; the bonding between coating and substrate and the bonding of substrate itself. But the previous two is often the key concern. The bonding strength between the coating and substrate has attracted much interest. Meanwhile the bonding strength of multi-layer coating itself is one of the essential characteristics. The research on element interdiffusion, reaction and microstructure at the interface of plasma cladding layer is vital for the bonding performance.

The paper takes large compressor rotor shaft and blade as the object to fabricate superior coating. Cobalt base coating is usually used to repair the shafts and blades. Co50 has good wear resistance, corrosion resistance and excellent red hardness and it is suitable for plasma cladding process. FV520B usually used to manufacture compressor rotor, so FV520B as the substrate material is a good choice. Therefore, surfaces of FV520B substrate were cladded with Co-based admixed powders (Co50, Nb and CeO_2) by plasma cladding equipment in the current research. Interfacial bonding properties of Co-based composite coating and substrate were determined by tensile tests. The paper applied a method, which describes the interfacial bonding performance between metallic coating and substrate or coating itself. In addition, the elastic modulus of coating and substrate was tested, respectively.

2. Experimental procedures

2.1. Materials and plasma cladding processing

A martensitic precipitation hardened stainless steel FV520B, 100 × 20 × 20 mm in size, was selected as the substrate material. The powders of three different compositions, Co50, Co50 + 2%Nb and Co50 + 2%Nb + 1%CeO_2 (wt%), with an average particle diameter ranging from 70 to 150 μm were selected as the cladding materials, and the composition of the cladding material-Co50 and substrate material-FV520B are listed in Table 1. The material supplier is Beijing General Research Institute of Mining and Metallurgy. The substrate was cleaned up and the powder was dried for 2 h at 120 °C before preparation process. A PAW-160 plasma cladding machine (designed by National Key Lab for Remanufacturing, Academy of Armored Forces Engineering) was employed to prepare the coating, and the schematic diagram of plasma cladding technology is shown in Fig. 1. The high heat input of the plasma arc produces a thin melt pool on the surface of the substrate material. Simultaneously the powders were filled into this melt pool by synchronous powder feeding system; in addition, cooling water and shielding gas join the cladding process as two protection ways. After the plasma arc left, the reduced temperature led to solidification. During

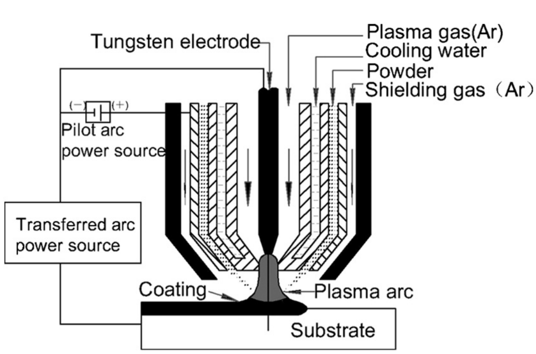


Fig. 1. Schematic diagrams of plasma cladding technology.

Table 2
Parameters of plasma cladding process.

Parameters	Value
Current (A)	100
Scanning velocity (mm/s)	3
powder feeding rate (g/min)	12
Feeding gas flow (L/h)	6
Protective gas flow (L/min)	3
Plasma gas flow (L/min)	2

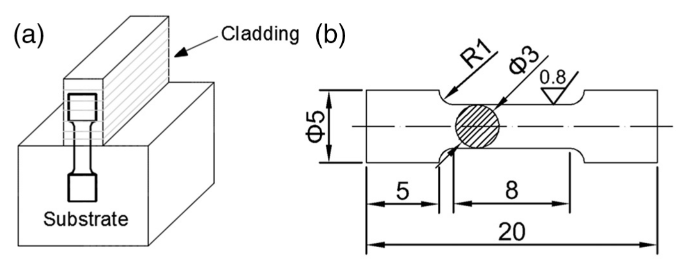


Fig. 2. (a) Design of test part after plasma cladding processing; (b) Size of the tensile specimen and processing conditions.

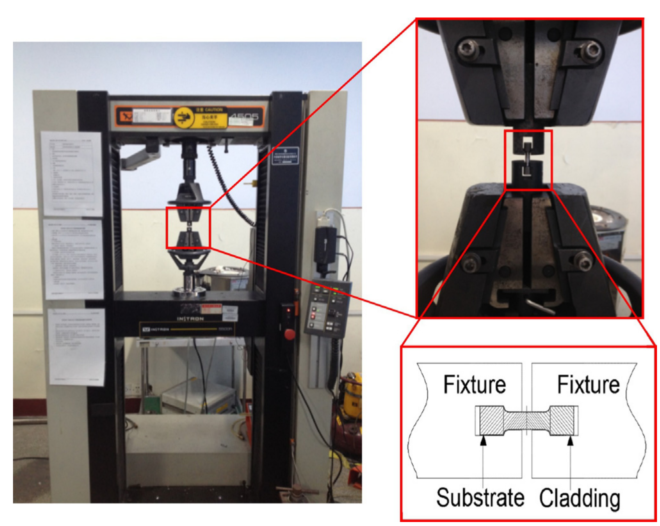


Fig. 3. Tensile test equipment and clamping way.