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Microstructure and properties of laser-cladded bimodal composite coatings derived by composition design

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ABSTRACT

The AlSiTiNi composite coatings were prepared on the surface of the 304 stainless steel by laser cladding. The results showed that a good metallurgical combination was found at the bonding area between the coating and the substrate. For the Al and Ti powders with different content, the bimodal microstructure was shown in all the coatings. However, the microstructure of the coating with a composition of 50%Al-20%Ti was more compact, and it was mainly composed of equiaxed crystal in the partially melted region and net-like structure in the fully melted region, while the partially melted region was embedded in the fully melted region. In addition, the phases of AlFe, FeNi and Al_5Cr were found in the coating. The highest micro-hardness of the coatings with the composition of 40%Al-30%Ti and 60%Al-10%Ti were 532.3 $HV_{0.2}$ and 556.8 $HV_{0.2}$, respectively. The highest micro-hardness of the coating with the composition of 50%Al-20%Ti has been increased to 758.5 $HV_{0.2}$, which was 3.4 times that of the substrate (223.2$HV_{0.2}$). Furthermore, the coating possesses low friction coefficient and high wear resistance. For the coatings with different contents, the 5A2T coating possesses the shortest the running-in period and the smallest wear loss.

1. Introduction

The powders and substrate is melted into the molten pool by high energy laser beam, and then the molten pool solidified to form the coating [1,2]. The different composition of the powder is essential for the coatings, which not only affects the morphology, the phase constituent and the microstructure, but also the properties of the coatings [3–5]. Currently, the most common powder materials include the nickel-based, iron-based, cobalt-based, aluminum-based and other self-fluxing alloy powders [6–9]. The coatings derived from different alloy powders possess different microstructure and properties.

Over the years, 304 stainless steel/Al_2O_3, FeAlSi, and Ti/Fe-based composite coatings have been prepared on the steel, and the results indicated that the composite coatings have dense microstructure and excellent wear resistances [10–12]. In addition, in order to improve the comprehensive performance of the coatings, ceramic particle powders were added to the coating or in situ synthesis of hard strengthening phase was performed. However, most of the researches focus on improving the performance of the coatings by hard phase reinforcement, while little research by forming the compact microstructure or multimodal microstructure [13,14].

As is well known, the bimodal microstructure, which has been extensively studied via heat treatments, semi-solid sintering and plasma spraying, usually lead to good comprehensive properties [15–18]. Owing to the compactness of the bimodal microstructure, the elongation, yield strength, plasticity and other mechanical properties would be improved. The strengthening mainly results from the contribution of ultrafine grains and the improvement of strain hardening capability of the grains.

Riveiro et al. [19] studied the coating derived from the al-based alloy powder on AISI304 stainless steel, and the results show that the coatings have good formability on the stainless steel, with great application prospect in fuel cells and catalytic converters. However, the coatings possess poor mechanical properties. In this work, the AlSiTiNi composite coating has been prepared by laser cladding on the 304 stainless steel, focusing on determining the optimal content of Al-Ti to obtain the bimodal microstructure of the coatings,

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Table 1
Chemical compositions of the 304stainless steel (wt%).

Element	C	Si	Mn	Cr	Ni	S	P
wt.(%)	≤0.08	≤1.0	≤2.0	18.0 ~ 20.0	8.0 ~ 10.0	≤0.03	≤0.045

Table 2
The chemical composition of the cladding powders (wt%).

Cladding powders	Al	Si	Ti	Ni
Sample 1	40	20	30	10
Sample 2	50	20	20	10
Sample 3	60	20	10	10

which would be beneficial to strengthening the hardness and wear resistance of the coatings. The aim of this study is to investigate the influence of the different Al-Ti content on the bimodal microstructure and mechanical properties.

2. Experiment

The 5kw continuous fiber lasers were applied for the laser cladding. The 304 stainless steel was selected as the substrate and the main chemical composition was shown in Table 1. Before laser cladding, the substrate was cut into the sheets of 50 × 50 × 6 mm, and then the surface of the substrate was pretreated. In addition, the surface oxide layer was removed by sandpaper of 160 meshes,

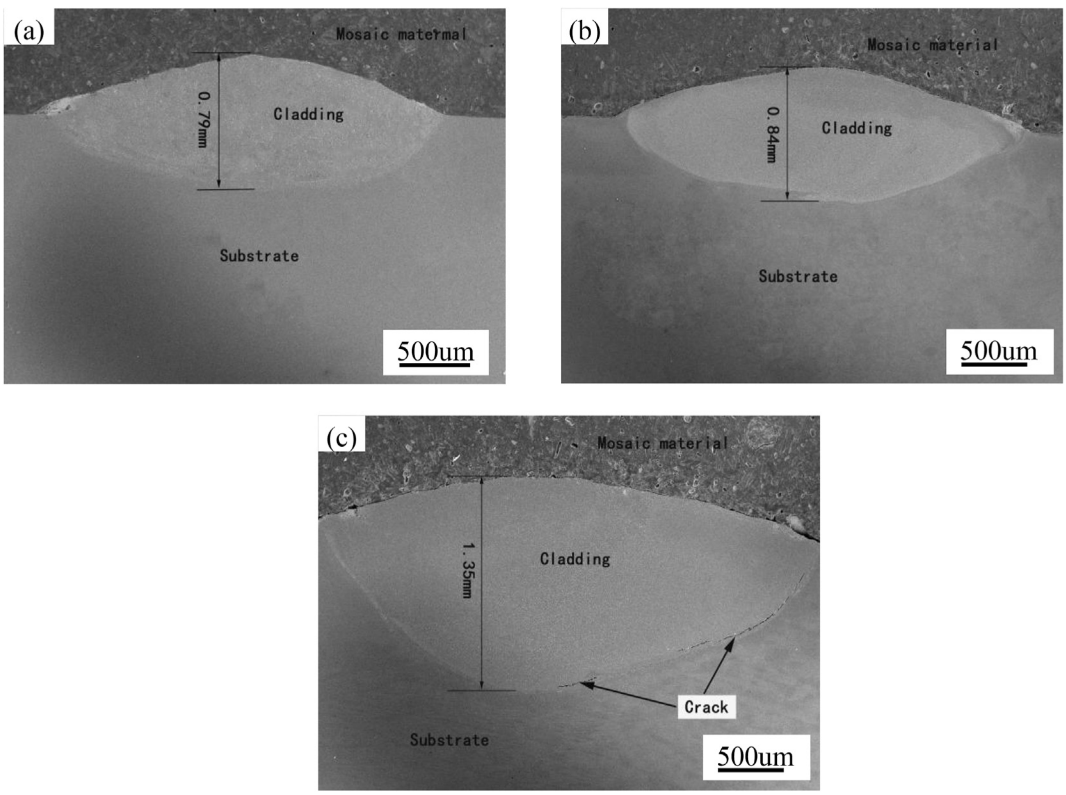

Fig. 1. Cross-section of the coatings with 40%Al-30%Ti. Laser power: (a) 1000 W, (b) 1500 W, (c) 2000 W.

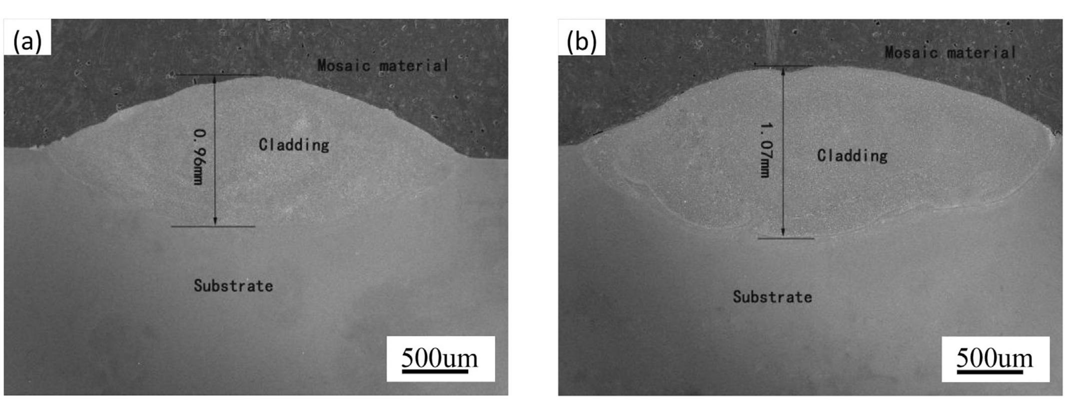

Fig. 2. Cross-section of the coatings: (a) 5A2T, (b) 6A1T.