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Microstructure and wear resistance of FeAl/Al_2O_3 intermetallic composite coating prepared by atmospheric plasma spraying

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ABSTRACT

FeAl intermetallic composite coating using Al_2O_3 as an additive has been fabricated by atmospheric plasma spraying. The microstructure and mechanical properties of the FeAl/Al_2O_3 composite coating were comparatively studied with those of pure FeAl coating. A uniform dispersion of Al_2O_3 in the FeAl matrix can be observed for FeAl/Al_2O_3 composite coating. Moreover, microhardness and adhesive strength improved after the incorporation of Al_2O_3 particles. The tribological results show that plasma-sprayed FeAl/Al_2O_3 composite coatings have excellent wear resistance under dry sliding wear test conditions due to the combination of the high yield strength of the intermetallic compound FeAl and the high hardness of the Al_2O_3 dispersoids.

1. Introduction

Iron–aluminum (FeAl) intermetallic compounds have been widely studied for their potential applications as high temperature bulk materials, due to their relatively low density and low cost as well as excellent anti-oxidation and anti-corrosion properties compared with Fe-based and Ni-based superalloys [1–3]. In order to use their excellent properties at elevated temperature in the form of a coating, several thermal spraying processes, such as plasma spraying [4–6], high-velocity oxy-fuel (HVOF) [7–9], wire-arc spraying [10], and cold spraying [11,12] have been used to deposit FeAl alloys onto carbon steels and stainless steels. However, relatively low tensile bonding strength and low hardness which results in poor wear properties limit their engineering application. In order to overcome those drawbacks, the FeAl intermetallic composite coating using ceramic as an additive has been prepared. Wang et al. [13] demonstrated that the cold-sprayed nanostructured FeAl/Al_2O_3 intermetallic composite coating was maintained at about 600 $HV_{0.1}$ at an annealing temperature below 500 °C. Wang and Yan [14] pointed out that FeAl intermetallic coatings that contained CeO_2 had fewer cracks, less porosity, higher hardness, and improved erosion and abrasive resistance as compared with pure FeAl coating. Grosdidier et al. [15] reported that the introduction of Y_2O_3 in the milled powder had an insignificant effect on the hardness and thermal stability of thermal sprayed FeAl coatings. And similarly, Mignone et al. [16] observed a slight difference in the oxidation resistance of FeAl alloys with and without Y_2O_3 addition. Yin et al. [17] prepared FeAl/CeO_2/ZrO_2 nano-composite coating by plasma spraying on 1Cr18Ni9Ti stainless steel and thus an increased wear resistance and an enhancement of mechanical property such as hardness and fracture toughness have been obtained compared with the pure FeAl coating. Nevertheless, the deposition of FeAl composite coatings using milled nano-scaled feedstock powder or cold spray process as mentioned above is a very cost intensive process.

Al_2O_3 as an available and raw ceramic material exhibited high hardness and excellent wear resistance at high temperatures. In this work, FeAl intermetallic composite coating using Al_2O_3 as an additive has been fabricated by atmospheric plasma spraying. Up to now, few works were devoted to the study of atmospheric plasma sprayed FeAl/Al_2O_3 composite coating. The microhardness, tensile bonding strength and dry sliding wear resistance of the FeAl/Al_2O_3 composite coating were comparatively studied with pure FeAl coating.

2. Materials and experimental procedures

FeAl powder (prepared at LERMPS laboratory) whose composition is Fe–35Al (wt.%), with an average particle size (D50) of 17 μm, and Al_2O_3 powder (MEDICOAT, Medipure, France) with an average particle size (D50) of about 30 μm, were used as feedstock. The FeAl powder was prepared by inert gas atomizing and thus has a general spherical shape (Fig. 1a). The commercial Al_2O_3 powder was characterized by angular particles as shown in Fig. 1b. Before spraying, FeAl and Al_2O_3 powders with a weight ratio of 70–30 were blended in a tumbling mixer for 2 h. Disk-shaped (φ25 × 10 mm) and plate-shaped (70 × 30 × 2 mm) stainless steels and Al alloys were employed as substrates. Among them, the disk-shaped substrates were used to measure the adhesive strength of the coatings. All the substrates which were fixed in a cylindrical holder (diameter of 160 mm) were grit-blasted prior to spraying. Grit-blasting was undertaken using pressure and suction operated machines with alumina grit. The grit particles were angular with a mean

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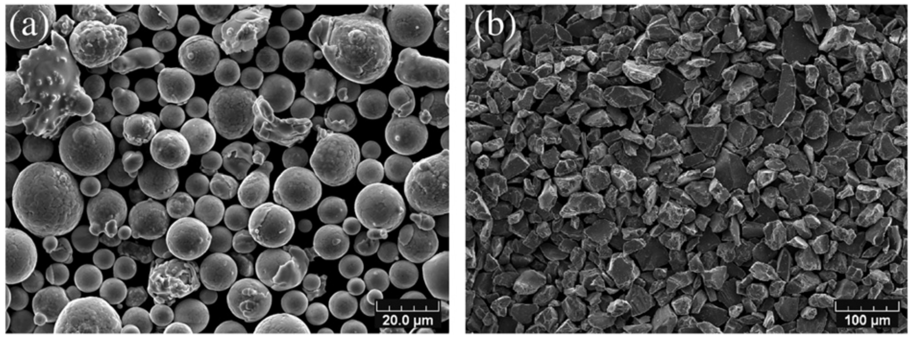

Fig. 1. SEM observation of (a) FeAl powder and (b) Al_2O_3 powder.

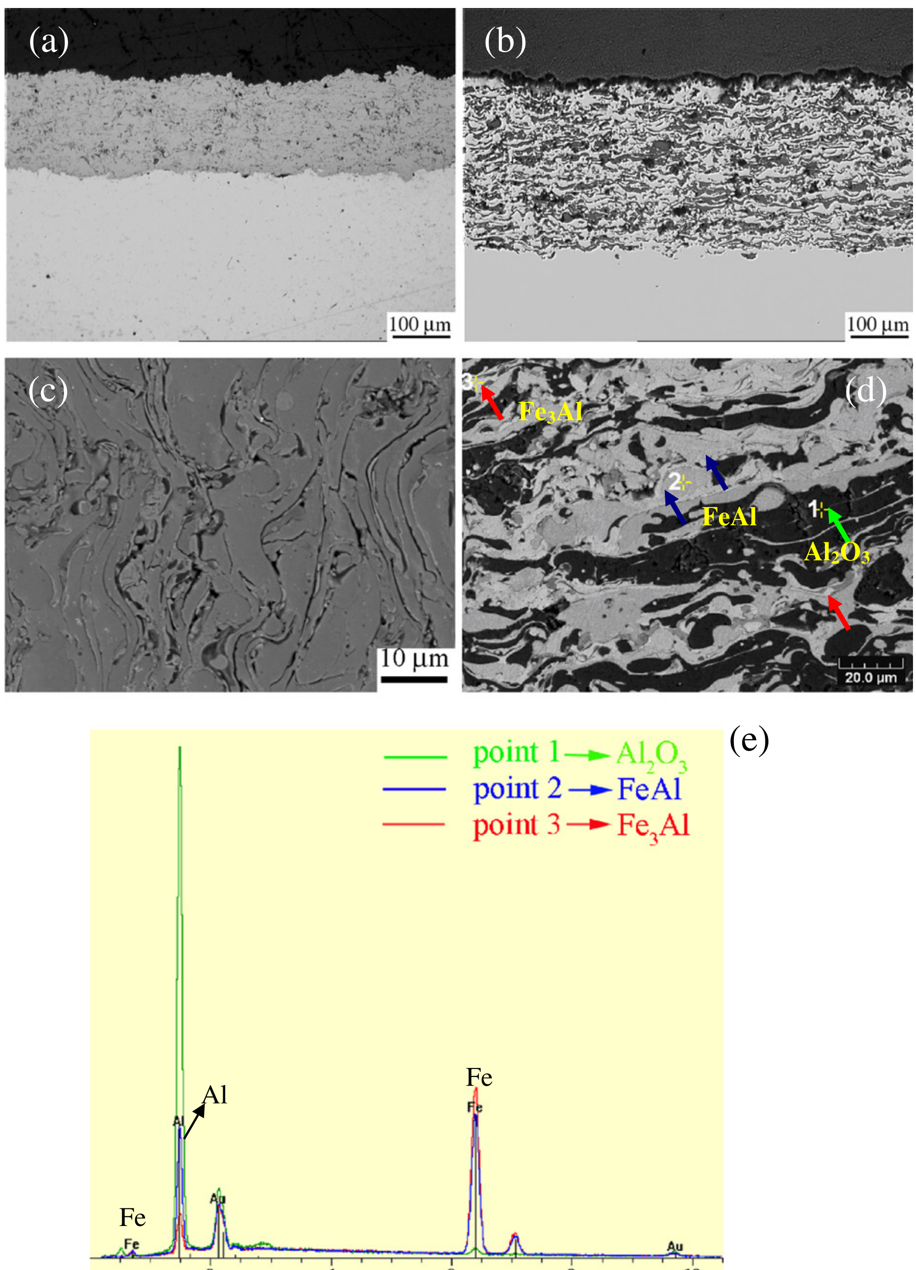

Fig. 2. OM observation of (a) pure FeAl and (b) $FeAl/Al_2O_3$ composite coatings deposited by APS, SEM observation of (c) pure FeAl and (d) $FeAl/Al_2O_3$ composite coatings and (e) the corresponding EDS analysis on the position marked with number in panel d.