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Microstructure Evolution and Mechanical Properties of Spray-deposited Al-21.47Si-4.73Fe-2.5Cu-0.9Mg Alloy

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Abstract: Al-Si-Fe-Cu-Mg alloy was prepared by spray deposition and was further processed by hot extrusion as well as T6 heat-treatment. The results indicate that the microstructure of the deposited alloy is composed of primary Si particles with average size of less than 5 μm, α-Al, Al_2CuMg, β-Al_5FeSi and δ-Al_4FeSi_2 (rectangular shape), and no eutectic silicon is found due to the special solidification behavior. The age hardening curves reveal two peaks. The uniform ultimate tensile strength (UTS) and the elongation of the peak-aged Al-Si-Fe-Cu-Mg alloy are 468.3 MPa, 0.61% at 298 K and 267.4 MPa, 6.42% at 573 K, respectively. The fracture surfaces display brittle fracture morphology at 298 K, whereas it varies to mixture of brittle and ductile failure with increasing the temperature.

Key words: spray deposition; hypereutectic Al-Si alloy; microstructure; aging; mechanical property

Hypereutectic Al-Si alloys possess excellent physical properties, including low density, high specific strength, high specific stiffness, good wear resistance and low coefficient of thermal expansion, which make them not only attractive for applications in piston, hydraulic press air compressor, and the sliding parts but also very suitable for the manufacturing of the high-speed brake parts and the wear-resistant parts[1-3]. It has been proven that the addition of Cu and Mg in hypereutectic Al-Si alloy can increase the room temperature strength as a result of precipitation hardening. However, Yang et al.[4] reported that the precipitation hardening phases are not stable at high temperatures. Recently, a large amount of work has certified that Fe is an effective element for improving high temperature strength[5]. Nevertheless, due to the relatively low cooling rate, the primary Si phase is coarse and the Al-Si-Fe intermetallic phases show long needle-like morphology in conventional casting alloy, which definitely lead to deterioration not only to the fracture toughness, but also to the stability of the microstructure[6]. Unfortunately, the large size, the irregular shape of these compounds, and the poor interfacial bonding between Al matrix and intermetallic compounds hinder the application of these materials fabrocated by conventional casting[7-9].

In order to solve these problems mentioned above, spray deposition process has gained favorable attention due to its high cooling rate[10,11]. A number of studies have been reported on microstructures of Al-Si-Fe alloy fabricated by spray deposition[12-14]. However, little attention has been devoted to investigate the mechanical properties and fracture patterns of this alloy.

Hypereutectic Al-Si-Fe-Cu-Mg alloy is fabricated by spray deposition followed by hot extrusion. The main purpose of this work is to investigate the mechanical property of this alloy both at room and elevated temperatures. Furthermore, the correlations between microstructure and mechanical property were also studied.

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1 Experimental

The Al-Si-Fe-Cu-Mg alloy was atomized by nitrogen gas at 933 K and was spray deposited on a cylindrical aluminum substrate. The distance between the atomizing nozzle and the substrate was kept constant at 450 mm during the deposition process. The atomization pressure was set as 1.5 MPa. The accurate chemical compositions of the alloy investigated are shown in Table 1. After being cut into cylindrical billets, the preform was extruded at the temperature of (733±5) K with an extrusion ratio of 36 : 1. After extrusion, the specimens were solution treated at (743±2) K for 1.5 h, followed by water quenching, and finally aged at (393±1) K for different hours.

The microstructures of the spray-deposited alloy were characterized with scanning electron microscopy (SEM). The specimens were prepared using standard metallographic techniques and were etched using Keller's reagent. The X-ray diffraction (XRD) experiments were performed on a Japan Rigaku diffractometer using CuKα radiation. The Vickers microhardness measurements were done at a load of 4.9 N and the loading time was 10 s using an HV-1000Z-type digital microhardness tester. At least five measurements were carried out and their average was taken as the accepted value. The room temperature tensile tests were performed on an INSTRON-5500R universal testing machine at a crosshead speed of 0.2 mm/min, and the elevated temperature tensile tests were conducted with an INSTRON-5569 universal testing machine at a crosshead speed of 0.5 mm/min and temperature ranging from 423 K to 573 K.

Table 1 Chemical compositions of Al-Si-Fe-Cu-Mg alloy

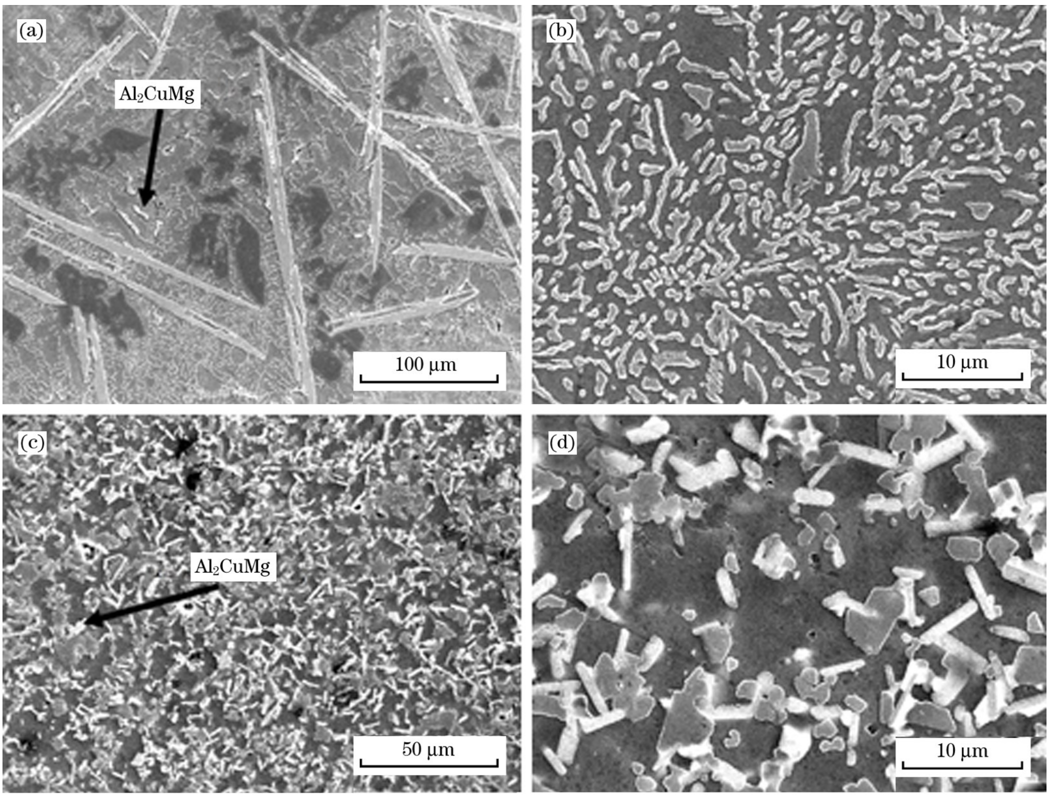
mass%

Si	Fe	Cu	Mg	Al
21.470	4.730	2.500	0.900	Balance

2 Results and Discussion

2.1 Microstructural investigation

Fig. 1 shows the microstructures of the Al-Si-Fe-Cu-Mg alloy prepared by different methods. As shown in Figs. 1(a) and 1(b), the microstructure consists of lamellar coarse primary Si phase (average size about 66 μm), long needle-like Al-Si-Fe intermetallic compound (average size above 200 μm), Al-Si eutectic and Al-Cu-Mg phase (arrowed in Fig. 1(a)) in the casting alloy. The phases in the as-cast alloy are analyzed by means of XRD, and the experimental results are shown in Fig. 2(a). In addition to the peaks of Al and Si phases, peaks corresponding to β-Al_4FeSi_2,



(a), (b) Casting; (c), (d) Spray deposition.

Fig. 1 Microstructures of Al-Si-Fe-Cu-Mg alloy prepared by different methods