MECHANICAL PROPERTIES OF FE BASED FIBER / ALUNIMUN ALLOY COMPOSITES FABRICATED BY LOW-PRESSURE INFILTRATION

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Abstract

FeCrSi fiber reinforced A366.0 matrix alloy composites was fabricated by low-pressure infiltration technique and gravity casting process. As infiltration flow and pressure of molten alloy to porous fiber preform was controlled in order to obtain laminar flow without collisions of molten metal, the composite without pores (porosity 0%) was obtained. Although the effect of fiber reinforcement on the strength on the improvement of mechanical properties at ambient temperature was not obtained, the composites have excellent tensile strength and fracture strength at high temperature. The good fracture strength at high temperature is caused by the deflection of crack, because crack generated by high temperure fracture test propagated bypassing the fiber.

1 Introduction

Aluminum alloy composites have been widely used in the automotive and electronics industry because of good mechanical and functional properties and easy property control. The degradation of infiltration pressure in composite fabrication process by casting has been attempted recently. By degrading applied pressure, the composites are able to be obtained by gravity casting, die-casting and sand casting. These processes were disseminated in many companies and have high productivity. Furthermore, theses process can fabricate complex shaped and large sized composites. On the other hand, in order to obtain the composites by low-pressure casting, the improvement of wettability between reinforcements and molten alloys are needed. In our previous study [1,2], the Steel based metal fiber was used for reinforcement in the composite because of good wettability between reinforcement and matrix. Furthermore, in order to obtain the dense composite, the infiltration simulation and the permeability of molten alloy to preform was attempted [3,4]. Some composites were fabricated by gravity casting. The aim of this study is to obtain the optimum fabrication condition for the degradation of porosity, then the mechanical properties fabricated by optimum condition was estimated.

2 Experimental Procedures

Reinforcement used is FeCrSi alloy (Fe 75mass% Cr 20mass% Si 5mass%) with 40μm in diameter fabricated by NHK Spring Co. in Japan. This fiber was obtained by rapid quenching by water-cooled cupper drum and has fine structure and good mechanical structure. Preform with 15 vol% and 20 vol % in rate of fiber in preform were fabricated by hot pressing. Preform forms like hollow ring with 36mm in inside diameter, 96mm in outside diameter and 8mm in thickness. Matrix used is A336.0 aluminum alloy (Al-13% Si-1.5%Ni-1.3%Cu-1.3%Mg). Then the composites were obtained by gravity casting with 0.1-0.8 MPa infiltration pressure of molten alloy. Fig. 1 shows the schematics of infiltration of molten aluminum alloy to preform using gravity casting machine. Preform was set at upside of die. Pressure of molten alloy was applied from upper side. Decompression with 0.05 MPa was applied at air vent. In order to control the flow of molten alloy in preform with one

direction in order to obtain dense composites without pores, barrier plate was settled on the preform during casting. The barrier plate was fabricated by steel sheet with 0.2 mm in thickness. Then, tensile strength and fatigue strength was estimated. The tensile test was carried out at a cross-head rate of 0.1 mm/min. The fatigue test was carry out within the temperature range from room temperature to 673 K at a frequency of 35 Hz under constant amplitude loading, using a servo-pulser fatigue testing machine. Microstructure of fracture surface and crack propagation was observed by scanning microscopy (SEM).

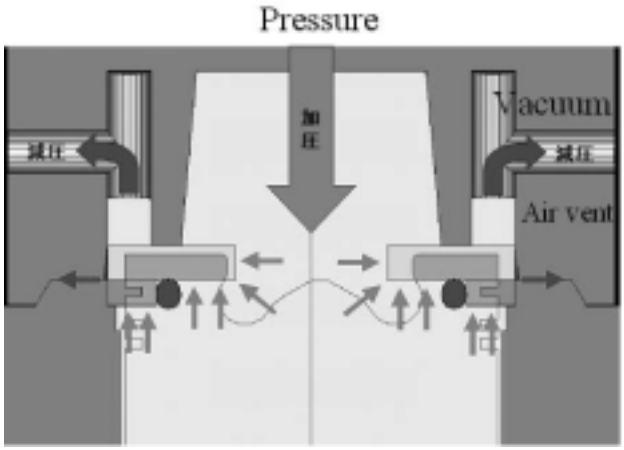

Fig. 1. Configuration of infiltration of molten alloy to preform by gravity casting.

3. Results and Discussion

The influence of the barrier plate on the generation of pores in the composites was studied. The purpose of the barrier plate was to suppress the generation of pores by controlling the flow of the molten alloy inside the preform. By setting the barrier plate on the preform, molten alloy in preform became to flow with one direction. Fig. 2 shows the configuration of pores in the composites fabricated without and with barrier plate. Consequently, porosity in composite degrade from3-6% to 0.3-0.7%. In the case of unidirectional infiltration, the molten alloy did not collide with itself because the barrier plate controlled the flow of the molten alloy. Therefore, if a barrier plate is introduced to ensure the unidirectional flow of the molten alloy inside the preform, the generation of porosity can be suppressed.

Fig. 3 shows the porosity of the composite produced with a barrier plate under an applied pressure of 0.4~0.8 MPa at the fixed pressure. The porosity of the composite decreased with increasing applied pressure. Even when the composite was fabricated under an applied pressure of 0.4 MPa, the applied pressure was not sufficient, because numerous fine pores were observed inside the composite. However, when the applied pressure was 0.8 MPa, there were no pores in the composite; therefore, an applied pressure of 0.8 MPa was sufficient to produce FeCrSi metal-fiber-reinforced aluminum-alloy composites without pores. Fig. 3 shows optical micrographs of the pores in the composites fabricated under low pressure: (a) 0.4 MPa, (b) 0.6 MPa, (c) 0.7 MPa and (d) 0.8 MPa. There were no pores at the applied pressure of 0.8 MPa. Under this condition, the molten alloy successfully infiltrated the FeCrSi fiber preform.

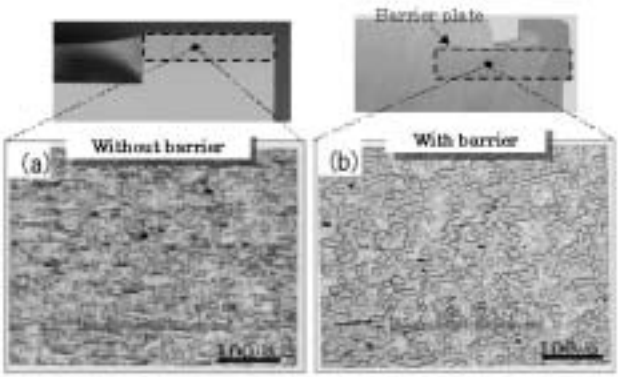

Fig. 2 Porosity inside the composite observed by optical microscopy;(a) without barrier plate, (b) with barrier plate.

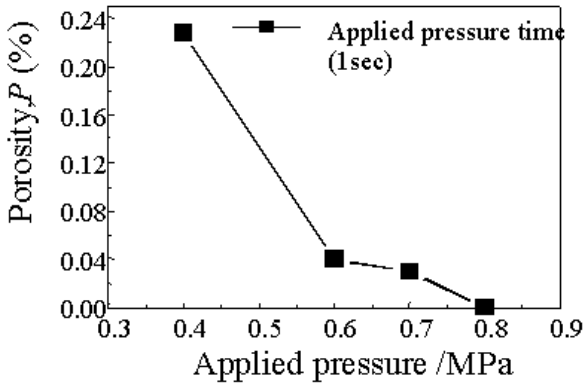

Fig. 3 Effect on applied pressure from 0.4MPa to 0.8MPa on porosity.

Then, the tensile and fatigue tests at high temperatures were carried out on composites reinforced with FeCrSi metal fiber whose volume fraction was 15% and 20%. Fig. 4 shows the tensile strength of monolithic alloy and composite at room temperature to 623K. As increasing temperature, the tensile strength decreased gradually. The strength of

composite at room temperature is lower than that of monolithic alloy. The strength of the composite at 573 K containing 20-vol% FeCrSi and that of monolithic A366.0 alloy were 150 MPa and 90 MPa, respectively. The strength of the composite was approximately 65% higher at 573K than that of the monolithic alloy. The tensile strength of the composite at 673K and that of the monolithic alloy were 100 MPa and 45 MPa, respectively. The tensile strength of the composite at 673 K was approximately 200% higher than that of the monolithic alloy. Furthermore, the tensile strength of the composite containing 20vol% fiber was approximately 23% higher at 573 K than that of the composite containing 15vol% fiber. FeCrSi metal fiber is very effective in improving the properties of the A366.0 alloy.

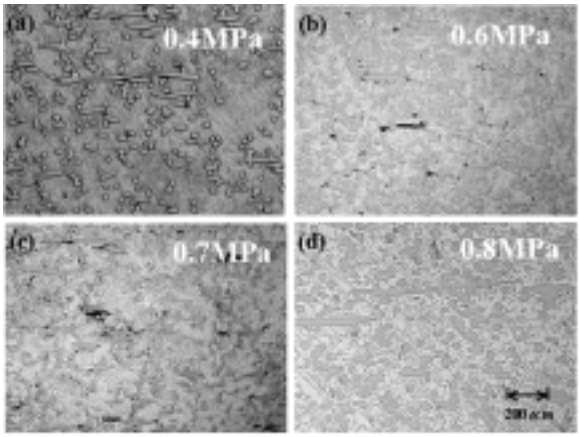

Fig. 4 Optical micrographs of porosity in composites fabricated by low pressure casting with (a) 0.4MPa, (b) 0.6MPa, (c) 0.7MPa and (d) 0.8MPa.]

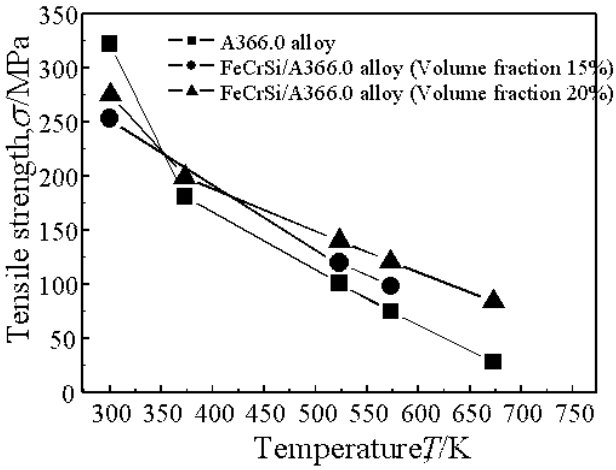

Fig. 5 Tensile strength of A336.0 aluminum alloy and FeCrSi/ A336.0 aluminum alloy composite at high temperature till 723K.

Fig. 6 shows the S-N curves of the composite with 20vol% reinforcement at 573K. The composites have 0% and 2-3% in porosity, which composites were fabricated with and without barrier plate, respectively. The composite with 0% porosity shows higher fatigue strength than the composite with 2-3 % porosity. The fatigue strength of the composite is improved with 30 % by degradation of porosity from 2-3% to 0%. The degradation of porosity is effective for the improvement of the fatigue strength.

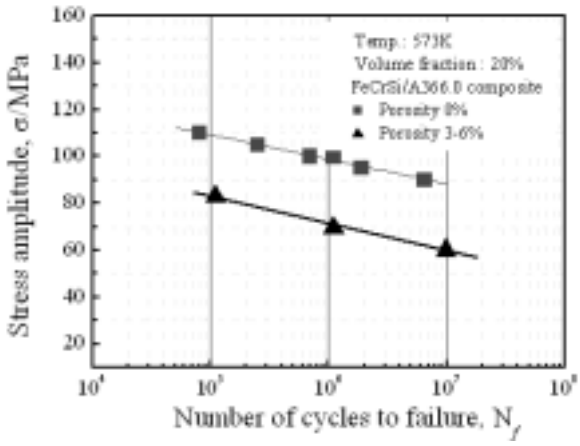

Fig. 6 S-N curves of 20 vol% FeCrSi/ A336.0 aluminum alloy composites with 0% and 3-5% in porosity at 623K.

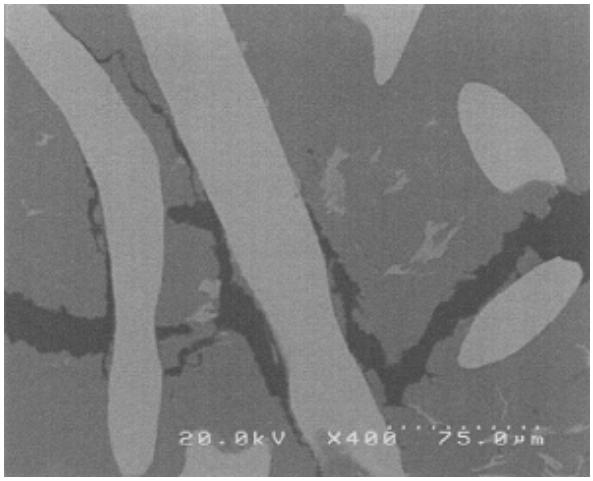

Fig. 7 Crack propagation of 20vol% FeCrSi/ A336.0 aluminum alloy composite by fatigue life testing.

Fig, 7 show the crack propagation of the composite by fatigue test at high temperature. Crack propagates in matrix around the fibers with some deflection. Necking of fiber in composites was observed. These phenomena lead to the improvement of the mechanical properties at high temperature.

Consequently, the composites have good mechanical properties at high temperature, and the

degradation of the porosity is effective for the improvement of the fatigue strength.

4. Conclusion

A FeCrSi fiber reinforced A336.0 aluminum alloy was fabricated using the low-pressure casting method and gravity casting. The mechanical properties and the fatigue strength at high temperatures of the developed composite were investigated. The results can be summarized as follows.

1) Barrier plate was effective for the degradation of porosity in composites because of lamellar flow of molten metal in preform.

2) As increasing applied pressure of molten metal, the porosity in the composites degrades gradually. At 0.8PMPa, the porosity reached to 0 %.

3) The composites have higher tensile strength and higher fatigue strength than the monolithic alloy at high temperature above 350K. As increasing temperature, the effect of fiber reinforcement was enhanced.

4) Crack propagates in matrix around the fibers with some deflection. Necking of fiber in composites was observed.

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