低圧含浸法を用いた $\text{Al}_2\text{O}_3/\text{Al}$ 複合材料の摩擦及び摩耗特性

Friction and wear Properties of $\text{Al}_2\text{O}_3/\text{Al}$ composite by using low-pressure casting method

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Low-pressure infiltration technique is useful for the preparation of high performance composites with large size and complex shape. In this study, the porous preform was fabricated from Al_2O_3 short fiber with $3\mu\text{m}$ in diameter. AC8A molten aluminum alloy was attempted to infiltrate perform of the various volume fractions. Al_2O_3 fiber preform with 10%, 15 and 20% in volume fraction (vol%) had good infiltration. For Al_2O_3 fiber preform, infiltration succeed until 20 vol% alumina fiber preform fabricated by using complex binder with SiO_2 sol and Al_2O_3 sol. Then, it was investigated the wear behavior of Al_2O_3 reinforced AC8A composites containing different volume fraction of 10-20%. The friction coefficients confirm that the abrasion resistances of Al_2O_3 reinforced AC8A composite are superior to those of the AC8A specimens, and that the composites are also superior in terms of wear loss.

Key Words: Metal Matrix Composites, Low-Pressure Infiltration Process, Fiber Reinforcement.

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 Al_2O_3 fiber which is contained SiO_2 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 [3-10]. 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. the aim of the study investigation is to study the wear behavior of Al_2O_3 reinforced AC8A composites containing different volume fraction of 10-20%. Subsurface deformation was investigated to understand the wear mechanism of the unreinforced alloy and the composites. Effect of volume fraction on wear behavior has also been studied.

2. Experimental Method

Reinforcement used is Al_2O_3 short fiber (97wt% Al_2O_3 - 3wt% SiO_2) with $3\mu\text{m}$ in diameter fabricated by DENKI Kagaku Kogyo K.K. in Japan. Preform was fabricated the volume fraction of 10vol%, 15 vol% and 20 vol % respectively. Preform forms like diameter of $\phi 30\text{mm}$ with height of 20mm. Matrix used is

AC8A aluminum alloy (Al-13% Si-1.5%Ni-1.3%Cu- 1.3%Mg). Then the composites were obtained by low pressure casting with 0.8 MPa infiltration pressure of molten alloy.

Pressure of molten alloy was applied from upper side. In order to control the flow of molten alloy in preform with one direction in order to obtain dense composites without pores, was settled on the preform during casting. Microstructure was observed by scanning microscopy (SEM).

The Volume fraction of reinforcement gives main effect of $\text{Al}_2\text{O}_3/\text{Al}$ composite manufacturing performance. Accordingly, in order to evaluate manufacturing performance of completed $\text{Al}_2\text{O}_3/\text{Al}$ composite, it was measured porosity and relative density of preform of volume fraction with 10%, 15% and 20%. Porosity was observed by image of SEM (scanning electronic microscope), and relative density was measured by an actual weigh using electronic scale of 0.0001g unit. So, we studied infiltration characteristics of $\text{Al}_2\text{O}_3/\text{Al}$ composite according to preform volume fraction. Moreover, we conducted wear tests on composites that were manufactured through low-pressure infiltration under differing preform volume fraction conditions to study the characteristics related to abrasion and friction. The wear test was conducted according to the regulations of ASTM E8, using a Ball on Disc method abrasion tester (R&B Friction & Wear Tester PD-102). The diameter of the abrasion track was 7.5 mm, the counterpart material was a SUJ-2 ball (800Hv) of high carbon chrome steel and the conditions were as follows.

In order to observe the wear properties according to preform volume fraction, the load of the specimen was maintained consistently at 30N and the speed of revolution was also kept uniformly at 50rpm. The sliding time applied was 3 hours (10.8ks), and a 2 minute Pre-track was granted to impose identical conditions on each test specimen. For the study of wear properties we examined the friction coefficient, wear loss, etc. according to the preform volume fraction. Also, a Scanning Electron Microscope was used for analysis after the wear test, in order to observe the abrasion track and

the wear phenomena, and it was examined additionally unique phenomena found on the fractures.

3. Results and Discussions

3.1 Microstructural characterization

Fig. 1 shows SEM image observing porosity of Al₂O₃/AC8A composite processed by low pressure infiltration with applied pressure, 0.8MPa. Fig. 1 (a) is showing Al₂O₃/AC8A composite of preform volume fraction 10%. When observing porosity of interface between Al₂O₃ fiber and matrix, that have image of clean interface that have not porosity. Accordingly, Al₂O₃/AC8A composite of volume fraction, 10% can process excellent Al₂O₃/AC8A composite by low pressure infiltration with applied pressure, 0.8 MPa. Fig. 1 (b) shows similar tendency with Al₂O₃/AC8A composite of volume fraction, 15%, but Al₂O₃/AC8A composite of volume fraction, 10% have a little porosity.

It seems that these are a very small amount of porosity observed at difficult location to infiltrate metal matrix between fiber and fiber. Al₂O₃/AC8A composite processing of volume fraction, 10% also is not problem by low pressure infiltration method of 0.8 MPa. In Fig. 1 (c), Al₂O₃/AC8A composite of volume fraction, 20% could observe porosities of interface between fiber and matrix. The causes of this porosity are effect of relatively increased fiber and infiltration pressure. In order to measure porosity, it was evaluated on manufacturing performance by relative density. Fig. 2 indicate graph of relative density, Al₂O₃/AC8A of preform volume fraction 10% and 15% is showing superior manufacturing performance, because of relatively easy permeation.

Fig. 1 Porosity with fiber of Volume fraction (10%, 15%, 20%)

Fig. 2 Relation between relative density and preform volume fraction of Al₂O₃/AC8A composite.

3.2 Wear Characteristics

Fig. 3 shows the friction coefficient derived by conducting a wear test for 3 hours (10.8ks) under the conditions of a sliding speed of 50rpm for the ball which was the counterpart material and a load of 30N. Fig. 4(a) shows the average coefficient of friction. AC8A matrix shows the coefficient of friction of 0.227. In the case of Al₂O₃/AC8A composite of volume fraction, 20% shows the coefficient of friction of 0.085. The coefficient of friction was found to drop with the increasing volume fraction. Wear loss results are shown in Fig. 4(b). The wear loss of Al₂O₃/AC8A composite of volume fraction, 20% was down to 10.4mg, while that of AC8A matrix was 23.6mg under testing conditions of 3hours. Al₂O₃/AC8A composite of volume fraction, 20% exhibited long wear life as compared with that of matrix and volume fraction, 10% and 15%.

Fig. 3 Relation between coefficient of friction and sliding time according to volume fraction.

Fig. 4 Friction and wear properties of $\text{Al}_2\text{O}_3/\text{Al}$ composites.

Fig. 5 shows the fracture forms of the wear track after the abrasion test using SEM, and the wear loss could be easily confirmed by the interval of the track widths according to preform volume traction. In image of $\text{Al}_2\text{O}_3/\text{AC8A}$ composite of volume fraction, 10%, due to the AC8A matrix, the main component, the overall fracture was observed to be in the form of abrasion wear. It was observed that as the preform volume fraction increases, wear power get accumulated and are excluded on track. The fiber is acting the antifriction between wear surface and counterpart material. Therefore, $\text{Al}_2\text{O}_3/\text{AC8A}$ composite of volume fraction, 20% is showing superior wear characteristics and delaying wear surface.

4. Conclusions

In this study, we manufactured the $\text{Al}_2\text{O}_3/\text{AC8A}$ composite compound that is usually used in automobile internal combustion engines and pistons using the low pressure infiltration method, and studied the characteristics of the structures that were generated in the process as well as their abrasion properties, leading to the following conclusions.

(1) $\text{Al}_2\text{O}_3/\text{AC8A}$ composite with volume fraction 10% and 15% is showing superior manufacturing performance, because of relatively easy permeation. $\text{Al}_2\text{O}_3/\text{AC8A}$ composite with volume fraction 20% could observe porosities of interface between fiber and metal matrix. The cause of this porosity is effect of relatively increased fiber and infiltration pressure.

(2) The friction coefficients confirm that the abrasion resistances of $\text{Al}_2\text{O}_3/\text{AC8A}$ composite that are reinforced with Al_2O_3 fiber are superior to those of the AC8A alloy, and that the composites are also superior in terms of wear loss.

(3) It was observed that as the preform volume fraction increases, wear power get accumulated and are excluded on track. The fiber is acting the antifriction between wear surface and composite.

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Fig. 5 Wear track on $\text{Al}_2\text{O}_3/\text{AC8A}$ composites. (a) with volume fraction, 10%

(b) volume fraction, 15%, (c) volume fraction, 20%

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