HIGH TEMPERATURE STRENGTH AND THE BOUNDARY STRENGTH BETWEEN MATRIX PART AND COMPOSITE PART OF SiC WHISKER REINFORCED ALUMINUM ALLOY COMPOSITE

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ABSTRACT

High temperature strength of composite and matrix, and the boundary strength between matrix part and composite part were examined. The composites were fabricated using a melting infiltration method with a die-casting machine. Strength of composite and matrix were measured by 3-point bending test at 293K, 373K, 473K, 523K, 573K, and 623K respectively. The boundary strength were measured by 4-point bending test at room temperature after heat treatment. Heat treatment was performed at 293K, 373K, 473K, 573K, and 623K for 3600 seconds in a vacuum respectively. The composite strength up to test temperature of 473K were 810MPa which were equal to 1.5 times of matrix strength, and furthermore, the composite strength were held to more than approximately 500MPa up to test temperature of 623K. The boundary strength were equal to a half of composite strength. The values were lower than matrix strength, and the failures occurred along the boundary face.

INTRODUCTION

Various ceramics whiskers or short fibers reinforced aluminum alloy composites have many excellent properties, for example heat resistance, wear resistance, and high Young's modulus. The composites reinforced with discontinuous fiber have also capability of shape forming. Generally, composites were almost made by high or low pressure squeeze casting, and in the previous study, mechanical properties[1], microstructures, effect of heat treatment[2], and interfacial structures[3] of the composite fabricated by these techniques were investigated for the past several years. However, die casting can be also available for one of the methods which can be formed the composites to near net shape. This processing approach was selected for present study. Such a modified casting process using die casting machine have considerable advantages such as near net shape forming, decrease of process cost, and increase of productivity. Consequently, if this method is applicable to production of composites, application to engineering materials of composites will be extended.

The purpose in this study is to estimate the high temperature strengths of composites which were fabricated by melting infiltration technique with die-casting machine, in addition, to estimate the effect of heat treatment on the strength of boundary between matrix part and composite part.

EXPERIMENTAL PROCEDURE

Silicon carbide whiskers were used as the reinforcement. The aluminum alloys used as matrix were Al-9mass%Si-1.2mass%Mg-0.4mass%Mn aluminum alloys. The whiskers were formed to the preforms with 15% apparent volume fraction. Alkylic Benzenedisulfonic acid sodium salt solution(0.43mass%) was used as the surface active agent in order to uniform the whiskers. The preforms were heated at 973K for 600 seconds before casting.

Temperature of aluminum melt, Die was 1073K and 413K respectively. The casting pressure was 52.3MPa, injection speed was 0.6 m/s, and pressure holding time was 20 seconds. Specimens used for testing were as-cast conditions. Volume fraction of the whiskers in the composites were measured at 23% on an average.

High temperature strength for composite and matrix were measured by 3-point bending test at room temperature, 373K, 473K, 523K, 573K and 623K, respectively. Simultaneously, the boundary strength between matrix part and composite part were measured by 4-point bending test at room temperature. To estimate the effect of heat treatment temperature, specimens for this bending tests were heated at 293K, 373K, 473K, 573K and 623K for 3600 seconds in vacuum before test. Dimensions of bending specimen were 3mm in height, 3mm in width, and 15mm in length. The extracted positions and dimensions of specimens which were cut from the cast block were given in Fig.1. Specimens for the high temperature bending test were cut from a radius direction, and for the boundary bending test were cut from a pressure infiltration direction. These bending tests were conducted with Instron testing machine at a cross head speed of 0.5 mm/min. Scanning electron microscope (SEM) was used to examine the fracture surface of specimens. X-ray diffraction measurements were carried out using X-ray diffractmeter. TEM specimens were prepared from 0.5mm thick plate cut using a precision cutter and were mechanically polished to a thickness of about 40 μm. Final thinning was carried out using an ion milling.

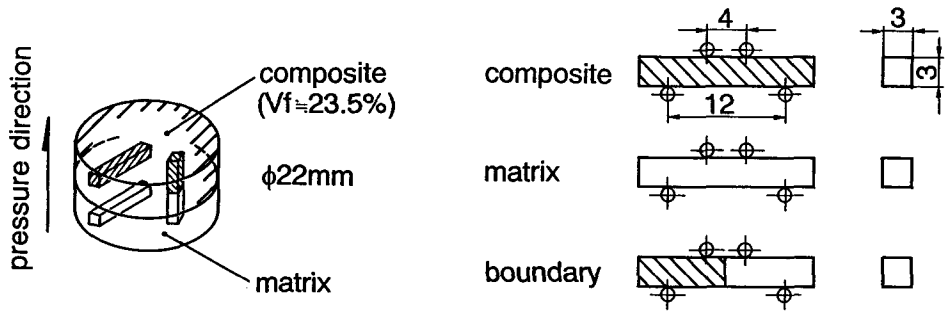

Fig.1 Extracted positions and dimensions of specimens

RESULTS AND DISCUSSION

Fig.2 shows the microstructures of composite and matrix. Optical micrograph of matrix, scanning electron micrograph of composite were given in Fig.2(b) and (c). Fig.2(a) shows a appearance of SiC whiskers. In the microstructures of matrix on Fig.2(b), distinctive primary alpha-phases and eutectic phase were observed. But in the microstructures of composite, primary alpha-phases and eutectic phases were not observed, and the microstructures were finer than that of matrix. Fig.2(c) shows a fairly uniform distribution of whiskers, and no voids were observed in composite microstructures. Fig.2(d) shows transmission electron micrograph of composite.

The whisker preforms were compressed to cause by infiltration pressure, but the whiskers existed as three-dimensional randomization in both whisker treatment(used the surface active agent) specimens and as-received(no treatment) specimens. Furthermore, it is observed that the whiskers are almost never damaged in comparison with as-received whiskers. The measurement of Vickers hardness were carried out both composite and matrix specimens. The Vickers hardness of composite with SiC whiskers of 21% volume fractions, and matrix were over HV190 and 120, respectively.

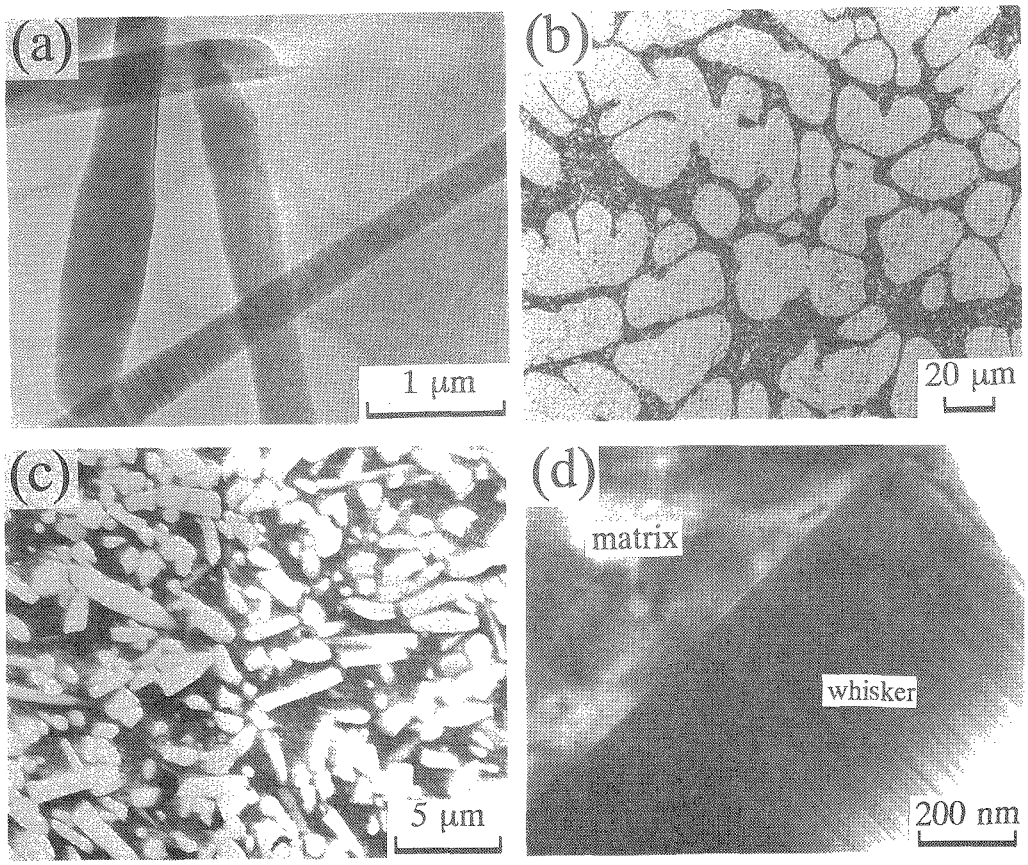

Fig.2 Appearance of SiC whisker and the microstructures of composite and matrix.
(a)as received SiC whisker(b)microstructure of matrix, (c)SEM and (d)TEM of composite

Fig.3 shows X-ray diffraction patterns of SiC whisker, matrix and composite in as cast conditions. It shows that effect of the surface active agent can be neglected in the composites.

Fig.4 shows changes in high temperature strength with test temperature for composite and matrix. The bending strength of matrix have a value of 550MPa up to test temperature of 473K. On the other hand, it was shown that composite strengths were obviously superior to matrix strength. The composite strength up to test temperature of 473K was about 810MPa which was equal to 1.5 times matrix strength, and further when the test temperature was increased to 623K from 473K, the strength was still held to more than 500MPa.

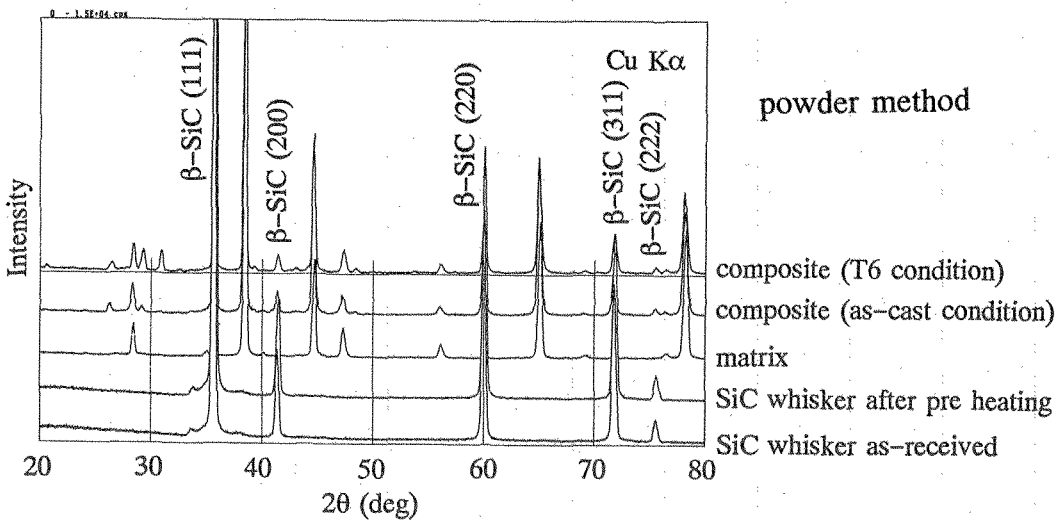

Fig.3 XRD patterns of whisker, matrix and composite

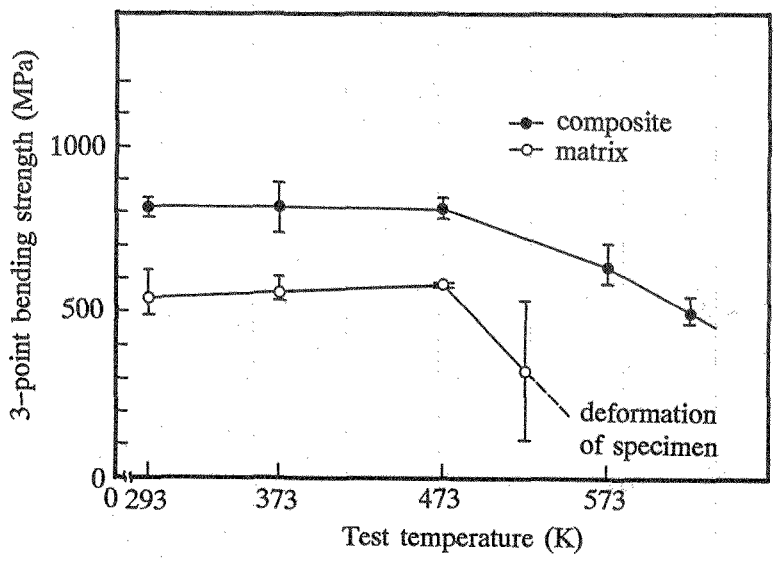

Fig.4 Changes in high temperature strength of composites and matrices

Fig.5 shows a dependence of heat treatment temperature on composite, matrix, and the boundary strength in the bending test. The boundary strength which was about 480MPa was equal to half of the composite strength up to a heat treatment temperature of 473K, and the values were lower at 25% of matrix strength. When the heat treatment temperature exceeded 473K, the boundary strength gradually decreased with increase of heat treatment temperature. In contrast to this, it was shown that the composite strength held approximately 900MPa in all specimens.

Fig.6 shows scanning electron micrographs of fracture surfaces after 4-point bending test. In fracture surfaces of composites on Fig.6(a), many small dimples with appearance of whiskers were observed, and morphology of these fracture surfaces correspond to the microstructures. In Fig.6(b), the failure of boundary bending specimens occurred along the boundary face

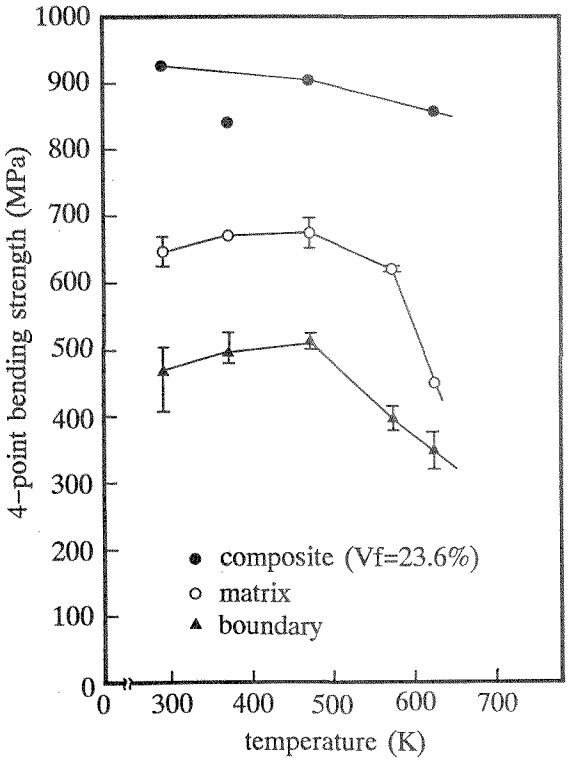

Fig.5 Dependence of heat treatment temperature on the composite, matrix, and boundary strength.

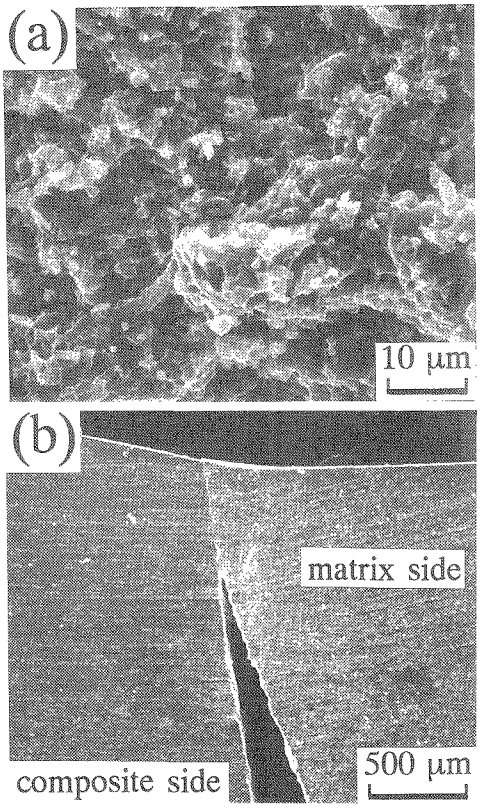

Fig.6 SEM of fracture surfaces (a)composite and (b)boundary specimens

CONCLUSIONS

The following conclusions were derived from the present study using a melting infiltration method with a die casting machine. High temperature strength of matrix have a value of 550MPa up to a test temperature of 473K. On the other hand, the composite strength up to test temperatures of 473K were approximately 810MPa which were equal to 1.5 times of matrix strength, and further, when the test temperature was increased to 623K from 473K, the strength was still held to more than 500MPa. The boundary strength which have about 480MPa were equal to a half of composite strength up to heat treatment temperature of 473K, and the values were lower at 25% of matrix strength. When the heat treatment temperature exceeded 473K, the boundary strength gradually decreased with an increase of heat treatment temperature. In contrast to this, it was shown that the composite strength held approximately 900MPa. The failure of all specimens in boundary bending tests occurred along the boundary face.

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