DEGRADATION OF SiC AND ZrC/Al ALLOY COMPOSITES UNDER HIGH TEMPERATURES

Makoto Kobashi and Takao Choh
Nagoya University
Department of Materials Processing Engineering
Faculty of Engineering
Furo-cho, Chikusa-ku, Nagoya 464-01

ABSTRACT

The interfacial reaction and the composite's strength have been investigated for the SiC_p/Al and ZrC_p/Al composites manufactured by a melt-stirring method. The presence of large Mg_2Si precipitates in the matrix (apart from the interface) was observed in case of the Al-Mg matrix composite. The strength of SiC/Al-3%Mg composite was lower than that of Al-3%Mg alloy matrix, although the strength of aluminum was improved by dispersing SiC particles. A cluster of SiC particles was found in a fracture surface of SiC particulate composite and considered to be a site of a crack initiation. A ZrC dispersion improved the strength of pure aluminum and Al-Mg alloy. This was due to the chemical stability and a homogeneous distribution of ZrC particles. The tensile strength of SiC/Al composite decreased with a heat treatment at 523K for 240 hours. Reaction products were apparently seen in the matrix of SiC/Al and SiC/Al-3wt%Mg composites which were heat treated at 803K for 100 hours, although ZrC particulate composites did not show a reaction product caused by a heat treatment.

1.INTRODUCTION

Melt-stirring method is considered to be a simple and promising process to synthesize a particulate metal matrix composites(MMCs). In this process, wettability plays an important role and a decomposition of ceramic phase during melt-stirring processing has a strong effect on the mechanical properties of MMCs. The interfacial reaction should be a minimum to avoid a degradation of mechanical properties, although a decomposition of ceramic phase probably occur in a wettable system. In this study, the strength of as-extruded composite and annealed composite was measured and microscopic observation of the composites was conducted to find out a suitable system which shows a minimum reactivity.

2.EXPERIMENTAL PROCEDURE

All composites used in this experiment were produced in our laboratory by melt-stirring method. Total amount 100g of aluminum or aluminum alloy was heated in MgO crucible under argon gas atmosphere. After molten aluminum was held at an experimental temperature(1073K), SiC or ZrC particles wrapped by an aluminum foil were preheated above the surface of the molten aluminum for 600 seconds. Then ceramic particles were added to the molten aluminum and melt-stirring was conducted. Melt stirring was continued for 300 seconds after particles had incorporated into liquid phase in order to improve the homogeneity of particle distribution. The molten aluminum containing ceramic particles was poured into metallic mold after a melt stirring. The as-cast ingot was hot extruded at a temperature of 773K to reduce the porosity of the composite, and test pieces for tensile testing was prepared from this extruded materials. A part of the test pieces was annealed at 523K and 803K to investigate a degradation of the strength of the composite materials. The volume fraction of SiC and ZrC particles was 12% and the average diameter of SiC and ZrC were 3.0 and 2.4 μ m, respectively. The cross section of the composites were observed by Scanning Electron Microscope(SEM) and Energy Probe Micro Analyzer(EPMA).

3.RESULTS AND DISCUSSION

3-1. Mechanical Properties of SiC/Al and ZrC/Al Composite

Stress-Strain curves and mechanical properties of SiC/Al and ZrC/Al composites are shown in Fig.1 and Table 1, respectively. According to Fig.1,

TABLE 1. Mechanical properties of SiC and ZrC/Al composite

	U.T.S./MPa	0.2% Proof stress/MPa	Elongation (%)	Young's modulus/GPa
SiC/Al composite	160	77	6.4	76
ZrC/Al composite	140	77	16	86

the elongation of SiC/Al composite is particularly smaller than that of ZrC/Al composite. One of the reasons of this poor elongation of SiC/Al composite is considered to be an inhomogeneous distribution of SiC particles. The distribution of ZrC particles in Al matrix is more homogeneous than that of SiC particles and a cluster of ZrC particles were rarely seen(1). When we consider the fact that the cluster of ceramic particles can be a site where fracture initiates(2), the existence of a cluster in SiC/Al composite is concluded to be a major reason for the poor elongation. According to the observation of the fracture surface by SEM shown in Fig.2, a cluster of SiC particles were observed. So we could confirm that the cluster strongly correlate with a fracture of the SiC/Al composite. Formation of a brittle phase due to an interfacial reaction is also thought as another factor for the poor elongation. Fig.3 shows results of X-ray analysis for a cross section of SiC/Al and ZrC/Al composites. According to Fig.3, a formation of Si and Al_4C_3 was confirmed for SiC/Al system and Al_3Zr was confirmed for ZrC/Al system. As a result of a difference in reaction products and matrix composition due to a different interfacial reaction, the mechanical properties of the matrix varied. Therefore, this is also a considerable reason for the difference in mechanical properties of composites.

3-2.Degradation in composite's strength caused by an annealing

A degradation of SiC and ZrC particles under high temperatures and its influence on the mechanical properties were investigated. Although high temperature strength is one of the most required properties of MMCs, a dissociation of ceramic phase and/or a formation of reaction products might occur when a composite material is used in high-temperature environment. Furthermore, these interfacial reactions probably induce the degradation of mechanical properties of MMCs. TABLE 2 shows the changes in the mechanical properties of SiC/Al, SiC/Al-3wt%Mg, ZrC/Al and ZrC/Al-3%Mg composite caused by annealing at 523K for 240 hours. The degradation in mechanical properties are clearly seen in TABLE 2. Then, we conducted annealing at higher temperatures to clarify more of the interfacial reactions. The experimental temperature was settled at 803K because annealing should be done under an eutectic temperature of Si and Al (850K). Fig.4 shows the fracture strength of the as-extruded SiC/Al and ZrC/Al and that of annealed SiC/Al and ZrC/Al composites. According to Fig. 4, the strength of SiC/Al composite decreased by annealing, although that of ZrC/Al did not decrease. According to the microscopic observation, many large reaction products were clearly found for annealed SiC/Al composite. A quantitative analysis conducted by X-ray microanalyzer, these reaction products were revealed as Al_4C_3 and Si. On the other hand, rarely change in microstructure were observed for ZrC/Al composite.

TABLE 2. Change of the tensile strength caused by the elevated temperature(E.T.) treatment (523K,240h)

	SiC/Al	ZrC/Al	SiC/Al-3%Mg	ZrC/Al-3%Mg
Before E.T. treatment	160	140	170	268
After E.T. treatment	145	138	133	269

In case of SiC/Al-3wt%Mg composite, an extreme degradation by annealing was observed as shown in Fig. 5. The reasons for this significant degradation are a mass change due to a reaction and the formation of the liquid phase because of a lower eutectic temperature of Al, Mg and Si. From an observation of a microstructure of annealed composite, most particles were revealed to be dissolved. Therefore, magnesium is concluded to enhance the interfacial reaction although it improves the strength of the matrix and also improves the wettability between SiC particles and molten aluminum(3).

4.CONCLUSIONS

1) As a result of the SiC and ZrC particle dispersion, the mechanical properties of the composites except for the elongation were improved.
2) Silicon and Al_4C_3 were detected in the cross section of SiC/Al composites as reaction products and Al_3Zr was observed for ZrC/Al composites.
3) The strength and the elongation of SiC/Al composite decreased by annealing at the temperature of 523K for 240hours.
4) Decomposition of SiC particles were revealed at 803K, although the decomposition of ZrC did not occur.

REFERENCES

(1) M.Kobashi, T.Choh and Y.Horibe: Journal of Japan Institute of Metal 54(1990),933-940

(2) N.Kanetake, T.Choh and M.Nomura: Proc. 2nd Japan International SAMPE Symposium, Dec.11-14(1991),788-795

(3) M.kobashi and T.Choh: Journal of Materials Transaction JIM, 31(1990),1101-1107

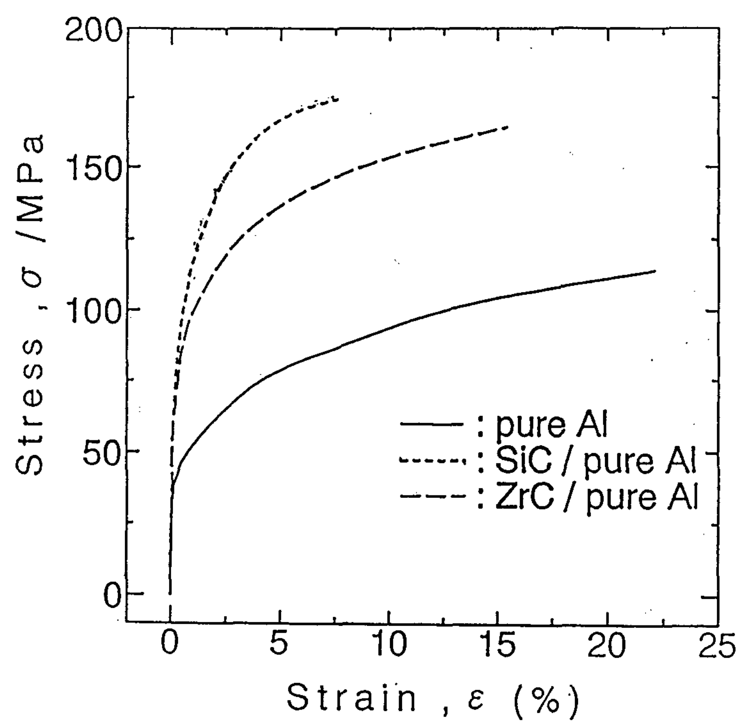

Fig.1 Stress-Strain curves of SiC and ZrC/Al composites

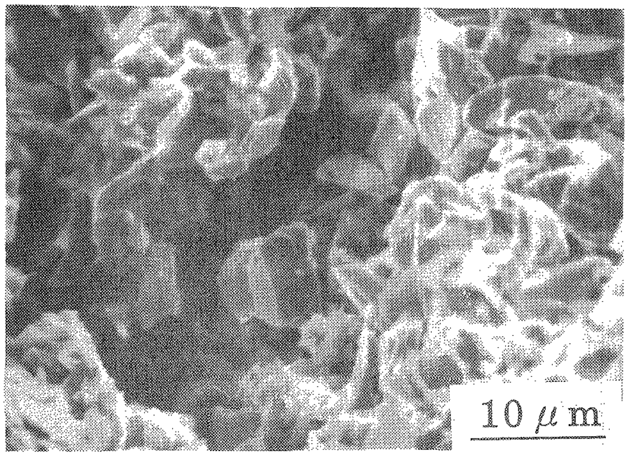

Fig.2 Scanning Electron Micrograph of the fracture surface of SiC/Al composite showing a cluster of SiC particles

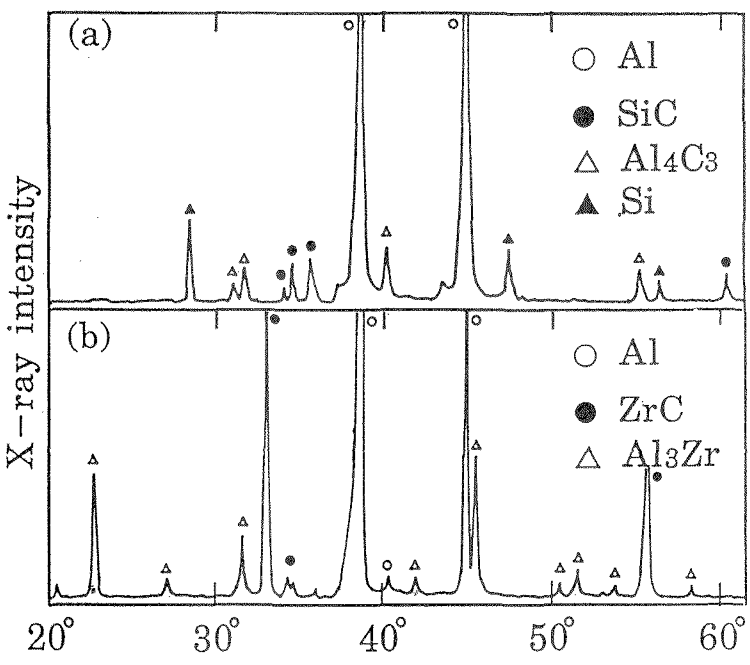

Fig.3 X-ray diffraction profiles of (a) SiC/Al composite and (b) ZrC/Al composite

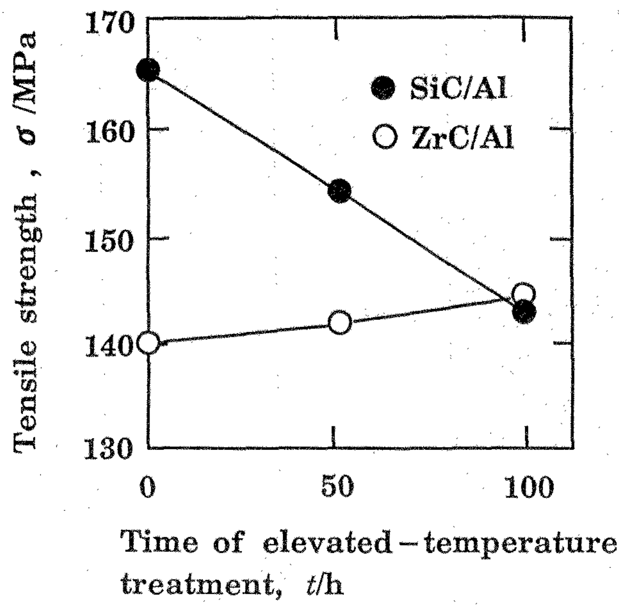

Fig.4 Effects of annealing time at 803K on the tensile strength of SiC and ZrC/Al composite

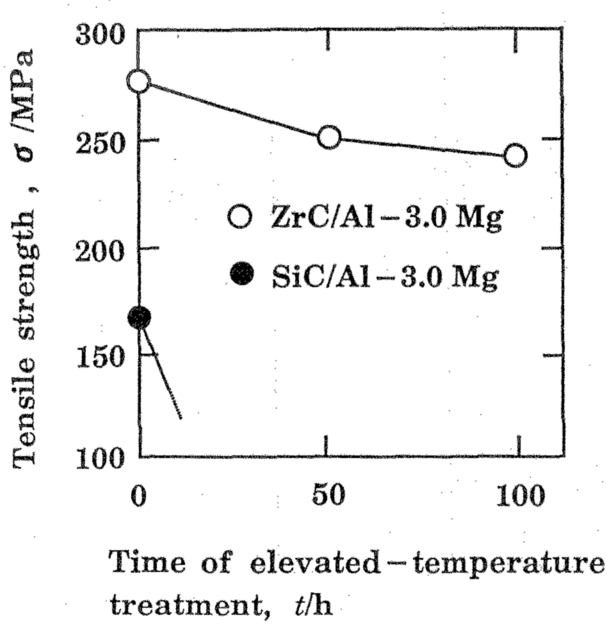

Fig.5 Effects of annealing time at 803K on the tensile strength of SiC and ZrC/Al-3wt%Mg composite