HIGH TEMPERATURE TENSILE PROPERTIES OF SiC WHISKER REINFORCED Al-Mg ALLOY COMPOSITES

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ABSTRACT Tensile properties of SiCw/Al-Mg alloy composites produced by squeeze casting and hot extrusion were investigated at temperature from 293K to 623K. Thetensile strength decreases with an increase of testing temperature and especially goes down at temperature more than 573K. The decrease of high temperature strength is explained by the dynamic recovery behavior resulting from high dislocation density in the matrix alloy of the composites. The elongation remarkably increases at high temperature because the debondings of the interface of SiC whiskers / matrix and no connection of the large voids easily occur during the high temperature tests deformation.

Keywords: *SiCw/Al-Mg alloy composite, tensile strength, high temperature tensile behavior*

1.INTRODUCTION

Recently, many works have been done for aluminum alloy matrix composites with the reinforcement of short fibers in order to develop advanced materials which have high specific strength, high elastic modulus, high heat resistance and wear resistance,etc.. Aluminum alloy matrix composites reinforced with ceramic whiskers are attractive for the practical application because of its good mechanical properties and machinability. However, it has been reported [1~ 4] that the expected strength cannot be obtained sufficiently at high temperature for the composites which have various kinds of matrix aluminum alloys. In particular,the mechanism of the degradation in strength of composites at high temperature is not elucidated yet. In this study, SiC whiskers reinforced solid-solution hardenable Al-Mg alloy matrix composites are fabricated by squeeze casting and their tensile properties at elevated temperatures are in detail investigated.

2.EXPERIMENTAL PROCEDURES

The matrix materials used were pure aluminum with the purity of 99.99 mass%,Al-3mass%Mg and Al-6mass%Mg alloy. The reinforcement used was the preform with 20% in volume fraction of SiC whiskers. Composites were produced by squeeze casting. Matrix materials were melted under an Ar gas atmosphere at 1123K, were cast into a metal mold where a SiC whisker preform which was pre-heated in a furnace under an Ar gas atmosphere at 1123K for 2 h was set and were solidified under an applied pressure of 75 MPa. The cast composites were hot-extruded under a condition of the extrusion retio of 10 : 1 at 773K, and the extruded composites with 8 mm in diameter were obtained. Specimens for the tensile test were machined from as-extruded composites and were tested under conditions of strain rates of 7.6×10^{-4} , 1.3×10^{-2} and 1.3×10^{-1} /s at elevated temperatures (R.T.~ 623K) after the solution heat treating at 703K for 0.5 h. In order to make a clear fracture behavior of composites, the fracture surfaces after tensile tests were examined by a scanning electoron microscope(SEM). The distribution of dislocations was observed by a transmission electron microscope(TEM) and was examined by an X-ray diffraction method as well.

3.RESULTS AND DISCUSSION

The temperature dependence of tensile strengths and elongations are shown in Fig.1 and Fig.2 respectively. At room temperature, the tensile strengths of composites are 2 times larger than that of matrix alloys. The effects of the solid-solution hardening on each matrix alloy of composites are maintained in the composites ,because the differences of the tensile strengths between SiCw/Al-3mass%Mg and SiCw/Al-6mass%Mg ailoy composites are the same with the differences of the tensile strengths between Al-3mass%Mg and Al-6mass%Mg alloys. The rate of decrease in tensile strengths of the composites with increasing temperature is larger than that of the matrix alloys. The composites, at 473K, have high tensile strengths which are 1.5 times larger than that of matrix alloys. But at the temperature above 473K, the higher Mg concentration in the composites, the larger the rate of decrease in the tensile strengths, and at the temperature above 573K the tensile strength of SiCw/Al-6mass%Mg alloy composite is the lowest among all of the tested materials except Al-3%Mg alloy. The elongation of SiCw/Al composite increases with increasing temperature, but decreases at the temperature of more than 473K.

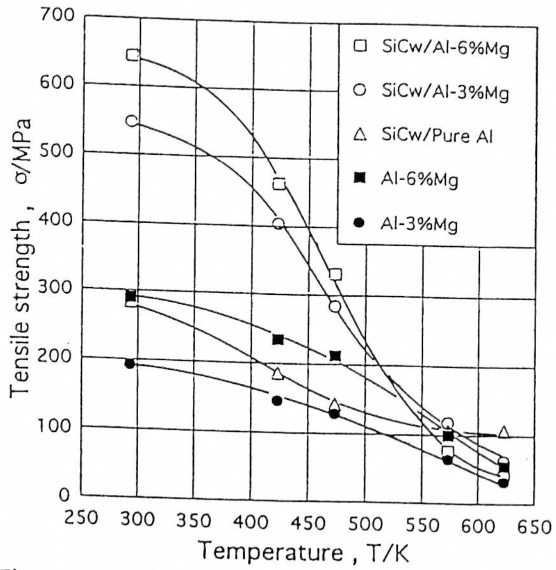

Fig.1 Dependence of tensile strength of composite materiales and matrix allorys on test temperature.

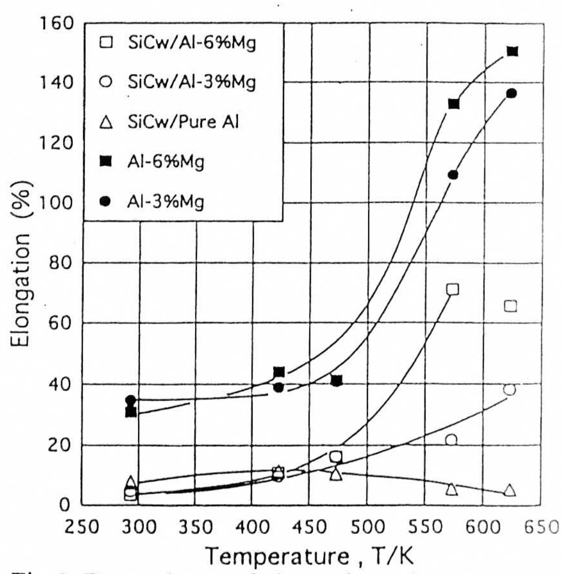

Fig.2 Dependence of elongation of composite materiales and matrix allorys on test temperature.

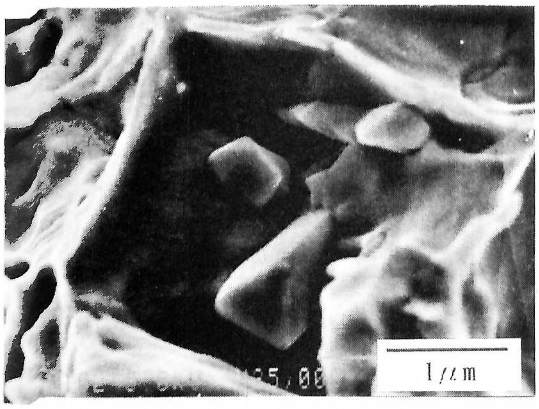

Fig.3 SEM photograph of fracture surface in SiCw/Al composite tested at 473K.

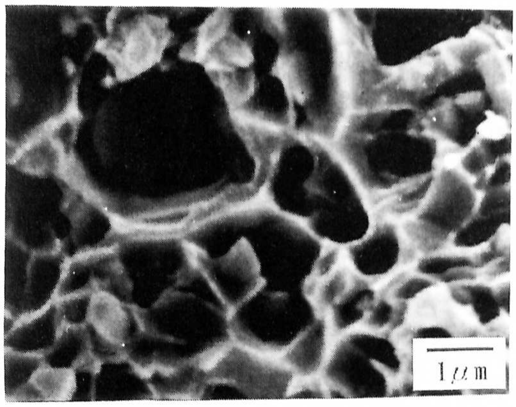

Fig.4 SEM photograph of fracture surface in SiCw/Al-Mg alloy composite tested at 473K.

The elongations of SiCw/Al-Mg alloy composites remarkably increase as the temperature increase. Especially ,the rate of the elongation in SiCw/Al-6mass%Mg alloy composite shows same tendency to that of the matrix alloy with increasing temperature. SEM photograph showing the fracture surface in SiCw/Al composite tested at 473K is shown in Fig.3. In the SiCw/Al composite which has low bonding strength at the interface between SiC whiskers and Al matrix, the spalling occurs at the interface and grows to large voids, as a result the fracture which is led from the localized deformation remarkably progresses. Since such a tendency of the fracture mode remarkably occurs at the testing temperatures more than 473K, the elongation of SiCw/Al composite decreases with increasing temperature. SEM photograph of the fracture surface in SiCw/Al-6mass%Mg alloy composite tested at 473K is shown in Fig.4. The spalling at the interface and the pulled out whiskers from the matrix alloy are not observed in the fracture surface of SiCw/Al-6mass%Mg alloy composite , and a good bonding at the interface is maintained up to high temperatures. The uniform deformation is continued and large elongations are obtained because of the less localized voids formation, growth and conecting of voids in the SiCw/Al-Mg alloy composites during high temperature tensile testing. The relations between tensile strengths and strain rates tested at 573K is shown in Fig.5. The tensile strengths in all tested materials as the strain rate increases. The increasing rates of the tensile strength against the strain rates in SiCw/Al-Mg alloy composites are larger than those in the matrix alloys and SiCw/Al composite.

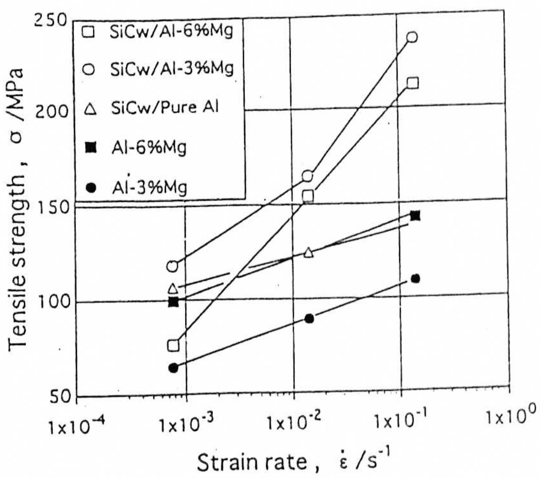

Fig.5 Dependence of tensile strength of composite materials and matrix alloys on strain rate tested at 573K.

The tensile strengths of SiCw/Al-6mass%Mg alloy composite tested with the strain rates above 10^{-2} /s are larger than those of SiCw/Al composite and matrix alloys. The relation between Mg concentration and the sensitivity exponent of strain rates,m value which is obtained from the results in Fig.5 for the composites is shown in Fig.6. All m-values show less than 0.2 and increase as the Mg concentration increases. As the results, it is clear that the higher Mg concentration in composites, the larger the dependence of deformation on the diffusion , and the higher the sensitivity of strain rates. The dependence of fracture surface morphologies in SiCw/Al-6mass%Mg alloy composite on strain rates tested at 573K is shown in Fig.7. The morphologies of fracture surface change from the structure influenced by diffusion, so largely to the dimple structure which is likely observed at low temperature tensile testing as the strain rate increases. These results corresponded to the increase in the tensile strength as the amounts of the work hardening increase because of the lack of diffusion for the dynamic recoverry. In oder to clarify the dependence of the dynamic recovery process in the composite on Mg concentration during high temperature tensile testing, the relation between tensile strengths and the temperature compensated strain rate parameter (Zener-Holomon parameter : Z) in this tested materials is investigated as shown in Fig.8. Z is defind as the following equation.

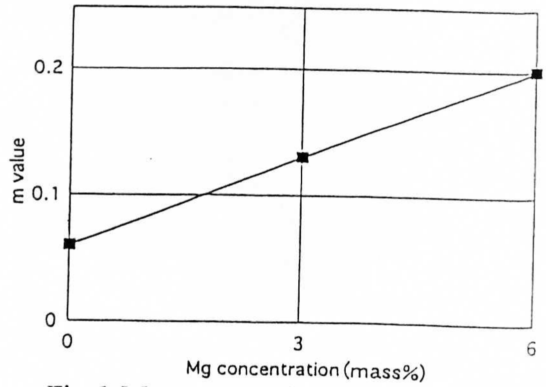

Fig.6 Mg concentration vs. m-value of SiCw/Al-Mg ally composites.

$$Z = \dot{\varepsilon} \exp (Q/RT) \quad (1)$$

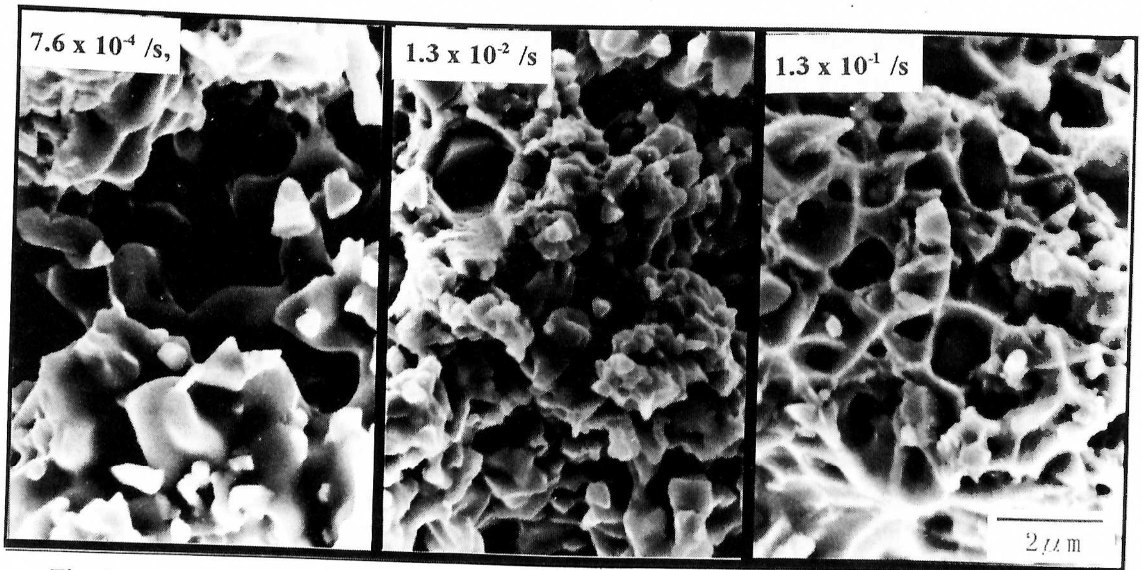

Fig.7 Dependence of fracture surface morphologies in SiCw/Al-6mass%Mg alloy composite on strain rates tested at 573K.

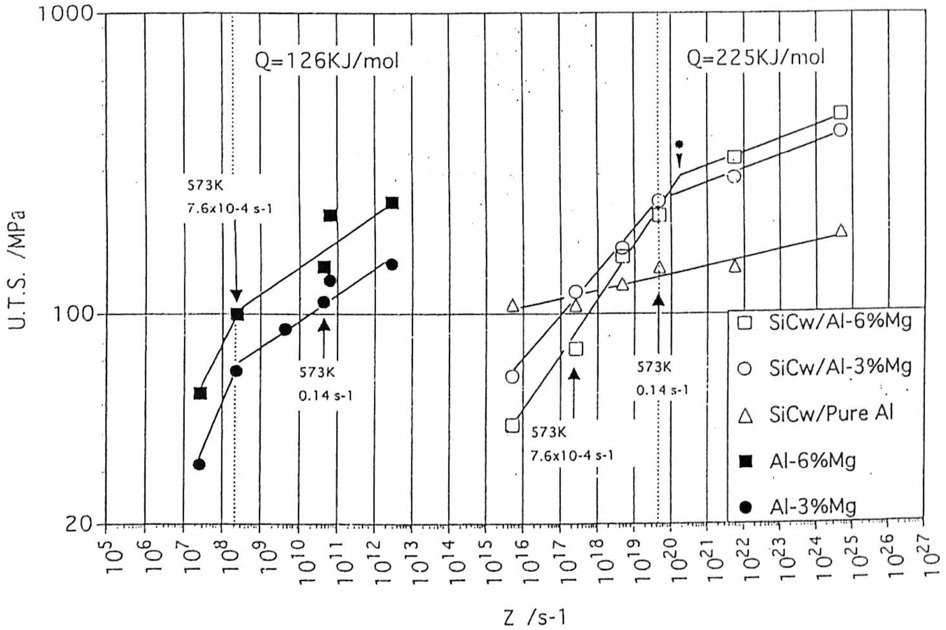

Fig.8 Relation between temperature compensated strain rate parameter and tensile strengths

where Q is the activation energy , $\dot{\varepsilon}$ is the strain rate. Q used were 126 KJ/mol led from the interdiffusion of Al-Mg alloy [5] and 225 KJ/mol led from the creep test data of the composite [6] respectively. It was reported that the differences of the dynamic recovery process in Al-Mg alloy was found in low and high Z regions and the changes of the dynamic recrystallization structure were found between two regions[7]. However the dynamic recrystallization structure is not observed by TEM observation in SiCw/Al-Mg alloy composites in this study. The changes in the gradient of the lines areremarkably detected in the neighborhood of $Z=10^{20}$/s (573K, 0.14/s) . This means that

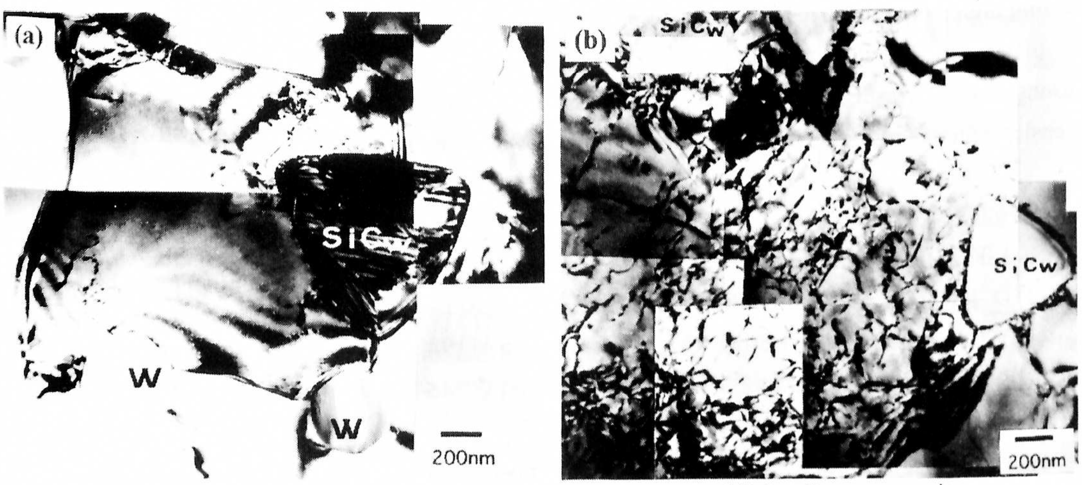

Fig.9 TEM images of (a) SiCw/Al and (b) SiCw/Al-6mass%Mg alloy composites before tensile testing.

the change of the dynamic recovery rate occurs in this region. Transmission electron micrographs of SiCw/Al and SiCw/Al-6mass%Mg alloy composites before tensile testing are shown in Fig.9. It is clear that the dislocation density in SiCw/Al-6mass%Mg alloy composite is higher than that in the SiCw/Al composite. The relation between Mg concentration and the half-value width of Al(331) by X-ray diffraction in composites is shown in Fig.10. The half-value width increases as the Mg concentration increases. This means that the dislocation density increases as the Mg concentration increases. In SiCw/Al-Mg alloy composite, the higher Mg concentration, the higher the density of dislocation introduced by the extrusion process and the quenching process from solution treatment temperature . As a result, the high strain enerergy is accumulated in the composite, which causes the marked progress of the dynamic recovery at the temperatures of more than 573K. Consequently, the large degradation of tensile strength occurs in SiCw/Al-Mg alloy composite.

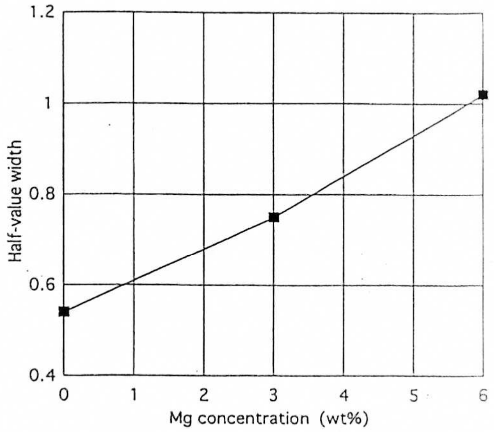

Fig.10 Half-value width of Al(331) by X-ray diffraction in composites.

4.CONCLUSIONS

(1) The decrease rate of the tensile strengths in the composite with increasing temperature is larger than that of the martrix alloys.

(2) At higher temperatures than 473K, the higher Mg concentration in the composites, the larger the decrease rate in the tensile strengths.

(3) The uniform deformation is maintained and the large elongations are obtained because of the less localized voids formation, growth and connecting of voids in SiCw/Al-Mg alloy composites during high temperature testing.

(4) In the SiCw/Al-Mg alloy composites, the large degradation of high temperature tensile strengths is explained by the marked progress of the dynamic recovery resulting from high dislocation density which is introduced by the extrusion process and the quenching process.

5.REFERENCES

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