Aluminum Matrix Carbon Fiber MMC

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ABSTRACT Recently, many markets including electronics, need materials with high thermal properties and durability. We have developed the MMC which has good machinability, high thermal conductivity and durability. This aluminum alloy matrix carbon fiber MMC (Gr/Al) is reinforced by pitch base graphite fiber. The Gr/Al shows a microstructure free from degrading compound on the fiber surface. Thermal properties are 220W/mk thermal conductivity and 9ppm /℃ CTE . It is possible to control the CTE by volume fraction of fiber. In the range from 313K to 373K, both the CTE and the thermal conductivity of Gr/Al decrease as the fiber content increases. The thermal fatigue depends on the fiber length in thermal cycling test. As for the Gr/Al with 350 μ m fiber , no degradation is observed on the CTE after 1000 cycle test.

Keywords: *graphite fiber,Al-graphite composite,fiber reinforced Metal,thermal conductivity,coefficient of thermal expansion,thermal cycling test*

1. INTRODUCTION

Metal matrix composites are now the obvious materials for electric and electronic devices. Aluminum-ceramics composites, in paticular, have been used to make a lot of parts.

In recent years, high modulus pitch base graphite fiber has been developed. This fiber's characteristics are low coefficient of thermal expansion (CTE) and high thermal conductivity. The composite made with this fiber retains low CTE and high thermal conductivity.

It is considered a suitable material for use in electric and electronic parts. However, this composite has a few problems , the graphite has poor wettability and bonding with aluminum [1], Al_4C_3 compound forms on the fiber surface and this compound degrades properties [2].

If a composite has the compound on the interface between fiber and matrix , it will be weakened from the thermal stress that occurs during thermal cycling .

Therefore, it is necessary to develop a composite that has good thermal fatigue properties. In this paper, we report on an aluminum matrix carbon fiber MMC (Gr/Al) which is reinforced with pitch base graphite fiber possessing properties of high thermal conductivity and low CTE.

2. EXPERIMENTAL PROCEDURE

Fig. 1 shows the manufacturing process of Gr/Al . In this experiment, high thermal conductivity graphite fiber was used. This fiber`s properties were 1400W/mK thermal conductivity, 800MPa Young's modulus and 1ppm/°C CTE. The aluminum alloy matrix contained 18wt%Si .

The graphite fiber preform was prepared by vacuum press process, made from a slurry containing inorganic binder and fiber. The fiber volume fraction is in the range of 25 to 40%. In the preform, the fibers were oriented by vacuum press process, parallel to the horizontal vacuum plane and dispersed in random directions to the vacuum plane, i. e. flat, various directions.

Composite samples were infiltrated by squeeze casting. Preforms were preheated in the air, then infiltrated with a molten aluminum alloy under a pressure of 100MPa for 30 sec.

After squeeze casting, the specimens were cut into pieces parallel to the vacuum plane to measure the thermal conductivity and CTE .

CTE was measured in the air by thermal expansion measurement apparatus. Measuring range was 313K ~373K . Heating ratio was 0. 083K/s.

Thermal conductivity was measured by the laser flash method.

In the thermal cycling test, the specimen was subjected to a thermal cycle of 208K (for 1. 8 ks) →463K (for 1. 8ks) in the air using a thermal shock test apparatus .

After the test , the changes of CTE and thermal conductivity were measured.

The Gr/Al microstructure was observed by metallographic microscope and scanning electron microscope (SEM) .

3. Results and Discussion

3. 1 Microstructure

Phot. 1 shows a typical microstructure of Gr/Al MMC (vf:35%, Matrix:Al-Si18wt%) made by squeeze casting. Dispersions of primary and eutectic Si crystals are observed in the matrix of MMC. Interlocking fibers are observed , but pores aren't observed between fibers.

On the fiber-matrix interface, only Al-Si eutectic structures are observed, Al_4C_3 formation isn't observed. In spite of the high temperature of the molten metal, no reaction occurred between fibers and the matrix, due to the short contact and solidification time .

Another reason is that the pitch base carbon fiber is less degraded by molten aluminum than PAN base carbon fiber [3)].

3. 2 Thermal properties

Fig. 2 and Fig. 3 show the CTE and the thermal conductivity at various fiber volume fractions of Gr/Al made by squeeze casting.

The CTE of Gr/Ar decreased as the fiber vf was increased and over 35vf% , it remained constant in the horizontal (x-y) plane . But in the vertical (z) direction the CTE is almost constant. CTEs of the fiber is anisotropic, i. e. -1ppm in axial direction, 20ppm in radial direction. And its 20ppm is near to the CTE of the matrix (18ppm) .

Fig. 3 shows the thermal conductivity of Gr/Al decreases in both horizontal and vertical planes as the fiber content increases. The increase of the fiber volume doesn`t work effectively. It can be considered that the fiber`s apparent thermal conductivity is reduced. The thermal resistance of the interface between fiber and matrix depends on the hoop force. The increase of the fiber amount results in the decrease of the CTE, reduceing the hoop force.

The thermal conductivity along the fiber axis is 1400W/mK, on the contrary to that of radial direction which is merely 3~5W/mK, therefore the thermal conductivity is dependent on the heat pass distance, Fig. 4 shows the effect of fiber length. The thermal conductivity of Gr/Al increases approximately 30W/mK as fiber length increased from 150 μ m to 350 μ m and the CTE decreases 1ppm. The increase of thermal conductivity is due to the increase of continuous heat pass distance.

The decrease of the CTE is due to increase of anchor effect on fiber-matrix interface along the longer fiber axis.

3.3 Thermal cycling test

Fig. 5 shows the CTE values after thermal cycling test on 150 and 350 μ m fiber. In 150 μ m fiber Gr/Al, the degradation in CTE is observed after 45 cycling. On the other hand in 350 μ m fiber Gr/Al, there is no degradation after 1000 cycling. We recognized that thermal fatigue depends on the fiber length.

4. Conclusions

1) The Gr/Al made by squeeze casting shows good microstructure with degrading compound formed on the fiber surface.

2) The Gr/Al at 35vf% shows 220W/mk thermal conductivity and 9ppm /°C CTE. .

3) It is possible to control the CTE of the Gr/Al by the fiber volume fraction. In the range from 313K to 373K, the CTE and the thermal conductivity of Gr/Al decreases as the fiber content increases.

4) In the thermal cycling test, thermal fatigue depends on the fiber length. In 350 μ m fiber Gr/Al , no degradation was observed upon the CTE after 1000 cycle test.

5. References

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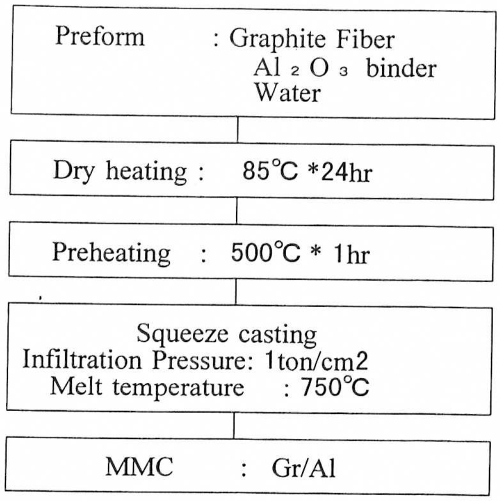
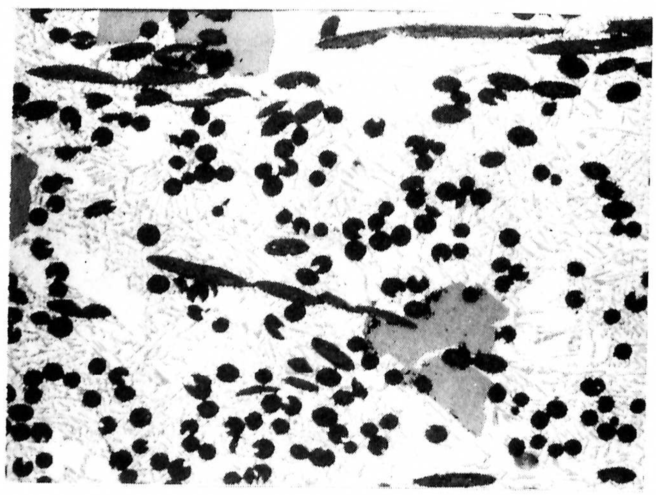


Fig. 1 Schematic illustration of Gr/Al manufacturing process



Phot. 2 Micro structure of Gr/Al(Vf:35% Matrix:Al-Si18wt%)

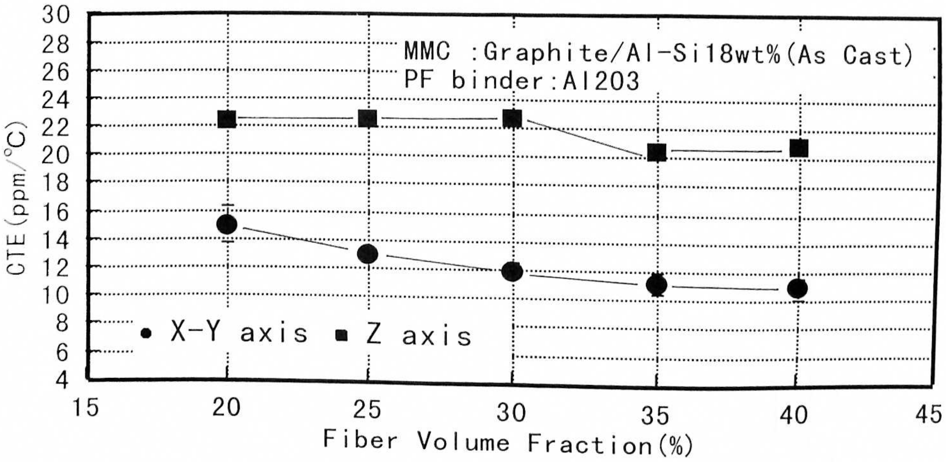


Fig. 2 Variation of Coefficient of thermal expansion with fiber volume for Gr/Al

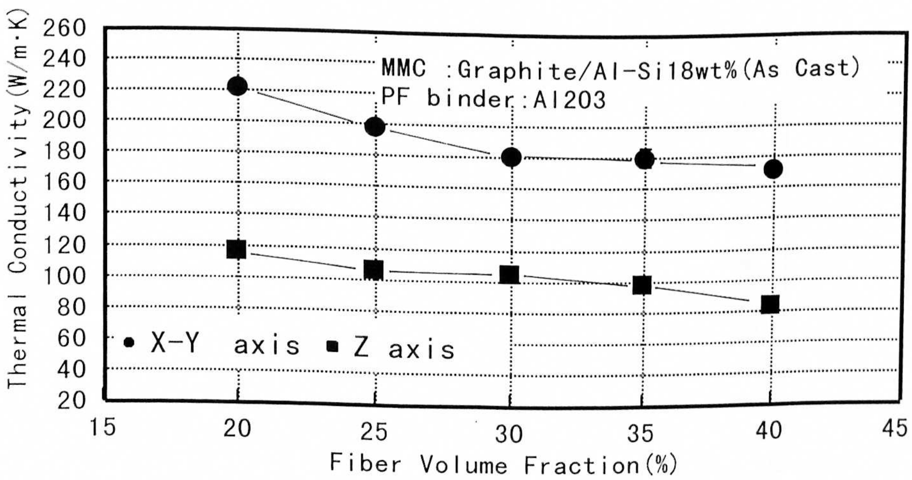


Fig. 3 Variation of thermal conductivity with fiber volume for Gr/Al

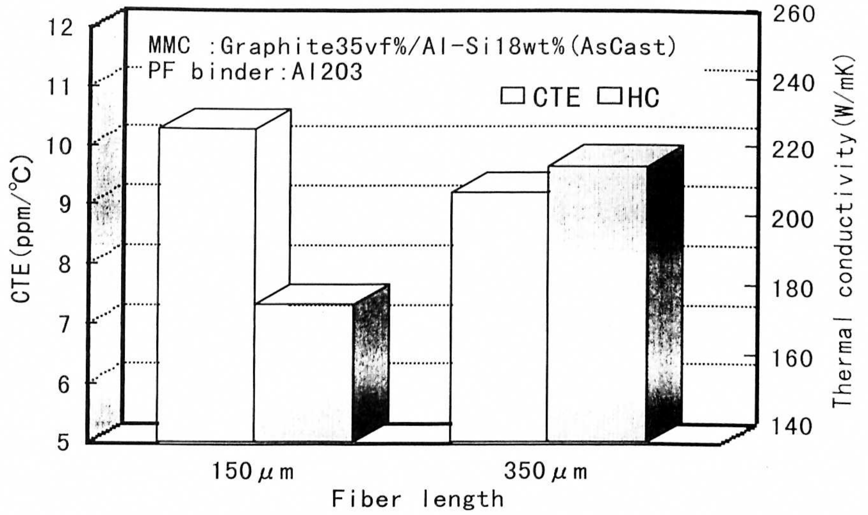


Fig. 4 Thermal properties with fiber length for Gr/Al

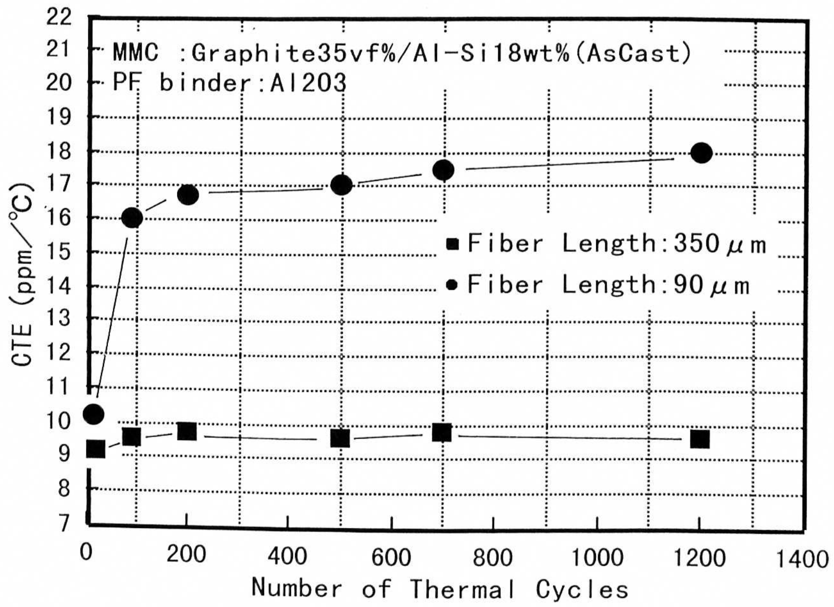


Fig. 5 Variation of CTE with number of thermal cycles for Gr/Al