EFFECT OF DIFFERENT DIMENSION STABILIZATION TECHNIQUES ON DIMENSION STABILITY OF SiC_p / Al COMPOSITES①

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ABSTRACT

The effect of different dimension stabilization treatments on the dimension stability of SiC_p / Al composites were investigated by the measurement of microyield strength, microcreep properties, dimension, residual stress and analyses of transmission electron microscopy. Results show that the heat cycle dimension stabilization techniques could efficiently decrease the residual stress, stabilize the dimension change, and increase resistance to microplastic deformation. The main reason was that the heat cycle dimension stabilization techniques might form stable dislocation structure in the SiC_p / Al composites.

Key words: dimension stabilization SiC_p / Al composite stable dislocation structure

1 INTRODUCTION

The aims of dimension stabilization treatment are to decrease efficiently the residual stress, increase the resistance to microplastic deformation on the base of structure stabilization in metal materials. The good stability of dislocation and phase structure must be assured in the metal materials so that the material has higher resistance to microplastic stress under long or short time load[1]. There are a number of dimension stabilization treatment methods decreasing the residual stress in the materials, such as annealing, long time ageing and heat cycle treatment and so on. The heat cycle treatment is widely used as dimension stabilization technique now, whose advantages are that the residual stress may be efficiently decreased, the dimension stability may be increased on the base of assuring mechanical properties of the materials.

In this paper, the mechanisms of dimension stabilization are explored by comparing with the different dimension stabilization techniques of SiC_p / Al composites to tap the application of SiC_p / Al composites.

2 MATERIALS AND EXPERIMENTAL METHODS

The composite material selected for investigation was a 6061 aluminium alloy containing 36 vol−% SiC particles, with a mean size

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of dia. 3.5 μm. SiC particles distribute homogeneously in the matrix alloy (see Fig. 1). The mechanical and physical properties of this material have been the subject of many prior investigations. This material was manufactured using squeeze casting techniques.

Fig. 1 Appearance of SiC particles (×2,000)

Specimens were solution treated at 530 ℃ for 1 h, water quenched and subsequently aged at 160 ℃ for 15 h. Three kinds of dimension stabilization techniques (labelled A, B, C) were selected. Technique A was the heat cycle treatment of being aged at 160 ℃ for 4h, then aged fast at −196 ℃ for 2 h, cycled 3 times; Technique B was the heat cycle treatment of being aged at 160 ℃ for 4 h, then aged fast at −78 ℃ for 2 h, cycled 3 times; Technique C was the long time aging treatment of being aged at 160 ℃ for 15 h (Fig. 2).

The microyield strength was measured with a Instron 1186 type electron tensile machine. The microcreep was measured with the microcreep testing machine made by ourselves. The testing temperature was 60 ℃, and the compressive stress on the specimens was 65 MPa. The microstructure was carefully observed on a H−800 type scanning transmission electron microscope (STEM) operated at 200 kV. TEM foils were prepared by grinding discs to a thickness <20 μm, mounting them on copper washers and argon ion beam milling at 15 ℃ and 1.5 kV. An argon ion beam table was cooled by liquid nitrogen to avoid possible damage during specimen preparation. The dimension was measured on a DBG−5 high precision Elmillimess with dia.5 mm × 25 mm specimens. The residual stress was measured on a D / max−rB X−ray diffractometer.

3 RESULTS AND DISCUSSION

3.1 *The Effect of Different Dimension Stabilization Techniques on the Dimension Stability of* SiC_p / 6061 *Composite on Load*

The dimension stability of the material depends mainly on the residual stress and the structure in the material on no load. Table 1 showes that the change of X−ray stress half−peak width characterizing residual stress after the SiC_p / 6061 composite was treated by three kinds of dimension stabilization techniques. Clearly, the residual stress in the SiC_p / 6061 composite treated by technique A was the least in these techniques. The change of dimension also proved this phenomenon (see Table 2). From Table 2, we can find that the change of specimen dimension of the SiC_p / 6061 composite treated by technique A was the smallest in these techniques with increase of time. The dislocation structure in the SiC_p / 6061 composite treated by three kinds of dimension stabilization techniques was shown in Fig. 3. From Fig. 2a, we found that the dislocation structure in the SiC_p / 6061 composite treated by technique A tended towards network, formed stable dislocation structure. The number and dimension of precipitation phase also change. In the SiC_p / 6061 composite treated by technique A, the number of small dispering precipi-

Table 1 The change of X-ray half-peak width characterizing residual stress after the SiC_p / 6061 composite treated by the dimension stabilization techniques

Techniques	Half-peak width
A	0.376
B	0.427
C	0.465

Table 2 The change of dimension after the SiC_p / 6061 composite treated by the dimension stabilization techniques

Techniques	$\Delta L / L_0$ / %	$\Delta L / L_0(40/d)$ / %	$\Delta L / L_0(70/d)$ / %
A	0.2936	0.0371	−0.0004
B	0.0452	0.3068	−0.0882
C	0.0041	0.0246	−0.0143

tation phases increased, the substructure hindered dislocations slipping, which was formed by interaction of the precipitation phases and dislocation network.

From the analyses mentioned above, we found that in SiC_p / 6061 composite treated by technique A, not only the residual stress decreased a lot, the specimen dimension changed little, but also the dislocation structure was stable. In SiC_p / 6061 composite, which has large difference in the expansion coefficients of SiC particles and matrix, large stresses generated at the interfaces between reinforcement and matrix on cooling, the restoration phenomenon would be generated when heated again, which made the residual stress decrease; and the bigger the temperature difference between upper limit and lower limit was, the larger the stress generated; the larger the driving force of lattice distortion was, the much residual stress decreased; the more stable dislocation structure was, the better dimension stability was.

3.2 *The Effect of Different Stabilization Techniques on the Dimension Stability of* SiC_p / 6061 *Composite on Load*

The dimension stability of the metal mat-

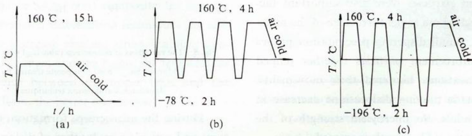

Fig. 2 The schematic drawingg of dimension stabilization techniques for SiC_p / 6061 composite treated by
(a)—Technique A; (b)—Technique B; (c)—Technique C

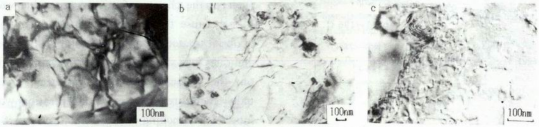

Fig. 3 The dislocation structure in SiC_p / 6061 composite treated by dimension stabilization techniques
(a)—Technique A; (b)—Technique B; (c)—Technique C

erials depends mainly on resistance to microplastic formation in the metal materials, that is the microyield strength and microcreep properties of the materials[1]. The variations of microyield strength with residual microplastic strain $\varepsilon_p^{1/2}$ for the SiC_p / 6061 composite treated by three kinds of dimension stabilization techniques were shown in Fig. 4. The microyield strength because of large stress in the SiC_p / 6061 composite treated by technique A was the highest in these techniques. The microplastic formation was generated near the interface because of large stress in the SiC_p / 6061 composite treated by the heat cycle dimension stabilization techniques. This microplastic formation acted the same as predeformation, i.e. moving dislocations was depleted, the dislocation movement became very deficient. These resulted in the increase of the microyield strength of the material. The precipitation phases and reinforcement particles were also important factors affecting microyield structure of the materials[3,4]. Small dispering precipitation phases and reinforcement particles together pinned the dislocations, hindered their movements. These made moving dislocations decrease in the materials. So microyield strength of the materials would be greatly increased.

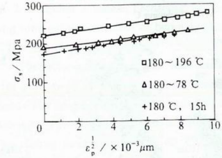

Fig. 4 The variations of microyield strength σ_s with residual microplastic strain $\varepsilon_p^{1/2}$ for the SiC_p / 6061 composite treated by dimension stabilization techniques

The variations of microcreep value with time for the SiC_p / 6061 composite treated by three kinds of dimension stabilization techniques were shown in Fig. 5. Clearly, the variation of microcreep value with time had two stages. At the beginning , the change of microcreep value was little; after 100 h the change of microcreep value became obvious, the change of microcreep value of the specimen treated by technique A was least in these techniques, i.e. the resistance to microcreep of the SiC_p / 6061 composite treated by technique A was the highest.

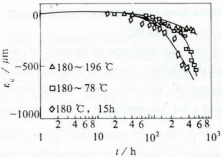

Fig. 5 The variations of microcreep value (ε_M) with time (t) for the SiC_p / 6061 composite treated by dimension stabilization techniques

During the microcreep, formation, movement and action on each other of dislocations and lattice defect were important factors affecting microcreep[4]. At the beginning of microcreep, the change of microcreep value was little because the dislocation structure in the material treated by dimension stabilization techniques was stable. As microcreep time went on, the dislocations pinned increased gradually, therefore, the stress concentration was loosed by launching dislocations to matrix. So this stage was the process of dislocations moving and reproducing continuously (see Fig. 6). The precipitation phases and reinforcement particles were important factors of increasing resistance to microcreep. During microcreep, a number of small dispering precipitation phases and reinforcement particles together with pinned dislocations, grain boundaries to hinder their movement (see Fig. 7).

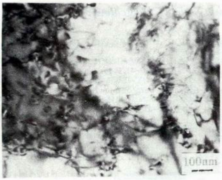

Fig. 6 The dislocation structure in SiC_p / 6061 composite after microcreep for 500 h (Technique C)

4 CONCLUSIONS

(1) In SiC_p / 6061 composite, the heat cycle dimension stabilization techniques can efficiently decrease residual stress, stabilize dimension change, and the bigger the temperature difference between the upper limit and the lower limit, the better the results;

(2) In SiC_p / 6061 composite, the heat cycle dimension stabilization techniques can efficiently increase resistance to microplastic formation, and the bigger the temperature difference between the upper limit and the lower limit, the better the results;

(3) In SiC_p / 6061 composite, the heat cycle for dimension stabilization techniques can form stable dislocation structure, precipitate a number of small dispering precipitation phases, and these precipitation phases and reinforcement particles together pin dislocations and grain boundaries, hinder their movement. These are the reasons of good dimension stability.

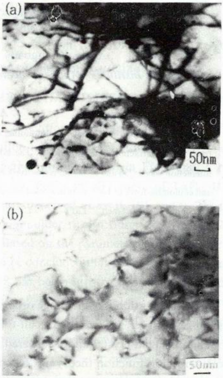

Fig. 7 The precipitation phases and reinforcement particles contributing to dimension stability of SiC_p / 6061 composite

(a)——Precipitation phases pin dislocation; (b)——Reinforcement particles hinder dislocations to move

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