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Study on Dimensional Stability of C_{sf}/Al Composites

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Short carbon fiber reinforced 1099Al and 2024Al composites with 50% volume fraction were fabricated by squeeze casting technology. It can be seen that short carbon fibers were distributed uniformly in the composites, without any clustering and segregation, and free of porosity and crack. The bending strength of C_{sf}/Al composites with 1099 Al alloy matrix was improved after annealing treatment. However, all are lower than that of C_{sf}/Al composites with 2024 Al alloy matrix. The bending strength of aging C_{sf}/2024Al composite is most highest (480MPa) and the specific strength is 218 MPa· cm^3/g, which is higher than the specific strength of traditional structural material. The dimensional stability of composites under the conditions of different heat treatment processes was studied by a method of thermal-cold cycling real-time measuring. Results show that the dimensional stability of C_{sf}/1099 composite treated by annealing is better than by casting and the dimensional stability of C_{sf}/2024 composite is better than that of 2024 Al alloy. Aging and thermal-cold cycling can improve the dimensional stability of C_{sf}/2024 composite under the conditions of 20℃~150℃ cycling 15 times and dimensional change of C_{sf}/2024 composite is 2×10^{-5}.

Keywords: *Short carbon fiber; Aluminum matrix composite; Dimensional stability*

1. Introduction

Carbon fiber reinforced aluminum matrix composites have a broad application prospect in the field of aerospace materials for their high specific strength and stiffness, low coefficient of expansion (CTE) and high thermal conductivity [1]. However, Short carbon fiber reinforced aluminum composites (C_{sf}/Al) is expected to be new materials in the applications of space devices [2], not only for their low cost, but also for overcomin of material anisotropy, especially, high specific strength and good dimensional stability.Dimensional stability of materials has a great influence on the device reliability. As a result, great attention has been paid to the dimensional stability of composites uesd in the field of aerospace[3-10]. Due to the coefficient of thermal expansion(CTE) mismatch between the matrix and reinforcement, any environmental fluctuation in temperature can introduce internal thermal stresses which can cause the local elastic or plastic deformation in the matrix near the reinforcement and introduce elastic or plastic strain, leading to an instability in component dimensions[11]. As used for precision devices requiring dimensional stability, a high resistance to microdeformation is needed. It is important to understand the factors that may affect their dimensional stability.

The paper simulated thermal-cold cycles of aerospace devices in the space environment [12,13] by a new method of thermal-cold cycling real-time measuring and investigated the influences of matrix alloy and heat treatment process on the dimensional stability of C_{sf}/Al composites, which establishes theoretical foundation for the C_{sf}/Al composites applications.

2. Experimental

2.1 Materials

Short carbon fiber was produced by clipped, milling and screening, which derived from high-strength carbon fibers of Jilin Carbon Plant. 1099 Al and 2024 Al alloy were used for the matrix. C_{sf}/Al composites with 50 vol.% short carbon fiber content were fabricated by squeeze-exhaust casting technology [14].

2.2 Heat treatment process

C_{sf}/1099 composite was as-cast state and annealed state and C_{sf}/2024 composite was as-cast state, aging state and thermal-cold cycling treatment state. The heat treatment process was shown in Tab.1.

2.3 Three-point bending strength testing

The three-point bending specimens with the sample sizes of 3 mm × 4 mm × 36 mm were obtained by linear cutting. After tensile surface was polished, the strain gauge was pasted on the middle of span. The three-point bending strength were measured on the Instron5569 machine (500Kg static load capacity, accuracy is 0.2Kg), while span was 30mm and loading rate was 0.5mm/min. Bending strength data was obtained by load-displacement curves and strain- time curves.

Tab.1 Heat treatment process of C_{sf}/Al composites

composites	Heat treatment	Heat treatment process
C_{sf}/1099	casting	——
	annealing	345℃/3h furnace cooling
C_{sf}/2024	casting	——
	aging	495℃Salt bath＋160℃/10h
	thermal-cold cycling	T6＋160℃/2h ⇔－70℃/5min cycling 3 times

2.4 Thermal-cold cycling real-time measuring method

The thermal-cold cycling on-line measurement was performed by DIL 402C (NETZSCH Corp.). The sample is a cylinder with a diameter of 6mm and a length of 25mm. During measurement, the samples were cycled under 20 ~ 150℃ for 15 complete cycles with a heating and cooling rate of 8℃/min. Before each cycle, the samples were maintained at 20℃ for 25min to ensure the equilibrium of temperature. The dimension change at 20℃ after each cycle was recorded, and data errors were from 10^{-7} to 10^{-6}.

3. Results and discussion

3.1 Microstructure

Fig. 1(a) and (b) show SEM micrographs of 50 vol.% casting C_{sf}/1099 and C_{sf}/2024 composites,

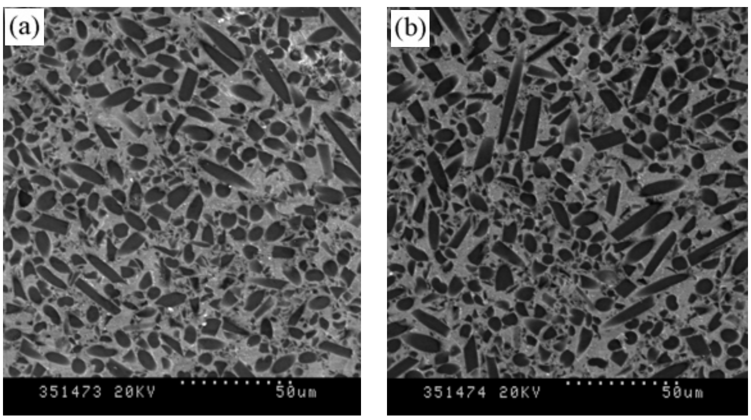

Fig.1 SEM microstructures of 50 vol.% C_{sf}/Al composites
(a) C_{sf}/1099 composite ; (b) C_{sf}/2024 composite

respectively. It can be seen that short carbon fibers were distributed uniformly in the composites, without any clustering and segregation, and free of porosity and crack.

3.2 Three-point bending strength

Table 2 presents the three-point bending strength of C_{sf}/Al composites. The bending strength of C_{sf}/Al composites with 1099 Al alloy matrix was improved after annealing treatment. However, all are lower than that of C_{sf}/Al composites with 2024 Al alloy matrix. The bending strength of aging C_{sf}/2024Al composite is most highest (480MPa) and the specific strength is 218 MPa· cm^3/g, which is higher than the specific strength of traditional structural material.

Table 2 Three-point bending strength of C_{sf}/Al composites

Materials	Heat treatment	Bending strength (MPa)	Specific strength (MPa· cm^3/g)
50%C_{sf}/1099	casting	230	105
	annealing	320	145
50%C_{sf}/2024	casting	360	164
	aging	480	218
	thermal-cold cycling	420	191

3.3 Dimensional stability of C_{sf}/Al Composite

Fig. 2 shows the dimension change-cycling time curves of annealing and casting C_{sf}/1099 composite under 20℃～150℃ thermal-cold cycling. Results show that the dimension of annealing and casting specimens are unstable under 15 times thermal-cold cycling, which indicates that the dimensional stability of C_{sf}/1099 composite is poor, but annealing treatment can make the dimension of composites under alternating temperatures from increasing to decreasing, which proves that annealing can change microstress condition. The casting matrix has macroscopic compressive stress and transforms to tensile stress after annealing treatment.

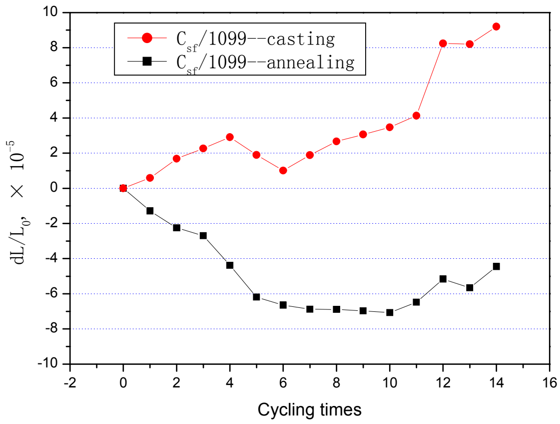

Fig.2 Dimension change-cycling time curves of C_{sf}/1099 composites under 20℃～150℃ thermal-cold cycling

Fig. 3 shows the dimension change-cycling time curves of thermal-cold cycling 2024 Al alloy, casting, aging and thermal-cold cycling C_{sf}/2024 composites under 20℃～150℃ thermal-cold cycling, respectively. The dimension changes of 2024 Al alloy (4×10^{-5}) is higher than that of C_{sf}/2024 composites, which indicates the dimension stability of C_{sf}/2024 composite is better than that of 2024 Al alloy. Aging and thermal-cold cycling can improve the dimensional stability significantly. The dimensional stability of C_{sf}/2024 after thermal-cold cycling is the best, and the total changing amount is 2×10^{-5}, which is 4-5 times compared with C_{sf}/Al composites, and 2 times compared with 2024 Al alloy.

Research[15] shows that microscopic stress was induced by hot mismatch between short carbon fiber and Al matrix under thermal-cold cycling and superimposed with residual stress in specimen The inducing local plastic deforming is the main factor leading to dimensional instability. The micro yielding stress of composites is higher than that of Al alloy and the plastic deforming resulting from materials is small, which is the reason why dimensional stability of composites is higher than that of Al alloy. Aging not only improves the micro yielding stress of matrix, but also decreases the residual stress of C_{sf}/2024 composites during casting. Re-thermal-cold cycling after aging can decrease the residual stress of composites further. Therefore, aging and thermal-cold cycling can improve dimensional stability significantly and the effect of thermal-cold cycling is better than that of aging.

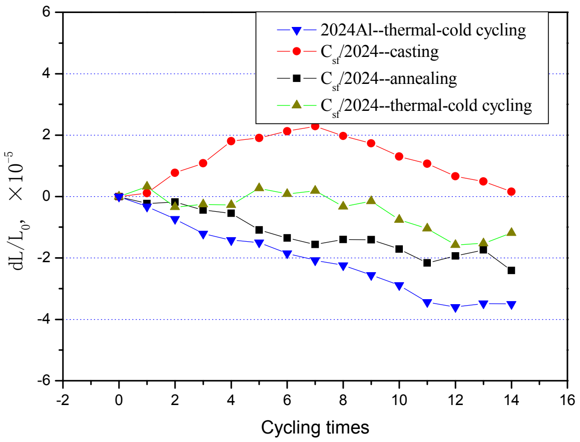

Fig. 3 Dimension change-cycling time curves of C_{sf}/2024 composites under 20℃～150℃ thermal-cold cycling

4. Conclusions

(1) C_{sf}/1099 composites has a larger dimension changing under thermal-cold cycling, but annealing can lead to the improving of dimensional stability.

(2) The dimensional stability of C_{sf}/2024 composites is better than that of 2024 Al alloy and aging and thermal-cold cycling can improve the dimensional stability of C_{sf}/2024 significantly. The dimensional stability of C_{sf}/2024 composites after thermal-cold cycling can be improved 2 times compared with 2024 Al, and the total amount is 2×10^{-5}.

References

[1] R.J. Wu. Metal Transaction. 33 (1997) 78-84.

[2] G.G. Zhang, S.J. Luo, W.B. Tian. Transactions of Nonferrous Metals Society of China. 12 (2002) 525-528.

[3] S.B. Ren , X.B. He, X.H. Qu, I.S. Humail, Y. Li. Composites Science and Technology. 67 (2007) 2103-2113.

[4] Y.D. Huang, N. Hort , H. Dieringa, K.U. Kainer. Composites Science and Technology. 65 (2005) 137-147.

[5] N. Chen, H.X. Zhang, M.Y. Gu, Y.P. Jin. Journal of Materials Processing Technology. 209(2009) 1471-1476.

[6] M.H. Song, G.H. Wu, G.Q. Chen, W.S. Yang. Transactions of Nonferrous Metals Society of China. 20 (2010) 47-53.

[7] S.G. Kang, D.H. Kang, C.G. Kim. NDT&E International. 42 (2009) 361–368.

[8] W.A. Uju, I.N.A. Oguocha. Materials Science and Engineering. A 526 (2009) 100-105.

[9] Y.D. Huang, N. Hort, H. Dieringa, P. Maier, K.U. Kainer. International Journal of Fatigue. 28 (2006) 1399-1405.

[10] R.Y. Kim, A.S. Crasto, G.A.Schoeppner. Composites Science and Technology. 60(2000)

2601–2608.
[11] J. Kiehn, E. Bohm, K.U. Kainer. Key Engineering Material. 127-131 (1997)861-868.
[12] X.F. Wang, G.H. Wu, X.L. Li, D.L. Sun. Transactions of Nonferrous Metals Society of China. 13 (2003) 1-4.
[13] R. Y. Kim, A. S. Cregory, G. A. Schoeppner. Composites Science and Technology. 60(2000) 2601-2608.
[14] G.H. Wu. Patent of People's Republic of China. No. ZL94114284.X.
[15] F. Yang, G.H. Wu, D.L. Sun. Acta Metall. Sinica.13(2000) 502-507.