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Damping capacity of in-situ TiC_p/2024 composites ①

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Abstract: The internal friction and the damping behaviors of in-situ TiC_p/2024 composites have been investigated in comparison with those of 2024 matrix alloy. The results showed that the damping properties of the TiC_p/2024 composites are superior to those of the matrix alloy and increase with increasing temperature and volume fraction of TiC. It was found that the damping properties were sensitive to frequency and temperature, and the dislocation damping and interface damping were the main factors which influence the damping behaviors of the composites. When the temperature was lower than 200 ℃, the dislocation damping was the main factor; when the temperature was higher than 200 ℃, the interface and boundary damping was the main factor.

Key words: TiC_p/2024 composites; damping capacity; dislocations; interfaces **Document code:** A

1 INTRODUCTION

Particulate aluminum matrix composites have been used as high properties materials in aerospace, space and shipbuilding industries because of their high special strengths and moduli, good wear resistance, thermal conductivities and electronic conductivities, low thermal explosion coefficients, and good damping properties[1]. In-situ TiC particulate aluminum composites can not only increase the modulus and strength, but also improve the damping properties which are important in reducing or omitting the vibration and noise in some dynamic structures. So much attention has been paid to improving the damping properties and investigating new preparing technologies. So far, many researches have been reported on damping behaviors of high damping alloys and SiC particle reinforced aluminum composites[1~7]. But little has been done on those of TiC_p/2024 composites. In this paper, the damping behaviors of in-situ TiC_p/2024 composites have been investigated by dynamic mechanical thermal analyzer.

2 EXPERIMENTAL

In-situ TiC_p/2024 composites with 2 ~ 3 μm TiC_p particles were used as experimental materials. During the preparation of the composites, master alloy with TiC_p particles was synthesized by thermal explosion firstly. Then the master alloy with 2024 alloy was melted and agitated in a vacuum furnace to distribute the TiC particles homogeneously in the matrix. After that, the composites were cast. Finally, the casting was extruded into a d12 mm bar, from which samples were cut. The internal frictions of in-situ TiC_p/2024 composites and those of the 2024 matrix alloy were measured in a dynamic mechanical thermal analyzer(DMTA). The maximum amplitude is 5×10^{-6}. The frequency is 1, 10, and 20 Hz, respectively. The temperature is between 40 ℃ and 400 ℃.

3 RESULTS AND ANALYSES

3.1 SEM and TEM observations

Fig.1 shows the microstructure of TiC_p/2024 composites observed by SEM. The maximum size and average size of TiC are 5 μm and 2 ~ 3 μm, respectively. The distribution of TiC in matrix is homogeneous.

The microstructure of the composites observed

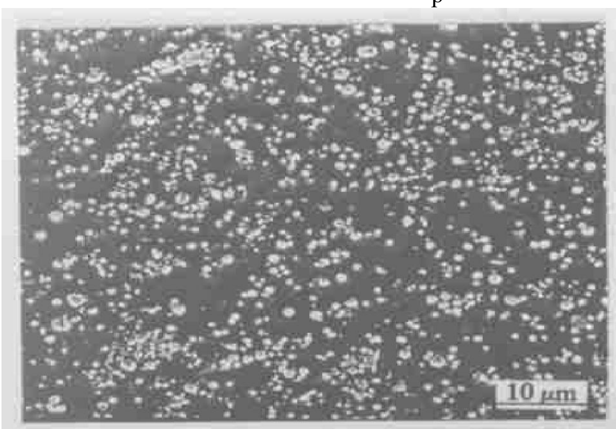

Fig.1 SEM micrograph of TiC_p/2024 composites

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by TEM is shown in Fig.2, in which high density of dislocations with bow-shape can be seen. Precipitation with nanometer size is observed at both ends of the dislocations and distributes homogeneously in the matrix.

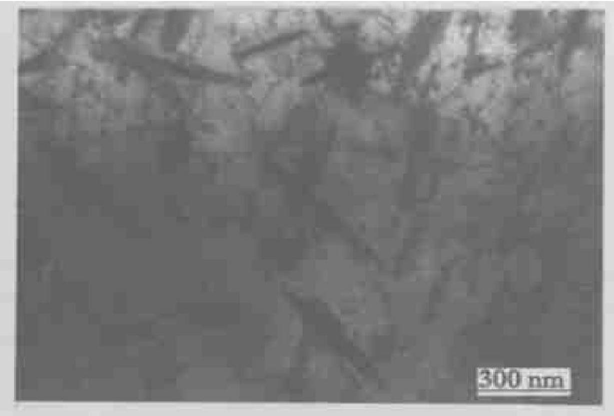

Fig.2 TEM micrograph of TiC_p/ 2024 composites

3.2 Damping characteristics of TiC_p/ 2024 composites

Fig.3 shows the damping-temperature curve of in-situ TiC_p/ 2024 composites with three frequencies. It was found that with increasing temperature the damping properties of the composites increase markedly, especially at low frequency. At 280 ℃, a damping peak is found, and it becomes more marked at high frequency. The damping properties-temperature curves of composites with different TiC contents and those of the 2024 matrix are shown in Fig.4. When the temperature is lower than 200 ℃, the damping properties of the composites are slightly higher than those of the matrix, and keep constant at 40 ~ 200 ℃. When the temperature is higher than 200 ℃, the damping properties of the composites are markedly higher than those of the matrix alloy.

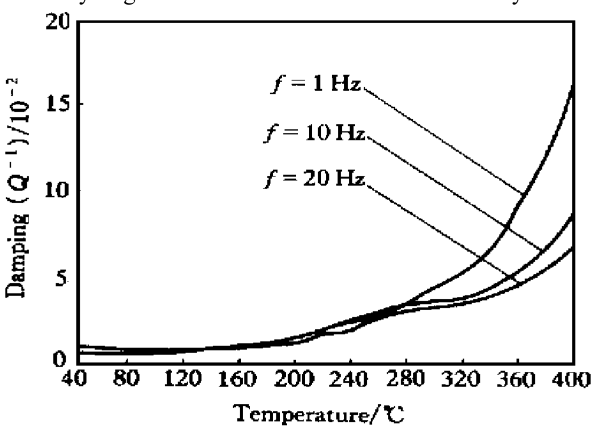

Fig.3 Relationship between damping capacity and temperature of TiC_p/ 2024 composites
(φ = 15 %, Amplitude = 5×10^{-6})

3.3 Damping behaviors of TiC_p/ 2024 composites

The better damping properties of composites can not be contributed mainly to the TiC particles, but to

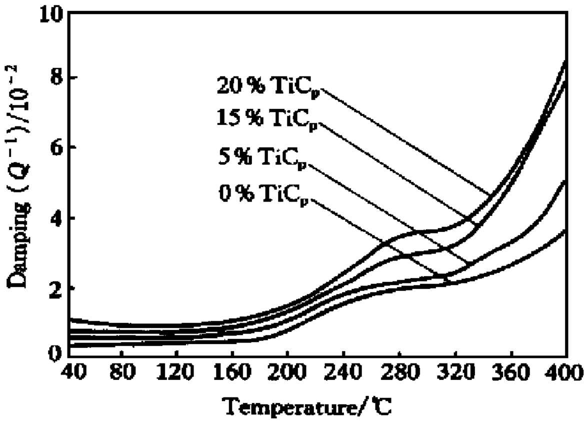

Fig.4 Comparison of damping capacities of TiC_p/ 2024 composites and 2024 alloy
(f = 20 Hz, Amplitude = 5×10^{-6})

the mismatch strain at the interface between TiC and matrix produced by the discrepancy of thermal shrinkage during solution treatment.

The mismatch strain can be expressed by $\varepsilon = \Delta\alpha \cdot \Delta t$, where $\Delta\alpha$ is the discrepancy between the coefficient of the thermal explosion of the matrix alloy and that of the TiC particles, and its value is about 15.6×10^{-6} ℃$^{-1}$; Δt is the discrepancy between the quenching temperature and the room temperature, and its value is about 465 ℃. After substituting $\Delta\alpha$ and Δt into the above equation, the mismatch strain of the composites is calculated to be 0.7245 %. The mismatch strain will produce large stress in the matrix and high density of dislocations around the TiC particles, as shown in Fig.5, thus improving the damping properties of the composites. Furthermore, the addition of TiC particles produces an amount of interfaces in the matrix, which is another important factor which increases the damping properties of the composites.

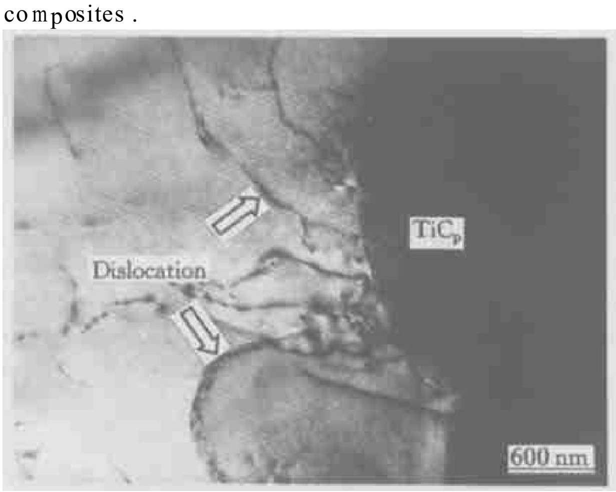

Fig.5 Dislocations surrounding TiC_p particle

In this experiment, the damping properties of the in-situ TiC_p/ 2024 composites at low temperatures (less than 200 ℃) is mainly controlled by the dislocation damping mechanism[11], which can be explained by G-L theory[8]. In G-L model, the dislocation is like a string bowing out from the pinned dislocation produced by impurities, precipitates and interfaces. Under the loop stress, dislocations can become a high internal friction source. By the function of external stress, the loop dislocations bow out, (Figs.6(b) and (c)), and with increasing stress, the pinned dislocation can break out at a weak pinned point, (Figs.6 (d) and (e)), to from dislocation circles. When the stress decreases, it will change along (g) → (f) → (e) → (d), up to (a). During this kind of dislocation movement, a partial vibration energy will be converted into thermal energy, and the damping properties will be improved. The higher the particle content, the higher the damping properties of the composites, as shown in Fig.4.

Fig.6 Mold of G-L dislocation damping

At high temperatures, the damping properties increase with increasing temperature. When the temperature is higher than 200 ℃, the damping properties increase rapidly and a damping peak appears at 280 ℃ (Fig.3), indicating that the dislocation is activated by the function of temperature and stress to break out of pinning.

Another reason for the high damping properties of the composites is interface damping, which is a characteristic damping source of the composites. Usually, the in-situ TiC_p/2024 composites are of good interface strength. At low temperatures (lower than 200 ℃), the applied stress in the damping measurement is less than the interface strength, so interface slip can not happen. With increasing temperature, the interface strength decreases, so interface slip happens, see Fig.7(a)[9]. The higher the temperature, the stronger the interface slip. Meanwhile, with increasing temperature the activated dislocations will move acceleratively and pile up at the interface. When the stress produced by the pile-ups of dislocations is high enough, the interface and grain boundary will start to slip, as shown in Fig.7(b)[9]. These consume a lot of energy and improve the high temperature damping properties, which has been proved by the experiment, as shown in Fig.3 and Fig.4.

Another characteristic of the high temperature damping properties is that they are higher at low frequency than at high frequency[2], as shown in Fig.3. The dislocation movement, which is like a bowed string, has a resonance characteristic. It can relax in one turn at low frequencies, but not at high frequencies. Meanwhile, when the frequency is high, almost all the dislocations will break out of pinning, but the stress still increases and the area of stress-strain loop curve still keeps unchanged. So the damping properties at high frequency are poorer than those at low frequencies.

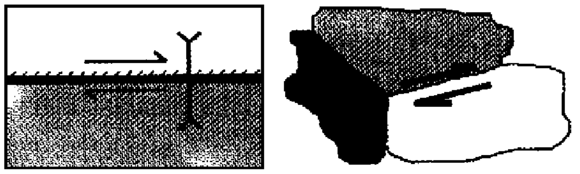

Fig.7 Schematic of high temperature damping behavior of metal matrix composites
(A) —Interface ship; (b) —Crystal boundary slip

REFERENCES

[1] ZHANG Ying-yuan, LE Yong-kang, et al. Mechanism of damping of higher strength and damping SiC_p reinforced 6061 Al MMC by spray deposition [A]. C-MRS. Advance in Energy Intelligent Materials and Gradient Materials [C], (in Chinese). Beijing: Metallurgical Industry Press, 1997: 330 ~ 340.

[2] ZHANG Xiao-nong, ZHANG Di and WU Ren-jie. Study on damping behavior of SiC_p/LY12 Al matrix composite [J]. Journal of Materials Engineering, 1998, 6: 20 ~ 22.

[3] ZUO Y Q, Smith D J and Partridge P G. Damping capacity of laminates composed of layers of titanium alloy MMC [J]. Materials Science and Technology, 1998, 14: 518 ~ 521.

[4] GE Ting-sui. Experimental and theoretical study on non-linear anelastic internal friction [J]. Acta Metallurgica Sinica, 1997, 33(1): 9 ~ 21.

[5] ZHANG Shu-ying, CAO Fu-yang, et al. Microstructure and damping properties of 2024Al/SiC_p metal matrix composites produced by spray codeposition [J]. Acta Materiae Composites Sinica, 1998, 15(1): 88 ~ 92.

[6] Updike C A, Bhagat R B, Pechersky M J, et al. The damping performance of aluminium based composites [J]. JOM, 1990, 42: 450.

[7] ZHANG J, Perez R J and Lavernia E J. Effect of SiC and graphite particulates on the damping behavior of metal matrix composites [J]. Acta Metall Mater, 1994, 24(2): 395.

[8] Geanato A and Lucke K J. Theory of mechanical damping due to dislocation [J]. Appl Phys, 1956, (27): 583 ~ 593.

[9] Clyne T W and Withers P J. An Introduction to Metal Matrix Composites [M]. New York: Cambridge University Press, 1995. 286.

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