DAMPING BEHAVIOUR STUDY IN RS/PM ALUMINIUM-LITHIUM ALLOY

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Abstract

The RS/PM aluminium-lithium alloy system studied in the present work is Al-Li-Cu-Mg-Zr. The temperature spectra and frequency spectra of damping capacity in the alloys were measured by the resonance method with the dynamic mechanical analyzer. The elastic modulus of any temperature were determined while the measuring temperature increased from −80 to +450℃. In comparison with the IM Al-Li alloy, the damping mechanism was discussed.

Introduction

As is well known the IM (Ingot Metallurgy) Al-Li alloys have been used in the aerospace industry. But the RS/PM (Rapid Solidification/Powder Metallurgy) Al-Li alloys are still studied for higher toughness and ductility. Much of the work on fracture toughness has been concerned with grain boundary behaviours in the IM Al-Li alloys[1], including research work on grain boundary internal friction[2]. However, it appears that there is no basic study of interface damping in the RS/PM Al-Li alloys. It is obvious that the toughness and ductility of the RS/PM alloys could be under the influence of the interface behaviors, such as phase boundary, grain boundary and primary powder boundary. The present investigation of interface damping behaviour was carried out by using the internal frictin technique.

Materials and Experiment

The composition of the RS/PM Aluminum-Lithium alloy studied in the present work is shown in Table 1. The process control is as follows: the cooling rate of the powders is 10^3-10^5K/s, the average diameter of the powder particle is about 40 μm and the extrusion rate is 34.

The damping behaviour Q^{-1} and modulus E' were measured on the $2\times5\times60$mm plate specimens by the resonance method with the dynamic mechanical analyzer DMA982. The Q^{-1} of any temperature can be determined through measuring the resonance frequency and damping of the system while the measuring temperature increased from -80 to $+450$°C.

Table 1. The Composition of RS/PM Al-Li-Cu-Mg-Zr Alloy(wt. %)

Element	Li	Cu	Mg	Zr	Ag	Fe	Si	Na	K	Al
Content	1. 50	4. 80	0. 4	0. 10	0. 4	0. 1	0. 12	25ppm	10ppm	balence

The relationship is as follows:

$$Q^{-1} = \mathrm{tg}\delta = \frac{C}{A} \cdot \frac{V - V_i(f \cdot A)}{f^2 - f_0^2} \tag{1}$$

Where δ is the phase difference of the mechanic damping, C is the damping coefficient. A is the transverse section area of the amplitude, V is the damping of the resonance system with a specimen, V_i is the damping of the resonance system without specimen, f is the resonance frequency of the system with a specimen, f_0 is the resonance frequency of the system without specimen. The results of all specimens were given by using the computer 1090B which was connected with the DMA 982.

Results and Discussion

The experimental results show that there are three maximums of the damping capacity and three losses of the modulus in the variation of Q^{-1} and E' with temperature.

A Q^{-1}-t curve is shown in Figure 1. E'-t curve is shown in Figure 2. It can be seen from Figure 1 that there are three peaks in this curve, which appeared at 12℃, 240℃ and 410℃ respectively. Comparing Ingot Metallurgy Al-Li-Cu-Mg-Zr alloy[3] with the present investigation of RS/PM alloy, the grain boundary damping peak of the latter appeared at 240℃ is much higher than IM alloy. According to T. S. Kê[4], the internal friction is determined by the product of the sliding distance and sliding resistance along the grain boundaries. The difference of the Q^{-1} peaks between RS/PM and IM Al-Li

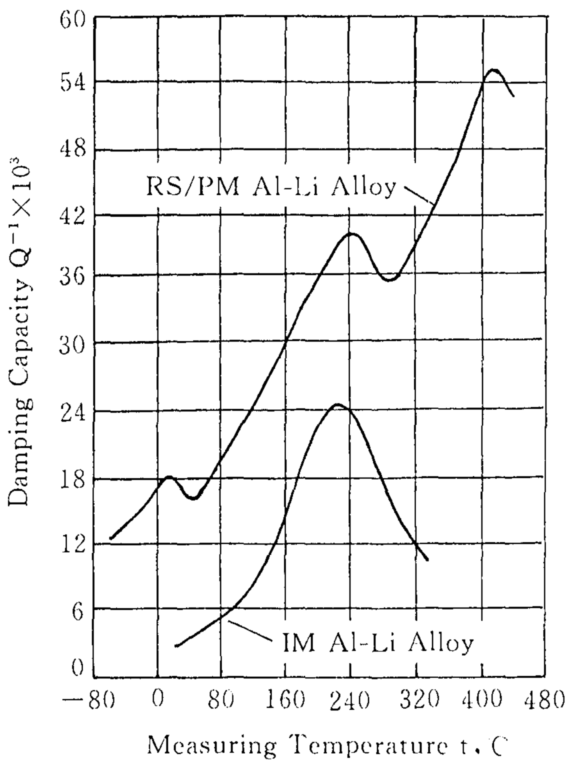

Figure 1. Variation of damping capacity with ascending temperature in the Al-Li-Cu-Mg-Zr alloys (solution treated for 1 hr at 520℃ and nutural aging). Frequency of vibration = 19. 8 Hz at room temperature. Amplitude of vibration = 0. 20mm.

alloys seems to be due to the more finer precipitates along grain boundaries in the powder particles of RS/PM alloy.

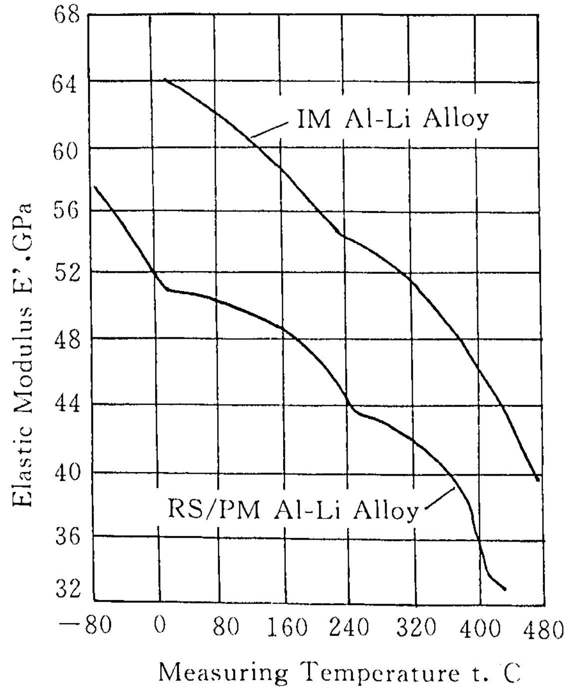

Figure 2. Variation of elastic modulus E' with ascending temperature in the Al-Li-Cu-Mg-Zr alloys (solution treated for 1 hr at 520℃ and nutural aging). Frequency of vibration = 19. 8 Hz at room temperature. Amplitude of vibration = 0. 20mm.

Generally speaking, at low temperature, the sliding distance along the grain boundaries is small and therefore the internal friction is small. At high temperature, the sliding resistance along the grain boundaries is small, so again the internal friction is small. Only in an intermediate temperature range, when both the sliding distance and the sliding resistance are appreciable, will the internal friction reaches a maximum. Specifically, the more finer precipitates the grain boundaries contain, the more sliding distance they have at low temperature. Also the more finer precipitates the grain boundaries contain, the more sliding resistance they have at high temperature. So whenever temperature it is, the internal friction value will be higher in the finer precipitates along grain boundaries. Of course, the damping capacity will reach a more higher maximum value in an intermediate temperature.

From Figure 1, the specimens after solution treated are in the natural aging condition. In this case, the $\delta'(Al_3Li)$, a metastable Li_2 ordered phase, precipitates homogeneously and coherently[5]. The δ' cube/cube oriented with the α (Al) formed the dislocation pinning, then the sliding along the phase boundaries should be slow-down. This view is supported by the measuring result of Q^{-1} at 12℃. But since the measuring temperature increases, with the effect of the artificial aging, the δ' coarsenes and transforms into the δ (AlLi) phase partially. The internal friction increases because of the more sliding along the phase boundaries.

At 410℃ in the Q^{-1}-t curvatre of RS/PM alloy (Figure 1), there is a maximum which is much higher than all others (grain boundary peak at 240℃ and phase boundary peak at 12℃). It seems to be the internal friction peak of primary powder boundary because only which appears in the RS/PM alloy, not in the IM aloy. However, the internal friction mechanism of primary powder boundary may not be the sliding along the interfaces. The stress relaxation between the primary powder boundaries could result in the interface damping. It is generally believed that the boundaries can be divided into two kinds of structure[6]: movable boundaries such as grain boundary and phase boundary; immovable boundaries such as primary powder boundary and inclusion boundary. Although the immovable boundaries can not slide or migrate, yet it could relax the stress by deformation of the particles.

A typical Q^{-1}-f curve is shown in Figure 3, where f is the resonance frequency of the system with a specimen. It is to be noted that the Q^{-1} of RS/PM Al-Li alloy at lower frequency (from 14—20Hz) is much less than the IM Al-Li alloy. But at higher frequency (above 20Hz), the Q^{-1} of RS/PM alloy creases rapidly. It will be seen from this that the higher frequency of resonance, the more damping capacity of the aluminium-lithium alloy. It is due to the more movability of the lithium atoms. Especially, in the RS/PM

Al-Li alloy are found more finer precipites along the three kinds of boundaries, to which second phase particles the more higher damping capacity is due.

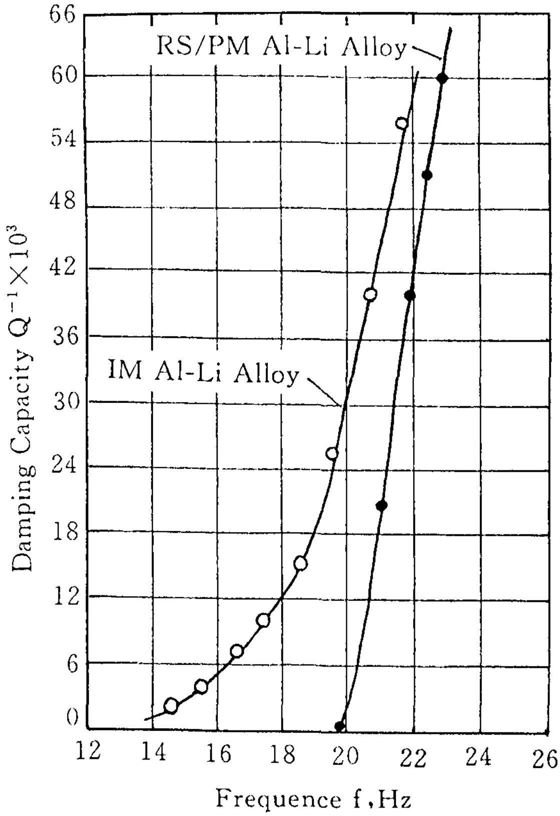

Figure 3. Variation of damping capacity with frequency of resonance in the Al-Li-Cu-Mg-Zr alloys (solution treated for 1 hr at 520℃ and nutural aging). Amplitude of vibration=0. 20mm.

Conclusion

1. Corresponding to the three interfaces (phase boundary, grain boundary and primary powder boundary) in the RS/PM aluminum-lithium alloys, the maximums of Q^{-1} appeared at 12℃, 240℃ and 410℃ respectively.

2. Comparing with the Ingot Metallurgy aluminum-lithium alloy, the gain boundary internal friction peak appeared at 240°C in the RS/PM aluminum-lithium alloy is much higher than the IM alloy. It seems to be due to the more finer precipitates along grain boundaries in the RS/PM alloy.

3. The stress relaxation between the primary powder boundaries could result in the interface damping of the RS/PM Al-Li alloy. This damping mechanism is different from the IM alloys.

4. The higher frequency of resonance, the more damping capacity of the aluminium-lithium alloy. It is due to the more movability of the lithium atoms.

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