A NEW STRUCTURAL MATERIAL FOR VIBRATION DAMPING—RS/PM Al—Li ALLOY

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ABSTRACT The RS/PM Al—Li alloy with phase boundaries, grain boundaries, interfaces between powder particles, and interfaces between the surface plated aluminum and the matrix of the alloy has been produced. The temperature spectra and frequency spectra of damping capacity of the alloy have been measured. To obtain a new stuctural material for vibration damping by using the damping effects of the multi—interfaces, the composition and the processing of the Al—Li alloy have been adjusted and optimized to have higher damping capacity and higher strength as well as higher fracture toughness.

Keywords: *structural material, vibration, interface, grain boundary, damping*

1. INTRODUCTION

Currently, the materials for vibration damping mostly are high polymers, such as foamed plastics, foam rubber and thermoplastics. But, the strength and toughnees of the polymers are not enough to have load—bearing capacity for structural components. In this case, the more attention has been paid to the metallic materials for vibration damping. They have higher strength and toughness to be used for machinery, and also have certain damping capacity to absorb the vibrating energe by themself which can be transformed into thermal energy to disspate in the air. However, the damping performance of the metals is not satisfactory, for example, their internal friction $Q^{-1}=10^{-3}\sim10^{-2}$ is much less than that of the polymers in which the $Q^{-1}=1\sim10^{2}$. Meanwhile, the temperature range of effective damping capacity of the metals is very limited only around room temperature. Therefore, the focus of studying the metallic materials for vibration damping is to increase the damping capacity and extend the effective temperature range[1,2].

Unfortunately, the obvious progress has not been made for the damping metals yet. The cause of stagnation is that all of the research projects only pay attention to a damping effect of single—interface. Then, the damping alloys of Al—Zn, Mn—Cu, Mg—Zr, Fe—Co, Fe—Cr—Al and so on have no good properties of vibration damping[3].

To obtain a new structural materials for vibration damping, the damping effect of multi—interfaces has been proposed in this paper and the RS/PM Al—Li alloy has been tested.

2. MATERIALS AND EXPERIMENTS

2.1 Composition of materials

The alloys studied in the present work were prepared from high—purity materials in argon gas atmosphere by the Beijing Research Institute of Non—Ferrous Metals. The chemical composition of the RS/PM Al—Li alloy is shown in Table1. For comparison, the compositions of two IM (Ingot Metallurgy) Al—Li alloys also are given in this table.

Table 1. The Chemical Compositions of Al—Li Alloys (wt. %)

No.	Metallurgy	Li	Cu	Mg	Zr	Ag	Fe	Si	Na, 10^{-4}	K, 10^{-4}	Al
1	RS/PM	1.50	4.80	0.40	0.10	0.40	0.10	0.12	25	10	balance
2	IM	1.50	4.80	0.40	0.10	0.40	0.10	0.12	25	10	balance
3	IM	2.57	0.96	0.36	0.15	—	0.03	0.03	3.7	4.0	balance

2.2 Experimental procedure

The process control of RS/PM Al—Li alloy is as follows: the cooling rate of the powders is 10^3—10^4K/S, the average diameter of the powder particle is about 40 μm and the all rods were plated by pure aluminum in the vaccum system as well as the extrusion rate is 34. The heat treating regimes of the RS/PM and IM Al—Li alloys are shown in Table 2.

There are four kinds of inferfaces in the RS/PM Al—Li alloy. They are: phase boundary, grain boundary, interface between the alloy powder particles, and interface between the surface plated aluminum and the matrix of RS/PM Al—Li alloy, which are shown in Figure 1.

The damping behaviour Q^{-1} and modulus E' were measured on 2×5×60 (mm) plate specimens. Through measuring the resonance frequency and damping of the system with the dynamic mechanical analyzer DMA 982, the Q^{-1} at any temperature can be determined while the measuring temperature increased from —150 to +450℃. The relation-ship is as follows:

$$Q^{-1}=\frac{C}{A}\cdot\frac{V-V_1(f-A)}{f^2-f_o^2} \quad (1)$$

Where C is the damping coefficient and A is the transverse section area of the amplitude, V and V_1 are the damping of the resonance system with or without a specimen respectively, f and f_o are the resonance frequency of the system with or without a specimen separately. By using the computer which was connected with the DMA 982, the measuring results of all specimens were given.

The mechanical properties also have been tested for the RS/PM Al—Li alloy

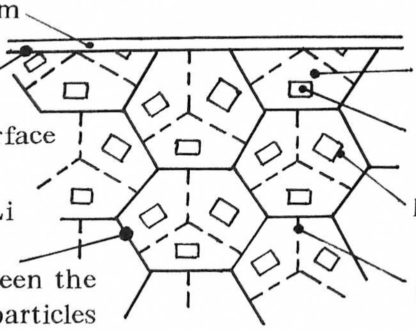

Figure 1. Four kinds of interfaces in the RS/PM Al—Li alloy

and IM Al—Li alloy. They are the tensile strength, yield strength, elongation and fracture toughness.

Table 2. The Heat Treating Regimes of the Al—Li Alloys

No.	Metallurgy	Solide solution treatment	Aging treatment
1	RS/PM	520℃/1h water cooling	Peak aging: 180℃/30h Over aging: 180℃/30h+190℃/1h
2	IM	520℃/1h water cooling	Under aging: natural aging, cold work 2%
3	IM	520℃/1h water cooling	under aging: natural aging

3. RESULTS AND DISCUSSION

3.1 Damping capacity

The experimental results are given in Figure 2. It can be seen that there are three peaks in the curve of RS/PM Al—Li alloy, which apeared at 12℃, 240℃ and 110℃ respectively.

Comparing the IM Al—Li (No. 3) with the RS/PM Al—Li (No. 1), the damping peak of grain boundary appeared at 240℃ in RS/PM alloy is much higher than IM alloy. It can be seen from Fignre 2, the damping maximum of grain boundary in IM Al—Li (No. 2) also is much less than RS/PM Al—Li (No. 1), but the corresponding temperature is at 80℃. This means that RS/PM Al—Li has much higher damping maximum of grain boundary than all of IM Al—Li alloys.

As is well known from T. S. Ke[4], the internal friction is determined by the product of the sliding distance and sliding resistance along the grain boundaries. From this point of view, the higher damping maximum of RS/PM alloy is due to the more finer precipitates along grain boundary than IM alloy. Specifically, the more finer precipitates the grain boundaries contain, the more sliding distance they have at low temperafure. Also the more finer precipitates the grain boundaries contain, the more sliding resistance they have at high temperature. So whenever temperature is, the internal friction value will be higher in RS/PM alloy. Of course, the damping capacity will reach a more higher maximum value in an intermendiate temperature. It is to be noted that the IM Al—Li (No. 2) has been cold worked in 2%, its internal friction value is the same with the IM Al—Li (No. 3) but the corresponding temperature decreased to 80℃. It seems to be due to the less stability of cold worked alloy for grain boundary sliding but there are no difference of the product of the sliding distance and sliding resistance along the grain boundaries.

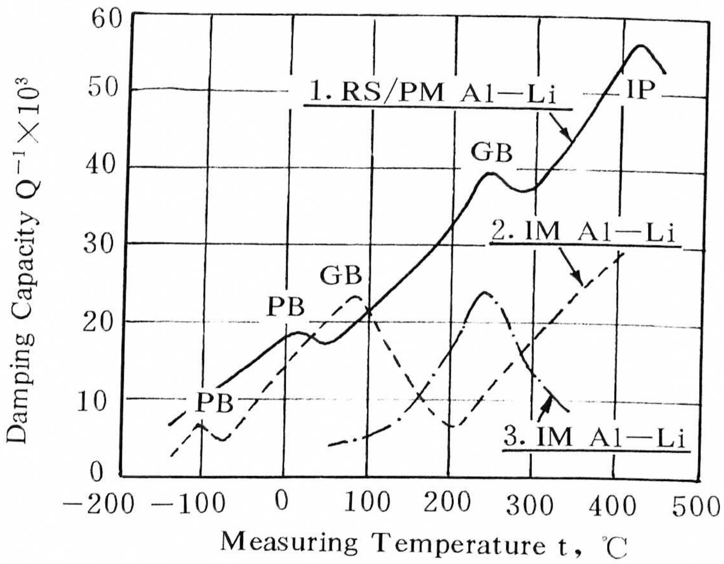

Figure 2. Variation of damping capacity with ascending temperature in the Al—Li alloys

Figure 2 also showed that the internal friction of phase boundary appeared at 12℃ for RS/PM Al—Li and appeared at −90℃ for IM Al—Li (No. 2). It can be understood that the δ′ (Al, Li) cube/cube oriented with the solide solution α (Al) formed the dislocation pinning, then the sliding along the phase boundaries should be slow—down. In this case, the infernal friction maximum is much less than that in grain bourdary. Especially, there are more dislocation pinning in the cold worked IM alloy, so the infernal friction peak is very lower and the corresponding temperature also decreased because of the unstability of cold work.

From the Q^{-1}— t curvature of RS/PM Al—Li (Figure 2), there is a maximum at 410℃ which is much higher than all others (grain boundary peak at 240℃ and phase boundary peak at 12℃). The damping mechanism of this interface between alloy powder particles could be the stress relaxation by deformation of the particles.

It can be summarized, as shown in Figure 3, the interface sliding could result in the internal friction of grain boundaries and phase boundaries while the deformation of the particles would cause the interface damping between the powder partieles by stress relaxation.

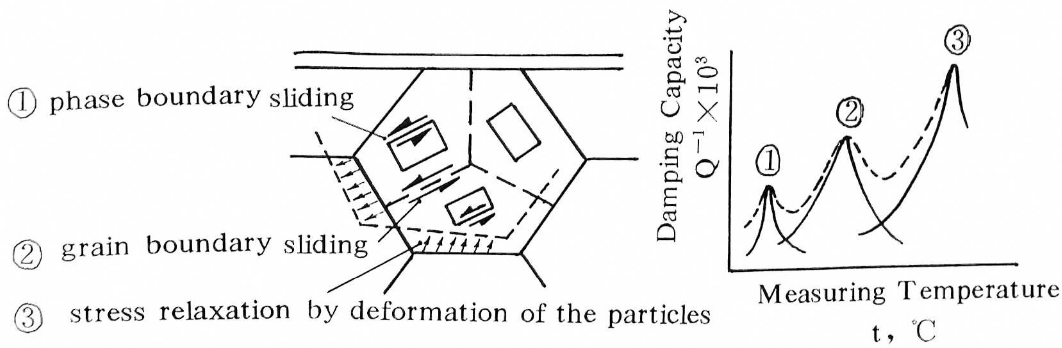

Figure 3. A Damping Mechanism of the multi—interfaces in RS/PM Al—Li Alloy

3.2 Mechanical properties

Table 3. The Mechanical Properties of RS/PM Al—Li and IM Al—Li at room temperature

No.	Metallurgy	aging time, h*	σ_b, MPa	σ_s, MPa	δ, %	K_{IC}, $MP_a\sqrt{m}$
1	RS/PM	30	615	490	10.5	21
		50	623	525	9.0	21
		80	625	540	8.0	21
2	IM	30	580	448	13.0	20
		50	593	475	12.5	20
		80	600	500	9.0	20
* 520℃/1h, water cooling, aging temperature 180℃						

The mechanical properties of RS/PM Al—Li and IM Al—Li,such as the tensile strength, yield strength, elongation and fracture toughness are given in Table 3. As compared with the IM Al—Li, the RS/PM Al—Li alloy has the same properties at room temperature. But the mechanical properties of RS/PM alloy from —150 ~ 20℃ are much better than IM alloy[5].

Summary, the RS/PM Al—Li alloy (No. 1) can be a new structual material for vibration damping because of the higher internal friction value in a wider temperature range from —90℃~450℃ and the better mechanical properties. Based on this research result, the RS/PM Al—Li could be improved and developed into more better structural alloy for vibration damping.

4. CONCLUSION

4.1 The internal friction value of the RS/PM Al—Li alloy is much higher than that of the IM Al—Li alloy.

4.2 The interface between alloy powder particles has highest internal friction which could be caused by the stress relaxation through the deformation of particles.

4.3 The interface sliding could result in the damping capacity of grain boundary and phase boundary in the RS/PM and IM Al—Li alloys. But the damping values of RS/PM alloy are much higher than that of IM alloy because of the more finer pracipitates.

4.4 From the mechanical properties and internal friction values, the RS/PM Al—Li alloy could be improved and developed into a more better structural alloy for vibration damping.

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Acknowledgements

This work was supported by the National Nature Science Foundation of China under Grant No. 59771047.