Journal of Manufacturing Engineering, March 2011, Vol. 6, Issue 2, pp 116-120

PREPARATION AND DAMPING BEHAVIOR OF A356.2/RHA COMPOSITES

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ABSTRACT

In an attempt to investigate the possibility of enhancing damping characteristics of structural metals, Rice Husk Ash (RHA) was reinforced with A356.2 alloy using Vortex method. Using this method 4%, 6% and 8% weight percent RHA composites were fabricated. Dynamic Mechanical Analyzer (DMA) is used to study the damping behavior of the as received, A356.2/RHA composites in the frequency ranging from 1Hz to 25Hz at room temperature. The results show that composites exhibit higher damping capacities than the unreinforced alloy. The related mechanisms are also discussed.

Keywords: *Damping Behavior, RHA Composites, A356.2 and Dynamic Mechanical Analyzer.*

1. Introduction

The damping capacity of a material is the fundamental property for designing and manufacturing structural components in dynamic applications. Materials with high damping capacity are very desirable to suppress mechanical vibration and transition of waves, thus decreasing noise and maintaining the stability of structural systems. Metal matrix composites (MMC's), mostly of aluminum are sensitive to vibration because of their light weight. With the increasing applications of metal matrix composites, the requirement for high damping capacity of the materials is becoming more and more important for the advanced structures. Many structural components of space vehicles and aircrafts demand materials with high specific stiffness, high specific strength and high specific damping in order to maintain high stability of systems [1, 2].

In MMCs, damping capacity can be improved through the additions of reinforcing phases that possess high intrinsic damping or that dramatically modify the matrix microstructure in such a way as to increase damping capacity [3, 4, 5, 6]. Discontinuously reinforced MMCs are particularly suitable for this purpose since these can be mass produced and also possess promising mechanical properties, and high damping capacity. SiC, Al_2O_3, and graphite are the most frequently used reinforcements in these MMCs.

In fact, most metal matrix composites have better damping capacities than the matrix alloys**.** The improvement of damping in composites can be contributed to the mechanism of increasing crystal defects in the matrix due to the incorporation of secondary phases, better damping capacities of some secondary phases, and absorption energy at the interface between the reinforcement and the matrix.

A356.2 alloys possess low density and high specific strength and stiffness, which can make them potential candidates to serve as the basis for high damping materials. However, most of the damping studies on Al MMCs have been done on systems based on 6061 Al or 2519 Al as matrices**.** This investigation aims at characterizing the damping behavior and mechanisms of damping in A356.2-RHA composites processed by stir casting technique [7, 8].

2. Experimental Work

2.1 Pretreatment of RHA

RHA particles procured from local sources contain moisture, inorganic matter and some carbonaceous material. In order free from, inorganic matter and some carbonaceous material pretreatment is done (Fig1) to RHA as discussed by S. Das, et. al [9]. The chemical composition of retreated RHA is shown in table 1.

2.2 Preparation of the composites

The matrix material model chosen for the preparation of composites is A356.2 with the chemical composition shown in table 2. Initially, A356.2 Al with the theoretic density of 2760 kg/m^3 alloy was fed into the graphite crucible and heated to about 750 ºC till the entire alloy in the crucible was melted.

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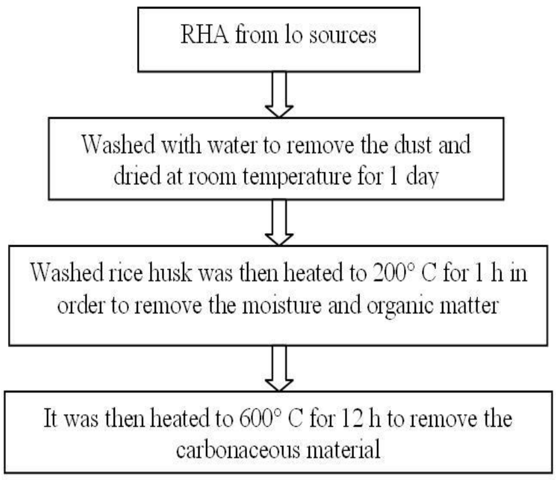

Fig. 1 Different Stages of Pretreatment of RHA

The reinforcement particles (RHA) were preheated to 800^{0}C for 1 hour before incorporation into the melt. After the molten metal was fully melted degassing tablet was added to reduce the porosity. The stirrer made up of stainless steel was lowered into the melt slowly to stir the molten metal at the speed of 500-700 rpm. The preheated RHA particles were added into the molten metal at a constant rate during the stirring time. The stirring was continued for another 5 min even after the completion of particle feeding. The mixture was poured into the mold which was also preheated to 500 ^{o}C for 30 min to obtain uniform solidification. Using this process 4, 6, and 8% by weight RHA particle-reinforced composites were produced.

Table 1: Chemical Composition of RHA

Constituent	Silica	Graphite	Cao	Mgo	K_2O	Fe_2O_3
%	90.23	4.77	1.58	0.53	0.39	0.21

Table 2: Chemical Composition of A356.2 Alloy

Si	Fe	Cu	Mn	Mg	Zn	Ni	Ti
6.5-7.5	0.15	0.03	0.10	0.4	0.07	0.05	0.1

3. Results

3.1 Microstructure analysis

JSM-6610LV Scanning electron microscope (SEM) equipped with energy dispersive X-ray analysis is used to study the microstructure of the A356.2/RHA composites. The samples for the SEM have been cut from tensile specimens and are ground by means of abrasive papers (P220, P400, P800, P1200) followed by cloth polishing. 95ml water and 5ml HF mixed solution is used as an etching agent. Good retention of Rice hush ash particles was clearly seen in the microstructures of A356.2/RHA composites.

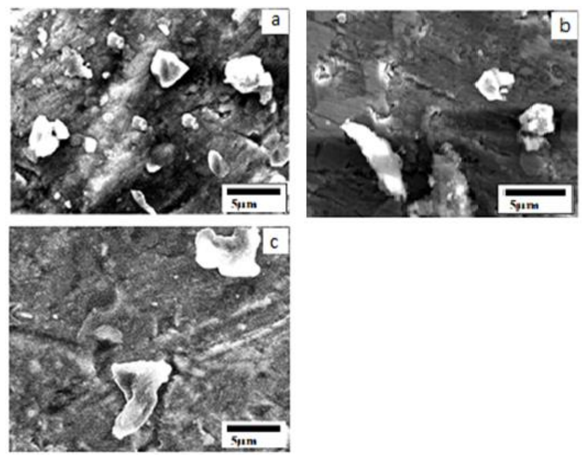

Fig. 2 Scanning Electron Micrograph of 356.2/RHA Composites (a) A356.2/8%RHA (b) 356.2/6%RHA (c) A356.2/4%RHA

3.2 Damping measurements

Many researches carried damping measurements in temperature sweep mode but the present work involves frequency sweep since the damping is to eliminate the noise and vibrations resulting from frequency in many industrial applications. In the present work damping measurements were carried out using a GABO Eplexor Dynamic Mechanical Analyzer (DMA) (Fig3). Rectangular specimens (30mmx12mmx1.5mm) were prepared by wire cut EDM for damping measurements. Tests were carried under a static load of 50N and a dynamic load of 40N at room temperature for the frequencies ranging from 1Hz to 25Hz using three-point bending testing mode. The damping capacity was determined by tan δ, where δ was the lag angle between the applied strain and the response stress. The damping capacity (tan δ) is calculated from the following relation.

$$\tan \delta = E''/ E', \qquad (1)$$

Where,

E' is the dynamic storage modulus and
E'' is loss modulus.

Fig. 3 GABO Eplexor DMA

4. Discussions

As A356.2 is a low damping material ($\tan\delta$=0.00549) which can be seen from fig4a and needs to enhance the damping capacity for many industrial applications. An attempt is made to enhance the damping capacity of A356.2 by incorporating RHA particles in the matrix. It can be clearly seen from the fig4a the damping capacity increases with the increase in the volume fraction of the reinforcement and the storage modulus increases with the addition of RHA particles but decrease with the increase in volume fraction of the reinforcement (fig4b).

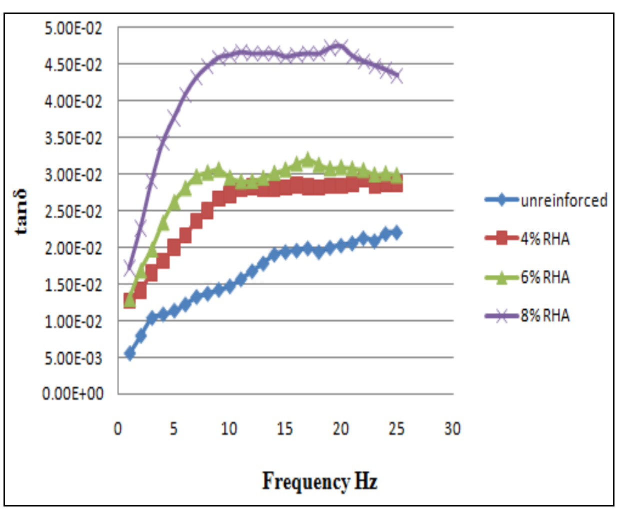

Fig. 4 (a) Comparison of Damping Capacity for Unreinforced, 4%, 6% and 8% RHA Composites

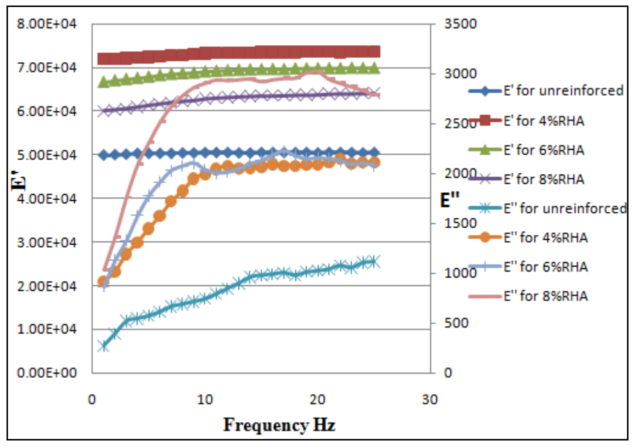

Fig. 4 (b) Comparison of E' and E'' for Unreinforced, 4%, 6% and 8% RHA Composites

4.1 Thermoelastic damping

In this mechanism, energy is dissipated through irreversible flow of heat within a material. Heat flow of the material due to stress induced thermal gradients. The thermoelastic effect may become apparent during heterogeneous deformation of materials such as bending of beams, where dissipation of energy occurs through heat flow from compressive regions to areas to the colder sections in tension. In particle reinforced MMCs, the existence of high stress concentrations around reinforcing particles may lead to heterogeneous deformations during vibration. The thermoelastic damping is related to the thermal relaxation constant Δ, and relaxation time, τ, by the following equation

$$\tan\delta = \Delta\,\omega\,\tau/\ 1+\tau^2\omega^2 \qquad (2)$$

Where

$$\Delta = E\alpha^2 T/C_v \text{ and} \qquad (3)$$

$$\tau = C_v h^2/\pi^2 k \qquad (4)$$

where E is the Young's modulus, α the coefficient of thermal expansion (CTE), T the absolute temperature, C_V the specific heat per unit volume, ω the angular frequency (ω = 2πf), h the beam thickness and k the thermal conductivity. According to Vaidya and chawla [10] and Taya and Arsenault [11] if the volume fraction is low the quantities for a particulate reinforced MMC (PMMC) are comparable to their counterparts of the matrix alloy. In the present work the maximum volume fraction taken is 0.08 (8%). Using the relevant data for A356.2 (α= $21.4\times10^{-6}/^0$C, k= 151J/sm^{0}C, C_v=963J/Kg^{0}C) E= 72.4Gpa, h=1.5mm) yields $\tan\delta$ in the order 9.1×10^{-4} at a frequency of 1Hz at room temperature which is not in good agreement with the experimental results. The extent of thermoelastic damping in particulate reinforced aluminum composites was studied by Bishop and Kinra [12]. Their results show thermoelastic damping is only significant when materials are tested above a vibration frequency of 100Hz. The present work involves frequency sweep in the range from 1 to 25Hz hence it is proposed that the increase in the damping capacity for the composites is not due to thermoelasticity.

4.2 Interfacial damping

The interface formed between a metal matrix and the reinforcement phase has been a topic of much discussion. This is because many composite properties are influenced by the nature of the interface. In a PMMC, two kinds of interfaces, strongly bonded interface and weakly bonded interface can be identified. For a strongly bonded interface, it is assumed that bonding between metal and ceramic is strong and there is no sliding between the matrix and reinforcement. When the interface is weakly bonded, sliding at the interface is more likely to occur. Interfaces between different phases in multi component material systems may offer many possibilities for vibration energy dissipation. Poorly bonded interfaces are generally expected to increase damping through frictional or columbic sliding mechanisms. Fig2a, 2b, 2c clearly shows that there is a good retention of the RHA particles but there is no good interfacial bonding between the reinforcement and the matrix, this is due to the poor wettability between the reinforcement and the matrix which results the increase in the damping capacity. Hence interfacial damping plays an important role in the present study.

4.3 Dislocation damping

Dislocation motion has been used extensively to explain damping in metallic systems at ambient temperatures. This mechanism is based on the principle of dislocation motion lagging behind applied stress. A mathematical model describing dislocation damping was developed by Granato and Lucke [13, 14]. In this model, dislocations are perceived as vibrating strings with ends pinned by defects in the crystal. At low vibration frequencies, the movement of a segment of dislocation is modeled after the equation of motion of a vibrating string. An expression [15] for this low frequency damping for dislocations with average pinning length (l) is expressed as in Equation 4.

$$\tan\delta = \Lambda B l^4 \omega / 36 G b^2 \qquad (5)$$

Where B is a viscous drag coefficient, l is average pinning length and Λ is the dislocation density. G and b are the shear modulus and Burgers vector respectively. The scenario is slightly different at high vibration frequencies. Dislocations break away from weak pinning points over a critical stress and sweep bigger areas. This motion leads to increased energy dissipation. The amount of damping predicted by this mechanism [16] is equal to,

$$Q^{-1} = C_1/\varepsilon_0 \exp(-C_2/\varepsilon_0) \qquad (6)$$

ε_0 is the strain amplitude, C_1 and C_2 are material constants which depend on the anisotropy of the material elastic constants, the orientation of specimen with respect to applied stress, the size of pining solute atoms, the lattice parameter of specimen and the dislocation density. Dislocation damping is expected to be high in PMMCs because of increased dislocation density at the matrix-reinforcement interface. Due to the big difference in coefficient of thermal expansion (CTE) between the matrix ($21.4x10^{-6}/^0C$) and reinforcement ($10.1x10^{-6}/^0C$), dislocations are sometimes generated when composite cools from high processing temperature to accommodate high residual mismatch strains.

5. Conclusions

RHA, industrial waste product was successfully incorporated in to the molten aluminum alloy through vortex method. Good retention of RHA particles can be seen from the microscopic analysis. Dynamic Mechanical Analyzer is used to study the damping behavior of as received and different weight fraction (4%, 6% and 8%) of RHA reinforced composites. Composites exhibit higher damping capacity than the unreinforced alloy and increases with the increase in weight percent of the reinforcement. The damping mechanism ascribed to dislocation and interfacial damping.

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Acknowledgments

The authors would like to thank **GITAM University**, **Visakhapatnam** for its financial support under Minor Research Scheme.

Nomenclature

E' dynamic storage modulus
E" is loss modulus
E is the Young's modulus,
α the coefficient of thermal expansion (CTE),
T the absolute temperature,
C_V the specific heat per unit volume,
ω the angular frequency

