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Damping behavior of commonly used reinforcement powders – An experimental approach

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ABSTRACT

With the advancement of composite technology, the selection of proper reinforcement in the matrix becomes vital, especially to enhance the damping capacity in metal matrix composites. The overall damping capacity of the composites greatly depends on the reinforcement used and is proportional to the individual damping capacities of the reinforcement. This paper is concerned with the measurement of damping behavior in elemental rice husk ash (RHA), fly ash (FA), silicon carbide (SiC) and graphite (Gr) powders. The damping measurements were carried on dynamic mechanical analyzer (DMA) at different frequencies of 0.1, 1 and 10 Hz over a continuous heating temperature from room temperature to 150 °C. The storage modulus and damping capacity were analyzed. The related mechanisms were discussed and presented.

1. Introduction

Good damping characteristics are very much enviable to suppress mechanical vibrations. The selection of materials exhibiting good damping along with high specific stiffness and high specific strength becomes vital. The damping capacity reflects the ability of a material to dissipate mechanical energy during vibration. Thus a material with high damping capacity will be able to reduce the vibration amplitude significantly. Aluminum, magnesium and their alloys possess excellent mechanical properties, but the damping properties were found to be stumpy, and hence composite technology is gaining its importance in recent days. Composite materials using high-strength and high-stiffness reinforcement phase in a suitable matrix are finding increasing usage in aerospace, military, automotive and sports industries. Among them, metal-matrix composites (MMCs) constitute a new class of materials that exhibits good mechanical properties in terms of stiffness, strength, hardness and wear resistance [1–3] compared to that of polymer based composites. In particular, the damping capacity in MMCs is high compared to the damping capacity of the parent materials [4]. The overall damping capacity of the composites greatly depends on the reinforcement used and is proportional to the individual damping capacities of the reinforcement which can be found using the rule of mixtures.

The effect of SiC and graphite particulates on the damping behavior of metal matrix composites has been investigated by Zhang et al. [5]. They demonstrated that the damping capacity of aluminum alloy was significantly improved by the addition of either SiC or graphite particulates. Wang et al. [6] showed that the addition of SiC particles in the aluminum alloy clearly increases the damping characteristics compared to the monolithic material. Wei et al. [7] pointed out that the damping capacity of the macroscopic graphite particulates reinforced pure aluminum composite is increased with a larger volume fraction of the reinforcements. However, this is accompanied with a decrease in dynamic modulus. Rohatgi et al. [8] investigated the damping capacity of graphite and silicon carbide particulate reinforced aluminum alloy composites. The damping capacity of graphite/Al alloy composites increased with the volume percentage of graphite within the range studied. However, no obvious improvements in damping capacity were observed by dispersion of silicon carbide in aluminum alloy.

In recent days, the utilization of waste byproducts as a secondary reinforcement has gained significant importance due to the increased properties. Among them, fly ash, an industrial waste and rice husk ash, an agricultural waste are available abundantly

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throughout the world and is being utilized by several researchers especially to enhance the damping properties of the base alloy. Prasad et al. [9] studied the damping behavior of rice husk ash reinforced A356.2 alloy. They observed that the damping behavior increases with the increase in the rice husk ash content. Experimental results of Sudarshan et al. [10] showed that the addition of fly ash in A356 alloy exhibited improved ambient temperature damping capacity. Wu et al. [11] studied the damping behavior of hollow sphere fly ash reinforced A6061 alloy. The results indicate that the damping capacity of the composites with a smaller reinforcement diameter is higher than that with a larger reinforcement diameter. A detailed review on the damping behavior of metal matrix composites has been presented by Prasad and Shoba [12], with more emphasis on type and size of different reinforcements. Finally, they demonstrated that composites are a better choice which simultaneously exhibits good mechanical properties and high damping capacity.

The damping properties of iron and graphite powders have been studied by Lian et al. [13]. Their results confirmed that the damping capacity of pure iron powders changes slowly at low strain amplitudes, increases at threshold strain amplitude, reaches a maximum, and then decreases. A similar trend has been observed for graphite powders and mixtures of graphite and iron powder composite. The damping behavior of nano-structured copper was carried by Srikanth et al. [14]. They considered elemental Cu powder with mechanically milled to obtain nano powder and elemental Cu powder with micro size and consolidated by die-cold compaction, to study the damping behavior. They observed that the damping capacity of the nano-grained material increases due to the changes in the microstructure.

From the above literature, one can see the importance of the reinforcement in enhancing the damping behavior of alloys. Hence, the selection of proper reinforcement plays a crucial role in improving the overall damping capacity in MMCs. The present study aims at finding the damping behavior of elemental RHA, FA, SiC and Gr powders using dynamic mechanical analyzer at different frequencies over a continuous heating temperature from room temperature to 150 °C.

2. Experimentation

In the present study, elemental RHA, FA, SiC and Gr powders with an average size of 25 μm, 35 μm, 37 μm and 49 μm were considered for damping measurements. SiC and Gr powders are procured from Otto Chemie Pvt. Ltd., Mumbai, whereas RHA and FA powders are procured from local sources. Before the damping measurements pre-treatment was done to RHA and FA particulates to free from inorganic and carbonaceous material. Initially, rice husk was thoroughly washed to remove the dust and then dried at room temperature for 1 day. To remove the moisture, rice husk was heated to 200°C–300 °C for 1 h. It was then heated to 600 °C for 12 h to remove the carbonaceous material. The color of rice hush changes to grayish white after this operation. Similar treatments have performed to fly ash. The RHA and FA thus obtained are used for damping measurements. The chemical composition of RHA and FA are presented in Tables 1 and 2 respectively. Perkin Elmer dynamic mechanical analyzer (Model: DMA 8000) is used to find the damping behavior, at three different frequencies of 0.1, 1 and 10 Hz over a continuous heating temperature from room temperature to 150 °C using single cantilever method. Tests were carried under a static load of 2 N, a dynamic load of 2 N and a constant strain of 0.010%. The particulates were filled in a rectangular plate of 12.7 × 7.4 × 1.34 mm for all the experiments. The experimental setup is shown in Fig. 1. In the present study, the measure of damping capacity utilized is loss tangent, tanδ. The calculation of the loss tangent and dynamic modulus by the DMA is based on the following forced vibration equation.

Table 1
Chemical composition of RHA (wt%).

Silica	Graphite	Calcium Oxide	Magnesium Oxide	Potassium Oxide	Ferric Oxide
90.23	4.77	1.58	0.53	0.39	0.21

Table 2
Chemical composition of FA (wt%).

Silica	Aluminum oxide	Calcium Oxide	Ferric Oxide
67.2	29.6	1.4	0.1

$$M\frac{d^2x}{dt^2} + \left(\eta_v + \frac{S''}{\omega} + \frac{kE''}{\omega}\right)\frac{dx}{dt} + (S' + kE')x = F_p \sin \omega t \tag{1}$$

where M denotes the vibrating system mass, η_v is the viscous damping term, S' and S'' represent the complex stiffness of the suspension, k is the sample geometry factor, both E′, storage or dynamic modulus, and E″, loss modulus refer to the real and the imaginary parts of the complex module of specimen respectively, x is the deflection at the driver end of the sample at which the external force $F_p \sin\omega t$ is applied. The DMA gives rise to the solution to kE′ and kE″. The damping capacity in terms of loss tangent (tanδ) or loss factor (η), is accordingly from

$$\tan\delta = \eta = \frac{E''}{E'} \tag{2}$$

JSM-6610LV scanning electron microscope (SEM) equipped with energy dispersive X-ray analyzer (EDX) is used to study the microstructure of the rice husk ash and fly ash particulates.

3. Results

3.1. Microstructural characterization

Microstructural characterization was done to FA and RHA particulates in order to study the shape of the particles. Fig. 2a,b and c show the scanning electron micrograph of FA and RHA and SiC particulates respectively. It is observed that the FA particles are found to be spherical in shape (Fig. 2a) and some of the RHA particles have hull like shape (Fig. 2b). From Fig. 2c it can be observed that the SiC particulates have sharply faceted geometry with irregular shaped particulates.

3.2. Damping capacity and storage modulus at 0.1 Hz

Fig. 3a shows the variation of damping capacity for FA with the temperature at 0.1 Hz. It could be observed that, FA exhibit maximum damping capacity at this frequency and found to decrease with the increase in temperature. A maximum value of 0.070 at room temperature and a minimum of 0.050 at 150 °C has been noticed. The damping capacity of SiC particulates was found to increase with the increase in temperature. The damping capacity of SiC ranges from 0.053 to 0.070 during the temperature range from 35 °C to 150 °C. The damping capacity of RHA and graphite particulates were found to be almost constant with temperature indicating there is no/marginal effect on the damping behavior of theses powders with the temperature at 0.1 Hz. However, graphite particulates exhibit more damping capacity than RHA particulates