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# Damping capacity and dynamic modulus of hot pressed AlSi composites reinforced with different SiC particle sized

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ABSTRACT

The effect of SiC particle size on the resultant damping capacity and dynamic modulus of aluminum metal matrix composites (AMMCs) was studied. Damping capacity, as well as dynamic Young's modulus, was measured at 1, 10 and 20 Hz, at room temperature. Image analysis and chemical composition were performed in order to investigate the AlSi–SiC interfacial reaction. The damping capacity of AlSi–$SiC_p$ composites, with three different particle size, was compared to AlSi unreinforced. The damping mechanisms involved were discussed in light of the results obtained from damping capacity. The results show that damping capacity and dynamic modulus of AlSi can be improved through the addition of SiC particles. Further, through a selection of specific sizes of SiC particles, it is possible to tailor the final composite stiffness and damping capacity.



## 1. Introduction

In dynamic systems and under strong acceleration and high speed, the structures can experience a high vibration level which cause undesirable high noise level and human discomfort (e.g. vehicle) [1]. Consequently, in structural applications (e.g. aerospace and automotive industries), noise reduction and attenuation of vibration have become important issues [2–6]. Rao [6] reported that the use of damping materials is a means to reduce vibration and noise.

The damping capacity is the ability of material to dissipate elastic strain energy [2,3,7], through atomic level interactions; vacancy diffusion; and dislocation and grain boundary motion [8]. Hook's law assumes that when loading/unloading a material, the applied load and the consequent deformation are perfectly in phase (throughout time). This is valid for quasi static conditions, but not exactly so for higher frequencies [9] and temperatures [10]. Therefore, under cyclic loading, damping capacity relates to the deviations to Hook's law, manifested by stress–strain hysteresis [9], noticeable by a loop in the stress–strain diagram. The area enclosed by this hysteresis loop (Fig. 1a), during one cycle, corresponds to the dissipated energy – a measure of the damping capacity [9]. Due to this fact, during a cycle, the strain curve is behind the stress curve (with an offset measured by $\phi$ – loss angle (Fig. 1b)) [9].

In fact, metals and alloys respond to an applied load by instantaneous elastic strain (time-independent) but also by an anelastic (relaxation) strain (time-dependent). This phenomenon relates to localized rearrangements of atoms and deformation propagation [9]. While at room temperature these atomic displacements are typically fractions of an atomic diameter, at high temperatures these can be extensive.

Regarding structural applications there is an increasing demand of materials possessing high damping capacity combined with high stiffness and low density [1]. Automobiles roof, hood and dash panels; wheelhouses; cargo bays and upper cowl, all in automotive industry, are possible components where these materials can be used.

Aluminum (Al) alloys have low damping capacity [11], but their increasing use, due to their light weight and specific mechanical properties [3,12,13], in the automotive industry has promoted the development of aluminum–metal matrix composites (AMCs) for damping applications. In fact, it has been reported that the introduction of ceramic particles in an Al matrix has proven to be beneficial for damping capacity as for mechanical properties [1,14–16].

Among widely used reinforcements, silicon carbide (SiC) and alumina ($Al_2O_3$) have been studied with aim of mechanical properties improvement [11]. Besides strength and modulus

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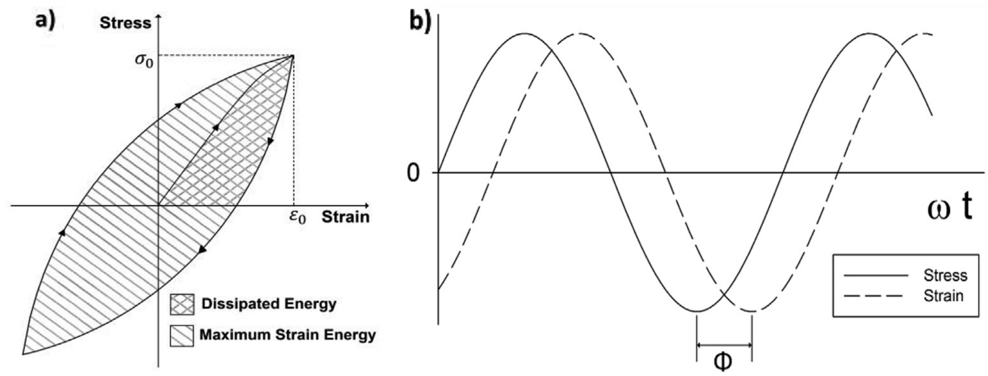


**Fig. 1.** a) Hysteresis curve for a non-linear material [8] and b) cyclic stress and strain [9].

increase by addition of silicon carbide particulates ($SiC_p$) a damping capacity improvement in Al alloys has been found when compared to the unreinforced Al alloy [1,17]. Additionally, Zhang and co-workers [18] showed that a damping capacity improvement can be achieved by adding other reinforcement (creating a hybrid composite).

Matrix composition, structure [19] and grain size [7] as well as the reinforcement shape, composition and volume fraction [12] strongly influence the damping behavior of these composites. The individual influence of each of these factors in the damping capacity is complex to detail and depends on several aspects, like strain amplitude, frequency and temperature [7]. Phase boundaries, grain boundaries, reinforcement/matrix interface and dislocations have also an important influence on damping [19]. In fact, studies on AMCs reported that ceramic particles lead to a damping behavior improvement at low temperatures, by increasing the dislocation density in the matrix [3,7,13].

This work is concerned with the influence of $SiC_p$ size in the damping capacity and dynamic modulus of SiC-reinforced aluminum–silicon (AlSi) composites, produced by a powder metallurgy (PM) process – hot pressing. These properties were obtained by performing Dynamic Mechanical Analysis (DMA) measured at frequencies: 1, 10 and 20 Hz, at room temperature. To the author's knowledge no previous study regarding damping capacity and dynamic modulus of AlSi–$SiC_p$ composites was performed regarding the use of a hot pressing method. It is known that this process provides specific properties on the obtained material namely on the porosity and metal-ceramic adhesion. Moreover the SiC particle size, in the size range of 13, 38.8 and 118 μm, was not studied as well.

## 2. Experimental procedure

### 2.1. Fabrication of AlSi–$SiC_p$ composites

Three different SiC particle-reinforced AlSi composites were produced by hot pressing route: AlSi–$SiC_p$ (13); AlSi–$SiC_p$ (38.8) and AlSi–$SiC_p$ (118).

Aluminum–Silicon (AlSi) spherical powder, with maximum particle diameter of 45 μm, was used as matrix. The chemical composition is listed in Table 1.

**Table 1**
Chemical composition of AlSi alloy (according to manufacturer).

| Element | Al | Si | Fe | Cu |
|---|---|---|---|---|
| wt% | 88.352 | 11.5 | 0.145 | 0.003 |

SiC particles with average diameter of 13, 38.8 and 118 μm were used (separately) as reinforcement. The same $SiC_p$ volume fraction: 8.6 vol.% was used for all these composites.

AlSi powder and SiC particles were mechanically mixed in a blender for 20 min. The obtained powder mixture was divided and placed inside graphite moulds, with 8 mm width and 43 mm length. Then, AlSi–$SiC_p$ samples were sintered by means of pressure-assisted sintering process (hot pressing), in vacuum ($10^{-2}$ mBar), using a high frequency induction furnace (schematically represented in Fig. 2).

The mould (and the powder mixture) was then placed inside the chamber, where the sample was initially compressed at 1 MPa and heated up to 500 °C, with a heating rate of 25 °C/min. When the temperature reached 500 °C the pressure on the samples was raised to 35 MPa (while the heating proceeds at 25 °C/min till 550 °C). The sample was maintained at 550 °C during 15 min under a pressure of 35 MPa. Afterward, the samples were cooled inside the mould, in vacuum, till room temperature. The obtained samples had average dimensions of: 3.4 × 8 × 42 mm.

Unreinforced AlSi samples were also produced for comparison purposes.

### 2.2. Microstructural and chemical characterization

The chemical composition of the obtained composites was carried out by means of *Scanning Electron Microscopy* (SEM) with *Energy Dispersive Spectrometer* (EDS). The analysis of SiC particles distribution on the AlSi matrix and interfacial reaction were performed by SEM.

### 2.3. Dynamic mechanical analysis (DMA)

The AlSi–$SiC_p$ and AlSi obtained specimens were prepared and cut in order to have 3 × 2 × 42 mm dimensions for DMA tests. These tests were performed in a Dynamic Mechanical Analyzer (DMA Q800, TA Instruments) using single cantilever testing mode (Fig. 3).

Room temperature DMA tests were performed for three frequencies: 1, 10 and 20 Hz, using constant strain amplitude.

There are several quantities to characterize damping capacity. In this work, damping capacity is evaluated in terms of tan delta and can be calculated according to:

$$\tan\phi = \frac{E''}{E'} \tag{1}$$

where $E'$ is the storage modulus, corresponding to the stiffness of the material, being proportional to the energy stored during a cycle