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Comparative Evaluation of the Damping Capacity of As-cast and t6 Temper a 356-sic AMMCS

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Abstract

The paper discusses the response to free vibration and also to forced vibration of the A356-SiC AMMCs in the as-cast and T6 temper conditions for the comparative assessment of the damping capacities. The base A356 aluminium alloy and seven A356-SiC composites with SiC percentage ranging from 2% to 12% were stir cast and cantilever specimens of 180 mm length were tested for their frequency and amplitude responses. From the results obtained, it was concluded that the A356-SiC composites with 8% SiC and 3% SiC in the T6 condition could be favourably considered as candidate materials for diesel engine parts in the automotive industry.

Keywords: *A356, SiC Particulates, AMMCs, Damping Ratio, T6 Treatment*

1. Introduction

The A356 and A357 series of aluminium alloys, possessing excellent castability, high strength-to-weight ratio and good welding (repair) characteristics are the preferred materials for automotive parts like pistons and engine blocks. By making particulate composites with reinforcements like SiC, Al_2O_3 and graphite, the desired properties for specific applications can be enhanced. In this paper, the reinforcement particulate SiC (100 μm), 2 to 12% was added to the A356 base alloy to obtain composites by the stir-casting technique.

In many applications, especially in the automotive industry, the materials used for making components have to satisfy the conditions of possessing good damping capacity (damping ratio), reasonably low amplitudes and frequencies at peak response. Mevada and Patel (2016) investigated structural damping under free vibration using computer software for assessment of relative damping ratios of different materials. The effect of T6 heat treatment on the damping behavior of AMMCs was analyzed by Prasad and Ramakrishna (2012) using a dynamic mechanical analyzer. Alaneme and Fajemisin (2018) investigated and compared the damping behaviours of composites of Al-Mg-Si alloy with 6 and 8% steel particles to the hybrid composites with 6 wt% steel, 2 wt% graphite and 8 wt% SiC particles. They found variation in damping properties with changes in test temperatures. Prasad and Shobha (2016) attempted to determine the damping mechanism in AMMCs with

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varying wt % of rice husk ash using a dynamic mechanical analyser. Zhang *et al.* (2005) investigated the damping capacity of A356 alloy after grain refinement. Zhang *et al.* (1993) also investigated the damping behavior of Al 2519 composites with many particulates and concluded that the composites having graphite powder as a constituent were superior in damping. Many researchers have conducted experiments to assess the damping characteristics of various aluminium alloys and their composites; however the literature is scanty in respect of studies carried out on the A356-SiC particulate composites. The objective of the present study was therefore to determine the damping characteristics of the A356-SiC composites, and to make a comparative evaluation of damping characteristics of this composites in the as-cast and T6 temper conditions.

2. Materials and Methods

A356-SiC composites with 2, 4, 6, 8, 10, and 12% SiC (100 μm) were prepared through the stir-casting route into finger moulds (180 mm L, 20 mm dia). The specimens for damping tests (180 mm L x 15 mm W x 3 mm Thk) were cut from the castings by the wire cutting technique. The designations used in this paper for the base alloy and composites are shown in Table-1.

Table 1. Designation of A356 base alloy and composites

Sl tno	% SiC	Designation of Alloy/ Composites
1	0	C1(As Cast A356)
2	0 +GM+GR	C2
3	2	C3
4	4	C4
5	6	C6
6	8	C8
7	10	C10
8	12	C12

2.1 Damping Measurements

The cantilever specimens were used in a damping experimental set-up shown in Figure 1. The damping specimens are shown in Figure 2.

Damping tests were carried out using both the frequency domain approach and the time domain approach. The damping specimen in the test arrangement had a single degree of freedom (SDOF) and hence all the responses were for SDOF. From the tests conducted on the eight compositions in the as-cast and T6 treated condition, two types of graphs were generated (the testing arrangement had a digital connection with a computer):

Figure 1. Damping test arrangement.

Figure 2. Damping test specimen.

1. Amplitude vs. Time graphs for free vibration responses for as-cast and T6 temper conditions.
2. Amplitude vs. Frequency graphs for forced vibration responses for as-cast and T6 temper conditions.

32 graphs were thus generated in total.

3. Results and Analysis

3.1 Free Vibration Responses

The free vibration responses at SDOF for C1 (base alloy A356), C3 (A356+2% SiC) and C8 (A356+8% SiC) in the as-cast condition are shown in Figures 3, 4, and 5. Similar graphs for these compositions in the T6 temper condition are shown in Figures 6, 7, and 8 (other graphs have been omitted from the paper for reasons of brevity).

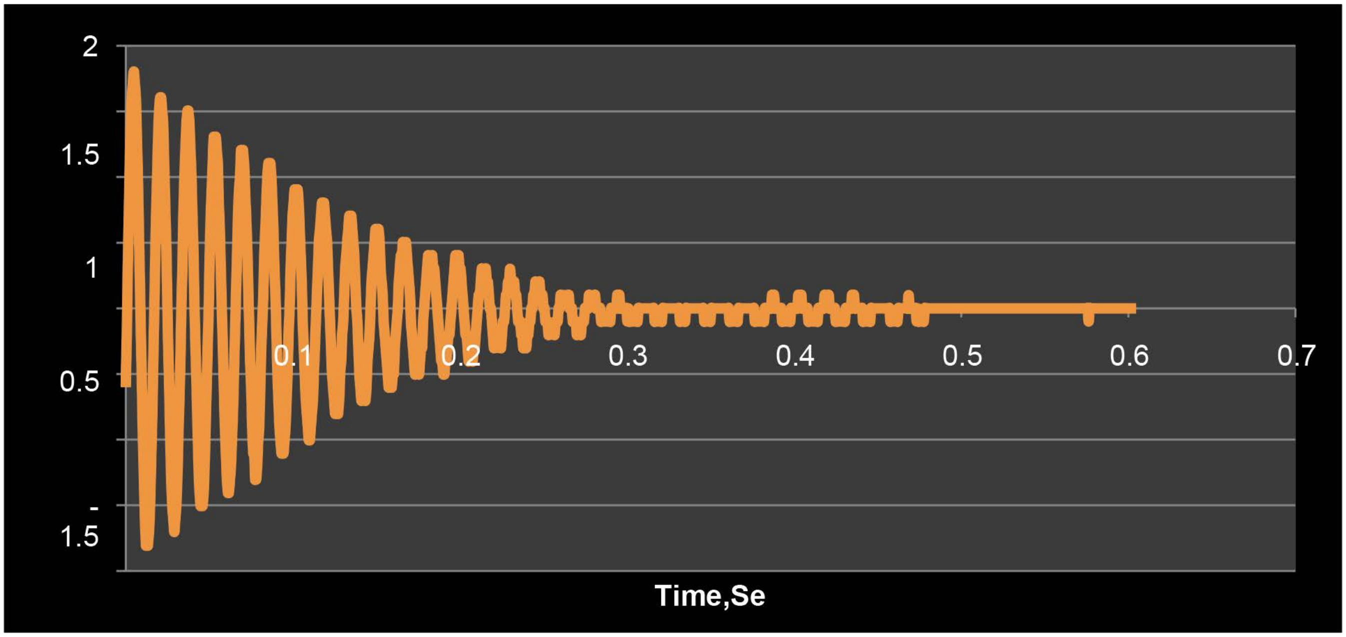

Figure 3. Free vibration response at SDOF for C1 (As-Cast).

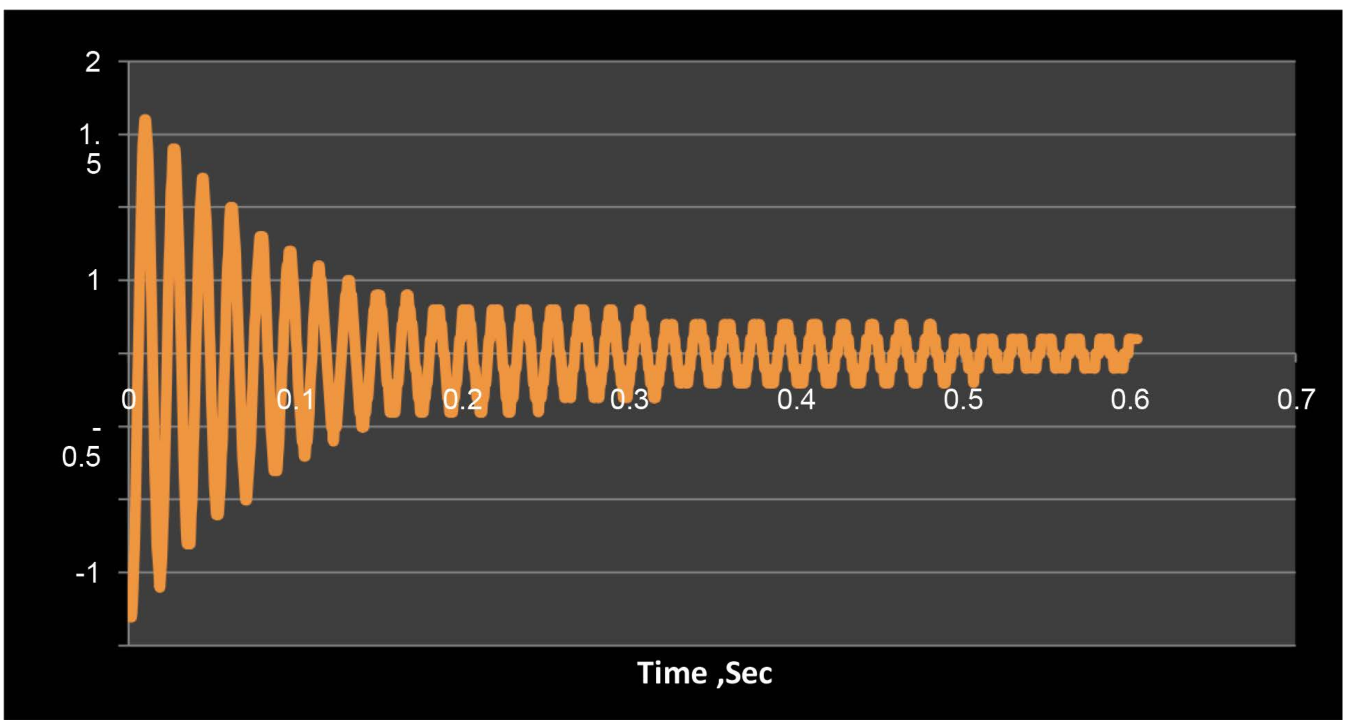

Figure 4. Free vibration response at SDOF for C3 (As-Cast).

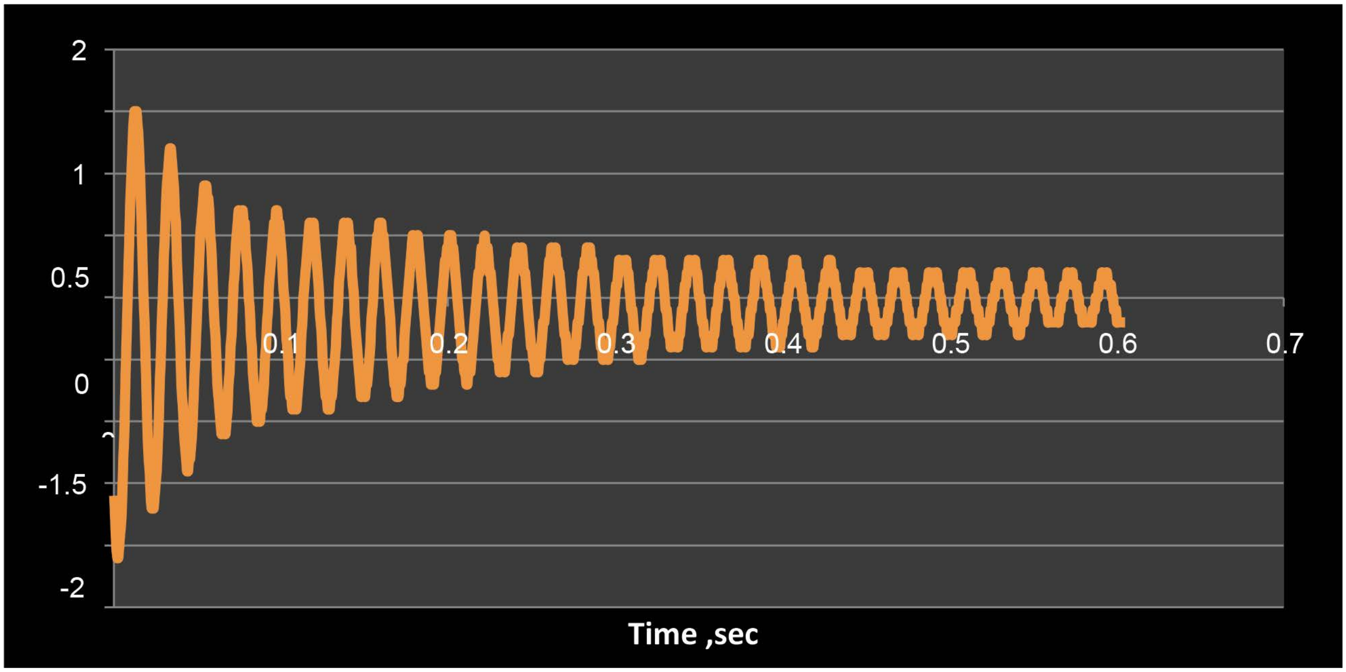

Figure 5. Free vibration response at SDOF for C8 (As-Cast).

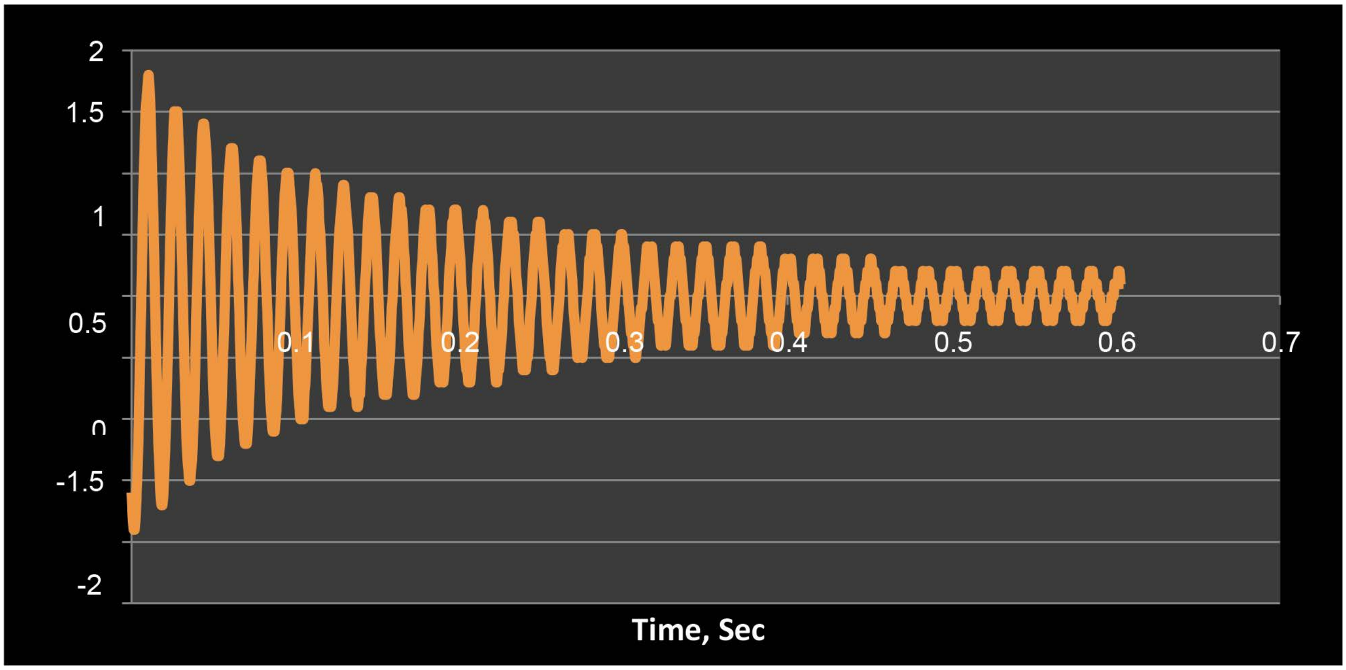

Figure 6. Free vibration response at SDOF for C1 (T6 Temper).

The damping ratios for all the 16 graphs (6 shown in the paper and 10 not shown) were calculated using the formula [xxx]:

$$\boldsymbol{\delta = \ln X_1/Xn} \qquad \text{eq. (1)}$$

where,

δ is the logarithmic decrement, and

X_1/Xn is the ratio of two successive amplitudes

The damping ratio, **ξ**, is calculated knowing the logarithmic decrement:

$$\boldsymbol{\xi = \delta\ \pi} \qquad \text{eq. (2)}$$

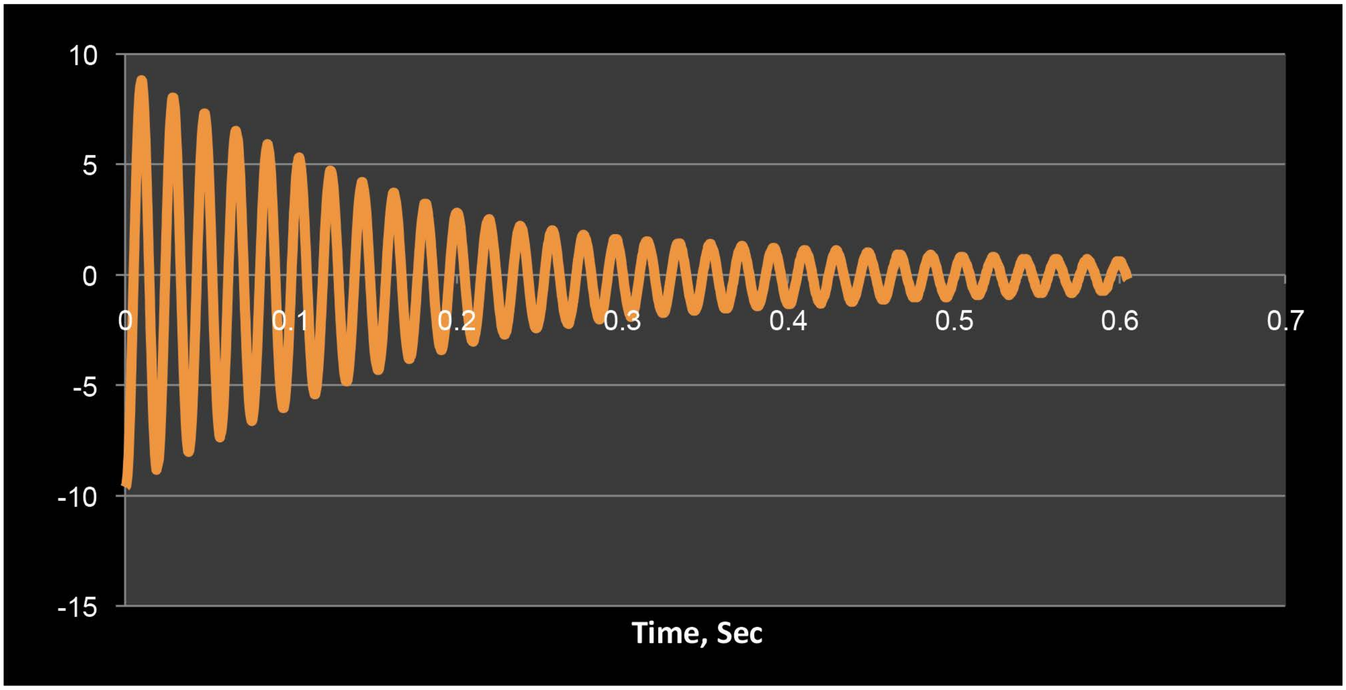

Figure 7. Free vibration response at SDOF for C3 (T6 Temper).

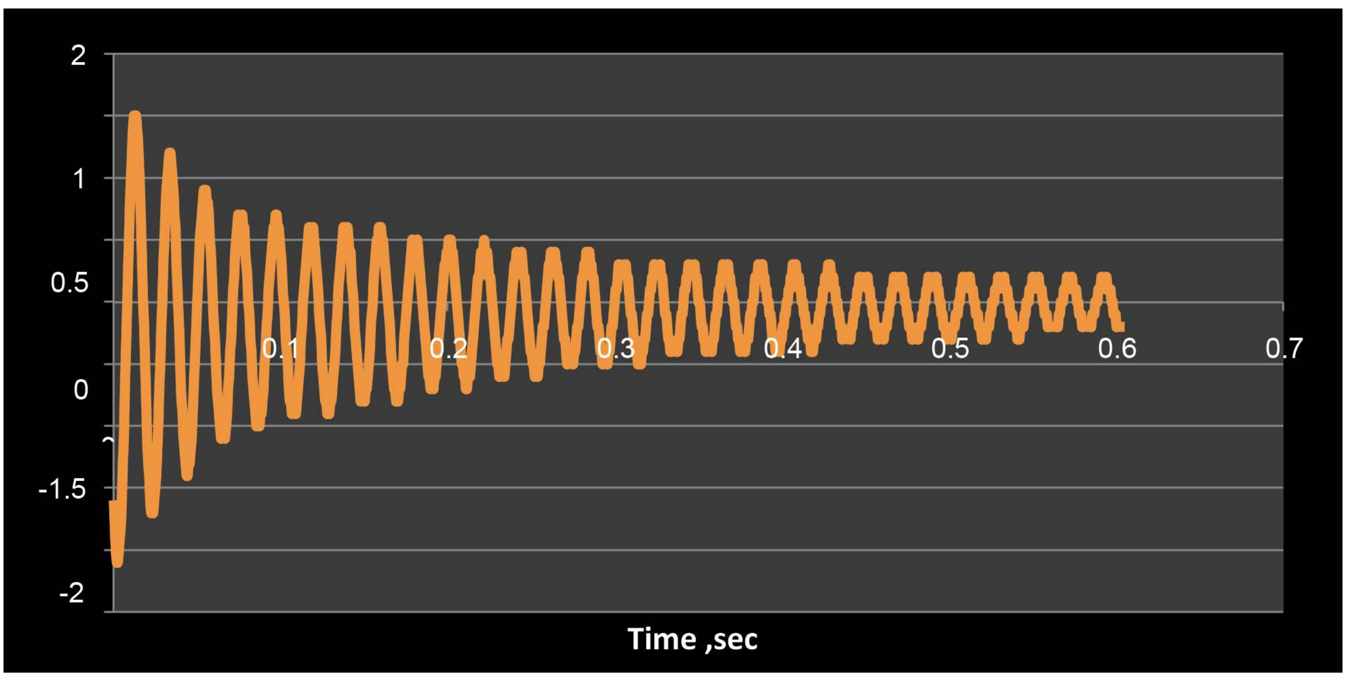

Figure 8. Free vibration response at SDOF for C8 (T6 Temper).

the damping ratios calculated in the manner described above are tabulated in Table- 2.

It is observed from Table 2 that the as-cast A356 alloy and its composites have higher damping ratios than the T6 tempered ones (on average about 1.64 times higher). Since high damping ratio is a desirable property for automotive components, it can be inferred that the as-cast composites with 64% higher damping ratio may be better suited for such applications. However, since the T6 tempered alloy and composites have superior mechanical properties,

Table 2. Values of damping ratios of A356 alloy and its composites

Alloy Designation	Damping ratio (ξ)		ξ (T6)/ ξ(As-Cast)
	As-Cast Condition	T6 Temper Condition	
As cast alloy C1	0.026	0.0107	0.412
C2	0.0243	0.004088	0.168
C3	0.02757	0.01838	0.667
C4	0.02205	0.01033	0.468
C6	0.02092	0.01443	0.690
C8	0.028112	0.01880	0.669
C10	0.01626	0.0157575	0.969
C12	0.01775	0.01484	0.836

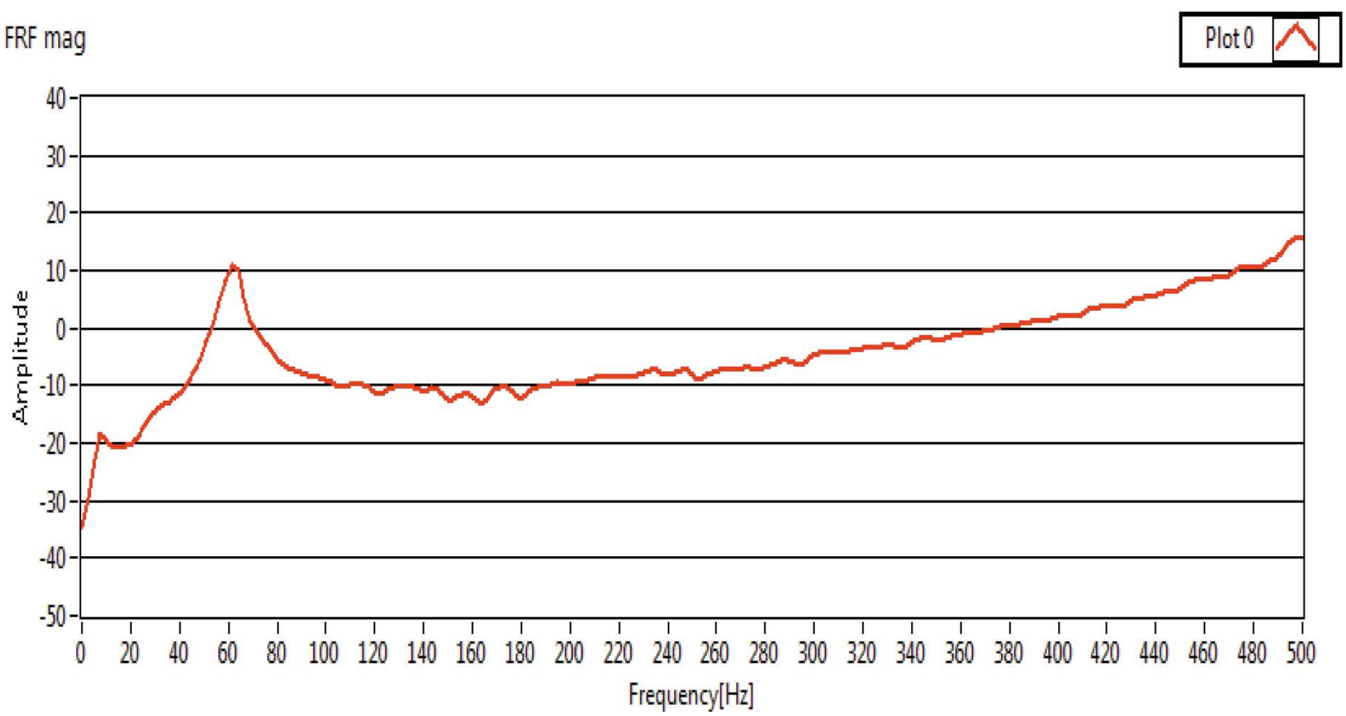

Figure 9. Forced vibration response at SDOF for C1 (As-Cast).

they will be preferred. Of the T6 tempered composites, C3 and C8 have the highest damping ratios and may be options for automotive components.

3.2 Forced Vibration Responses

The forced vibration responses at SDOF for C1 (base alloy A356), C3 (A356+2% SiC) and C8 (A356+8% SiC) in the as-cast condition are shown in Figures 9, 10, and 11. Similar graphs for these compositions in the T6 temper condition are shown in Figures 12, 13, and 14 (other graphs have been omitted from the paper for reasons of brevity).

From Figures 9–14, two parameters are extracted, (i) the amplitude at peak response, and (ii) the frequency at peak response. The values of amplitude and frequency derived from all the 16 graphs (6 shown in this paper and 10 not shown) are recorded in Table 3.

It is seen from Table 3 that the amplitudes at peak response are quite low (<25 Hz) for both the as-cast and T6 tempered conditions. The frequencies at peak response lie in the range 46-62 Hz. The normal frequencies encountered in the automobiles is slightly higher for petrol engines (60-100 Hz), while for the diesel-based systems, the normal operating frequencies are much less

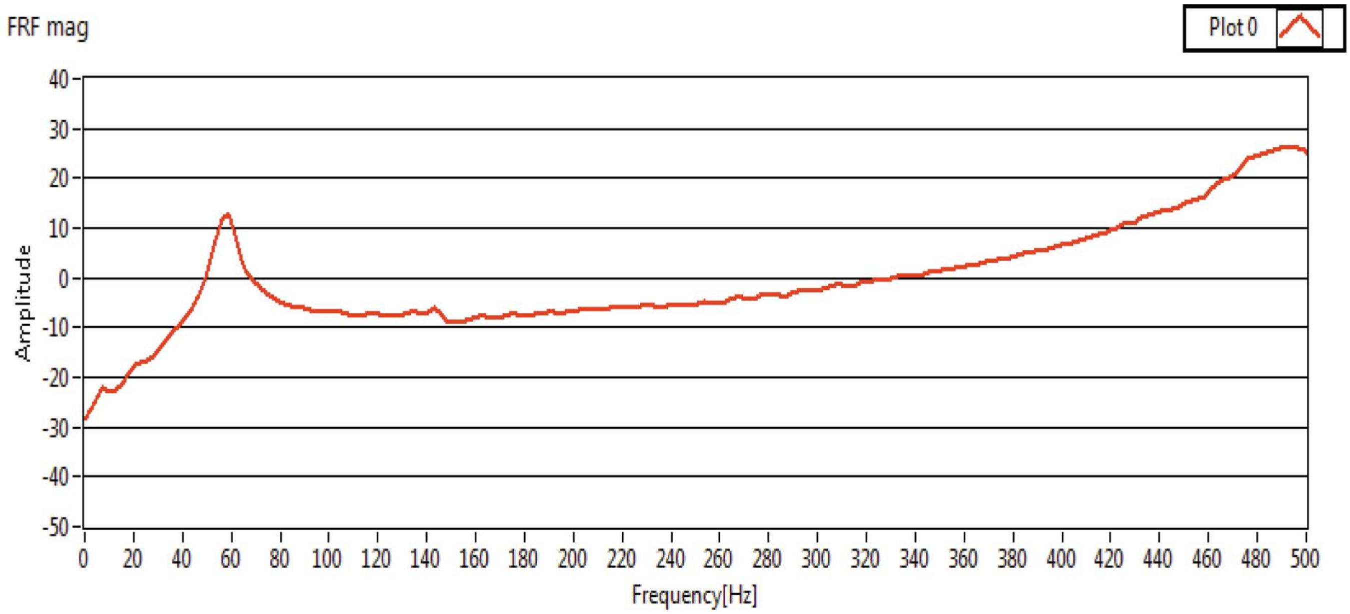

Figure 10. Forced vibration response at SDOF for C3 (As-Cast).

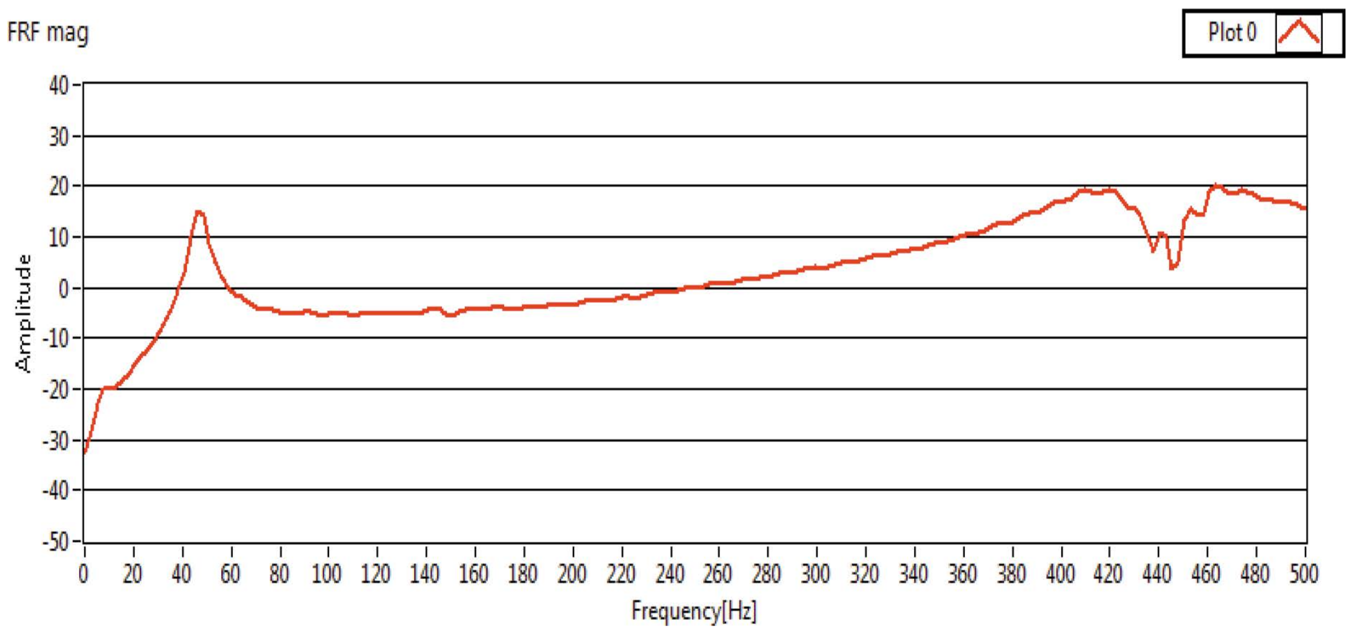

Figure 11. Forced vibration response at SDOF for C8 (As-Cast).

(20–40 Hz). Therefore, the A356 alloy and its composites with SiC may be favourably suited for applications in diesel-based systems.

4. Summary and Conclusions

Cantilever specimens of A356 aluminium alloy and A356-SiC composites of varying SiC percentages, in as-cast and T6 temper conditions, have been tested under conditions of free as well as forced vibration response to find the damping ratio, amplitude and frequency peak response.

The following conclusions could be drawn from the study:

1. The amplitudes at the peak response were all within reasonable limits of 25m, indicating that all the alloy/

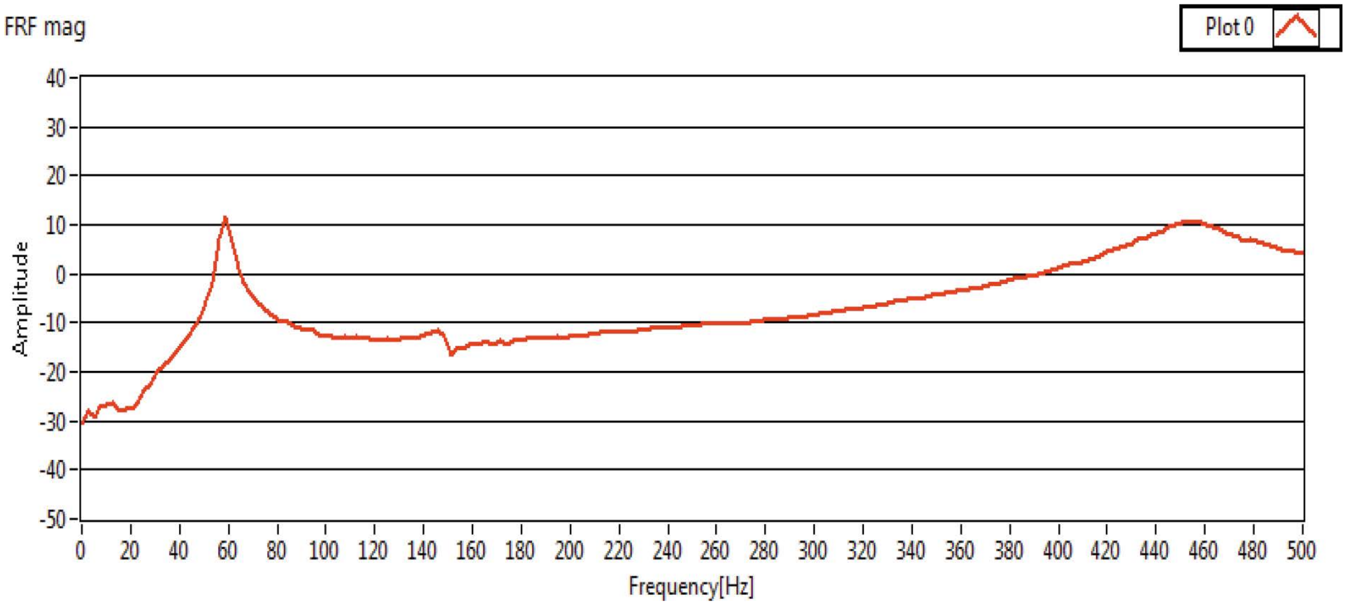

Figure 12. Forced vibration response at SDOF for C1 (T6 Temper).

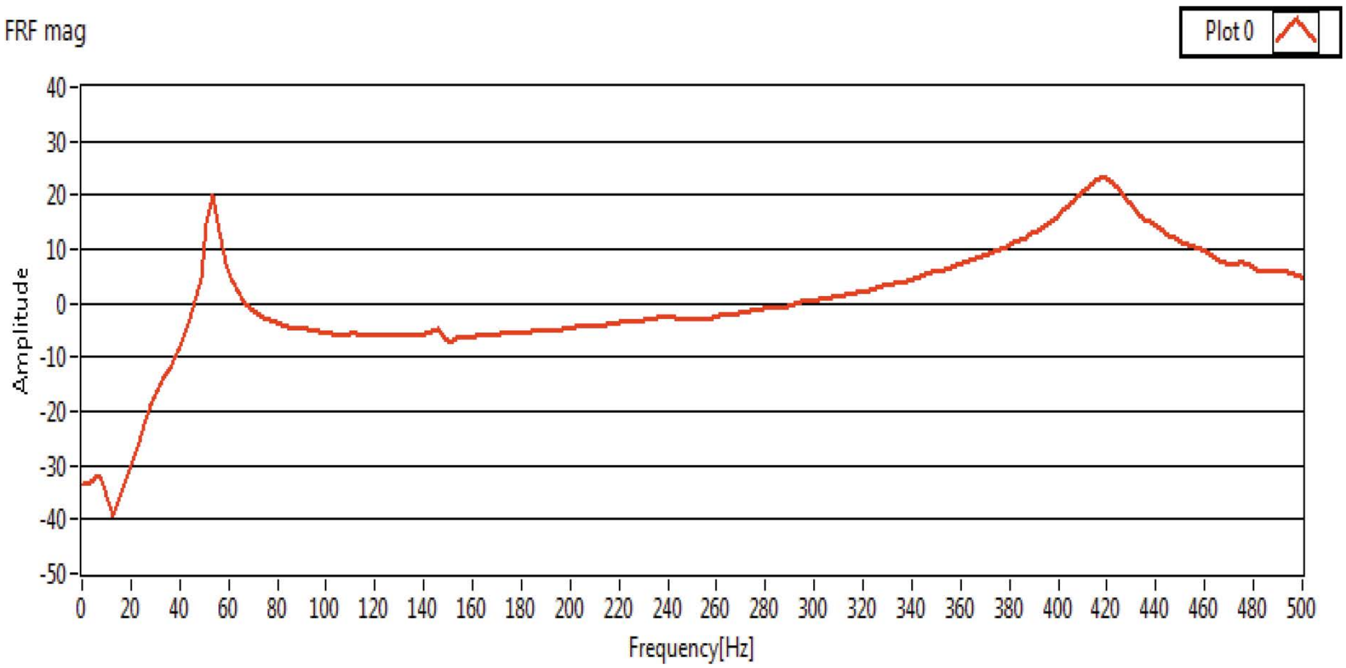

Figure 13. Forced vibration response at SDOF for C3 (T6 Temper).

composite combinations studied were suitable for automobile applications from the vibration/damping point of view.

2. The frequencies at peak response were in the range 46–62 Hz. Since the normal operative frequencies in diesel-based systems are much lower at 20–40 Hz, the composites studied would be amenable for applications in diesel-based systems.
3. Forced vibration behavior is an important aspect for automotive component applications. In this respect, all the alloy composite compositions studied yielded similar results. Hence, selection based on forced vibration tests may not be possible.
4. On the other hand, the free vibration behavior is affected significantly by both heat treatment and SiC%. The as-cast A356 alloy or its composites are

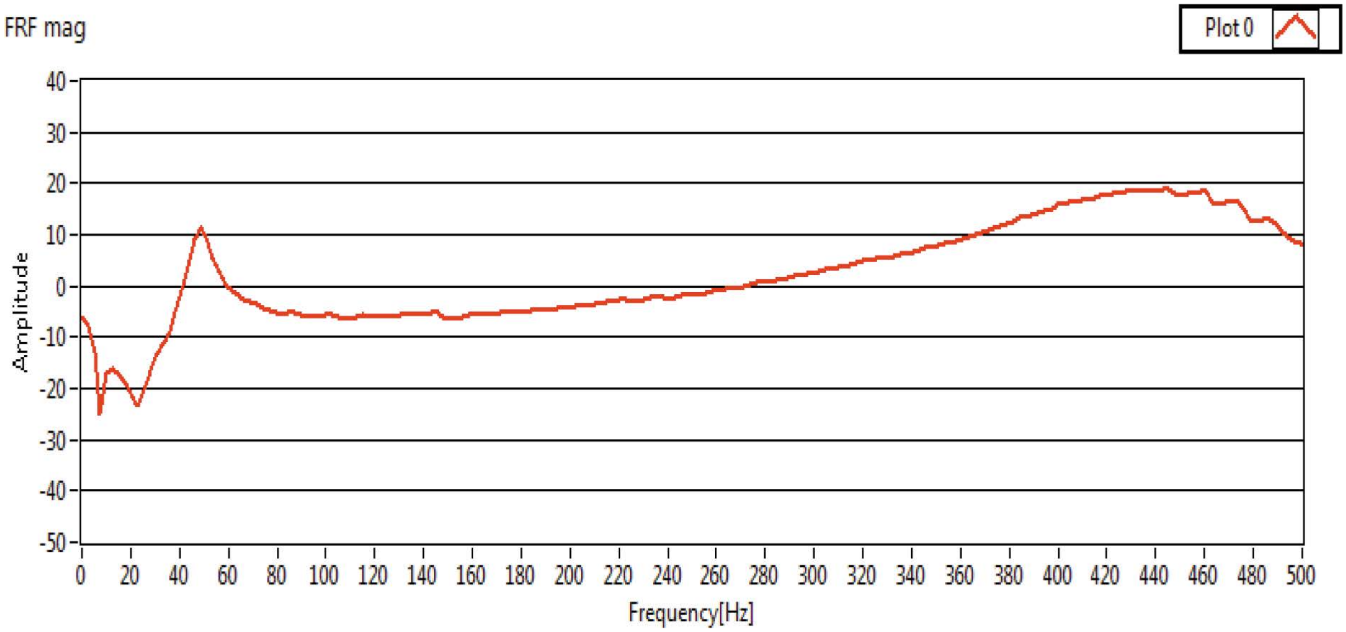

Figure 14. Forced vibration response at SDOF for C8 (T6 Temper)

Table 3. Values of amplitude and frequency at peak response for A356 alloy and its composites in the forced vibration conditions

Alloy Designation	Amplitude at Peak Response		Frequency at Peak Response	
	As-Cast	T6 Temper	As-Cast	T6 Temper
C1	11	62	11.7	59
C2	12.5	51	23	51
C3	13	59	20	54
C4	13.58	54	13	51.5
C6	16	53	13.2	56
C8	11	48	15	46
C10	13	52	23	47
C12	16	56	16	57

superior to T6 treated materials. However, considering strength aspects, T6 temper materials are preferred. It is seen that free damping reaches completion within one second and hence all the T6 tempered materials (A356 and its composites) can be candidate materials for automotive components.

5. Of the T6 tempered materials C8 (8% SiC), and C3 (2% SiC) appear to be the best options for automotive components.
6. The ranking of A356 and its composites (T6 temper) for usage as component materials from vibration and damping point of view is from (worst to best).
   C2-C4-C1-C6-C12-C10-C8-C3

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