DAMPING PROPERTIES OF A357 ALLOYS AND A357-STAINLESS STEEL COMPOSITES FABRICATED UNDER DIFFERENT CONDITIONS

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Damping Properties of A357 Alloys And A357-Stainless Steel Composites Fabricated Under Different Conditions

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LIST OF ABBREVIATIONS

MMCs : Metal matrix composites.
PMCs : Polymer matrix composites.
CMCs : Ceramic matrix composites.
AMCs : Aluminium matrix composites.
SEM : Scanning electron microscopy.
EDS : Energy dispersive spectrometry.
DMA : Dynamic mechanical analyzer.
DMTA : Dynamic mechanical thermal analyzer.
DSC : Differential scanning calorimetry.
SSw : Stainless steel wire.
CTE : Coefficient of thermal expansion.
ECAP : Equal channel angular pressing.
GP zones : Guinier-Preston zones
DAMPING PROPERTIES OF A357 ALLOYS AND A357-STAINLESS STEEL COMPOSITES FABRICATED UNDER DIFFERENT CONDITIONS

ABSTRACT

The lab scale gravity casting technique was used to produce alloy specimens of nonsuperheated A357 alloy, superheated A357 alloy and composite specimens of superheated A357-0.5 and 1.0 wt.% stainless steel composites. The primary cast ingot A357 alloy was melted in graphite crucible before pouring into the stainless steel mould at 700ºC for all specimens. Meanwhile, prior to pouring, the preform of 304 stainless steel wires were aligned in stainless steel mould to produce superheated A357-0.5 and 1.0 wt.% stainless steel composites respectively. The main objective of this research is to study the effect of superheating on the microstructures and dynamic mechanical properties, to identify the phases that present in all the specimens and also to identify the appropriate damping mechanisms in all specimens at lower and elevated temperatures. The superheating had refined the eutectic Si particles and changed the shapes of α-Al dendrites in superheated A357 alloys. The superheating also changed the shapes of π-Al₈FeMg₃Si₆ intermetallic phase and Mg₂Si phase in superheated A357 alloys. Superheated A357-0.5 wt.% stainless steel composite showed poor bonding and less intensified of coarser eutectic Si particles around the matrix-reinforcement interface. Superheated A357-1.0 wt.% stainless steel composite showed good bonding and more intensified of finer eutectic Si particles around the matrix-reinforcement interface. However, no interface reaction layer was observed at the matrix-reinforcement interface of the composite specimens. Dynamic mechanical properties such as storage modulus, loss modulus and damping capacity were investigated by dynamic mechanical analyzer (DMA). Superheated A357-1.0 wt.% stainless steel composite showed the highest storage modulus of 66.30 GPa at 50ºC. Superheated A357-0.5 wt.% stainless steel composite showed the highest loss modulus of 4.10 GPa at 380ºC. Superheated A357 alloys showed the highest damping capacity of 0.0842 GPa at 380ºC. Dislocation damping was the mechanism at lower temperatures range (50 to 280ºC) for the alloys and the composites. Meanwhile, grain boundary damping and interfacial damping were the mechanisms at elevated temperatures range (281 to 380ºC) for the composite and only grain boundary damping was the mechanism at elevated temperature range for the alloys. Differential scanning calorimetry (DSC) study at lower temperatures range (100 to 450ºC) of solution treated alloys and composite specimens showed the presence of two exothermic reactions (precipitation of θ" and θ') and an endothermic reaction (dissolution of θ") while at elevated temperatures range (530 to 630ºC) of solution treated alloys and composite specimens showed three endothermic reactions (Al dendrites, Al + Si and Al + Si + Mg₂Si + π-Al₈FeMg₃Si₆).
CHAPTER 1

INTRODUCTION

1.1 Background

Dynamic mechanical properties which represented by dynamic moduli (storage modulus and loss modulus) and damping capacity remain the prime importance in many engineering fields particularly which exposed to the dynamic applications. Knowledge of damping in a dynamic behaviour is essential in utilisation, analysis and testing of the components.

The damping capacity is the capacity of a material to convert mechanical energy of vibrations into heat that is dissipated in the materials (Rohatgi et al., 1994). When a high damping materials is effectively utilised in a structure exposed to a cyclic loading, this property allows undesirable noise and vibration to be passively attenuated and remove to the surroundings as heat (Perez et al, 1993). The damping mechanism of materials is also become practical significant as the degree of damping affects the mechanism under cyclic loading.

In metals and alloys, damping capacity can be improved by the addition of the reinforcements. Aluminium alloys have low damping capacity values in the range of 0.40 to 0.70 x $10^{-3}$ compared to other alloys such as steel (1.60 to 4.80 x $10^{-3}$) and
magnesium (39.80 to 79.60 x 10^{-3}) (Zhang et al. 1993a). Previously, the damping capacity of Al-4 wt.% Cu alloys progressively increases with increasing amounts of mica particles dispersed in the matrix reported by Deonath et al. (1981). According to finding by Perez et al. (1993), the damping capacity of the Al 6061 alloy was increased with increasing volume fraction of graphite particles. The latest investigation was found by Wang et al. (2009) on the improvement of damping capacity in Li$_3$La$_3$Ta$_2$O$_{12}$ particulates reinforced aluminum matrix composites (AMCs).

The measurement of damping capacity in the discontinuous particles reinforced AMCs were widely done as previously mentioned. However, very limited measurement of damping capacity was carried out in continuous fibre reinforced aluminium composites. One of the measurements of damping capacity in the continuous fibre reinforced aluminium composites was reported by Wolfenden and Wolla (1989) on the alumina and tungsten continuous fibre reinforced aluminium composites.

Al–Si alloys as important light metals are widely used in automotive, transportation, construction and leisure industry due to their excellent wear resistance, pressure tightness, fluidity, and shrinkage (Ejiofor & Reddy, 1997). It was reported that Al–Si alloys had relative low damping capacity (Zhang et al, 1993b), which largely limited their application in both high damping capacity and mechanical properties needed. However, various methods to improve damping capacity were accompanied by decreasing in strength (Perez et al., 1993; Zhang et al., 1994; Wei et al., 2002). Therefore, further studies are still of necessity for Al–Si alloys to achieve significant improvement in both damping capacity and mechanical properties.
The damping capacity of the alloys can be improved by microstructural modification. Improvement of damping capacity was achieved by grain refinement in A356 alloy with grain refiner (Zhang et al., 2005; Zhang et al., 2008) and ultrafine-grained in pure aluminium L2 by combination of equal channel angular pressing (ECAP) and annealing process (Zhang et al., 2006). Improvement of damping capacity also was achieved by formation of GP zone with the application of age hardening on Al-7Si-0.3Mg alloy (Lee, 2005).

1.2 Problem Statements

In this study, several scientific curiosities have led to the problem statements as follows:

1. In general, aluminium alloys are weak in strength, modulus and hardness compared to steel (Zhang et al., 2005). So, it is necessary to develop new aluminium matrix composite to overcome these problems.

2. Very few investigations of damping capacity in continuous aluminium matrix composites (AMCs) were reported (Wolfenden and Wolla, 1989). However, none of the research was done on the measurement of damping capacity and damping mechanisms in the continuous wire reinforced AMCs particularly on the application of the dynamic force in the parallel direction to the continuous reinforcement.

3. Microstructure plays an important role in determining the resulted damping capacity (Srikanth et al., 2004). Different types of MMCs either produced by powder metallurgy or casting technique will
influence the damping capacity. So, it is necessary to control the microstructure to produce the optimum damping capacity.

1.3 Research Objectives

In the present work, several research objectives are proposed according to the problems in the areas of MMCs:

1. To analyse the resulted microstructure that took place in nonsuperheated A357 alloy, superheated A357 alloy and composite specimens of superheated A357-0.5 and 1.0 wt.% stainless steel composites.

2. To study and analyse the storage modulus, loss modulus and damping capacity in nonsuperheated A357 alloy, superheated A357 alloy and composite specimens of superheated A357-0.5 and 1.0 wt.% stainless steel composites.

3. To identify the appropriate damping mechanisms in the alloys and composites from 50º to 380ºC.

4. To correlate the microstructure and damping properties in nonsuperheated A357 alloy, superheated A357 alloy and composite specimens of superheated A357-0.5 and 1.0 wt.% stainless steel composites.

5. To identify the phases that present in alloys and composites by using differential scanning calorimetry (DSC).